

**The OSGi Alliance
OSGi Core**

**Release 7
April 2018**



**OSGiTM
Alliance**

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1 Introduction

The OSGi™ Alliance was founded in March 1999. Its mission is to create open specifications for the network delivery of managed services to local networks and devices. The OSGi organization is the leading standard for next-generation Internet services to homes, cars, mobile phones, desktops, small offices, and other environments.

The OSGi Core specification delivers an open, common architecture for service providers, developers, software vendors, gateway operators and equipment vendors to develop, deploy and manage services in a coordinated fashion. It enables an entirely new category of smart devices due to its flexible and managed deployment of services. OSGi specifications target set-top boxes, service gateways, cable modems, consumer electronics, PCs, industrial computers, cars, mobile phones, and more. Devices that implement the OSGi specifications will enable service providers like telcos, cable operators, utilities, and others to deliver differentiated and valuable services over their networks.

This is the sixth release of the OSGi Core specification developed by representatives from OSGi member companies. The OSGi Core Release 7 mostly extends the existing APIs into new areas. The few modifications to existing APIs are backward compatible so that applications for previous releases should run unmodified on Release 7 Frameworks. The built-in version management mechanisms allow bundles written for the new release to adapt to the old Framework implementations, if necessary.

1.1 OSGi Framework Overview

The Framework forms the core of the OSGi Specifications. It provides a general-purpose, secure, and managed Java framework that supports the deployment of extensible and downloadable applications known as *bundles*.

OSGi-compliant devices can download and install OSGi bundles, and remove them when they are no longer required. The Framework manages the installation and update of bundles in an OSGi environment in a dynamic and scalable fashion. To achieve this, it manages the dependencies between bundles and services in detail.

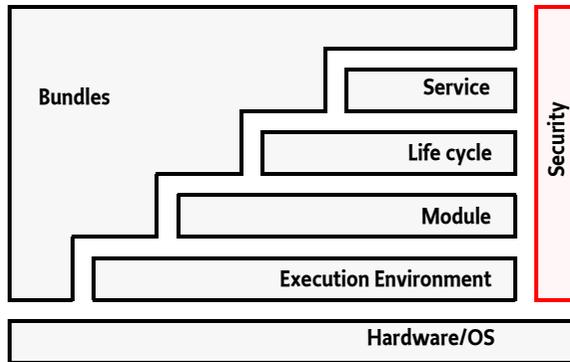
It provides the bundle developer with the resources necessary to take advantage of Java's platform independence and dynamic code-loading capability in order to easily develop services for small-memory devices that can be deployed on a large scale.

The functionality of the Framework is divided in the following layers:

- Security Layer
- Module Layer
- Life Cycle Layer
- Service Layer
- Actual Services

This layering is depicted in Figure 1.1.

Figure 1.1 Layering



The Security Layer is based on Java security but adds a number of constraints and fills in some of the blanks that standard Java leaves open. It defines a secure packaging format as well as the runtime interaction with the Java security layer. The Security Layer is described in *Security Layer* on page 19.

The Module Layer defines a modularization model for Java. It addresses some of the shortcomings of Java's deployment model. The modularization layer has strict rules for sharing Java packages between bundles or hiding packages from other bundles. The Module Layer can be used without the life cycle and Service Layer. The Life Cycle Layer provides an API to manage the *bundles* in the Module Layer, while the Service Layer provides a communication model for the bundles. The Module Layer is described in *Module Layer* on page 33.

The Life Cycle Layer provides a life cycle API to bundles. This API provides a runtime model for bundles. It defines how bundles are started and stopped as well as how bundles are installed, updated and uninstalled. Additionally, it provides a comprehensive event API to allow a management bundle to control the operations of the OSGi framework. The Life Cycle Layer requires the Module Layer but the Security Layer is optional. A more extensive description of the Life Cycle layer can be found at *Life Cycle Layer* on page 99.

The Service Layer provides a dynamic, concise and consistent programming model for Java bundle developers, simplifying the development and deployment of service bundles by de-coupling the service's specification (Java interface) from its implementations. This model allows bundle developers to bind to services only using their interface specifications. The selection of a specific implementation, optimized for a specific need or from a specific vendor, can thus be deferred to run-time.

The framework uses the service layer to provide an extension mechanism, called hooks. Hooks are services that are used by the framework to provide additional functionality.

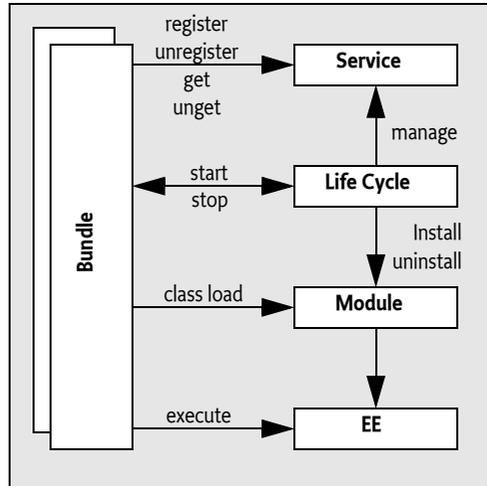
A consistent programming model helps bundle developers cope with scalability issues in many different dimensions - critical because the Framework is intended to run on a variety of devices whose differing hardware characteristics may affect many aspects of a service implementation. Consistent interfaces insure that the software components can be mixed and matched and still result in stable systems.

The Framework allows bundles to select an available implementation at run-time through the Framework service registry. Bundles register new services, receive notifications about the state of services, or look up existing services to adapt to the current capabilities of the device. This aspect of the Framework makes an installed bundle extensible after deployment: new bundles can be installed for added features or existing bundles can be modified and updated without requiring the system to be restarted.

The Service Layer is described in *Service Layer* on page 133.

The interactions between the layers is depicted in Figure 1.2.

Figure 1.2 Interactions between layers



1.2 Reader Level

This specification is written for the following audiences:

- Application developers
- Framework and system service developers (system developers)
- Architects

The OSGi Specifications assume that the reader has at least one year of practical experience in writing Java programs. Experience with embedded systems and server environments is a plus. Application developers must be aware that the OSGi environment is significantly more dynamic than traditional desktop or server environments.

System developers require a *very* deep understanding of Java. At least three years of Java coding experience in a system environment is recommended. A Framework implementation will use areas of Java that are not normally encountered in traditional applications. Detailed understanding is required of class loaders, garbage collection, Java security, and Java native library loading.

Architects should focus on the introduction of each subject. This introduction contains a general overview of the subject, the requirements that influenced its design, and a short description of its operation as well as the entities that are used. The introductory sections require knowledge of Java concepts like classes and interfaces, but should not require coding experience.

Most of these specifications are equally applicable to application developers and system developers.

1.3 Conventions and Terms

1.3.1 Typography

A fixed width, non-serif typeface (*sample*) indicates the term is a Java package, class, interface, or member name. Text written in this typeface is always related to coding.

Emphasis (*sample*) is used the first time an important concept is introduced. Its explanation usually follows directly after the introduction.

When an example contains a line that must be broken into multiple lines, the « character is used. Spaces must be ignored in this case. For example:

```
http://www.acme.com/sp/ «
file?abc=12
```

is equivalent to:

```
http://www.acme.com/sp/file?abc=12
```

1.3.2 General Syntax Definitions

In many cases in these specifications, a syntax must be described. This syntax is based on the following symbols:

*	Repetition of the previous element zero or more times, e.g. (' ' element)*
+	Repetition one or more times
?	Previous element is optional
(...)	Grouping
'...'	Literal
	Or
[...]	Set (one of)
..	list, e.g. 1..5 is the list 1 2 3 4 5
<...>	Externally defined token
-	Not

The following terminals are pre defined and used throughout the specifications:

ws	::= <see Character.isWhitespace>
digit	::= [0..9]
alpha	::= [a..zA..Z]
alphanum	::= alpha digit
token	::= (alphanum '_' '-')+
number	::= digit+
jletter	::= <see [1] <i>Java Language Specification</i> for JavaLetter>
jletterordigit	::= <see [1] <i>Java Language Specification</i> for JavaLetterOrDigit>
qname	::= <see [1] <i>Java Language Specification</i> for fully qualified class names>
identifier	::= jletter jletterordigit *
extended	::= (alphanum '_' '-' '.')+
quoted-string	::= '"' (-["\#x0D#x0A#x00] '\"' '\\')* '''
argument	::= extended quoted-string
parameter	::= directive attribute
directive	::= extended ':' argument
attribute	::= extended '=' argument
unique-name	::= identifier ('.' identifier)*
symbolic-name	::= token ('.' token)*
package-name	::= unique-name
path	::= special-chars+ quoted-string
special-chars	::= -["\#x0D#x0A#x00:;, <see [1] <i>Java Language Specification</i>

for whitespace>]

Whitespaces between terminals are ignored unless specifically noted. Any value that contains a space, a comma, colon, semi-colon, equal sign or any other character that is part of a terminal in the grammar must be quoted.

1.3.3 Object Oriented Terminology

Concepts like classes, interfaces, objects, and services are distinct but subtly different. For example, "LogService" could mean an instance of the class `LogService`, could refer to the class `LogService`, or could indicate the functionality of the overall Log Service. Experts usually understand the meaning from the context, but this understanding requires mental effort. To highlight these subtle differences, the following conventions are used.

When the class is intended, its name is spelled exactly as in the Java source code and displayed in a fixed-width typeface: for example, the "HttpService class", "a method in the `HttpContext` class" or "a `javax.servlet.Servlet` object". A class name is used in its fully qualified form, like `javax.servlet.Servlet`, when the package is not obvious from the context, nor is it in one of the well known java packages like `java.lang`, `java.io`, `java.util` and `java.net`. Otherwise, the package is omitted like in `String`.

In many cases, a type can be used as a scalar but also a collection of that type or an array of that type. In those cases, a simple `+` will be suffixed to the type. For example `String+`, indicates that a `String`, a `String[]`, and a `Collection<String>` are all valid forms.

Exception and permission classes are not followed by the word "object". Readability is improved when the "object" suffix is avoided. For example, "to throw a `SecurityException`" and to "to have `FilePermission`" is more readable than "to have a `FilePermission` object".

Permissions can further be qualified with their actions. `ServicePermission[com.acme.*,GET|REGISTER]` means a `ServicePermission` with the action `GET` and `REGISTER` for all service names starting with `com.acme`. A `ServicePermission[Producer|Consumer, REGISTER]` means the `ServicePermission` for the `Producer` or `Consumer` class with `REGISTER` action.

When discussing functionality of a class rather than the implementation details, the class name is written as normal text. This convention is often used when discussing services. For example, "the `User Admin` service" is more readable.

Some services have the word "Service" embedded in their class name. In those cases, the word "service" is only used once but is written with an upper case `S`. For example, "the `Log Service` performs".

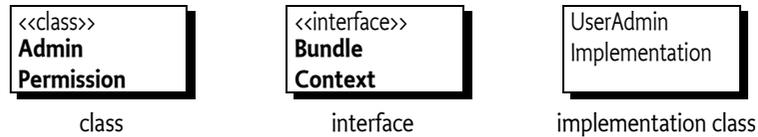
Service objects are registered with the OSGi Framework. Registration consists of the service object, a set of properties, and a list of classes and interfaces implemented by this service object. The classes and interfaces are used for type safety *and* naming. Therefore, it is said that a service object is registered *under* a class/interface. For example, "This service object is registered under `PermissionAdmin`."

1.3.4 Diagrams

The diagrams in this document illustrate the specification and are not normative. Their purpose is to provide a high-level overview on a single page. The following paragraphs describe the symbols and conventions used in these diagrams.

Classes or interfaces are depicted as rectangles, as in Figure 1.3. Interfaces are indicated with the qualifier `<<interface>>` as the first line. The name of the class/interface is indicated in bold when it is part of the specification. Implementation classes are sometimes shown to demonstrate a possible implementation. Implementation class names are shown in plain text. In certain cases class names are abbreviated. This is indicated by ending the abbreviation with a full stop.

Figure 1.3 Class and interface symbol



If an interface or class is used as a service object, it will have a black triangle in the bottom right corner.

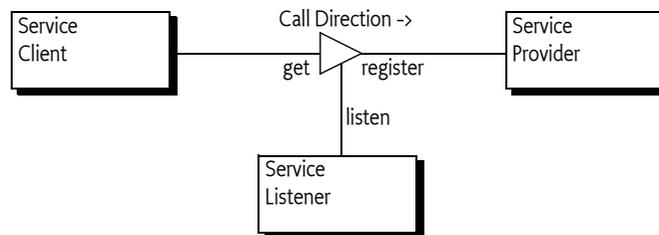
Figure 1.4 Service symbol



Service are crucial interaction elements and they can occur many times in diagrams describing services. Therefore, an alternative service symbol is the triangle. Triangles can be connected in different ways, representing different meanings:

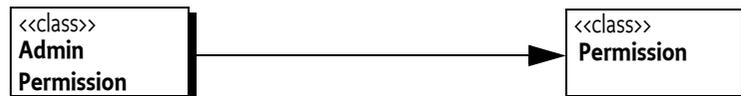
- *Point* - Connections to the point of a triangle indicate the registration. This makes the point of the triangle point to the object that receives the method calls from the service users.
- *Straight Side* - Connections to the straight side indicate service clients. Clients call the methods of the service.
- *Angled Side* - The angled side is reserved for service listeners.

Figure 1.5 Alternative Service symbol



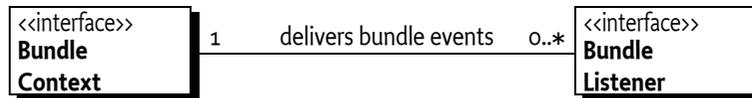
Inheritance (the extends or implements keyword in Java class definitions) is indicated with an arrow. Figure 1.6 shows that the AdminPermission class implements or extends the Permission class.

Figure 1.6 Inheritance (implements or extends) symbol



Relations are depicted with a line. The cardinality of the relation is given explicitly when relevant. Figure 1.7 shows that each (1) BundleContext object is related to 0 or more BundleListener objects, and that each BundleListener object is related to a single BundleContext object. Relations usually have some description associated with them. This description should be read from left to right and top to bottom, and includes the classes on both sides. For example: "A BundleContext object delivers bundle events to zero or more BundleListener objects."

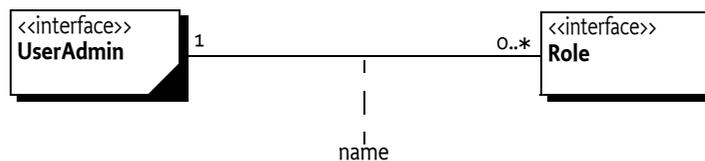
Figure 1.7 Relations symbol



Associations are depicted with a dashed line. Associations are between classes, and an association can be placed on a relation. For example, "every ServiceRegistration object has an associated ServiceReference object." This association does not have to be a hard relationship, but could be derived in some way.

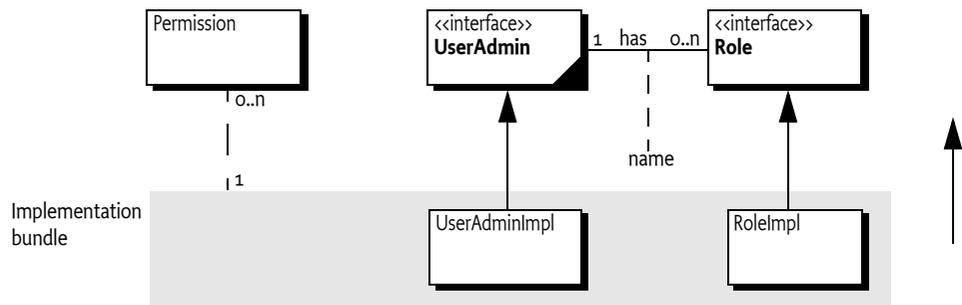
When a relationship is qualified by a name or an object, it is indicated by drawing a dotted line perpendicular to the relation and connecting this line to a class box or a description. Figure 1.8 shows that the relationship between a UserAdmin class and a Role class is qualified by a name. Such an association is usually implemented with a Dictionary or Map object.

Figure 1.8 Associations symbol



Bundles are entities that are visible in normal application programming. For example, when a bundle is stopped, all its services will be unregistered. Therefore, the classes/interfaces that are grouped in bundles are shown on a grey rectangle as is shown in Figure 1.9.

Figure 1.9 Bundles



1.3.5 Key Words

This specification consistently uses the words *can*, *should*, and *must*. Their meaning is well-defined in:

- *must* - An absolute requirement. Both the Framework implementation and bundles have obligations that are required to be fulfilled to conform to this specification.
- *should* - Recommended. It is strongly recommended to follow the description, but reasons may exist to deviate from this recommendation.
- *may* or *can* - Optional. Implementations must still be interoperable when these items are not implemented.

1.3.6 Numbered Lists

When a specification uses a numbered list, unless otherwise specified, the intention is that the actions described by the items in the list happen in the numerical order of the items. From a Java con-

currency point-of-view, this means that the actions described in lower numbered items *happens-before* the actions described in higher numbered items.

1.4 Version Information

This document specifies OSGi Core Release 7. This specification is backward compatible to all prior releases.

All Security, Module, Life Cycle and Service Layers are part of the Framework Specification

Components in this specification have their own specification version, independent of the document release number. The following table summarizes the packages and specification versions for the different subjects.

When a component is represented in a bundle, a version is needed in the declaration of the Import-Package or Export-Package manifest headers.

Table 1.1 Packages and versions OSGi Core

Item	Package	Version
Framework Specification (all layers)	org.osgi.framework	Version 1.9
Framework Launching	org.osgi.framework.launch	Version 1.2
6 <i>Resource API Specification</i>	org.osgi.resource	Version 1.0
7 <i>Bundle Wiring API Specification</i>	org.osgi.framework.wiring	Version 1.2
8 <i>Framework Namespaces Specification</i>	org.osgi.framework.namespace	Version 1.1
9 <i>Start Level API Specification</i>	org.osgi.framework.startlevel	Version 1.0
50 <i>Conditional Permission Admin Service Specification</i>	org.osgi.service.condpermadmin	Version 1.1
51 <i>Permission Admin Service Specification</i>	org.osgi.service.permissionadmin	Version 1.2
52 <i>URL Handlers Service Specification</i>	org.osgi.service.url	Version 1.0
53 <i>Resolver Hook Service Specification</i>	org.osgi.framework.hooks.resolver	Version 1.0
54 <i>Bundle Hook Service Specification</i>	org.osgi.framework.hooks.bundle	Version 1.1
55 <i>Service Hook Service Specification</i>	org.osgi.framework.hooks.service	Version 1.1
56 <i>Weaving Hook Service Specification</i>	org.osgi.framework.hooks.weaving	Version 1.1
57 <i>Data Transfer Objects Specification</i>	org.osgi.dto	Version 1.1
	org.osgi.framework.dto	
	org.osgi.framework.startlevel.dto	
	org.osgi.framework.wiring.dto	
	org.osgi.resource.dto	
58 <i>Resolver Service Specification</i>	org.osgi.service.resolver	Version 1.1
701 <i>Tracker Specification</i>	org.osgi.util.tracker	Version 1.5
Versioning Annotations	org.osgi.annotation.versioning	Version 1.1
Bundle Annotations	org.osgi.annotation.bundle	Version 1.0

A compliant framework implementation must implement all of the specifications in this document except as outlined below.

- 50 *Conditional Permission Admin Service Specification* and 51 *Permission Admin Service Specification* are mandatory only if 2 *Security Layer* is supported and a Security Manager is installed.
- 52 *URL Handlers Service Specification* is mandatory if the framework implementation system bundle exports the org.osgi.service.url package.

- 701 *Tracker Specification* is optional.

1.5 References

- [1] *Java Language Specification*
<http://docs.oracle.com/javase/specs/>

1.6 Changes

- Added *Numbered Lists* to specify the *happens-before* relationship between items in numbered lists.
- Added `org.osgi.annotation.bundle`.
- *Resolver Service Specification* moved to Core from OSGi Compendium, Chapter 136.

2 Security Layer

Version 1.9

2.1 Introduction

The OSGi Security Layer is an optional layer that underlies the OSGi framework. The layer is based on the Java security architecture. It provides the infrastructure to deploy and manage applications that must run in fine-grained controlled environments.

2.1.1 Essentials

- *Fine-grained* - The control of applications running in an OSGi Framework must allow for detailed control of those applications.
- *Manageable* - The security layer itself does not define an API to control the applications. The management of the security layer is left to the life cycle layer.
- *Optional* - The security layer is optional.

2.2 Security Overview

The Framework security model is based on the Java specification. If security checks are performed, they must be done according to [3] *Java Security Architecture*. It is assumed that the reader is familiar with this specification. The security layer is optional, see *Optional Security* on page 19.

2.2.1 Code Authentication

The OSGi framework can authenticate code in the following ways:

- By location
- By signer

At higher layers there are defined services that can manage the permissions that are associated with the authenticated unit of code. These services are:

- *Permission Admin service* - Manages the permission based on full location strings.
- *Conditional Permission Admin service* - Manages the permissions based on a comprehensive conditional model, where the conditions can test for location or signer.

For signing, this requires the JAR files to be signed; this is described in *Digitally Signed JAR Files* on page 20.

2.2.2 Optional Security

The Java platform on which the Framework runs must provide the Java Security APIs necessary for Java permissions. On resource-constrained platforms, these Java Security APIs may be stubs that allow the bundle classes to be loaded and executed, but the stubs never actually perform the security checks. The behavior of these stubs must be as follows:

- `checkPermission` - Return without throwing a `SecurityException`.

- checkGuard - Return without throwing a SecurityException.
- implies - Return true.

This behavior allows code to run as if all bundles have AllPermission.

2.3 Digitally Signed JAR Files

This section defines in detail how JAR files must be signed. This section therefore overlaps with the different JAR file specifications that are part of the different versions of Java. The reason for this duplication is that there are many aspects left as optional or not well-defined in these specifications. A reference was therefore insufficient.

Digitally signing is a security feature that verifies the following:

- Authenticates the signer
- Ensures that the content has not been modified after it was signed by the principal.

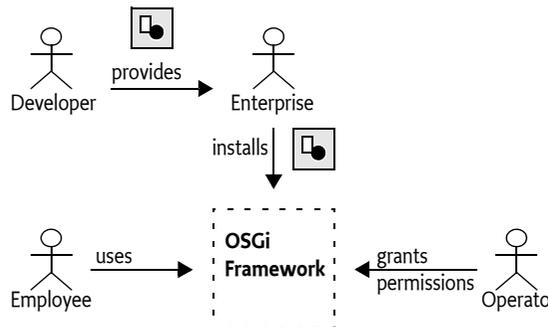
In an OSGi Framework, the principals that signed a JAR become associated with that JAR. This association is then used to:

- Grant permissions to a JAR based on the authenticated principal
- Target a set of bundles by principal for a permission to operate on or with those bundles

For example, an Operator can grant the ACME company the right to use networking on their devices. The ACME company can then use networking in every bundle they digitally sign and deploy on the Operator's device. Also, a specific bundle can be granted permission to only manage the life cycle of bundles that are signed by the ACME company.

Signing provides a powerful delegation model. It allows an Operator to grant a restricted set of permissions to a company, after which the company can create JARs that can use those permissions, without requiring any intervention of, or communication with, the Operator for each particular JAR. This delegation model is shown graphically in Figure 2.1.

Figure 2.1 Delegation model



Digital signing is based on *public key cryptography*. Public key cryptography uses a system where there are two mathematically related keys: a public and a private key. The public key is shared with the world and can be dispersed freely, usually in the form of a certificate. The private key must be kept a secret.

Messages signed with the private key can only be verified correctly with the public key. This can be used to authenticate the signer of a message (assuming the public key is trusted, this is discussed in *Certificates* on page 23).

The digital signing process used is based on Java JAR signing. The process of signing is repeated, restricted and augmented here to improve the interoperability of OSGi bundles.

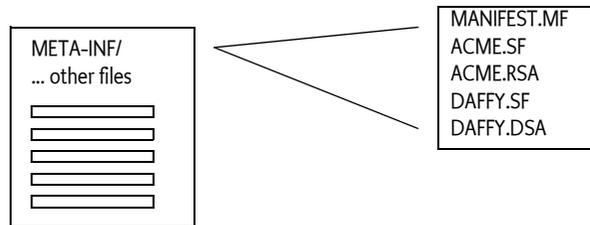
2.3.1 JAR Structure and Manifest

A JAR can be signed by multiple signers. Each signer must store two resources in the JAR file. These resources are:

- A signature instruction resource that has a similar format like the Manifest. It must have a .SF extension. This file provides digests for the complete manifest file.
- A PKCS#7 resource that contains the digital signature of the signature instruction resource. See [10] *Public Key Cryptography Standard #7* for information about its format.

These JAR file signing resources must be placed in the META-INF directory. For signing, the META-INF directory is special because files in there are not signed in the normal way. These signing resources must come directly after the MANIFEST.MF file, and before *any* other resources in a JAR stream. If this is not the case, then a Framework should not accept the signatures and must treat the bundle as unsigned. This ordering is important because it allows the receiver of the JAR file to stream the contents without buffering. All the security information is available before any resources are loaded. This model is shown in Figure 2.2.

Figure 2.2 Signer files in JAR



The signature instruction resource contains digests of the Manifest resource, not the actual resource data itself. A digest is a one way function that computes a value from the bytes of a resource in such a way that it is very difficult to create a set of bytes that matches that digest value.

The JAR Manifest must therefore contain one or more digests of the actual resources. These digests must be placed in their name section of the manifest. The name of the digest header is constructed with its algorithm followed by -Digest. An example is the SHA-256-Digest. It is recommended that OSGi Framework implementations support the following digest algorithms.

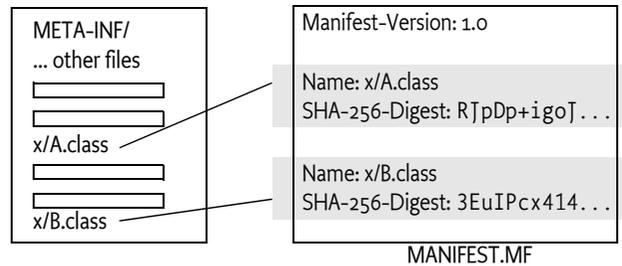
- *SHA-1* - Delivers a 160 bit hash. It is defined in [6] *Secure Hash Standard*.
- *SHA-256* - Delivers a 256 bit hash. It is defined in [6] *Secure Hash Standard*.

The hash must be encoded with a Base 64 encoding. Base 64 encoding is defined in [7] *RFC 1421 Privacy Enhancement for Internet Electronic Mail*.

For example, a manifest could look like:

```
Manifest-Version: 1.0
Bundle-Name: DisplayManifest
↵
Name: x/A.class
SHA-256-Digest: 7CCToQk6yvRusxN10uSwr v37UY/ fdz6aHou29mbswsM=
↵
Name: x/B.class
SHA-256-Digest: C+0CG/ cy13WD2sq8dRZm+dNWAHI j m4RQmUvELLv7DVU=
↵
```

Graphically this looks like Figure 2.3.

Figure 2.3 *Signer files in JAR*

OSGi JARs must be signed by one or more signers that sign all resources except the ones in the META-INF directory; the default behavior of the jarsigner tool. This is a restriction with respect to standard Java JAR signing; there is no partial signing for an OSGi JAR. The OSGi specification only supports fully signed bundles. The reason for this restriction is because partially signing can break the protection of private packages. It also simplifies the security API because all code of a bundle is using the same protection domain.

Signature files in nested JAR files (For example JARs on the Bundle-ClassPath) must be ignored. These nested JAR files must share the same protection domain as their containing bundle. They must be treated as if their resources were stored directly in the outer JAR.

Each signature is based on two resources. The first file is the signature instruction file; this file must have a file name with an extension .SF. A signature file has the same syntax as the manifest, except that it starts with Signature-Version: 1.0 instead of Manifest-Version: 1.0.

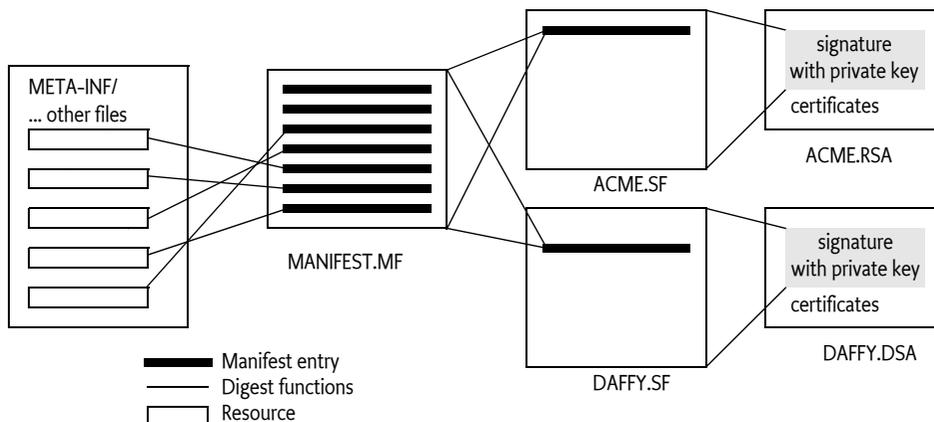
The only relevant part of the signature resource is the digest of the Manifest resource. The name of the header must be the name algorithm (e.g. SHA-256) followed by -Digest-Manifest. For example:

```
Signature-Version: 1.0
SHA-256-Digest-Manifest: HmK7445BA7n5UYI9xZKfSdMAPci44Jn7ZcmoyoiWoM=
```

The signature resource can contain name sections as well. However, these name sections should be ignored.

If there are multiple signers, then their signature instruction resources can be identical if they use the same digest algorithms. However, each signer must still have its own signature instruction file. That is, it is not allowed to share the signature resource between signers.

The indirection of the signature instruction files digests is depicted in Figure 2.4 for two signers: ACME and DAFFY.

Figure 2.4 *Manifest, signature instruction files and digests in JAR*

2.3.2 Java JAR File Restrictions

OSGi bundles are always valid JAR files. However, there are a few restrictions that apply to bundles that do not apply to JAR files.

- Bundles do not support partially signed bundles. The manifest must contain name sections for all resources but should not have entries for resources in the META-INF directory. Signed entries in the META-INF directory must be verified. Sub directories of META-INF must be treated like any other JAR directory.
- The name sections in the signature files are ignored. Only the Manifest digest is used.

2.3.3 Valid Signature

A bundle can be signed with a *signature* by multiple signers. A signature contains a pair of a signature file, with a SF extension and a PKCS#7 resource that has the same name as the signature file but with either an RSA or DSA extension.

Such a signature is valid when:

- The signature file has an entry for the META-INF/MANIFEST.MF resource.
- The manifest entry must contain a SHA-256 and/or SHA-1 digest for the complete manifest.
- All listed digests match the manifest.
- The PKCS#7 resource is a valid signature (either signed using RSA or DSA as indicated by the extension) for the signature resource.

For a complete bundle to be validly signed it is necessary that all signatures are valid. That is, if one of the signatures is invalid, the whole bundle must be treated as unsigned.

2.3.4 Signing Algorithms

Several different available algorithms can perform digital signing. OSGi Framework implementations should support the following algorithms:

- *DSA* - The Digital Signature Algorithm. This standard is defined in [8] *DSA*. This is a USA government standard for Digital Signature Standard. The signature resource name must have an extension of *.DSA*.
- *RSA* - Rivest, Shamir and Adleman. A public key algorithm that is very popular. It is defined in [9] *RSA*. The extension of the signature resource name must be *.RSA*.

The signature files for RSA and DSA are stored in a PKCS#7 format. This is a format that has a structure as defined in [10] *Public Key Cryptography Standard #7*. The PKCS#7 standard provides access to the algorithm specific signing information as well as the certificate with the public key of the signer. The verification algorithm uses the public key to verify that:

- The digital signature matches the signature instruction resource.
- The signature was created with the private key associated with the certificate.

The complete signing structure is shown in Figure 2.4.

2.3.5 Certificates

A certificate is a general term for a signed document containing a name and public key information. Such a certificate can take many forms but the OSGi JAR signing is based on the X.509 certificate format. It has been around for many years and is part of the OSI group of standards. X.509 is defined in [2] *X.509 Certificates*.

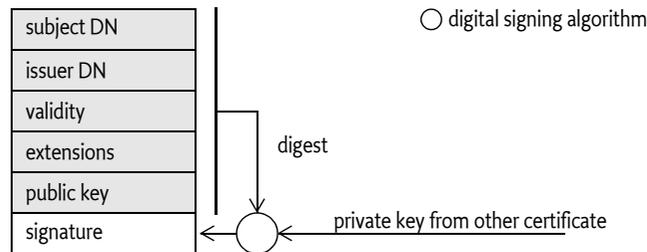
An X.509 certificate contains the following elements:

- *Subject Name* - The subject name is a unique identifier for the object being certified. In the case of a person this might include the name, nationality and e-mail address, the organization, and the department within that organization. This identifier is a Distinguished Name, which is defined in *Distinguished Names* on page 25.
- *Issuer Name* - The Issuer name is a Distinguished Name for the principal that signed this certificate.
- *Certificate Extensions* - A certificate can also include pictures, codification of fingerprints, passport number, and other extensions.
- *Public Key Information* - A public key can be used with an encryption technique that requires its private counterpart to decrypt, and vice versa. The public key can be shared freely, the private key must be kept secret. The public key information specifies an algorithm identifier (such as DSA or RSA) and the subject's public key.
- *Validity* - A Certificate can be valid for only a limited time.
- *Certifying Authority Signature* - The Certificate Authority signs the first elements and thereby adds credibility to the certificate. The receiver of a certificate can check the signature against a set of trusted certifying authorities. If the receiver trusts that certifying authority, it can trust the statement that the certificate makes.

The structure of a certificate is depicted in Figure 2.5.

Figure 2.5

Structure of a certificate

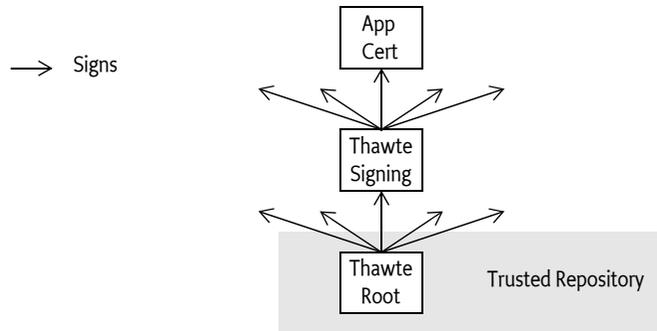


Certificates can be freely dispersed; they do not contain any secret information. Therefore, the PKCS#7 resource contains the signing certificate. It cannot be trusted at face value because the certificate is carried in the bundle itself. A perpetrator can easily create its own certificate with any content. The receiver can only verify that the certificate was signed by the owner of the public key (the issuer) and that it has not been tampered with. However, before the statement in the certificate can be trusted, it is necessary to authenticate the certificate itself. It is therefore necessary to establish a *trust model*.

One trust model, supported but not required by the OSGi specifications, is placing the signing certificate in a repository. Any certificate in this repository is treated as trusted by default. However, placing all possible certificates in this repository does not scale well. In an open model, a device would have to contain hundreds of thousands of certificates. The management of the certificates could easily become overwhelming.

The solution is to sign a certificate by another certificate, and this process can be repeated several times. This delegation process forms a *chain of certificates*. All certificates for this chain are carried in the PKCS#7 file: if one of those certificates can be found in the trusted repository, the other dependent ones can be trusted, on the condition that all the certificates are valid. This model scales very well because only a few certificates of trusted signers need to be maintained. This is the model used in web browsers, as depicted in Figure 2.6.

Figure 2.6 Certificate authorities fan out



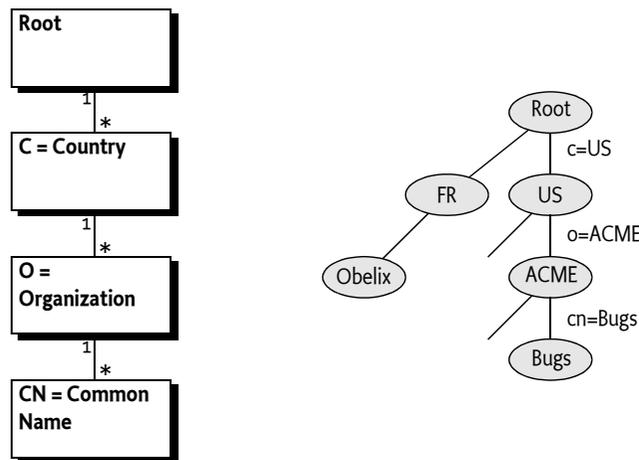
This specification does not specify access to the trusted repository. It is implementation specific how this repository is populated and maintained.

2.3.6 Distinguished Names

An X.509 name is a *Distinguished Name* (DN). A DN is a highly structured name, officially identifying a node in an hierarchical namespace. The DN concept was developed for the X.500 directory service which envisioned a world wide namespace managed by PTTs. Today, the DN is used as an identifier in a local namespace, as in a namespace designed by an Operator. For example, given a namespace that looks like Figure 2.7, the DN identifying Bugs looks like:

cn=Bug, o=ACME, c=US

Figure 2.7 Country, Company, Person based namespace.



The traversal of the namespace is *reversed* from the order in the DN, the first part specifies the least significant but most specific part. That is, the order of the attribute assertions is significant. Two DNs with the same attributes but different order are different DNs.

In the example, a node is searched in the root that has an attribute c (countryName) with a value that is US. This node is searched for a child that has an attribute o (organizationName) with a value of ACME. And the ACME node is searched for a child node with an attribute cn (commonName) that has a value "Bugs Bunny".

The tree based model is the official definition of a DN from the X.500 standards. However, in practice today, many DNs contain attributes that have no relation to a tree. For example, many DNs contain comments and copyrights in the ou (organizationalUnit) attribute.

The DN from an X.509 certificate is expressed in a binary structure defined by ASN.1 (a type language defined by ISO). However, the Distinguished Name is often used in interaction with humans. Sometimes, users of a system have to acknowledge the use of a certificate or an employee of an Operator must grant permissions based on a Distinguished Name of a customer. It is therefore paramount that the Distinguished Name has a good human readable string representation. The expressiveness of the ASN.1 type language makes this non-trivial. This specification only uses DN strings as defined in [1] *RFC 2253 Lightweight Directory Access Protocol (v3): UTF-8 String Representation of Distinguished Names* with a number of extensions that are specified by the `javax.security.auth.x500.X500Principal` class in CANONICAL form.

However, the complexity of the encoding/decoding is caused by the use of rarely used types and features (binary data, multi-valued RDNs, foreign alphabets, and attributes that have special matching rules). These features must be supported by a compliant implementation but should be avoided by users. In practice, these features are rarely used today.

The format of a string DN is as follows:

```

dn          ::= rdn ( ',' rdn ) *
rdn         ::= attribute ( '+' attribute ) *
attribute   ::= name '=' value
name        ::= readable | oid
oid         ::= number ( '.' number ) * // See 1.3.2
readable    ::= <see attribute table>
value       ::= <escaped string>

```

Spaces before and after the separators are ignored, spaces inside a value are significant but multiple embedded spaces are collapsed into a single space. Wildcard asterisks (`'\u002A'`) are not allowed in a value part. The following characters must be escaped with a reverse solidus (`'\u005C'`):

comma	','	\u002C
plus	+'	\u002B
double quote	''	\u0022
reverse solidus	'\'	\u005C
less than	'<'	\u003C
greater than	'>'	\u003E
semicolon	';'	\u003B

Reverse solidi (`'\u005C'`) must already be escaped in Java strings, requiring 2 reverse solidi in Java source code. For example:

```

DN:          cn = Bugs Bunny, o = ACME++, C=US
Canonical form: cn=bugs bunny,o=acme\+\+,c=us
Java String:  "cn=Bugs Bunny,o=ACME\+\+\+,c=US"

```

The full Unicode character set is available and can be used in DNs. String objects must be normalized and put in canonical form before being compared.

```

DN:          cn = Bugs Bunny, o = Đ Þ, C=US
Canonical form: cn=bugs bunny,o=đ þ,c=us
Java String:  "cn = Bugs Bunny, o = Đ Þ, C=US"

```

The names of attributes (attributes types as they are also called) are actually translated into an Object Identifier (OID). An OID is a dotted decimal number, like 2.5.4.3 for the `cn` (`commonName`) attribute name. It is therefore not possible to use any attribute name because the implementation must know the aliasing as well as the comparison rules. Therefore only the attributes that are listed in the following table are allowed (in short or long form):

<code>commonName</code>	<code>cn</code>	2.5.4.3	ITU X.520
-------------------------	-----------------	---------	-----------

surName	sn	2.5.4.4
countryName	c	2.5.4.6
localityName	l	2.5.4.7
stateOrProvinceName	st	2.5.4.8
organizationName	o	2.5.4.10
organizationalUnitName	ou	2.5.4.11
title		2.5.4.12
givenName		2.5.4.42
initials		2.5.4.43
generationQualifier		2.5.4.44
dnQualifier		2.5.4.46
streetAddress	street	RFC 2256
domainComponent	dc	RFC 1274
userid	uid	RFC 1274/2798?
emailAddress		RFC 2985
serialNumber		RFC 2985

The following DN:

```
2.5.4.3=Bugs Bunny,organizationName=ACME,2.5.4.6=US
```

Is therefore identical to:

```
cn=Bugs Bunny,o=ACME,c=US
```

The attribute types officially define a matching rule, potentially allowing cases sensitive and case insensitive. The attributes in the previous list all match case insensitive. Therefore, an OSGi DN must not depend on case sensitivity.

The X.500 standard supports multi-valued RDNs, however, their use is not recommended. See [12] *Understanding and Deploying LDAP Directory Services* for the rationale of this recommendation. Multi-valued RDNs separate their constituents with a plus sign ('+' \u002B). Their order is not significant. For example:

```
cn=Bugs Bunny+dc=x.com+title=Manager,o=ACME,c=US
```

Which is the same as

```
dc=x.com+cn=Bugs Bunny+title=Manager,o=ACME,c=US
```

2.3.7 Certificate Matching

Certificates are matched by their Subject DN. Before matching, DN's, they must first be put in canonical form according to the algorithm specified in `javax.security.auth.x500.X500Principal`.

DNs can also be compared using wildcards. A wildcard asterisk ('*' \u002A) replaces all possible values. Due to the structure of the DN, the comparison is more complicated than string-based wildcard matching.

A wildcard can stand for a number of RDNs, or the value of a single RDN. DN's with a wildcard must be canonicalized before they are compared. This means, among other things, that spaces must be ignored, except in values.

The format of a wildcard DN match is:

```
CertificateMatch ::= dn-match ( ';' dn-match ) *
dn-match        ::= ( '*' | rdn-match )
                  ( ',' rdn-match ) * | '-'
```

```

rdn-match      ::= name '=' value-match
value-match    ::= '*' | value-star
value-star     ::= < value, requires escaped '*' and '-' >

```

The most simple case is a single wildcard; it must match any DN. A wildcard can also replace the first list of RDNs of a DN. The first RDNs are the least significant. Such lists of matched RDNs can be empty.

For example, a DN with a wildcard that matches all nodes descendant from the ACME node in Figure 2.7 on page 25, looks like:

```
*, o=ACME, c=US
```

This wildcard DN matches the following DNs:

```

cn = Bugs Bunny, o = ACME, c = US
ou = Carots, cn=Daffy Duck, o=ACME, c=US
street = 9C\, Avenue St. Drézéry, o=ACME, c=US
dc=www, dc=acme, dc=com, o=ACME, c=US
o=ACME, c=US

```

The following DNs must not match:

```

street = 9C\, Avenue St. Drézéry, o=ACME, c=FR
dc=www, dc=acme, dc=com, c=US

```

If a wildcard is used for a value of an RDN, the value must be exactly *. The wildcard must match any value, and no substring matching must be done. For example:

```
cn=*, o=ACME, c=*
```

This DN with wildcard must match the following DNs:

```

cn=Bugs Bunny, o=ACME, c=US
cn = Daffy Duck , o = ACME , c = US
cn=Road Runner, o=ACME, c=NL

```

But not:

```

o=ACME, c=NL
dc=acme.com, cn=Bugs Bunny, o=ACME, c=US

```

Both forms of wildcard usage can be combined in a single matching DN. For example, to match any DN that is from the ACME company worldwide, use:

```
*, o=ACME, c=*
```

Matching of a DN takes place in the context of a certificate. This certificate is part of a *certificate chain*, see *Certificates* on page 23. Each certificate has a Subject DN and an Issuer DN. The Issuer DN is the Subject DN used to sign the first certificate of the chain. DN matching can therefore be extended to match the signer. The semicolon (';' \u003B) must be used to separate DNs in a chain.

The following example matches a certificate signed by Tweety Inc. in the US.

```
* ; ou=S & V, o=Tweety Inc., c=US
```

The wildcard matches zero or one certificates, however, sometimes it is necessary to match a longer chain. The minus sign ('-' \u002D) represents zero or more certificates, whereas the asterisk only represents a single certificate. For example, to match a certificate where the Tweety Inc. is in the certificate chain, use the following expression:

- ; *, o=Tweety Inc., c=US

The previous example matched if the Tweety Inc. certificate was trusted, or was signed by a trusted certificate. Certain certificates are trusted because they are known by the Framework, how they are known is implementation-defined.

2.4 Permissions

The OSGi Framework uses Java permissions for securing bundles. Each bundle is associated with a set of permissions. During runtime, the permissions are queried when a permission is requested through the Security Manager. If a Framework uses postponed conditions, then it must install its own security manager, otherwise it can use any Security Manager.

The management of the bundle's permissions is handled through Conditional Permission Admin, Permission Admin, or another security agent.

2.4.1 Implied Permissions

Implied permissions are permissions that the framework grants a bundle without any specific action. These permissions are necessary for normal operation. For example, each bundle gets permissions to read, write, and delete the bundle persistent storage area. The standard list of implied permissions is as follows:

- File Permission for the bundle persistent storage area, for the READ, WRITE, and DELETE actions.
- Property Permission with the READ action for `org.osgi.framework.*`.
- Admin Permission with the RESOURCE, METADATA, CLASS, and CONTEXT actions for the bundle itself.
- Capability Permission REQUIRE for the `org.osgi.ee` namespace.
- Capability Permission REQUIRE for the `org.osgi.native` namespace.
- Package Permission IMPORT for `java.*`.

2.4.2 Filter Based Permissions

OSGi supports a number of permissions that are granted when the target of the permissions is related to a bundle. For example, Admin Permission can grant a bundle the permission to manage other bundles. This is expressed by using a *filter expression* for the *name* of the permission. When the permission is checked, the filter is evaluated with specific permission attributes as well as attributes that describe the bundle's identity. For example, a bundle can get permission to get all services registered by bundles coming from a specific location:

```
ServicePermission("(location=https://www.acme.com/*)", GET )
```

This provides a very powerful model because it allows operators to let a group of bundles closely collaborate without requiring ad hoc namespaces for services, packages, and bundles. Using the signer or location as the target for a permission, will allow the maintenance of the permission management to be significantly reduced. It is not necessary to configure for individual bundles: the signer or location is effectively used as a grouping mechanism.

The filter can contain the following keys:

- *id* - The bundle ID of a bundle. For example:
(id=256)
- *location* - The location of a bundle. Filter wildcards for Strings are supported, allowing the value to specify a set of bundles. For example:

(location=https://www.acme.com/download/*)

- *signer* - A Distinguished Name chain. See *Certificate Matching* on page 27 for more information how Distinguished Names are matched. Wildcards in a DN are not matched according to the filter string rules, but according to the rules defined for a DN chain. The wildcard asterisk ('*' \u002A) must be escaped with a reverse solidus ('\ \u005C) to avoid being interpreted as a filter wildcard. For example:

(signer=*,o=ACME,c=NL)

- *name* - The symbolic name of a bundle. Filter wildcards for Strings are supported allowing the value to specify a set of bundles. A single symbolic name may also map to a set of bundles. For example:

(name=com.acme.*)

The name parameter of the permission can also be a single wildcard asterisk ('*' \u002A). In that case all bundles must match.

2.4.2.1

Multiple Signers

A bundle can be signed by multiple signers, in that case the signer will match against any of the signers' DN. Using multiple signers is both a feature as well as it is a possible threat. From a management perspective it is beneficial to be able to use signatures to handle the grouping. However, it could also be used to maliciously manage a trusted bundle.

For example a trusted bundle signed by T, could later have a signature added by an untrusted party U. This will grant the bundle the permissions of both T and U, which ordinarily is a desirable feature. However, If the permissions associated with signer U also allow the management of bundles signed by U, then U could unexpectedly gain the permission to manage this trusted bundle. For example, it could now start and stop this trusted bundle. This unexpected effect of becoming eligible to be managed should be carefully considered when multiple signers are used. The deny policies in Conditional Permission Admin can be used to prevent this case from causing harm.

2.5 References

- [1] *RFC 2253 Lightweight Directory Access Protocol (v3): UTF-8 String Representation of Distinguished Names*
<http://www.ietf.org/rfc/rfc2253.txt>
- [2] *X.509 Certificates*
<http://www.ietf.org/rfc/rfc2459.txt>
- [3] *Java Security Architecture*
<https://docs.oracle.com/javase/8/docs/technotes/guides/security/spec/security-spec.doc.html>
- [4] *Java Package Versioning Specification*
<https://docs.oracle.com/javase/8/docs/technotes/guides/versioning/index.html>
- [5] *Manifest Format*
https://docs.oracle.com/javase/8/docs/technotes/guides/jar/jar.html#JAR_Manifest
- [6] *Secure Hash Standard*
<http://csrc.nist.gov/publications/fips/fips180-4/fips-180-4.pdf>
- [7] *RFC 1421 Privacy Enhancement for Internet Electronic Mail*
<http://www.ietf.org/rfc/rfc1421.txt>
- [8] *DSA*
<http://www.itl.nist.gov/fipspubs/fip186.htm>

- [9] *RSA*
<http://www.ietf.org/rfc/rfc2313.txt> which is superseded by <http://www.ietf.org/rfc/rfc2437.txt>
- [10] *Public Key Cryptography Standard #7*
<http://www.rsasecurity.com/rsalabs/node.asp?id=2129>
- [11] *Unicode Normalization UAX # 15*
<http://www.unicode.org/reports/tr15/>
- [12] *Understanding and Deploying LDAP Directory Services*
ISBN 1-57870-070-1

2.6 Changes

- Updated references to current URLs.
- Removed MD5 and added SHA-256 digest algorithms.
- Added Package Permission IMPORT for java.* to the implied permissions. See *Implied Permissions* on page 29.

3 Module Layer

Version 1.9

3.1 Introduction

The standard Java platform provides only limited support for packaging, deploying, and validating Java-based applications and components. Because of this, many Java-based projects, such as JBoss and NetBeans, have resorted to creating custom module-oriented layers with specialized class loaders for packaging, deploying, and validating applications and components. The OSGi Framework provides a generic and standardized solution for Java modularization.

3.2 Bundles

The Framework defines a unit of modularization, called a *bundle*. A bundle is comprised of Java classes and other resources, which together can provide functions to end users. Bundles can share Java *packages* among an *exporter* bundle and an *importer* bundle in a well-defined way. In the OSGi framework, bundles are the only entities for deploying Java-based applications.

A bundle is deployed as a Java Archive (JAR) file. JAR files are used to store applications and their resources in a standard ZIP-based file format. This format is defined by [9] *Zip File Format*. Bundles normally share the Java Archive extension of `.jar`. However, there is a special MIME type reserved for OSGi bundles that can be used to distinguish bundles from normal JAR files. This MIME type is:

```
application/vnd.osgi.bundle
```

The type is defined in [15] *OSGi IANA Mime Type*.

A bundle is a JAR file that:

- Contains the resources necessary to provide some functionality. These resources may be class files for the Java programming language, as well as other data such as HTML files, help files, icons, and so on. A bundle JAR file can also embed additional JAR files that are available as resources and classes. This is however not recursive.
- Contains a manifest file describing the contents of the JAR file and providing information about the bundle. This file uses headers to specify information that the Framework needs to install correctly and activate a bundle. For example, it states dependencies on other resources, such as Java packages, that must be available to the bundle before it can run.
- Can contain optional documentation in the OSGI-OPT directory of the JAR file or one of its sub-directories. Any information in this directory is optional. For example, the OSGI-OPT directory is useful to store the source code of a bundle. Management systems may remove this information to save storage space in the OSGi framework.
- Can be a multi-release JAR. See *Multi-release JAR* on page 41.

Once a bundle is resolved, its functionality is provided to other bundles installed in the OSGi framework.

3.2.1 Bundle Manifest Headers

A bundle can carry descriptive information about itself in the manifest file that is contained in its JAR file under the name of META-INF/MANIFEST.MF.

The Framework defines OSGi manifest headers such as Export-Package and Bundle-ClassPath, which bundle developers use to supply descriptive information about a bundle. Manifest headers must strictly follow the rules for manifest headers as defined in [10] *Manifest Format*.

A Framework implementation must:

- Process the main section of the manifest. Individual sections of the manifest are only used during bundle signature verification.
- Ignore unrecognized manifest headers. The bundle developer can define additional manifest headers as needed.
- Ignore unknown attributes and directives.

All specified manifest headers are listed in the following sections. All headers are optional, unless specifically indicated.

3.2.1.1 Bundle-ActivationPolicy: lazy

The Bundle-ActivationPolicy specifies how the framework should activate the bundle once started. See *Activation Policies* on page 117.

3.2.1.2 Bundle-Activator: com.acme.fw.Activator

The Bundle-Activator header specifies the name of the class used to start and stop the bundle. See *Starting Bundles* on page 115.

3.2.1.3 Bundle-Category: osgi, test, nursery

The Bundle-Category header holds a comma-separated list of category names.

3.2.1.4 Bundle-ClassPath: /jar/http.jar.

The Bundle-ClassPath header defines a comma-separated list of JAR file path names or directories (inside the bundle) containing classes and resources. The full stop ('.' \u002E) specifies the root directory of the bundle's JAR. The full stop is also the default. See *Bundle Class Path* on page 67.

3.2.1.5 Bundle-ContactAddress: 2400 Oswego Road, Austin, TX 74563

The Bundle-ContactAddress header provides the contact address of the vendor.

3.2.1.6 Bundle-Copyright: OSGi (c) 2002

The Bundle-Copyright header contains the copyright specification for this bundle.

3.2.1.7 Bundle-Description: Network Firewall

The Bundle-Description header defines a short description of this bundle.

3.2.1.8 Bundle-Developers: pkriens; email=pkriens@osgi.org; name="Peter Kriens"; organization="OSGi Alliance"

The Bundle-Developers header provides an optional machine readable form of information about the developers of the bundle. This header is purely informational and must not be processed by the OSGi Framework.

The syntax for this header is as follows:

```
Bundle-Developers ::= developer ( ',' developer ) *
developer         ::= identifier ( ';' developer-attr ) *
```

```

identifier      ::= argument
developer-attr ::= email | name | organization |
                 organization-url | roles | timezone
email           ::= 'email' '=' <email>
name           ::= 'name' '=' argument
organization    ::= 'organization' '=' argument
organization-url ::= 'organizationUrl' '=' <url>
roles          ::= 'roles' '=' argument
timezone       ::= 'timezone' '=' argument

```

This header has the following attributes:

- email - (optional) The email address of the developer.
- name - (optional) The name of the developer.
- organization - (optional) The name of the organization of the developer.
- organization-url - (optional) The URL for the organization of the developer.
- roles - (optional) The roles of the developer. This is a comma separated list of role names.
- timezone - (optional) The time zone of where the developer resides. The time zone can be an id such as America/New_York or a numerical offset in hours from UTC.

See [26] *Maven POM Reference, Developers* for more information. Tools can use the information in this header for POM generation.

3.2.1.9 Bundle-DocURL: <http://www.example.com/Firewall/doc>

The Bundle-DocURL headers must contain a URL pointing to documentation about this bundle.

3.2.1.10 Bundle-Icon: [/icons/acme-logo.png](#);size=64

The optional Bundle-Icon header provides a list of URLs to icons representing this bundle in different sizes. The following attribute is permitted:

- size - (integer) Specifies the size of the icon in pixels horizontal. It is recommended to always include a 64x64 icon.

The URLs are interpreted as relative to the bundle. That is, if a URL with a scheme is provided, then this is taken as an absolute URL. Otherwise, the path points to an entry in the JAR file, taking any attached fragments into account. Implementations that want to use this header should at least support the Portable Network Graphics (PNG) format, see [18] *Portable Network Graphics (PNG) Specification (Second Edition)*.

3.2.1.11 Bundle-License: Apache-2.0; link="http://opensource.org/licenses/apache2.0.php"

The Bundle-License header provides an optional machine readable form of license information. The purpose of this header is to automate some of the license processing required by many organizations like for example license acceptance before a bundle is used. The header is structured to provide the use of unique license naming to merge acceptance requests, as well as links to human readable information about the included licenses. This header is purely informational for management agents and must not be processed by the OSGi Framework.

The syntax for this header is as follows:

```

Bundle-License ::= '<<EXTERNAL>>' |
                 ( license ( ',' license ) * )
license        ::= license-identifier ( ';' license-attr ) *
license-attr   ::= description | link
description    ::= 'description' '=' string

```

```
link ::= 'link' '=' <url>
```

This header has the following attributes:

- `license-identifier` - Provides a globally unique identifier for this license, preferably world wide, but it should at least be unique with respect to the other clauses. The magic identifier `<<EXTERNAL>>` is used to indicate that this artifact does not specify any license information but that licensing information is provided in some other way. This is also the default value of this header.

This identifier should be one of the identifiers defined by [25] *Software Package Data Exchange (SPDX) License List*. Clients of this bundle can assume that licenses with the same identifier refer to the same license. This can for example be used to minimize the click through licenses.

Alternatively, the identifier can be the canonical URL of the license, it must not be localized by the translator. This URL does not have to exist but must not be used for later versions of the license. It is recommended to use URLs from [19] *Open Source Initiative*. Other licenses should use the following structure, but this is not mandated:

```
http://<domain-name>/licenses/
    <license-name>-<version>.<extension>
```

- `description` - (optional) Provide the description of the license. This is a short description that is usable in a list box on a UI to select more information about the license.
- `link` - (optional) Provide a URL to a page that defines or explains the license. If this link is absent, the `name` field is used for this purpose. The URL is relative to the root of the bundle. That is, it is possible to refer to a file inside the bundle.

If the `Bundle-License` statement is absent, then this does not mean that the bundle is not licensed. Licensing could be handled outside the bundle and the `<<EXTERNAL>>` form should be assumed. This header is informational and may not have any legal bearing. Consult a lawyer before using this header to automate licensing processing.

3.2.1.12 **Bundle-Localization: OSGI-INF/l1on/bundle**

The `Bundle-Localization` header contains the location in the bundle where localization files can be found. The default value is `OSGI-INF/l1on/bundle`. Translations are by default therefore `OSGI-INF/l1on/bundle_de.properties`, `OSGI-INF/l1on/bundle_nl.properties`, etc. See *Manifest Localization* on page 83.

3.2.1.13 **Bundle-ManifestVersion: 2**

The `Bundle-ManifestVersion` header defines that the bundle follows the rules of this specification. The `Bundle-ManifestVersion` header determines whether the bundle follows the rules of this specification. It is 1 (the default) for Release 3 Bundles, 2 for Release 4 and later. Future version of the OSGi framework can define higher numbers for this header.

3.2.1.14 **Bundle-Name: Firewall**

The `Bundle-Name` header defines a readable name for this bundle. This should be a short, human-readable name that can contain spaces.

3.2.1.15 **Bundle-NativeCode: /lib/http.DLL; osname = QNX; osversion = 3.1**

The `Bundle-NativeCode` header contains a specification of native code libraries contained in this bundle. See *Loading Native Code Libraries* on page 76.

3.2.1.16 **Bundle-RequiredExecutionEnvironment: CDC-1.0/Foundation-1.0**

The `Bundle-RequiredExecutionEnvironment` contains a comma-separated list of execution environments that must be present on the OSGi framework. See *Execution Environment* on page 48. This header is deprecated.

3.2.1.17 Bundle-SCM: url=https://github.com/bndtools/bnd, connection=scm:git:https://github.com/bndtools/bnd.git, developerConnection=scm:git:git@github.com:bndtools/bnd.git

The Bundle-SCM header provides an optional machine readable form of information about the source code of the bundle. This header is purely informational and must not be processed by the OSGi Framework.

The syntax for this header is as follows:

```
Bundle-SCM          ::= scm-attr ( ',' scm-attr ) *
scm-attr            ::= url | connection | developer-connection | tag
url                 ::= 'url' '=' <url>
connection          ::= 'connection' '=' <uri>
developer-connection ::= 'developerConnection' '=' <uri>
tag                 ::= 'tag' '=' argument
```

This header has the following attributes:

- url - (optional) The URL to browse the source code repository.
- connection - (optional) The scm: URI for read access to the source code repository.
- developer-connection - (optional) The scm: URI for write access to the source code repository.
- tag - (optional) The tag within the source code repository.

See [27] *Maven POM Reference*, SCM for more information. Tools can use the information in this header for POM generation.

3.2.1.18 Bundle-SymbolicName: com.acme.daffy

The Bundle-SymbolicName header specifies a non-localizable name for this bundle. The bundle symbolic name together with a version must identify a unique bundle though it can be installed multiple times in a framework. The bundle symbolic name should be based on the reverse domain name convention, see *Bundle-SymbolicName* on page 53. This header must be set.

3.2.1.19 Bundle-UpdateLocation: http://www.acme.com/Firewall/bundle.jar

The Bundle-UpdateLocation header specifies a URL where an update for this bundle should come from. If the bundle is updated, this location should be used, if present, to retrieve the updated JAR file.

3.2.1.20 Bundle-Vendor: OSGi Alliance

The Bundle-Vendor header contains a human-readable description of the bundle vendor.

3.2.1.21 Bundle-Version: 1.1

The Bundle-Version header specifies the version of this bundle. See *Version* on page 38. The default value is 0.0.0

3.2.1.22 DynamicImport-Package: com.acme.plugin.*

The DynamicImport-Package header contains a comma-separated list of package names that should be dynamically imported when needed. See *Dynamic Import Package* on page 69.

3.2.1.23 Export-Package: org.osgi.util.tracker;version=1.3

The Export-Package header contains a declaration of exported packages. See *Export-Package* on page 55.

3.2.1.24 Export-Service: org.osgi.service.log.LogService

Deprecated.

3.2.1.25 Fragment-Host: org.eclipse.swt; bundle-version="[3.0.0,4.0.0]"

The Fragment-Host header defines the host bundles for this fragment. See *Fragment-Host* on page 88

3.2.1.26 Import-Package: org.osgi.util.tracker,org.osgi.service.io;version=1.4

The Import-Package header declares the imported packages for this bundle. See *Import-Package* on page 54.

3.2.1.27 Import-Service: org.osgi.service.log.LogService

Deprecated

3.2.1.28 Provide-Capability: com.acme.dict; from=nl; to=de; version:Version=1.2

Specifies that a bundle provides a set of Capabilities, see *Dependencies* on page 42.

3.2.1.29 Require-Bundle: com.acme.chess

The Require-Bundle header specifies that all exported packages from another bundle must be imported, effectively requiring the public interface of another bundle. See *Require-Bundle* on page 84

3.2.1.30 Require-Capability: osgi.ee; filter="(&(osgi.ee=AcmeMin)(version=1.1))"

Specifies that a bundle requires other bundles to provide a capability, see *Dependencies* on page 42.

3.2.2 Custom Headers

The manifest is an excellent place to provide metadata belonging to a bundle. This is true for the OSGi Alliance but it is also valid for other organizations. For historic reasons, the OSGi Alliance claims the default namespace, specifically headers that indicate OSGi related matters like names that contain Bundle, Import, Export, etc. Organizations that want to use headers that do not clash with OSGi Alliance defined names or bundle header names from other organizations should prefix custom headers with x-, for example x-LazyStart.

Organizations external to the OSGi Alliance can request header names in the OSGi namespace. The OSGi Alliance maintains a registry of such names at [16] *OSGi Header Registry*.

The [Header](#) annotation can be used on a class or package to specify a header for a bundle. This annotation can be processed by bundle assembly tools to generate the specified header information in the bundle's manifest.

3.2.3 Header Value Syntax

Each Manifest header has its own syntax. In all descriptions, the syntax is defined with [11] *W3C EBNF*. These following sections define a number of commonly used terminals.

3.2.4 Common Header Syntax

Many Manifest header values share a common syntax. This syntax consists of:

```
header ::= clause ( ',' clause ) *
clause ::= path ( ';' path ) *
         ( ';' parameter ) *    // See 1.3.2
```

A parameter can be either a *directive* or an *attribute*. A directive is an instruction that has some implied semantics for the Framework. An attribute is used for matching and comparison purposes.

3.2.5 Version

Version specifications are used in several places. A version has the following grammar:

```

version      ::=
    major( '.' minor ( '.' micro ( '.' qualifier )? )? )?

major        ::= number                // See 1.3.2
minor        ::= number
micro        ::= number
qualifier    ::= ( alphanum | '_' | '-' )+

```

A version must not contain any white space. The default value for a version is o.o.o.

Versions are supported in the API with the [Version](#) class.

The [Version](#) annotation can be used in package-info.java source files to document the version of a package. This annotation can be processed by bundle assembly tools when generating the version information for a bundle's Export-Package manifest header.

3.2.6 Version Ranges

A version range describes a range of versions using a mathematical interval notation. See [12] *Mathematical Convention for Interval Notation*. The syntax of a version range is:

```

version-range ::= interval | atleast
interval      ::= ( '[' | '(' ) floor ',' ceiling ( ']' | ')' )
atleast       ::= version
floor         ::= version
ceiling       ::= version

```

If a version range is specified as a single version, it must be interpreted as the range [version,∞). The default for a non-specified version range is 0, which maps to [o.o.o,∞).

Note that the use of a comma in the version range requires it to be enclosed in double quotes. For example:

```

Import-Package: com.acme.foo;version="[1.23,2)", «
                com.acme.bar;version="[4.0, 5.0)"

```

In the following table, for each specified range in the left-hand column, a version x is considered to be a member of the range if the predicate in the right-hand column is true.

Table 3.1 Examples of version ranges

Example	Predicate
[1.2.3, 4.5.6)	1.2.3 <= x < 4.5.6
[1.2.3, 4.5.6]	1.2.3 <= x <= 4.5.6
(1.2.3, 4.5.6)	1.2.3 < x < 4.5.6
(1.2.3, 4.5.6]	1.2.3 < x <= 4.5.6
1.2.3	1.2.3 <= x

Version Ranges are supported in the API with the [VersionRange](#) class.

3.2.7 Filter Syntax

The OSGi specifications use filter expressions extensively. Filter expressions allow for a concise description of a *constraint*. The syntax of a filter string is based upon the string representation of LDAP search filters as defined in [5] *A String Representation of LDAP Search Filters*. It should be noted that RFC 2254: A String Representation of LDAP Search Filters supersedes RFC 1960, but only adds extensible matching and is not applicable to this OSGi Framework API.

The string representation of an LDAP search filter uses a prefix format and is defined by the following grammar:

```

filter      ::= '(' filter-comp ')'
filter-comp ::= and | or | not | operation
and         ::= '&' filter-list
or          ::= '|' filter-list
not         ::= '!' filter
filter-list ::= filter | filter filter-list
operation  ::= simple | present | substring
simple      ::= attr filter-type value
filter-type ::= equal | approx | greater-eq | less-eq
equal      ::= '='
approx     ::= '-='
greater-eq ::= '>='
less-eq    ::= '<='
present    ::= attr '*'
substring  ::= attr '=' initial any final
initial    ::= () | value
any        ::= '*' star-value
star-value ::= () | value '*' star-value
final      ::= () | value
value      ::= <see text>
attr       ::= <see text>

```

`attr` is a string representing an attribute key or name. Attribute names are not case sensitive; that is, `cn` and `CN` both refer to the same attribute. `attr` must not contain the characters `'='`, `'>'`, `'<'`, `'~'`, `'('` or `')'`. `attr` may contain embedded spaces but leading and trailing spaces must be ignored.

`value` is a string representing the value, or part of one, which will be compared against a value in the filtered properties.

If `value` must contain one of the characters reverse solidus (`'\'` \u005C), asterisk (`'*'` \u002A), parentheses open (`'('` \u0028) or parentheses close (`')'` \u0029), then these characters should be preceded with the reverse solidus (`'\'` \u005C) character. Spaces are significant in `value`. Space characters are defined by `Character.isWhiteSpace()`.

Although both the `substring` and `present` productions can produce the `attr=*` construct, this construct is used only to denote a presence filter.

The `substring` production only works for attributes that are of type `String`, `Collection of String` or `String[]`. In all other cases the result must be false.

The evaluation of the approximate match (`'-='`) filter type is implementation specific but should at least ignore case and white space differences. Codes such as `Soundex` or other smart *closeness* comparisons could be used.

Values specified in the filter are compared to values in the properties against which the filter is evaluated. The comparison of these values is not straightforward. Strings compare differently than numbers, and it is also possible for a property to have multiple values.

Property keys are case insensitive. The object class of the property's value defines the comparison type. The properties values should be of the following types:

Figure 3.1 Primary Property Types

```

type      ::= scalar | collection | array
scalar    ::= String | Integer | Long | Float
           | Double | Byte | Short
           | Character | Boolean
primitive ::= int | long | float | double | byte
           | short | char | boolean
array     ::= <Array of primitive>
           | <Array of scalar>
collection ::= <Collection of scalar>

```

The following rules apply for comparison:

- *String* - Use String comparison
- *Integer, Long, Float, Double, Byte, Short, Character objects and primitives* - Use numerical comparison. The value should be trimmed of any extraneous white space before the comparison.
- *Boolean objects* - Use comparison defined by `Boolean.valueOf(value).booleanValue()`. The value should be trimmed of any extraneous white space before this conversion is applied.
- *Array or Collection elements* - Comparison is determined by the object type of the element

Array and Collection elements may be a mix of scalar types. Array and Collection elements may also be null. If the type of the property value is not one of the above types, then it could be possible to create an instance of the above type. The following conversions must be tried in the given order:

1. A public static method on the required type called `valueOf` that returns an instance of the given type and takes a single String argument.
2. A public constructor taking a single String argument.

If one of these methods is available then the Framework must construct a temporary object by passing the value as the String argument. If the constructor/function is not directly accessible then the invocation should use the `setAccessible` method to make it accessible.

The resulting object must be used to compare with the property value according to the following comparison rules:

- *Comparable objects* - Comparison through the Comparable interface
- *Other objects* - Equality comparison

If none of the above comparison rules apply, then the result of the comparison is false.

A filter matches a property with multiple values if it matches at least one of those values. For example:

```

Dictionary dict = new Hashtable();
dict.put( "cn", new String[] { "a", "b", "c" } );

```

The dict will match against a filter with `(cn=a)` as well as `(cn=b)`.

Service properties are often defined to take a type, a collection of that type, or an array of that type. In those cases, a simple + will be suffixed to the type name. For example `String+`, indicates that a String, a `String[]`, and a `Collection<String>` are all valid forms.

Filters are supported in the API with the `Filter` type. Filters can be created with the `FrameworkUtil.createFilter(String)` method or the `BundleContext.createFilter(String)` method.

3.2.8 Multi-release JAR

A bundle JAR file can be a multi-release JAR. See [28] *Multi-release JAR File*. When a bundle is a multi-release JAR, that is, the manifest contains

Multi-Release: true

then the Framework must look for a supplemental manifest file, OSGI-INF/MANIFEST.MF, in the versioned directories. For example:

```
META-INF/versions/9/OSGI-INF/MANIFEST.MF
```

The Framework must first look in the versioned directory for the major version of the current Java platform and then prior versioned directories in descending order. The first supplemental manifest file found must be used and the Framework must replace the values of the following manifest headers in the manifest with the values of these headers, if present, in the supplemental manifest file.

- Import-Package
- Require-Capability

Any other headers in the supplemental manifest file must be ignored.

The Framework APIs which provide access to the bundle metadata, such as `getHeaders()` and `BundleRevision` and `BundleWiring`, must present the supplemented manifest information. That is, the main manifest with the replacement values from a supplemental manifest, if any, for the running Java platform version.

Both fragment bundles as well as non-fragment bundles can be multi-release JARs.

Support for multi-release JARs must only be active on Java 9 and later. On Java 8 and earlier, the JAR must be treated as a non-multi-release JAR.

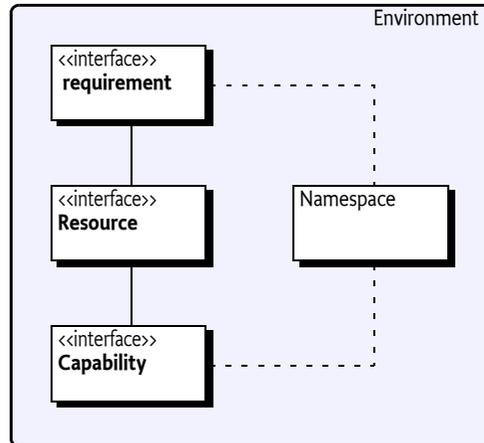
3.3 Dependencies

OSGi dependency handling is based on a very general model that describes the dependency relationships. This model consists of a small number of primitive concepts:

- *Environment* - A container or framework that installs Resources.
- *Resource* - An abstraction for an artifact that needs to become installed in some way to provide its intended function. A Bundle is modeled by a Resource but for example a display or secure USB key store can also be Resources.
- *Namespace* - Defines what it means for the Environment when a requirement and capability match in a given Namespace.
- *Capability* - Describing a feature or function of the Resource when installed in the Environment. A capability has attributes and directives.
- *Requirement* - An assertion on the availability of a capability in the Environment. A requirement has attributes and directives. The filter directive contains the filter to assert the attributes of the capability in the same Namespace.

The relations between these entities are depicted in Figure 3.2.

Figure 3.2 Core Requirement/Capability model



A Resource in general has dependencies on other Resources or can satisfy other Resource's dependencies. Dependency types can vary wildly, a Bundle can require packages from another Bundle (Import-Package), or a Fragment needs a host Bundle (Fragment-Host), or a Bundle requires access to a high resolution display. The OSGi Core specification demonstrates that it is possible to describe these varying types of dependencies with dedicated headers, optimized for each case. However, this model requires that every type of dependency will go through a specification process, limiting the usefulness for parties not participating in this process. Therefore, this specification provides a generic dependency model based on *Namespaces*. A Namespace is the *type* of a dependency. For example, the `osgi.wiring.package` Namespace defines the semantics for Import-Package and Export-Package headers by specifying a number of *attributes* and *directives*. Attributes are used for matching and directives provide information about the semantics of the Namespace. For example, in the case of the `osgi.wiring.host` Namespace (Fragments) the capability's attributes are:

- `osgi.wiring.host` - (String) The host's name.
- `bundle-version` - (Version) The host's version.
- * - Any other attributes are allowed.

The OSGi Framework Namespaces are defined in classes, see *Framework Namespaces Specification* on page 171.

The purpose of a Namespace is to create an attribute/directive based language that describes a dependency in a generic way unrelated to the specific dependency type. A number of Namespaces have been defined by the OSGi Alliance in this and other specifications. OSGi namespaces start with the reserved `osgi.` prefix. For example, the `osgi.ee` namespace defines a capability for specifying an execution environment. A Namespace can also be defined by other organizations and individuals. To minimize name clashes it is recommended to use the reverse domain name rule used for packages and bundle symbolic names. It is also recommended to register these Namespaces with the OSGi Alliance, see [17] *OSGi Namespace Registry* to prevent clashes.

Given a Namespace, it is possible to declare a *capability* of that Namespace. A capability provides the values for the attributes and directives defined in the Namespace. For example, it is possible to translate the Export-Package header to a capability in the `osgi.wiring` package Namespace.

Given a capability, it is possible to specify a *requirement*. A requirement has a filter that can match the attributes of the capability, if so, the requirement is *satisfied*. Requirements are always associated with a given Namespace, like the capability, and can therefore only be *satisfied* by Capabilities in the same Namespace. A requirement is satisfied when its filter, as specified with the filter directive, matches a capability's attributes. The filter language specification can be found in *Filter Syntax*

on page 39. A requirement can be *mandatory* or *optional*, as set with its resolution directive. A requirement can have single or multiple cardinality, indicating it requires at least one or more Capabilities.

A Resource that declares requirements can only provide its intended functionality when its mandatory requirements are satisfied by one or more Capabilities, which in general means they come from other Resources. A Resource that has all its mandatory requirements satisfied is said to be *resolved* and must provide the functionality described by its Capabilities. A capability can only satisfy a requirement if its Resource is resolved.

The process of matching up requirements to capabilities is called *resolving*. In this process, the resolver must create *Wires* that link requirements to Capabilities. Both the Wire and the requirement/ Capability have a reference to a Resource. In certain cases the requirement/ capability can be declared in one Resource but wired from another Resource. Therefore, a requirement/ capability can have a *declared* Resource, which is the Resource that declares it. However, when a Resource is *wired* the Wire has a *provider* or *requirer* Resource which can differ from the corresponding declared Resource. When the declared Resource differs from the provider/requirer it is called *hosting*. This separation is caused by Fragments; with Fragments some requirements and Capabilities are hosted and others remain part of the Fragment.

Only requirements that are *effective* must be wired. Each requirement is intended for a certain state of the system. For example, the OSGi Framework only resolves requirements when the requirement has the effective directive set to resolve.

Once a set of Resources are resolved the Environment, for example the OSGi Framework for bundles, creates a *Wiring* per Resource to hold the resolved state. This state includes the Wires as well as all Capabilities and requirements, regardless if they are wired or not.

The Wires between a requirement and a capability must be created according to the semantics implied by their Namespace. The Wires coming out of a resolve operation can be used during run time as specified in their Namespace. For example, the `osgi.wiring.*` Namespaces are used to control the Class Loading, see *Bundle Wiring API Specification* on page 157. However, they can also serve other purposes as outlined by their Namespace. For example, a Wire could specify a Dependency Injection source and target.

Interfaces for the generic model are defined in *Resource API Specification* on page 151. The *Bundle Wiring API Specification* on page 157 chapter describes the Wiring API that is based on this generic package. The generic API is intended for other specifications that want to be compatible with the generic OSGi Core framework's Capability /Requirement model.

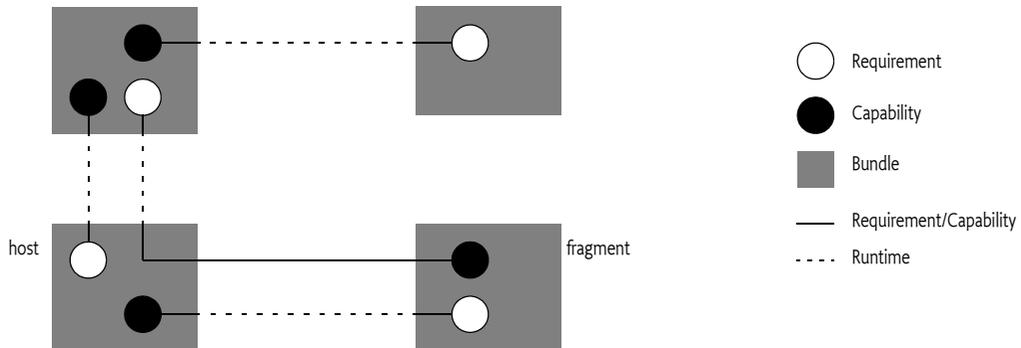
3.3.1

Bundles

All bundles depend on one or more external entities and this is expressed as requirements and Capabilities. Once a bundle is resolved, it assumes that those dependencies are *satisfied*. The Require-Capability and Provide-Capability headers are manifest headers that *declare* generic requirements and Capabilities in any Namespace. However, a number of manifest headers in the OSGi specifications are actually requirements on Capabilities specified by other OSGi manifest headers. For example, an Import-Package clause is a requirement on the capability specified by an Export-Package clause. The attributes on an Import-Package clause are treated as assertions on the attributes of the corresponding Export-Package clause. This specification therefore contains a number of Namespaces for these OSGi manifest headers: `osgi.wiring.bundle`, `osgi.wiring.package`, and `osgi.wiring.host`. These namespaces influence the resolver and define the class loading process. For example, a Require-Bundle clause is a requirement that ensures that the exported packages of the required bundle are available to the requirer's class loader.

The OSGi resolving process is described in *Resolving Process* on page 65. The diagramming technique of the Requirement/Capability model is depicted in Figure 3.3, the details of the wiring are further explained in *Bundle Wiring API Specification* on page 157.

Figure 3.3 Requirements and Capabilities and their Wiring



3.3.2 Example Use Case

A bundle has Windows 7 specific Java code and requires a display that has a resolution of at least 1000x1000 pixels. It also relies on a bundle providing an IP-number-to-location table.

These dependencies on the environment and another bundle can be expressed with the requirement header in the bundle as follows:

```
Require-Capability:
  com.microsoft; filter="(&(api=win32) (version=7))",
  com.acme.display; filter="(&(width>=1000) (height>=1000))",
  com.acme.ip2loc
```

Each clause lives in a namespace, for example com.microsoft. A namespace defines the semantics of the attributes as well as optional rules.

The deployer of the environment sets the following launching property when starting the framework:

```
org.osgi.framework.system.capabilities.extra= «
  com.acme.display; width:Long=1920; height:Long=1080; interlace=p, «
  com.microsoft; edition=home; version:Version=7; api=win32
```

The framework will be able to satisfy the display requirement but it cannot satisfy the ip2loc table requirement. The deployer can then install the bundle with the ip2loc table. This bundle specifies the following header:

```
Provide-Capability: com.acme.ip2loc; version:Version=1.2
```

After installing and resolving this bundle, the framework can resolve the original bundle because there is now a provider of the ip2loc table.

3.3.3 Bundle Capabilities

A generic capability for a Bundle is defined with the Provide-Capability header. This header has the following syntax:

```
Provide-Capability ::= capability (',' capability)*
capability         ::= name-space
                   ( ';' directive | typed-attr)*
name-space        ::= symbolic-name
typed-attr       ::= extended ( ':' type)? '=' argument
type              ::= scalar | list
```

```

scalar          ::= 'String' | 'Version' | 'Long'
                  | 'Double'
list           ::= 'List' ( '<' scalar '>' )?

```

The [Capability](#) annotation can be used on a class or package to specify a capability to be provided by the bundle. This annotation can be processed by bundle assembly tools to add the capability to the Provide-Capability header in the bundle's manifest.

The header has the following directives architected:

- `effective` - (resolve) Specifies the time a capability is available, either `resolve` (default) or another name. The OSGi framework resolver only considers Capabilities without an `effective` directive or `effective:=resolve`. Capabilities with other values for the `effective` directive can be considered by an external agent.
- `uses` - The `uses` directive lists package names that are used by this capability. This information is intended to be used for `uses` constraints, see *Package Constraints* on page 60.

Namespaces can define additional directives and attributes.

3-3-4 Bundle Capability Attributes

Attributes can be *typed*. Typing is important because it defines how attributes compare. Comparing two versions as strings does not provide the proper comparison semantics for versions. In similar vein, lexicographical ordering is different than numeric ordering.

Types are specified between the attribute name and the equal sign (`'=' \u003D`), the separator is a colon (`':' \u003A`). For example, for a `Long`:

```
attr:Long=24
```

If no type is specified, the `String` type is assumed.

The parsing rules of the corresponding type's `String` constructor are then used to create a new instance that is placed in the capability's map. Numeric types must trim white space around the value, for other types spaces around the argument are not ignored, however, white space is skipped by the manifest parsing rules. That is:

```

attr:Long=      23      ,           //ok
attr:Version="  23     ",         // error
attr:Long="     23     ",         // ok, because numeric

```

Multi-valued attributes can be constructed with the `List` type. The `List` type can specify a scalar type for the list elements. If no element type is specified, `String` is assumed. Parsing of the corresponding argument list must be done according to the following rules:

- Element values in the list are separated by commas (`',' \u002C`).
- White space around an element value must be trimmed for non-`String` element types.
- Commas or reverse solidi (`'\ ' \u005C`) that are part of an element value must be escaped by prefixing them with a reverse solidus. In practice, this requires escaping with two reverse solidi because a reverse solidus must already be escaped in strings.

The whole argument must be surrounded by quotes because the comma is a significant token in the manifest grammar.

The version attribute requires the `Version` type to be specified to be compared as a `Version` rather than as a `String`:

```
version:Version=1.23
```

For example:

```
Provide-Capability: «
  com.acme.dictionary; from:String=nl; to=de; version:Version=3.4, «
  com.acme.dictionary; from:String=de; to=nl; version:Version=4.1, «
  com.acme.ip2location; country:List="nl,be,fr,uk"; version:Version=1.3, «
  com.acme.seps;          tokens:List<String>="\\,.,;\\\""
```

3.3.5 System Bundle Capabilities

Capabilities can also be provided by the system bundle by specifying the following launch properties:

```
org.osgi.framework.system.capabilities
org.osgi.framework.system.capabilities.extra
```

The format for these system properties is identical to the Provide-Capability header. A framework must parse these properties and use them in the resolving process as if provided by the system bundle.

There are two properties so that the framework can specify its default Capabilities in `org.osgi.framework.system.capabilities` while the deployer can specify specific deployment Capabilities in the `org.osgi.framework.system.capabilities.extra` system property. Frameworks can often deduce many Capabilities from their environment.

The following is an example capability header for the system bundle as defined by the deployer:

```
map.put("org.osgi.framework.system.capabilities.extra",
  "com.acme.screen; width:Long=640; height:Long=480; card=GeForce");
```

3.3.6 Bundle Requirements

The Bundle's Require-Capability header has the following grammar:

```
Require-Capability ::= requirement ( ',' requirement ) *
requirement        ::= name-space ( ';' directive | typed-attr ) *
```

Requirements have attributes that can be set with the Require-Capability header. The purpose of these attributes are to provide further information about the requirement; they are not assertions as they are in the Import-Package, Require-Bundle, and Fragment-Host headers. The attributes of these headers are mapped to the filter directive in their corresponding namespaces.

The [Requirement](#) annotation can be used on a class or package to specify a capability to be required by the bundle. This annotation can be processed by bundle assembly tools to add the requirement to the Require-Capability header in the bundle's manifest.

The following directives are architected for the Require-Capability header:

- **effective** - (resolve) Specifies the time a requirement is considered, either resolve (default) or another name. The OSGi framework resolver only considers requirements without an effective directive or `effective:=resolve`. Other requirements can be considered by an external agent. Additional names for the effective directive should be registered with the OSGi Alliance.
- **resolution** - (mandatory|optional) A mandatory requirement forbids the bundle to resolve when the requirement is not satisfied; an optional requirement allows a bundle to resolve even if the requirement is not satisfied. No wirings are created when this requirement cannot be resolved, this can result in Class Not Found Exceptions when the bundle attempts to use a package that was not resolved because it was optional. The default is mandatory.
- **filter** - (Filter) A filter expression that is asserted on the Capabilities belonging to the given namespace. The matching of the filter against the capability is done on one capability at a time. A fil-

ter like `(&(a=1)(b=2))` matches only a capability that specifies both attributes at the required value, not two capabilities that each specify one of the attributes correctly. A filter is optional, if no filter directive is specified the requirement always matches. The attribute names in the filter expression are used to locate capability attributes in a case sensitive manner.

- cardinality - (single|multiple) Indicates if the requirement can be wired a single time or multiple times. The default is single.

Additional directives are ignored during resolving. Attributes on the requirement clause are also ignored.

3.4 Execution Environment

The Java environment provides all packages in the `java.*` namespace. Prior to Java SE 9, this namespace was not well defined and could be different for different runtime environments. For example, Java SE 5 is not equal to Java SE 7 and an Android environment has substantial differences to a Java SE environment. However, Java SE 6 is backward compatible for Java SE 5, Java SE 1.4, Java SE 1.3 and Java SE 1.2. That is, applications written for Java SE 1.3 must run unchanged on a Java SE 5 environment.

These differences and backward compatibilities can not be captured using versions because they are *variations*. For example, [22] *Google Android* is a variation of a Java SE 5 environment, as is [23] *Google App Engine* and [24] *Google Web Toolkit*. All these variations have a different set of packages, types, and methods in the `java.*` namespace.

Starting in Java SE 9, the platform has been modularized and its packages organized into a set of modules. Depending upon how the platform is configured for execution, some modules and their contained packages may not be present at runtime. However, Java SE 9 provides a standard way to interrogate the Java platform for the packages currently available at runtime. Therefore, the Framework must set the `org.osgi.framework.system.packages` launching property, see *Launching Properties* on page 102, to the list of Java platform packages currently available at runtime.

For Java platform versions prior to Java SE 9, the Framework must also set the `org.osgi.framework.system.packages` launching property to the list of Java platform packages generally known to be available at runtime. Since there is no standard way to interrogate the Java platform for the packages currently available at runtime, a Framework implementation may use a pre-defined list of packages for the Java platform version.

In addition to specifying the version of the execution environment via an `osgi.ee` requirement, see *osgi.ee Namespace* on page 172, a Bundle may also import `java.*` packages using the `Import-Package` header. Imports of `java.*` packages by a bundle will be used during the resolution process, see *Resolving Process* on page 65, to ensure the bundle has visibility to the requested packages by wiring the bundle's import of a `java.*` package to the export of the `java.*` package by the Framework's system bundle. However, a bundle always loads classes in `java.*` packages via parent delegation. See *Parent Delegation* on page 70. Therefore, a bundle is not required to import a `java.*` package to have visibility to the classes in the package, if the package is present in the current runtime. It only needs to import a `java.*` package to have the resolution process ensure the package is available from the execution environment. This can avoid a `NoClassDefFoundError` during execution of the bundle due to a missing `java.*` package required by the bundle.

3.4.1 Bundle-RequiredExecutionEnvironment

The `Bundle-RequiredExecutionEnvironment` manifest header provides the same function as the *osgi.ee Namespace* on page 172. It allows a bundle to depend on the execution environment. This header is deprecated but must be fully supported by a compliant framework. Bundles should not mix these headers but use either an `osgi.ee` requirement or this header. If both are used, both constraints must be met to resolve.

The syntax of this header is a list of comma-separated names of execution environments.

```
Bundle-RequiredExecutionEnvironment ::= ee-name ( ',' ee-name )*

ee-name ::= bree | <ee name>
bree ::= token ( '-' version )? ( '/' token ( '-' version )? )?
```

For example:

```
Bundle-RequiredExecutionEnvironment: CDC-1.0/Foundation-1.0, «
    OSGi/Minimum-1.1
```

If a bundle includes this header in the manifest then the bundle must only use methods with signatures that are contained within a proper subset of all mentioned execution environments. Bundles should list all (known) execution environments on which it can run the bundle.

A bundle can only resolve if the framework is running on a VM which implements one of the listed required execution environments. Frameworks should recognize that the current VM can implement multiple execution environments. For example, Java 6 is backward compatible with Java 5 and a bundle requiring the Java 6 execution environment must resolve on a Java 6 VM.

The Bundle-RequiredExecutionEnvironment header can not prevent a bundle from installing.

The `org.osgi.framework.executionenvironment` launching property defines the current execution environment with a comma separated list of execution environment names. If not set, the framework must provide an appropriate value. This property is also deprecated, its function is replaced with `org.osgi.framework.system.capabilities[.extra]`.

An example:

```
org.osgi.framework.executionenvironment =
    JavaSE-1.5, J2SE-1.4, JavaSE-1.4, JavaSE-1.3, OSGi/Minimum-1.1
```

Frameworks must convert a Bundle-RequiredExecutionEnvironment header to a requirement in the `osgi.ee` namespace when used in the Wiring API, see *Bundle Wiring API Specification* on page 157. Since the header uses opaque names for the execution environments there is no guaranteed algorithm to map the `ee-name` to a Require-Capability header. However, the suggested names so far for popular execution environments do have a structure that can be used to create such a header, this pattern was reflected in the `bree` term. The structure of the `bree` term for the existing recommendations is:

```
n1 ( '-' v )? ( '/' n2 ( '-' v )? )?
```

For example:

```
CDC-1.0/Foundation-1.0
OSGi/Minimum-1.2
J2SE-1.4
JavaSE-1.4
```

Each `bree` term that matches this pattern can thus be converted into an equivalent `osgi.ee` Require-Capability filter. First variable `n1` must be replaced with `JavaSE` when it is `J2SE` since the Require-Capability header uses a single name for the Java Standard Edition. The filter directive can then be constructed from `n1`, `v`, and `n2`. If `n2` is not defined or `v` is not defined then the parenthesized parts in which they participate are not used in the expansion.

```
bree-filter ::= '(&(osgi.ee=' n1 ( '/' n2 )? )' ( '(version=' v )' )? )'
```

If the bree term cannot be parsed into the given constituents then the filter must look like:

```
filter ::= '(osgi.ee=' <ee name> ')'
```

Some examples:

```
CDC-1.0/Foundation-1.0      (&(osgi.ee=CDC/Foundation) (version=1.0))
OSGi/Minimum-1.2          (&(osgi.ee=OSGi/Minimum) (version=1.2))
J2SE-1.4                   (&(osgi.ee=JavaSE) (version=1.4))
JavaSE-1.6                 (&(osgi.ee=JavaSE) (version=1.6))
AA/BB-1.7                  (&(osgi.ee=AA/BB) (version=1.7))
V1-1.5/V2-1.6             (osgi.ee=V1-1.5/V2-1.6)
MyEE-badVersion           (osgi.ee=MyEE-badVersion)
```

Each element of the Bundle-RequiredExecutionEnvironment is ORed together in the final osgi.ee requirement's filter directive. For example:

```
Bundle-RequiredExecutionEnvironment:
  CDC-1.0/Foundation-1.0,
  OSGi/Minimum-1.2,
  J2SE-1.4,
  JavaSE-1.6,
  AA/BB-1.7,
  V1-1.5/V2-1.6,
  MyEE-badVersion
```

This must be converted into the following Require-Capability:

```
Require-Capability:osgi.ee; filter="(|
  (&(osgi.ee=CDC/Foundation) (version=1.0))
  (&(osgi.ee=OSGi/Minimum) (version=1.2))
  (&(osgi.ee=JavaSE) (version=1.4))
  (&(osgi.ee=JavaSE) (version=1.6))
  (&(osgi.ee=AA/BB) (version=1.7))
  (osgi.ee=V1-1.5/V2-1.6)
  (osgi.ee=MyEE-badVersion)
)"
```

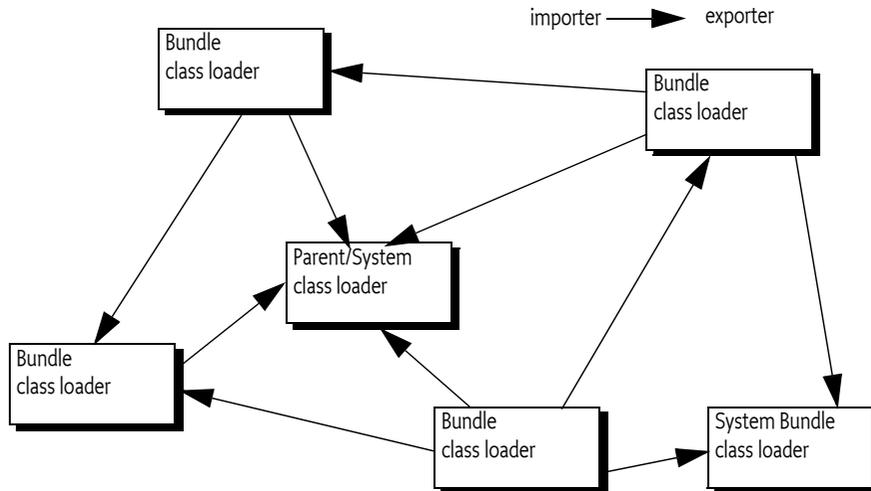
Every `org.osgi.resource.Resource` representing a Bundle which has a Bundle-RequiredExecutionEnvironment header must have the converted osgi.ee requirement in the list returned by [getRequirements\(String\)](#) for the osgi.ee namespace. In cases where the bundle already has a requirement for the osgi.ee namespace no merging is done, the bundle will simply have an additional osgi.ee requirement added.

3.5 Class Loading Architecture

Many bundles can share a single virtual machine (VM), see [1] *Java Virtual Machine Specification*. Within this VM, bundles can hide packages and classes from other bundles, as well as share packages with other bundles.

The key mechanism to hide and share packages is the Java *class loader* that loads classes from a subset of the bundle-space using well-defined rules. Each bundle has a single class loader. That class loader forms a class loading delegation network with other bundles as shown in Figure 3.4.

Figure 3.4 Delegation model



The class loader can load classes and resources from:

- *Boot class path* - The boot class path contains the `java.*` packages and its implementation packages.
- *Framework class path* - The Framework usually has a separate class loader for the Framework implementation classes as well as key service interface classes.
- *Bundle Space* - The bundle space consists of the JAR file that is associated with the bundle, plus any additional JAR that are closely tied to the bundle, like *fragments*, see *Fragment Bundles* on page 87.

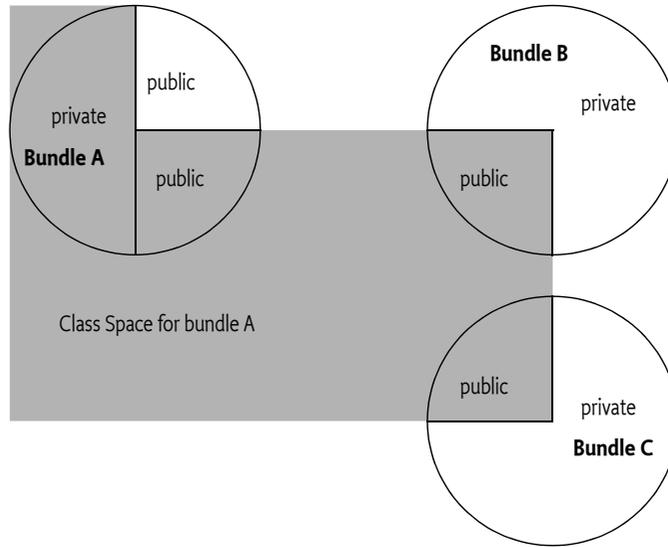
A *class space* is then all classes reachable from a given bundle's class loader. Thus, a class space for a given bundle can contain classes from:

- The parent class loader (normally `java.*` packages from the boot class path)
- Imported packages
- Required bundles
- The bundle's class path (*private packages*)
- Attached fragments

A class space must be consistent, such that it *never* contains two classes with the same fully qualified name (to prevent Class Cast Exceptions). However, separate class spaces in an OSGi Platform may contain classes with the same fully qualified name. The modularization layer supports a model where multiple versions of the same class are loaded in the same VM.

Figure 3.5 shows the class space for a Bundle A. The right top of Bundle A is not in the class space because it illustrates that sometimes packages inside a bundle are not accessible to the Bundle itself when an export is substituted.

Figure 3.5 Class Space



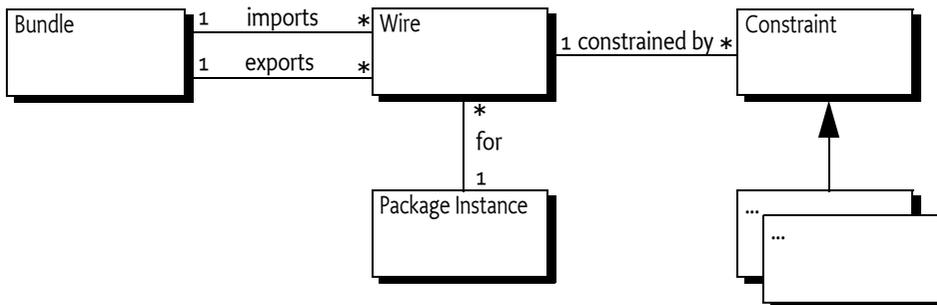
The Framework therefore has a number of responsibilities related to class loading. Before a bundle is used, it must resolve the constraints that a set of bundles place on the sharing of packages. Then select the best possibilities to create a *wiring*. See *Resolving Process* on page 65 for further information. The runtime aspects are described in *Runtime Class Loading* on page 67.

3.5.1 Resolving

The Framework must *resolve* bundles. Resolving is the process where any external dependencies are satisfied and then importers are *wired* to exporters. Resolving is a process of satisfying constraints; constraints that are provided by the *Dependencies* on page 42 section and constraints by the different manifest headers like Import/Export Package, Require-Bundle, and Fragment-Host. The resolving process must take place before any code from a bundle can be loaded or executed.

A *wire* is an actual connection between an *exporter* and an *importer*, which are both bundles. A wire is associated with a number of constraints that are defined by its importer's and exporter's manifest headers. A *valid* wire is a wire that has satisfied all its constraints. Figure 3.6 depicts the class structure of the wiring model. Not all constraints result in a wire.

Figure 3.6 Example class structure of wiring



3.6 Resolving Metadata

The following sections define the manifest headers that provide the metadata for the resolver.

3.6.1 Bundle-ManifestVersion

A bundle manifest must express the version of the OSGi manifest header syntax in the Bundle-ManifestVersion header. Bundles exploiting this version of the Framework specification (or later) must specify this header. The syntax of this header is as follows:

```
Bundle-ManifestVersion ::= number //See 1.3.2
```

The Framework bundle manifest version must be '2'. Bundle manifests written to previous specifications' manifest syntax are taken to have a bundle manifest version of '1', although there is no way to express this in such manifests. Therefore, any other value than 2 for this header is invalid unless the Framework explicitly supports such a later version.

OSGi Framework implementations should support bundle manifests without a Bundle-ManifestVersion header and assume Framework 1.2 compatibility at the appropriate places.

Version 2 bundle manifests must specify the bundle symbolic name. They need not specify the bundle version because the version header has a default value.

3.6.2 Bundle-SymbolicName

The Bundle-SymbolicName manifest header is a mandatory header. The bundle symbolic name and bundle version identify a unique bundle. This does not always imply that this pair is unique in a framework, in certain cases the same bundle can be installed multiple times in the same framework, see *Bundle Identifiers* on page 113.

A bundle gets its unique Bundle-SymbolicName from the developer. The Bundle-Name manifest header provides a human-readable name for a bundle and is therefore not replaced by this header.

The Bundle-SymbolicName manifest header must conform to the following syntax:

```
Bundle-SymbolicName ::= symbolic-name
                        ( ';' parameter ) * // See 1.3.2
```

The framework must recognize the following directives for the Bundle-SymbolicName header:

- **singleton** - Indicates that the bundle can only have a single version resolved in an environment. A value of true indicates that the bundle is a *singleton bundle*. The default value is false. The Framework must resolve at most one bundle when multiple versions of a singleton bundle with the same symbolic name are installed. Singleton bundles do not affect the resolution of non-singleton bundles with the same symbolic name.
- **fragment-attachment** - Defines how fragments are allowed to be attached, see the fragments in *Fragment Bundles* on page 87. The following values are valid for this directive:
 - **always** - (Default) Fragments can attach at any time while the host is resolved or during the process of resolving.
 - **never** - No fragments are allowed.
 - **resolve-time** - Fragments must only be attached during resolving.
- **mandatory** - Provide a list of mandatory attributes. If these attributes are not specifically used in the requirement (Require-Bundle, Fragment-Host) then this bundle must not match. See *Mandatory Attributes* on page 63.

The header allows the use of arbitrary attributes that can be required by the Require-Bundle and Fragment-Host headers. The following attribute is predefined:

- **bundle-version** - The value of the Bundle-Version header or 0 if no such header is present. Explicitly setting this attribute is an error.

For example:

```
Bundle-SymbolicName: com.acme.foo;singleton:=true
```

3.6.3 Bundle-Version

Bundle-Version is an optional header; the default value is o.o.o.

```
Bundle-Version ::= version // See 3.2.5
```

If the minor or micro version components are not specified, they have a default value of o. If the qualifier component is not specified, it has a default value of the empty string ("").

Versions are comparable. Their comparison is done numerically and sequentially on the major, minor, and micro components and lastly using the String class compareTo method for the qualifier.

A version is considered equal to another version if the major, minor, micro, and the qualifier components are equal (using String method compareTo).

Example:

```
Bundle-Version: 22.3.58.build-345678
```

3.6.4 Import-Package

The Import-Package header defines the constraints on the imports of shared packages. The syntax of the Import-Package header is:

```
Import-Package ::= import ( ' ' import ) *
import ::= package-names ( ' ; ' parameter ) *
package-names ::= package-name
                ( ' ; ' package-name ) * // See 1.3.2
```

The header allows many packages to be imported. An *import definition* is the description of a single package for a bundle. The syntax permits multiple package names, separated by semi-colons, to be described in a short form.

Import package directives are:

- resolution - Indicates that the packages must be resolved if the value is mandatory, which is the default. If mandatory packages cannot be resolved, then the bundle must fail to resolve. A value of optional indicates that the packages are optional. See *Optional Packages* on page 60.

The developer can specify arbitrary matching attributes. See *Attribute Matching* on page 63. The following arbitrary matching attributes are predefined:

- version - A version-range to select the exporter's package version. The syntax must follow *Version Ranges* on page 39. For more information on version selection, see *Semantic Versioning* on page 58. If this attribute is not specified, it is assumed to be [o.o.o, ∞).
- specification-version - This attribute is an alias of the version attribute only to ease migration from earlier versions. If the version attribute is present, the values must be equal.
- bundle-symbolic-name - The bundle symbolic name of the exporting bundle. In the case of a fragment bundle, this will be the host bundle's symbolic name.
- bundle-version - A version-range to select the bundle version of the exporting bundle. The default value is [o.o.o, ∞). See *Semantic Versioning* on page 58. In the case of a fragment bundle, the version is from the host bundle.

In order to be allowed to import a package, a bundle must have PackagePermission[<package-name>, IMPORT]. See PackagePermission for more information.

An error aborts an installation or update when:

- A directive or attribute appears multiple times, or
- There are multiple import definitions for the same package, or
- The version and specification-version attributes do not match.

Example of a correct definition:

```
Import-Package: com.acme.foo;com.acme.bar; «
    version="[1.23,1.24]"; «
    resolution:=mandatory
```

3.6.5 Export-Package

The syntax of the Export-Package header is similar to the Import-Package header; only the directives and attributes are different.

```
Export-Package ::= export ( ',' export)*
export         ::= package-names ( ';' parameter )*
package-names ::= package-name           // See 1.3.2
                ( ';' package-name )*
```

The header allows many packages to be exported. An *export definition* is the description of a single package export for a bundle. The syntax permits the declaration of multiple packages in one clause by separating the package names with a semi-colon. Multiple export definitions for the same package are allowed for example, when different attributes are needed for different importers. The [Export](#) annotation can be applied to a package to specify the package is to be exported. This annotation can be processed by bundle assembly tools to add the annotated package to the Export-Package header in the bundle's manifest.

Export directives are:

- *uses* - A comma-separated list of package names that are used by the exported package. Note that the use of a comma in the value requires it to be enclosed in double quotes. If this exported package is chosen as an export, then the resolver must ensure that importers of this package wire to the same versions of the package in this list. See *Package Constraints* on page 60.
- *mandatory* - A comma-separated list of attribute names. Note that the use of a comma in the value requires it to be enclosed in double quotes. A bundle importing the package must specify the mandatory attributes, with a value that matches, to resolve to the exported package. See *Mandatory Attributes* on page 63.
- *include* - A comma-separated list of class names that must be visible to an importer. Note that the use of a comma in the value requires it to be enclosed in double quotes. For class filtering, see *Class Filtering* on page 63.
- *exclude* - A comma-separated list of class names that must be invisible to an importer. Note that the use of a comma in the value requires it to be enclosed in double quotes. For class filtering, see *Class Filtering* on page 63.

The following attributes are part of this specification:

- *version* - The version of the named packages with syntax as defined in *Version* on page 38. It defines the version of the associated packages. The default value is o.o.o.
- *specification-version* - An alias for the version attribute only to ease migration from earlier versions. If the version attribute is present, the values must be equal.

Additionally, arbitrary matching attributes may be specified. See *Attribute Matching* on page 63.

The Framework will automatically associate each package export definition with the following attributes:

- `bundle-symbolic-name` - The bundle symbolic name of the exporting bundle. In the case of a fragment bundle, this is the host bundle's symbolic name.
- `bundle-version` - The bundle version of the exporting bundle. In the case of a fragment bundle, this is the host bundle's version.

An installation or update must be aborted when any of the following conditions is true:

- a directive or attribute appears multiple times
- the `bundle-symbolic-name` or `bundle-version` attribute is specified in the `Export-Package` header.

An export definition does not imply an automatic import definition. A bundle that exports a package and does not import that package will get that package via its bundle class path. Such an exported only package can be used by other bundles, but the exporting bundle does not accept a substitution for this package from another bundle.

In order to export a package, a bundle must have `PackagePermission[<package>, EXPORTONLY]`.

Example:

```
Export-Package: com.acme.foo;com.acme.bar;version=1.23
```

3.6.6 Importing Exported Packages

Bundles that collaborate require the same class loader for types used in the collaboration. If multiple bundles export packages with collaboration types then they will have to be placed in disjoint class-spaces, making collaboration impossible. Collaboration is significantly improved when bundles are willing to import exported packages; these imports will allow a framework to *substitute* exports for imports.

Though substitution is recommended to increase collaboration, it is not always possible. Importing exported packages can only work when those packages are pure API and not encumbered with implementation details. Import of exported packages should only be done when:

- The exported package does not use private packages. If an exported package uses private packages then it might not be substitutable and is therefore not clean API.
- There is at least one private package that references the exported package. If no such reference exist, there is no purpose in importing it.

In practice, importing exported packages can only be done with clean API-implementation separation. OSGi services are carefully designed to be as standalone as possible. Many libraries intertwine API and implementation in the same package making it impossible to substitute the API packages.

Importing an exported package must use a version range according to its compatibility requirements, being either a consumer or a provider of that API. See *Semantic Versioning* on page 58 for more information.

3.6.7 Interpretation of Legacy Bundles

Bundles that are not marked with a `Bundle-ManifestVersion` that equals 2 or more must treat the headers according the definitions in the Release 3. More specifically, the Framework must map the Release 3 headers to the appropriate Release 4 headers:

- *Import-Package* - An import definition must change the `specification-version` attribute to the `version` attribute. An import definition without a `specification-version` needs no replacement since the default version value of `0.0.0` gives the same semantics as Release 3.
- *Export-Package* - An export definition must change the `specification-version` attribute to the `version` attribute. The export definition must be appended with the `uses` directive. The `uses` directive must contain all imported and exported packages for the given bundle. Additionally, if

there is no import definition for this package, then an import definition for this package with the package version must be added.

- *DynamicImport-Package* - A dynamic import definition is unmodified.

A bundle manifest which mixes legacy syntax with bundle manifest version 2 syntax is in error and must cause the containing bundle to fail to install.

The `specification-version` attribute is a deprecated synonym for the `version` attribute in bundle manifest version 2 headers.

3.7 Constraint Solving

The OSGi Framework package resolver provides a number of mechanisms to match imports to exports. The following sections describe these mechanisms in detail.

3.7.1 Diagrams and Syntax

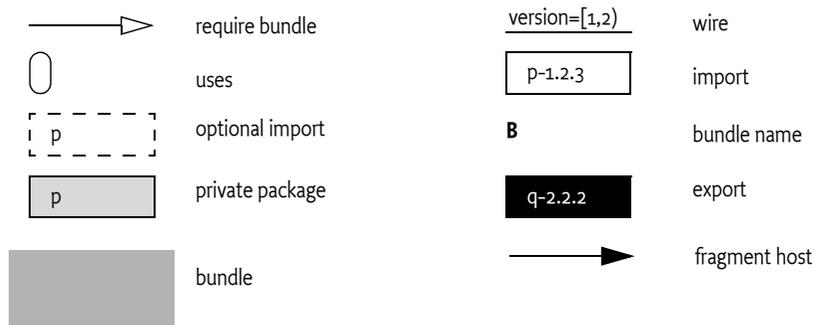
Wires create a graph of nodes. Both the wires as well as nodes (bundles) carry a significant amount of information. In the next sections, the following conventions are used to explain the many details.

Bundles are named A, B, C, ... That is, uppercase characters starting from the character A. Packages are named p, q, r, s, t, ... In other words, lower case characters starting from p. If a version is important, it is indicated with a dash followed by the version: q-1.0. The syntax A.p means the package definition (either import or export) of package p by bundle A.

Import definitions are graphically shown by a white box. Export definitions are displayed with a black box. Packages that are not exported or imported are called private packages. They are indicated with diagonal lines.

Bundles are a set of connected boxes. Constraints are written on the wires, which are represented by lines.

Figure 3.7 Legend of wiring instance diagrams, and example

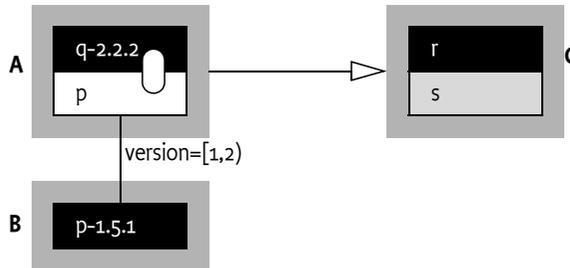


For example:

```
A: Import-Package: p; version="[1,2)"
   Export-Package: q; version=2.2.2; uses:=p
   Require-Bundle: C
B: Export-Package: p; version=1.5.1
C: Export-Package: r
```

Figure 3.8 shows the same setup graphically.

Figure 3.8 Example bundle diagram



3.7.2 Version Constraints

Version constraints are a mechanism whereby an import definition can declare a precise version or a version range for matching an export definition.

An import definition must specify a version range as the value for its version attribute, and the exporter must specify a version as the value for its version attribute. Matching is done with the rules for version range matches as described in *Version Ranges* on page 39.

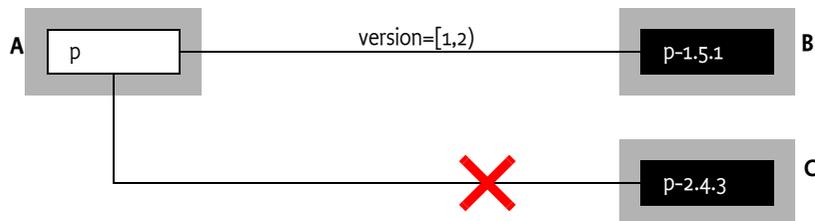
For example, the following import and export definition resolve correctly because the version range in the import definition matches the version in the export definition:

A: Import-Package: p; version=" [1,2) "

B: Export-Package: p; version=1.5.1

Figure 3.9 graphically shows how a constraint can exclude an exporter.

Figure 3.9 Version Constrained



3.7.3 Semantic Versioning

Version ranges encode the assumptions about *binary compatibility*. Though the OSGi frameworks do not enforce a specific encoding for a compatibility policy, it is strongly recommended to use the following semantics.

Traditionally, compatibility has always been between two parties. One is the consumer of the code and the other is the provider of the code. API based design introduces a third party in the compatibility policy:

- The API itself
- The *provider* of the API
- The *consumer* of the API

A provider of an API is closely bound to that API. Virtually any change to that API makes a provider implementation incompatible with the new version of the API. However, API changes have more leeway from the perspective of a consumer of that API. Many API changes can be made backward

compatible for consumers but hardly any API change can be made backward compatible for a provider of that API.

A provider of an API should therefore import that API with a smaller range than a consumer of that API. This policy can be encoded in a version range. The rules are summarized as follows:

- major - Changes for an incompatible update for both a consumer and a provider of an API.
- minor - Changes for a backward compatible update for a consumer but not for a provider.
- micro - A change that does not affect the API, for example, a typo in a comment or a bug fix in an implementation.

Both consumers and providers should use the version they are compiled against as their base version. It is recommended to ignore the micro part of the version because systems tend to become very rigid if they require the latest bug fix to be deployed all the time. For example, when compiled against version 4.2.1.V201007221030, the base version should be 4.2.

A consumer of an API should therefore import a range that starts with the base version and ends with the next major change, for example: [4.2,5). A provider of an API should import a range that starts with the base version up to the next minor change, for example: [4.2,4.3).

3.7.4 Type Roles for Semantic Versioning

As mentioned in *Semantic Versioning* on page 58, there are two roles for clients of an API package: API consumers and API providers. API consumers use the API and API providers implement the API. For the types in an API, it is important that the API clearly document which of those types are only to be implemented or extended by API providers and which of those types can be implemented or extended by API consumers. For example, listener interfaces are generally implemented by API consumers and instances of them passed to API providers.

API providers are sensitive to changes in types implemented or extended by both API consumers and API providers. An API provider must implement any new changes in API provider types and must understand and likely invoke any new changes in API consumer types. An API consumer can generally ignore compatible changes in API provider types unless it wants to invoke the new function. But an API consumer is sensitive to changes in API consumer types and will probably need modification to implement the new function. For example, in the [org.osgi.framework](#) package, the [BundleContext](#) type is implemented by the Framework which is the API provider. Adding a new method to [BundleContext](#) will require all Framework implementations to be updated to implement the new method. Bundles, which are the API consumers, do not have to change unless they wish to call the new method. However, the [BundleActivator](#) type is implemented by bundles and adding a new method to [BundleActivator](#) will require all bundles implementing this interface to be modified to implement the new method and will also require all Framework implementations to be modified to utilize the new method. Thus the [BundleContext](#) type has an API provider role and the [BundleActivator](#) type has an API consumer role in the [org.osgi.framework](#) API package.

Since there are generally many API consumer and few API providers, API evolution must be very careful when considering changes to API consumer types while being more relaxed about changes to API provider types. This is because you will need to change the few API providers to support an updated API but you do not want to require the many existing API consumers to change when an API is updated. API consumers should only need to change when the API consumer wants to take advantage of new API.

The [ProviderType](#) and [ConsumerType](#) annotations can be used in source files to document the roles of types in a package. API types marked [ProviderType](#) must not be implemented or extended by API consumers. These annotations can be processed by bundle assembly tools that support Semantic Versioning when generating the version range information for a bundle's Import-Package manifest header.

3.7.5 Optional Packages

A bundle can indicate that it does not require a package to resolve correctly, but it may use the package if it is available. For example, logging is important, but the absence of a log service should not prevent a bundle from running.

Optional imports can be specified in the following ways:

- *Dynamic Imports* - The `DynamicImport-Package` header is intended to look for an exported package when that package is needed. The key use case for dynamic import is the `Class.forName` method when a bundle does not know in advance the class name it may be requested to load.
- *Resolution Directive* - The resolution directive on an import definition specifying the value `optional`. A bundle may successfully resolve if a suitable optional package is not present.

The key difference between these two mechanisms is when the wires are made. An attempt is made to establish a wire for a dynamic import every time there is an attempt to load a class in that package, whereas the wire for a resolution optional package may only be established when the bundle is resolved.

The resolution directive of the import definition can take the value `mandatory` or `optional`.

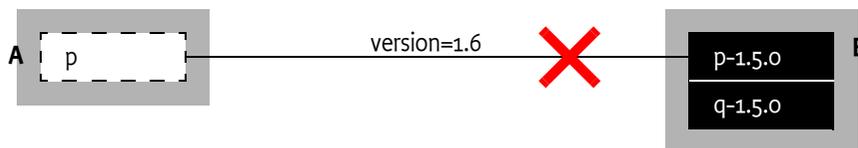
- `mandatory` - (Default) Indicates that the package must be wired for the bundle to resolve.
- `optional` - Indicates that the importing bundle may resolve without the package being wired. If the package is not wired, the class loading will treat this package as if it is not imported.

The following example will resolve even though bundle B does not provide the correct version (the package will *not* be available to the code when bundle A is resolved).

```
A: Import-Package: p; «
    resolution:=optional; «
    version=1.6
B: Export-Package: p; «
    q; «
    version=1.5.0
```

Figure 3.10

Optional import



The implementation of a bundle that uses optional packages must be prepared to handle the fact that the packages may not be available: that is, an exception can be thrown when there is a reference to a class from a missing package. This can be prevented by including a fallback package on the bundle's class path. When an optional package cannot be resolved, any attempts by the bundle to load classes from it will follow normal bundle class loading search order as if the import never existed. It will load it from the bundle's class path or in the end through dynamic class loading when set for that bundle and package.

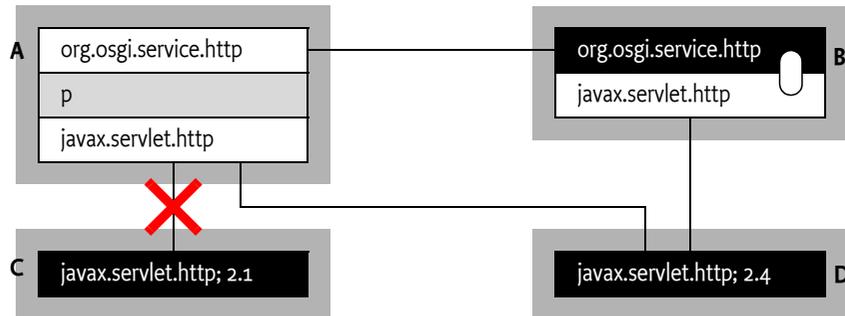
3.7.6 Package Constraints

Classes can depend on classes in other packages. For example, when they extend classes from another package, or these other classes appear in method signatures. It can therefore be said that a package *uses* other packages. These inter-package dependencies are modeled with the `uses` directive on the `Export-Package` header.

For example, `org.osgi.service.http` depends on the package `javax.servlet` because it is used in the API. The export definition of the `org.osgi.service.http` must therefore contain the `uses` directive with the `javax.servlet` package as its value.

Class space consistency can only be ensured if a bundle has only one exporter for each package. For example, the Http Service implementation requires servlets to extend the `javax.servlet.http.HttpServlet` base class. If the Http Service bundle would import version 2.4 and the client bundle would import version 2.1 then a class cast exception is bound to happen. This is depicted in Figure 3.11.

Figure 3.11 Uses directive in B, forces A to use javax.servlet from D



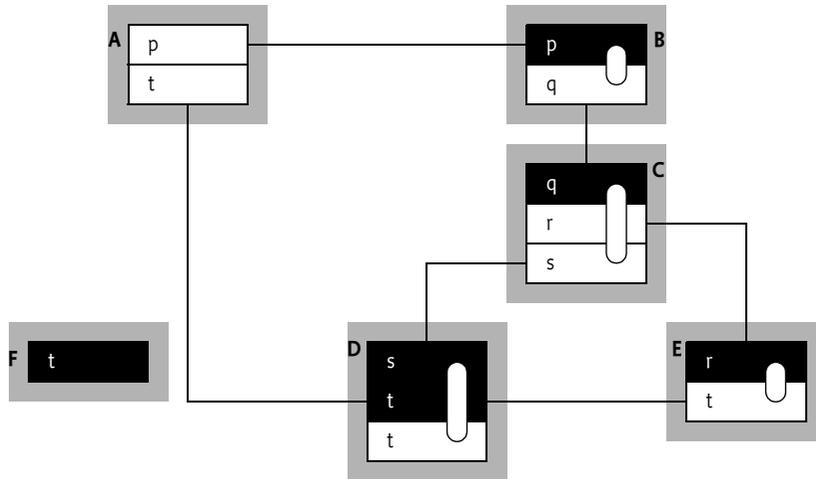
If a bundle imports a package from an exporter then the export definition of that package can imply constraints on a number of other packages through the `uses` directive. The `uses` directive lists the packages that the exporter depends upon and therefore constrains the resolver for imports. These constraints ensure that a set of bundles share the same class loader for the same package.

When an importer imports a package with `uses` constraints, the resolver must wire the import to the exporter named in the `uses` constraint. This exporter may in turn imply additional constraints, and so on. The act of wiring a single import of a package to an exporter can therefore imply a large set of constraints. The term *implied package constraints* refers to the complete set of constraints constructed from recursively traversing the wires. Implied package constraints are not automatic imports; rather, implied package constraints only constrain how an import definition must be wired.

For example, in Figure 3.12, bundle A imports package `p`. Assume this import definition is wired to bundle B. Due to the `uses` directive (the ellipse symbols indicates the `uses` directive) this implies a constraint on package `q`.

Further, assuming that the import for package `q` is wired to bundle C, then this implies a constraint on the import of package `r` and `s`. Continuing, assuming `C.s` and `C.r` are wired to bundle D and E respectively. These bundles both add package `t` to the set of implied packages for bundle A.

Figure 3.12 Implied Packages



To maintain class space consistency, the Framework must ensure that none of its bundle imports conflicts with any of that bundle's implied packages.

For the example, this means that the Framework must ensure that the import definition of A.t is wired to package D.t. Wiring this import definition to package F.t violates the class space consistency. This violation occurs because bundle A could be confronted with objects with the same class name but from the class loaders of bundle D and F. This would potentially create `ClassCastException`s. Alternatively, if all bundles are wired to F.t, then the problem also goes away.

Another scenario with this case is depicted in Figure 3.11. Bundle A imports the Http Service classes from bundle B. Bundle B has grouped the `org.osgi.service.http` and the `javax.servlet` and bundle A is therefore constrained to wire `javax.servlet` to the same exporter as bundle B.

As an example of a situation where the uses directive makes resolving impossible consider the following setup that is correctly resolved:

```
A: Import-Package: q; version=" [1.0, 1.0] "
   Export-Package: p; uses:="q, r", r
B: Export-Package: q; version=1.0
C: Export-Package: q; version=2.0
```

These specific constraints can be resolved because the import A.q can be wired to the export B.q but not C.q due to the version constraint.

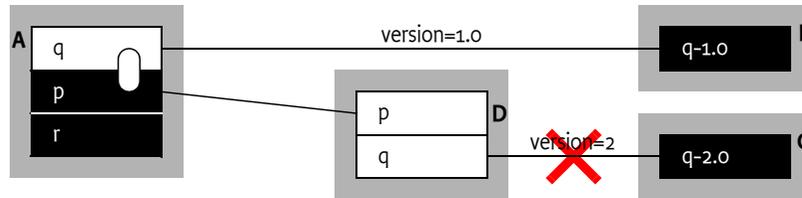
Adding a bundle D will now not be possible:

```
D: Import-Package: p, q; version=2.0
```

Package D.p must be wired to package A.p because bundle A is the only exporter. However, this implies the use of package q due the uses directive in the package A.q import. Package A.q is wired to B.q-1.0. However, import package D.q requires version 2.0 and can therefore not be resolved without violating the class space constraint.

This scenario is depicted in Figure 3.13.

Figure 3.13 Uses directive and resolving



3-7-7 Attribute Matching

Attribute matching is a generic mechanism to allow the importer and exporter to influence the matching process in a declarative way. In order for an import definition to be resolved to an export definition, the values of the attributes specified by the import definition must match the values of the attributes of the export definition. By default, a match is not prevented if the export definition contains attributes that do not occur in the import definition. The mandatory directive in the export definition can reverse this by listing all attributes that the Framework must match in the import definition. Any attributes specified in the DynamicImport-Package is ignored during the resolve phase but can influence runtime class loading.

For example, the following statements will match.

```
A: Import-Package: com.acme.foo; company=ACME
B: Export-Package: com.acme.foo; «
    company="ACME"; «
    security=false
```

Attribute values are compared string wise except for the version and bundle-version attributes which use version range comparisons. Leading and trailing white space in attribute values must be ignored.

Attribute matching also works for the Require-Bundle and Fragment-Host headers; the attributes to be matched are specified on the Bundle-SymbolicName header.

3-7-8 Mandatory Attributes

There are two types of attributes: *mandatory* and *optional*. Mandatory attributes must be specified in the import definition to match. Optional attributes are ignored when they are not referenced by the importer. Attributes are optional by default.

The exporter can specify mandatory attributes with the mandatory directive in the export definition. This directive contains a comma-separated list of attribute names that must be specified by the importer to match.

For example, the following import definition must not match the export definition because security is a mandatory attribute:

```
A: Import-Package: com.acme.foo; company=ACME
B: Export-Package: com.acme.foo; «
    company="ACME"; «
    security=false; «
    mandatory:=security
```

3-7-9 Class Filtering

An exporter can limit the visibility of the classes in a package with the include and exclude directives on the export definition. The value of each of these directives is a comma-separated list of class names. Note that the use of a comma in the value requires it to be enclosed in double quotes.

Class names must not include their package name and do not end with `.class`. That is, the class `com.acme.foo.Daffy` is named `Daffy` in either list. The class name can include multiple wildcard asterisks (`*` \u002A).

The default for the `include` directive is an asterisk (`*` \u002A) (wildcard matching all names), and for the `exclude` directive, so that no classes are excluded, an empty list that matches no names. If `include` or `exclude` directive are specified, the corresponding default is overridden.

A class is only visible if it is:

- Matched with an entry in the included list, *and*
- Not matched with an entry in the excluded list.

In all other cases, loading or finding fails, and a `Class Not Found Exception` is thrown for a class load. The ordering of `include` and `exclude` is not significant.

The following example shows an `export` statement, and a list of files with their visibility status.

```
Export-Package: com.acme.foo; include:="Qux*,BarImpl"; «
                exclude:=QuxImpl
```

```
com/acme/foo
  QuxFoo           visible
  QuxBar           visible
  QuxImpl          excluded
  BarImpl          visible
```

Care must be taken when using filters. For example, a new version of a module that is intended to be backward compatible with an earlier version should not filter out classes that were not filtered out by the earlier version. In addition, when modularizing existing code, filtering out classes from an exported package may break users of the package.

For example, packages defined by standard bodies often require an implementation class in the standardized package to have package access to the specification classes.

```
package org.acme.open;
public class Specified {
    static Specified implementation;
    public void foo() { implementation.foo(); }
}

package org.acme.open;
public class Implementation {
    public void initialize(Specified implementation) {
        Specified.implementation = implementation;
    }
}
```

The `Implementation` class must not be available to external bundles because it allows the implementation to be set. By excluding the `Implementation` class, only the exporting bundle can see this class. The `export` definition for this header could look like:

```
Export-Package: org.acme.open; exclude:=Implementation
```

3.7.10 Provider Selection

Provider selection allows the importer to select which bundles can be considered as exporters. Provider selection is used when there is no specification contract between the importer and the ex-

porter. The importer tightly couples itself to a specific exporter, typically the bundle that was used for testing. To make the wiring less brittle, the importer can optionally specify a range of bundle versions that will match.

An importer can select an exporter with the import attributes `bundle-symbolic-name` and `bundle-version`. The Framework automatically provides these attributes for each export definition. These attributes must not be specified in an export definition.

The export definition `bundle-symbolic-name` attribute will contain the bundle symbolic name as specified in the `Bundle-SymbolicName` header without any parameters. The export definition `bundle-version` attribute is set to the value of the `Bundle-Version` header or its default of 0.0.0 when absent.

The `bundle-symbolic-name` is matched as an attribute. The `bundle-version` attribute is matched using the version range rules as defined in *Version Ranges* on page 39. The import definition must be a version range and the export definition is a version.

For example, the following definitions will match:

```
A: Bundle-SymbolicName: A
   Import-Package: com.acme.foo; <
     bundle-symbolic-name=B; <
     bundle-version=" [1.41, 2.0.0) "
```

```
B: Bundle-SymbolicName: B
   Bundle-Version: 1.41
   Export-Package: com.acme.foo
```

The following statements will not match because bundle B does not specify a version and thus defaults to 0.0.0:

```
A: Bundle-SymbolicName: A
   Import-Package: com.acme.foo; <
     bundle-symbolic-name=B; <
     bundle-version=" [1.41, 2.0.0) "
```

```
B: Bundle-SymbolicName: B
   Export-Package: com.acme.foo; version=1.42
```

Selecting an exporter by symbolic name can result in brittleness because of hard coupling of the package to the bundle. For example, if the exporter eventually needs to be refactored into multiple separate bundles, all importers must be changed. Other arbitrary matching attributes do not have this disadvantage as they can be specified independently of the exporting bundle.

The brittleness problem of the bundle symbolic name in bundle refactoring can be partly overcome by writing a façade bundle using the same bundle symbolic name as the original bundle.

3.8 Resolving Process

Resolving is the process that creates a wiring between bundles. Constraints on the wires are statically defined by:

- Any mandatory requirement must be matched to at least one capability in the same namespace provided by any of the resolved bundles, including itself and the system bundle.
- The required execution environments as defined by the `Bundle-RequiredExecutionEnvironment` header.
- Native code

- Import and export packages (the `DynamicImport-Package` header is ignored in this phase)
- Required bundles, which import all exported packages from a bundle as defined in *Requiring Bundles* on page 84.
- Fragments, which provide their contents and definitions to the host as defined in *Fragment Bundles* on page 87

A bundle can only be resolved when a number of constraints are satisfied:

- *Execution Environment* - The underlying VM implements at least one of the execution environments listed in the `Bundle-RequiredExecutionEnvironment` header. See *osgi.ee Namespace* on page 172.
- *Native code* - The native code dependencies specified in the `Bundle-NativeCode` header must be resolved. See *Loading Native Code Libraries* on page 76.

The resolving process is then a constraint-solving algorithm that can be described in terms of requirements on wiring relations. The resolving process is an iterative process that searches through the solution space.

A bundle can be resolved if the following conditions are met:

- All its mandatory requirements are satisfied
- All its mandatory imports are wired
- All its mandatory required bundles are available and their exports wired

A wire is only created when the following conditions are met:

- The importer's version range matches the exporter's version. See *Semantic Versioning* on page 58.
- The importer specifies all mandatory attributes from the exporter. See *Mandatory Attributes* on page 63.
- All the importer's attributes match the attributes of the corresponding exporter. See *Attribute Matching* on page 63
- Implied packages referring to the same package as the wire are wired to the same exporter. See *Package Constraints* on page 60.
- The wire is connected to a valid exporter.

The following list defines the preferences, if multiple choices are possible, in order of decreasing priority:

- A resolved exporter must be preferred over an unresolved exporter.
- An exporter with a higher version is preferred over an exporter with a lower version.
- An exporter with a lower bundle ID is preferred over a bundle with a higher ID.

3.8.1 Importing and Exporting the Same Package

If a bundle has both import and export definitions for the *same* package, then the Framework needs to decide which to choose.

It must first try to resolve the overlapping import definition. The following outcomes are possible:

- *External* - If this resolves to an export statement in another bundle, then the overlapping export definition in this bundle is discarded.
- *Internal* - If it is resolved to an export statement in this bundle, then the overlapping import definition in this bundle is discarded.
- *Unresolved* - There is no matching export definition. In this case the framework is free to discard either the overlapping export definition or overlapping import definition in this bundle. If the

export definition is discarded and the import definition is not optional then the bundle will fail to resolve.

The above only applies to the import and export package definitions of a bundle. For namespaces other than `osgi.wiring.package`, a requirement definition of a bundle may be wired to a capability definition of that same bundle.

3.9 Runtime Class Loading

Each bundle installed in the Framework must not have an associated class loader until after it is resolved. After a bundle is resolved, the Framework must create one class loader for each bundle that is not a fragment. The framework may delay creation of the class loader until it is actually needed.

One class loader per bundle allows all resources within a bundle to have package level access to all other resources in the bundle within the same package. This class loader provides each bundle with its own namespace, to avoid name conflicts, and allows resource sharing with other bundles.

This class loader must use the wiring as calculated in the resolving process to find the appropriate exporters. If a class is not found in the imports, additional headers in the manifest can control the searching of classes and resources in additional places.

The following sections define the factors that influence the runtime class loading and then define the exact search order the Framework must follow when a class or resource is loaded.

3.9.1 Bundle Class Path

JAR, ZIP, directories, etc. are called *containers*. Containers contain *entries* organized in hierarchical paths. During runtime, an entry from a bundle can actually come from different containers because of attached fragments. The order in which an entry can be found is significant because it can shadow other entries. For a bundle, the search order for a named entry is:

- First the container of the (host) bundle
- Then the (optional) fragment containers in ascending id order

This search order is called the *entry path*. A *resource* (or class) is not loaded via the entry path, but it is loaded through the *bundle class path*. The bundle class path provides an additional indirection on top of the entry path. It defines an ordered list of *container paths*. Each container path can be found on the entry path.

Each container, independent of any other containers, can be a multi-release container. See *Multi-release Container* on page 69.

The full stop (`' \u002E`) container path is a synonym for the solidus (`' / \u002F`) or the root of a container. The full stop is the default value for a bundle or fragment if no `Bundle-ClassPath` header is specified.

The `Bundle-ClassPath` manifest header must conform to the following syntax:

```
Bundle-ClassPath ::= entry ( ',' entry ) *
entry           ::= target ( ';' target ) * ( ';' parameter ) *
target          ::= path | '.' // See 1.3.2
```

The Framework must ignore any unrecognized parameters.

The content of the *effective* bundle class path is constructed from the bundle's `Bundle-ClassPath` header, concatenated with the `Bundle-ClassPath` headers of any fragments, in ascending bundle id order. The effective `Bundle-ClassPath` is calculated during resolve time, however, a dynamically attached fragment can append elements at the end if the Framework supports dynamically attached fragments.

An element from the bundle's Bundle-ClassPath header refers to the first match when searched through the entry path, while a fragment's Bundle-ClassPath can refer only to an entry in its own container.

An example can illustrate this:

```
A: Bundle-ClassPath: ., resource.jar
B: Fragment-Host: A
```

The previous example uses an effective bundle class path of:

```
/, resource.jar, B:/
```

The first element / is the root of a container. The bundle always has a root and can therefore always be found in the (host) bundle. The second element is first looked up in the host bundle's container, and if not found, the entry is looked up in the container of B. The Framework must use the first entry that matches. The last element in the effective bundle class path is the / from fragment B; the / is the default because there is no Bundle-ClassPath specified. However, a fragment can only refer to an internal entry. This full stop therefore refers to the root of the container of fragment B. Assuming, fragment B contains an entry for resource.jar and bundle A does not, then the search order must be:

```
A: /
B: resource.jar
B: /
```

The Framework must ignore a container path in the bundle class-path if the container cannot be located when it is needed, which can happen at any time after the bundle is resolved. However, the Framework should publish a Framework Event of type INFO once with an appropriate message for each entry that cannot be located at all.

An entry on the Bundle-ClassPath can refer to a directory in the container. However, it is not always possible to establish the directory's existence. For example, directories can be omitted in JAR/ZIP files. In such a case, a Framework must probe the directory to see if any resources can be found in this directory. That is, even if the directory construct is absent in the container, if resources can be found assuming this directory, than it must still be chosen for the Bundle-ClassPath.

A host bundle can allow a fragment to insert code ahead of its own code by naming a container in its Bundle-ClassPath that will be provided by a fragment. Fragments can never unilaterally insert code ahead of their host's bundle class path. The following example illustrates the possibilities of the bundle class path in more detail:

```
A: Bundle-SymbolicName: A
   Bundle-ClassPath: /, required.jar, optional, default.jar
   content ...
   required.jar
   default.jar
B: Bundle-SymbolicName: B
   Bundle-ClassPath: fragment.jar
   Fragment-Host: A
   content ...
   optional/
   content ...
   fragment.jar
```

The names of the bundle class path elements indicate their intention. The required.jar is a container that provides mandatory functionality, it is packaged in bundle A. The optional container is a directory containing optional classes, and the default.jar is a JAR entry with backup code. In this example, the effective bundle class path is:

```
A: /
A: required.jar
B: optional
A: default.jar
B: fragment.jar
```

This will expand to the following (logical) search order for a resource X.class:

```
A: /X.class
A: required.jar!X.class
B: optional/X.class
A: default.jar!X.class
B: fragment.jar!X.class
```

The exclamation mark (!) indicates a load from a JAR resource.

3.9.1.1 Multi-release Container

A container can be a *multi-release container*. A multi-release container supports versioned directories as specified in [28] *Multi-release JAR File*. When a container is a multi-release container, that is, the container has a META-INF/MANIFEST.MF manifest which specifies

```
Multi-Release: true
```

then the Framework must search the container's versioned directories when attempting to locate an entry in the container.

Support for multi-release containers must only be active on Java 9 and later. On Java 8 and earlier, the container must be treated as a non-multi-release container.

3.9.2 Dynamic Import Package

Dynamic imports are matched to export definitions (to form package wirings) during class loading, and therefore do not affect module resolution. Dynamic imports apply only to packages for which no wire has been established and no definition could be found in any other way. Dynamic import is used as a last resort.

```
DynamicImport-Package ::= dynamic-description
                        ( ',' dynamic-description )*
dynamic-description ::= wildcard-names ( ';' parameter )*
wildcard-names      ::= wildcard-name ( ';' wildcard-name )*
wildcard-name       ::= package-name
                        | ( package-name '*' ) // See 1.3.2
                        | '*'
```

No directives are architected by the Framework for DynamicImport-Package. Arbitrary matching attributes may be specified. The following matching attributes are architected by the Framework:

- `version` – A version range to select the version of an export definition. The default value is 0.0.0.
- `bundle-symbolic-name` - The bundle symbolic name of the exporting bundle.
- `bundle-version` - a version range to select the bundle version of the exporting bundle. The default value is o.o.o.

Packages may be named explicitly or by using wild-carded expressions such as `org.foo.*` and `*`. The wildcard can stand for any suffix, including multiple sub-packages. If a wildcard is used, then the package identified by the prefix must *not* be included. That is, `org.foo.*` will include all sub-packages of `org.foo` but it must not include package `org.foo` itself.

Dynamic imports must be searched in the order in which they are specified. The order is particularly important when package names with wildcards are used. The order will then determine the order in which matching occurs. This means that the more specific package specifications should appear before the broader specifications. For example, the following `DynamicImport-Package` header indicates a preference for packages supplied by ACME:

```
DynamicImport-Package: *; vendor=acme, *
```

If multiple packages need to be dynamically imported with identical parameters, the syntax permits a list of packages, separated by semicolons, to be specified before the parameters.

During class loading, the package of the class being loaded is compared against the specified list of (possibly wild-carded) package names. Each matching package name is used in turn to attempt to wire to an export using the same rules as `Import-Package`. If a wiring attempt is successful (taking any uses constraints into account), the search is forwarded to the exporter's class loader where class loading continues. The wiring must not subsequently be modified, even if the class cannot be loaded. This implies that once a package is dynamically resolved, subsequent attempts to load classes or resources from that package are treated as normal imports.

In order for a `DynamicImport-Package` to be resolved to an export statement, all attributes of the dynamic import definition must match the attributes of the export statement. All mandatory arbitrary attributes (as specified by the exporter, see *Mandatory Attributes* on page 63) must be specified in the dynamic import definition and match.

Once a wire is established, any uses constraints from the exporter must be obeyed for further dynamic imports.

Dynamic imports are very similar to optional packages, see *Optional Packages* on page 60, but differ in the fact that they are handled after the bundle is resolved.

3.9.3 Parent Delegation

The Framework must always delegate any package that starts with `java.` to the parent class loader.

Certain Java virtual machines, also Oracle's VMs, appear to make the erroneous assumption that the delegation to the parent class loader always occurs. This implicit assumption of strictly hierarchical class loader delegation can result in `NoClassDefFoundErrors`. This happens if the virtual machine implementation expects to find its own implementation classes from any arbitrary class loader, requiring that packages loaded from the boot class loader not be restricted to only the `java.*` packages.

Other packages that must be loaded from the boot class loader can therefore be specified with the `System` property:

```
org.osgi.framework.bootdelegation
```

This property must contain a list with the following format:

```
org.osgi.framework.bootdelegation ::= boot-description
    ( ',' boot-description ) *
boot-description ::= package-name // See 1.3.2
    | ( package-name '*' )
    | '*'
```

The `*` wildcard means deep matching, that is, `com.acme.*`, matches any sub-package of package `com.acme`, however, it does not match `com.acme`. Packages that match this list must be loaded from the parent class loader. The `java.*` prefix is always implied; it does not have to be specified.

The single wildcard means that the Framework must always delegate to the parent class loader first, which is the same as the Release 3 behavior. For example, when running on an Oracle JVM, it may be necessary to specify a value like:

```
org.osgi.framework.bootdelegation=sun.*,com.sun.*
```

With such a property value, the Framework must delegate all `java.*`, `sun.*`, and `com.sun.*` packages to the parent class loader.

3.9.4 Overall Search Order

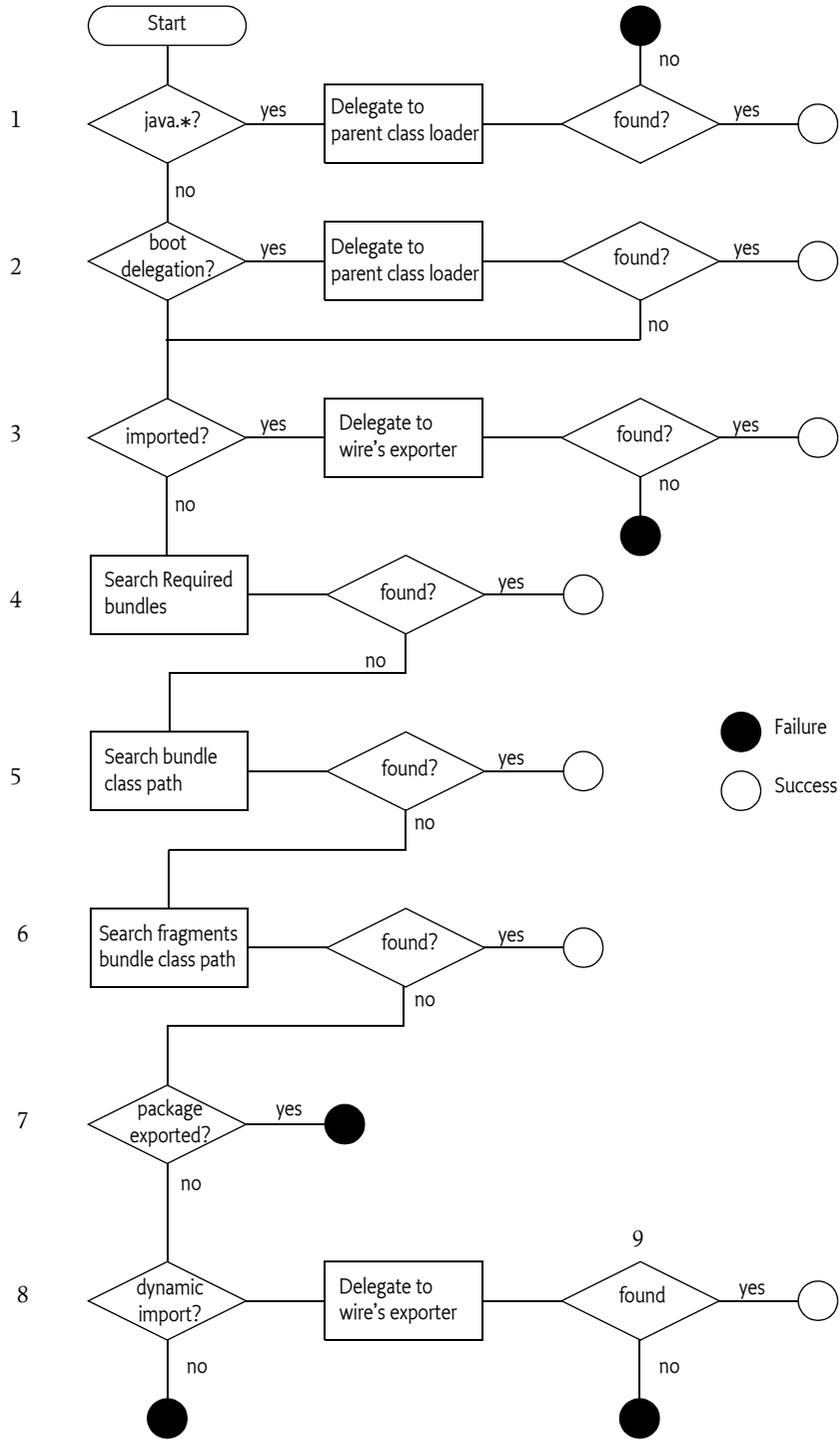
Frameworks must adhere to the following rules for class or resource loading. When a bundle's class loader is requested to load a class or find a resource, the search must be performed in the following order:

1. If the class or resource is in a `java.*` package, the request is delegated to the parent class loader; otherwise, the search continues with the next step. If the request is delegated to the parent class loader and the class or resource is not found, then the search terminates and the request fails.
2. If the class or resource is from a package included in the boot delegation list (`org.osgi.framework.bootdelegation`), then the request is delegated to the parent class loader. If the class or resource is found there, the search ends.
3. If the class or resource is in a package that is imported using `Import-Package` or was imported dynamically in a previous load, then the request is delegated to the exporting bundle's class loader; otherwise the search continues with the next step. If the request is delegated to an exporting class loader and the class or resource is not found, then the search terminates and the request fails.
4. If the class or resource is in a package that is imported from one or more other bundles using `Require-Bundle`, the request is delegated to the class loaders of the other bundles, in the order in which they are specified in this bundle's manifest. This entails a depth-first strategy; all required bundles are searched before the bundle class path is used. If the class or resource is not found, then the search continues with the next step.
5. Search the bundle's embedded class path, see *Bundle Class Path* on page 67. If the class or resource is not found, then continue with the next step.
6. If the class or resource is in a package that is exported by the bundle or the package is imported by the bundle (using `Import-Package` or `Require-Bundle`), then the search ends and the class or resource is not found.
7. Otherwise, if the class or resource is in a package that is imported using `DynamicImport-Package`, then a dynamic import of the package is now attempted. An exporter must conform to any implied package constraints. If an appropriate exporter is found, a wire is established so that future loads of the package are handled in step 3. If a dynamic wire is not established, then the request fails.
8. If the dynamic import of the package is established, the request is delegated to the exporting bundle's class loader. If the request is delegated to an exporting class loader and the class or resource is not found, then the search terminates and the request fails.

When delegating to another bundle class loader, the delegated request enters this algorithm at step 4.

The following non-normative flow chart illustrates the search order described above:

Figure 3.14 Flow chart for class loading (non-normative)



3.9.5 Parent Class Loader

The set of implicitly visible packages are all `java.*` packages, since these packages are required by the Java runtime, and using multiple versions at the same time is not easy. For example, all objects must extend the same `Object` class.

A bundle must not declare exports for `java.*` packages; doing so is an error and any such bundle must fail to install or update. A bundle may declare imports for `java.*` packages; but this is for resolution purposes only. All other packages visible through the parent class loader must be hidden from executing bundles.

However, the Framework must explicitly export relevant packages from the parent class loader. The system property

```
org.osgi.framework.system.packages
```

contains the export packages descriptions for the system bundle. This property employs the standard `Export-Package` manifest header syntax:

```
org.osgi.framework.system.packages ::= package-description
                                     ( ',' package-description )*
```

Some classes on the boot class path assume that they can use any class loader to load other classes on the boot class path, which is not true for a bundle class loader. Framework implementations should attempt to load these classes from the boot class path.

The system bundle (bundle ID zero) is used to export non-`java.*` packages from the parent class loader. Export definitions from the system bundle are treated like normal exports, meaning that they can have version numbers, and are used to resolve import definitions as part of the normal bundle resolving process. Other bundles may provide alternative implementations of the same packages.

The set of export definitions for the parent class loader can either be set by this property or calculated by the Framework. The export definitions must have the `bundle-symbolic-name` and `bundle-version` attributes with the implementation-specific bundle symbolic name and bundle version value of the system bundle.

Exposing packages from the parent class loader in this fashion must also take into account any uses directives of the underlying packages. For example, the definition of `javax.crypto.spec` must declare its usage of `javax.crypto.interfaces` and `javax.crypto`.

3.9.6 Resource Loading

A resource in a bundle can be accessed through the class loader of that bundle but it can also be accessed with the `getResource(String)`, `getEntry(String)`, `findEntries(String,String,boolean)` and other methods or the methods on the *Bundle Wiring API Specification* on page 157. All these methods return a `URL` object or an `Enumeration` object of `URL` objects. The `URL`s are called *bundle entry URLs*. The schemes for the `URL`s returned by these methods can differ and are implementation dependent.

Bundle entry `URL`s are normally created by the Framework, however, in certain cases bundles need to manipulate the `URL` to find related resources. The Framework is therefore required to ensure that:

- Bundle entry `URL`s must be hierarchical (See [13] *RFC 2396 Uniform Resource Identifiers URI: Generic Syntax*)
- Usable as a context for constructing another `URL`.
- The `java.net.URLStreamHandler` class used for a bundle entry `URL` must be available to the `java.net.URL` class to setup a `URL` that uses the protocol scheme defined by the Framework.
- The `getPath` method for a bundle entry `URL` must return an absolute path (a path that starts with `'/'`) to a resource or entry in a bundle. For example, the `URL` returned from `getEntry("myimages/test.gif")` must have a path of `/myimages/test.gif`.

For example, a class can take a URL to an `index.html` bundle resource and map URLs in this resource to other files in the same JAR directory.

```
public class BundleResource implements HttpContext{
    URL root; // to index.html in bundle
    URL getResource( String resource ) {
        return new URL( root, resource );
    }
    ...
}
```

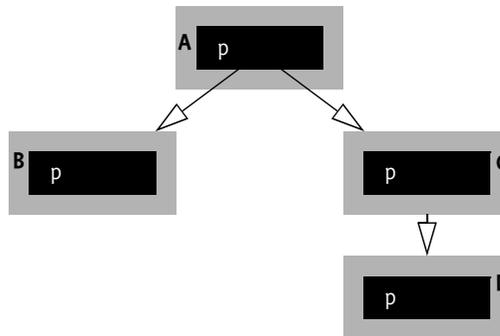
3.9.7 Bundle Cycles

Multiple required bundles can export the same package. Bundles which export the same package involved in a require bundle cycle can lead to lookup cycles when searching for classes and resources from the package. Consider the following definitions:

A: Require-Bundle: B, C
 C: Require-Bundle: D

These definitions are depicted in Figure 3.15.

Figure 3.15 Depth First search with Require Bundle

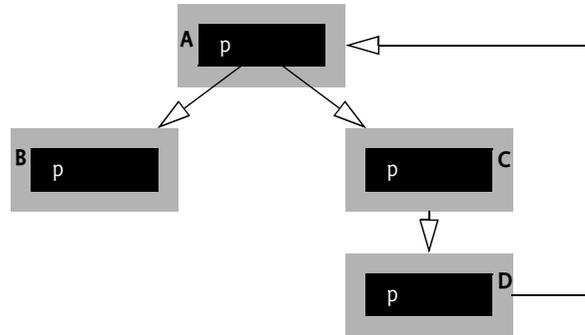


Each of the bundles exports the package `p`. In this example, bundle A requires bundle B, and bundle C requires bundle D. When bundle A loads a class or resource from package `p`, then the required bundle search order is the following: B, D, C, A. This is a depth first search order because required bundles are searched before the bundle class path is searched (see step 4). The required bundles are searched in the order that they appear in the Require-Bundle header. The depth first search order can introduce endless search cycles if the dependency graph has a cycle in it.

Using the previous setup, a cycle can be introduced if bundle D requires bundle A as depicted in Figure 3.16.

D: Require-Bundle: A

Figure 3.16 Cycles



When the class loader for bundle A loads a class or resource from package p then the bundle search order would be the following: B, B, B,... if cycles were not taken into account.

Since a cycle was introduced each time bundle D is reached the search will recur back to A and start over. The framework must prevent such dependency cycles from causing endless recursive lookups.

To avoid endless looping, the Framework must mark each bundle upon first visiting it and not explore the required bundles of a previously visited bundle. Using the visited pattern on the dependency graph above will result in the following bundle search order: B, D, C, A.

3.9.8 Code Executed Before Started

Packages exported from a bundle are exposed to other bundles as soon as the bundle has been resolved. This condition could mean that another bundle could call methods in an exported package *before* the bundle exporting the package is started.

3.9.9 Finding an Object's Bundle

There are scenarios where a bundle is required in code that has no access to a Bundle Context. For this reason, the framework provides the following methods:

- *Framework Util* - Through the FrameworkUtil class with the `getBundle(Class)` method. The framework provides this method to allow code to find the bundle of an object without having the permission to get the class loader. The method returns null when the class does not originate from a bundle.
- *Class Loader* - An OSGi framework must ensure that the class loader of a class that comes from a bundle implements the `BundleReference` interface. This allows legacy code to find an object's bundle by getting its class loader and casting it to a `BundleReference` object, which provides access to the Bundle. However, this requires the code to have the permission to access the class loader. The following code fragment shows how to obtain a Bundle object from any object.

```

ClassLoader cl = target.getClassLoader();
if ( cl instanceof BundleReference ) {
    BundleReference ref = (BundleReference) cl;
    Bundle b = ref.getBundle();
    ...
}
  
```

In an OSGi system, not all objects belong to the framework. It is therefore possible to get hold of a class loader that does not implement the `BundleReference` interface, for example the boot class path loader.

3.10 Loading Native Code Libraries

Dependency on native code is expressed in the Bundle-NativeCode header. The framework must verify this header and satisfy its dependencies before it attempts to resolve the bundle. However, a bundle can be installed without an exception if the header is properly formatted according to its syntax. If the header contains invalid information, or can not be satisfied, errors will be reported during resolving.

A Java VM has a special way of handling native code. When a class loaded by a bundle's class loader attempts to load a native library, by calling `System.loadLibrary`, the `findLibrary` method of the bundle's class loader must be called to return the file path in which the Framework has made the requested native library available. The parameter to the `findLibrary` method is the name of the library in operating system independent form, like `http`. The bundle class loader can use the `mapLibraryName` method from the VM to map this name to an operating system dependent name, like `libhttp.so`.

The bundle's class loader must attempt to find the native library by examining the selected native code clauses, if any, of the bundle associated with the class loader and each attached fragment. Fragments are examined in ascending bundle ID order. If the library is not referenced in any of the selected native code clauses then null must be returned which allows the parent class loader to search for the native library.

The bundle must have the required `RuntimePermission[loadLibrary. <library name>]` in order to load native code in the OSGi framework.

The Bundle-NativeCode manifest header must conform to the following syntax:

```
Bundle-NativeCode ::= nativecode
                    ( ',' nativecode )* ( ',' optional ) ?
nativecode         ::= path ( ';' path )* // See 1.3.2
                    ( ';' parameter )*
optional          ::= '*'
```

When locating a path in a bundle the Framework must attempt to locate the path relative to the root of the bundle that contains the corresponding native code clause in its manifest header.

The following attributes are architected:

- `osname` - Name of the operating system. The value of this attribute must be the name of the operating system upon which the native libraries run. A number of canonical names are defined in Table 4.3.
- `osversion` - The operating system version. The value of this attribute must be a version range as defined in *Version Ranges* on page 39.
- `processor` - The processor architecture. The value of this attribute must be the name of the processor architecture upon which the native libraries run. A number of canonical names are defined in Table 4.2.
- `language` - The ISO code for a language. The value of this attribute must be the name of the language for which the native libraries have been localized.
- `selection-filter` - A selection filter. The value of this attribute must be a filter expression that indicates if the native code clause should be selected or not.

If a selection-filter attribute contains an invalid filter, then the bundle must fail to install with a Bundle Exception of type `NATIVECODE_ERROR`. The following is a typical example of a native code declaration in a bundle's manifest:

```
Bundle-NativeCode: lib/http.dll ; lib/zlib.dll; «
                   osname = Windows95 ; «
```

```

        osname = Windows98 ; «
        osname = WindowsNT ; «
        processor = x86 ; «
        selection-filter = «
            "(com.acme.windowing=win32)"; «
        language = en ; «
        language = se , «
    lib/solaris/libhttp.so ; «
        osname = Solaris ; «
        osname = SunOS ; «
        processor = sparc, «
    lib/linux/libhttp.so ; «
        osname = Linux ; «
        processor = mips; «
        selection-filter = «
            "(com.acme.windowing=gtk) "

```

If multiple native code libraries need to be installed on one platform, they must all be specified in the same clause for that platform.

If a `Bundle-NativeCode` clause contains duplicate parameter entries, the corresponding values must be OR'ed together. This feature must be carefully used because the result is not always obvious. This is highlighted by the following example:

```

// The effect of this header has probably
// not the intended effect!
Bundle-NativeCode: lib/http.DLL ; «
    osname = Windows95 ; «
    osversion = "3.1" ; «
    osname = WindowsXP ; «
    osversion = "5.1" ; «
    processor = x86

```

The above example implies that the native library will load on Windows XP 3.1 and later, which was probably not intended. The single clause should be split in two clauses:

```

Bundle-NativeCode: lib/http.DLL ; «
    osname = Windows95 ; «
    osversion = 3.1; «
    processor = x86, «
    lib/http.DLL ; «
        osname = WindowsXP ; «
        osversion = 5.1; «
        processor = x86

```

Any paths specified in the matching clause must be present in the bundle or any of its attached fragments for a bundle to resolve. The framework must report a `Bundle Exception` with the `NATIVECODE_ERROR` as error code when the bundle can not be resolved due to a native code problem.

If the optional `*` is specified at the end of the `Bundle-NativeCode` manifest header, the bundle will still resolve even if the `Bundle-NativeCode` header has no matching clauses.

The following is a typical example of a native code declaration in a bundle's manifest with an optional clause:

```

Bundle-NativeCode: lib/win32/winxp/optimized.dll; «
    lib/win32/native.dll ; «

```

```

    osname = WindowsXP ; «
    processor = x86 , «
lib/win32/native.dll ; «
    osname = Windows95 ; «
    osname = Windows98 ; «
    osname = WindowsNT ; «
    osname = Windows2000; «
    processor = x86 , «
    *

```

Frameworks must convert a Bundle-NativeCode header to a requirement in the `osgi.native` namespace when used in the Wiring API, see *Bundle Wiring API Specification* on page 157. Each native code clause specified in a Bundle-NativeCode header is converted into a filter component for the `osgi.native` requirement filter directive using the following architected matching attributes:

- `osgi.native.osname` - Uses the approximate equals (`~=`) filter type to evaluate the value specified by the `osname` Bundle-NativeCode attribute.
- `osgi.native.osversion` - Create a `VersionRange` using the value specified by the `osversion` Bundle-NativeCode attribute and then create a filter string out of the `VersionRange`.
- `osgi.native.processor` - Uses the approximate equals (`~=`) filter type to evaluate the value specified by the `processor` Bundle-NativeCode attribute.
- `osgi.native.language` - Uses the approximate equals (`~=`) filter type to evaluate the value specified by the `language` Bundle-NativeCode attribute.

In cases where the same Bundle-NativeCode attribute is specified multiple times within the same clause then the filter components for each value for that attribute are ORed together. For example, if `osname` attribute is specified as both "Windows95" and "Windows7" then the resulting filter will contain:

```

( |
    (osgi.native.osname-=Windows95)
    (osgi.native.osname-=Windows7)
)

```

If the selection-filter Bundle-NativeCode attribute is specified then the specified filter is included as a component of the native code clauses AND filter type. Consider the following Bundle-NativeCode header which contains a single clause:

```

Bundle-NativeCode: «
    lib/http.dll; lib/zlib.dll; «
    osname=Windows95; «
    osname=Windows98; «
    osname=WindowsNT; «
    processor=x86; «
    selection-filter="(com.acme.windowing=win32)"; «
    language=en; «
    language=se

```

This clause would get translated into the following AND filter type:

```

Require-Capability: «
    osgi.native; «
    filter:=" «
        (& «
            (| «

```

```

        (osgi.native.osname-=Windows95) «
        (osgi.native.osname-=Windows98) «
        (osgi.native.osname-=WindowsNT) «
    ) «
    (osgi.native.processor-=x86) «
    (| «
        (osgi.native.language-=en) «
        (osgi.native.language-=se) «
    ) «
    (com.acme.windowing=win32) «
)"

```

The Bundle-NativeCode header may specify multiple clauses, each having their own list of native code paths and set of matching attributes. Instead of using a separate `osgi.native` requirement for each Bundle-NativeCode clause, the complete Bundle-NativeCode header is specified as a single `osgi.native` requirement. This is done by using an OR filter type using all of the individual Bundle-NativeCode clause filter components (as specified above) as components of a single filter directive. Consider the following Bundle-NativeCode header which contains three clauses:

```

Bundle-NativeCode: «
    lib/http.dll; lib/zlib.dll; «
        osname=Windows95; «
        osname=Windows98; «
        osname=WindowsNT; «
        processor=x86; «
        selection-filter = "(com.acme.windowing=win32)"; «
        language=en; «
        language=se, «
    lib/solaris/libhttp.so; «
        osname=Solaris; «
        osname=SunOS; «
        processor=sparc, «
    lib/linux/libhttp.so; «
        osname=Linux; «
        processor=mips; «
        selection-filter="(com.acme.windowing=gtk) "

```

This Bundle-NativeCode header would get translated into the following `osgi.native` filter directive:

```

(|
  (&
    (|
      (osgi.native.osname-=Windows95)
      (osgi.native.osname-=Windows98)
      (osgi.native.osname-=WindowsNT)
    )
    (osgi.native.processor-=x86)
    (|
      (osgi.native.language-=en)
      (osgi.native.language-=se)
    )
    (com.acme.windowing=win32)
  )
  (&
    (|
      (osgi.native.osname-=Solaris)

```

```

        (osgi.native.osname~=SunOs)
    )
    (osgi.native.processor~=sparc)
)
(&
    (osgi.native.osname~=Linux)
    (osgi.native.processor~=mips)
    (com.acme.windowing=gtk)
)
)

```

If the optional '*' is specified at the end of the Bundle-NativeCode manifest header, then the native code for the bundle is considered to be optional. When the Framework converts a Bundle-Native-Code header into an osgi.native requirement which is designated as optional then the requirement resolution directive must be set to optional

3.10.1 Native Code Algorithm

In the description of this algorithm, [x] represents the value of the launching property x (see *Launching Properties* on page 102) and ~= represents the match operation. The match operation is a case insensitive comparison. Certain properties can be aliased. In those cases, the manifest header should contain the generic name for that property but the Framework should attempt to include aliases when it matches.

The Framework must select the native code clause using the following algorithm:

1. Only select the native code clauses for which the following expressions all evaluate to true.
 - osname ~= [org.osgi.framework.os.name] or osname is not specified
 - processor ~= [org.osgi.framework.processor] or processor is not specified
 - osverson range includes [org.osgi.framework.os.version] or osverson is not specified
 - language ~= [org.osgi.framework.language] or language is not specified
 - selection-filter evaluates to true when using the values of the launching properties or selection-filter is not specified
2. If no native clauses were selected in step 1, this algorithm is terminated. A Bundle Exception is thrown if the optional clause is not present.
3. The selected clauses are now sorted in the following priority order:
 - osverson: floor of the osverson range in descending order, osverson not specified
 - language: language specified, language not specified
 - Position in the Bundle-NativeCode manifest header: lexical left to right.
4. The first clause of the sorted clauses from step 3 must be used as the selected native code clause.

If a native code library in a selected native code clause cannot be found within the bundle then the bundle is still allowed to resolve. A missing native code library will result in an error being thrown at runtime when the bundle attempts to load the native code (for example, by invoking the method `System.loadLibrary()`).

If the selected clause contains multiple libraries with the same base file name then only the lexically left most library with that base file name will be used. For example, if the selected clause contains the libraries `lib1/http.dll`; `lib2/http.dll`; `lib3/foo.dll`; `a/b/c/http.dll` then only `http.dll` in `lib1` and `foo.dll` will be used.

Designing a bundle native code header can become quickly complicated when different operating systems, libraries, and languages are used. The best practice for designing the header is to place all parameters in a table. Every targeted environment is then a row in that table. See Table 3.2 for an example.

Table 3.2 *Native code table*

Libraries	osname	osversion	processor	language	filter
nativecodewin32.dll, delta.dll	win32		x86	en	
nativecodegtk.so	linux		x86	en	(com.acme.windowing=gtk)
nativecodeqt.so	linux		x86	en	(com.acme.windowing=qt)

This table makes it easier to detect missing combinations. This table is then mapped to the `Bundle-NativeCode` header in the following code example.

```
Bundle-NativeCode: nativecodewin32.dll; «
    delta.dll; «
    osname=win32; «
    processor=x86; «
    language=en; «
nativecodegtk.so; «
    osname=linux; «
    processor=x86; «
    language=en; «
    selection-filter= «
        "(com.acme.windowing=gtk)", «
nativecodeqt.so; «
    osname=linux; «
    processor=x86; «
    language=en; «
    selection-filter = «
        "(com.acme.windowing=qt)"
```

3.10.2 Considerations Using Native Libraries

There are some restrictions on loading native libraries due to the nature of class loaders. In order to preserve namespace separation in class loaders, only one class loader can load a native library as specified by an absolute path. Loading of a native library file by multiple class loaders (from multiple bundles, for example) will result in a linkage error.

Care should be taken to use multiple libraries with the same file name but in a different directory in the JAR. For example, `foo/http.dll` and `bar/http.dll`. The Framework must only use the first library and ignore later defined libraries with the same name. In the example, only `foo/http.dll` will be visible.

A native library is unloaded only when the class loader that loaded it has been garbage collected.

When a bundle is uninstalled or updated, any native libraries loaded by the bundle remain in memory until the bundle's class loader is garbage collected. The garbage collection will not happen until all references to objects in the bundle have been garbage collected, and all bundles importing packages from the updated or uninstalled bundle are refreshed. This implies that native libraries loaded from the system class loader always remain in memory because the system class loader is never garbage collected.

It is not uncommon that native code libraries have dependencies on other native code libraries. This specification does not support these dependencies, it is assumed that native libraries delivered in bundles should not rely on other native libraries.

3.11 Localization

A bundle contains a significant amount of information that is human-readable. Some of this information may require different translations depending on the user's language, country, and any special variant preferences, a.k.a. the *locale*. This section describes how a bundle can provide common translations for the manifest and other configuration resources depending on a locale.

Bundle localization entries share a common base name. To find a potential localization entry, an underscore ('_' \u005F) is added plus a number of suffixes, separated by another underscore, and finally appended with the suffix `.properties`. The suffixes are defined in `java.util.Locale`. The order for the suffixes this must be:

- language
- country
- variant

For example, the following files provide manifest translations for English, Dutch (Belgium and the Netherlands) and Swedish.

```
OSGI-INF/110n/bundle_en.properties
OSGI-INF/110n/bundle_n1_BE.properties
OSGI-INF/110n/bundle_n1_NL.properties
OSGI-INF/110n/bundle_sv.properties
```

The Framework searches for localization entries by appending suffixes to the localization base name according to a specified locale and finally appending the `.properties` suffix. If a translation is not found, the locale must be made more generic by first removing the variant, then the country and finally the language until an entry is found that contains a valid translation. For example, looking up a translation for the locale `en_GB_welsh` will search in the following order:

```
OSGI-INF/110n/bundle_en_GB_welsh.properties
OSGI-INF/110n/bundle_en_GB.properties
OSGI-INF/110n/bundle_en.properties
OSGI-INF/110n/bundle.properties
```

This allows localization files for more specific locales to override localizations from less specific localization files.

3.11.1 Finding Localization Entries

Localization entries can be contained in the bundle or delivered in fragments. The framework must search for localization entries using the following search rules based on the bundle type:

- **fragment bundle** - If the bundle is a *resolved* fragment, then the search for localization data must delegate to the attached host bundle with the highest version. If the fragment is not resolved, then the framework must search the fragment's JAR for the localization entry.
- **other bundle** - The framework must first search in the bundle's JAR for the localization entry. If the entry is not found and the bundle has fragments, then the attached fragment JARs must be searched for the localization entry.

The bundle's class loader is not used to search for localization entries. Only the contents of the bundle and its attached fragments are searched. The bundle will still be searched for localization entries even if the full stop ('.' \u002E) is not in the bundle class path.

3.11.2 Manifest Localization

Localized values are stored in property resources within the bundle. The default base name of the bundle localization property files is `OSGI-INF/l10n/bundle`. The `Bundle-Localization` manifest header can be used to override the default base name for the localization files. This location is relative to the root of the bundle and bundle fragments.

A localization entry contains key/value entries for localized information. All headers in a bundle's manifest can be localized. However, the Framework must always use the non-localized versions of headers that have Framework semantics.

A localization key can be specified as the value of a bundle's manifest header using the following syntax:

```
header-value ::= '%' text
text ::= < any value which is both a valid manifest header value
        and a valid property key name >
```

For example, consider the following bundle manifest entries:

```
Bundle-Name: %acme bundle
Bundle-Vendor: %acme corporation
Bundle-Description: %acme description
Bundle-Activator: com.acme.bundle.Activator
Acme-Defined-Header: %acme special header
```

User-defined headers can also be localized. Spaces in the localization keys are explicitly allowed.

The previous example manifest entries could be localized by the following entries in the manifest localization entry `OSGI-INF/l10n/bundle.properties`.

```
# bundle.properties
acme\ bundle=The ACME Bundle
acme\ corporation=The ACME Corporation
acme\ description=The ACME Bundle provides all of the ACME\ services
acme\ special\ header=user-defined Acme Data
```

The above manifest entries could also have French localizations in the manifest localization entry `OSGI-INF/l10n/bundle_fr_FR.properties`.

3.12 Bundle Validity

If the `Bundle-ManifestVersion` is not specified, then the bundle manifest version defaults to 1, and certain Release 4 syntax, such as a new manifest header, is ignored rather than causing an error. Release 3 bundles must be treated according to the Release 3 specification.

The following (non-exhaustive) list of errors causes a bundle to fail to install:

- Missing `Bundle-SymbolicName`.
- Duplicate attribute or duplicate directive (except in the `Bundle-Native code` clause).
- Multiple imports of a given package.
- Export of `java.*` packages.
- `Export-Package`, `Bundle-SymbolicName`, or `Fragment-Host` with a mandatory attribute that is not defined.
- Installing or updating a bundle to a bundle that has the same symbolic name and version as another installed bundle (unless this is allowed, see *Bundle Identifiers* on page 113).

- Any syntactic error (for example, improperly formatted version or bundle symbolic name, unrecognized directive value, etc.).
- Specification-version and version specified together (for the same package(s)) but with different values on manifest headers that treat them as synonyms. For example:

```
Import-Package p; specification-version=1; version=2
```

would fail to install, but:

```
Import-Package p; specification-version=1, q; version=2
```

would not be an error.

- The manifest lists a OSGI-INF/permissions.perm file but no such file is present.
- Bundle-ManifestVersion value not equal to 2, unless the Framework specifically recognizes the semantics of a later release.
- Requiring the same bundle symbolic name more than once.

3.13 Requiring Bundles

The Framework supports a mechanism where bundles can be directly wired to other bundles. The following sections define the relevant headers and then discuss the possible scenarios. At the end, some of the (sometimes unexpected) consequences of using Require-Bundle are discussed.

3.13.1 Require-Bundle

The Require-Bundle manifest header contains a list of required bundle symbolic names, with optional attribute assertions. These bundles are searched after the imports are searched but before the bundle's class path is searched. Fragment or extension bundles cannot be required.

The framework must take *all* exported packages from a required bundle, including any packages exported by attached fragments, and wire these packages to the requiring bundle.

The Require-Bundle manifest header must conform to the following syntax:

```
Require-Bundle      ::= bundle-description
                    ( ',' bundle-description ) *
bundle-description ::= symbolic-name           // See 1.3.2
                    ( ';' parameter ) *
```

The following directives can be used in the Require-Bundle header:

- *visibility* - If the value is *private* (default), then all visible packages from the required bundles are not re-exported. If the value is *reexport* then bundles that require this bundle will transitively have access to these required bundle's exported packages. That is, if bundle A requires bundle B, and bundle B requires bundle C with *visibility:=reexport* then bundle A will have access to all bundle C's exported packages as if bundle A had required bundle C.
- *resolution* - If the value is *mandatory* (default) then the required bundle must exist for this bundle to resolve. If the value is *optional*, the bundle will resolve even if the required bundle does not exist.

The following matching attribute is architected by the Framework:

- *bundle-version* - The value of this attribute is a version range to select the bundle version of the required bundle. See *Version Ranges* on page 39. The default value is `[0.0.0,∞)`.

The Bundle-SymbolicName header can specify further arbitrary attributes that must be matched before a bundle is eligible.

A specific symbolic name can only be required once, listing the same symbolic name multiple times must be regarded as an install error.

Requiring bundles must get wired to all exported packages of all their required bundles including exported packages from their attached fragments. This means that any mandatory attributes on these exports must be ignored. However, if a required bundle's exported package is substituted for an imported package, then the requiring bundles must get wired to the same exported package that the required bundle is wired to ensure class space consistency.

For example, assume that bundle A exports and imports package p and bundle B requires bundle A:

```
Bundle A
Export-Package: p;x=1;mandatory:=x
Import-Package: p
```

```
Bundle B
Require-Bundle: A
```

In this constellation, bundle B will get package p from the same source as bundle A. Bundle A can get the package from itself if it is chosen as an exporter for p, but it can also get the package from another bundle because it also imports it. In all cases, bundle B must use exactly the same exporter for package p as bundle A.

A given package may be available from more than one of the required bundles. Such packages are named *split packages* because they derive their contents from different bundles. If these different bundles provide the same classes unpredictable shadowing of classes can arise, see *Issues With Requiring Bundles* on page 86. However, split packages without shadowing are explicitly permitted.

For example, take the following setup:

```
A: Require-Bundle: B
   Export-Package: p
B: Export-Package: p;partial=true;mandatory:=partial
```

If bundle C imports package p, it will be wired to package A.p, however the contents will come from B.p > A.p. The mandatory attribute on bundle B's export definition ensures that bundle B is not accidentally selected as exporter for package p. Split packages have a number drawbacks that are discussed in *Issues With Requiring Bundles* on page 86.

Resources and classes from a split package must be searched in the order in which the required bundles are specified in the Require-Bundle header.

As an example, assume that a bundle requires a number of required bundles and a number of language resources (also bundles) that are optional.

```
Require-Bundle: com.acme.facade;visibility:=reexport, «
com.acme.bar.one;visibility:=reexport, «
com.acme.bar.two;visibility:=reexport, «
com.acme.bar._nl;visibility:=reexport;resolution:=optional, «
com.acme.bar._en;visibility:=reexport;resolution:=optional
```

A bundle may both import packages (via Import-Package) and require one or more bundles (via Require-Bundle), but if a package is imported via Import-Package, it is not also visible via Require-Bundle: Import-Package takes priority over Require-Bundle, and packages which are exported by a required bundle and imported via Import-Package must *not* be treated as split packages.

In order to be allowed to require a named bundle, the requiring bundle must have BundlePermission[<bundle symbolic name>, REQUIRE], where the bundle symbolic name is the name of the bundle that is required. The required bundle must be able to provide the bundle and must therefore have BundlePermission[<bundle symbolic name>, PROVIDE], where the name des-

ignates the requiring bundle. In the case a fragment bundle requires another bundle, the Bundle Permission must be checked against the fragment bundle's Protection Domain.

3.13.2 Split Package Compatibility

A package is a split package whenever there are multiple *sources* for the package; only bundles using the Require-Bundle header can have split packages.

A source is a bundle that provides the given package. Both the required bundles as well as the requiring bundle can act as a source. The required bundles and the requiring bundle can only contribute their exported packages.

Exported split packages from two bundles are compatible if the package sources for one are a subset of the other.

3.13.3 Issues With Requiring Bundles

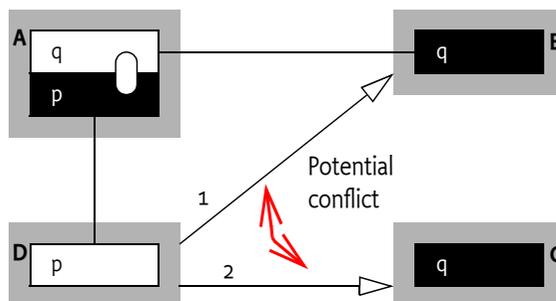
The preferred way of wiring bundles is to use the Import-Package and Export-Package headers because they couple the importer and exporter to a much lesser extent. Bundles can be refactored to have a different package composition without causing other bundles to fail.

The Require-Bundle header provides a way for a bundle to bind to all the exports of another bundle, regardless of what those exports are. Though this can seem convenient at first, it has a number of drawbacks:

- *Split Packages* - Classes from the same package can come from different bundles with Require bundle, such a package is called a split package. Split packages have the following drawbacks:
 - *Completeness* - Split packages are open ended, it is difficult to guarantee that all the intended pieces of a split package have actually been included.
 - *Ordering* - If the same classes are present in more than one required bundle, then the ordering of Require-Bundle is significant. A wrong ordering can cause hard to trace errors, similar to the traditional class path model of Java.
 - *Performance* - A class must be searched in all providers when packages are split. This potentially increases the number of times that a ClassNotFoundException must be thrown which can potentially introduce a significant overhead.
 - *Confusing* - It is easy to find a setup where there is lots of potential for confusion. For example, the following setup is non-intuitive.

```
A: Export-Package: p;uses:=q
   Import-Package: q
B: Export-Package: q
C: Export-Package: q
D: Require-Bundle: B, C
   Import-Package: p
```

Figure 3.17 Split packages and package constraints



In this example, bundle D merges the split package `q` from bundles B and bundle C, however, importing package `p` from bundle A puts a uses constraint on package `p` for package `q`. This implies that bundle D can see the valid package `q` from bundle B but also the invalid package `q` from bundle C. This wiring is allowed because in almost all cases there will be no problem. However, the consistency can be violated in the rare case when package `C.q` contains classes that are also in package `B.q`.

- *Mutable Exports* - The feature of `visibility:=reexport` that the export signature of the requiring bundle can unexpectedly change depending on the export signature of the required bundle.
- *Shadowing* - The classes in the requiring bundle that are shadowed by those in a required bundle depend on the export signature of the required bundle and the classes the required bundle contains. (By contrast, `Import-Package, except with resolution:=optional`, shadows whole packages regardless of the exporter.)

3.14 Fragment Bundles

Fragments are bundles that can be *attached* to one or more *host bundles* by the Framework. Attaching is done as part of resolving: the Framework appends the relevant definitions of the fragment bundles to the host's definitions before the host is resolved. Fragments are therefore treated as part of the host, including any permitted headers; they must not have their own class loader though fragments must have their own Protection Domain.

Fragments can be attached to multiple hosts with the same symbolic name but different versions. If multiple fragments with the same symbolic name match the same host, then the Framework must only select one fragment, this must be the fragment with the highest version.

A key use case for fragments is providing translation files for different locales. This allows the translation files to be treated and shipped independently from the main application bundle.

When an attached fragment is updated, the content of the previous fragment must remain attached to its host bundles. The new content of the updated fragment must not be allowed to attach to the host bundles until the Framework is restarted or the host bundle is refreshed. During this time, an attached fragment will have two versions: the old version, attached to the old version of the host, and a new fragment bundle that can get attached to a new version or to a different host bundle. The exact configuration can be discovered with the *Bundle Wiring API Specification* on page 157.

When attaching a fragment bundle to a host bundle the Framework must perform the following steps:

1. Append the import definitions for the Fragment bundle that do not *conflict* with an import definition of the host to the import definitions of the host bundle. A Fragment can provide an import statement for a private package of the host. The private package in the host is hidden in that case.
2. Append the Require-Bundle entries of the fragment bundle that do not conflict with a Require-Bundle entry of the host to the Require-Bundle entries of the host bundle.
3. Append the export definitions of a Fragment bundle to the export definitions of the host bundle unless the exact definition (directives and attributes must match) is already present in the host. Fragment bundles can therefore add additional exports for the same package name. The bundle-version attributes and bundle-symbolic-name attributes will reflect the host bundle.
4. Append the Provide-Capability clauses of the fragment to the Provide-Capability clauses of the host
5. Append the Require-Capability clauses of the fragment to the Require-Capability clauses of the host

A host and a fragment conflict when they cannot resolve to provide a consistent class space. If a conflict is found, the Fragment bundle is not attached to the host bundle.

A Fragment bundle must enter the resolved state only if it has been successfully attached to at least one host bundle.

During runtime, the fragment's JAR is searched after the host's bundle class path as described in *Fragments During Runtime* on page 88.

A Fragment bundle can not be required by another bundle with the Require-Bundle header.

3.14.1 Fragment-Host

The Fragment-Host manifest header links the fragment to its potential hosts. It must conform to the following syntax:

```
Fragment-Host      ::= bundle-description
bundle-description ::= symbolic-name
                    ( ';' parameter )* // See 1.3.2
```

The following directives are architected by the Framework for Fragment-Host:

- extension - Indicates this extension is a system or boot class path extension. It is only applicable when the Fragment-Host is the System Bundle. This is discussed in *Extension Bundles* on page 90. The following values are supported:
 - framework - The fragment bundle is a Framework extension bundle (default).
 - bootclasspath - The fragment bundle is a boot class path extension bundle.

The fragment must be the bundle symbolic name of the implementation specific system bundle or the alias system.bundle. The Framework should fail to install an extension bundle when the bundle symbolic name is not referring to the system bundle.

The following attributes are architected by the Framework for Fragment-Host:

- bundle-version - The version range to select the host bundle. If a range is used, then the fragment can attach to multiple hosts. See *Semantic Versioning* on page 58. The default value is [0.0.0,∞).

The Fragment-Host header can assert arbitrary attributes that must be matched before a host is eligible.

When a fragment bundle is attached to a host bundle, it logically becomes part of it. All classes and resources within the fragment bundle must be loaded using the class loader (or Bundle object) of its host bundle. The fragment bundles of a host bundle must be attached to a host bundle in the order that the fragment bundles are installed, which is in ascending bundle ID order. If an error occurs during the attachment of a fragment bundle then the fragment bundle must not be attached to the host. A fragment bundle must enter the resolved state only if it has been successfully attached to one or more host bundles.

In order for a host bundle to allow fragments to attach, the host bundle must have BundlePermission[<bundle symbolic name>,HOST]. In order to be allowed to attach to a host bundle, a fragment bundle must have BundlePermission[<bundle symbolic name>,FRAGMENT].

3.14.2 Fragments During Runtime

All class or resource loading of a fragment is handled through the host's class loader or Bundle object, a fragment must never have its own class loader, it therefore fails the class and resource loading methods of the Bundle object. Fragment bundles are treated as if they are an intrinsic part of their hosts.

Though a fragment bundle does not have its own class loader, it still must have a separate Protection Domain when it is not an extension fragment. Each fragment can have its own permissions linked to the fragment bundle's location and signer.

A host bundle's class path is searched before a fragment's class path. This implies that packages can be split over the host and any of its fragments. Searching the fragments must be done in ascending bundle ID order. This is the order that the fragment bundles were installed.

Figure 3.18 Resource/class searching with fragments

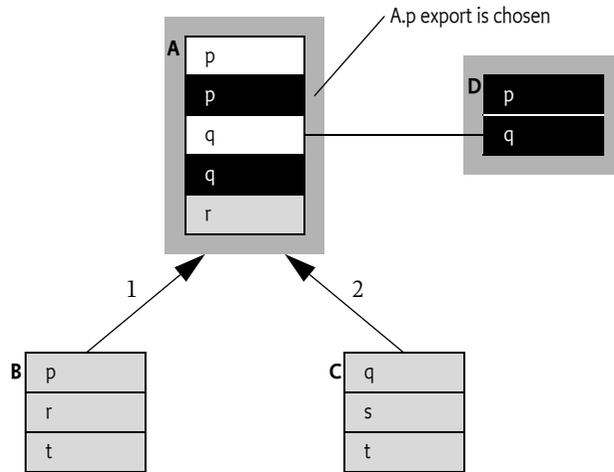


Figure 3.18 shows a setup with two fragments. Bundle B is installed before bundle C and both bundle B and bundle C attach to bundle A. The following table shows where different packages originate in this setup. Note that the order of the append (>) is significant.

Table 3.3 Effect of fragments on searching

Package Requested	From	Remark
p	A.p > B.p	Bundle A exports package p, therefore, it will search its class path for p. This class path consists of the JAR and then its Fragment bundles.
q	D.q	The import does not handle split packages and package q is imported from bundle D. Therefore, C.q is not found.
r	A.r > B.r	Package r is not imported and therefore comes from the class path.
s	C.s	
t	B.t > C.t	

In the example above, if package p had been imported from bundle D, the table would have looked quite different. Package p would have come from bundle D, and bundle A's own contents as well as the contents of bundle B would have been ignored.

If package q had bundle D, then the class path would have to be searched, and A.q would have consisted of A.q > C.q.

Fragments must remain attached to a host as long as the host remains resolved. When a host bundle becomes unresolved, then all its attached Fragment bundles must be detached from the host bundle. When a fragment bundle becomes unresolved the Framework must:

- Detach it from the host
- Re-resolve the host bundles

- Reattach the remaining attached fragment bundles.

A Fragment bundle can become unresolved by calling the `refreshBundles(Collection,FrameworkListener...)` method.

3.14.3 Illegal Manifest Header for Fragment Bundles

The following list contains the headers that must not be used in a fragment bundle:

- Bundle-Activator

3.15 Extension Bundles

Extension bundles can deliver optional parts of the Framework implementation. The contents of extension bundles cannot be provided by the normal bundles because they need to be loaded by the framework implementation.

Framework extensions are necessary to provide implementation aspects of the Framework. For example, a Framework vendor could supply the optional services like Permission Admin service and Start Level API with Framework extension bundles.

An extension bundle should use the bundle symbolic name of the implementation system bundle, or it can use the alias of the system bundle, which is `system.bundle`.

The following example uses the Fragment-Host manifest header to specify an extension bundle for any Framework implementation.

```
Fragment-Host: system.bundle
```

The following example uses the Fragment-Host manifest header to specify an extension bundle for a specific Framework implementation.

```
Fragment-Host: com.acme.impl.framework
```

The following describe the life cycle of an extension bundle:

1. When an extension bundle is installed it enters the INSTALLED state.
2. The extension bundle is allowed to enter the RESOLVED state at the frameworks discretion. For example, a framework may choose to immediately resolve the extension after it has entered the INSTALLED state. If all requirements of an extension bundle are satisfied then resolving the extension bundle must not require a framework restart.
3. If a RESOLVED extension bundle is refreshed then the framework must shutdown and the framework must be re-launched. In this case a Framework Event is fired of type `STOPPED_SYSTEM_REFRESHED`.
4. When a RESOLVED extension bundle is updated or UNINSTALLED, it is not allowed to re-enter the RESOLVED state. If the extension bundle is refreshed then the Framework must shutdown and the framework must be re-launched. In this case a Framework Event is fired of type `STOPPED_SYSTEM_REFRESHED`.

It is valid to update an extension bundle to a bundle of another type. If the old extension bundle is resolved then it must be attached as a fragment to the system bundle. When this bundle is updated the old content of the bundle must remain attached to the system bundle until the system bundle is refreshed or the extension bundle is refreshed (using the Wiring API). This must initiate and Framework shutdown and restart. When the framework comes back up the new content of the bundle may be resolved.

All Bundle events should be dispatched for extension bundles as for ordinary bundles.

3.15.1 Illegal Manifest Headers for Extension Bundles

An extension bundle must throw a `BundleException` if it is installed or updated and it specifies any of the following headers.

- `Require-Bundle`
- `Bundle-NativeCode`
- `DynamicImport-Package`
- `Bundle-Activator`

Extension bundles are permitted to specify an `Export-Package` header. Any exported packages specified by an extension bundle must be hosted (exported) by the System Bundle when the extension bundle is resolved.

Extension bundles are permitted to specify `Import-Package` and `Require-Capability` headers to declare dependencies on packages and capabilities.

3.15.2 Resolving Extensions

Extension bundles may specify requirements on packages (`Import-Package`) and capabilities (`Require-Capability`). An extension bundle is allowed to become resolved when all of its mandatory requirements are wired to valid packages or capabilities.

Extension bundle requirements may only be wired to packages and capabilities provided by the system bundle or another extension bundle that is also attached to the system bundle. All other capabilities are considered invalid for resolving an extension bundle. This ensures that the system bundle wiring never hosts a requirement from an extension bundle which is wired to a capability hosted by another bundle other than the system bundle.

3.15.3 Class Path Treatment

A extension bundle's JAR is appended to the class path of the Framework. Extension bundles that are resolved together must have their JAR appended in the order in which the extension bundles are installed: that is, ascending bundle ID order.

3.15.4 Extension Bundle Activator

A extension may hook into the Framework initialization and shutdown process by specifying an Extension Bundle Activator. The `BundleActivator` interface defines methods that the Framework invokes when the Framework is initialized and shutdown.

To inform the OSGi environment of a fully qualified class name serving as its Extension Bundle Activator, a framework extension developer must declare an `ExtensionBundle-Activator` manifest header in the framework extension bundle's manifest file. The following is an example of an `ExtensionBundle-Activator`:

```
ExtensionBundle-Activator: com.acme.Activator
```

The class acting as an Extension Bundle Activator must implement the `BundleActivator` interface, be declared public, and have a public default constructor so an instance of it may be created with `Class.newInstance`.

Supplying an Extension Bundle Activator is optional and only valid for Extension Bundles. For normal Bundles and Fragments, the `ExtensionBundle-Activator` must be ignored.

3.15.4.1 Framework Initialization and Shutdown

An Extension Bundle Activator allows a framework extension to hook into the Framework initialization and shutdown process. *Initializing the Framework* on page 109 describes how the start method for Extension Bundle Activators is called during Framework initialization. *Stopping a Frame-*

work on page 110 describes how the stop method for Extension Bundle Activators is called during Framework shutdown.

3.15.4.2 Installing

When an extension bundle is installed, a Framework must allow the extension to become resolved dynamically, without a Framework restart. When an extension bundle is resolved dynamically after Framework initialization, then the Extension Bundle Activator start method must be called as soon as the extension bundle is resolved. This must happen before the Bundle Event of type RESOLVED is fired for the extension bundle.

3.15.4.3 Update and Uninstall

Unlike normal bundles, updating or uninstalling an extension bundle does not take effect until the Framework is shutdown and restarted. The original content of the extension bundle must remain attached to the system bundle and the Extension Bundle Activator must not have its stop method called until the Framework is shutdown.

3.15.5 Support Properties

Frameworks must implement fragments, require bundle, and extensions. They must therefore set the following properties to true.

- `org.osgi.supports.framework.requirebundle`
- `org.osgi.supports.framework.fragments`
- `org.osgi.supports.framework.extension`

3.16 Security

3.16.1 Extension Bundles

In an environment that has Java security enabled the Framework must perform an additional security check before allowing an extension bundle to be installed. In order for an extension bundle to successfully install, the Framework must check that the extension bundle has All Permissions assigned to it. This means that the permissions of an extension bundle must be setup before the extension bundle is installed.

AllPermission must be granted to extension bundles because they will be loaded under the Protection Domain of either the boot class path or the Framework implementation. Both of these Protection Domains have All Permissions granted to them. Attempting to install an extension bundle that has not already been granted All Permissions must result in a Bundle Exception.

The installer of an extension bundle must have AdminPermission[<extension bundle>,EXTENSIONLIFECYCLE] to install an extension bundle.

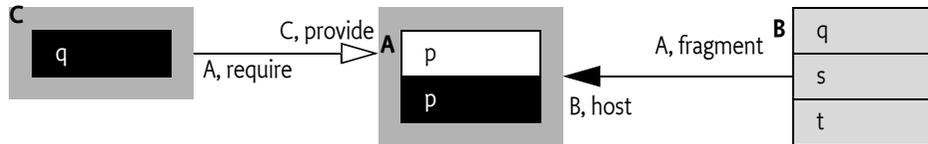
3.16.2 Bundle Permission

Most package sharing permissions are based on Package Permission. However, fragments and required bundles use the bundle symbolic name to handle sharing. The Bundle Permission is used to control this type of package sharing.

The name parameter of the Bundle Permission is a bundle symbolic name. The symbolic name is used as the identifier for the *target bundle*. A wild card (`"*" \u002E,\u002A`) is permitted at the end of the name.

For example, for fragment bundle A to attach to its host bundle B then fragment bundle A requires BundlePermission("B", "fragment") so that A is permitted to target host bundle B. The direction of the actions is depicted in Figure 3.19.

Figure 3.19 Permissions and bundle sharing



The following actions are architected:

- provide - Permission to provide packages to the target bundle.
- require - Permission to require packages from the target bundle.
- host - Permission to attach to the target fragment bundle.
- fragment - Permission to attach as a fragment to the target host bundle.

When a fragment contains a Require-Bundle header, the Framework must check the permission against the domain of the fragment.

3.16.3 Package Permission

Bundles can only import and export packages for which they have the required permission. A PackagePermission must be valid across all versions of a package.

A PackagePermission has two parameters:

- The name, either the name of the target package (with a possible wildcard character at the end) or a filter expression that can verify the exporting bundle. A filter expression can test for the package name with the package.name key. A filter can only be used for an IMPORT action. Filters are described in *Filter Based Permissions* on page 29.
- The action, either IMPORT or EXPORTONLY.

For example, the following Package Permission permits to import any package from a bundle downloaded from ACME:

```
PackagePermission(" (location=http://www.acme.com/*", IMPORT)
```

When a fragment adds imports and exports to the host, the framework must check the protection domain of the fragment and not of the related host.

3.16.4 Resource Permissions

A Framework must always give a bundle the RESOURCE, METADATA, and CLASS AdminPermission actions to access the resources contained within:

- Itself
- Any attached fragments
- Any resources from imported packages

A resource in a bundle may also be accessed by using certain methods on Bundle. The caller of these methods must have AdminPermission[bundle, RESOURCE].

If the caller does not have the necessary permission, a resource is not accessible and null must be returned. Otherwise, a URL object to the resource must be returned. These URLs are called *bundle resource URLs*. Once the URL object is returned, no further permission checks are performed when the contents of the resource are accessed. The URL object must use a scheme defined by the Framework implementation.

Bundle resource URLs are normally created by the Framework, however, in certain cases bundles need to manipulate the URL to find related resources. For example, a URL can be constructed to a resource that is in the same directory as a given resource.

URLs that are not constructed by the Framework must follow slightly different security rules due to the design of the `java.net.URL` class. Not all constructors of the URL class interact with the URL Stream Handler classes (the implementation specific part). Other constructors call at least the `parseURL` method in the URL Stream Handler where the security check can take place. This design makes it impossible for the Framework check the permissions during construction of a bundle resource URL.

The following constructors use the `parseURL` method and are therefore checked when a bundle resource URL is constructed.

```
URL(String spec)
URL(URL context, String spec)
URL(URL context, String spec, URLStreamHandler handler)
```

When one of these constructors is called for a bundle resource URL, the implementation of the Framework must check the caller for the necessary permissions in the `parseURL` method. If the caller does not have the necessary permissions then the `parseURL` method must throw a `SecurityException`. This will cause a `MalformedURLException` to be thrown by the URL constructor. If the caller has the necessary permissions, then the URL object is setup to access the bundle resource without further checks.

The following `java.net.URL` constructors do not call the `parseURL` method in the URL Stream Handler, making it impossible for the Framework to verify the permission during construction.

```
URL(String protocol, String host, int port, String file)
URL(String protocol, String host, int port, String file, URLStreamHandler handler)
URL(String protocol, String host, String file)
```

Bundle resource URLs that are created with these constructors cannot perform the permission check during creation and must therefore delay the permission check. When the content of the URL is accessed, the Framework must throw a `SecurityException` if the caller does not have `AdminPermission[bundle, RESOURCE]` for the bundle referenced by the URL.

3.16.5 Capability Permission

The Capability Permission provides a means to limit access to certain Capabilities when security is on. A Capability Permission is a Filter based Permission, as described in *Filter Based Permissions* on page 29, giving access to the following additional property:

- `capability.namespace` - The namespace of the requirement or provided capability.

The filter can also assert information from the *target* bundle. The target bundle is always the bundle that provides the capability. This means that a requirer can be restricted to receive a capability from a specific bundle.

Capabilities in a namespace for which the resolving bundle has no permission are not available to other bundles. Requirements in a namespace for which a bundle has no permission can never be satisfied.

The Capability Permission has the following actions:

- **REQUIRE** - Imply permission to require the given namespace. The target bundle that can be asserted in the filter is the bundle providing the capability.
- **PROVIDE** - Imply permission to provide a capability in the given namespace, the target bundle is the bundle that is checked for the permission.

The Capability Permission has the following constructors:

- `CapabilityPermission(String,String)` - Constructor to set the filter and actions. This constructor is also used to verify the provide action.

- `CapabilityPermission(String,Map,Bundle,String)` - Special constructor to verify the permission against the namespace. The bundle is the bundle providing the capability.

3.16.6 Permission Checks

Since multiple bundles can export permission classes with the same class name, the Framework must make sure that permission checks are performed using the correct class. For example, a bundle that calls the `checkPermission` method provides an instance of the `Permission` class:

```
void foo(String name) {
    checkPermission(new FooPermission(name, "foo"));
}
```

This class of this `Permission` instance comes from a particular source. Permissions can only be tested against instances that come from the same source.

Therefore, the Framework needs to look up permissions based on *class* rather than *class name*. When it needs to instantiate a permission it must use the class of the permission being checked to do the instantiation. This is a complication for Framework implementers; bundle programmers are not affected.

Consider the following example:

```
Bundle A
  Import-Package: p
  Export-Package: q
Bundle B
  Import-Package: p
```

- Bundle A uses a `p.FooService`. Usage of this class checks `q.FooPermission` whenever one of its methods is invoked.
- Bundle B has a `FooPermission` in its Protection Domain in a (Conditional) Permission Info object.
- Bundle B invokes a method in the `FooService` that was given by bundle A.
- The `FooService` calls the `checkPermission` method with a new `FooPermission` instance.
- The Framework must use a `FooPermission` object that is from the same class loader as the given `FooPermission` object before it can call the `implies` method. In this case, the `FooPermission` class comes from package `A.q`.

After the permission check, bundle B will have a `FooPermission` instantiated using a class from a package it does not import. It is therefore possible that the Framework has to instantiate multiple variations of the `FooPermission` class to satisfy the needs of different bundles.

3.17 References

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<http://www.ietf.org/rfc/rfc2068.txt>
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https://docs.oracle.com/javase/8/docs/technotes/guides/jar/jar.html#JAR_Manifest
 - [11] *W3C EBNF*
<http://www.w3c.org/TR/REC-xml#sec-notation>
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<https://maven.apache.org/pom.html#Developers>
- [27] *Maven POM Reference, SCM*
<https://maven.apache.org/pom.html#SCM>
- [28] *Multi-release JAR File*
<https://docs.oracle.com/javase/9/docs/specs/jar/jar.html#Multi-release>

3.18 Changes

- Updated *Bundle-License: Apache-2.0*; link="<http://opensource.org/licenses/apache2.0.php>" on page 35 to recommend using license identifiers from [25] *Software Package Data Exchange (SPDX) License List*.
- Added *Bundle-Developers: pkriens; email=pkriens@osgi.org; name="Peter Kriens"; organization="OSGi Alliance"* on page 34 to hold information about the bundle's developers.
- Added *Bundle-SCM: url=https://github.com/bndtools/bnd, connection=scm:git:https://github.com/bndtools/bnd.git, developerConnection=scm:git:git@github.com:bndtools/bnd.git* on page 37 to hold information about the bundle's software configuration management system.
- Updated to reference the new bundle annotations in `org.osgi.annotation.bundle`.
- Removed specification for bootclasspath extension bundles.
- Added FrameworkEvent type `STOPPED_SYSTEM_REFRESHED`.
- Allow extension bundles to specify package and capability requirements.
- Mandate support for dynamically resolving extension bundles.
- Added support for multi-release JARs. See *Multi-release JAR* on page 41.
- Bundles may now import `java.*` packages to ensure the Java platform provides the required `java.*` packages. See *Execution Environment* on page 48. Importing a `java.*` package only affects bundle resolution and wiring. Classes in `java.*` packages are always loaded from the parent class loader. See *Parent Delegation* on page 70.

4 Life Cycle Layer

Version 1.9

4.1 Introduction

The Life Cycle Layer provides an API to control the security and life cycle operations of bundles. The layer is based on the module and security layer.

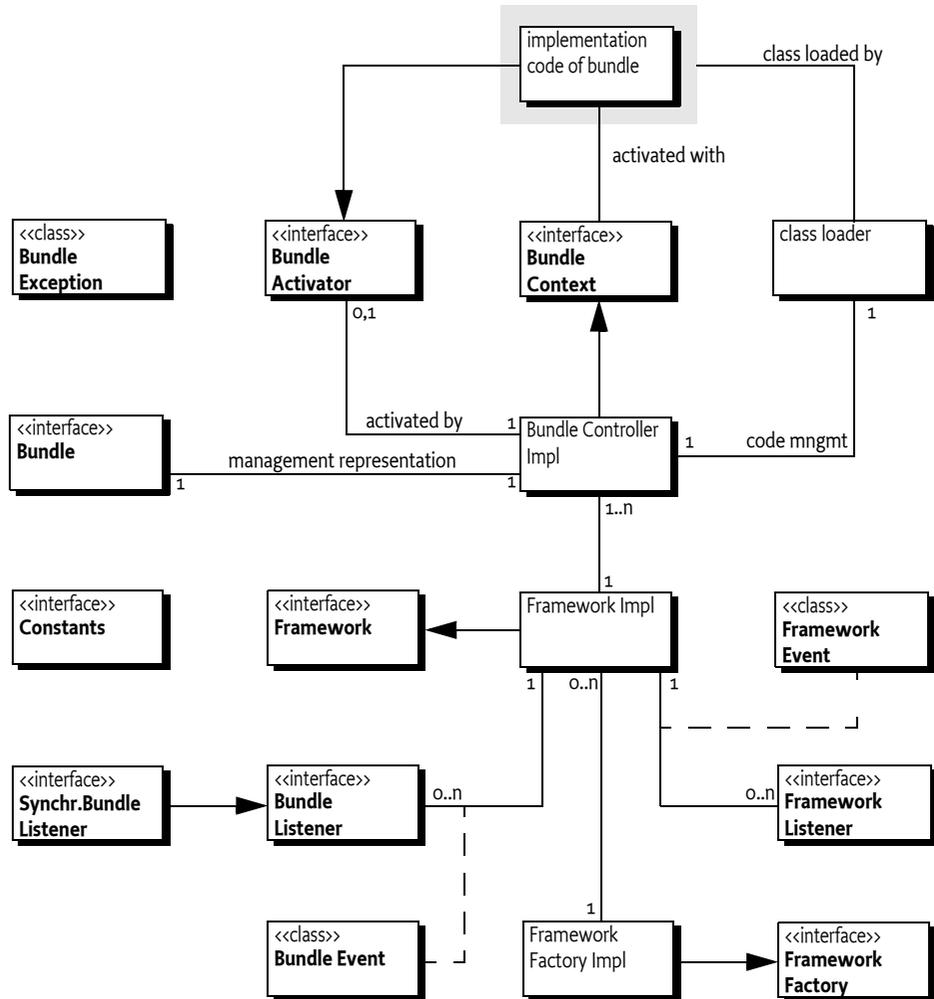
4.1.1 Essentials

- *Complete* - The Life Cycle layer must implement an API that fully covers the installation, starting, stopping, updating, uninstallation, and monitoring of bundles.
- *Reflective* - The API must provide full insight into the actual state of the Framework.
- *Secure* - It must be possible to use the API in a secure environment using fine-grained permissions. However, security must be optional.
- *Manageable* - It must be possible to manage a OSGi framework remotely.
- *Launching* - It must be able to launch an implementation of a framework in a standardized way.

4.1.2 Entities

- *Bundle* - Represents an installed bundle in the Framework.
- *Bundle Context* - A bundle's execution context within the Framework. The Framework passes this to a Bundle Activator when a bundle is started or stopped.
- *Bundle Activator* - An interface implemented by a class in a bundle that is used to start and stop that bundle.
- *Bundle Event* - An event that signals a life cycle operation on a bundle. This event is received via a (Synchronous) Bundle Listener.
- *Framework Event* - An event that signals an error or Framework state change. The event is received via a Framework Listener.
- *Bundle Listener* - A listener to Bundle Events.
- *Synchronous Bundle Listener* - A listener to synchronously delivered Bundle Events.
- *Framework Listener* - A listener to Framework events.
- *Bundle Exception* - An Exception thrown when Framework operations fail.
- *System Bundle* - A bundle that represents the Framework.
- *Framework* - An interface implemented by an object that represents the actual framework. It allows external management of a Framework.
- *Framework Factory* - An interface implemented by Framework providers that allows the creation of a framework object.

Figure 4.1 Class diagram org.osgi.framework Life Cycle Layer



4.2 Frameworks

This section outlines how a *launcher* can launch a framework implementation and then manage it, regardless of the implementation type of the framework. This allows a launcher to embed an OSGi framework without having to provide code that differs between different implementations.

4.2.1 Launching and Controlling a Framework

Code that wants to use one of the OSGi Framework implementations must provide the chosen framework implementation on the class path, or create a special class loader that loads the code and resources from that implementation. How this is achieved, is outside this specification.

A framework implementation must provide a *factory* class. A factory class is an indirection to create a framework implementation object. The implementation factory class must implement the [FrameworkFactory](#) interface. The launcher can use the following ways to get this class name:

- Service Provider Configuration model, see *Java Service Provider Configuration Support* on page 112,

- Get it from some configuration and use `Class.forName`, or
- Hardcode the name.

The `FrameworkFactory` interface has a single method: `newFramework(Map)`. The map provides the sole configuration properties for the framework object. The result of this method is a *framework object*, this object implements the `Framework` interface. The `Framework` interface extends the `Bundle` interface and adds methods to handle the issues unique to launching a framework. The framework object can be seen as the system bundle, though the framework object and the system bundle do not have to be identical, implementations are allowed to implement them in different objects.

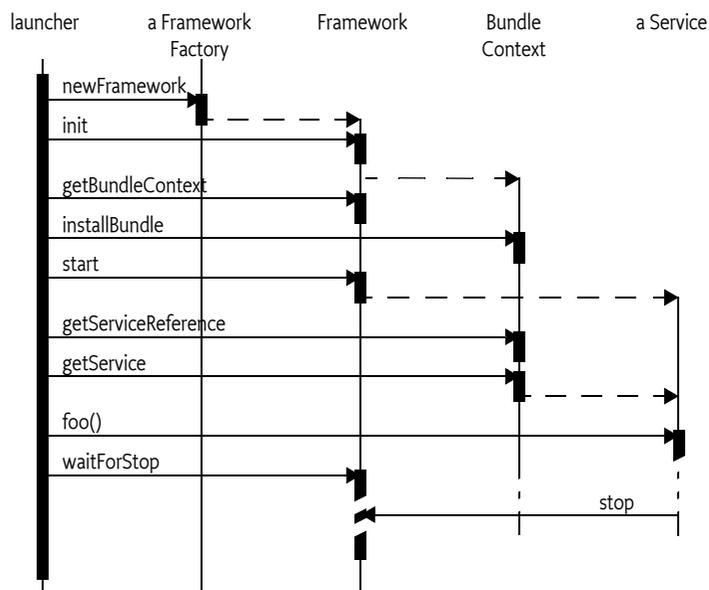
Before the framework object can be used, the launcher must first *initialize* it by calling the `init` method. After initialization, the framework object can provide a valid Bundle Context and has registered any framework services, but any installed bundles must be in the `INSTALLED` state. The launcher can then configure the framework object by installing bundles, interacting with the framework services, or registering launcher services. The launcher can also start bundles, but these bundles will not be started until the framework object becomes `ACTIVE`.

After the framework object is properly configured, the launcher can *start* it by calling the `start` method. The framework object will become `ACTIVE`, and it will move the `startlevel` (if present) to the configured start level. This can then resolve and start any installed bundle. After a framework has become `ACTIVE`, it can be stopped from the framework object, or through the system bundle.

The launcher can wait for a framework object to be stopped with the `waitForStop` method. This method will block until the framework is completely stopped and return a Framework event indicating the cause of the stop. After the framework object has been shutdown, and the `waitForStop` method has returned, all installed bundles will be in the `INSTALLED` state. The same framework object can be re-initialized, and started again, any number of times.

The action diagram in Figure 4.2 shows a typical session. A new framework is created and initialized. The launcher then gets the Bundle Context, installs a bundle and starts the framework. It then gets a service, calls a method and then waits for the framework to stop. The service waits some time and calls `stop` on the System Bundle. The dotted lines indicate some non-specified interactions that are implementation dependent.

Figure 4.2 Action Diagram for Framework Launching



If security is enabled, then the launcher and the framework require All Permission. If All Permission is not available, then the framework must throw a Security Exception.

The following code shows how a framework can be launched.

```
void launch( String factoryName, File[] bundles)
    throws Exception {
    Map p = new HashMap();
    p.put( "org.osgi.framework.storage",
        System.getProperty("user.home")
        + File.separator+"osgi");

    FrameworkFactory factory =
        (FrameworkFactory) Class.forName( factoryName )
                                .newInstance();

    Framework framework = factory.newFramework(p);
    framework.init();

    BundleContext context = framework.getBundleContext();

    for ( File bundle : bundles )
        context.installBundle( bundle.toURL().toString() );

    framework.start();
    framework.waitForStop(0);
}
```

4.2.2 Launching Properties

The Map object given as a parameter to the `newFramework` method provides the *configuration properties* to the framework. This parameter may be null, in that case the framework must be started with reasonable defaults for the environment it is started in. For example, the framework should export the JRE packages as system packages and it should store its bundles in an appropriate place. The framework must not look in the System properties for configuration properties, the specified configuration properties are complete.

The configuration properties may contain any implementation specific properties. The properties in Table 4.1 must be supported by all conformant frameworks.

The configuration properties plus any defaults set by the framework and the fixed properties set by the framework all together form the *launching properties* for the framework.

Table 4.1 Framework Launching Properties

Property Name	Description
org.osgi.framework.« bootdelegation	Set the boot delegation mask, see <i>Parent Delegation</i> on page 70.

Property Name	Description
org.osgi.framework.« bsnversion	Allow installation of multiple bundles with the same bundle symbolic name or restrict this. The property can have the following values: <ul style="list-style-type: none"> • single - A combination of equal bundle symbolic name and equal version is unique in the framework. Installing a second bundle with the same bundle symbolic name and version is an error. • multiple - The combination of bundle symbolic name and version is not unique in the framework. • managed - (Default) Using a Bundle Collision Hook to filter any non-colliding bundles, see <i>Bundle Hook Service Specification</i> on page 393.
org.osgi.framework.« bundle.parent	This property is used to specify what class loader is used for boot delegation. That is, java.* and the packages specified on the org.osgi.framework.bootdelegation. All other packages must be accessed through a wire. <p>This property can have the following values:</p> <ul style="list-style-type: none"> • boot - The boot class loader of the VM. This is the default. • app - The application class loader • ext - The extension class loader • framework - The class loader of the framework
org.osgi.framework.« command.execpermission	Specifies an optional OS specific command to set file permissions on a bundle's native code. This is required on some operating systems to use native libraries. For example, on a UNIX style OS you could have the following value: <pre>org.osgi.framework.command.execpermission=« "chmod +rx \${abspath}"</pre> The <code>\${abspath}</code> macro will be substituted for the actual file path.
org.osgi.framework.« executionenvironment	A comma-separated list of provided execution environments (EE). All methods of each listed EE must be present on the OSGi framework. For example, this property could contain: <pre>CDC-1.1/Foundation-1.1,OSGi/Minimum-1.2</pre>
org.osgi.framework.language	A OSGi framework implementation must provide <i>all</i> the signatures that are defined in the mentioned EEs. Thus, the execution environment for a specific OSGi framework Server must be the combined set of all signatures of all EEs in the org.osgi.framework.executionenvironment property. <p>This property is deprecated; its function is replaced with org.osgi.framework.system.capabilities[.extra].</p> The language used by the framework for the selection of native code. If not set, the framework must provide a value. See [7] <i>Codes for the Representation of Names of Languages</i> for valid values.

Property Name	Description
org.osgi.framework.library.« extensions	<p>A comma separated list of additional library file extensions that must be used when searching for native code. If not set, then only the library name returned by <code>System.mapLibraryName(String)</code> will be used. This list of extensions is needed for certain operating systems which allow more than one extension for native libraries. For example, the AIX operating system allows library extensions of <code>.a</code> and <code>.so</code>, but <code>System.mapLibraryName(String)</code> will only return names with the <code>.a</code> extension. For example:</p> <pre>org.osgi.framework.library.extensions= a,so,dll</pre>
org.osgi.framework.os.name	<p>The name of the operating system as used in the native code clause. If not set, then the framework must provide a default value. Table 4.3 defines a list of operating system names. New operating system names are made available on the OSGi web site, see [11] <i>OSGi Reference Names</i>. Names should be matched case insensitive.</p>
org.osgi.framework.os.version	<p>The version of the operating system as used in the native code clause. If not set, then the framework must provide a default value. If the operating system reported version does not fit the standard version syntax (<i>e.g.</i> <code>2.4.32-kwt</code>), then the launcher should define this launching property with a valid version value.</p>
org.osgi.framework.processor	<p>The name of the processor as used in the native code clause. If not set, then the framework must provide a value. Table 4.2 defines a list of processor names. New processors are made available on the OSGi web site, see [11] <i>OSGi Reference Names</i>. Names should be matched case insensitive.</p>
org.osgi.framework.security	<p>Specifies the type of security manager the framework must use. If not specified then the framework will not set the VM security manager. The following type is architected:</p> <ul style="list-style-type: none"> • <code>osgi</code> - Enables a security manager that supports all security aspects of the OSGi Core specifications (including postponed conditions). <p>If specified, and there is a security manager already installed, then a <code>SecurityException</code> must be thrown when the Framework is initialized.</p> <p>For example:</p> <pre>org.osgi.framework.security = osgi</pre>
org.osgi.framework.startlevel.« beginning	<p>Specifies the beginning start level of the framework. See <i>Start Level API Specification</i> on page 181 for more information.</p> <pre>org.osgi.framework.startlevel.beginning = 3</pre>

Property Name	Description
org.osgi.framework.storage	A valid file path in the file system to a directory. If the specified directory does not exist then the framework must create the directory. If the specified path exists, but is not a directory, or if the framework fails to create the storage directory, then the framework initialization must fail with an exception being thrown. The framework is free to use this directory as it sees fit, for example, completely erase all files and directories in it. If this property is not set, the framework must set this property to a reasonable platform default.
org.osgi.framework.storage.«clean	<p data-bbox="671 425 1322 517">Specifies if and when the storage area for the framework should be cleaned. If no value is specified, the framework storage area will not be cleaned. The possible values is:</p> <ul data-bbox="671 535 1322 665" style="list-style-type: none"> • onFirstInit - The framework storage area will be cleaned before the Framework bundle is initialized for the first time. Subsequent inits, starts or updates of the Framework bundle will not result in cleaning the framework storage area. <p data-bbox="671 683 1322 711">For example:</p> <pre data-bbox="671 729 1322 766">org.osgi.framework.storage.clean = onFirstInit</pre> <p data-bbox="671 785 1322 905">It could seem logical to provide delete on exit and clean at initialization. However, restrictions in common Java VM implementations make it impossible to provide this functionality reliably.</p>
org.osgi.framework.system.«capabilities	<p data-bbox="671 905 1322 1090">Specifies the capabilities of the environment in the grammar specified for the Provide-Capability header, see <i>Dependencies</i> on page 42. These capabilities must be provided from the system bundle. If this property is not set, the framework must calculate this header based on the environment. It should at least set the following namespaces:</p> <ul data-bbox="671 1108 1322 1182" style="list-style-type: none"> • osgi.ee • osgi.native
org.osgi.framework.system.«capabilities.extra	<p data-bbox="671 1182 1322 1256">Deployers should use the org.osgi.framework.system.capabilities.extra property.</p> <p data-bbox="671 1256 1322 1367">Capabilities defined in this property are added to the org.osgi.framework.system.capabilities property. The purpose of the extra property is to be set by the deployer. The grammar for this property is identical to the other capabilities property.</p>
org.osgi.framework.system.«packages	<p data-bbox="671 1367 1322 1500">The packages that must be exported from the System Bundle. If not set, the framework must provide a reasonable default for the current execution environment. See <i>Execution Environment</i> on page 48.</p>

Property Name	Description
org.osgi.framework.system.« packages.extra	<p>Packages specified in this property are added to the org.osgi.framework.system.packages property and therefore have the same syntax. This allows the configurator to only define the additional packages and leave the standard execution environment packages to be defined by the framework. For example:</p> <pre>org.osgi.framework.system.packages.extra=« org.acme.foo; version=1.2, org.acme.foo.impl</pre>
org.osgi.framework.trust.« repositories	<p>This property is used to configure trust repositories for the framework. The value is path of files. The file paths are separated by the pathSeparator defined in the File class. Each file path should point to a key store. The Framework must support the JKS type but can support other key store types. The framework will use the key stores as trust repositories to authenticate certificates of trusted signers. The key stores must only be used as read-only trust repositories to access public keys. The keystore must not have a password. For example:</p> <pre>org.osgi.framework.trust.repositories = « /var/trust/keystore.jks: -/.cert/certs.jks</pre>
org.osgi.framework.« windowssystem	<p>Provide the name of the current window system. This can be used by the native code clause, <i>Native Code Algorithm</i> on page 80. If not set, the framework should provide a value that depends on the current environment.</p>

Table 4.2 Processor Names

Name	Aliases	Description
68k		Motorola 68000
ARM		<i>Intel Strong ARM. Deprecated because it does not specify the endianness. See the following two rows.</i>
arm_le		Intel Strong ARM Little Endian mode
arm_be		Intel String ARM Big Endian mode
Alpha		Compaq (ex DEC)
ia64n		Hewlett Packard 32 bit
ia64w		Hewlett Packard 64 bit mode
Ignite	p3c1k	PTSC
Mips		SGI
PARisc		Hewlett Packard
PowerPC	power ppc	Motorola/IBM Power PC
PowerPC-64	ppc64	IBM Power PC 64-bit Big Endian mode
PowerPC-64-LE	ppc64le	IBM Power PC 64-bit Little Endian mode
Sh4		Hitachi
Sparc		Sun Microsystems
Sparcv9		Sun Microsystems

Name	Aliases	Description
S390		IBM Mainframe 31 bit
S390x		IBM Mainframe 64-bit
V850E		NEC V850E
x86	pentium i386 i486 i586 i686	Intel & AMD 32 bit
x86-64	amd64 em64t x86_64	AMD/Intel 64 bit x86 architecture

Table 4.3 *Operating System Names*

Name	Aliases	Description
AIX		IBM
DigitalUnix		Compaq
Embos		Segger Embedded Software Solutions
Epoc32	SymbianOS	Symbian OS
FreeBSD		Free BSD
HPUX	hp-ux	Hewlett Packard
IRIX		Silicon Graphics
Linux		Open source
MacOS	"Mac OS"	Apple
MacOSX	"Mac OS X"	Apple
NetBSD		Open source
Netware		Novell
OpenBSD		Open source
OS2	OS/2	IBM
QNX	procnto	QNX
Solaris	SunOS	Sun Microsystems
VxWorks		WindRiver Systems
Windows95	Win95 "Windows 95" Win32	Microsoft
Windows98	Win98 "Windows 98" Win32	Microsoft
WindowsNT	WinNT "Windows NT" "Windows NT (unknown)" Win32	Microsoft
WindowsCE	WinCE "Windows CE"	Microsoft
Windows2000	Win2000 "Windows 2000" Win32	Microsoft
Windows2003	Win2003 "Windows 2003" Win32 "Windows Server 2003"	Microsoft
WindowsXP	WinXP "Windows XP" Win32	Microsoft
WindowsVista	WinVista "Windows Vista" Win32	Microsoft
Windows7	Win7 "Windows 7" Win32	Microsoft
Windows8	Win8 "Windows 8" "Windows 8.1" "Windows 8.2" "Windows 8.3" Win32	Microsoft
Windows10	Win10 "Windows 10" Win32	Microsoft
WindowsServer2008	"Windows Server 2008" "Windows 2008" Windows2008 Win2008 Win32	Microsoft
WindowsServer2008R2	"Windows Server 2008 R2" "Windows 2008 R2" Windows2008R2 Win2008R2 Win32	Microsoft

Name	Aliases	Description
WindowsServer2012	"Windows Server 2012" "Win-dows 2012" Windows2012 Win2012 Win32	Microsoft
WindowsServer2012R2	"Windows Server 2012 R2" "Win-dows 2012 R2" Windows2012R2 Win2012R2 Win32	Microsoft
WindowsServer2015	"Windows Server 2015" "Windows 2015" Windows2015 Win2015 Win32	Microsoft
WindowsServer2015R2	"Windows Server 2015 R2" "Win-dows 2015 R2" Windows2015R2 Win2015R2 Win32	Microsoft
WindowsServer2016	"Windows Server 2016" "Win-dows 2016" Windows2016 Win2016 Win32	Microsoft
z/OS		IBM

The properties in the following table are the fixed properties of the framework. The values of these properties are established by the framework implementation and added to the launching properties. If these properties are set in the configuration properties, the framework must ignore them.

Table 4.4 Fixed Framework Launching Properties

Property name	Description
org.osgi.framework.version	The specification version number implemented by the Framework implementation. The specification version number of this specification is 1.9.
org.osgi.framework.vendor	The vendor of the Framework implementation.
org.osgi.framework.uuid	Unique id for the framework instance, see <i>Framework UUID</i> on page 112.
org.osgi.supports.« framework.extension	Support for framework extensions is mandatory, must therefore be set to true, see <i>Extension Bundles</i> on page 90.
org.osgi.supports.« bootclasspath.extension	Must be set to true or false, see <i>Requiring Bundles</i> on page 84.
org.osgi.supports.« framework.fragment	Support for fragment bundles is mandatory, must therefore be set to true, see <i>Fragment Bundles</i> on page 87.
org.osgi.supports.« framework.requirebundle	Support for Require Bundle is mandatory, must therefore be set to true, see <i>Requiring Bundles</i> on page 84.

All launching properties are available through the `getProperty(String)` method. See *Environment Properties* on page 125.

4.2.3 Life Cycle of a Framework

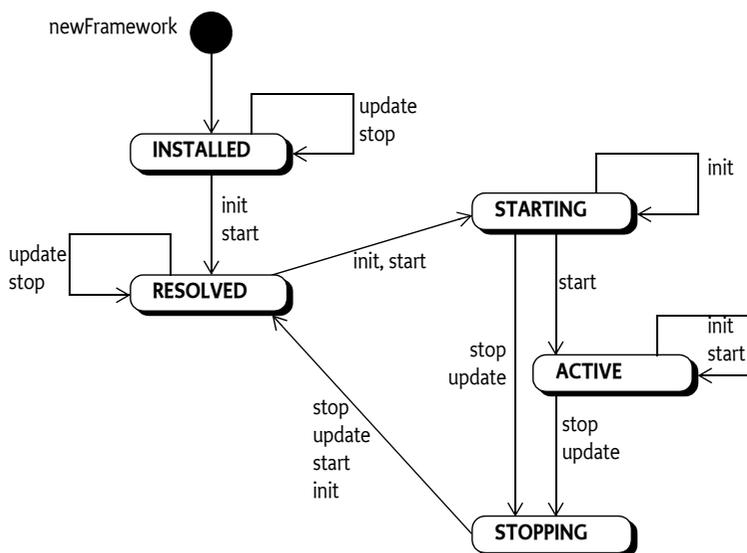
Once the framework is created, it must be in the INSTALLED state. In this state, the framework is not active and there is no valid Bundle Context. From this point on, the framework object can go through its life cycle with the following methods.

- `init` - If the framework object is not active, then this method moves the framework object into the STARTING state.
- `start` - Ensure that the framework is in the ACTIVE state. This method can be called only on the framework because there are no bundles running yet.

- update - Stop the framework. This returns the Framework event `STOPPED_UPDATE` or `STOPPED_BOOTCLASSPATH_MODIFIED` to the `waitForStop` method and then restarts the framework to its previous state. The launcher should then take the appropriate action and then call the `waitForStop` method again or reboot the VM. The update method can be called on the framework or on the system bundle. If the framework is not active, this has no effect.
- stop - Move the framework into the `RESOLVED` state via the `STOPPING` state. This will return a Framework `STOPPED` event from the `waitForStop` method. The Framework's Bundle Context is no longer valid. The framework must be initialized again to get a new, valid Bundle Context. The stop method can be called on the framework or on the system bundle.
- uninstall - Must not be called, will throw an Exception when called.

Figure 4.3 on page 109 shows how the previous methods traverse the state diagram.

Figure 4.3 State diagram Framework



4.2.4 Initializing the Framework

Before the framework can be used, it must be *initialized*. Initialization is caused by one of the `init` methods or implicitly by the `start` method. An initialized framework is operational, but none of its bundles are active. This is reflected in the `STARTING` state. As long as the framework is in this state, new bundles can be installed without any installed code interfering. Existing bundles must all be in the `INSTALLED` or `RESOLVED` state. In this state, the framework will run at start level 0.

A framework object can be initialized multiple times. After initialization:

- Event handling is enabled
- The security manager is configured
- Start level is set to 0
- The framework object has a valid Bundle Context
- Any installed bundle is in the `INSTALLED` or `RESOLVED` state
- Framework services are available
- The framework state is `STARTING`
- Has a valid UUID
- The system bundle can adapt to any of its defined types

- All resolved extension bundle activators start methods have been called

4.2.4.1 Start Extension Activators

The Extension Bundle Activator start method is called to inform the framework extension that the Framework is initializing, see *Extension Bundle Activator* on page 91.

During the initialization process a framework must attempt to resolve all installed Framework Extensions. All resolve operations that occur during initialization must be scoped to only include the system bundle and the extension bundles. This is necessary to avoid resolution operations which change the wiring of normal bundles before all of the Extension Bundle Activators have been called.

The last step during Framework initialization is to call the start method of each Extension Bundle Activator declared by resolved framework extensions. While calling Extension Bundle Activator start methods the framework must be in the STARTING state and have a valid bundle context. Any exception thrown by an Extension Bundle Activator start method must be wrapped in a BundleException and broadcast as an [ERROR](#).

4.2.4.2 Init Framework Listeners

The Framework `init(FrameworkListener...)` method may be called with a list of framework listeners. Any framework events broadcast during the initialization process must be delivered to the specified framework listeners in the order they are specified before returning from the `init` method. After returning from `init`, the specified listeners are no longer notified of framework events. This allows a launcher to initialize a Framework with an `init` framework listener in order to detect errors from framework extension activators.

4.2.5 Starting the Framework

After the framework has been initialized, it can be started with the `start` method. This `start` method must be called on the framework object. The `start` method moves the framework into the ACTIVE state. If the framework was not initialized, it must be initialized first.

In the active state, all installed bundles previously recorded as being started must be started as described in the `Bundle.start` method. Any exceptions that occur during startup must be wrapped in a `BundleException` and then published as a Framework `ERROR` event. Bundles, and their different states, are discussed in *The Bundle Object* on page 113. If the Framework implements the optional Start Level specification, this behavior can be different. See *Start Level API Specification* on page 181. Any bundles that specify an activation policy must be treated according to their activation policy, see *Activation Policies* on page 117.

After the system bundle enters the ACTIVE state, a Framework `STARTED` event is broadcast.

4.2.6 Stopping a Framework

Shutdown can be initiated by stopping the system bundle, covered in *The System Bundle* on page 125 or calling the `stop` method on the framework object. When the framework is shut down, it first enters the STOPPING state. All ACTIVE bundles are stopped as described in the `Bundle.stop` method, except that their persistently recorded start state is kept unchanged. Any exceptions that occur during shutdown must be wrapped in a `BundleException` and then published as a Framework event of type `FrameworkEvent.ERROR`. If the Framework implements the optional Start Level specification, this behavior can be different. See *Start Level API Specification* on page 181. During the shutdown, bundles with a lazy policy must not be activated even when classes are loaded from them and they are not yet activated.

The framework then moves to start level 0, calls `stop` on the Extension Bundle Activators (see *Stop Extension Activators* on page 111), stops event handling and releases any resources (like threads, class loaders, etc.) it held. The framework then enters the RESOLVED state and destroys the Bundle Context. The last action is to notify any threads that are waiting in the `waitForStop` method. The Framework must be re-initialized if it needs to be used again.

After a framework object is stopped and in the resolved state, it can be initialized and started again. Framework implementations must ensure that holding on to a framework object does not consume significant resources.

4.2.6.1 Stop Extension Activators

The Extension Bundle Activator stop method is called to inform the framework extension that the Framework is shutting down, see *Extension Bundle Activator* on page 91. Before disabling event handling during the Framework shutdown process, the framework must call the stop method for each Extension Bundle Activator that was started successfully. While calling Extension Bundle Activator stop methods, the framework must be in the STOPPING state and have a valid bundle context. Any exception thrown by an Extension Bundle Activator stop method must be wrapped in a BundleException and broadcast as an [ERROR](#).

The framework must guarantee that if the start method has executed successfully for an Extension Bundle Activator, that same BundleActivator object must be called on its stop method when the framework is shutdown. After calling the stop method, that particular BundleActivator object must never be used again. An Extension Bundle Activators that threw an exception during start must not be called on shutdown.

4.2.7 Embedding a Framework

The launcher is not running as an OSGi bundle, it is a plain Java application. However, often this launcher needs to communicate with the bundles inside the framework. The launcher can use the Bundle Context of the framework object to get and register services. However, it must ensure that there is class compatibility between its objects and objects from the bundle. A framework will not automatically share packages between the launcher code and the bundles. Packages must be explicitly exported from the parent class loader. The `org.osgi.framework.system.packages.extra` is specifically designed to hold any application packages that needs to be shared between the OSGi bundles and the application. Packages in that property are added to the system packages of the framework, which are packages exported by the system bundle from its parent loader. Care should be taken to ensure that all these system packages are visible to the class loader that loaded the framework.

The OSGi Framework is running in a multi-threaded environment. After the framework is started, it will start bundles and these bundles will be activated. Activated bundles normally start background threads or react on events from other bundles. That is, after the start method returns, the framework has moved to the ACTIVE state and many bundles can be busy on different threads. At this point, the framework object can be stopped by the launcher through the framework object, or by a bundle through the System Bundle's stop method.

The `waitForStop(long)` method on the framework object is included to handle any launcher cleanup that is required after the framework has completely stopped. It blocks until the framework has been completely shutdown. It returns one of the following Framework events to indicate the reason for stopping:

- [STOPPED](#) - This framework object has been shutdown. It can be restarted.
- [STOPPED_UPDATE](#) - This Framework object has been updated. The framework will begin to restart. The framework will return to its state before it was updated, either ACTIVE or STARTING.
- [STOPPED_BOOTCLASSPATH_MODIFIED](#) - This framework object has been stopped because a boot class path extension bundle has been installed or updated. The VM must be restarted in order for the changed boot class path to take affect.
- [ERROR](#) - The Framework encountered an error while shutting down or an error has occurred that forced the framework to shutdown.
- [WAIT_TIMEDOUT](#) - This method has timed out and returned before this Framework has stopped.

4.2.8 Framework UUID

Each framework must have a unique identity every time before the framework is started. This identity is reflected in the framework property:

```
org.osgi.framework.uuid
```

The value of this property must reflect a string defined in [14] *IETF RFC 1422 A Universally Unique Identifier (UUID) URN Namespace* with the urn:uuid: prefix. For example:

```
f81d4fae-7dec-11d0-a765-00a0c91e6bf6
```

The Java UUID class is capable of generating such a UUID. However, as long as the external representation is maintained frameworks are free to create a unique global id in another way.

Setting this property in the configuration properties has no effect, the framework must override it.

4.2.9 Daemon Threads

A Java VM will automatically exit when there are only daemon threads running. This can create the situation where the VM exits when the Framework uses only daemon threads and all threads created by bundles are also daemon threads. A Framework must therefore ensure that the VM does not exit when there are still active bundles. One way to achieve this, is to keep at least one non-daemon thread alive at all times.

4.2.10 Java Service Provider Configuration Support

The Java Service Provider Configuration model, as described in [13] *Java Service Provider Configuration*, provides a way to obtain the name of the framework factory by reading a resource in the JAR. In this specification, it is assumed that the framework implementation is on the class path. The name is obtained by reading the content of the configuration resource with the path META-INF/services/org.osgi.framework.launch.FrameworkFactory.

For example, if the com.acme.osgi framework has a factory class com.acme.osgi.Factory, then it should have the following resource:

```
META-INF/services/org.osgi.framework.launch.FrameworkFactory
```

And the contents should be:

```
# ACME Impl. for OSGi framework
com.acme.osgi.Factory
```

In contrast with the [13] *Java Service Provider Configuration*, there must only be one class name listed in the resource. However, launchers should be aware that the class path could contain multiple resources with the same name.

Java 6 has introduced the java.util.ServiceLoader class that simplifies creating objects through these types of factories. The following code assumes there is a framework implementation JAR on the class path:

```
ServiceLoader<FrameworkFactory> sl =
    ServiceLoader.load(FrameworkFactory.class);

Iterator<FrameworkFactory> it = sl.iterator();
if ( it.hasNext() ) {
    Framework fw = it.next().newFramework(null);
    ...
}
```

4.3 Bundles

A bundle represents a JAR file that is executed in an OSGi Framework. The class loading aspects of this concept were specified in the Module Layer. However, the Module Layer does not define how a bundle is installed, updated, and uninstalled. These life cycle operations are defined here.

The installation of a bundle can only be performed by another bundle or through implementation specific means (for example as a command line parameter of the Framework implementation).

A Bundle is started through its Bundle Activator. Its Bundle Activator is identified by the Bundle-Activator manifest header. The given class must implement the BundleActivator interface. This interface has a start and stop method that is used by the bundle programmer to register itself as listener and start any necessary threads. The stop method must clean up and stop any running threads.

Upon the activation of a bundle, it receives a Bundle Context. The Bundle Context interface's methods can roughly be divided in the following categories:

- *Information* - Access to information about the rest of the Framework.
- *Life Cycle* - The possibility to install other bundles.
- *Service Registry* - The service registry is discussed in *Service Layer* on page 133.

4.4 The Bundle Object

For each bundle installed in the OSGi framework, there is an associated [Bundle](#) object. The Bundle object for a bundle can be used to manage the bundle's life cycle. This is usually done with a Management Agent, which is also a Bundle.

4.4.1 Bundle Identifiers

A bundle is identified by a number of names that vary in their scope:

- *Bundle identifier* - A long that is a Framework assigned unique identifier for the full lifetime of a bundle, even if it is updated or the Framework is restarted. Its purpose is to distinguish bundles in a Framework. Bundle identifiers are assigned in ascending order to bundles when they are installed. The method `getBundleId()` returns a bundle's identifier.
- *Bundle location* - A name assigned by the management agent (Operator) to a bundle during the installation. This string is normally interpreted as a URL to the JAR file but this is not mandatory. Within a particular Framework, a location must be unique. A location string uniquely identifies a bundle and must not change when a bundle is updated. The `getLocation()` method retrieves the location of a bundle.
- *Bundle Symbolic Name and Bundle Version* - A name and version assigned by the developer. The combination of Bundle Version and Bundle Symbolic Name is a globally unique identifier for a bundle. The `getSymbolicName()` method returns the assigned bundle name. The `Bundle.getVersion()` method returns the version. Though the pair is unique, it is possible to install the same bundle multiple times if the `org.osgi.framework.bsntversion` framework launching property is set to managed or multiple, see also *Bundle Collision Hook* on page 396.

4.4.2 Bundle State

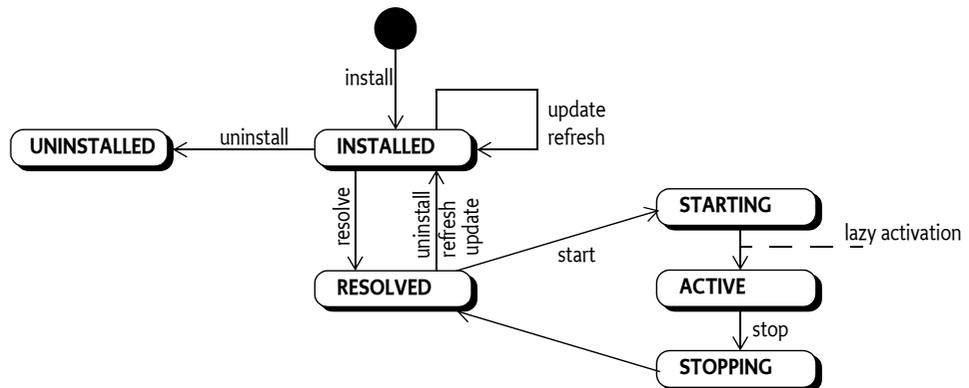
A bundle can be in one of the following states:

- **INSTALLED** - The bundle has been successfully installed.
- **RESOLVED** - All Java classes that the bundle needs are available. This state indicates that the bundle is either ready to be started or has stopped.

- **STARTING** - The bundle is being started, the `BundleActivator.start` method will be called, and this method has not yet returned. When the bundle has a lazy activation policy, the bundle will remain in the **STARTING** state until the bundle is activated. See *Activation Policies* on page 117 for more information.
- **ACTIVE** - The bundle has been successfully activated and is running; its `Bundle Activator start` method has been called and returned.
- **STOPPING** - The bundle is being stopped. The `BundleActivator.stop` method has been called but the stop method has not yet returned.
- **UNINSTALLED** - The bundle has been uninstalled. It cannot move into another state.

Figure 4.4

State diagram Bundle



When a bundle is installed, it is stored in the persistent storage of the Framework and remains there until it is explicitly uninstalled. Whether a bundle has been started or stopped must be recorded in the persistent storage of the Framework. A bundle that has been persistently recorded as started must be started whenever the Framework starts until the bundle is explicitly stopped. The Start Level API influences the actual starting and stopping of bundles. See *Start Level API Specification* on page 181.

The `Bundle` interface defines a `getState()` method for returning a bundle's state.

If this specification uses the term *active* to describe a state, then this includes the **STARTING** and **STOPPING** states.

Bundle states are expressed as a bit-mask though a bundle can only be in one state at any time. The following code sample can be used to determine if a bundle is in the **STARTING**, **ACTIVE**, or **STOPPING** state:

```
if ((b.getState() & (STARTING | ACTIVE | STOPPING)) != 0)
    doActive()
```

4.4.3 Installing Bundles

The `BundleContext` interface, which is given to the `Bundle Activator` of a bundle, defines the following methods for installing a bundle:

- `installBundle(String)` - Installs a bundle from the specified location string (which should be a URL).
- `installBundle(String,InputStream)` - Installs a bundle from the specified `InputStream` object.

A bundle must be valid before it is installed, otherwise the install must fail. The validity of a bundle is discussed in *Bundle Validity* on page 83.

If the to be installed bundle has a bundle symbolic name and version pair that is already installed in the framework then the installation is only valid when the `org.osgi.framework.bsnversion` frame-

work launching property is set to multiple or managed. See *Bundle Collision Hook* on page 396 for more information.

Every bundle is uniquely identified by its location string. If an installed bundle is using the specified location, the `installBundle` methods must return the Bundle object for that installed bundle and not install a new bundle.

The Framework must assign a unique bundle identifier that is higher than any previous bundle identifier.

The installation of a bundle in the Framework must be:

- *Persistent* - The bundle must remain installed across Framework and Java VM invocations until it is explicitly uninstalled.
- *Atomic* - The `install` method must completely install the bundle or, if the installation fails, the OSGi framework must be left in the same state as it was in before the method was called.

Once a bundle has been installed, a Bundle object is created and all remaining life cycle operations must be performed upon this object. The returned Bundle object can be used to start, stop, update, and uninstall the bundle.

4.4.4 Resolving Bundles

A bundle can enter the RESOLVED state when the Framework has successfully resolved the bundle's dependencies as described in the manifest. These dependencies are described in *Resolving Process* on page 65.

4.4.5 Starting Bundles

A bundle can be *started* by calling one of the start methods on its Bundle object or the Framework can automatically start the bundle if the bundle is *ready* and the *autostart setting* of the bundle indicates that it must be started.

A bundle is *ready* if following conditions are all met:

- The bundle can be resolved
- If the optional Start Level API is used, then the bundle's start level is met.

Once a bundle is started, a bundle must be *activated*, see *Activation* on page 116, to give control to the bundle so that it can initialize. This activation can take place immediately (*eager activation*), or upon the first class load from the bundle (*lazy activation*). A started bundle may need to be automatically started again by the framework after a restart or changes in the start level. The framework therefore maintains a persistent *autostart setting* for each bundle. This autostart setting can have the following values:

- *Stopped* - The bundle should not be started.
- *Started with eager activation* - The bundle must be started once it is ready and it must then be eagerly activated.
- *Started with declared activation* - The bundle must be started once it is ready and it must then be activated according to its declared activation policy. See *Activation Policies* on page 117.

The Bundle interface defines the `start(int)` method for starting a bundle and controlling the autostart setting. The `start(int)` method takes an integer option, the following values have been defined for this option:

- 0 - Start the bundle with eager activation and set the autostart setting to *Started with eager activation*. If the bundle was already started with the lazy activation policy and is awaiting activation, then it must be activated immediately.

- **START_TRANSIENT** - Identical to 0 in behavior, however, the autostart setting must *not* be altered. If the bundle can not be started, for example, the bundle is not ready, then a Bundle Exception must be thrown.
- **START_ACTIVATION_POLICY** - Start the bundle using the activation policy declared in the manifest's Bundle-ActivationPolicy header and set the autostart setting to *Started with declared activation*.
- **START_ACTIVATION_POLICY | START_TRANSIENT** - Start the bundle with the bundle's declared activation policy but do not alter the autostart setting.

The Framework must attempt to resolve the bundle, if not already resolved, when trying to start the bundle. If the bundle fails to resolve, the start method must throw a BundleException. In this case, the bundle's autostart setting must still be set unless START_TRANSIENT is used.

When the start method returns without an exception, the state of the bundle will either be ACTIVE or STARTING, depending on the declared activation policy and whether it was used. If the start method throws an exception, then the bundle will not be in either of these states and the stop method will not be called for this Bundle Activator instance.

The `start()` method calls `start(o)`.

The optional Start Level API influences the actual order of starting and stopping of bundles. See *Start Level API Specification* on page 181. Fragment bundles can not be started and must cause a Bundle Exception when there is an attempt to start them.

4.4.6 Activation

A bundle is activated by calling its Bundle Activator object, if one exists. The `BundleActivator` interface defines methods that the Framework invokes when it starts and stops the bundle.

To inform the OSGi environment of the fully qualified class name serving as its Bundle Activator, a bundle developer must declare a Bundle-Activator manifest header in the bundle's manifest file. The Framework must instantiate a new object of this class and cast it to a `BundleActivator` instance. It must then call the `BundleActivator.start` method to start the bundle.

The following is an example of a Bundle-Activator manifest header:

```
Bundle-Activator: com.acme.Activator
```

A class acting as a Bundle Activator must implement the `BundleActivator` interface, be declared public, and have a public default constructor so an instance of it may be created with `Class.newInstance`.

Supplying a Bundle Activator is optional. For example, a library bundle that only exports a number of packages does not need to define a Bundle Activator. In addition, other mechanism exists to obtain control and get a Bundle Context, like for example the Service Component Runtime.

The `BundleActivator` interface defines these methods for starting and stopping a bundle:

- **start(BundleContext)** - This method can allocate resources that a bundle needs, start threads, register services, and more. If this method does not register any services, the bundle can register services it needs later: for example, in a callback or an external event, as long as it is in the ACTIVE state. If the `start(BundleContext)` method throws an exception, the Framework must mark the bundle as stopped and send out STOPPING and STOPPED events but it must not call the `BundleActivator.stop(BundleContext)` method. The start method must therefore be careful to clean up any resources it creates in the start method when it throws an exception.
- **stop(BundleContext)** - This method must undo all the actions of the `BundleActivator.start(BundleContext)` method. However, it is unnecessary to unregister services or Framework listeners, because they must be cleaned up by the Framework anyway. This method is only called when the bundle has reached the ACTIVE state. That is, when the start method has thrown exception, the stop method is never called for the same instance.

A Bundle Activator must be created when a Bundle is started, implying the creation of a class loader. For larger systems, this greedy strategy can significantly increase startup times and unnecessarily increase the memory footprint. Mechanisms such as the Service Component Runtime and activation policies can mitigate these problems.

Fragment bundles must not have a Bundle Activator specified.

4.4.6.1 Activation Policies

The activation of a bundle can also be deferred to a later time from its start using an *activation policy*. This policy is specified in the Bundle-ActivationPolicy header with the following syntax:

```
Bundle-ActivationPolicy ::= policy ( ';' directive )*  
policy ::= 'lazy'
```

The only policy defined is the lazy activation policy. If no Bundle-ActivationPolicy header is specified, the bundle will use eager activation.

4.4.6.2 Lazy Activation Policy

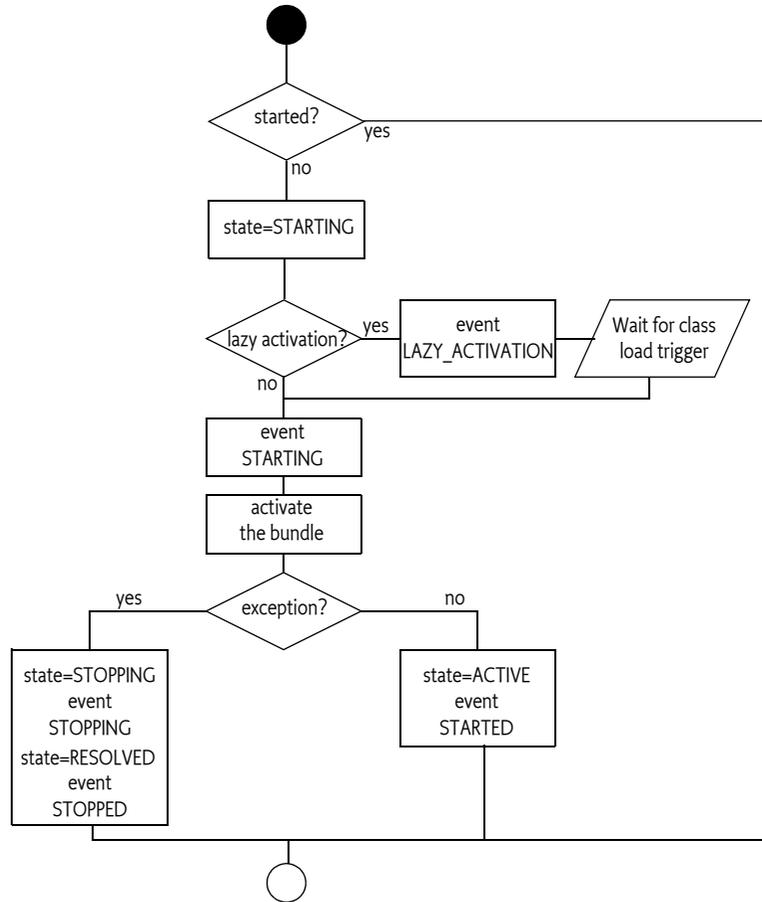
A lazy activation policy indicates that the bundle, once started, must not be activated until it receives the first request to load a class. This request can originate either during normal class loading or via the Bundle loadClass method. Resource loading and a request for a class that is re-directed to another bundle must not trigger the activation. The first request is relative to the bundle class loader, a bundle will not be lazily started if it is stopped and then started again without being refreshed in the mean time.

This change from the default eager activation policy is reflected in the state of the bundle and its events. When a bundle is started using a lazy activation policy, the following steps must be taken:

- A Bundle Context is created for the bundle.
- The bundle state is moved to the **STARTING** state.
- The **LAZY_ACTIVATION** event is fired.
- The system waits for a class load from the bundle to occur.
- The normal **STARTING** event is fired.
- The bundle is activated.
- The bundle state is moved to **ACTIVE**.
- The **STARTED** event is fired.

If the activation fails because the Bundle Activator start method has thrown an exception, the bundle must be stopped without calling the Bundle Activator stop method. These steps are pictured in a flow chart in Figure 4.5. This flow chart also shows the difference in activation policy of the normal eager activation and the lazy activation.

Figure 4.5 Starting with eager activation versus lazy activation



The lazy activation policy allows a Framework implementation to defer the creation of the bundle class loader and activation of the bundle until the bundle is first used; potentially saving resources and initialization time during startup.

By default, any class loaded from the bundle can trigger the lazy activation, however, resource loads must not trigger the activation. The lazy activation policy can define which classes cause the activation with the following directives:

- `include` - A list of package names that must trigger the activation when a class is loaded from any of these packages. The default is all package names present in the bundle.
- `exclude` - A list of package names that must not trigger the activation of the bundle when a class is loaded from any of these packages. The default is no package names.

For example:

```
Bundle-ActivationPolicy: lazy; «
    include:="com.acme.service.base,com.acme.service.help"
```

When a class load triggers the lazy activation, the Framework must first define the triggering class. This definition can trigger additional lazy activations. These activations must be deferred until all transitive class loads and defines have finished. Thereafter, the activations must be executed in the reverse order of detection. That is, the last detected activation must be executed first. Only after

all deferred activations are finished must the class load that triggered the activation return with the loaded class. If an error occurs during this process, it should be reported as a Framework ERROR event. However, the class load must succeed normally. A bundle that fails its lazy activation should not be activated again until the framework is restarted or the bundle is explicitly started by calling the Bundle start method.

4.4.6.3 Restoring State After Refresh or Update

The refresh operation, see *Refreshing* on page 167, and the update methods can cause other bundles to be stopped. Started bundles can be in the ACTIVE state or waiting to be activated, depending on their activation policy. The following rules must be applied when restoring the state after an update or refresh:

- An ACTIVE or STARTING bundle must be started *transiently* after an update or refresh operation to not change its persistent autostart state.
- If the bundle was in the STARTING state due to lazy activation, the bundle's activation policy should be used when starting the bundle.

4.4.7 Stopping Bundles

The Bundle interface defines the stop(int) method for stopping a bundle. This calls the stop method when the bundle is in the ACTIVE state and sets the bundle's state to RESOLVED. The stop(int) takes an integer option. The following value has been defined for this option:

- 0 - If the bundle was activated, then deactivate the bundle and sets the autostart setting for this bundle to *Stopped*.
- `STOP_TRANSIENT` - If the bundle was activated, then deactivate the bundle. Does not alter the autostart setting for this bundle.

The stop() method calls stop(0).

The optional Start Level API influences the actual order of starting and stopping of bundles. See *Start Level API Specification* on page 181.

Attempting to stop a Fragment bundle must result in a Bundle Exception.

4.4.8 Deactivation

The BundleActivator interface defines a stop(BundleContext) method, which is invoked by the Framework to stop a bundle. This method must release any resources allocated since activation. All threads associated with the stopping bundle should be stopped immediately. The threaded code may no longer use Framework-related objects (such as services and BundleContext objects) once the stop method returns.

If the stopping bundle had registered any services or Framework listeners during its lifetime, then the Framework must automatically unregister all registered services and Framework listeners when the bundle is stopped. It is therefore unnecessary from the Framework's point of view to unregister any services or Framework listeners in the stop method.

The Framework must guarantee that if a BundleActivator.start method has executed successfully, that same BundleActivator object must be called with its BundleActivator.stop method when the bundle is deactivated. After calling the stop method, that particular BundleActivator object must never be used again.

Packages exported by a stopped bundle continue to be available to other bundles. This continued export implies that other bundles can execute code from a stopped bundle, and the designer of a bundle should assure that this is not harmful. Exporting interfaces only is one way to prevent such unwanted execution when the bundle is not started. Generally, to ensure they cannot be executed, interfaces should not contain executable code.

4.4.9 Updating Bundles

The Bundle interface defines two methods for updating a bundle:

- `update()` - This method updates a bundle.
- `update(InputStream)` - This method updates a bundle from the specified InputStream object.

The update process supports migration from one revision of a bundle to a newer revision of the same bundle. The capabilities provided by the new revision must be immediately available to the Framework. If the old bundle revision has an `isInUse()` bundle wiring then all capabilities provided by the old bundle wiring must remain available for existing bundles and future resolves until the bundle is refreshed, see *Refreshing* on page 167, or the Framework is restarted. Otherwise the capabilities provided by the old revision must be removed.

After the update operation is complete, the framework must attempt to move the bundle to the same state as it was before the operation taking the activation policy into account, without changing the autostart setting. This is described in more detail in *Restoring State After Refresh or Update* on page 119.

An updater of a bundle must have `AdminPermission[<bundle>,LIFECYCLE]` for both the installed bundle as well as the new bundle. The parameters of `AdminPermission` are explained in *Admin Permission* on page 129.

4.4.10 Uninstalling Bundles

The Bundle interface defines the `uninstall()` method for uninstalling a bundle from the Framework. This method causes the Framework to notify other bundles that the bundle is being uninstalled, and sets the bundle's state to UNINSTALLED. To whatever extent possible, the Framework must remove any resources related to the bundle. This method must always uninstall the bundle from the persistent storage of the Framework.

If the uninstalled bundle has one or more revisions with `isInUse()` bundle wirings then all capabilities provided by the old in use bundle wirings must remain available for existing bundles and future resolves until the bundle is refreshed, see *Refreshing* on page 167, or the Framework is restarted. Otherwise the capabilities provided by the old revision must be removed.

4.4.11 Detecting Bundle Modifications

The Bundle object provides a convenient way to detect modifications in a bundle. The Framework must keep the time that a bundle is modified by any of the life cycle operations or, in the case of multi-release JARs, by changing the version of Java platform being used. See *Multi-release JAR* on page 41. The `getLastModified()` method will return the last time the bundle was effectively modified. This last modified time must be stored persistently.

The method must return the number of milliseconds since midnight Jan. 1, 1970 UTC with the condition that a modification must always result in a higher value than the previous last modified time of any bundle.

The `getLastModified()` method is very useful when a bundle is caching resources from another bundle and needs to refresh the cache when the other bundle is effectively modified. A modification in the other bundle can happen while the caching bundle is not active. The last modified time is therefore a convenient way to track modifications in bundles.

4.4.12 Retrieving Manifest Headers

The Bundle interface defines two methods to return manifest header information: `getHeaders()` and `getHeaders(String)`.

- `getHeaders()` - Returns a Dictionary object that contains the bundle's manifest headers and values as key/value pairs. The values returned are localized according to the default locale returned by `java.util.Locale.getDefault`.
- `getHeaders(String)` - Returns a Dictionary object that contains the bundle's manifest headers and values as key/value pairs. The returned values are localized using the specified locale. The locale may take the following values:
 - `null` - The default locale returned by `java.util.Locale.getDefault` is used. This makes this method identical to the `getHeaders()` method.
 - *Empty string* - The dictionary will contain the raw (unlocalized) manifest headers including any leading '%'.
 • *A Specific Locale* - The given locale is used to localize the manifest headers.

If the bundle is a multi-release JAR, see *Multi-release JAR* on page 41, then the returned manifest header information must be the supplemented manifest information. That is, the main manifest with the replacement values from a supplemental manifest, if any, for the current Java platform version.

Localization is performed according to the description in *Localization* on page 82. If no translation is found for a specific key, the Dictionary returned by `Bundle.getHeaders` will return the raw values as specified in the manifest header values without the leading '%' character.

These methods require `AdminPermission[<bundle>, METADATA]` because some of the manifest header information may be sensitive, such as the packages listed in the `Export-Package` header. Bundles always have permission to read their own headers.

The `getHeaders` methods must continue to provide the manifest header information after the bundle enters the `UNINSTALLED` state. After the bundle has been uninstalled, this method will only return manifest headers that are raw or localized for the default locale at the time the bundle was uninstalled.

A framework implementation must use only the raw (unlocalized) manifest headers when processing manifest headers. Localizations must not influence the operations of the Framework.

4.4.13 Loading Classes

In certain cases, it is necessary to load classes as if they were loaded from inside the bundle. The `loadClass(String)` method gives access to the bundle class loader. This method can be used to:

- Load plugins from another bundle
- Start an application model activator
- Interact with legacy code

For example, an application model could use this feature to load the initial class from the bundle and start it according to the rules of the application model.

```
void appStart() {
    Class initializer = bundle.loadClass(activator);
    if ( initializer != null ) {
        App app = (App) initializer.newInstance();
        app.activate();
    }
}
```

Loading a class from a bundle can cause it to be activated if the bundle uses a lazy activation policy.

4.4.14 Access to Resources

The resources from a bundle can come from different sources. They can come from the raw JAR file, Fragment bundles, imported packages, or the bundle class path. Different use cases require a dif-

ferent resource search strategy. The Bundle interface provides a number of methods that access resources but use different strategies. The following search strategies are supported:

- *Class Space* - The `getResource(String)` and `getResources(String)` provide access to resources that is consistent with the class space as described in *Overall Search Order* on page 71. Following the search order can make certain parts of the JAR files inaccessible. These methods require that the bundle is resolved. If the bundle is not resolved, the Framework must attempt to resolve it.

The search order can hide certain directories of the JAR file. Split packages are taken into account; therefore, resources with the same package names can come from different JARs. If the bundle is unresolved (or cannot be resolved), the `getResource` and `getResources` methods must only load resources from the bundle class path. This search strategy should be used by code that wants to access its own resources. Calling either method can cause the creation of a class loader and force the bundle to become resolved.

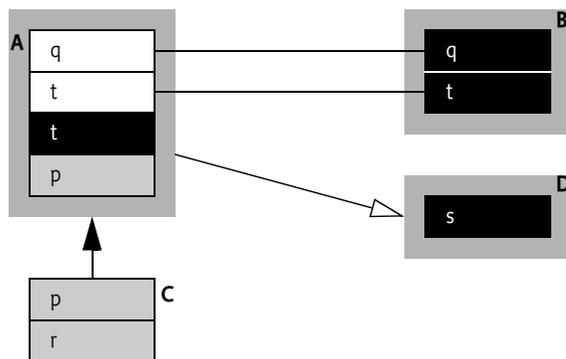
- *JAR File* - The `getEntry(String)` and `getEntryPaths(String)` methods provide access to the resources in the bundle's JAR file. No searching is involved, only the raw JAR file is taken into account. The purpose of these methods is to provide low-level access without requiring that the bundle is resolved.
- *Bundle Space* - The `findEntries(String,String,boolean)` is an intermediate form. Useful when configuration or setup information is needed from another bundle. It considers Fragment bundles but it must never create a class loader or use the bundle class path. The method provides access to all directories in the associated JAR files.

For example, consider the following setup:

```
A: Require-Bundle: D
   Import-Package: q, t
   Export-Package: t
B: Export-Package: q, t
C: Fragment-Host: A
D: Export-Package: s
```

This setup is depicted in Figure 4.6.

Figure 4.6 Setup for showing the difference between `getResource` and `getEntry`



The following table shows the effect of getting a resource from this setup when bundle A is resolved.

Table 4.5 Differences between `getResource`, `getEntry`, and `findEntries` for resolved bundle A

Resource	<code>getResource</code>	<code>getEntry</code>	<code>findEntries</code>
q	B.q	null	null
p	A.p > C.p	A.p	A.p > C.p
r	C.r	null	C.r

Resource	getResource	getEntry	findEntries
s	D.s	null	null
t	B.t	A.t	A.t

The following table shows the same cases as the previous table but now for an unresolved bundle A.

Table 4.6 *Differences between getResource, getEntry, and findEntries for an unresolved bundle A*

Resource	getResource	getEntry	findEntries
q	null	null	null
p	A.p	A.p	A.p
r	null	null	null
s	null	null	null
t	A.t	A.t	A.t

4.4.15 Permissions of a Bundle

The Bundle interface defines a method for returning information pertaining to a bundle's permissions: `hasPermission(Object)`. This method returns true if the bundle's Protection Domain has the specified permission, and false if it does not, or if the object specified by the argument is not an instance of `java.security.Permission`. Fragments also have their own Protection Domain.

The parameter type is `Object` so that the Framework can be implemented on Java platforms that do not support Java based security.

See *The Permission Check* on page 336 for more information about the permission checks.

4.4.16 Access to a Bundle's Bundle Context

Bundles that have been started have a Bundle Context. This object is a *capability*; it is intended to be used only by the bundle. However, there are a number of cases where bundles must act on behalf of other bundles. For example, the Service Component Runtime registers services on behalf of other bundles. The framework therefore provides access to another bundle's context via the `getBundleContext()` method. If there is no Bundle Context for that Bundle because the bundle is a fragment bundle or the bundle state is not in `{ STARTING, ACTIVE, STOPPING }`, then null must be returned.

This method is potentially harmful because it allows any bundle to act as any other bundle. In a secure system, the method is protected by requiring `AdminPermission[* ,CONTEXT]`.

4.4.17 Adaptations

The `adapt(Class)` method allows the Bundle to be *adapted* to different types. The purpose of this method is to provide more specialized access to the Bundle object, access that is not always needed by most clients of the interface. For example, the `adapt` method can be used to adapt a Bundle object to the current `BundleWiring` object (if resolved). The `adapt` method is used as follows:

```
BundleWiring bw = aBundle.adapt(BundleWiring.class);
```

The following table shows the minimum list of types that can be used in the `adapt` method. However, implementations and specifications can extend this list.

Table 4.7 *Minimum set of classes that can be adapted from Bundle*

Class	Description
<code>AccessControlContext</code>	The Access Control Context for this bundle according to <i>Permissions of a Bundle</i> on page 123.
<code>BundleContext</code>	The Bundle Context for this bundle.
<code>BundleRevision</code>	The current Bundle Revision for this bundle, see <i>Bundle Wiring API Specification</i> on page 157.

Class	Description
BundleRevisions	All existing Bundle Revision objects for this bundle, see <i>Bundle Wiring API Specification</i> on page 157.
BundleStartLevel	The Bundle Start Level for this bundle, see <i>Start Level API Specification</i> on page 181.
BundleWiring	The Bundle Wiring for the current Bundle Revision, see <i>Bundle Wiring API Specification</i> on page 157.
Framework	The Framework object from the launching API if this bundle is the System Bundle, see <i>Frameworks</i> on page 100.
FrameworkStartLevel	The Framework Start Level if this is the System Bundle, see <i>Start Level API Specification</i> on page 181.
FrameworkWiring	The Framework Wiring if this bundle is the System Bundle. See <i>Bundle Wiring API Specification</i> on page 157.

4.5 The Bundle Context

The relationship between the Framework and its installed bundles is realized by the use of [BundleContext](#) objects. A `BundleContext` object represents the execution context of a single bundle within the OSGi framework, and acts as a proxy to the underlying Framework.

A `BundleContext` object is created by the Framework when a bundle is started. The bundle can use this private `BundleContext` object for the following purposes:

- Installing new bundles into the OSGi environment. See *Installing Bundles* on page 114.
- Interrogating other bundles installed in the OSGi environment. See *Getting Bundle Information* on page 124.
- Obtaining a persistent storage area. See *Persistent Storage* on page 125.
- Retrieving service objects of registered services. See *Service References* on page 135.
- Registering services in the Framework service. See *Registering Services* on page 135.
- Subscribing or unsubscribing to events broadcast by the Framework. See *Listeners* on page 127.

When a bundle is started, the Framework creates a `BundleContext` object and provides this object as an argument to the `start(BundleContext)` method of the bundle's Bundle Activator. Each bundle is provided with its own `BundleContext` object; these objects should not be passed between bundles, since the `BundleContext` object is related to the security and resource allocation aspects of a bundle.

After the `stop(BundleContext)` method has returned, the `BundleContext` object must no longer be used. Framework implementations must throw an exception if the `BundleContext` object is used after a bundle is stopped.

The `BundleContext` object is only valid during the { `STARTING`, `ACTIVE`, `STOPPING` } states of a bundle. However, the `BundleContext` object becomes invalid after `stop(BundleContext)` returns (if the bundle has a Bundle Activator). The `BundleContext` object becomes invalid before disposing of any remaining registered services and releasing any remaining services in use. Since those activities can result in other bundles being called (for example, Service Listeners for `UNREGISTERING` events and Service Factories for unget operations), those other bundles can observe the stopping bundle in the `STOPPING` state but with an invalid `BundleContext` object.

4.5.1 Getting Bundle Information

The `BundleContext` interface defines methods to retrieve information about bundles installed in the OSGi framework:

- `getBundle()` - Returns the single Bundle object associated with the `BundleContext` object.

- `getBundles()` - Returns an array of the bundles currently installed in the Framework.
- `getBundle(long)` - Returns the Bundle object specified by the unique identifier, or null if no matching bundle is found.

Bundle access is not restricted; any bundle can enumerate the set of installed bundles. Information that can identify a bundle, however (such as its location, or its header information), is only provided to callers that have `AdminPermission[<bundle>,METADATA]`.

4.5.2 Persistent Storage

The Framework should provide a private persistent storage area for each installed bundle on platforms with some form of file system support.

The `BundleContext` interface defines access to this storage in terms of the `File` class, which supports platform-independent definitions of file and directory names.

The `BundleContext` interface defines a method to access the private persistent storage area: `getDataFile(String)`. This method takes a relative file name as an argument. It translates this file name into an absolute file name in the bundle's persistent storage area. It then returns a `File` object. This method returns null if there is no support for persistent storage.

The Framework must automatically provide the bundle with `FilePermission[<storage area>, READ | WRITE | DELETE]` to allow the bundle to read, write, and delete files in that storage area.

If `EXECUTE` permissions is required, then a relative path name can be used in the `File Permission` definition. For example, `FilePermission[bin/*,EXECUTE]` specifies that the sub-directory in the bundle's private data area may contain executables. This only provides execute permission within the Java environment and does not handle the potential underlying operating system issues related to executables.

This special treatment applies only to `FilePermission` objects assigned to a bundle. Default permissions must not receive this special treatment. A `FilePermission` for a relative path name assigned via the `setDefaultPermission` method must be ignored.

4.5.3 Environment Properties

The `BundleContext` interface defines a method for returning information pertaining to Framework properties: `getProperty(String)`. This method can be used to return the Framework launching properties; see *Launching Properties* on page 102. This method will examine the System properties if the requested property is not available in the launching properties.

4.6 The System Bundle

In addition to normal bundles, the Framework itself is represented as a bundle. The bundle representing the Framework is referred to as the *system bundle*. Through the system bundle, the Framework may register services that can be used by other bundles. Examples of such a service is the `Conditional Permission Admin` service.

The system bundle resembles the framework object when a framework is launched, but implementations are not required to use the same object for the framework object and the system bundle. However, both objects must have bundle id 0, same location, and bundle symbolic name.

The system bundle is listed in the set of installed bundles returned by `BundleContext.getBundles()`, although it differs from other bundles in the following ways:

- The system bundle is always assigned a bundle identifier of zero (0).
- The system bundle `getLocation` method returns the string: "System Bundle", as defined in the `Constants` interface.

- The system bundle has a bundle symbolic name that is unique for a specific version. However, the name `system.bundle` must be recognized as an alias to this implementation-defined name.
- The system bundle's life cycle cannot be managed like normal bundles. Its life cycle methods must behave as follows:
 - `start` - Does nothing because the system bundle is already started.
 - `stop` - Returns immediately and shuts down the Framework on another thread.
 - `update` - Returns immediately, then stops and restarts the Framework on another thread.
 - `uninstall` - The Framework must throw a `BundleException` indicating that the system bundle cannot be uninstalled.

See *Frameworks* on page 100 for more information about the starting and stopping of the Framework.

4.6.1 System Bundle Information

The capabilities of the system bundle are obtained by adapting the system bundle to a [BundleWiring](#) as described in *Adaptations* on page 123. This is in preference to parsing the system bundle's headers.

The system bundle's `Bundle.getHeaders` method returns a Dictionary object with implementation-specific manifest headers. The following headers of this OSGi specification can be returned in this dictionary. Headers not mentioned in this table should not be used.

Table 4.8 Supported headers in the system bundle `getHeaders` method

Header	Type	Description
Bundle-ContactAddress	optional	Recommended to provide the framework vendor's contact address.
Bundle-Copyright	optional	Recommended to provide the framework's copyright information.
Bundle-Description	optional	Recommended description of the framework.
Bundle-DocURL	optional	Recommended documentation URL pointing to further information about the framework.
Bundle-Icon	optional	Recommended pointer to a preferably PNG icon representing this framework.
Bundle-Localization	optional	Recommended localization information.
Bundle-License	optional	License information about this framework implementation.
Bundle-ManifestVersion	mandatory	The maximum version of the manifest version understood by this framework.
Bundle-Name	optional	Recommended human readable name of this framework.
Bundle-Required<< ExecutionEnvironment	mandatory	Mandatory: the list of execution environments supported by this framework. This header is deprecated, see <i>osgi.ee Namespace</i> on page 172.
Bundle-SymbolicName	mandatory	The implementation name for this framework.
Bundle-Vendor	optional	Recommended vendor information
Bundle-Version	mandatory	The version of this framework implementation.
Export-Package	mandatory	Contains packages that are exported by the Framework like <code>org.osgi.framework</code> but also the packages listed in the framework property <code>org.osgi.framework.system.packages</code> or <code>org.osgi.framework.system.packages.extra</code> .

4.7 Events

The OSGi Framework Life Cycle layer supports the following types of events:

- **BundleEvent** - Reports changes in the life cycle of bundles.
- **FrameworkEvent** - Reports that the Framework is started, start level has changed, packages have been refreshed, or that an error has been encountered.

The actual event that is reported is available with the `getType` method. The integer that is returned from this method can be one of the constant names that are described in the class. However, events can, and will be, extended in the future. Unrecognized event types should be ignored.

4.7.1 Listeners

A listener interface is associated with each type of event. The following list describes these listeners.

- **BundleListener** and **SynchronousBundleListener** - Called with an event of type **BundleEvent** when a bundle's life cycle information has been changed.

SynchronousBundleListener objects are called synchronously during the processing of the event and must be called before any BundleListener object is called. The following events are sent by the Framework after it has moved to a different state:
 - **INSTALLED** - Sent after a bundle is installed. The state is now Bundle **INSTALLED** state.
 - **RESOLVED** - Sent when the Framework has resolved a bundle. The state is now the Bundle **RESOLVED** state.
 - **LAZY_ACTIVATION** - The bundle has specified an activation policy; its activation is deferred to a later point in time. The state is set to the Bundle **STARTING** state. This is only sent to SynchronousBundleListener objects.
 - **STARTING** - Sent when the Framework is about to activate a bundle. This is only sent to SynchronousBundleListener objects. The state is now the Bundle **STARTING** state.
 - **STARTED** - Sent when the Framework has started a bundle. The state is now the Bundle **ACTIVE** state.
 - **STOPPING** - Sent when the Framework is about to stop a bundle or the start method of the Bundle Activator has thrown an exception and the bundle is stopped. This event indicates that the Bundle Context will be destroyed. This event is only sent to SynchronousBundleListener objects.
 - **STOPPED** - Sent when the Framework has stopped a bundle.
 - **UNINSTALLED** - Sent when the Framework has uninstalled a bundle
 - **UNRESOLVED** - Sent when the Framework detects that a bundle becomes unresolved; this could happen when the bundle is refreshed or updated. When a set of bundles are refreshed using the Wiring API then each bundle in the set must have an UNRESOLVED BundleEvent published. The UNRESOLVED BundleEvent must be published after all the bundles in the set have been stopped and, in the case of a synchronous bundle listener, *before* any of the bundles in the set are re-started. RESOLVED and UNRESOLVED do not have to be paired.
 - **UPDATED** - Sent after a bundle is updated.
- **FrameworkListener** - Called with an event of type **FrameworkEvent**. Framework events are of type:
 - **ERROR** - Important error that requires the immediate attention of an operator.
 - **INFO** - General information that is of interest in special situations.
 - **PACKAGES_REFRESHED** - The Framework has refreshed the packages.
 - **STARTED** - The Framework has performed all initialization and is running in normal mode.

- **STARTLEVEL_CHANGED** - Is sent by the Framework after a new start level has been set and processed.
- **STOPPED** - Sent by the Framework because of a stop operation on the system bundle.
- **STOPPED_BOOTCLASSPATH_MODIFIED** - Sent by the Framework because of a stop operation on the system bundle and a boot class path extension bundle has been installed or updated.
- **STOPPED_UPDATE** - Sent by the Framework because of an update operation on the system bundle. The Framework will be restarted after this event is fired.
- **WARNING** - A warning to the operator that is not crucial but may indicate a potential error situation.
- **WAIT_TIMEDOUT** - Returned from the `waitForStop` method when the Framework did not stop before the given wait time-out expired.

BundleContext interface methods are defined which can be used to add and remove each type of listener.

Events can be asynchronously delivered, unless otherwise stated, meaning that they are not necessarily delivered by the same thread that generated the event. The thread used to call an event listener is not defined.

The Framework must publish a `FrameworkEvent.ERROR` if a callback to an event listener generates an unchecked exception - except when the callback happens while delivering a `FrameworkEvent.ERROR` (to prevent an infinite loop).

Synchronous events have the unfortunate effect that, in rare cases, events can be delivered out of order to a listener. For example, a Service Event `UNREGISTERING` can be delivered before its corresponding Service Event `REGISTERED`. One pathological case is when a service listener (for example a Service Tracker) unregisters a service that it receives in the `REGISTERED` event for. If there are listeners queued behind the pathological listener then they see the unregistering before they see the registration.

4.7.2

Delivering Events

If the Framework delivers an event asynchronously, it must:

- Collect a snapshot of the listener list at the time the event is published (rather than doing so in the future just prior to event delivery), but before the event is delivered, so that listeners do not enter the list after the event happened.
- Ensure, at the time the snapshot is taken, that listeners on the list still belong to active bundles at the time the event is delivered.
- It is possible to use more than one thread to deliver events. If this is the case then each handler must receive the events in the same order as the events were posted. This ensures that handlers see events in the expected order.

If the Framework did not capture the current listener list when the event was published, but instead waited until just prior to event delivery, then the following error could occur: a bundle could have started and registered a listener, and then the bundle could see its own `BundleEvent.INSTALLED` event.

The following three scenarios illustrate this concept.

1. Scenario one event sequence:
 - Event A is published.
 - Listener 1 is registered.
 - Asynchronous delivery of Event A is attempted.

Expected Behavior: Listener 1 must not receive Event A, because it was not registered at the time the event was published.

2. Scenario two event sequence:

- Listener 2 is registered.
- Event B is published.
- Listener 2 is unregistered.
- Asynchronous delivery of Event B is attempted.

Expected Behavior: Listener 2 receives Event B, because Listener 2 was registered at the time Event B was published.

3. Scenario three event sequence:

- Listener 3 is registered.
- Event C is published.
- The bundle that registered Listener 3 is stopped.
- Asynchronous delivery of Event C is attempted.

Expected Behavior: Listener 3 must not receive Event C, because its Bundle Context object is invalid.

4.7.3 Synchronization Pitfalls

Generally, a bundle that calls a listener should not hold any Java monitors. This means that neither the Framework nor the originator of a synchronous event should be in a monitor when a callback is initiated.

The purpose of a Java monitor is to protect the update of data structures. This should be a small region of code that does not call any code the effect of which cannot be overseen. Calling the OSGi Framework from synchronized code can cause unexpected side effects. One of these side effects might be *deadlock*. A deadlock is the situation where two threads are blocked because they are waiting for each other.

Time-outs can be used to break deadlocks, but Java monitors do not have time-outs. Therefore, the code will hang forever until the system is reset (Java has deprecated all methods that can stop a thread). This type of deadlock is prevented by not calling the Framework (or other code that might cause callbacks) in a synchronized block.

If locks are necessary when calling other code, use the Java monitor to create semaphores that can time-out and thus provide an opportunity to escape a deadlocked situation.

4.8 Security

4.8.1 Admin Permission

The Admin Permission is a permission used to grant the right to manage the Framework with the option to restrict this right to a subset of bundles, called *targets*. For example, an Operator can give a bundle the right to only manage bundles of a signer that has a subject name of ACME:

```
org.osgi.framework.AdminPermission(
    "(signer=\\*, o=ACME, c=us)", ... )
```

The actions of the Admin Permission are fine-grained. They allow the deployer to assign only the permissions that are necessary for a bundle. For example, an HTTP implementation could be granted access to all resources of all bundles.

```
org.osgi.framework.AdminPermission("*",
    "resource" )
```

Code that needs to check Admin Permission must always use the constructor that takes a bundle as parameter: [AdminPermission\(Bundle,String\)](#) with a single action.

For example, the implementation of the `loadClass` method must check that the caller has access to the class space:

```
public class BundleImpl implements Bundle{

    Class loadClass(String name) {
        securityManager.checkPermission(
            new AdminPermission(this, "class") );
        ...
    }
}
```

The Admin Permission takes a filter as its name. Filter based permissions are described in *Filter Based Permissions* on page 29.

4.8.1.1

Actions

The action parameter of Admin Permission will specify the subset of privileged administrative operations that are allowed by the Framework. The actions that are architected are listed in the following table. Future versions of the specification, as well as additional system services, can add additional actions. The given set should therefore not be assumed to be a closed set.

Table 4.9

Admin Permission actions

Action	Used in
METADATA	Bundle.getHeaders
	Bundle.getLocation
	Bundle.getResource
RESOURCE	Bundle.getResources
	Bundle.getEntry
	Bundle.getEntryPaths
	Bundle.findEntries
	Bundle resource/entry URL creation
CLASS	Bundle.loadClass
LIFECYCLE	BundleContext.installBundle
	Bundle.update
	Bundle.uninstall
EXECUTE	Bundle.start
	Bundle.stop
LISTENER	BundleStartLevel.setBundleStartLevel
	BundleContext.addBundleListener for SynchronousBundleListener
	BundleContext.removeBundleListener for SynchronousBundleListener
EXTENSIONLIFECYCLE	BundleContext.installBundle for extension bundles
	Bundle.update for extension bundles
	Bundle.uninstall for extension bundles
RESOLVE	FrameworkWiring.refreshBundles
	FrameworkWiring.resolveBundles
STARTLEVEL	FrameworkStartLevel.setStartLevel
	FrameworkStartLevel.setInitialBundleStartLevel

Action	Used in
CONTEXT	Bundle.getBundleContext
WEAVE	WovenClass.setBytes WovenClass.getDynamicImports

The special action "*" will represent all actions.

Each bundle must be given `AdminPermission(<bundle identifier>, "resource,metadata,class,context")` so that it can access its own resources and context. This is an implicit permission that must be automatically given to all bundles by the Framework.

4.8.2 Privileged Callbacks

The following interfaces define bundle callbacks that are invoked by the Framework:

- BundleActivator
- ServiceFactory
- BundleListener, ServiceListener, and FrameworkListener
- Framework hook services

When any of these callbacks are invoked by the Framework, the bundle that caused the callback may still be on the stack. For example, when one bundle installs and then starts another bundle, the installer bundle may be on the stack when the `BundleActivator.start` method of the installed bundle is called. Likewise, when a bundle registers a service object, it may be on the stack when the Framework calls back the `serviceChanged` method of all qualifying `ServiceListener` objects.

Whenever any of these bundle callbacks try to access a protected resource or operation, the access control mechanism should consider not only the permissions of the bundle receiving the callback, but also those of the Framework and any other bundles on the stack. This means that in these callbacks, bundle programmers normally would use `doPrivileged` calls around any methods protected by a permission check (such as getting or registering service objects).

In order to reduce the number of `doPrivileged` calls by bundle programmers, the Framework must perform a `doPrivileged` call around any bundle callbacks. The Framework should have `java.security.AllPermission`. Therefore, a bundle programmer can assume that the bundle is not further restricted except for its own permissions.

Bundle programmers do not need to use `doPrivileged` calls in their implementations of any callbacks registered with and invoked by the Framework.

For any other callbacks that are registered with a service object and therefore get invoked by the service-providing bundle directly, `doPrivileged` calls must be used in the callback implementation if the bundle's own privileges are to be exercised. Otherwise, the callback must fail if the bundle that initiated the callback lacks the required permissions.

A framework must never load classes in a `doPrivileged` region, but must instead use the current stack. This means that static initializers and constructors must not assume that they are privileged. Any privileged code in a static initializer must be guarded with a `doPrivileged` region in the static initializer. Likewise, a framework must not instantiate a `BundleActivator` object in a `doPrivileged` region, but must instead use the current stack. This means that the `BundleActivator` constructor must not assume that it is privileged.

4.8.3 Lazy Activation

The activation policy, see *Activation Policies* on page 117, can indirectly cause the activation of a bundle. `AdminPermission[* , CLASS]` therefore implies the `EXECUTE` action during a `loadClass` method call.

Normal class loading caused by executing Java class code must not require AdminPermission[* ,EXECUTE].

4.9 References

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- [13] *Java Service Provider Configuration*
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- [14] *IETF RFC 1422 A Universally Unique Identifier (UUID) URN Namespace*
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4.10 Changes

- Launching property `org.osgi.framework.storage` must be set when default value used.
- Added support for multi-release JARs. See *Detecting Bundle Modifications* on page 120 and *Retrieving Manifest Headers* on page 120.

5 Service Layer

Version 1.9

5.1 Introduction

The OSGi Service Layer defines a dynamic collaborative model that is highly integrated with the Life Cycle Layer. The *service* model is a publish, find and bind model. A service is a normal Java object that is registered under one or more Java interfaces with the service registry. Bundles can register services, search for them, or receive notifications when their registration state changes.

5.1.1 Essentials

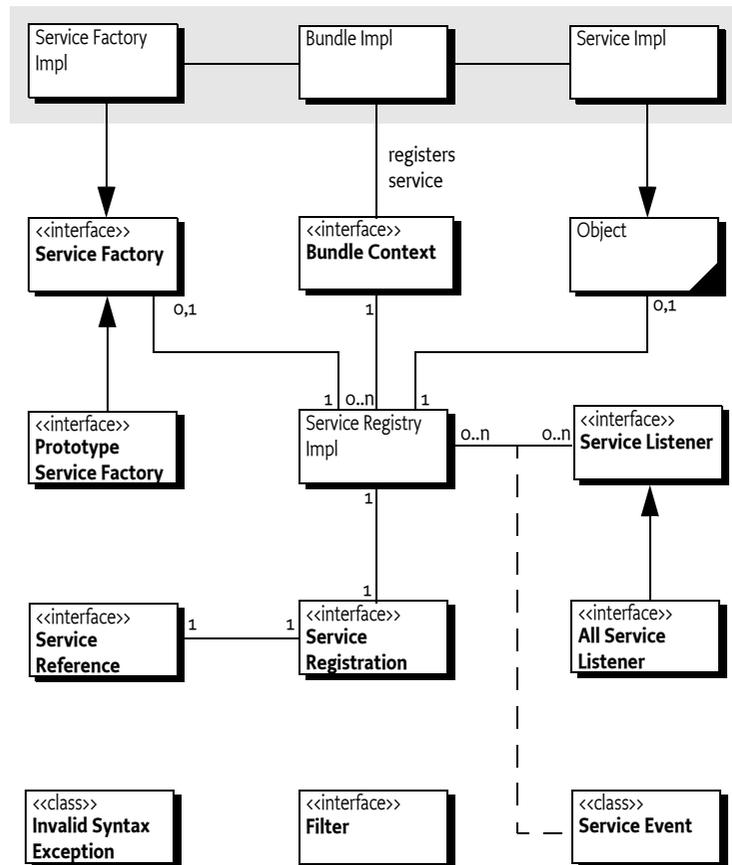
- *Collaborative* - The service layer must provide a mechanism for bundles to publish, find, and bind to each other's services without having a priori knowledge of those bundles.
- *Dynamic* - The service mechanism must be able to handle changes in the outside world and underlying structures directly.
- *Secure* - It must be possible to restrict access to services.
- *Reflective* - Provide full access to the Service Layer's internal state.
- *Versioning* - Provide mechanisms that make it possible to handle the fact that bundles and their services evolve over time.
- *Persistent Identifier* - Provide a means for bundles to track services across Framework restarts.

5.1.2 Entities

- *Service* - An object registered with the service registry under one or more interfaces together with properties. The service can be discovered and used by bundles.
- *Service Registry* - Holds the service registrations.
- *Service Reference* - A reference to a service. Provides access to the service's properties but not the actual service object. The service object must be acquired through a bundle's Bundle Context.
- *Service Registration* - The receipt provided when a service is registered. The service registration allows the update of the service properties and the unregistration of the service.
- *Service Permission* - The permission to use an interface name when registering or using a service.
- *Service Scope* - Indicates how service objects are obtained when requesting a service object. The following service scopes are defined: *singleton*, *bundle*, and *prototype*. The default service scope is *singleton*.
- *Service Factory* - A facility to let the registering bundle customize the service object for each using bundle. When using a Service Factory, the service scope of the service is *bundle*.
- *Prototype Service Factory* - A facility to let the registering bundle customize the service object for each caller. When using a Prototype Service Factory, the service scope of the service is *prototype*.
- *Service Objects* - A facility to let the using bundle obtain multiple service objects for a service with *prototype* service scope.
- *Service Listener* - A listener to Service Events.
- *Service Event* - An event holding information about the registration, modification, or unregistration of a service object.

- *Filter* - An object that implements a simple but powerful filter language. It can select on properties.
- *Invalid Syntax Exception* - The exception thrown when a filter expression contains an error.

Figure 5.1 Class Diagram org.osgi.framework Service Layer



5.2 Services

In the OSGi framework, bundles are built around a set of cooperating services available from a shared service registry. Such an OSGi service is defined semantically by its *service interface* and implemented as a *service object*.

The service interface should be specified with as few implementation details as possible. OSGi has specified many service interfaces for common needs and will specify more in the future.

The service object is owned by, and runs within, a bundle. This bundle must register the service object with the Framework service registry so that the service's functionality is available to other bundles under control of the Framework.

Dependencies between the bundle owning the service and the bundles using it are managed by the Framework. For example, when a bundle is stopped, all the services registered with the Framework by that bundle must be automatically unregistered.

The Framework maps services to their underlying service objects, and provides a simple but powerful query mechanism that enables a bundle to request the services it needs. The Framework also pro-

vides an event mechanism so that bundles can receive events of services that are registered, modified, or unregistered.

5.2.1 Service References

In general, registered service objects are referenced through `ServiceReference` objects. This avoids creating unnecessary dynamic service dependencies between bundles when a bundle needs to know about a service but does not require the service object itself.

A `ServiceReference` object can be stored and passed on to other bundles without the implications of dependencies. A `ServiceReference` object encapsulates the properties and other meta-information about the service object it represents. This meta-information can be queried by a bundle to assist in the selection of a service that best suits its needs.

When a bundle queries the Framework service registry for services, the Framework must provide the requesting bundle with the `ServiceReference` objects of the requested services, rather than with the services themselves. See *Locating Services* on page 139.

A `ServiceReference` object may also be obtained from a `ServiceRegistration` object.

A `ServiceReference` object is valid only as long as the service is registered. However, its properties must remain available as long as the `ServiceReference` object exists.

When a bundle wishes to use the service object, it can be obtained by using the `ServiceReference`. See *Getting Service Objects* on page 141.

5.2.2 Service Interfaces

A *service interface* is the specification of the service's public methods.

In practice, a bundle developer creates a service object by implementing its service interface and registers the service object with the Framework service registry. Once a bundle has registered a service object under an interface name, the associated service can be acquired by bundles under that interface name, and its methods can be accessed by way of its service interface. The Framework also supports registering service objects under a class name, so references to service interface in this specification can be interpreted to be an interface or class.

When requesting a service object from the Framework, a bundle can specify the name of the service interface that the requested service object must implement. In the request, the bundle may also specify a filter string to narrow the search.

Many service interfaces are defined and specified by organizations such as the OSGi Alliance. A service interface that has been accepted as a standard can be implemented and used by any number of bundle developers.

5.2.3 Registering Services

A bundle publishes a service by registering a service object with the Framework service registry. A service object registered with the Framework is exposed to other bundles installed in the OSGi environment.

Every registered service object has a unique `ServiceRegistration` object, and has one or more `ServiceReference` objects that refer to it. These `ServiceReference` objects expose the registration properties of the service, including the set of service interfaces they implement. The `ServiceReference` object can then be used to acquire a service object that implements the desired service interface.

The Framework permits bundles to register and unregister service objects dynamically. Therefore, a bundle is permitted to register service objects at any time during the `STARTING`, `ACTIVE` or `STOPPING` states.

A bundle registers a service object with the Framework by calling one of the `BundleContext.registerService` methods on its `BundleContext` object:

- `registerService(String, Object, Dictionary)` - For a service object registered under a single service interface.
- `registerService(String[], Object, Dictionary)` - For a service object registered under multiple service interfaces.
- `registerService(Class, S, Dictionary)` - For a service object registered under a single service interface using the class object for the interface name.

The names of the service interfaces under which a bundle wants to register its service are provided as arguments to the `registerService` methods. The Framework must ensure that the service object actually is an instance of each specified service interfaces, unless the object is a Service Factory. See *Service Factory* on page 146 and *Prototype Service Factory* on page 146.

To perform this check, the Framework must load the Class object for each specified service interface from either the bundle or a shared package. For each Class object, `Class.isInstance` must be called and return true on the Class object with the service object as the argument.

The service object being registered may be further described by a Dictionary object, which contains the properties of the service as a collection of key/value pairs.

The service interface names under which a service object has been successfully registered are automatically added to the service's properties under the key `objectClass`. This value must be set automatically by the Framework and any value provided by the bundle must be overridden.

If the service object is successfully registered, the Framework must return a `ServiceRegistration` object to the caller. A service object can be unregistered only by the holder of its `ServiceRegistration` object (see the `unregister()` method). Every successful service object registration must yield a unique `ServiceRegistration` object even if the same service object is registered multiple times.

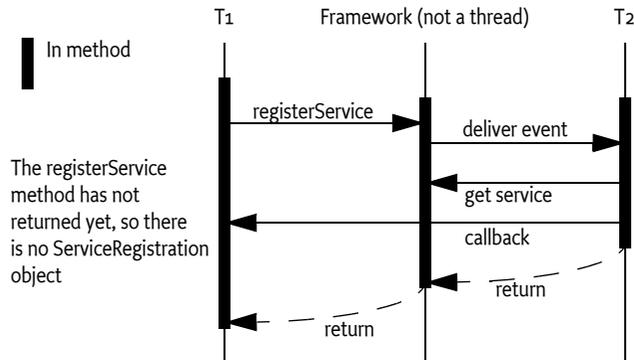
Using the `ServiceRegistration` object is the only way to reliably change the service's properties after it has been registered (see the `setProperty(Dictionary)` method). Modifying a service's Dictionary object after the service object is registered may not have any effect on the service's properties.

The process of registering a service object is subject to a permission check. The registering bundle must have `ServicePermission[<name>, REGISTER]` to register the service object under all the service interfaces specified. Otherwise, the service object must not be registered, and a `SecurityException` must be thrown.

5.2.4 Early Need for ServiceRegistration Object

The registration of a service object will cause all registered `ServiceListener` objects to be notified. This is a synchronous notification. This means that such a listener can get access to the service and call its methods before the `registerService` method has returned the `ServiceRegistration` object. In certain cases, access to the `ServiceRegistration` object is necessary in such a callback. However, the registering bundle has not yet received the `ServiceRegistration` object. Figure 5.2 on page 137 shows such a sequence.

Figure 5.2 Service Registration and registration



In a case as described previously, access to the registration object can be obtained via a `ServiceFactory` object or `PrototypeServiceFactory` object. If a `ServiceFactory` object or `PrototypeServiceFactory` object is registered, the Framework must call-back the registering bundle with the `ServiceFactory` method `getService(Bundle,ServiceRegistration)` or the `PrototypeServiceFactory` method `getService(Bundle,ServiceRegistration)`. The required `ServiceRegistration` object is passed as a parameter to these methods.

5.2.5 Service Properties

Properties hold information as key/value pairs. The key must be a `String` object and the value should be a type recognized by `Filter` objects (see *Filters* on page 145 for a list). Multiple values for the same key are supported with arrays (`[]`) and `Collection` objects.

The values of properties should be limited to primitive or standard Java types to prevent unwanted inter bundle dependencies. The Framework cannot detect dependencies that are created by the exchange of objects between bundles via the service properties.

The key of a property is not case sensitive. `ObjectClass`, `OBJECTCLASS` and `objectclass` all are the same property key. A Framework must return the key in `ServiceReference.getPropertyKeys` in exactly the same case as it was last set. When a `Dictionary` object that contains keys that only differ in case is passed, the Framework must raise an exception.

The service properties are intended to provide information *about* the service. The properties should not be used to participate in the actual function of the service. Modifying the properties for the service registration is a potentially expensive operation. For example, a Framework may pre-process the properties into an index during registration to speed up later look-ups.

The `Filter` interface supports complex filtering; it can be used to find matching services. Therefore, all properties share a single namespace in the Framework service registry. As a result, it is important to use descriptive names or formal definitions of shorter names to prevent conflicts. Several OSGi specifications reserve parts of this namespace. All properties starting with the prefix `service.` and the property `objectClass` are reserved for use by OSGi specifications.

Table 5.1 contains a list of pre-defined properties.

Table 5.1 Standard Service Properties (+ indicates scalar, array of, or collection of)

Property Key	Type	Constants	Property Description
objectClass [†]	String[]	OBJECTCLASS	The objectClass property contains the set of interface names under which a service object is registered with the Framework. The Framework must set this property automatically. The Framework must guarantee that when a service object is retrieved with <code>getService(ServiceReference)</code> , it can be cast to any of the interface names.
service.bundleid [†]	Long	SERVICE_BUNDLEID	The service.bundleid property identifies the bundle registering the service. The Framework must set this property automatically with the value of the bundle id of the registering bundle.
service.description	String	SERVICE_DESCRIPTION	The service.description property is intended to be used as documentation and is optional. Frameworks and bundles can use this property to provide a short description of a registered service object. The purpose is mainly for debugging because there is no support for localization.
service.id [†]	Long	SERVICE_ID	Every registered service object is assigned a unique, non-negative service.id by the Framework. This number is added to the service's properties. The Framework assigns a unique, non-negative value to every registered service object that is larger than values provided to all previously registered service objects.
service.pid	String+	SERVICE_PID	The service.pid property optionally identifies a persistent, unique identifier for the service object. See <i>Persistent Identifier (PID)</i> on page 139.
service.scope [†]	String	SERVICE_SCOPE	The service.scope property identifies the service's scope. The Framework must set this property automatically. If the registered service object implements <code>PrototypeServiceFactory</code> , then the value will be <code>prototype</code> . Otherwise, if the registered service object implements <code>ServiceFactory</code> , then the value will be <code>bundle</code> . Otherwise, the value will be <code>singleton</code> . See <i>Service Scope</i> on page 140.
service.ranking	Integer	SERVICE_RANKING	See <i>Service Ranking Order</i> on page 139.
service.vendor	String	SERVICE_VENDOR	This optional property can be used by the bundle registering the service object to indicate the vendor.

[†] The values for these service properties must be set by the Framework. Any values specified for these service properties during service registration or service properties update must be ignored.

5.2.6 Service Ranking Order

When registering a service object, a bundle may optionally specify a `SERVICE_RANKING` service property of type `Integer`. This number specifies a ranking order between services. The highest number has the highest ranking and the lowest number (including negative numbers) has the lowest ranking. If no `service.ranking` service property is specified or its type is not `Integer` then a ranking of 0 must be used.

The *ranking order* is defined as follows:

- Sorted on descending ranking number (highest first)
- If the ranking numbers are equal, sorted on ascending `service.id` property (oldest first).

This ordering is complete because service ids are never reused and handed out in order of their registration time. That is, a service that is registered later will have a higher service id. Therefore, the ranking order is in descending `service.ranking` numeric order where ties give a preference to the earlier registrant.

The ranking order is the reverse of the natural ordering of a `ServiceReference` object.

The purpose of the ranking order is to allow:

- *Selection* - When a single service must be chosen but multiple services qualify then the service with the highest ranking must be selected.
- *Ordering* - When multiple services must be used in a specified order.

5.2.7 Persistent Identifier (PID)

The purpose of a Persistent Identifier (PID) is to identify a service across Framework restarts. Services that can reference the same underlying entity every time they are registered should therefore use a service property that contains a PID. The name of the service property for PID is defined as `service.pid`. The PID is a unique identifier for a service that persists over multiple invocations of the Framework. For a given service, the same PID should always be used. If the bundle is stopped and later started, the same PID must always be used.

The format of the PID should be:

```
pid ::= symbolic-name // See 1.3.2
```

5.2.8 Locating Services

In order to use a service object and call its methods, a bundle must first obtain a `ServiceReference` object. The `BundleContext` interface defines a number of methods a bundle can call to obtain `ServiceReference` objects from the Framework:

- `getServiceReference(String)`, `getServiceReference(Class)` - These methods returns a `ServiceReference` object to a service object that implements, and was registered under, the name of the specified service interface. If multiple such service objects exist, a `ServiceReference` object to the service object with the highest `SERVICE_RANKING` is returned. If there is a tie in ranking, a `ServiceReference` object to the service object with the lowest `SERVICE_ID` (the service object that was registered first) is returned. If no matching service objects are registered then null must be returned.
- `getServiceReferences(String,String)`, `getServiceReferences(Class,String)` - These methods returns an array or collection, respectively, of `ServiceReference` objects for service objects that:
 - Implement and were registered under the specified service interface.
 - Satisfy the search filter specified. The filter syntax is further explained in *Filters* on page 145.

If no matching service objects are registered then null must be returned by the `getServiceReferences(String,String)` method and an empty collection must be returned by the `getServiceReferences(Class,String)` method.

The caller receives zero or more `ServiceReference` objects. These objects can be used to retrieve properties of the underlying service, or they can be used to obtain the actual service object. See *Getting Service Objects* on page 141.

The above methods require that the caller has the necessary `ServicePermission[ServiceReference, GET]` to get the service object for the returned Service Reference. If the caller lacks the required permission, these methods must not include that Service Reference in the result.

5.2.9 Getting Service Properties

To allow for interrogation of service properties, the `ServiceReference` interface defines these two methods:

- `getPropertyKeys()` - Returns an array of the property keys that are available.
- `getProperty(String)` - Returns the value of a property.

Both of these methods must continue to provide information about the referenced service object, even after it has been unregistered from the Framework. This requirement can be useful when a `ServiceReference` object is stored with the Log Service.

5.2.10 Information About Services

The `Bundle` interface defines these two methods for returning information pertaining to service usage of the bundles:

- `getRegisteredServices()` - Returns the `ServiceReference` objects for the service objects that the bundle has registered with the Framework.
- `getServicesInUse()` - Returns the `ServiceReference` objects for the service objects that the bundle is currently using.

5.2.11 Service Exceptions

The Service Exception is a Run Time exception that can be used by the Framework to report errors or by user code that needs to signal a problem with a service. An exception type available from this exception provides the detailed information about the problem that caused the exception to be thrown.

Implementations of the framework or user code are allowed to throw sub classes of the `ServiceException` class. If a sub class is thrown for a reason other than one of the specified types, then the type should be set to `SUBCLASSED`. Sub classes that provide additional information for a specified type should use the specified type.

5.2.12 Services and Concurrency

Services published on one thread and obtained on another thread must be safe to use. That is, the Framework must guarantee that there is a *happens-before* relationship between the time a service is registered and the time a service object or Service Reference is obtained. That is both the registering and obtaining threads must be properly synchronized with each other.

5.3 Service Scope

The `SERVICE_SCOPE` service property identifies the scope of the registered service object. The following service scopes are supported by the Framework:

- **SCOPE_SINGLETON** - Identifies the registered service object as a single service object which will be used by all bundles requesting the service object.
- **SCOPE_BUNDLE** - Identifies the registered service object as a Service Factory. A Service Factory allows the registering bundle to customize the service object for each bundle requesting the service object. See *Service Factory* on page 146
- **SCOPE_PROTOTYPE** - Identifies the registered service object as a Prototype Service Factory. A Prototype Service Factory allows the registering bundle to customize the service object for each request for the service object. See *Prototype Service Factory* on page 146.

The Framework must set the **SERVICE_SCOPE** service property automatically depending on the type of registered service object. If the registered service object implements **PrototypeServiceFactory**, then the value must be **SCOPE_PROTOTYPE**. Otherwise, if the registered service object implements **ServiceFactory**, then the value must be **SCOPE_BUNDLE**. Otherwise, the value must be **SCOPE_SINGLETON**. The **SERVICE_SCOPE** service property allows bundles to determine whether multiple service objects can be obtained for the service. Component models like Declarative Services and Blueprint need to know if they can properly obtain multiple service objects for referenced services.

5.4 Getting Service Objects

There are two methods available to get service objects from the service registry:

- **BundleContext.getService(ServiceReference)** - This method should be used if the using bundle only needs a single service object.
- **ServiceObjects.getService()** - This method should be used if the service has **SCOPE_PROTOTYPE** scope and the using bundle needs multiple service objects.

These methods are used to obtain an actual service object so that the Framework can manage dependencies. If a bundle retrieves a service object, that bundle becomes dependent upon the life cycle of the registered service object. This dependency is tracked by the **BundleContext** object used to obtain the service object, directly or indirectly by a **ServiceObjects** object, and is one reason that it is important to be careful when sharing **BundleContext** and **ServiceObjects** objects with other bundles.

5.4.1 Getting a Single Service Object

The **BundleContext** is used when a bundle only needs a single service object. The **BundleContext.getService(ServiceReference)** method returns an object that implements the interfaces as defined by the **objectClass** property. A bundle making multiple calls to this method, without releasing the service object, will receive the same service object.

This method has the following characteristics:

- Returns null if the underlying service object has been unregistered.
- Determines if the caller has **ServicePermission[ServiceReference,GET]**, to get a service object associated with the specified Service Reference. This permission check is necessary so that **ServiceReference** objects can be passed around freely without compromising security.
- Increments the usage count of the service by one for this **BundleContext** object.
- If the service has **SCOPE_SINGLETON** scope then the registered service object is returned. Otherwise, if the bundle context's usage count of the service is one, the registered service object is cast to a **ServiceFactory** object and the **getService(Bundle,ServiceRegistration)** method is called to create a customized service object for the calling bundle which is then cached and returned. Otherwise, a cached copy of this customized service object is returned. See *Service Factory* on page 146 for more information about **ServiceFactory** objects.

The `BundleContext.getService(ServiceReference)` method will only return a single service object for the bundle even if the service has `SCOPE_PROTOTYPE` scope. See *Getting Multiple Service Objects* on page 142 for information on how to obtain multiple service objects for a service with `SCOPE_PROTOTYPE` scope.

5.4.2 Getting Multiple Service Objects

A `ServiceObjects` object is used when the service has `SCOPE_PROTOTYPE` scope and a bundle needs multiple service objects. A `ServiceObjects` object is associated with a single service and is obtained by calling the `BundleContext.getServiceObjects(ServiceReference)` method. The caller must have `ServicePermission[ServiceReference,GET]`, to get a `ServiceObjects` object for a service.

The `ServiceObjects.getService()` method can be used to obtain multiple service objects for the associated service.

This method has the following characteristics for a service with `SCOPE_PROTOTYPE` scope:

- Returns null if the underlying service object has been unregistered.
- The registered service object is cast to a `PrototypeServiceFactory` object and the `getService(Bundle,ServiceRegistration)` method is called to create a customized service object. See *Prototype Service Factory* on page 146 for more information about `PrototypeServiceFactory` objects.
- The usage count for the customized service object is incremented.
- The customized service object is returned.

The `ServiceObjects.getService()` method will only return a single service object for the bundle if the service has `SCOPE_SINGLETON` or `SCOPE_BUNDLE` scope. That is, the method behaves the same as the `BundleContext.getService(ServiceReference)` method and only a single service object is available. See *Getting a Single Service Object* on page 141.

5.5 Releasing Service Objects

A bundle must release a service object to remove the dynamic dependency on the bundle that registered the service object. Depending on how a service object was obtained, one of the following methods is used to release a service object:

- `BundleContext.ungetService(ServiceReference)` - This method should be used if the bundle is using a single service object and needs to release the single service object. See *Getting a Single Service Object* on page 141.
- `ServiceObjects.ungetService(S)` - This method should be used if the bundle is using multiple service objects and needs to release one of the service objects. See *Getting Multiple Service Objects* on page 142.

5.5.1 Releasing a Single Service Object

The `BundleContext` interface defines a method to release a single service object: `ungetService(ServiceReference)`

This method has the following characteristics:

- If the usage count of the service for this `BundleContext` object is zero or the service has been unregistered, false is returned.
- The usage count of the service for this `BundleContext` object is decremented by one.
- If the usage count of the service for this `BundleContext` object is now zero and the service has `SCOPE_BUNDLE` or `SCOPE_PROTOTYPE` scope, the registered service object is cast to a `Service-`

`Factory` object and the `ungetService(Bundle,ServiceRegistration,S)` method is called to release the previously cached customized service object for the calling bundle. The cached customized service object must be unreferenced by the Framework so it may be garbage collected. See *Service Factory* on page 146 for more information about `ServiceFactory` objects.

- `true` is returned.

5.5.2 Releasing Multiple Service Objects

A `ServiceObjects` object can be used to obtain multiple service objects for the `associated` service if the service has `SCOPE_PROTOTYPE` scope. The `ServiceObjects` interface defines a method to release one of the service objects obtained by a bundle: `ungetService(S)`. If the associated service has `SCOPE_SINGLETON` or `SCOPE_BUNDLE` scope, this method behaves the same as calling the `BundleContext.ungetService(ServiceReference)` method.

For a service with `SCOPE_PROTOTYPE` scope, the following steps are required to release the specified service object:

- If the associated service has been unregistered, this method returns without doing anything.
- If the specified service object is null or was not provided by a `ServiceObjects` for the `associated` service, then an `IllegalArgumentException` is thrown.
- The usage count for the specified service object is decremented.
- If the usage count for the specified service object is now zero, the registered service object is cast to a `PrototypeServiceFactory` object and the `ungetService(Bundle,ServiceRegistration,S)` method is called to release the specified service object. The specified service object must be unreferenced by the Framework so it may be garbage collected. See *Prototype Service Factory* on page 146 for more information about `PrototypeServiceFactory` objects.

5.6 Service Events

- `ServiceEvent` - Reports registration, unregistration, and property changes for service objects. All events of this kind must be delivered synchronously. The type of the event is given by the `getType()` method, which returns an `int`. Event types can be extended in the future; unknown event types should be ignored.
- `ServiceListener` - Called with a `ServiceEvent` when a service object has been registered or modified, or is in the process of unregistering. A security check must be performed for each registered listener when a `ServiceEvent` occurs. The listener must not be called unless the bundle which registered the listener has the required `ServicePermission[ServiceReference,GET]` for the corresponding `ServiceReference`.
- `AllServiceListener` - Services can only be seen when the service interface/class is not incompatible with the getter. The `AllServiceListener` is a marker interface that indicates that the getter wants to receive events for all services even if they are incompatible. See *Multiple Version Export Considerations* on page 148.
- `UnfilteredServiceListener` - Extenders (bundles that can act on behalf of other bundles) frequently require unfiltered access to the service events for efficiency reasons. However, when they register without a filter then the `Service Hooks`, see *Service Hook Service Specification* on page 401, cannot provide the filter expression to the hooks. This filter information is sometimes necessary to detect when certain services are needed. Therefore, the `UnfilteredServiceListener` interface is a marker interface that instructs the framework to never filter service events but still pass the filter to the `Service Hooks`. Extenders should use a single `UnfilteredServiceListener` object with a compound filter.

A bundle that uses a service object should register a `ServiceListener` object to track the availability of the service object, and take appropriate action when the service object is unregistering.

5.6.1 Service Event Types

The following service events are defined:

- **REGISTERED** - A service object has been registered. This event is synchronously delivered after the service object has been registered with the Framework.
- **MODIFIED** - The properties of a service have been modified. This event is synchronously delivered after the service properties have been modified.
- **MODIFIED_ENDMATCH** - Listeners registered with a filter can not see the MODIFIED event when a modification makes the filter no longer match. The lack of this notification complicates tracking a service with a filter. The MODIFIED_ENDMATCH event is therefore delivered if the old service properties matched the given filter but the modified properties do not. This event is synchronously delivered after the service properties have been modified.
- **UNREGISTERING** - A service object is in the process of being unregistered. This event is synchronously delivered before the service object has completed unregistering. That is, during the delivery of this event, the service object is still valid. The bundle receiving this event must release all references to this service before this method returns.

New service event types can be added in future specifications

5.7 Stale References

The Framework must manage the dependencies between bundles. This management is, however, restricted to Framework structures. Bundles must listen to events generated by the Framework to clean up and remove *stale references*.

A stale reference is a reference to a Java object that belongs to the class loader of a bundle that is stopped or is associated with a service object that is unregistered. Standard Java does not provide any generic means to clean up stale references, and bundle developers must analyze their code carefully to ensure that stale references are deleted.

Stale references are potentially harmful because they hinder the Java garbage collector from harvesting the classes, and possibly the instances, of stopped bundles. This may result in significantly increased memory usage and can cause updating native code libraries to fail. Bundles using services are strongly recommended to use either the Service Tracker or Declarative Services.

Service developers can minimize the consequences of (but not completely prevent) stale references by using the following mechanisms:

- Implement service objects using the `ServiceFactory` or `PrototypeServiceFactory` interface. The methods in the `ServiceFactory` and `PrototypeServiceFactory` interface simplify tracking bundles that use their service objects. See *Service Factory* on page 146 and *Prototype Service Factory* on page 146.
- Use indirection in the service object implementations. Service objects handed out to other bundles should use a pointer to the actual service implementation. When the service object becomes invalid, the pointer is set to null, effectively removing the reference to the actual service implementation.

The behavior of a service object that becomes unregistered is undefined. Such service objects may continue to work properly or throw an exception at their discretion. This type of error should be logged.

5.8 Filters

The Framework provides a [Filter](#) interface, and uses a filter syntax in the `getServiceReferences` methods that is defined in *Filter Syntax* on page 39. Filter objects can be created by calling [BundleContext.createFilter\(String\)](#) or [FrameworkUtil.createFilter\(String\)](#) with the chosen filter string. The filter supports the following match methods:

- [match\(ServiceReference\)](#) - Match the properties of the Service Reference performing key lookup in a case insensitive way.
- [match\(Dictionary\)](#) - Match the entries in the given Dictionary object performing key lookup in a case insensitive way.
- [matchCase\(Dictionary\)](#) - Match the entries in the given Dictionary object performing key lookup in a case sensitive way.
- [matches\(Map\)](#) - Match the entries in the given Map object. The map defines the case sensitivity of the match, standard maps are case sensitive but for example a `TreeMap(String.CASE_INSENSITIVE_ORDER)` provides a case insensitive map.

A Filter object can be used numerous times to determine if the match argument, a `ServiceReference` object, a `Map` object, or a `Dictionary` object, matches the filter string that was used to create the Filter object.

This matching requires comparing the value string in the filter to a target object from the service properties or dictionary. This comparison can be executed with the `Comparable` interface if the target object's class implements the `Comparable` interface. If the target object's class does not implement `Comparable`, the `=`, `~=`, `<=` `>=` operators must return only true when the objects are equal (using the `equals(Object)` method).

The value string in the filter can be converted into an object suitable for comparison with the target object if the target object's class implements either a static `valueOf` method taking a single `String` object or a constructor taking a single `String` object. That is, if the target object is of class `Target`, the class `Target` must implement one of the following methods:

- A static `valueOf(String)` method whose return type is assignable to `Target`
- A `Target(String)` constructor

The `Target` class does not need to be a public class.

If during the evaluation of the filter a target object throws an exception, then this exception must not be re-thrown but caught. The result of the evaluation must then be interpreted as false.

The following example shows how a class can verify the ordering of an enumeration with a filter.

```
public class B implements Comparable {
    String keys[] = {"bugs", "daffy", "elmer", "pepe"};
    int          index;

    public B(String s) {
        for ( index=0; index<keys.length; index++ )
            if ( keys[index].equals(s) )
                return;
    }

    public int compareTo( Object other ) {
        B vother = (B) other;
        return index - vother.index;
    }
}
```

```
}
```

The class could be used with the following filter:

```
(!(enum>=elmer)) -> matches bugs and daffy
```

The `Filter.toString` method must always return the filter string with unnecessary white space removed.

5.9 Service Factory

A Service Factory allows customization of the service object that is returned to a calling bundle. See *Getting a Single Service Object* on page 141. See also *Prototype Service Factory* on page 146.

Often, the service object that is registered by a bundle is returned directly to all using bundles. Such a service has `SCOPE_SINGLETON` scope. If, however, the registered service object implements the `ServiceFactory` interface, the service has `SCOPE_BUNDLE` scope and the Framework must call methods on the registered object to obtain a customized service object for each distinct bundle that gets the service.

When the customized service object is no longer used by a bundle - for example, when that bundle is stopped - then the Framework must notify the `ServiceFactory` object to release the customized service object.

`ServiceFactory` objects help manage bundle dependencies that are not explicitly managed by the Framework. By binding a returned service object to the requesting bundle, the service can be notified when that bundle ceases to use the customized service object, such as when it is stopped, and release resources associated with providing the service to that bundle.

The `ServiceFactory` interface defines the following methods:

- `getService(Bundle,ServiceRegistration)` - This method is called by the Framework when it needs to obtain a customized service object for a requesting bundle. See *Getting Service Objects* on page 141.

The Framework must check the customized service object returned by this method. If it is not an instance of all the classes named when the Service Factory was registered, null is returned to the requesting bundle. This check must be done as specified in *Registering Services* on page 135.

If this method is called recursively for the same bundle then it must return null to break the recursion.

- `ungetService(Bundle,ServiceRegistration,S)` - This method is called by the Framework when it needs to release a customized service object for a requesting bundle. See *Releasing Service Objects* on page 142.

5.10 Prototype Service Factory

A Prototype Service Factory allows customization of service objects and allows multiple service objects to be used by a bundle. See *Getting Multiple Service Objects* on page 142. See also *Service Factory* on page 146.

Often, the service object that is registered by a bundle is returned directly to all using bundles. Such a service has `SCOPE_SINGLETON` scope. If, however, the registered service object implements the `PrototypeServiceFactory` interface, the service has `SCOPE_PROTOTYPE` scope and the Framework must call methods on the registered service object to create customized service object instances for each call to `ServiceObjects.getService()`. Services with `SCOPE_PROTOTYPE` are useful for service

objects that maintain state for the duration of usage and the using bundles require multiple service objects at the same time.

When the customized service objects are no longer used by a bundle - for example, when that bundle is stopped - then the Framework must notify the `PrototypeServiceFactory` object to release all the customized service objects.

`PrototypeServiceFactory` objects help manage bundle dependencies that are not explicitly managed by the Framework. By binding a returned service object to the requesting bundle and optionally some other stateful information, the Prototype Service Factory can be notified when that bundle ceases to use a customized service object, such as when it is stopped, and release resources associated with providing a customized service object to that bundle.

The `PrototypeServiceFactory` interface defines the following methods:

- `getService(Bundle,ServiceRegistration)` - This method is called by the Framework when it needs to obtain a customized service object for a requesting bundle. See *Getting Service Objects* on page 141.

The Framework must check the customized service object returned by this method. If it is not an instance of all the classes named when the Service Factory was registered, null is returned to the requesting bundle. This check must be done as specified in *Registering Services* on page 135.

For each customized services object returned by this method, the Framework must hold a reference to it until it is released. This is necessary so the Framework can release all unused and unreleased customized service objects - for example, when a requesting bundle is stopped or the service object is unregistered.

Since this method can return the same service object repeatedly, the framework must maintain a usage count for each customized service object so that it is only released when its usage count returns to zero.

- `ungetService(Bundle,ServiceRegistration,S)` - This method is called by the Framework when it needs to release a customized service object for a requesting bundle. See *Releasing Service Objects* on page 142.

5.11 Unregistering Services

The `ServiceRegistration` interface defines the `unregister()` method to unregister the service object. This must remove the service object from the Framework service registry. Any `ServiceReference` object for this `ServiceRegistration` object can no longer be used to access the service object.

The fact that this method is on the `ServiceRegistration` object ensures that only the bundle holding this object can unregister the associated service object. The bundle that unregisters a service object, however, might not be the same bundle that registered it. As an example, the registering bundle could have passed the `ServiceRegistration` object to another bundle, endowing that bundle with the responsibility of unregistering the service object. Passing `ServiceRegistration` objects should be done with caution.

After `unregister()` successfully completes, the service objects must be:

- Completely removed from the Framework service registry. Therefore, `ServiceReference` objects obtained for that service object can no longer be used to access a service object. Attempts to get a service object must return null.
- Unregistered, even if other bundles had dependencies upon it. Bundles must be notified of the unregistration through the publishing of a `ServiceEvent` of type `UNREGISTERING`. This event is sent synchronously in order to give bundles the opportunity to release service objects.

After receiving an event of type `UNREGISTERING`, a bundle should release the service objects and release any references it has to the service objects, so that the service objects can be garbage collected by the Java VM.

- Released by all using bundles. For each bundle with unreleased service objects after all invoked `ServiceListener` objects have returned, the Framework must release all the service objects.

5.12 Multiple Version Export Considerations

Allowing multiple bundles to export a package with a given name causes some complications for Framework implementers and bundle programmers: The class name no longer uniquely identifies the exported class. This affects the service registry and permission checking.

5.12.1 Service Registry

Bundles must not be exposed to service objects for which there are conflicting class loaders. A bundle that gets a service object should be able to expect that it can safely cast the service object to any of the associated interfaces or classes under which the service object was registered and that it can access. No `ClassCastException`s should occur because those interfaces do not come from the same class loader. The service registry must therefore ensure that bundles can only see service objects that are *not incompatible* with the bundle. A service object is not incompatible with the bundle getting the service object when that bundle is not wired to another source class loader for this interface package than the bundle registering the service object. That is, it is either wired to the same source class loader or it has no wire for that package at all.

It is paramount that bundles are not accidentally confronted with incompatible service objects. Therefore, the following methods need to filter `ServiceReference` objects depending on the incompatibility of the interfaces with the calling bundle and only return `ServiceReference` objects for services object that are not incompatible with the calling bundle for the specified interface. The bundle is identified by the used `BundleContext`:

- `getServiceReference(String)`
- `getServiceReference(Class)`
- `getServiceReferences(String,String)`
- `getServiceReferences(Class,String)`

The `getAllServiceReferences(String,String)` method provides access to the service registry without any compatibility restrictions. `ServiceReferences` acquired through this method can be used to obtain service objects which can cause a `Class Cast Exception` when casting to the specified class name.

The `ServiceReference.isAssignableTo(Bundle,String)` method is also available to test if the bundle that registered the service object referenced by this `ServiceReference` and the specified bundle are both wired to same source for the specified interface.

5.12.2 Service Events

Service events must only be delivered to event listeners registered by bundles that are not incompatible with the referenced service object.

Some bundles need to listen to all service events regardless of any compatibility issues. A special type of `ServiceListener` can therefore be used: `AllServiceListener`. This is a marker interface; it extends `ServiceListener`. Listeners that use this marker interface indicate to the Framework that the bundle registering the event listener wants to see events for all services, including for service objects that are incompatible with the bundle.

5.13 Security

5.13.1 Service Permission

A `ServicePermission` has the following parameters.

- *target* - Either the interface name or a filter expression for the GET action. The interface name may end with a wildcard to match multiple interface names. See `java.security.BasicPermission` for a discussion of wildcards. Filters are explained in *Filter Based Permissions* on page 29. The filter expression can additionally test for the service interface name with the `objectClass` key. Additionally, a service permission can also test for service properties that are part of the service registration. In general, all the service properties are usable in the filter expression. However, when there is a name conflict with the bundle identification properties, then the key can be prefixed with the commercial at sign ('@' \u0040). For example, `@id` will refer to a service property with the name `id`.
- *action* - Supported actions are:
 - REGISTER - Indicates that the permission holder may register the service object
 - GET - Indicates that the holder may get the service.

When an object is being registered as a service object using `BundleContext.registerService`, the registering bundle must have the `ServicePermission` to register all the named classes. See *Registering Services* on page 135.

When a `ServiceReference` object is obtained from the service registry, see *Locating Services* on page 139, the calling bundle must have the required `ServicePermission[ServiceReference, GET]` to get the service object for each returned Service Reference.

When a service object is obtained using a `ServiceReference` object, see *Getting Service Objects* on page 141, the calling code must have the required `ServicePermission[ServiceReference, GET]` to get the service object associated with the Service Reference.

`ServicePermission` must be used as a filter for the service events received by the Service Listener, as well as for the methods to enumerate services, including `Bundle.getRegisteredServices` and `Bundle.getServicesInUse`. The Framework must assure that a bundle must not be able to detect the presence of a service that it does not have permission to access.

5.14 Changes

- Updated *Prototype Service Factory* on page 146 to specify that customized service objects must be use counted.

6 Resource API Specification

Version 1.0

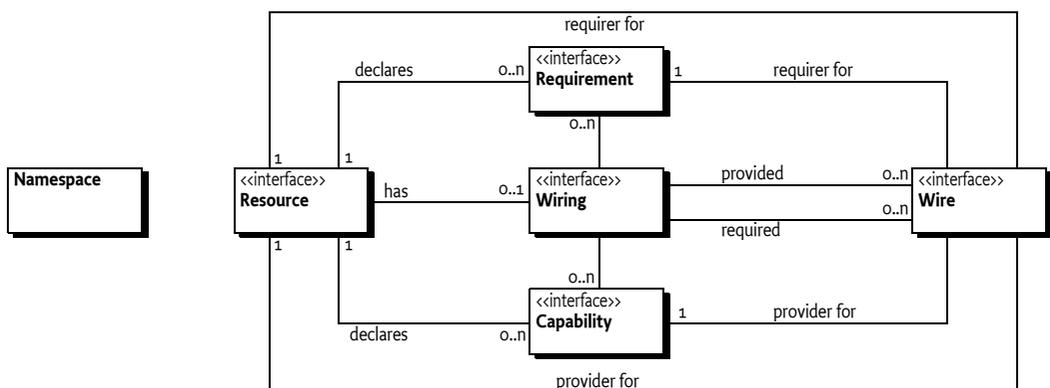
6.1 Introduction

This section describes the API for the generic Requirement-Capability model as introduced in the *Dependencies* on page 42. This API is not used directly by the Framework, the purpose of specifying this base API is to allow it to be used as building block for other specifications.

6.1.1 Entities

- *Resource* - An entity that can be installed in an Environment where it will provide its Capabilities when all its Requirements are satisfied.
- *Environment* - A framework or container that contains one or more Resources.
- *Namespace* - Defines the semantics of the Requirements and Capabilities; a Requirement can only match a Capability when they are in the same Namespace. A Namespace is similar to a type in an object oriented language.
- *Requirement* - An assertion on a Capability in a Namespace. The assertion uses the OSGi filter language to match the attributes of a Capability. The filter is specified as a directive; a Requirement can also have other directives and attributes.
- *Capability* - An attribute based description of a quality of a Resource when installed in an Environment.
- *Wiring* - The wired state of a Resource.
- *Wire* - Connects a Requirement to a matching Capability.

Figure 6.1 Class diagram for *org.osgi.resource*



6.2 Resources

The OSGi dependency model is introduced in *Dependencies* on page 42 ; it is based on a generic *Requirements/Capability* model. In this model a *Resource* models something that can be installed in an *Environment* but has Requirements that must be satisfied by Capabilities available in that the Envi-

ronment. However, once it is installed and resolved into the Environment it provides its declared Capabilities to that Environment. Bundles are Resources, an example of a Requirement is an Import-Package clause, and an example of a Capability is an Export-Package clause.

The `org.osgi.resource` package contains a base API that defines a number of interfaces that model this generic model.

The `org.osgi.framework.wiring` package provides an API for reflecting the wiring of an OSGi Framework. The purpose of the separation is to allow the management agents to treat the system in a uniform way. That is, it allows a wide array of resources and environments to be modeled, and thus managed, in a uniform way. The Resource API is therefore primarily a building block for other specifications.

The [Capability](#) and [Requirement](#) class are almost identical in their signature. They both provide the following methods:

- `getAttributes()` - Return a map with the attributes
- `getDirectives()` - Return a map with the directives
- `getNamespace()` - Return the Namespace
- `getResource()` - Return the Resource

The key difference between a Requirement and a Capability is that a Capability provides attributes that are matched by an OSGi filter specified in a Requirement's filter directive.

6.3 Namespaces

The *Namespace* acts as the type of a Capability and Requirement. A Capability and a Requirement can only match when they are in the same Namespace. The Namespaces in use by the OSGi Core specification are defined in *Framework Namespaces Specification* on page 171. Other specifications can, however, define their own Namespaces.

A Namespace defines:

- *Requirement Attributes* - Any attributes that are allowed to be used on a Requirement declaration.
- *Requirement Directives* - Any directives that are allowed to be used on a Requirement declaration.
- *Capability Attributes* - Any attributes that are allowed to be used on a Capability, these attributes are available for matching.
- *Capability Directives* - Any defined directives that are allowed to be used on the Capability
- *Semantics* - The Namespace definition defines what the meaning is of a Capability. This can include actions in the Environment like for example being wired with certain rules.

6.3.1 Matching

A Requirement matches a Capability when:

- They have the same Namespace, and
- The Requirement's filter matches the Capability's attributes, and
- If the Namespace is an `osgi.wiring.*` Namespace then the mandatory directive must be supported.

Other Namespaces must not introduce additional matching rules.

6.4 Resolution

Before a Resource can provide its functionality it must be *resolved* against the Environment. The Environment can provide a number of Capabilities of its own but in general the Capabilities come from the of the installed Resources. The *resolver* must find a set of *Wires* between Requirements and Capabilities in an Environment such that each mandatory Requirement is satisfied with at least one Capability, and the constraints of the involved Namespaces are all met.

Resolving is an NP-complete problem since there are many solutions, it is easy to test if a solution is right, but there is no algorithm to calculate a solution. In practice, for the OSGi resolvers it is possible to find solutions in a reasonable amount of time. However, the nature of NP-complete problems makes it difficult to set exact rules: many solutions are correct. Constraining the resolvers too much would stifle innovation and likely cause performance problems.

In general the Environment has an existing *Wiring* state for already installed Resources. The resolver then calculates a resolution, which is a set of Wires that should be added to the existing Wiring state by installing the Resources. A Wire is a connection from a Requirement to a Capability. A Requirement or Capability is *declared* in a Resource. This is depicted in Figure 6.2.

Figure 6.2

Wire and declared Resources

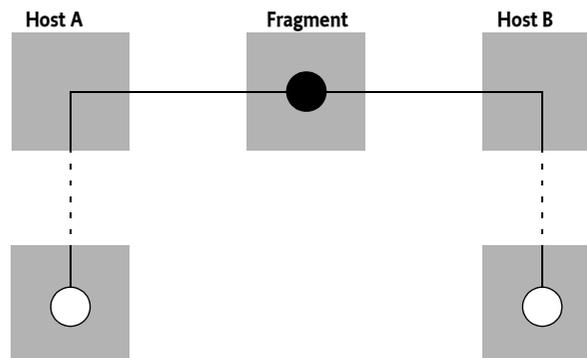


6.4.1 Hosted Requirements and Capabilities

Though each Capability and Requirement is declared in a Resource, it can however be *hosted* by another Resource. For example, when a Fragment has an Export-Package header it is in reality its host that will provide that package. There is therefore a clear distinction between the Resource that declares the Capability/Requirement and the run time Wiring state that hosts that Capability. For this reason, a Wire connects a Requirement and a Capability but links separately to the Resources that host the Requirement and the Capability. Figure 6.3 depicts a hosted Capability. The Capability from the Fragment bundle is hosted by Host A and Host B.

Figure 6.3

Hosted Capability Example



For this reason, the [Wire](#) class provides the following methods:

- [getRequirement\(\)](#) - The Requirement wired from.

- `getRequirer()` - The Resource that hosts the Requirement.
- `getCapability()` - The Capability that is wired to.
- `getProvider()` - The Resource that hosts the Capability.

6.4.2 Resolution

Requirements can be optional or mandatory, as specified in the resolution directive, which is only available on the Requirement. Optional Requirements do not have to be satisfied by the Resolver. Environments can be eager or relaxed in finding Resources to resolve optional Requirements. All mandatory Requirements of a Resource must be satisfied before that Resource's Capabilities can be provided to the Environment.

The syntax of the resolution directive is therefore:

```
resolution ::= 'optional' | 'mandatory'
```

The default is mandatory.

6.4.3 Effectiveness

Both Requirements and Capabilities support the effective directive. This directive provides a name that can be used by the Environment to control the resolving process. During a resolve process, the Environment can then decide one or more names that must match the effective directive.

For the OSGi Framework, the name resolve is reserved, this is also the default. The syntax is therefore:

```
effective ::= <name>
```

6.4.4 Mandatory Attributes

If a Capability has declared a mandatory directive and the Namespace starts with `osgi.wiring` then it mandates that the names listed directive are used in the filter and must match. The syntax for the mandatory attribute is:

```
mandatory ::= extended ( ', ' extended )*
```

6.4.5 Cardinality

The cardinality directive defines if a Requirement can be wired to multiple Capabilities or must be wired to at most one. The syntax for the directive is:

```
cardinality ::= 'single' | 'multiple'
```

The default is single.

6.4.6 Class Space Consistency

Though the Requirement/Capability model is generic it is linked closely with the class loading architecture of OSGi frameworks, particularly class space consistency, see *Constraint Solving* on page 57. For this reason, each Capability can specify its *uses constraints* with the `uses` Capability directive. The `uses` directive always contains a comma separated list of package names. The resolver must ensure that any resolution does not violate the class space consistency based on these constraints. `Uses` constraints can be specified on any Capability, not just Capabilities related to class loading, and are always about Java packages. The syntax of the directive is:

```
uses ::= package-name ( ', ' package-name )*
```

6.5 Wiring

A resolver calculates a set of Wires between Requirements and Capabilities based on an existing, potentially empty, state. The existing state in the Environment is represented in a set of [Wiring](#) objects. Such an object represents the Wiring state of a Resource in an Environment. It provides access to all hosted Requirements and Capabilities as well as existing Wires. It has the following methods to conveniently provide access to the state:

- [getResource\(\)](#) - The related Resource.
- [getProvidedResourceWires\(String\)](#) - Get any Wires, in the given Namespace, where the related Resource is the provider.
- [getRequiredResourceWires\(String\)](#) - Get any Wires, in the given Namespace, where the related Resource is the requirer.
- [getResourceCapabilities\(String\)](#) - Get the hosted Capabilities of the related Resource.
- [getResourceRequirements\(String\)](#) - Get the hosted Requirements of the Related Resource.

7 Bundle Wiring API Specification

Version 1.2

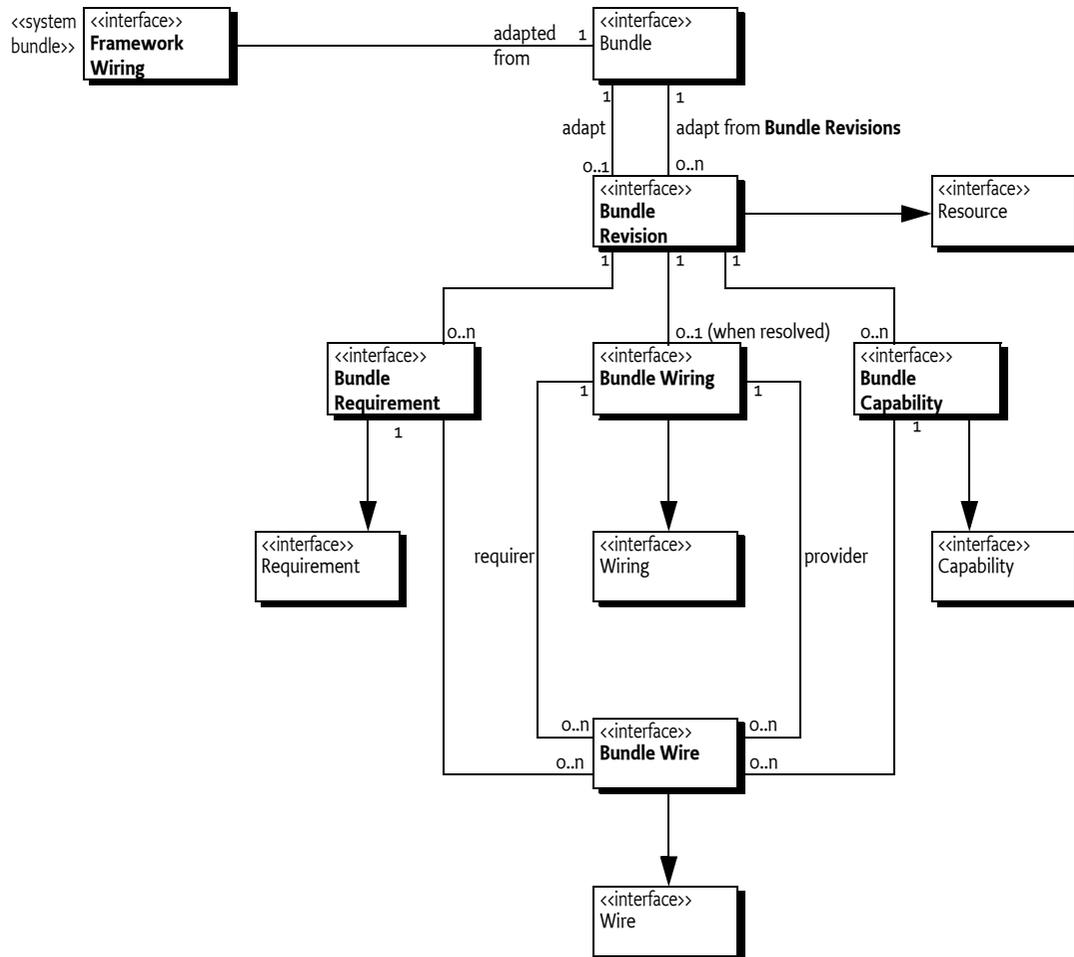
7.1 Introduction

A key aspect of the OSGi framework is managing the dependencies between the bundles. These dependencies are expressed as manifest headers that can be grouped into *requirements* and *capabilities* as defined in *Resource API Specification* on page 151. For example, an Export-Package clause is a capability and an Import-Package clause is a requirement. During the resolving phase the requirements are resolved to matching capabilities by creating a *Bundle Wire*. Some of the wires can influence how the classes are loaded from bundles during runtime.

This section outlines the API to introspect the wiring between the requirements and capabilities of resolved bundles.

7.1.1 Entities

- *Bundle Revision* - Represents the class/resource container of an install or update (that is, the JAR, directory, or other form of archive). Each update creates a new Bundle Revision and an uninstall removes the Bundle Revisions. A Bundle Revision is modeled after a Resource.
- *Namespace* - Bundle Requirements and Bundle Capabilities are defined in a namespace, namespaces define the semantics of the requirements and capabilities. The `osgi.wiring.bundle`, `osgi.wiring.host` and `osgi.wiring.package` from the Framework Namespaces are defined in *Framework Namespaces Specification* on page 171.
- *Bundle Requirement* - Represents a requirement header, either the Require-Capability header or any of the manifest headers referred to in the *Framework Namespaces Specification* on page 171 that map to a requirement.
- *Bundle Capability* - A quality of a Bundle Revision that is provided when the revision is installed. Implemented as a set of attributes that are part of a namespace. A Bundle Capability represents either the Provide-Capability manifest header clauses, or any headers defined in the OSGi namespaces that map to a capability.
- *Bundle Wiring* - Created each time when a Bundle Revision is resolved for holding the wires to other Bundle Wirings as well as maintaining the run time state. Used by the framework to control class loading depending on the semantics of the OSGi namespaces.
- *Bundle Wire* - Connects a Bundle Requirement to a Bundle Capability as well as the requirer Bundle Wiring and provider Bundle Wiring.
- *Framework Wiring* - Provides access to manage and initiate refresh and resolving.

Figure 7.1 Class Diagram *org.osgi.framework.wiring* (with relations to *org.osgi.resource*)

7.2 Using the Wiring API

This section explains how the wiring API can be used without fully explaining all the concepts in depth. The next sections outline the formal specification.

7.2.1 Synopsis

The Bundle Context `installBundle` method installs a bundle and returns a Bundle object. This install provides the classes and resources in a JAR, directory or some other form, as an *environment*. This resource is represented as a *Bundle Revision*.

A Bundle Revision *declares* a number of *Bundle Capabilities* as well as a number of *Bundle Requirements*. A capability represents a set of attributes and a requirement is a filter on those attributes. For a requirement to be applicable to a capability, they must reside in the same *namespace*. The namespace groups requirements and capabilities and defines the semantics for a resolved requirement/capability pair. This pair is represented as a *Bundle Wire*.

Capabilities can be anything: certificates, screen size, the packages, the bundle itself or the capability to act as host for a fragment. Some capabilities and requirements are from the Provide-Capability

and Require-Capability headers, others are defined by the OSGi headers defined in *Module Layer* on page 33, the namespaces for these OSGi specific headers are defined in *Framework Namespaces Specification* on page 171.

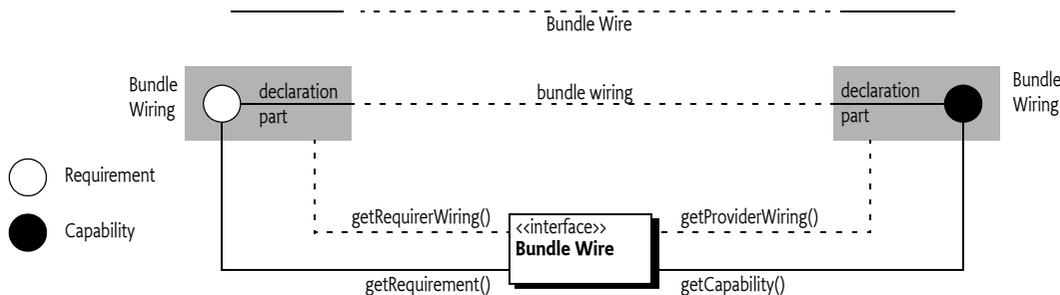
The framework wires the Bundle Requirements to Bundle Capabilities during the resolving operation. The framework must resolve all the requirements to matching capabilities according to the semantics of their namespaces before it can declare a bundle to be resolved. For generic namespaces it is sufficient to find a matching capability for each requirement. However, for the OSGi namespaces additional rules are implied. For example, the `osgi.wiring.host` namespace implies all the rules around OSGi fragment bundles.

Once a bundle is in the RESOLVED state it gets a *Bundle Wiring*, the Bundle Wiring represents the run time state of the Bundle Revision. The Bundle Wiring holds the *Bundle Wires*. A Bundle Wire ties a single Bundle Requirement to a single Bundle Capability as well as tying the Bundle Wiring that holds the requirement to the Bundle Wiring that holds the capability. The Bundle Wires that flow from a Bundle Wiring's Requirement to a capability are the *required wires*, they can be obtained with `getRequiredWires(String)`. Bundle Wires that come from a Bundle Wiring's Capability to a requirement are the *provided wires*, they can be obtained with `getProvidedWires(String)`. The same requirements and capabilities can be used in different wires.

Namespace rules can be complex. For example, in the case of fragments they imply that any capabilities from the fragment are actually available from its hosts. In the case of exported packages that are also imported the resolver can choose to pick either. These examples demonstrate that the resolver must be able to differentiate between the Bundle Revision's declared requirements and capabilities and the run time state, the Bundle Wiring, of the corresponding Bundle Revision. A Bundle Revision's Bundle Wiring therefore provides the actual run time requirements and capabilities as chosen by the resolver with the Bundle Wiring's `getRequirements(String)` and `getCapabilities(String)` methods. Any optional declared requirements that were not satisfied are not in the list of requirements. All dynamic requirements that can potentially be satisfied at run time are in this requirements list.

The BundleWiring objects are therefore not necessarily associated with the same Bundle Revisions that originate the declared Bundle Requirement and the declared Bundle Capability. It is therefore that the diagramming technique used in Figure 7.2 uses dotted lines for the Bundle Wiring connection. That is, the connections from the Bundle Wire to the requirer BundleWiring object and to the provider BundleWiring object. It then uses solid lines for the connection to the declared requirement and capability in their Bundle Revisions. This technique makes it possible to depict fragments where a capability in the fragment is actually available from the host's Bundle Wiring.

Figure 7.2 Requirements and Capabilities Diagramming



BundleWiring objects can continue to exist and operate as long as there are wires from other BundleWiring objects, even after a bundle is updated. The only way to break this non-current wiring is to *refresh* the bundles that are involved. The refresh operation computes a transitive closure of all dependent bundles, and re-resolves them. Any active bundles in this closure will be stopped and restarted. This operation can be activated on the *Framework Wiring*.

The wiring API is based on the `Bundle.adapt()` method, see *Adaptations* on page 123. This method allows the `Bundle` object to be adapted to another type. For example:

```
BundleWiring current = bundle.adapt(BundleWiring.class);
if ( current != null ) {
    ...
}
```

For this API, the following adaptations of the `Bundle` object are supported:

- **BundleRevision** - Provides access to the current revision at the time of the `adapt` method call. A `Bundle` will always have a current `Bundle Revision` until it is uninstalled.
- **BundleWiring** - Provides access to the current `Bundle Wiring` at the time of the `adapt` method call. A current `Bundle Wiring` object only exists (the `adapt` method returns non-null) when the bundle is resolved.
- **BundleRevisions** - Provides access to all the `BundleRevision` objects that are still in use. A `Bundle` always has a `BundleRevisions` object, the `adapt` method must never return null.
- **FrameworkWiring** - Can only be adapted from the system bundle with bundle id 0. Provides access to the management methods like `refresh` and `resolve`, and information about bundles that are pending removal, and the dependency closure of a set of bundles.

The `Bundle Wiring` API is usable during launching after the `init` method has returned.

After an `uninstall` the `adapt` method will always return null for `BundleRevision` or `BundleWiring`. However, it is possible that the `Bundle Revision` and/or its `Bundle Wiring` are reachable through other bundles.

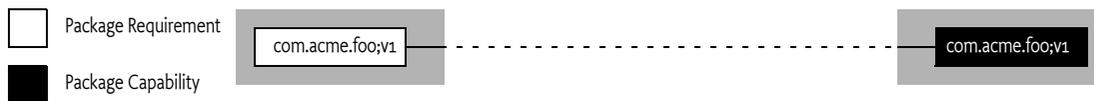
7.2.2 Finding the Imported Packages

Packages are reflected in the `osgi.wiring.package` namespace. An `Import-Package` clause is mapped to an `osgi.wiring.package` requirement and an `Export-Package` clause is mapped into the corresponding capability. For example:

```
Import-Package: com.acme.foo;version=1
Export-Package: com.acme.foo;version=1
```

In the `Requirements/Capabilities` model this is depicted as in Figure 7.3:

Figure 7.3 Example Import/Export Package with Requirements/Capabilities Model



The following code prints the bundles that bundle A is wired to through `Import-Package` statements:

```
void printImports( Bundle A ) {
    BundleWiring wA = A.adapt( BundleWiring.class );
    for ( BundleWire wire :
        wA.getRequiredWires(PACKAGE_NAMESPACE) ) {
        String pack = (String) wire.getCapability().getAttributes()
            .get(PACKAGE_NAMESPACE);
        Bundle bundle = wire.getProviderWiring()
    }
```

```

        .getBundle());
    System.out.println(pack + " - " + bundle.getLocation());
}
}

```

7.2.3 Attached Fragments

Fragments use the `osgi.wiring.host` namespace to control their attachment. A fragment has a requirement for a host capability, this is a capability with the bundle symbolic name and version. If a fragment is attached then there is a wire from the fragment's Bundle Wiring to the host's Bundle Wiring.

The following snippet finds the attached fragments of a bundle:

```

Set<BundleWiring> attachedFragments( BundleA ) {
    Set<BundleWiring> result = new HashSet<BundleWiring>();
    BundleWiring wA = A.adapt( BundleWiring.class );

    for ( BundleWire wire : wA.getProvidedWires(HOST_NAMESPACE)) {
        result.add( wire.getRequirerWiring() );
    }
    return result;
}

```

7.3 Bundle Wiring

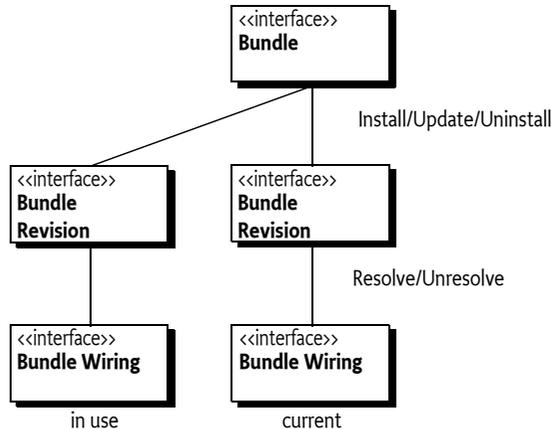
A bundle provides a simplified view of the state of the framework: it is either resolved or not. If it is resolved, bundles can become active and collaborate with other resolved bundles. During the time a bundle is resolved, and thus can see the environment, it will see a consistent stable state with respect to its code dependencies. Other bundles can be started and stopped, installed, updated, and uninstalled during the life cycle of a bundle. However, as long as a bundle is resolved it will continue to load classes from the bundle revisions it was wired to when it was initially resolved, even if those bundles are updated or uninstalled.

The consequence of this model is that each bundle can have multiple *revisions*, and each revision can have an optional *wiring* at any moment in time. Management agents have the need to see this more complex state to be able to predict the impact of management actions and to help diagnose problems.

There are two important event types that complicate the overall state. The install and update events provide a new *Bundle Revision* for a bundle and the uninstall event disconnects any Bundle Revisions from the bundle. The Bundle Revision contains the resources and the metadata defining, among other things, what type of bundle it is and what its dependencies are. An update can therefore change every aspect of a bundle. For example, an update could turn a non-fragment bundle into a fragment.

The other event types that is of interest here are the RESOLVED and UNRESOLVED events. Resolving a bundle creates a *Bundle Wiring* based on the then current Bundle Revision. During resolving, a Bundle Wiring uses the requirements from the Bundle Revision to create *wires* to other Bundle Revisions; the wires are used to control the class loading process. Once a Bundle Wiring is required by another Bundle Wiring, or it is the current wiring, it is said to be *in use*. This model is depicted in Figure 7.4.

Figure 7.4 Relationship between events, revisions, and wirings



The framework never eagerly disconnects the wires between Bundle Wirings, a disconnect happens only under control of the management agent when the `refreshBundles(Collection,FrameworkListener...)` method is called or when all requiring bundles become uninstalled. When a bundle is updated, its existing `BundleWiring` objects will continue to serve classes and resources to bundles that use it. The update, even though it provides a new revision, has no effect on resolved bundles with respect to class loading. Also, the installation of a new bundle could allow new wires but they must not affect the existing wiring until `refreshBundles(Collection,FrameworkListener...)` is called (with the exception for dynamic imports). Though the class loading wires remain in place, proper bundles should react to the changes in the dynamic state. That is, when a bundle is updated it will be stopped, allowing others to remove any references they have to that bundle. However, even in those cases the wirings will remain until the bundle is unresolvable during a refresh cycle.

After an update, the existing `Bundle Wiring` is no longer *current* for the bundle.

`Bundle Wirings` that are not in use (no other `Bundle Wiring` is wired to it) can be removed immediately but in-use `Bundle Wirings` must remain in place until they become no longer in use. These non-current in-use `Bundle Wirings` are called *pending for removal*.

To forcefully remove all these non-current in use `Bundle Wirings` the framework can *refresh* a set of bundles at the request of a management agent. The refresh will create a transitive dependency graph on an initial set of bundles and then unresolves each bundle in the graph, which will make any of the stale `Bundle Wirings` no longer in use so they can be cleaned up. After this refresh, any previously active bundles will be restored to their previous state.

The purpose of this non-eager behavior is to allow for efficient handling of multiple updates/installs/uninstalls. Refreshing the wires after each such event requires the start and stop of the dependent bundles, disrupting the operations of the system unnecessary often. It is therefore better to batch up a number of such operations and then *refresh* the system once. However, the implication of this optimization is that the actual wiring between bundles can quickly become an intricate web of connections between revisions of bundles.

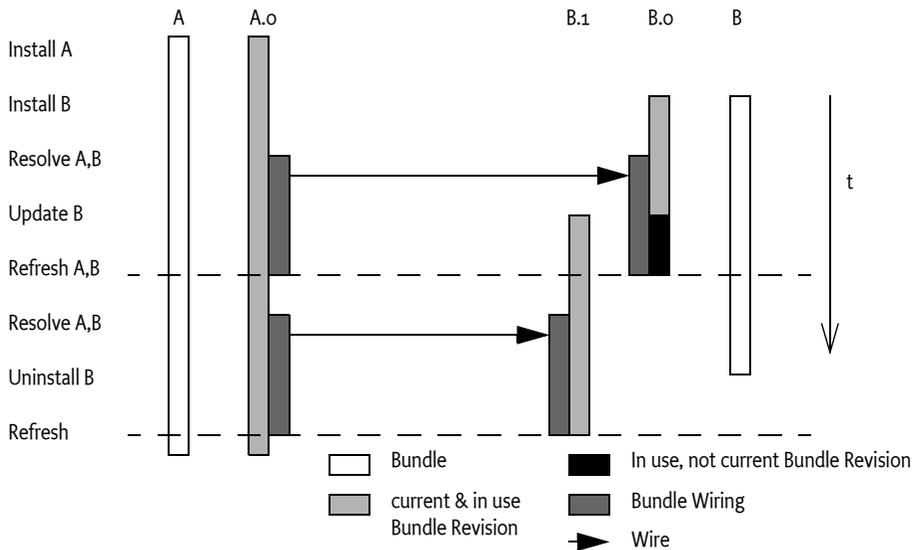
For example, assume a bundle A is installed. At installation, it will have a single `Bundle Revision`, called A.o. Next, bundle B is installed, it will have a `Bundle Revision` B.o. Assuming `Bundle Revision` A.o requires a capability in bundle B, resolving bundle A and bundle B will create a `Bundle Wiring` for `Bundle Revision` A.o linking to a `Bundle Wiring` for `Bundle Revision` B.o. If bundle B is now updated, it will create a second `Bundle Revision`, B.1. However, the current `Bundle Wiring` for bundle A (`Bundle Revision` A.o) will remain wired to `Bundle Revision` B.o as long as bundle A and bundle B remain resolved, even though the current `Bundle Revision` for bundle B has now become B.1. As long as `Bundle Revision` A.o remains resolved, bundle B's resolved state has no impact.

Bundles are only actually unresolved when they are *refreshed*, the UNRESOLVED event only indicates that a Bundle is updated or uninstalled. Refreshing happens on a per bundle basis but takes any Bundle Wirings into account that depend on the refreshed bundle. In the previous example, if bundle B is refreshed, it will automatically refresh bundle A because A is wired to B. That is, bundle B is in use by A. The refresh will stop bundles A and B and then unresolve both of them. Unresolving basically means removing any reference from the framework to the Bundle Wirings of the involved bundles. This unreferencing will allow the garbage collector to remove any remains, like for example the class loader and the activator, unless some bundles illegally hold on to references. Once a Bundle Wiring is no longer required by the framework, it is set to be not in use, regardless of stale references.

Normally, after unresolving, the bundles are started again in their original state, forcing them to resolve again. In the previous example, Bundle Revision A.o will then be connected to the Bundle Revision B.1 through newly created BundleWiring objects. The old Bundle Wiring for B.o will no longer be in use and will thus be garbage collected.

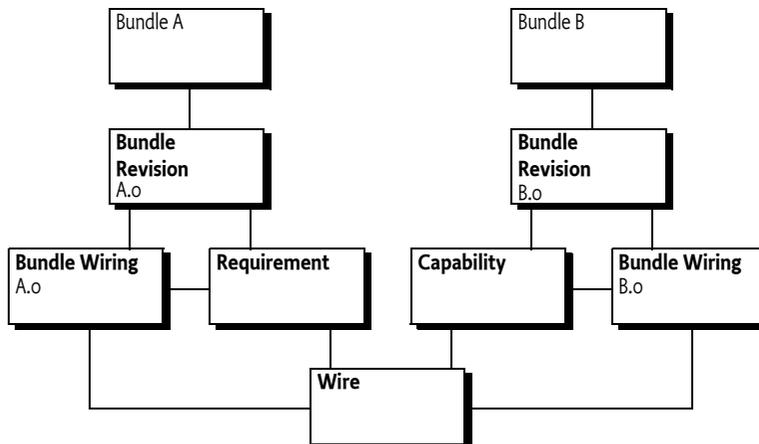
This example is depicted in Figure 7.5. This picture shows when the different objects are created and discarded. In this picture bundle B is not started.

Figure 7.5 The Bundle Revisions and Bundle Wirings over time



The resolver is responsible for wiring Bundle Requirements and Bundle Capabilities to each other while adhering to the semantics defined in their namespace. For each paired Bundle Requirement and Bundle Capability the resolver creates a Bundle Wire that links the Bundle Requirement, the requiring Bundle Wiring, the providing Bundle Wiring, and the Bundle Capability. The relationships between a bundle A and bundle B, where A requires some capability in B, is depicted in Figure 7.6.

Figure 7.6 Bundle A requires Bundle B Wiring Instances



The OSGi framework can add wires and new requirements and capabilities after resolving during run time. This mechanism is for example used in `DynamicImport-Package`, dynamic attaching of fragments, and byte code weaving.

7.4 Fragments

The type of a bundle is available on the Bundle Revision because a Bundle can change from a fragment to a normal bundle or vice versa after an update. The `getTypes()` method is used to obtain a bitmap that is either 0 or has the following bit set:

- `TYPE_FRAGMENT` - If this bit is set the Bundle Revision is a fragment.

The type is a bitmap allowing future versions of this specification to add new types that can be a combination of existing and new types. The following example displays how a Bundle is checked to be a fragment:

```

BundleRevision rev = aBundle.adapt(BundleRevision.class);
if ( rev != null && (rev.getTypes() & TYPE_FRAGMENT) != 0 ){
    ... // do the fragment thing
}

```

A fragment bundle will show all its declared capabilities and requirements on its Bundle Revision but during resolving the resolver only considers the `osgi.wiring.host` and `osgi.ee` requirements and the `osgi.identity` capability and requirements.

The `osgi.wiring.host` requirement represents the `Fragment-Host` header. A fragment can be attached to different hosts and each attachment creates a wire from the fragment's Bundle Wiring to the host's Bundle Wiring. The `osgi.ee` requirement is also never hosted.

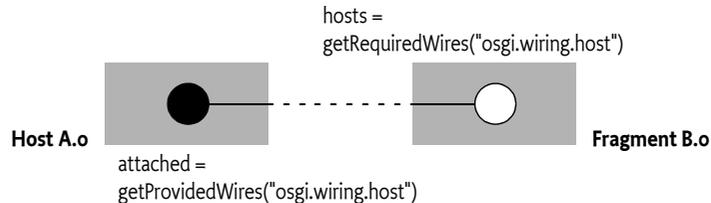
The `osgi.identity` capability of a fragment is part of the fragment's Bundle Wiring and is not part of a host bundle's Bundle Wiring. That is, each Bundle Wiring has exactly one `osgi.identity` capability. However, `osgi.identity` requirements declared by a fragment are not part of the fragment's Bundle Wiring and are instead hosted by the host bundle's Bundle Wiring.

Any other requirements and capabilities in a fragment bundle never become part of the fragment's Bundle Wiring; they are treated as part of the host's requirements and capabilities when the fragment is attached to that host.

To find the attached fragment for a host bundle it is necessary to find the wires for the `osgi.wiring.host` capability. The requiring end of such a wire is the attached fragment and the providing end is the attaching host.

For example, bundle A is a host and bundle B is a fragment as depicted in Figure 7.7 on page 165.

Figure 7.7

Fragments and Wiring

Then, to find the attached fragments for Bundle Revision Ao:

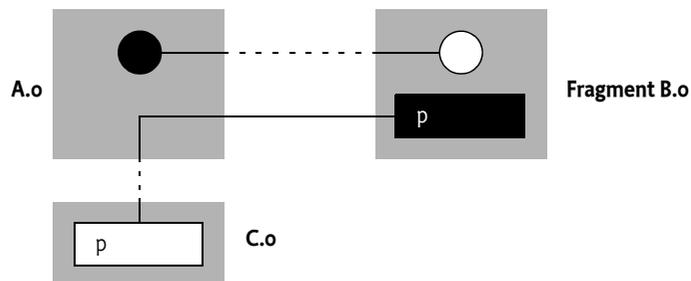
```
List<BundleWiring> attached = new ArrayList<BundleWiring>();
for ( BundleWire wire : A0.getBundleWiring().getProvidedWires(HOST_NAMESPACE))
    attached.add( wire.getRequirerWiring() );
```

It is also possible to calculate the reverse dependency for finding the hosts of a fragment. For the previous example, the bundles that attach fragment B can be found with:

```
List<BundleWiring> hosts = new ArrayList<BundleWiring>();
for ( BundleWire wire : B0.getBundleWiring().getRequiredWires(HOST_NAMESPACE))
    hosts.add( wire.getProviderWiring() );
```

The `osgi.wiring.host` namespace mandates that the resolver moves the Bundle Requirements and Bundle Capabilities from the fragment in all other namespaces than the `osgi.wiring.host`, `osgi.identity` and `osgi.ee` namespaces to the host bundle. For example, if the fragment exports a package `p`, then this package is exported by the host. In such a case, the BundleRequirement and BundleCapability objects remain associated with the Bundle Revision of the fragment. However, the Bundle Wire has the appropriate Bundle Wiring of the host. This is depicted in Figure 7.8 on page 165. Package `p` is declared a capability in fragment B.o but when wired the Bundle Wiring of host A.o will be the provider.

Figure 7.8

Exporting a Package from a Fragment

The previous example is also depicted as an instance diagram in Figure 7.9 on page 166.

7.5.1 Refreshing

The update of bundles will create new Bundle Revisions while the existing Bundle Wirings remain wired to their previous Bundle Revisions. This stale wiring must be cleaned up and the `refreshBundles(Collection, FrameworkListener...)` method achieves this.

The `refreshBundles` method works from an initial collection of bundles that is used to seed the calculation of the *dependency closure*. The dependency closure is calculated by expanding the seed dependency closure to include any bundle that has a Bundle Wiring that depends on any bundle in the dependency closure. This is a recursive definition so the dependency closure contains the list of transitive dependencies on the initial seed collection.

This dependency closure can be obtained separately with the `getDependencyClosure(Collection)` method providing it with the same seed. If no seed is provided, that is a null argument is given, the `refreshBundles` method will be identical to calling it with the result of the `getRemovalPendingBundles()` method as the seed collection. This default will ensure that all stale Bundle Wirings will be cleaned up.

The refresh process will stop any bundles in the considered collection while recording their state and, if active, their starting option (for example `START_TRANSIENT`). Stopping must take any start level rules into account.

The refresh must then unresolve all the bundles in the considered collection. Unresolving will cause all the removal pending Bundle Wirings to become no longer in use because there are no longer any bundles requiring them. This will make the Bundle Wirings available for garbage collection because they are then no longer reachable from the framework API.

The framework must then attempt to restore the state as it was before the refresh taking all the framework rules into account, including start levels, start options, and activation options.

The actual refresh operation will take place in the background because it can be a long running operation. The refresh operation will send out a global framework event `PACKAGES_REFRESHED`. However, catching this event properly is non-trivial. For this reason, the `refreshBundle` method also allows a callback by specifying an optional Framework Listener in the method invocation that will only be called when the method is finished. For example:

```
fw.refreshBundles( null, new FrameworkListener() {
    public void frameworkEvent(FrameworkEvent ev) {
        System.out.println("Refresh finished");
    }
});
```

7.6 Container Scanning

A resolved bundle can consist of a number of containers: the basic bundle container (usually a JAR), embedded JARs or directories, and fragments. Containers contain *entries* but the Bundle-ClassPath header turns these entries into a single namespace, called *resources*. These concepts are fully defined in *Bundle Class Path* on page 67.

The wiring API provides two different ways to iterate over the contents in the containers that constitute a resolved bundle:

- *Bundle Class Path Order* - Scan the bundle class path containers.
- *Entry Order* - Scan all the entries that constitute a bundle and its attached fragments.

These two different ways are outlined in the following sections.

7.6.1 Bundle Class Path Order

Once a bundle is resolved all its container namespaces are flattened to a single namespace that is then used by the class loader. Flattening has as a consequence that certain resources will disappear from the view, which resource remains and which disappear depends on the order of the flattening. The OSGi specification defines exactly what this order is. However, the rules for this ordering are many and non-trivial. For this reason, a Bundle Wiring allows the iteration over the resources of a bundle in the bundle class path order, reflecting the same flattening as that what the class loader will do. A bundle must be resolved to be able to iterate over its resources.

The method used to iterate over the resources in bundle class path order is [listResources\(String,String,int\)](#). This method takes a starting path in the namespace, a pattern to match (for example *.class for class resources) and a flag to indicate if the scan should recurse into directories or not.

When the bundle class path has a multi-release container, see *Multi-release Container* on page 69, and an argument to the [listResources\(String,String,int\)](#) method would include a resource name in the method result if the resource was not available from the root directory but is available from a versioned directory visible on the current Java version, then the method result must include the resource name from the root directory. For example, if the multi-release container has the following entry

```
META-INF/versions/9/com/foo/resource.txt
```

and the call `listResources("/com/foo", "*.txt", 0)` is made when running on Java 9, or later, the result must include

```
com/foo/resource.txt
```

The [listResources\(String,String,int\)](#) method has no counterpart in the standard class loader API.

7.6.2 Entry Order

A Bundle Wiring reflects a resolved bundle. This wiring constitutes the bundle and any attached fragments. The [findEntries\(String,String,int\)](#) method is similar to the Bundle's [findEntries\(String,String,boolean\)](#) method. The Bundle's method will be identical when the bundle can be resolved, if the bundle cannot resolve the Bundle's `findEntries` method has a fallback that allows iteration without attached fragments. The Bundle Wiring's [findEntries\(String,String,int\)](#) is always against a resolved bundle because it is on a Bundle Wiring.

7.6.3 Class Loader Access

The class loader can also be obtained from the BundleWiring class with the [getClassLoader\(\)](#) method.

7.7 Security

The Bundle Wiring API requires Adapt Permission with action ADAPT for the following types:

- `org.osgi.framework.wiring.BundleWiring`
- `org.osgi.framework.wiring.BundleRevision`
- `org.osgi.framework.wiring.BundleRevisions`
- `org.osgi.framework.wiring.FrameworkWiring`

The Framework Wiring methods that mutate state require an additional Admin Permission with the action:

- RESOLVE (for the system bundle) - For [refreshBundles\(Collection,FrameworkListener...\)](#) and [resolveBundles\(Collection\)](#)

7.8 Changes

- Added support for multi-release JARs. See *Bundle Class Path Order* on page 168.

8 Framework Namespaces Specification

Version 1.1

8.1 Introduction

A key aspect of the OSGi dependency model based on requirements and capabilities is the concept of a *namespace*. A Namespace defines the semantics of a Requirement-Capability pair. This generic model is defined in *Resource API Specification* on page 151. This section defines a number of namespaces that are part of the OSGi Core specification. The `osgi.wiring.*` namespaces map to the module layer, others are used as foundations for other specifications.

Namespaces that are mapped from OSGi manifest headers must never be specified as generic requirements or capabilities in the manifest. The purpose of these namespaces is only to provide the Modularity manifest headers in generic form; the framework must translate the specific manifest headers defined in the *Module Layer* on page 33 to their generic form so that requirements and capabilities can be used in a uniform way, regardless if they originate from specialized or generic manifest headers.

Each namespace is defined with the following items:

- *Name* - the name of an attribute or directive
- *Kind* - Defines where the attribute or directive can be used
 - CA - Capability Attribute
 - CD - Capability Directive
 - RA - Requirement Attribute
 - RD - Requirement Directive
- *M/O* - Mandatory (M) or Optional (O).
- *Type* - The data Type
- *Syntax* - Any syntax rules. The syntax refers in general to the syntaxes defined in *General Syntax Definitions* on page 12 and *Common Header Syntax* on page 38 and later sections.

Attributes on manifest headers that define capabilities are used as matching attributes in the requirement's filter and are available as the attributes of a Capability object. Attributes on manifest headers that define requirements are translated to a conjunction of assertions in the filter that correspond to the semantics of their header. That is, these attributes on requiring manifest headers are not visible on the Requirement objects as attributes.

Unless an attribute is specifically overridden, all namespaces inherit the attributes and directives of the default namespace as defined in Table 8.1 and in [Namespace](#).

Table 8.1 *Default Namespace*

Name	Kind	M/O	Type	Syntax	Description
uses	CD	O	String	package-name (';' package-name)*	A list of packages used in calculation class space consistency.

Name	Kind	M/O	Type	Syntax	Description
effective	RD, CD	O	String	'resolve' <any name>	A name indicating if a resolve operation applies to this requirement. Default and only defined value is resolve.
resolution	RD	O	String	'mandatory' 'optional'	If mandatory, then this requirement must be satisfied before the resource is resolved. The default is mandatory.
filter	RD	O	String	filter	The given filter is matched against the capability's attributes to satisfy the requirement. A filter is optional, if no filter directive is specified the requirement always matches.
cardinality	RD	O	String	'multiple' 'single'	Allow the requirement to be satisfied by just one capability or provide wires to any capability that satisfies the requirement.
mandatory	CD	O	String	extended (',' extended)*	List of attribute names that the requirement's filter must assert to be equal to the values in the capability's attributes. This directive must only be used for the <code>osgi.wiring.*</code> namespaces and is forbidden in any other namespace.

Namespaces can have any additional attributes and directives, both defined in a namespace as well as ad-hoc. However, none of these additional directives or attributes must require different or additional matching rules.

All directives and attributes specified on the OSGi manifest headers that are translated to requirements and capabilities are visible in these capabilities and requirements, except when they are specifically noted to be ignored in the definition of a namespace.

8.2 osgi.ee Namespace

An OSGi Framework must register capabilities for all the execution environments the Java VM is known to be backward compatible with. For example, if the Java VM provides Java SE 6, then it is backward compatible with 1.2, 1.3, 1.4, 1.5, and 1.6. The `osgi.ee` capability defines the provided versions as a comma separated list. For example:

```
Provide-Capability: «
  osgi.ee; «
    osgi.ee="OSGi/Minimum"; «
    version:List<Version>="1.0,1.1,1.2", «
  osgi.ee; «
    osgi.ee="JavaSE"; «
    version:List<Version>="1.2,1.3,1.4,1.5,1.6"
```

Bundles can require the `osgi.ee` capability if they have a dependency on a specific execution environment, for example:

```
Require-Capability: «
  osgi.ee; filter:="(&(osgi.ee=JavaSE) (version=1.6))"
```

This is useful when the bundle contains class files compiled to target a version of the Java VM and thus cannot be loaded by prior versions of the Java VM. If a bundle needs to require that specific `java.*` packages are available in the runtime, it should use the `Import-Package` header to require those packages. See *Execution Environment* on page 48.

The `osgi.ee` requirement is not hosted when it is part of a Fragment. That is, a requirement from this namespace must be treated as part of the Fragment Bundle and must not be hosted.

The `osgi.ee` capability is defined in table Table 8.2 and in the [ExecutionEnvironmentNamespace](#) class.

Table 8.2 *osgi.ee Namespace definition*

Name	Kind	M/O	Type	Syntax	Description
<code>osgi.ee</code>	CA	M	String	<code>-(ws ')+</code>	The name of the execution environment. The name can contain any character except white space (as defined by Java) or the comma (<code>'\u002C'</code>) character.
<code>version</code>	CA	M	List <code><Version></code>	<code>version (';' version)*</code>	A comma separated list of versions, comparisons must be done with version ordering because the version attribute must be declared with the List <code><Version></code> type.

Provide-Capability headers in the `osgi.ee` namespace must not be used in a bundle's manifest; Require-Capability with this namespace is allowed. An `osgi.ee` requirement is the replacement for the Bundle-RequiredExecutionEnvironment header in *Bundle-RequiredExecutionEnvironment* on page 48.

The names for the execution environments are not normatively defined in this specification except those defined in Table 8.3. A list of well-known (non-normative) names are maintained at [1] *Specification References*.

Table 8.3 *osgi.ee execution environment names*

Name	Description
<code>JavaSE</code>	Should be used for all Java SE execution environments since Java 1.2. The name for the Java Runtime Environment has changed several times but for all environments the Java SE name must be used.
<code>JavaSE/compact1</code>	Java SE Embedded compact1 profile.
<code>JavaSE/compact2</code>	Java SE Embedded compact2 profile.
<code>JavaSE/compact3</code>	Java SE Embedded compact3 profile.
<code>OSGi/Minimum</code>	The OSGi Minimum execution environment.

8.3 `osgi.wiring.package` Namespace

The `osgi.wiring.package` namespace reflects the information in the manifest `Import-Package`, `DynamicImport-Package`, and `Export-Package` clauses as defined *Import-Package* on page 54, *Export-Package* on page 55, and *Dynamic Import Package* on page 69.

The `Import-Package` header and `DynamicImport-Package` headers are represented as a Bundle Requirement for each of their clauses. The `Export-Package` header is represented as a Bundle Capability for each clause. `DynamicImport-Package` clauses have a resolution directive set to `dynamic` and can only be wired after the bundle has been resolved.

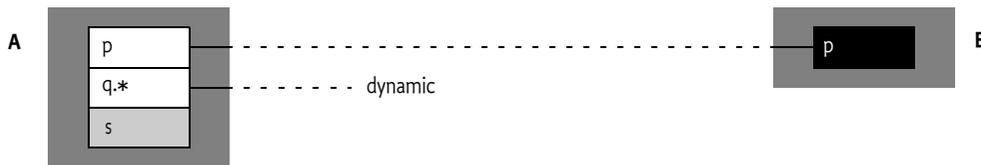
For example, the following bundles:

```
Bundle A:
  Import-Package: p
  DynamicImport-Package: q.*
```

```
Bundle B:
  Export-Package: p
```

This example is depicted in Figure 8.1. Package p is wired to a Bundle Revision of bundle B because it exports package p. The DynamicImport-Package clause is not wired but this can change when during run time package s refers to a class that cannot be found.

Figure 8.1 Example *osgi.wiring.package* Namespace



The *osgi.wiring.package* attributes are defined in Table 8.4 and in the [PackageNamespace](#) class.

Table 8.4 *osgi.wiring.package* Namespace definition

Name	Kind	M/O	Type	Syntax	Description
<i>osgi.wiring.package</i>	CA	M	String	package-name	The name of the package.
version	CA	M	Version	version	A version of the exported package
bundle-symbolic-name	CA	M	String	symbolic-name	The bundle symbolic name of the bundle that exports the package
bundle-version	CA	M	Version	version	The bundle version as defined in the Bundle-Version header.
*	CA	O	String	*	Any attributes defined on the Export-Package clause
resolution	RD	O	String	'dynamic' 'mandatory' 'optional'	This directive is inherited from the default namespace but this namespace adds an additional value dynamic.

The following directives must be ignored when specified on the Import-Package, or Export-Package, or DynamicImport-Package manifest headers:

- effective
- cardinality

The requirements and capabilities in the *osgi.wiring.package* namespace must never be used in the Require-Capability and Provide-Capability headers.

8.4 *osgi.wiring.bundle* Namespace

The *osgi.wiring.bundle* namespace reflects the information in the bundle headers for the purpose of requiring another bundle. The Require-Bundle header is a requirement on the capability provided by the pair of Bundle-SymbolicName/Bundle-Version headers. Requiring this namespace through a Require-Bundle header creates a wire from the requiring bundle to the required bundle.

A bundle must only provide this capability when the Bundle-ManifestVersion >= 2. The *osgi.wiring.bundle* attributes are defined in table Table 8.5 and in the [BundleNamespace](#) class.

Table 8.5 *osgi.wiring.bundle* Namespace definition

Name	Kind	M/O	Type	Syntax	Description
<i>osgi.wiring.bundle</i>	CA	M	String	symbolic-name	The name of the bundle as defined in the Bundle-SymbolicName header.
bundle-version	CA	M	Version	version	The version of the bundle as defined in the Bundle-Version header.

Name	Kind	M/O	Type	Syntax	Description
singleton	CD	O	String	'true' 'false'	Indicates if this is a singleton bundle, see <i>Bundle-SymbolicName</i> on page 53.
visibility	RD	O	String	'private' 'reexport'	See <i>Require-Bundle</i> on page 84.

The effect of the `osgi.wiring.bundle` namespace is that the exported packages of any required bundles become available to the requirer as defined in the *Requiring Bundles* on page 84. A Bundle Wire in the `osgi.wiring.bundle` namespace does not imply the availability of `osgi.wiring.package` Bundle Wires that correspond to the required bundle's exported packages. If there is a need to know what packages will become available then this must be deduced from the `osgi.wiring.package` capabilities of the required bundle.

The following directives must be ignored when specified on the `Require-Bundle` or `Bundle-SymbolicName` manifest headers:

- `uses`
- `effective`
- `cardinality`

The requirements and capabilities in the `osgi.wiring.bundle` namespace must not be used in the `Require-Capability` and `Provide-Capability` headers.

8.5 osgi.wiring.host Namespace

The `osgi.wiring.host` namespace reflects the information in the bundle headers for the purpose of fragments. The `Fragment-Host` header is a requirement on the capability that is provided by the pair of `Bundle-SymbolicName/Bundle-Version` headers. Satisfying this requirement allows a fragment to attach itself to a host. A bundle must only provide this capability when the `fragment-attachment` directive allows fragments to attach and the `Bundle-ManifestVersion` ≥ 2 .

The `osgi.wiring.host` namespace is defined in table Table 8.6 and in the [HostNamespace](#) class.

Table 8.6 *osgi.wiring.host* Namespace definition

Name	Kind	M/O	Type	Syntax	Description
<code>osgi.wiring.host</code>	CA	M	String	<code>symbolic-name</code>	The name of the bundle as defined in the <code>Bundle-SymbolicName</code> header.
<code>bundle-version</code>	CA	M	Version	<code>version</code>	The version of the bundle as defined in the <code>Bundle-Version</code> header.
<code>fragment-attachment</code>	CD	O	String	'always' 'resolve-time' 'never'	Indicates how, or if, a fragment can attach to this host. This capability is defined on the <code>Bundle-SymbolicName</code> header with its corresponding <code>fragment-attachment</code> directive. See <i>Bundle-SymbolicName</i> on page 53.
<code>extension</code>	RD	O	String	'framework' 'bootclasspath'	Indicates if the requiring fragment bundle is a framework or boot class path extension. See <i>Fragment-Host</i> on page 88.

The effect of the `osgi.wiring.host` namespace is that all declared capabilities and requirements of the fragment, except the `osgi.wiring.host` and `osgi.ee` requirements and the `osgi.identity` capability, are merged with the host bundle as defined in the *Fragment Bundles* on page 87.

The following directives must be ignored when specified on the `Fragment-Host` or `Bundle-SymbolicName` manifest headers:

- `uses`

- effective
- cardinality

The requirements and capabilities in the `osgi.wiring.host` namespace must not be used in the Require-Capability and Provide-Capability headers.

8.6 osgi.identity Namespace

The `osgi.identity` namespace has a capability that can uniquely identify a resource. Its purpose is to identify a type for the resource and then provide a name that is unique for that type. That is, the type can be `osgi.bundle` and then the name is a `Bundle-SymbolicName`. For example, for a certificate the type could be `x509` and the name could then its SHA-1 fingerprint. Each must have associated rules for the names uses as the identity name. It is required that the value of the `osgi.identity` attribute, plus the value of the type attribute, plus the version attribute are a unique combination.

The definition of the `osgi.identity` namespace is in Table 8.7 and in the `IdentityNamespace` class.

Table 8.7

osgi.identity Namespace definition

Name	Kind	M/O	Type	Syntax	Description
<code>osgi.identity</code>	CA	M	String	<code>symbolic-name</code>	The identity of the resource, for an OSGi bundle this is the bundle symbolic name.
<code>type</code>	CA	M	String	<code>osgi.bundle</code> <code>osgi.fragment</code> 'unknown' <any>	The type of the resource
<code>version</code>	CA	M	Version	<code>version</code>	The version of the resource
<code>singleton</code>	CD	O	String	'true' 'false'	If this resource is a singleton. The default value is false.
<code>copyright</code>	CA	O	String		A human readable copyright notice as defined for the <code>Bundle-Copyright</code> header.
<code>description</code>	CA	O	String		A human readable description of the resource as defined for the <code>Bundle-Description</code> header.
<code>documentation</code>	CA	O	String	<url>	A URL to where documentation of the resource can be found as defined for the <code>Bundle-DocURL</code> header.
<code>license</code>	CA	O	String	<url>	A URL to the license for this resource. The URL must be the name of the license as defined in the <code>Bundle-License</code> header.
<code>classifier</code>	RD	O	String	<see text>	A name for the relation. Though any name is usable, a number of names are defined in <i>Related Resources</i> on page 176.

Provide-Capability headers in the `osgi.identity` Namespace must not be used in the manifest, Require-Capability with this Namespace is allowed.

8.6.1 Related Resources

A resource can have related resources. For example, a Bundle can have Javadoc, source code, link to a source control management system, etc. It is assumed that these artifacts are also resources. It is therefore necessary that a resource can specify a relation with another resource.

A resource can specify a relation to other resource by declaring an optional requirement to that other resource. Such relation requirements should be placed in another effective time than resolve to not interfere with resolving, for example the effective time meta. The requirements should be in to the osgi.identity namespace and assert:

- `osgi.identity` - The name of the resource.
- `type` - The type of the resource.
- `version` - The version of the resource.

The requirement must then add a directive classifier that defines the related type so that tools like IDEs can find the relations by iteration over all the `osgi.identity` requirements that have a classifier directive. In general, these requirement should be optional and have a cardinality of single.

The following values are defined for the classifier directive:

- `sources` - An archive containing the source code in the same directory layout as this resource.
- `javadoc` - An archive containing the Javadoc in the same directory layout as this resource
- `*` - Any other names

For example, a bundle could contain the following requirement modeling a relation:

```
Require-Capability: «
  osgi.identity; «
    filter:="(&(osgi.identity=org.example.foo-source) (version=1.1))"; «
    effective:=meta; «
    classifier:=sources; «
    resolution:=optional
```

The code to retrieve a related resource could look like:

```
Repository repository = ...;

InputStream getRelated(Resource resource, String classifier)
  throws IOException {
  for ( Requirement r : resource.getRequirements("osgi.identity")) {
    if ( classifier.equals(r.getDirectives().get("classifier"))){
      Collection<Capability> caps =
        repository.findProviders(Collections.singleton(r)).get(r);

      if ( caps==null || caps.isEmpty())
        continue;

      Capability c = caps.iterator().next();
      Resource related = c.getResource();
      return ((RepositoryContent)related).getContent();
    }
  }
  return null;
}
```

8.7 osgi.native Namespace

The `osgi.native` namespace is used to describe the native environment in which the Framework is executing. An OSGi Framework must provide a capability in the `osgi.native` namespace that represents the native environment in which the Framework is executing. For example, the following ca-

pability is provided when running a 64-bit VM on a Windows 7 machine with the language set to en_US:

```
Provide-Capability: «
  osgi.native; «
    osgi.native.osname:List<String>="Windows7,Windows 7,Win7,Win32"; «
    osgi.native.osversion:Version="7.0"; «
    osgi.native.processor:List<String>="x86-64,amd64,em64t,x86_64"; «
    osgi.native.language="en"
```

Provide-Capability headers in the osgi.native namespace must not be used in a bundle's manifest. Bundles can require an osgi.native capability which matches the native environment required for the bundle to function properly, for example:

```
Require-Capability: «
  osgi.native; «
    filter:=" «
      (& «
        (osgi.native.osname-=win32) «
        (osgi.native.processor-=x86-64) «
        (osgi.native.language-=en) «
      )"
```

The osgi.native namespace is not used to specify native code paths packaged within a bundle. The Bundle-NativeCode header is used to specify native code paths. The OSGi Framework converts a Bundle-NativeCode into an osgi.native requirement which describes the native environment required to execute native code packaged within a Bundle (see *Loading Native Code Libraries* on page 76). There is no need for a bundle to specify both a Bundle-NativeCode header and an osgi.native requirement.

Native code included in a Fragment Bundle gets loaded by the class loaders of the Host Bundles the Fragment is attached to, therefore the osgi.native requirement is hosted when it is part of a Fragment. That is, a requirement from this namespace must be treated as part of the Host Bundles the Fragment is attached to.

The osgi.native capability is defined in table Table 8.8 and in the [NativeNamespace](#) class.

Table 8.8 *osgi.native Namespace definition*

Name	Kind	M/O	Type	Syntax	Description
osgi.native.osname	CA	M	List <String>	osname (';' osname)*	A comma separated list of canonical os name aliases to the org.osgi.framework.os.name launching property value (See Table 4.3 and [11] <i>OSGi Reference Names</i>). For example, an org.osgi.framework.os.name value of Windows95 will get a List<String> value of Windows95,Windows 95,Win95,Win32
osgi.native.osversion	CA	M	Version	version	A Version as parsed from the value of the org.osgi.framework.os.version launching property
osgi.native.processor	CA	M	List <String>	processor (';' processor)*	A comma separated list of canonical processor aliases to the org.osgi.framework.processor launching property value (See Table 4.2 and [11] <i>OSGi Reference Names</i>). For example, an org.osgi.framework.processor value of x86 will get a List<String> value of x86,pentium,i386,i486,i586,i686

Name	Kind	M/O	Type	Syntax	Description
osgi.native.language	CA	M	String		The value of the <code>org.osgi.framework.language</code> launching property

In addition to the attributes defined in Table 8.8 an OSGi Framework must populate the `osgi.native` capability attributes with the values included in the Framework launching properties (see *Launching Properties* on page 102). Launching property keys that start with `osgi.native.` are excluded to prevent collisions with the defined capability attribute keys.

8.8 References

- [1] *Specification References*
<https://www.osgi.org/developer/specifications/reference/>

8.9 Changes

- Added `osgi.ee` capability names for Java SE Embedded compact profiles in *osgi.ee Namespace* on page 172.
- Updated `osgi.ee` description to indicate that bundles should import the `java.*` packages they require to ensure the runtime provides them.

9 Start Level API Specification

Version 1.0

9.1 Introduction

This specification describes how to enable a management agent to control the relative starting and stopping order of bundles in an OSGi framework.

The management agent can set the start levels for bundles and set the active start level of the Framework, which will start and stop the appropriate bundles. Only bundles that have a start level less or equal to this active start level must be active. The purpose of the Start Level API is to allow the management agent to control, in detail, what bundles will be started and stopped and when this occurs.

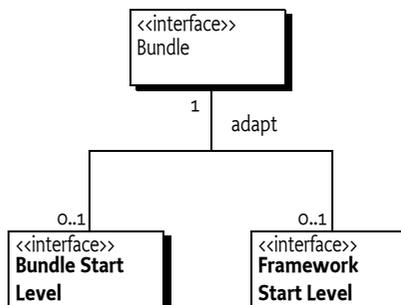
9.1.1 Essentials

- *Ordering* - A management agent should be able to order the startup and shutdown sequences of bundles.
- *Levels* - The management agent should support a virtually unlimited number of levels.

9.1.2 Entities

- *Bundle Start Level* - The adapter on a bundle that is used by a management agent to order the start-up and shutdown sequences of bundles.
- *Framework Start Level* - The adapter that is used to set the framework start levels.
- *Management Agent* - A bundle that is provided by the Operator to implement an Operator specific policy.
- *Framework Event* - See *Events* on page 127.
- *Framework Listener* - See *Listeners* on page 127.

Figure 9.1 Class Diagram `org.osgi.framework.startlevel` package



9.2 Start Level API

The Start Level API provides the following functions:

- Controls the beginning start level of the OSGi Framework.

- Is used to modify the active start level of the Framework.
- Can be used to assign a specific start level to a bundle.
- Can set the initial start level for newly installed bundles.

Defining the order in which bundles are started and stopped is useful for the following:

- *Safe mode* - The management agent can implement a *safe mode*. In this mode, only fully trusted bundles are started. Safe mode might be necessary when a bundle causes a failure at startup that disrupts normal operation and prevents correction of the problem.
- *Splash screen* - If the total startup time is long, it might be desirable to show a splash screen during initialization. This improves the user's perception of the boot time of the device. The startup ordering can ensure that the right bundle is started first.
- *Handling erratic bundles* - Problems can occur because bundles require services to be available when they are activated (this is a programming error). By controlling the start order, the management agent can prevent these problems.
- *High priority bundles* - Certain tasks such as metering need to run as quickly as possible and cannot have a long startup delay. These bundles can be started first.

Start levels are not intended to be used for ensuring that dependencies are met when a bundle is started. Any of the life cycle actions (install/update/uninstall) can cause a dependency to become unavailable regardless of start levels.

9.2.1 Adaptations

This specification provides two adaptations of a Bundle object to a:

- `BundleStartLevel` - Used to get and set the start level on a specific bundle.
- `FrameworkStartLevel` - Used to get and control the framework start level. This adaptation must return null for any other bundle than the system bundle (bundle 0).

9.2.2 Bundle Start Level Bundle Adaptation

The adaptation provides the following methods:

- `setStartLevel(int)` - Sets the current start level for the adapted bundle.
- `getStartLevel()` - Gets the current start level for the adapted bundle.
- `isActivationPolicyUsed()` - Answer if the activation policy is used.
- `isPersistentlyStarted()` - Answer if this bundle as persistently started.

9.2.3 Framework Start Level Bundle Adaptation

The Framework Start Level adaptation is only possible for the system bundle. Other bundles must return null for this adaptation. The adaptation provides the following methods:

- `getInitialBundleStartLevel()` - Return the start level to assign for newly installed bundles.
- `setInitialBundleStartLevel(int)` - Set the initial start level.
- `getStartLevel()` - Get the current framework start level.
- `setStartLevel(int,FrameworkListener...)` - Set the current framework start level and provide an optional callback Framework Listener. This listener is called back when the set start level has been reached.

9.3 The Concept of a Start Level

A *start level* is defined as a non-negative integer. A start level of 0 (zero) is the state in which the Framework has either not been launched or has completed shutdown (these two states are consid-

ered equivalent). In this state, no bundles are running. Progressively higher integral values represent progressively higher start levels. For example, 2 is a higher start level than 1. The Framework must support all positive int values (`Integer.MAX_VALUE`) for start levels.

The Framework has an *active start level* that is used to decide which bundles can be started. All bundles must be assigned a *bundle start level*. This is the minimum start level to start a bundle. The bundle start level can be set with the `setStartLevel(int)` method on the `BundleStartLevel` object. When a bundle is installed, it is initially assigned the bundle start level returned by `getInitialBundleStartLevel()` on a `FrameworkStartLevel` object. The initial bundle start level to be used when bundles are installed can be set with `setInitialBundleStartLevel(int)`.

In addition, a bundle can be persistently marked as *started* or *stopped* with the `Bundle` start and stop methods. A bundle cannot run unless it is marked started, regardless of the bundle's start level.

9.3.1 Changing the Active Start Level

A management agent can influence the active start level with the `setStartLevel(int)` method. The Framework must then increase or decrease the active start level by 1 until the requested start level is reached. The process of starting or stopping bundles, which is initiated by the `setStartLevel(int)` method, must take place asynchronously.

This means that the *active start level* (the one that is active at a certain moment in time) must be changed to a new start level, called the *requested start level*. The active and requested levels differ during a certain period when the Framework starts and stops the appropriate bundles. Moving from the active start level to the requested start level must take place in increments of one (1).

If the requested start level is higher than the active start level, the Framework must increase the start level by one and then start all bundles that meet the following criteria:

- Bundles that are persistently marked started, and
- Bundles that have a bundle start level equal to the new active start level.

The Framework continues increasing the active start level and starting the appropriate bundles until it has started all bundles with a bundle start level that equals the requested start level.

The Framework must not increase to the next active start level until all started bundles have returned from their `BundleActivator.start` method normally or with an exception. A `FrameworkEvent.ERROR` must be broadcast when the `BundleActivator.start` method throws an exception.

If the requested start level is lower than the active start level, the Framework must stop all bundles that have a bundle start level that is equal to the active start level. The Framework must then decrease the active start level by 1. If the active start level is still higher than the requested start level, it should continue stopping the appropriate bundles and decreasing the active start level until the requested start level is reached. A `FrameworkEvent.ERROR` must be broadcast when the `BundleActivator.stop` method throws an exception.

If the requested start level is the active start level, the Framework will not start or stop any bundles.

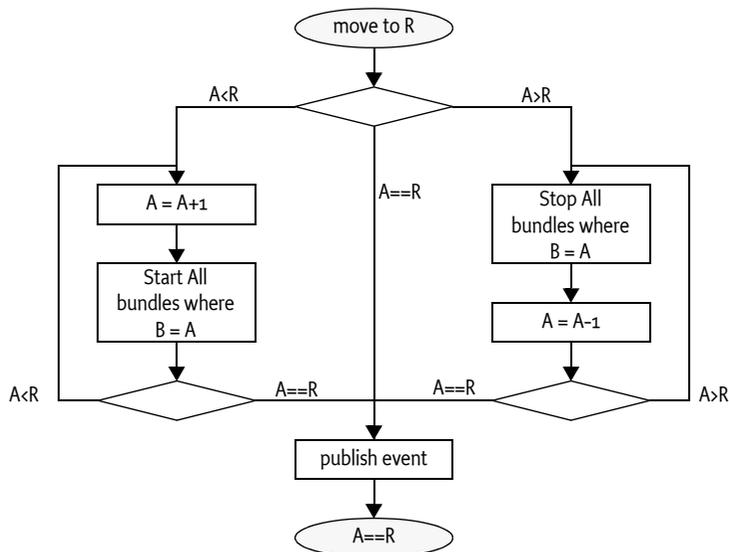
When the requested start level is reached and all bundles satisfy the condition that their bundle start level \leq active start level in order to be started, then the `FrameworkEvent.STARTLEVEL_CHANGED` event must be sent to all registered `FrameworkListener` objects. If the requested start level and active start level are equal, then this event may arrive before the `setStartLevel` method has returned.

It must therefore always be true that:

- A bundle is started, or will be started soon, if the start level is less or equal to the active start level.
- A bundle is stopped, or will be stopped soon, when it has a start level more than the active start level.

These steps are depicted in the flow chart in Figure 9.2.

Figure 9.2 Move to requested start level R , active level is A , B is a bundle's start level



If the Framework is currently involved in changing the active start level, it must first reach the previously requested start level before it is allowed to continue with a newly requested start level. For example, assume the active start level is 5 and the Framework is requested to transition to start level 3. Before start level 3 is reached, another request is made to transition to start level 7. In this case, the OSGi Framework must first complete the transition to start level 3 before it transitions to start level 7.

9.3.2 Startup Sequence

At startup, the Framework must have an active start level of zero. It must then move the active start level to the *beginning start level*. The beginning start level is specified with an argument when starting the Framework or through some other means, which is left undefined here. If no beginning start level is given, the Framework must assume a beginning start level of one (1).

The Framework must launch and then set the requested start level to the beginning start level. It must then follow the procedure described in *Changing the Active Start Level* on page 183 to make the active start level equal the beginning start level, with the exception of the `FrameworkEvent.START_LEVEL_CHANGED` event broadcast. During launching, the Framework must broadcast a `FrameworkEvent.STARTED` event when the beginning start level is reached.

9.3.3 Shutdown Sequence

When the Framework shuts down, the requested start level must be set to zero. The Framework must then follow the process described in *Changing the Active Start Level* on page 183 to make the active start level equal to zero.

9.3.4 Changing a Bundle's Start Level

Bundles are assigned an initial start level when they are installed. The default value for the initial start level is set to one, but can be changed with the `setInitialBundleStartLevel(int)` method on the `FrameworkStartLevel` object. A bundle's start level will not change when the `setInitialBundleStartLevel(int)` method later modifies the default initial start level.

Once installed, the start level of a bundle can be changed with `setStartLevel(int)`. When a bundle's start level is changed and the bundle is marked persistently to be started, then the OSGi Framework

must compare the new bundle start level to the active start level. For example, assume that the active start level is 5 and a bundle with start level 5 is started. If the bundle's start level subsequently is changed to 6 then this bundle must be stopped by the OSGi Framework but it must still be marked persistently to be started.

9.3.5 Starting a Bundle

If a bundle is started by calling the `Bundle.start` method, then the OSGi Framework must mark the bundle as persistently started. The OSGi Framework must not actually start a bundle when the active start level is less than the bundle's start level. In that case, the state must not change.

9.3.6 Exceptions in the Bundle Activator

If the `BundleActivator.start` or `stop` method throws an `Exception`, then the handling of this `Exception` is different depending who invoked the start or stop method.

If the bundle is started/stopped due to a change in the active start level or the bundle's start level, then the `Exception` must be wrapped in a `BundleException` and broadcast as a `FrameworkEvent.ERROR` event. Otherwise, a new `BundleException` must be created containing the exception and this `BundleException` is then thrown to the caller.

9.3.7 System Bundle

The System Bundle is defined to have a start level of zero. The start level of the System Bundle cannot be changed.

9.4 Example Applications

The Start Level API allows a management agent to implement many different startup schemes. The following sections show some examples.

9.4.1 Safe Mode Startup Scheme

A management agent can implement a *safe mode* in which it runs trusted bundles at level 1 and runs itself on level 2. When the management agent gets control, it constructs a list of all applications to be started. This list can be constructed from `BundleContext.getBundles()`. The management agent checks each bundle to determine if it is not started but is marked to be started persistently by calling the `isPersistentlyStarted()` method of the Start Level API.

Before it starts each bundle, the management agent persistently records the bundle to be started and then starts the bundle. This continues until all bundles are started. When all bundles are successfully started, the management agent persistently records that all bundles started without problems.

If the OSGi framework is restarted, the management agent should inspect the persistently recorded information. If the persistently recorded information indicates a bundle failure, the management agent should try to restart the system without that application bundle since that bundle failed. Alternatively, it could contact its Remote Manager and ask for assistance.

9.4.2 Splash Screen Startup Scheme

A splash screen is a popup containing startup information about an application. The popup provides feedback to the end user indicating that the system is still initializing. The Start Level API can be used by a bundle to pop-up a splash screen before any other bundle is started, and remove it once all bundles have been started. The splash-screen bundle would start at start level 1 and all other bundles would start at start level 2 or higher.

```
class SplashScreen implements
    BundleActivator, FrameworkListener {
```

```
    Screen    screen;
    public void start(BundleContext context) {
        context.addFrameworkListener( this );
        screen = createSplash();
        screen.open();
    }
    public void stop(BundleContext context) {
        screen.close();
    }
    public void frameworkEvent( FrameworkEvent event ) {
        if ( event.getType() == FrameworkEvent.STARTED )
            screen.close();
    }
    Screen createSplash() { ... }
}
```

9.5 Security

The Start Level API requires Adapt Permission with action ADAPT for the following type:

- org.osgi.framework.startlevel.BundleStartLevel
- org.osgi.framework.startlevel.FrameworkStartLevel

The Start Level methods that mutate state require an additional Admin Permission with the action:

- EXECUTE - For bundles that must be able to modify a bundle's start level
- STARTLEVEL - For modifying the Framework's active start level.

10 Framework API

10.1 org.osgi.framework

Framework Package Version 1.9.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.framework; version="[1.9,2.0]"
```

10.1.1 Summary

- `AdaptPermission` - A bundle's authority to adapt an object to a type.
- `AdminPermission` - A bundle's authority to perform specific privileged administrative operations on or to get sensitive information about a bundle.
- `AllServiceListener` - A `ServiceEvent` listener that does not filter based upon package wiring.
- `Bundle` - An installed bundle in the Framework.
- `BundleActivator` - Customizes the starting and stopping of a bundle.
- `BundleContext` - A bundle's execution context within the Framework.
- `BundleEvent` - An event from the Framework describing a bundle lifecycle change.
- `BundleException` - A Framework exception used to indicate that a bundle lifecycle problem occurred.
- `BundleListener` - A `BundleEvent` listener.
- `BundlePermission` - A bundle's authority to require or provide a bundle or to receive or attach fragments.
- `BundleReference` - A reference to a `Bundle`.
- `CapabilityPermission` - A bundle's authority to provide or require a capability.
- `Configurable` - Supports a configuration object.
- `Constants` - Defines standard names for the OSGi environment system properties, service properties, and Manifest header attribute keys.
- `Filter` - An RFC 1960 [<http://www.ietf.org/rfc/rfc1960.txt>]-based Filter.
- `FrameworkEvent` - A general event from the Framework.
- `FrameworkListener` - A `FrameworkEvent` listener.
- `FrameworkUtil` - Framework Utility class.
- `InvalidSyntaxException` - A Framework exception used to indicate that a filter string has an invalid syntax.
- `PackagePermission` - A bundle's authority to import or export a package.
- `PrototypeServiceFactory` - A factory for prototype scope services.
- `ServiceEvent` - An event from the Framework describing a service lifecycle change.
- `ServiceException` - A service exception used to indicate that a service problem occurred.
- `ServiceFactory` - A factory for bundle scope services.
- `ServiceListener` - A `ServiceEvent` listener.
- `ServiceObjects` - Allows multiple service objects for a service to be obtained.
- `ServicePermission` - A bundle's authority to register or get a service.

- `ServiceReference` - A reference to a service.
- `ServiceRegistration` - A registered service.
- `SynchronousBundleListener` - A synchronous `BundleEvent` listener.
- `UnfilteredServiceListener` - A `ServiceEvent` listener that does *not* filter based upon any filter string specified to `BundleContext.addServiceListener(ServiceListener, String)`.
- `Version` - Version identifier for capabilities such as bundles and packages.
- `VersionRange` - Version range.

10.1.2 **public final class AdaptPermission extends BasicPermission**

A bundle's authority to adapt an object to a type.

`AdaptPermission` has one action: `adapt`.

Concurrency Thread-safe

10.1.2.1 **public static final String ADAPT = "adapt"**

The action string initiate.

10.1.2.2 **public AdaptPermission(String filter, String actions)**

filter A filter expression. Filter attribute names are processed in a case sensitive manner. A special value of "*" can be used to match all adaptations.

actions `adapt`.

- Creates a new granted `AdaptPermission` object. This constructor must only be used to create a permission that is going to be checked.

Examples:

```
(adaptClass=com.acme.*)
(&(signer=\*,o=ACME,c=US)(adaptClass=com.acme.*))
(signer=\*,o=ACME,c=US)
```

When a signer key is used within the filter expression the signer value must escape the special filter chars ('*', '(', ')').

The name is specified as a filter expression. The filter gives access to the following attributes:

- `signer` - A Distinguished Name chain used to sign the exporting bundle. Wildcards in a DN are not matched according to the filter string rules, but according to the rules defined for a DN chain.
- `location` - The location of the exporting bundle.
- `id` - The bundle ID of the exporting bundle.
- `name` - The symbolic name of the exporting bundle.
- `adaptClass` - The name of the type to which an object can be adapted.

Filter attribute names are processed in a case sensitive manner.

Throws `IllegalArgumentException`— If the filter has an invalid syntax.

10.1.2.3 **public AdaptPermission(String adaptClass, Bundle adaptableBundle, String actions)**

adaptClass The name of the type to which an object can be adapted.

adaptableBundle The bundle associated with the object being adapted.

actions `adapt`.

- Creates a new requested `AdaptPermission` object to be used by the code that must perform `checkPermission`. `AdaptPermission` objects created with this constructor cannot be added to an `AdaptPermission` permission collection.

10.1.2.4 **public boolean equals(Object obj)**

obj The object to test for equality with this `AdaptPermission` object.

- Determines the equality of two `AdaptPermission` objects. This method checks that specified permission has the same name and `AdaptPermission` actions as this `AdaptPermission` object.

Returns true if *obj* is a `AdaptPermission`, and has the same name and actions as this `AdaptPermission` object; false otherwise.

10.1.2.5 **public String getActions()**

- Returns the canonical string representation of the `AdaptPermission` actions. Always returns present `AdaptPermission` actions in the following order: `adapt`.

Returns Canonical string representation of the `AdaptPermission` actions.

10.1.2.6 **public int hashCode()**

- Returns the hash code value for this object.

Returns A hash code value for this object.

10.1.2.7 **public boolean implies(Permission p)**

p The requested permission.

- Determines if the specified permission is implied by this object.

This method checks that the filter of the target is implied by the `adapt` class name of this object. The list of `AdaptPermission` actions must either match or allow for the list of the target object to imply the target `AdaptPermission` action.

Returns true if the specified permission is implied by this object; false otherwise.

10.1.2.8 **public PermissionCollection newPermissionCollection()**

- Returns a new `PermissionCollection` object suitable for storing `AdaptPermission` objects.

Returns A new `PermissionCollection` object.

10.1.3 **public final class AdminPermission extends BasicPermission**

A bundle's authority to perform specific privileged administrative operations on or to get sensitive information about a bundle. The actions for this permission are:

Action	Methods
class	<code>Bundle.loadClass</code>
execute	<code>Bundle.start</code> <code>Bundle.stop</code> <code>BundleStartLevel.setStartLevel</code>
extensionLifecycle	<code>BundleContext.installBundle</code> for extension bundles <code>Bundle.update</code> for extension bundles <code>Bundle.uninstall</code> for extension bundles
lifecycle	<code>BundleContext.installBundle</code>

	Bundle.update
	Bundle.uninstall
listener	BundleContext.addBundleListener for SynchronousBundleListener BundleContext.removeBundleListener for SynchronousBundleListener
metadata	Bundle.getHeaders Bundle.getLocation
resolve	FrameworkWiring.refreshBundles FrameworkWiring.resolveBundles
resource	Bundle.getResource Bundle.getResources Bundle.getEntry Bundle.getEntryPaths Bundle.findEntries Bundle resource/entry URL creation
startlevel	FrameworkStartLevel.setStartLevel FrameworkStartLevel.setInitialBundleStartLevel
context	Bundle.getBundleContext
weave	WovenClass.getBytes WovenClass.setBytes WovenClass.getDynamicImports for modification

The special action "*" will represent all actions. The resolve action is implied by the class, execute and resource actions.

The name of this permission is a filter expression. The filter gives access to the following attributes:

- signer - A Distinguished Name chain used to sign a bundle. Wildcards in a DN are not matched according to the filter string rules, but according to the rules defined for a DN chain.
- location - The location of a bundle.
- id - The bundle ID of the designated bundle.
- name - The symbolic name of a bundle.

Filter attribute names are processed in a case sensitive manner.

Concurrency Thread-safe

10.1.3.1 **public static final String CLASS = "class"**

The action string class. The class action implies the resolve action.

Since 1.3

10.1.3.2 **public static final String CONTEXT = "context"**

The action string context.

Since 1.4

10.1.3.3 **public static final String EXECUTE = "execute"**

The action string execute. The execute action implies the resolve action.

Since 1.3

10.1.3.4 **public static final String EXTENSIONLIFECYCLE = "extensionLifecycle"**

The action string extensionLifecycle.

Since 1.3

10.1.3.5 public static final String LIFECYCLE = "lifecycle"

The action string lifecycle.

Since 1.3

10.1.3.6 public static final String LISTENER = "listener"

The action string listener.

Since 1.3

10.1.3.7 public static final String METADATA = "metadata"

The action string metadata.

Since 1.3

10.1.3.8 public static final String RESOLVE = "resolve"

The action string resolve. The resolve action is implied by the class, execute and resource actions.

Since 1.3

10.1.3.9 public static final String RESOURCE = "resource"

The action string resource. The resource action implies the resolve action.

Since 1.3

10.1.3.10 public static final String STARTLEVEL = "startlevel"

The action string startlevel.

Since 1.3

10.1.3.11 public static final String WEAVE = "weave"

The action string weave.

Since 1.6

10.1.3.12 public AdminPermission()

- Creates a new AdminPermission object that matches all bundles and has all actions. Equivalent to AdminPermission("*", "*");

10.1.3.13 public AdminPermission(String filter, String actions)

filter A filter expression that can use signer, location, id, and name keys. A value of "*" or null matches all bundle. Filter attribute names are processed in a case sensitive manner.

actions class, execute, extensionLifecycle, lifecycle, listener, metadata, resolve, resource, startlevel, context or weave. A value of "*" or null indicates all actions.

- Create a new AdminPermission. This constructor must only be used to create a permission that is going to be checked.

Examples:

```
(signer=\*, o=ACME, c=US)
(&(signer=\*, o=ACME, c=US) (name=com. acme. *)
 (location=http://www. acme. com/bundles/*)
 (id>=1)
```

When a signer key is used within the filter expression the signer value must escape the special filter chars ('*', '(', ')').

Null arguments are equivalent to "*".

Throws `IllegalArgumentException`– If the filter has an invalid syntax.

10.1.3.14 **public AdminPermission(Bundle bundle, String actions)**

bundle A bundle.

actions class, execute, extensionLifecycle, lifecycle, listener, metadata, resolve, resource, startlevel, context, weave. A value of "*" or null indicates all actions.

- Creates a new requested AdminPermission object to be used by the code that must perform check-Permission. AdminPermission objects created with this constructor cannot be added to an AdminPermission permission collection.

Since 1.3

10.1.3.15 **public boolean equals(Object obj)**

obj The object being compared for equality with this object.

- Determines the equality of two AdminPermission objects.

Returns true if obj is equivalent to this AdminPermission; false otherwise.

10.1.3.16 **public String getActions()**

- Returns the canonical string representation of the AdminPermission actions.

Always returns present AdminPermission actions in the following order: class, execute, extensionLifecycle, lifecycle, listener, metadata, resolve, resource, startlevel, context, weave.

Returns Canonical string representation of the AdminPermission actions.

10.1.3.17 **public int hashCode()**

- Returns the hash code value for this object.

Returns Hash code value for this object.

10.1.3.18 **public boolean implies(Permission p)**

p The requested permission.

- Determines if the specified permission is implied by this object. This method throws an exception if the specified permission was not constructed with a bundle.

This method returns true if the specified permission is an AdminPermission AND

- this object's filter matches the specified permission's bundle ID, bundle symbolic name, bundle location and bundle signer distinguished name chain OR
- this object's filter is "*"

AND this object's actions include all of the specified permission's actions.

Special case: if the specified permission was constructed with "*" filter, then this method returns true if this object's filter is "*" and this object's actions include all of the specified permission's actions

Returns true if the specified permission is implied by this object; false otherwise.

10.1.3.19 **public PermissionCollection newPermissionCollection()**

- Returns a new PermissionCollection object suitable for storing AdminPermissions.

Returns A new PermissionCollection object.

10.1.4 **public interface AllServiceListener** **extends ServiceListener**

A ServiceEvent listener that does not filter based upon package wiring. AllServiceListener is a listener interface that may be implemented by a bundle developer. When a ServiceEvent is fired, it is synchronously delivered to an AllServiceListener. The Framework may deliver ServiceEvent objects to an AllServiceListener out of order and may concurrently call and/or reenter an AllServiceListener.

An AllServiceListener object is registered with the Framework using the BundleContext.addServiceListener method. AllServiceListener objects are called with a ServiceEvent object when a service is registered, modified, or is in the process of unregistering.

ServiceEvent object delivery to AllServiceListener objects is filtered by the filter specified when the listener was registered. If the Java Runtime Environment supports permissions, then additional filtering is done. ServiceEvent objects are only delivered to the listener if the bundle which defines the listener object's class has the appropriate ServicePermission to get the service using at least one of the named classes under which the service was registered.

Unlike normal ServiceListener objects, AllServiceListener objects receive all ServiceEvent objects regardless of whether the package source of the listening bundle is equal to the package source of the bundle that registered the service. This means that the listener may not be able to cast the service object to any of its corresponding service interfaces if the service object is retrieved.

See Also ServiceEvent, ServicePermission

Since 1.3

Concurrency Thread-safe

10.1.5 **public interface Bundle** **extends Comparable<Bundle>**

An installed bundle in the Framework.

A Bundle object is the access point to define the lifecycle of an installed bundle. Each bundle installed in the OSGi environment must have an associated Bundle object.

A bundle must have a unique identity, a long, chosen by the Framework. This identity must not change during the lifecycle of a bundle, even when the bundle is updated. Uninstalling and then re-installing the bundle must create a new unique identity.

A bundle can be in one of six states:

- UNINSTALLED
- INSTALLED
- RESOLVED
- STARTING
- STOPPING
- ACTIVE

Values assigned to these states have no specified ordering; they represent bit values that may be ORed together to determine if a bundle is in one of the valid states.

A bundle should only have active threads of execution when its state is one of STARTING, ACTIVE, or STOPPING. An UNINSTALLED bundle can not be set to another state; it is a zombie and can only be reached because references are kept somewhere.

The Framework is the only entity that is allowed to create Bundle objects, and these objects are only valid within the Framework that created them.

Bundles have a natural ordering such that if two Bundles have the same bundle id they are equal. A Bundle is less than another Bundle if it has a lower bundle id and is greater if it has a higher bundle id.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.1.5.1 **public static final int ACTIVE = 32**

The bundle is now running.

A bundle is in the ACTIVE state when it has been successfully started and activated.

The value of ACTIVE is 0x00000020.

10.1.5.2 **public static final int INSTALLED = 2**

The bundle is installed but not yet resolved.

A bundle is in the INSTALLED state when it has been installed in the Framework but is not or cannot be resolved.

This state is visible if the bundle's code dependencies are not resolved. The Framework may attempt to resolve an INSTALLED bundle's code dependencies and move the bundle to the RESOLVED state.

The value of INSTALLED is 0x00000002.

10.1.5.3 **public static final int RESOLVED = 4**

The bundle is resolved and is able to be started.

A bundle is in the RESOLVED state when the Framework has successfully resolved the bundle's code dependencies. These dependencies include:

- The bundle's class path from its Constants.BUNDLE_CLASSPATH Manifest header.
- The bundle's package dependencies from its Constants.EXPORT_PACKAGE and Constants.IMPORT_PACKAGE Manifest headers.
- The bundle's required bundle dependencies from its Constants.REQUIRE_BUNDLE Manifest header.
- A fragment bundle's host dependency from its Constants.FRAGMENT_HOST Manifest header.

Note that the bundle is not active yet. A bundle must be put in the RESOLVED state before it can be started. The Framework may attempt to resolve a bundle at any time.

The value of RESOLVED is 0x00000004.

10.1.5.4 **public static final int SIGNERS_ALL = 1**

Request that all certificates used to sign the bundle be returned.

See Also getSignerCertificates(int)

Since 1.5

10.1.5.5 **public static final int SIGNERS_TRUSTED = 2**

Request that only certificates used to sign the bundle that are trusted by the framework be returned.

See Also getSignerCertificates(int)

Since 1.5

10.1.5.6 **public static final int START_ACTIVATION_POLICY = 2**

The bundle start operation must activate the bundle according to the bundle's declared activation policy.

This bit may be set when calling `start(int)` to notify the framework that the bundle must be activated using the bundle's declared activation policy.

See Also `Constants.BUNDLE_ACTIVATIONPOLICY`, `start(int)`

Since 1.4

10.1.5.7 **public static final int START_TRANSIENT = 1**

The bundle start operation is transient and the persistent autostart setting of the bundle is not modified.

This bit may be set when calling `start(int)` to notify the framework that the autostart setting of the bundle must not be modified. If this bit is not set, then the autostart setting of the bundle is modified.

See Also `start(int)`

Since 1.4

10.1.5.8 **public static final int STARTING = 8**

The bundle is in the process of starting.

A bundle is in the `STARTING` state when its start method is active. A bundle must be in this state when the bundle's `BundleActivator.start(BundleContext)` is called. If the `BundleActivator.start` method completes without exception, then the bundle has successfully started and must move to the `ACTIVE` state.

If the bundle has a lazy activation policy, then the bundle may remain in this state for some time until the activation is triggered.

The value of `STARTING` is `0x00000008`.

10.1.5.9 **public static final int STOP_TRANSIENT = 1**

The bundle stop is transient and the persistent autostart setting of the bundle is not modified.

This bit may be set when calling `stop(int)` to notify the framework that the autostart setting of the bundle must not be modified. If this bit is not set, then the autostart setting of the bundle is modified.

See Also `stop(int)`

Since 1.4

10.1.5.10 **public static final int STOPPING = 16**

The bundle is in the process of stopping.

A bundle is in the `STOPPING` state when its stop method is active. A bundle must be in this state when the bundle's `BundleActivator.stop(BundleContext)` method is called. When the `BundleActivator.stop` method completes the bundle is stopped and must move to the `RESOLVED` state.

The value of `STOPPING` is `0x00000010`.

10.1.5.11 **public static final int UNINSTALLED = 1**

The bundle is uninstalled and may not be used.

The `UNINSTALLED` state is only visible after a bundle is uninstalled; the bundle is in an unusable state but references to the `Bundle` object may still be available and used for introspection.

The value of `UNINSTALLED` is `0x00000001`.

10.1.5.12 public A adapt(Class<A> type)*Type Parameters* <A>

<A> The type to which this bundle is to be adapted.

type Class object for the type to which this bundle is to be adapted.

- Adapt this bundle to the specified type.

Adapting this bundle to the specified type may require certain checks, including security checks, to succeed. If a check does not succeed, then this bundle cannot be adapted and null is returned.

Returns The object, of the specified type, to which this bundle has been adapted or null if this bundle cannot be adapted to the specified type.

Throws SecurityException– If the caller does not have the appropriate AdaptPermission[type,this,ADAPT], and the Java Runtime Environment supports permissions.

Since 1.6

10.1.5.13 public Enumeration<URL> findEntries(String path, String filePattern, boolean recurse)

path The path name in which to look. The path is always relative to the root of this bundle and may begin with "/". A path value of "/" indicates the root of this bundle.

filePattern The file name pattern for selecting entries in the specified path. The pattern is only matched against the last element of the entry path. If the entry is a directory then the trailing "/" is not used for pattern matching. Substring matching is supported, as specified in the Filter specification, using the wildcard character ("*"). If null is specified, this is equivalent to "*" and matches all files.

recurse If true, recurse into subdirectories. Otherwise only return entries from the specified path.

- Returns entries in this bundle and its attached fragments. This bundle's class loader is not used to search for entries. Only the contents of this bundle and its attached fragments are searched for the specified entries. If this bundle's state is INSTALLED, this method must attempt to resolve this bundle before attempting to find entries.

This method is intended to be used to obtain configuration, setup, localization and other information from this bundle. This method takes into account that the "contents" of this bundle can be extended with fragments. This "bundle space" is not a namespace with unique members; the same entry name can be present multiple times. This method therefore returns an enumeration of URL objects. These URLs can come from different JARs but have the same path name. This method can either return only entries in the specified path or recurse into subdirectories returning entries in the directory tree beginning at the specified path. Fragments can be attached after this bundle is resolved, possibly changing the set of URLs returned by this method. If this bundle is not resolved, only the entries in the JAR file of this bundle are returned.

Examples:

```
// List all XML files in the OSGI-INF directory and below
Enumeration e = b.findEntries("OSGI-INF", "*.xml", true);
```

```
// Find a specific localization file
Enumeration e = b.findEntries("OSGI-INF/l10n",
    "bundle_nl_DU.properties", false);
if (e.hasMoreElements())
    return (URL) e.nextElement();
```

URLs for directory entries must have their path end with "/".

Note: Jar and zip files are not required to include directory entries. URLs to directory entries will not be returned if the bundle contents do not contain directory entries.

Returns An enumeration of URL objects for each matching entry, or null if no matching entry could be found or if the caller does not have the appropriate `AdminPermission[this,RESOURCE]`, and the Java Runtime Environment supports permissions. The URLs are sorted such that entries from this bundle are returned first followed by the entries from attached fragments in attachment order. If this bundle is a fragment, then only matching entries in this fragment are returned.

Throws `IllegalStateException`– If this bundle has been uninstalled.

Since 1.3

10.1.5.14 **public BundleContext getBundleContext()**

- Returns this bundle's `BundleContext`. The returned `BundleContext` can be used by the caller to act on behalf of this bundle.

If this bundle is not in the `STARTING`, `ACTIVE`, or `STOPPING` states or this bundle is a fragment bundle, then this bundle has no valid `BundleContext`. This method will return null if this bundle has no valid `BundleContext`.

Returns A `BundleContext` for this bundle or null if this bundle has no valid `BundleContext`.

Throws `SecurityException`– If the caller does not have the appropriate `AdminPermission[this,CONTEXT]`, and the Java Runtime Environment supports permissions.

Since 1.4

10.1.5.15 **public long getBundleId()**

- Returns this bundle's unique identifier. This bundle is assigned a unique identifier by the Framework when it was installed in the OSGi environment.

A bundle's unique identifier has the following attributes:

- Is unique and persistent.
- Is a long.
- Its value is not reused for another bundle, even after a bundle is uninstalled.
- Does not change while a bundle remains installed.
- Does not change when a bundle is updated.

This method must continue to return this bundle's unique identifier while this bundle is in the `UNINSTALLED` state.

Returns The unique identifier of this bundle.

10.1.5.16 **public File getDataFile(String filename)**

filename A relative name to the file to be accessed.

- Creates a `File` object for a file in the persistent storage area provided for this bundle by the Framework. This method will return null if the platform does not have file system support or this bundle is a fragment bundle.

A `File` object for the base directory of the persistent storage area provided for this bundle by the Framework can be obtained by calling this method with an empty string as `filename`.

If the Java Runtime Environment supports permissions, the Framework will ensure that this bundle has the `java.io.FilePermission` with actions `read`, `write`, `delete` for all files (recursively) in the persistent storage area provided for this bundle.

Returns A `File` object that represents the requested file or null if the platform does not have file system support or this bundle is a fragment bundle.

Throws `IllegalStateException`– If this bundle has been uninstalled.

Since 1.6

10.1.5.17 public URL getEntry(String path)

path The path name of the entry.

- Returns a URL to the entry at the specified path in this bundle. This bundle's class loader is not used to search for the entry. Only the contents of this bundle are searched for the entry.

The specified path is always relative to the root of this bundle and may begin with "/". A path value of "/" indicates the root of this bundle.

Note: Jar and zip files are not required to include directory entries. URLs to directory entries will not be returned if the bundle contents do not contain directory entries.

Returns A URL to the entry, or null if no entry could be found or if the caller does not have the appropriate AdminPermission[this,RESOURCE] and the Java Runtime Environment supports permissions.

Throws IllegalStateException– If this bundle has been uninstalled.

Since 1.3

10.1.5.18 public Enumeration<String> getEntryPaths(String path)

path The path name for which to return entry paths.

- Returns an Enumeration of all the paths (String objects) to entries within this bundle whose longest sub-path matches the specified path. This bundle's class loader is not used to search for entries. Only the contents of this bundle are searched.

The specified path is always relative to the root of this bundle and may begin with a "/". A path value of "/" indicates the root of this bundle.

Returned paths indicating subdirectory paths end with a "/". The returned paths are all relative to the root of this bundle and must not begin with "/".

Note: Jar and zip files are not required to include directory entries. Paths to directory entries will not be returned if the bundle contents do not contain directory entries.

Returns An Enumeration of the entry paths (String objects) or null if no entry could be found or if the caller does not have the appropriate AdminPermission[this,RESOURCE] and the Java Runtime Environment supports permissions.

Throws IllegalStateException– If this bundle has been uninstalled.

Since 1.3

10.1.5.19 public Dictionary<String, String> getHeaders()

- Returns this bundle's Manifest headers and values. This method returns all the Manifest headers and values from the main section of this bundle's Manifest file; that is, all lines prior to the first blank line.

Manifest header names are case-insensitive. The methods of the returned Dictionary object must operate on header names in a case-insensitive manner. If a Manifest header value starts with "%", it must be localized according to the default locale. If no localization is found for a header value, the header value without the leading "%" is returned.

For example, the following Manifest headers and values are included if they are present in the Manifest file:

```
Bundle-Name
Bundle-Vendor
Bundle-Version
Bundle-Description
Bundle-DocURL
Bundle-ContactAddress
```

This method must continue to return Manifest header information while this bundle is in the UNINSTALLED state.

Returns An unmodifiable Dictionary object containing this bundle's Manifest headers and values.

Throws SecurityException— If the caller does not have the appropriate AdminPermission[this,METADATA], and the Java Runtime Environment supports permissions.

See Also Constants.BUNDLE_LOCALIZATION

10.1.5.20 **public Dictionary<String, String> getHeaders(String locale)**

locale The locale name into which the header values are to be localized. If the specified locale is null then the locale returned by java.util.Locale.getDefault is used. If the specified locale is the empty string, this method will return the raw (unlocalized) manifest headers including any leading "%".

- Returns this bundle's Manifest headers and values localized to the specified locale.

This method performs the same function as Bundle.getHeaders() except the manifest header values are localized to the specified locale.

If a Manifest header value starts with "%", it must be localized according to the specified locale. If a locale is specified and cannot be found, then the header values must be returned using the default locale. Localizations are searched for in the following order:

```

bn + "_" + Ls + "_" + Cs + "_" + Vs
bn + "_" + Ls + "_" + Cs
bn + "_" + Ls
bn + "_" + Ld + "_" + Cd + "_" + Vd
bn + "_" + Ld + "_" + Cd
bn + "_" + Ld
bn

```

Where bn is this bundle's localization basename, Ls, Cs and Vs are the specified locale (language, country, variant) and Ld, Cd and Vd are the default locale (language, country, variant). If null is specified as the locale string, the header values must be localized using the default locale. If the empty string ("") is specified as the locale string, the header values must not be localized and the raw (unlocalized) header values, including any leading "%", must be returned. If no localization is found for a header value, the header value without the leading "%" is returned.

This method must continue to return Manifest header information while this bundle is in the UNINSTALLED state, however the header values must only be available in the raw and default locale values.

Returns An unmodifiable Dictionary object containing this bundle's Manifest headers and values.

Throws SecurityException— If the caller does not have the appropriate AdminPermission[this,METADATA], and the Java Runtime Environment supports permissions.

See Also getHeaders(), Constants.BUNDLE_LOCALIZATION

Since 1.3

10.1.5.21 **public long getLastModified()**

- Returns the time when this bundle was last modified. A bundle is considered to be modified when it is installed, updated or uninstalled.

The time value is the number of milliseconds since January 1, 1970, 00:00:00 UTC.

Returns The time when this bundle was last modified.

Since 1.3

10.1.5.22 public String getLocation()

- Returns this bundle's location identifier.

The location identifier is the location passed to `BundleContext.installBundle` when a bundle is installed. The location identifier does not change while this bundle remains installed, even if this bundle is updated.

This method must continue to return this bundle's location identifier while this bundle is in the UNINSTALLED state.

Returns The string representation of this bundle's location identifier.

Throws `SecurityException`– If the caller does not have the appropriate `AdminPermission[this,METADATA]`, and the Java Runtime Environment supports permissions.

10.1.5.23 public ServiceReference<?>[] getRegisteredServices()

- Returns this bundle's `ServiceReference` list for all services it has registered or null if this bundle has no registered services.

If the Java runtime supports permissions, a `ServiceReference` object to a service is included in the returned list only if the caller has the `ServicePermission` to get the service using at least one of the named classes the service was registered under.

The list is valid at the time of the call to this method, however, as the Framework is a very dynamic environment, services can be modified or unregistered at anytime.

Returns An array of `ServiceReference` objects or null.

Throws `IllegalStateException`– If this bundle has been uninstalled.

See Also `ServiceRegistration`, `ServiceReference`, `ServicePermission`

10.1.5.24 public URL getResource(String name)

name The name of the resource. See `ClassLoader.getResource` for a description of the format of a resource name.

- Find the specified resource from this bundle's class loader. This bundle's class loader is called to search for the specified resource. If this bundle's state is `INSTALLED`, this method must attempt to resolve this bundle before attempting to get the specified resource. If this bundle cannot be resolved, then only this bundle must be searched for the specified resource. Imported packages cannot be searched when this bundle has not been resolved. If this bundle is a fragment bundle then null is returned.

Note: Jar and zip files are not required to include directory entries. URLs to directory entries will not be returned if the bundle contents do not contain directory entries.

Returns A URL to the named resource, or null if the resource could not be found or if this bundle is a fragment bundle or if the caller does not have the appropriate `AdminPermission[this,RESOURCE]`, and the Java Runtime Environment supports permissions.

Throws `IllegalStateException`– If this bundle has been uninstalled.

See Also `getEntry(String)`, `findEntries(String, String, boolean)`

Since 1.1

10.1.5.25 public Enumeration<URL> getResources(String name) throws IOException

name The name of the resource. See `ClassLoader.getResources` for a description of the format of a resource name.

- Find the specified resources from this bundle's class loader. This bundle's class loader is called to search for the specified resources. If this bundle's state is `INSTALLED`, this method must attempt to resolve this bundle before attempting to get the specified resources. If this bundle cannot be re-

solved, then only this bundle must be searched for the specified resources. Imported packages cannot be searched when a bundle has not been resolved. If this bundle is a fragment bundle then null is returned.

Note: Jar and zip files are not required to include directory entries. URLs to directory entries will not be returned if the bundle contents do not contain directory entries.

Returns An enumeration of URLs to the named resources, or null if the resource could not be found or if this bundle is a fragment bundle or if the caller does not have the appropriate `AdminPermission[this,RESOURCE]`, and the Java Runtime Environment supports permissions.

Throws `IllegalStateException`– If this bundle has been uninstalled.
`IOException`– If there is an I/O error.

Since 1.3

10.1.5.26 **public ServiceReference<?>[] getServicesInUse()**

- Returns this bundle's `ServiceReference` list for all services it is using or returns null if this bundle is not using any services. A bundle is considered to be using a service if it has any unreleased service objects.

If the Java Runtime Environment supports permissions, a `ServiceReference` object to a service is included in the returned list only if the caller has the `ServicePermission` to get the service using at least one of the named classes the service was registered under.

The list is valid at the time of the call to this method, however, as the Framework is a very dynamic environment, services can be modified or unregistered at anytime.

Returns An array of `ServiceReference` objects or null.

Throws `IllegalStateException`– If this bundle has been uninstalled.

See Also `ServiceReference`, `ServicePermission`

10.1.5.27 **public Map<X509Certificate, List<X509Certificate>> getSignerCertificates(int signersType)**

signersType If `SIGNERS_ALL` is specified, then information on all signers of this bundle is returned. If `SIGNERS_TRUSTED` is specified, then only information on the signers of this bundle trusted by the framework is returned.

- Return the certificates for the signers of this bundle and the certificate chains for those signers.

Returns The `X509Certificates` for the signers of this bundle and the `X509Certificate` chains for those signers. The keys of the `Map` are the `X509Certificates` of the signers of this bundle. The value for a key is a `List` containing the `X509Certificate` chain for the signer. The first item in the `List` is the signer's `X509Certificate` which is then followed by the rest of the `X509Certificate` chain. The returned `Map` will be empty if there are no signers. The returned `Map` is the property of the caller who is free to modify it.

Throws `IllegalArgumentException`– If the specified `signersType` is not `SIGNERS_ALL` or `SIGNERS_TRUSTED`.

Since 1.5

10.1.5.28 **public int getState()**

- Returns this bundle's current state.

A bundle can be in only one state at any time.

Returns An element of `UNINSTALLED`, `INSTALLED`, `RESOLVED`, `STARTING`, `STOPPING`, `ACTIVE`.

10.1.5.29 public String getSymbolicName()

- Returns the symbolic name of this bundle as specified by its Bundle-SymbolicName manifest header. The bundle symbolic name should be based on the reverse domain name naming convention like that used for java packages.

This method must continue to return this bundle's symbolic name while this bundle is in the UNINSTALLED state.

Returns The symbolic name of this bundle or null if this bundle does not have a symbolic name.

Since 1.3

10.1.5.30 public Version getVersion()

- Returns the version of this bundle as specified by its Bundle-Version manifest header. If this bundle does not have a specified version then Version.emptyVersion is returned.

This method must continue to return this bundle's version while this bundle is in the UNINSTALLED state.

Returns The version of this bundle.

Since 1.5

10.1.5.31 public boolean hasPermission(Object permission)

permission The permission to verify.

- Determines if this bundle has the specified permissions.

If the Java Runtime Environment does not support permissions, this method always returns true.

permission is of type Object to avoid referencing the java.security.Permission class directly. This is to allow the Framework to be implemented in Java environments which do not support permissions.

If the Java Runtime Environment does support permissions, this bundle and all its resources including embedded JAR files, belong to the same java.security.ProtectionDomain; that is, they must share the same set of permissions.

Returns true if this bundle has the specified permission or the permissions possessed by this bundle imply the specified permission; false if this bundle does not have the specified permission or permission is not an instance of java.security.Permission.

Throws IllegalStateException – If this bundle has been uninstalled.

10.1.5.32 public Class<?> loadClass(String name) throws ClassNotFoundException

name The name of the class to load.

- Loads the specified class using this bundle's class loader.

If this bundle is a fragment bundle then this method must throw a ClassNotFoundException.

If this bundle's state is INSTALLED, this method must attempt to resolve this bundle before attempting to load the class.

If this bundle cannot be resolved, a Framework event of type FrameworkEvent.ERROR is fired containing a BundleException with details of the reason this bundle could not be resolved. This method must then throw a ClassNotFoundException.

If this bundle's state is UNINSTALLED, then an IllegalStateException is thrown.

Returns The Class object for the requested class.

Throws `ClassNotFoundException`– If no such class can be found or if this bundle is a fragment bundle or if the caller does not have the appropriate `AdminPermission[this,CLASS]`, and the Java Runtime Environment supports permissions.

`IllegalStateException`– If this bundle has been uninstalled.

Since 1.3

10.1.5.33 **public void start(int options) throws BundleException**

options The options for starting this bundle. See `START_TRANSIENT` and `START_ACTIVATION_POLICY`. The Framework must ignore unrecognized options.

- Starts this bundle.

If this bundle's state is `UNINSTALLED` then an `IllegalStateException` is thrown.

If the current start level is less than this bundle's start level:

- If the `START_TRANSIENT` option is set, then a `BundleException` is thrown indicating this bundle cannot be started due to the Framework's current start level.
- Otherwise, the Framework must set this bundle's persistent autostart setting to *Started with declared activation* if the `START_ACTIVATION_POLICY` option is set or *Started with eager activation* if not set.

When the Framework's current start level becomes equal to or more than this bundle's start level, this bundle will be started.

Otherwise, the following steps are required to start this bundle:

1. If this bundle is in the process of being activated or deactivated then this method must wait for activation or deactivation to complete before continuing. If this does not occur in a reasonable time, a `BundleException` is thrown to indicate this bundle was unable to be started.
2. If the `START_TRANSIENT` option is not set then set this bundle's autostart setting to *Started with declared activation* if the `START_ACTIVATION_POLICY` option is set or *Started with eager activation* if not set. When the Framework is restarted and this bundle's autostart setting is not *Stopped*, this bundle must be automatically started.
3. If this bundle's state is `ACTIVE` then this method returns immediately.
4. If this bundle's state is not `RESOLVED`, an attempt is made to resolve this bundle. If the Framework cannot resolve this bundle, a `BundleException` is thrown.
5. If the `START_ACTIVATION_POLICY` option is set and this bundle's declared activation policy is lazy then:
 - If this bundle's state is `STARTING` then this method returns immediately.
 - This bundle's state is set to `STARTING`.
 - A bundle event of type `BundleEvent.LAZY_ACTIVATION` is fired.
 - This method returns immediately and the remaining steps will be followed when this bundle's activation is later triggered.
6. This bundle's state is set to `STARTING`.
7. A bundle event of type `BundleEvent.STARTING` is fired.
8. The `BundleActivator.start(BundleContext)` method of this bundle's `BundleActivator`, if one is specified, is called. If the `BundleActivator` is invalid or throws an exception then:
 - This bundle's state is set to `STOPPING`.
 - A bundle event of type `BundleEvent.STOPPING` is fired.
 - Any services registered by this bundle must be unregistered.
 - Any services used by this bundle must be released.
 - Any listeners registered by this bundle must be removed.

- This bundle's state is set to RESOLVED.
 - A bundle event of type BundleEvent.STOPPED is fired.
 - A BundleException is then thrown.
9. This bundle's state is set to ACTIVE.
10. A bundle event of type BundleEvent.STARTED is fired.

Preconditions

- `getState()` in { INSTALLED, RESOLVED } or { INSTALLED, RESOLVED, STARTING } if this bundle has a lazy activation policy.

Postconditions, no exceptions thrown

- Bundle autostart setting is modified unless the START_TRANSIENT option was set.
- `getState()` in { ACTIVE } unless the lazy activation policy was used.
- `BundleActivator.start()` has been called and did not throw an exception unless the lazy activation policy was used.

Postconditions, when an exception is thrown

- Depending on when the exception occurred, bundle autostart setting is modified unless the START_TRANSIENT option was set.
- `getState()` not in { STARTING, ACTIVE }.

Throws BundleException— If this bundle could not be started. BundleException types thrown by this method include: BundleException.START_TRANSIENT_ERROR, BundleException.NATIVECODE_ERROR, BundleException.RESOLVE_ERROR, BundleException.STATECHANGE_ERROR, and BundleException.ACTIVATOR_ERROR.

IllegalStateException— If this bundle has been uninstalled or this bundle tries to change its own state.

SecurityException— If the caller does not have the appropriate AdminPermission[this,EXECUTE], and the Java Runtime Environment supports permissions.

Since 1.4

10.1.5.34 **public void start() throws BundleException**

- Starts this bundle with no options.

This method performs the same function as calling `start(o)`.

Throws BundleException— If this bundle could not be started. BundleException types thrown by this method include: BundleException.NATIVECODE_ERROR, BundleException.RESOLVE_ERROR, BundleException.STATECHANGE_ERROR, and BundleException.ACTIVATOR_ERROR.

IllegalStateException— If this bundle has been uninstalled or this bundle tries to change its own state.

SecurityException— If the caller does not have the appropriate AdminPermission[this,EXECUTE], and the Java Runtime Environment supports permissions.

See Also `start(int)`

10.1.5.35 **public void stop(int options) throws BundleException**

options The options for stopping this bundle. See STOP_TRANSIENT. The Framework must ignore unrecognized options.

- Stops this bundle.

The following steps are required to stop a bundle:

1. If this bundle's state is UNINSTALLED then an `IllegalStateException` is thrown.
2. If this bundle is in the process of being activated or deactivated then this method must wait for activation or deactivation to complete before continuing. If this does not occur in a reasonable time, a `BundleException` is thrown to indicate this bundle was unable to be stopped.
3. If the `STOP_TRANSIENT` option is not set then set this bundle's persistent autostart setting to *Stopped*. When the Framework is restarted and this bundle's autostart setting is *Stopped*, this bundle must not be automatically started.
4. If this bundle's state is not `STARTING` or `ACTIVE` then this method returns immediately.
5. This bundle's state is set to `STOPPING`.
6. A bundle event of type `BundleEvent.STOPPING` is fired.
7. If this bundle's state was `ACTIVE` prior to setting the state to `STOPPING`, the `BundleActivator.stop(BundleContext)` method of this bundle's `BundleActivator`, if one is specified, is called. If that method throws an exception, this method must continue to stop this bundle and a `BundleException` must be thrown after completion of the remaining steps.
8. Any services registered by this bundle must be unregistered.
9. Any services used by this bundle must be released.
10. Any listeners registered by this bundle must be removed.
11. If this bundle's state is `UNINSTALLED`, because this bundle was uninstalled while the `BundleActivator.stop` method was running, a `BundleException` must be thrown.
12. This bundle's state is set to `RESOLVED`.
13. A bundle event of type `BundleEvent.STOPPED` is fired.

Preconditions

- `getState()` in `{ ACTIVE }`.

Postconditions, no exceptions thrown

- Bundle autostart setting is modified unless the `STOP_TRANSIENT` option was set.
- `getState()` not in `{ ACTIVE, STOPPING }`.
- `BundleActivator.stop` has been called and did not throw an exception.

Postconditions, when an exception is thrown

- Bundle autostart setting is modified unless the `STOP_TRANSIENT` option was set.

Throws `BundleException`—`BundleException` types thrown by this method include: `BundleException.STATECHANGE_ERROR` and `BundleException.ACTIVATOR_ERROR`.

`IllegalStateException`—If this bundle has been uninstalled or this bundle tries to change its own state.

`SecurityException`—If the caller does not have the appropriate `AdminPermission[this,EXECUTE]`, and the Java Runtime Environment supports permissions.

Since 1.4

10.1.5.36 **public void stop() throws BundleException**

- Stops this bundle with no options.

This method performs the same function as calling `stop(o)`.

Throws `BundleException`—`BundleException` types thrown by this method include: `BundleException.STATECHANGE_ERROR` and `BundleException.ACTIVATOR_ERROR`.

`IllegalStateException`– If this bundle has been uninstalled or this bundle tries to change its own state.

`SecurityException`– If the caller does not have the appropriate `AdminPermission[this,EXECUTE]`, and the Java Runtime Environment supports permissions.

See Also `start(int)`

10.1.5.37 **public void uninstall() throws BundleException**

- Uninstalls this bundle.

This method causes the Framework to notify other bundles that this bundle is being uninstalled, and then puts this bundle into the UNINSTALLED state. The Framework must remove any resources related to this bundle that it is able to remove.

If this bundle has exported any packages, the Framework must continue to make these packages available to their importing bundles until the `FrameworkWiring.refreshBundles` method has been called or the Framework is relaunched.

The following steps are required to uninstall a bundle:

1. If this bundle's state is UNINSTALLED then an `IllegalStateException` is thrown.
2. If this bundle's state is ACTIVE, STARTING or STOPPING, this bundle is stopped as described in the `Bundle.stop` method. If `Bundle.stop` throws an exception, a Framework event of type `FrameworkEvent.ERROR` is fired containing the exception.
3. This bundle's state is set to UNINSTALLED.
4. A bundle event of type `BundleEvent.UNINSTALLED` is fired.
5. This bundle and any persistent storage area provided for this bundle by the Framework are removed.

Preconditions

- `getState()` not in { UNINSTALLED }.

Postconditions, no exceptions thrown

- `getState()` in { UNINSTALLED }.
- This bundle has been uninstalled.

Postconditions, when an exception is thrown

- `getState()` not in { UNINSTALLED }.
- This Bundle has not been uninstalled.

Throws `BundleException`– If the uninstall failed. This can occur if another thread is attempting to change this bundle's state and does not complete in a timely manner. `BundleException` types thrown by this method include: `BundleException.STATECHANGE_ERROR`

`IllegalStateException`– If this bundle has been uninstalled or this bundle tries to change its own state.

`SecurityException`– If the caller does not have the appropriate `AdminPermission[this,LIFECYCLE]`, and the Java Runtime Environment supports permissions.

See Also `stop()`

10.1.5.38 **public void update(InputStream input) throws BundleException**

input The `InputStream` from which to read the new bundle or null to indicate the Framework must create the input stream from this bundle's `Bundle-UpdateLocation` Manifest header, if present, or this

bundle's original location. The input stream must always be closed when this method completes, even if an exception is thrown.

- Updates this bundle from an `InputStream`.

If the specified `InputStream` is null, the Framework must create the `InputStream` from which to read the updated bundle by interpreting, in an implementation dependent manner, this bundle's `Bundle-UpdateLocation` Manifest header, if present, or this bundle's original location.

If this bundle's state is `ACTIVE`, it must be stopped before the update and started after the update successfully completes.

If this bundle has exported any packages that are imported by another bundle, these packages must remain exported until the `FrameworkWiring.refreshBundles` method has been called or the Framework is relaunched.

The following steps are required to update a bundle:

1. If this bundle's state is `UNINSTALLED` then an `IllegalStateException` is thrown.
2. If this bundle's state is `ACTIVE`, `STARTING` or `STOPPING`, this bundle is stopped as described in the `Bundle.stop` method. If `Bundle.stop` throws an exception, the exception is rethrown terminating the update.
3. The updated version of this bundle is read from the input stream and installed. If the Framework is unable to install the updated version of this bundle, the original version of this bundle must be restored and a `BundleException` must be thrown after completion of the remaining steps.
4. This bundle's state is set to `INSTALLED`.
5. If the updated version of this bundle was successfully installed, a bundle event of type `BundleEvent.UPDATED` is fired.
6. If this bundle's state was originally `ACTIVE`, the updated bundle is started as described in the `Bundle.start` method. If `Bundle.start` throws an exception, a Framework event of type `FrameworkEvent.ERROR` is fired containing the exception.

Preconditions

- `getState()` not in `{ UNINSTALLED }`.

Postconditions, no exceptions thrown

- `getState()` in `{ INSTALLED, RESOLVED, ACTIVE }`.
- This bundle has been updated.

Postconditions, when an exception is thrown

- `getState()` in `{ INSTALLED, RESOLVED, ACTIVE }`.
- Original bundle is still used; no update occurred.

Throws `BundleException`— If this bundle could not be updated. `BundleException` types thrown by this method include: `BundleException.READ_ERROR`, `BundleException.DUPLICATE_BUNDLE_ERROR`, `BundleException.MANIFEST_ERROR`, `BundleException.NATIVECODE_ERROR`, `BundleException.RESOLVE_ERROR`, `BundleException.STATECHANGE_ERROR`, and `BundleException.ACTIVATOR_ERROR`.

`IllegalStateException`— If this bundle has been uninstalled or this bundle tries to change its own state.

`SecurityException`— If the caller does not have the appropriate `AdminPermission[this, LIFECYCLE]` for both the current bundle and the updated bundle, and the Java Runtime Environment supports permissions.

See Also `stop()`, `start()`

10.1.5.39 public void update() throws BundleException

- Updates this bundle.

This method performs the same function as calling `update(InputStream)` with a null `InputStream`.

Throws `BundleException`— If this bundle could not be updated. `BundleException` types thrown by this method include: `BundleException.READ_ERROR`, `BundleException.DUPLICATE_BUNDLE_ERROR`, `BundleException.MANIFEST_ERROR`, `BundleException.NATIVECODE_ERROR`, `BundleException.RESOLVE_ERROR`, `BundleException.STATECHANGE_ERROR`, and `BundleException.ACTIVATOR_ERROR`.

`IllegalStateException`— If this bundle has been uninstalled or this bundle tries to change its own state.

`SecurityException`— If the caller does not have the appropriate `AdminPermission[this,LIFECYCLE]` for both the current bundle and the updated bundle, and the Java Runtime Environment supports permissions.

See Also `update(InputStream)`

10.1.6 public interface BundleActivator

Customizes the starting and stopping of a bundle.

`BundleActivator` is an interface that may be implemented when a bundle is started or stopped. The Framework can create instances of a bundle's `BundleActivator` as required. If an instance's `BundleActivator.start` method executes successfully, it is guaranteed that the same instance's `BundleActivator.stop` method will be called when the bundle is to be stopped. The Framework must not concurrently call a `BundleActivator` object.

`BundleActivator` is specified through the `Bundle-Activator` Manifest header. A bundle can only specify a single `BundleActivator` in the Manifest file. Fragment bundles must not have a `BundleActivator`. The form of the Manifest header is:

`Bundle-Activator: class-name`

where *class-name* is a fully qualified Java classname.

The specified `BundleActivator` class must have a public constructor that takes no parameters so that a `BundleActivator` object can be created by `Class.newInstance()`.

Concurrency Not Thread-safe

10.1.6.1 public void start(BundleContext context) throws Exception

context The execution context of the bundle being started.

- Called when this bundle is started so the Framework can perform the bundle-specific activities necessary to start this bundle. This method can be used to register services or to allocate any resources that this bundle needs.

This method must complete and return to its caller in a timely manner.

Throws `Exception`— If this method throws an exception, this bundle is marked as stopped and the Framework will remove this bundle's listeners, unregister all services registered by this bundle, and release all services used by this bundle.

10.1.6.2 public void stop(BundleContext context) throws Exception

context The execution context of the bundle being stopped.

- Called when this bundle is stopped so the Framework can perform the bundle-specific activities necessary to stop the bundle. In general, this method should undo the work that the `BundleActivator.start` method started. There should be no active threads that were started by this bundle when this bundle returns. A stopped bundle must not call any Framework objects.

This method must complete and return to its caller in a timely manner.

Throws Exception— If this method throws an exception, the bundle is still marked as stopped, and the Framework will remove the bundle's listeners, unregister all services registered by the bundle, and release all services used by the bundle.

10.1.7 **public interface BundleContext extends BundleReference**

A bundle's execution context within the Framework. The context is used to grant access to other methods so that this bundle can interact with the Framework.

BundleContext methods allow a bundle to:

- Subscribe to events published by the Framework.
- Register service objects with the Framework service registry.
- Retrieve ServiceReferences from the Framework service registry.
- Get and release service objects for a referenced service.
- Install new bundles in the Framework.
- Get the list of bundles installed in the Framework.
- Get the Bundle object for a bundle.
- Create File objects for files in a persistent storage area provided for the bundle by the Framework.

A BundleContext object will be created for a bundle when the bundle is started. The Bundle object associated with a BundleContext object is called the *context bundle*.

The BundleContext object will be passed to the BundleActivator.start(BundleContext) method during activation of the context bundle. The same BundleContext object will be passed to the BundleActivator.stop(BundleContext) method when the context bundle is stopped. A BundleContext object is generally for the private use of its associated bundle and is not meant to be shared with other bundles in the OSGi environment.

The BundleContext object is only valid during the execution of its context bundle; that is, during the period from when the context bundle is in the STARTING, STOPPING, and ACTIVE bundle states. However, the BundleContext object becomes invalid after BundleActivator.stop(BundleContext) returns (if the bundle has a Bundle Activator). The BundleContext object becomes invalid before disposing of any remaining registered services and releasing any remaining services in use. Since those activities can result in other bundles being called (for example, ServiceListeners for ServiceEvent.UNREGISTERING events and ServiceFactorys for unget operations), those other bundles can observe the stopping bundle in the STOPPING state but with an invalid BundleContext object. If the BundleContext object is used after it has become invalid, an IllegalStateException must be thrown. The BundleContext object must never be reused after its context bundle is stopped.

Two BundleContext objects are equal if they both refer to the same execution context of a bundle. The Framework is the only entity that can create BundleContext objects and they are only valid within the Framework that created them.

A Bundle can be adapted to its BundleContext. In order for this to succeed, the caller must have the appropriate AdminPermission[bundle,CONTEXT] if the Java Runtime Environment supports permissions.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.1.7.1 **public void addBundleListener(BundleListener listener)**

listener The BundleListener to be added.

- Adds the specified BundleListener object to the context bundle's list of listeners if not already present. BundleListener objects are notified when a bundle has a lifecycle state change.

If the context bundle's list of listeners already contains a listener *l* such that (*l*==listener), this method does nothing.

Throws IllegalStateException– If this BundleContext is no longer valid.

SecurityException– If listener is a SynchronousBundleListener and the caller does not have the appropriate AdminPermission[context bundle,LISTENER], and the Java Runtime Environment supports permissions.

See Also BundleEvent, BundleListener

10.1.7.2 **public void addFrameworkListener(FrameworkListener listener)**

listener The FrameworkListener object to be added.

- Adds the specified FrameworkListener object to the context bundle's list of listeners if not already present. FrameworkListeners are notified of general Framework events.

If the context bundle's list of listeners already contains a listener *l* such that (*l*==listener), this method does nothing.

Throws IllegalStateException– If this BundleContext is no longer valid.

See Also FrameworkEvent, FrameworkListener

10.1.7.3 **public void addServiceListener(ServiceListener listener, String filter) throws InvalidSyntaxException**

listener The ServiceListener object to be added.

filter The filter criteria.

- Adds the specified ServiceListener object with the specified filter to the context bundle's list of listeners. See Filter for a description of the filter syntax. ServiceListener objects are notified when a service has a lifecycle state change.

If the context bundle's list of listeners already contains a listener *l* such that (*l*==listener), then this method replaces that listener's filter (which may be null) with the specified one (which may be null).

The listener is called if the filter criteria is met. To filter based upon the class of the service, the filter should reference the Constants.OBJECTCLASS property. If filter is null, all services are considered to match the filter.

When using a filter, it is possible that the ServiceEvent s for the complete lifecycle of a service will not be delivered to the listener. For example, if the filter only matches when the property *x* has the value 1, the listener will not be called if the service is registered with the property *x* not set to the value 1. Subsequently, when the service is modified setting property *x* to the value 1, the filter will match and the listener will be called with a ServiceEvent of type MODIFIED. Thus, the listener will not be called with a ServiceEvent of type REGISTERED.

If the Java Runtime Environment supports permissions, the ServiceListener object will be notified of a service event only if the bundle that is registering it has the ServicePermission to get the service using at least one of the named classes the service was registered under.

Throws InvalidSyntaxException– If filter contains an invalid filter string that cannot be parsed.

IllegalStateException– If this BundleContext is no longer valid.

See Also ServiceEvent, ServiceListener, ServicePermission

10.1.7.4 **public void addServiceListener(ServiceListener listener)**

listener The ServiceListener object to be added.

- Adds the specified ServiceListener object to the context bundle's list of listeners.

This method is the same as calling `BundleContext.addServiceListener(ServiceListener listener, String filter)` with filter set to null.

Throws `IllegalStateException`– If this `BundleContext` is no longer valid.

See Also `addServiceListener(ServiceListener, String)`

10.1.7.5 **public Filter createFilter(String filter) throws InvalidSyntaxException**

filter The filter string.

- Creates a `Filter` object. This `Filter` object may be used to match a `ServiceReference` object or a Dictionary object.

If the filter cannot be parsed, an `InvalidSyntaxException` will be thrown with a human readable message where the filter became unparseable.

Returns A `Filter` object encapsulating the filter string.

Throws `InvalidSyntaxException`– If filter contains an invalid filter string that cannot be parsed.

`NullPointerException`– If filter is null.

`IllegalStateException`– If this `BundleContext` is no longer valid.

See Also Framework specification for a description of the filter string syntax., `FrameworkUtil.createFilter(String)`

Since 1.1

10.1.7.6 **public ServiceReference<?>[] getAllServiceReferences(String clazz, String filter) throws InvalidSyntaxException**

clazz The class name with which the service was registered or null for all services.

filter The filter expression or null for all services.

- Returns an array of `ServiceReference` objects. The returned array of `ServiceReference` objects contains services that were registered under the specified class and match the specified filter expression.

The list is valid at the time of the call to this method. However since the Framework is a very dynamic environment, services can be modified or unregistered at any time.

The specified filter expression is used to select the registered services whose service properties contain keys and values which satisfy the filter expression. See `Filter` for a description of the filter syntax. If the specified filter is null, all registered services are considered to match the filter. If the specified filter expression cannot be parsed, an `InvalidSyntaxException` will be thrown with a human readable message where the filter became unparseable.

The result is an array of `ServiceReference` objects for all services that meet all of the following conditions:

- If the specified class name, `clazz`, is not null, the service must have been registered with the specified class name. The complete list of class names with which a service was registered is available from the service's `objectClass` property.
- If the specified filter is not null, the filter expression must match the service.
- If the Java Runtime Environment supports permissions, the caller must have `ServicePermission` with the GET action for at least one of the class names under which the service was registered.

Returns An array of `ServiceReference` objects or null if no services are registered which satisfy the search.

Throws `InvalidSyntaxException`– If the specified filter contains an invalid filter expression that cannot be parsed.

`IllegalStateException`– If this `BundleContext` is no longer valid.

Since 1.3

10.1.7.7 **public Bundle getBundle()**

- Returns the Bundle object associated with this BundleContext. This bundle is called the context bundle.

Returns The Bundle object associated with this BundleContext.

Throws IllegalStateException– If this BundleContext is no longer valid.

10.1.7.8 **public Bundle getBundle(long id)**

id The identifier of the bundle to retrieve.

- Returns the bundle with the specified identifier.

Returns A Bundle object or null if the identifier does not match any installed bundle.

10.1.7.9 **public Bundle getBundle(String location)**

location The location of the bundle to retrieve.

- Returns the bundle with the specified location.

Returns A Bundle object or null if the location does not match any installed bundle.

Since 1.6

10.1.7.10 **public Bundle[] getBundles()**

- Returns a list of all installed bundles.

This method returns a list of all bundles installed in the OSGi environment at the time of the call to this method. However, since the Framework is a very dynamic environment, bundles can be installed or uninstalled at anytime.

Returns An array of Bundle objects, one object per installed bundle.

10.1.7.11 **public File getDataFile(String filename)**

filename A relative name to the file to be accessed.

- Creates a File object for a file in the persistent storage area provided for the bundle by the Framework. This method will return null if the platform does not have file system support.

A File object for the base directory of the persistent storage area provided for the context bundle by the Framework can be obtained by calling this method with an empty string as filename.

If the Java Runtime Environment supports permissions, the Framework will ensure that the bundle has the java.io.FilePermission with actions read,write,delete for all files (recursively) in the persistent storage area provided for the context bundle.

Returns A File object that represents the requested file or null if the platform does not have file system support.

Throws IllegalStateException– If this BundleContext is no longer valid.

10.1.7.12 **public String getProperty(String key)**

key The name of the requested property.

- Returns the value of the specified property. If the key is not found in the Framework properties, the system properties are then searched. The method returns null if the property is not found.

All bundles must have permission to read properties whose names start with "org.osgi.".

Returns The value of the requested property, or null if the property is undefined.

Throws `SecurityException`– If the caller does not have the appropriate `PropertyPermission` to read the property, and the Java Runtime Environment supports permissions.

10.1.7.13 **public `S` getService(`ServiceReference<S>` reference)**

Type Parameters `<S>`

`<S>` Type of Service.

reference A reference to the service.

- Returns the service object for the service referenced by the specified `ServiceReference` object.

A bundle's use of a service object obtained from this method is tracked by the bundle's use count of that service. Each time the service object is returned by `getService(ServiceReference)` the context bundle's use count for the service is incremented by one. Each time the service object is released by `ungetService(ServiceReference)` the context bundle's use count for the service is decremented by one.

When a bundle's use count for the service drops to zero, the bundle should no longer use the service object.

This method will always return null when the service associated with the specified reference has been unregistered.

The following steps are required to get the service object:

1. If the service has been unregistered, null is returned.
2. If the context bundle's use count for the service is currently zero and the service has bundle or prototype scope, the `ServiceFactory.getService(Bundle, ServiceRegistration)` method is called to supply the service object for the context bundle. If the service object returned by the `ServiceFactory` object is null, not an instance of all the classes named when the service was registered or the `ServiceFactory` object throws an exception or will be recursively called for the context bundle, null is returned and a `FrameworkEvent.ERROR` containing a `ServiceException` describing the error is fired. The supplied service object is cached by the `Framework`. While the context bundle's use count for the service is greater than zero, subsequent calls to get the service object for the context bundle will return the cached service object.
3. The context bundle's use count for the service is incremented by one.
4. The service object for the service is returned.

Returns A service object for the service associated with `reference` or null if the service is not registered, the service object returned by a `ServiceFactory` does not implement the classes under which it was registered or the `ServiceFactory` threw an exception.

Throws `SecurityException`– If the caller does not have the `ServicePermission` to get the service using at least one of the named classes the service was registered under and the Java Runtime Environment supports permissions.

`IllegalStateException`– If this `BundleContext` is no longer valid.

`IllegalArgumentException`– If the specified `ServiceReference` was not created by the same framework instance as this `BundleContext`.

See Also `ungetService(ServiceReference)`, `ServiceFactory`

10.1.7.14 **public `ServiceObjects<S>` getServiceObjects(`ServiceReference<S>` reference)**

Type Parameters `<S>`

`<S>` Type of Service.

reference A reference to the service.

- Returns the ServiceObjects object for the service referenced by the specified ServiceReference object.

The ServiceObjects object can be used to obtain multiple service objects for services with prototype scope.

For services with singleton or bundle scope, the ServiceObjects.getService() method behaves the same as the getService(ServiceReference) method and the ServiceObjects.ungetService(Object) method behaves the same as the ungetService(ServiceReference) method. That is, only one, use-counted service object is available from the ServiceObjects object.

This method will always return null when the service associated with the specified reference has been unregistered.

Returns A ServiceObjects object for the service associated with the specified reference or null if the service is not registered.

Throws SecurityException— If the caller does not have the ServicePermission to get the service using at least one of the named classes the service was registered under and the Java Runtime Environment supports permissions.

IllegalStateException— If this BundleContext is no longer valid.

IllegalArgumentException— If the specified ServiceReference was not created by the same framework instance as this BundleContext.

See Also PrototypeServiceFactory

Since 1.8

10.1.7.15 **public ServiceReference<?> getServiceReference(String clazz)**

clazz The class name with which the service was registered.

- Returns a ServiceReference object for a service that implements and was registered under the specified class.

The returned ServiceReference object is valid at the time of the call to this method. However as the Framework is a very dynamic environment, services can be modified or unregistered at any time.

This method is the same as calling getServiceReferences(String, String) with a null filter expression and then finding the reference with the highest priority. It is provided as a convenience for when the caller is interested in any service that implements the specified class.

If multiple such services exist, the service with the highest priority is selected. This priority is defined as the service reference with the highest ranking (as specified in its Constants.SERVICE_RANKING property) is returned.

If there is a tie in ranking, the service with the lowest service id (as specified in its Constants.SERVICE_ID property); that is, the service that was registered first is returned.

Returns A ServiceReference object, or null if no services are registered which implement the named class.

Throws IllegalStateException— If this BundleContext is no longer valid.

See Also getServiceReferences(String, String)

10.1.7.16 **public ServiceReference<S> getServiceReference(Class<S> clazz)**

Type Parameters <S>

<S> Type of Service.

clazz The class under whose name the service was registered. Must not be null.

- Returns a ServiceReference object for a service that implements and was registered under the name of the specified class.

The returned `ServiceReference` object is valid at the time of the call to this method. However as the Framework is a very dynamic environment, services can be modified or unregistered at any time.

This method is the same as calling `getServiceReferences(Class, String)` with a null filter expression. It is provided as a convenience for when the caller is interested in any service that implements the specified class.

If multiple such services exist, the service with the highest ranking (as specified in its `Constants.SERVICE_RANKING` property) is returned.

If there is a tie in ranking, the service with the lowest service id (as specified in its `Constants.SERVICE_ID` property); that is, the service that was registered first is returned.

Returns A `ServiceReference` object, or null if no services are registered which implement the specified class.

Throws `IllegalStateException`– If this `BundleContext` is no longer valid.

See Also `getServiceReferences(Class, String)`

Since 1.6

10.1.7.17 **public ServiceReference<?>[] getServiceReferences(String clazz, String filter) throws InvalidSyntaxException**

clazz The class name with which the service was registered or null for all services.

filter The filter expression or null for all services.

- Returns an array of `ServiceReference` objects. The returned array of `ServiceReference` objects contains services that were registered under the specified class, match the specified filter expression, and the packages for the class names under which the services were registered match the context bundle's packages as defined in `ServiceReference.isAssignableTo(Bundle, String)`.

The list is valid at the time of the call to this method. However since the Framework is a very dynamic environment, services can be modified or unregistered at any time.

The specified filter expression is used to select the registered services whose service properties contain keys and values which satisfy the filter expression. See `Filter` for a description of the filter syntax. If the specified filter is null, all registered services are considered to match the filter. If the specified filter expression cannot be parsed, an `InvalidSyntaxException` will be thrown with a human readable message where the filter became unparseable.

The result is an array of `ServiceReference` objects for all services that meet all of the following conditions:

- If the specified class name, `clazz`, is not null, the service must have been registered with the specified class name. The complete list of class names with which a service was registered is available from the service's `objectClass` property.
- If the specified filter is not null, the filter expression must match the service.
- If the Java Runtime Environment supports permissions, the caller must have `ServicePermission` with the GET action for at least one of the class names under which the service was registered.
- For each class name with which the service was registered, calling `ServiceReference.isAssignableTo(Bundle, String)` with the context bundle and the class name on the service's `ServiceReference` object must return true

Returns An array of `ServiceReference` objects or null if no services are registered which satisfy the search.

Throws `InvalidSyntaxException`– If the specified filter contains an invalid filter expression that cannot be parsed.

`IllegalStateException`– If this `BundleContext` is no longer valid.

10.1.7.18 **public Collection<ServiceReference<S>> getServiceReferences(Class<S> clazz, String filter) throws InvalidSyntaxException**

Type Parameters <S>

<S> Type of Service

clazz The class under whose name the service was registered. Must not be null.

filter The filter expression or null for all services.

- Returns a collection of `ServiceReference` objects. The returned collection of `ServiceReference` objects contains services that were registered under the name of the specified class, match the specified filter expression, and the packages for the class names under which the services were registered match the context bundle's packages as defined in `ServiceReference.isAssignableTo(Bundle, String)`.

The collection is valid at the time of the call to this method. However since the Framework is a very dynamic environment, services can be modified or unregistered at any time.

The specified filter expression is used to select the registered services whose service properties contain keys and values which satisfy the filter expression. See `Filter` for a description of the filter syntax. If the specified filter is null, all registered services are considered to match the filter. If the specified filter expression cannot be parsed, an `InvalidSyntaxException` will be thrown with a human readable message where the filter became unparseable.

The result is a collection of `ServiceReference` objects for all services that meet all of the following conditions:

- The service must have been registered with the name of the specified class. The complete list of class names with which a service was registered is available from the service's `objectClass` property.
- If the specified filter is not null, the filter expression must match the service.
- If the Java Runtime Environment supports permissions, the caller must have `ServicePermission` with the `GET` action for at least one of the class names under which the service was registered.
- For each class name with which the service was registered, calling `ServiceReference.isAssignableTo(Bundle, String)` with the context bundle and the class name on the service's `ServiceReference` object must return `true`

Returns A collection of `ServiceReference` objects. May be empty if no services are registered which satisfy the search.

Throws `InvalidSyntaxException`—If the specified filter contains an invalid filter expression that cannot be parsed.

`IllegalStateException`—If this `BundleContext` is no longer valid.

Since 1.6

10.1.7.19 **public Bundle installBundle(String location, InputStream input) throws BundleException**

location The location identifier of the bundle to install.

input The `InputStream` object from which this bundle will be read or null to indicate the Framework must create the input stream from the specified location identifier. The input stream must always be closed when this method completes, even if an exception is thrown.

- Installs a bundle from the specified `InputStream` object.

If the specified `InputStream` is null, the Framework must create the `InputStream` from which to read the bundle by interpreting, in an implementation dependent manner, the specified location.

The specified location identifier will be used as the identity of the bundle. Every installed bundle is uniquely identified by its location identifier which is typically in the form of a URL.

The following steps are required to install a bundle:

1. If a bundle containing the same location identifier is already installed, the Bundle object for that bundle is returned.
2. The bundle's content is read from the input stream. If this fails, a BundleException is thrown.
3. The bundle's associated resources are allocated. The associated resources minimally consist of a unique identifier and a persistent storage area if the platform has file system support. If this step fails, a BundleException is thrown.
4. The bundle's state is set to INSTALLED.
5. A bundle event of type BundleEvent.INSTALLED is fired.
6. The Bundle object for the newly or previously installed bundle is returned.

Postconditions, no exceptions thrown

- getState() in { INSTALLED, RESOLVED }.
- Bundle has a unique ID.

Postconditions, when an exception is thrown

- Bundle is not installed. If there was an existing bundle for the specified location, then that bundle must still be in the state it was prior to calling this method.

Returns The Bundle object of the installed bundle.

Throws BundleException— If the installation failed. BundleException types thrown by this method include: BundleException.READ_ERROR, BundleException.DUPLICATE_BUNDLE_ERROR, BundleException.MANIFEST_ERROR, and BundleException.REJECTED_BY_HOOK.

SecurityException— If the caller does not have the appropriate AdminPermission[installed bundle,LIFECYCLE], and the Java Runtime Environment supports permissions.

IllegalStateException— If this BundleContext is no longer valid.

10.1.7.20 public Bundle installBundle(String location) throws BundleException

location The location identifier of the bundle to install.

- Installs a bundle from the specified location identifier.

This method performs the same function as calling installBundle(String,InputStream) with the specified location identifier and a null InputStream.

Returns The Bundle object of the installed bundle.

Throws BundleException— If the installation failed. BundleException types thrown by this method include: BundleException.READ_ERROR, BundleException.DUPLICATE_BUNDLE_ERROR, BundleException.MANIFEST_ERROR, and BundleException.REJECTED_BY_HOOK.

SecurityException— If the caller does not have the appropriate AdminPermission[installed bundle,LIFECYCLE], and the Java Runtime Environment supports permissions.

IllegalStateException— If this BundleContext is no longer valid.

See Also installBundle(String,InputStream)

10.1.7.21 public ServiceRegistration<?> registerService(String[] clazzes, Object service, Dictionary<String, ?> properties)

clazzes The class names under which the service can be located. The class names in this array will be stored in the service's properties under the key Constants.OBJECTCLASS.

service The service object or an object implementing ServiceFactory.

properties The properties for this service. The keys in the properties object must all be String objects. See Constants for a list of standard service property keys. Changes should not be made to this object after calling this method. To update the service's properties the `ServiceRegistration.setProperties(Dictionary)` method must be called. The set of properties may be null if the service has no properties.

- Registers the specified service object with the specified properties under the specified class names into the Framework. A `ServiceRegistration` object is returned. The `ServiceRegistration` object is for the private use of the bundle registering the service and should not be shared with other bundles. The registering bundle is defined to be the context bundle. Other bundles can locate the service by using one of the `getServiceReferences(Class, String)`, `getServiceReferences(String, String)`, `getServiceReference(Class)` or `getServiceReference(String)` methods.

A bundle can register a service object that implements the `ServiceFactory` interface to have more flexibility in providing service objects to other bundles.

The following steps are required to register a service:

1. If service does not implement `ServiceFactory`, an `IllegalArgumentException` is thrown if service is not an instance of all the specified class names.
2. The Framework adds the following service properties to the service properties from the specified `Dictionary` (which may be null):
 - A property named `Constants.SERVICE_ID` identifying the registration number of the service
 - A property named `Constants.OBJECTCLASS` containing all the specified classes.
 - A property named `Constants.SERVICE_SCOPE` identifying the scope of the service.
 - A property named `Constants.SERVICE_BUNDLEID` identifying the context bundle.

Properties with these names in the specified `Dictionary` will be ignored.
3. The service is added to the Framework service registry and may now be used by other bundles.
4. A service event of type `ServiceEvent.REGISTERED` is fired.
5. A `ServiceRegistration` object for this registration is returned.

Returns A `ServiceRegistration` object for use by the bundle registering the service to update the service's properties or to unregister the service.

Throws `IllegalArgumentException`– If one of the following is true:

- service is null.
- service does not implement `ServiceFactory` and is not an instance of all the specified classes.
- properties contains case variants of the same key name.

`SecurityException`– If the caller does not have the `ServicePermission` to register the service for all the named classes and the Java Runtime Environment supports permissions.

`IllegalStateException`– If this `BundleContext` is no longer valid.

See Also `ServiceRegistration`, `PrototypeServiceFactory`, `ServiceFactory`

10.1.7.22 **public ServiceRegistration<?> registerService(String clazz, Object service, Dictionary<String, ?> properties)**

clazz The class name under which the service can be located.

service The service object or an object implementing `ServiceFactory`.

properties The properties for this service.

- Registers the specified service object with the specified properties under the specified class name with the Framework.

This method is otherwise identical to `registerService(String[], Object, Dictionary)` and is provided as a convenience when service will only be registered under a single class name. Note that even in this

case the value of the service's Constants.OBJECTCLASS property will be an array of string, rather than just a single string.

Returns A ServiceRegistration object for use by the bundle registering the service to update the service's properties or to unregister the service.

Throws IllegalStateException– If this BundleContext is no longer valid.

See Also registerService(String[], Object, Dictionary)

10.1.7.23 **public ServiceRegistration<S> registerService(Class<S> clazz, S service, Dictionary<String, ?> properties)**

Type Parameters <S>

<S> Type of Service.

clazz The class under whose name the service can be located.

service The service object or an object implementing ServiceFactory.

properties The properties for this service.

- Registers the specified service object with the specified properties under the name of the specified class with the Framework.

This method is otherwise identical to registerService(String, Object, Dictionary) and is provided to return a type safe ServiceRegistration.

Returns A ServiceRegistration object for use by the bundle registering the service to update the service's properties or to unregister the service.

Throws IllegalStateException– If this BundleContext is no longer valid.

See Also registerService(String, Object, Dictionary)

Since 1.6

10.1.7.24 **public ServiceRegistration<S> registerService(Class<S> clazz, ServiceFactory<S> factory, Dictionary<String, ?> properties)**

Type Parameters <S>

<S> Type of Service.

clazz The class under whose name the service can be located.

factory The ServiceFactory object.

properties The properties for this service.

- Registers the specified service factory object with the specified properties under the name of the specified class with the Framework.

This method is otherwise identical to registerService(Class, Object, Dictionary) and is provided to return a type safe ServiceRegistration when registering a ServiceFactory.

Returns A ServiceRegistration object for use by the bundle registering the service to update the service's properties or to unregister the service.

Throws IllegalStateException– If this BundleContext is no longer valid.

See Also registerService(Class, Object, Dictionary)

Since 1.8

10.1.7.25 **public void removeBundleListener(BundleListener listener)**

listener The BundleListener object to be removed.

- Removes the specified BundleListener object from the context bundle's list of listeners.

If listener is not contained in the context bundle's list of listeners, this method does nothing.

Throws `IllegalStateException`– If this `BundleContext` is no longer valid.

`SecurityException`– If listener is a `SynchronousBundleListener` and the caller does not have the appropriate `AdminPermission[context bundle, LISTENER]`, and the Java Runtime Environment supports permissions.

10.1.7.26 **public void removeFrameworkListener(FrameworkListener listener)**

listener The `FrameworkListener` object to be removed.

- Removes the specified `FrameworkListener` object from the context bundle's list of listeners.

If listener is not contained in the context bundle's list of listeners, this method does nothing.

Throws `IllegalStateException`– If this `BundleContext` is no longer valid.

10.1.7.27 **public void removeServiceListener(ServiceListener listener)**

listener The `ServiceListener` to be removed.

- Removes the specified `ServiceListener` object from the context bundle's list of listeners.

If listener is not contained in this context bundle's list of listeners, this method does nothing.

Throws `IllegalStateException`– If this `BundleContext` is no longer valid.

10.1.7.28 **public boolean ungetService(ServiceReference<?> reference)**

reference A reference to the service to be released.

- Releases the service object for the service referenced by the specified `ServiceReference` object. If the context bundle's use count for the service is zero, this method returns false. Otherwise, the context bundle's use count for the service is decremented by one.

The service object must no longer be used and all references to it should be destroyed when a bundle's use count for the service drops to zero.

The following steps are required to release the service object:

1. If the context bundle's use count for the service is zero or the service has been unregistered, false is returned.
2. The context bundle's use count for the service is decremented by one.
3. If the context bundle's use count for the service is now zero and the service has bundle or prototype scope, the `ServiceFactory.ungetService(Bundle, ServiceRegistration, Object)` method is called to release the service object for the context bundle.
4. true is returned.

Returns false if the context bundle's use count for the service is zero or if the service has been unregistered; true otherwise.

Throws `IllegalStateException`– If this `BundleContext` is no longer valid.

`IllegalArgumentException`– If the specified `ServiceReference` was not created by the same framework instance as this `BundleContext`.

See Also `getService(ServiceReference)`, `ServiceFactory`

10.1.8 **public class BundleEvent extends EventObject**

An event from the Framework describing a bundle lifecycle change.

BundleEvent objects are delivered to SynchronousBundleListeners and BundleListeners when a change occurs in a bundle's lifecycle. A type code is used to identify the event type for future extensibility.

OSGi Alliance reserves the right to extend the set of types.

See Also BundleListener, SynchronousBundleListener

Concurrency Immutable

10.1.8.1 public static final int INSTALLED = 1

The bundle has been installed.

See Also BundleContext.installBundle(String)

10.1.8.2 public static final int LAZY_ACTIVATION = 512

The bundle will be lazily activated.

The bundle has a lazy activation policy and is waiting to be activated. It is now in the STARTING state and has a valid BundleContext. This event is only delivered to SynchronousBundleListeners. It is not delivered to BundleListeners.

Since 1.4

10.1.8.3 public static final int RESOLVED = 32

The bundle has been resolved.

See Also Bundle.RESOLVED

Since 1.3

10.1.8.4 public static final int STARTED = 2

The bundle has been started.

The bundle's BundleActivator start method has been executed if the bundle has a bundle activator class.

See Also Bundle.start()

10.1.8.5 public static final int STARTING = 128

The bundle is about to be activated.

The bundle's BundleActivator start method is about to be called if the bundle has a bundle activator class. This event is only delivered to SynchronousBundleListeners. It is not delivered to BundleListeners.

See Also Bundle.start()

Since 1.3

10.1.8.6 public static final int STOPPED = 4

The bundle has been stopped.

The bundle's BundleActivator stop method has been executed if the bundle has a bundle activator class.

See Also Bundle.stop()

10.1.8.7 public static final int STOPPING = 256

The bundle is about to be deactivated.

The bundle's BundleActivator stop method is about to be called if the bundle has a bundle activator class. This event is only delivered to SynchronousBundleListener s. It is not delivered to BundleListeners.

See Also Bundle.stop()

Since 1.3

10.1.8.8 **public static final int UNINSTALLED = 16**

The bundle has been uninstalled.

See Also Bundle.uninstall()

10.1.8.9 **public static final int UNRESOLVED = 64**

The bundle has been unresolved.

See Also Bundle.INSTALLED

Since 1.3

10.1.8.10 **public static final int UPDATED = 8**

The bundle has been updated.

See Also Bundle.update()

10.1.8.11 **public BundleEvent(int type, Bundle bundle, Bundle origin)**

type The event type.

bundle The bundle which had a lifecycle change.

origin The bundle which is the origin of the event. For the event type INSTALLED, this is the bundle whose context was used to install the bundle. Otherwise it is the bundle itself.

- Creates a bundle event of the specified type.

Since 1.6

10.1.8.12 **public BundleEvent(int type, Bundle bundle)**

type The event type.

bundle The bundle which had a lifecycle change. This bundle is used as the origin of the event.

- Creates a bundle event of the specified type.

10.1.8.13 **public Bundle getBundle()**

- Returns the bundle which had a lifecycle change. This bundle is the source of the event.

Returns The bundle that had a change occur in its lifecycle.

10.1.8.14 **public Bundle getOrigin()**

- Returns the bundle that was the origin of the event.

For the event type INSTALLED, this is the bundle whose context was used to install the bundle. Otherwise it is the bundle itself.

Returns The bundle that was the origin of the event.

Since 1.6

10.1.8.15 **public int getType()**

- Returns the type of lifecycle event. The type values are:

- INSTALLED
- RESOLVED
- LAZY_ACTIVATION
- STARTING
- STARTED
- STOPPING
- STOPPED
- UPDATED
- UNRESOLVED
- UNINSTALLED

Returns The type of lifecycle event.

10.1.9 **public class BundleException extends Exception**

A Framework exception used to indicate that a bundle lifecycle problem occurred.

A BundleException object is created by the Framework to denote an exception condition in the lifecycle of a bundle. BundleExceptions should not be created by bundle developers. A type code is used to identify the exception type for future extendability.

OSGi Alliance reserves the right to extend the set of types.

This exception conforms to the general purpose exception chaining mechanism.

10.1.9.1 **public static final int ACTIVATOR_ERROR = 5**

The bundle activator was in error.

Since 1.5

10.1.9.2 **public static final int DUPLICATE_BUNDLE_ERROR = 9**

The install or update operation failed because another already installed bundle has the same symbolic name and version. This exception type will only occur if the framework is configured to only allow a single bundle to be installed for a given symbolic name and version.

See Also Constants.FRAMEWORK_BSNVERSION

Since 1.5

10.1.9.3 **public static final int INVALID_OPERATION = 2**

The operation was invalid.

Since 1.5

10.1.9.4 **public static final int MANIFEST_ERROR = 3**

The bundle manifest was in error.

Since 1.5

10.1.9.5 **public static final int NATIVECODE_ERROR = 8**

The bundle could not be resolved due to an error with the Bundle-NativeCode header.

Since 1.5

10.1.9.6 **public static final int READ_ERROR = 11**

The framework received an error while reading the input stream for a bundle.

Since 1.6

10.1.9.7 **public static final int REJECTED_BY_HOOK = 12**

A framework hook rejected the operation.

Since 1.6

10.1.9.8 **public static final int RESOLVE_ERROR = 4**

The bundle was not resolved.

Since 1.5

10.1.9.9 **public static final int SECURITY_ERROR = 6**

The operation failed due to insufficient permissions.

Since 1.5

10.1.9.10 **public static final int START_TRANSIENT_ERROR = 10**

The start transient operation failed because the start level of the bundle is greater than the current framework start level

Since 1.5

10.1.9.11 **public static final int STATECHANGE_ERROR = 7**

The operation failed to complete the requested lifecycle state change.

Since 1.5

10.1.9.12 **public static final int UNSPECIFIED = 0**

No exception type is specified.

Since 1.5

10.1.9.13 **public static final int UNSUPPORTED_OPERATION = 1**

The operation was unsupported. This type can be used anywhere a BundleException can be thrown.

Since 1.5

10.1.9.14 **public BundleException(String msg, Throwable cause)**

msg The associated message.

cause The cause of this exception.

- Creates a BundleException with the specified message and exception cause.

10.1.9.15 **public BundleException(String msg)**

msg The message.

- Creates a BundleException with the specified message.

10.1.9.16 **public BundleException(String msg, int type, Throwable cause)**

msg The associated message.

type The type for this exception.

cause The cause of this exception.

- Creates a BundleException with the specified message, type and exception cause.

Since 1.5

10.1.9.17 **public BundleException(String msg, int type)**

msg The message.

type The type for this exception.

- Creates a BundleException with the specified message and type.

Since 1.5

10.1.9.18 **public Throwable getCause()**

- Returns the cause of this exception or null if no cause was set.

Returns The cause of this exception or null if no cause was set.

Since 1.3

10.1.9.19 **public Throwable getNestedException()**

- Returns the cause of this exception or null if no cause was specified when this exception was created. This method predates the general purpose exception chaining mechanism. The `getCause()` method is now the preferred means of obtaining this information.

Returns The result of calling `getCause()`.

10.1.9.20 **public int getType()**

- Returns the type for this exception or UNSPECIFIED if the type was unspecified or unknown.

Returns The type of this exception.

Since 1.5

10.1.9.21 **public Throwable initCause(Throwable cause)**

cause The cause of this exception.

- Initializes the cause of this exception to the specified value.

Returns This exception.

Throws IllegalArgumentException– If the specified cause is this exception.

IllegalStateException– If the cause of this exception has already been set.

Since 1.3

10.1.10 **public interface BundleListener**
extends EventListener

A BundleEvent listener. BundleListener is a listener interface that may be implemented by a bundle developer. When a BundleEvent is fired, it is asynchronously delivered to a BundleListener. The Framework delivers BundleEvent objects to a BundleListener in order and must not concurrently call a BundleListener.

A BundleListener object is registered with the Framework using the `BundleContext.addBundleListener(BundleListener)` method. BundleListeners are called with a BundleEvent object when a bundle has been installed, resolved, started, stopped, updated, unresolved, or uninstalled.

See Also BundleEvent

Concurrency Not Thread-safe

10.1.10.1 public void bundleChanged(BundleEvent event)*event* The BundleEvent.

- Receives notification that a bundle has had a lifecycle change.

10.1.11 public final class BundlePermission extends BasicPermission

A bundle's authority to require or provide a bundle or to receive or attach fragments.

A bundle symbolic name defines a unique fully qualified name. Wildcards may be used.

```
name ::= <symbolic name> | <symbolic name ending in ".*"> | *
```

Examples:

```
org.osgi.example.bundle
org.osgi.example.*
*
```

BundlePermission has four actions: provide, require, host, and fragment. The provide action implies the require action.

Since 1.3*Concurrency* Thread-safe**10.1.11.1 public static final String FRAGMENT = "fragment"**

The action string fragment.

10.1.11.2 public static final String HOST = "host"

The action string host.

10.1.11.3 public static final String PROVIDE = "provide"

The action string provide. The provide action implies the require action.

10.1.11.4 public static final String REQUIRE = "require"

The action string require. The require action is implied by the provide action.

10.1.11.5 public BundlePermission(String symbolicName, String actions)*symbolicName* The bundle symbolic name.*actions* provide,require, host, fragment (canonical order).

- Defines the authority to provide and/or require and or specify a host fragment symbolic name within the OSGi environment.

Bundle Permissions are granted over all possible versions of a bundle. A bundle that needs to provide a bundle must have the appropriate BundlePermission for the symbolic name; a bundle that requires a bundle must have the appropriate BundlePermission for that symbolic name; a bundle that specifies a fragment host must have the appropriate BundlePermission for that symbolic name.

10.1.11.6 public boolean equals(Object obj)*obj* The object to test for equality with this BundlePermission object.

- Determines the equality of two BundlePermission objects. This method checks that specified bundle has the same bundle symbolic name and BundlePermission actions as this BundlePermission object.

Returns true if obj is a BundlePermission, and has the same bundle symbolic name and actions as this BundlePermission object; false otherwise.

10.1.11.7 **public String getActions()**

- Returns the canonical string representation of the BundlePermission actions.
Always returns present BundlePermission actions in the following order: provide, require, host, fragment.

Returns Canonical string representation of the BundlePermission actions.

10.1.11.8 **public int hashCode()**

- Returns the hash code value for this object.

Returns A hash code value for this object.

10.1.11.9 **public boolean implies(Permission p)**

- p* The requested permission.
- Determines if the specified permission is implied by this object.

This method checks that the symbolic name of the target is implied by the symbolic name of this object. The list of BundlePermission actions must either match or allow for the list of the target object to imply the target BundlePermission action.

The permission to provide a bundle implies the permission to require the named symbolic name.

```
x.y.*, "provide" -> x.y.z, "provide" is true
*, "require" -> x.y, "require" is true
*, "provide" -> x.y, "require" is true
x.y, "provide" -> x.y.z, "provide" is false
```

Returns true if the specified BundlePermission action is implied by this object; false otherwise.

10.1.11.10 **public PermissionCollection newPermissionCollection()**

- Returns a new PermissionCollection object suitable for storing BundlePermission objects.

Returns A new PermissionCollection object.

10.1.12 **public interface BundleReference**

A reference to a Bundle.

Since 1.5

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.1.12.1 **public Bundle getBundle()**

- Returns the Bundle object associated with this BundleReference.

Returns The Bundle object associated with this BundleReference.

10.1.13 **public final class CapabilityPermission extends BasicPermission**

A bundle's authority to provide or require a capability.

- The provide action allows a bundle to provide a capability matching the specified filter.
- The require action allows a bundle to require a capability matching the specified filter.

Since 1.6

Concurrency Thread-safe

10.1.13.1 **public static final String PROVIDE = "provide"**

The action string provide.

10.1.13.2 **public static final String REQUIRE = "require"**

The action string require.

10.1.13.3 **public CapabilityPermission(String name, String actions)**

name The capability namespace or a filter over the attributes.

actions require,provide (canonical order)

- Create a new CapabilityPermission.

The name is specified as a dot-separated string. Wildcards may be used.

```
name ::= <namespace> | <namespace ending in ".*"> | *
```

Examples:

```
com.acme.capability.*
org.foo.capability
*
```

For the require action, the name can also be a filter expression. The filter gives access to the capability attributes as well as the following attributes:

- *signer* - A Distinguished Name chain used to sign the bundle providing the capability. Wildcards in a DN are not matched according to the filter string rules, but according to the rules defined for a DN chain.
- *location* - The location of the bundle providing the capability.
- *id* - The bundle ID of the bundle providing the capability.
- *name* - The symbolic name of the bundle providing the capability.
- *capability.namespace* - The namespace of the required capability.

Since the above attribute names may conflict with attribute names of a capability, you can prefix an attribute name with '@' in the filter expression to match against the capability attributes and not one of the above attributes. Filter attribute names are processed in a case sensitive manner.

There are two possible actions: require and provide. The require permission allows the owner of this permission to require a capability matching the attributes. The provide permission allows the bundle to provide a capability in the specified capability namespace.

Throws `IllegalArgumentException`– If the specified name is a filter expression and either the specified action is not require or the filter has an invalid syntax.

10.1.13.4 **public CapabilityPermission(String namespace, Map<String, ?> attributes, Bundle providingBundle, String actions)**

namespace The requested capability namespace.

attributes The requested capability attributes.

providingBundle The bundle providing the requested capability.

actions The action require.

- Creates a new requested CapabilityPermission object to be used by code that must perform check-Permission for the require action. CapabilityPermission objects created with this constructor cannot be added to a CapabilityPermission permission collection.

Throws IllegalArgumentException– If the specified action is not require or attributes or providingBundle are null.

10.1.13.5 **public boolean equals(Object obj)**

obj The object to test for equality.

- Determines the equality of two CapabilityPermission objects. Checks that specified object has the same name and action as this CapabilityPermission.

Returns true if obj is a CapabilityPermission, and has the same name and actions as this CapabilityPermission object; false otherwise.

10.1.13.6 **public String getActions()**

- Returns the canonical string representation of the actions. Always returns present actions in the following order: require, provide.

Returns The canonical string representation of the actions.

10.1.13.7 **public int hashCode()**

- Returns the hash code value for this object.

Returns Hash code value for this object.

10.1.13.8 **public boolean implies(Permission p)**

p The target permission to check.

- Determines if a CapabilityPermission object "implies" the specified permission.

Returns true if the specified permission is implied by this object; false otherwise.

10.1.13.9 **public PermissionCollection newPermissionCollection()**

- Returns a new PermissionCollection object for storing CapabilityPermission objects.

Returns A new PermissionCollection object suitable for storing CapabilityPermission objects.

10.1.14 **public interface Configurable**

Supports a configuration object.

Configurable is an interface that should be used by a bundle developer in support of a configurable service. Bundles that need to configure a service may test to determine if the service object is an instance of Configurable.

Deprecated As of 1.2. Please use Configuration Admin service.

10.1.14.1 **public Object getConfigurationObject()**

- Returns this service's configuration object.

Services implementing Configurable should take care when returning a service configuration object since this object is probably sensitive.

If the Java Runtime Environment supports permissions, it is recommended that the caller is checked for some appropriate permission before returning the configuration object.

Returns The configuration object for this service.

Throws `SecurityException`— If the caller does not have an appropriate permission and the Java Runtime Environment supports permissions.

Deprecated As of 1.2. Please use Configuration Admin service.

10.1.15 **public interface Constants**

Defines standard names for the OSGi environment system properties, service properties, and Manifest header attribute keys.

The values associated with these keys are of type `String`, unless otherwise indicated.

Since 1.1

Provider Type Consumers of this API must not implement this type

10.1.15.1 **public static final String ACTIVATION_LAZY = "lazy"**

Bundle activation policy declaring the bundle must be activated when the first class load is made from the bundle.

A bundle with the lazy activation policy that is started with the `START_ACTIVATION_POLICY` option will wait in the `STARTING` state until the first class load from the bundle occurs. The bundle will then be activated before the class is returned to the requester.

The activation policy value is specified as in the `Bundle-ActivationPolicy` manifest header like:

```
Bundle-ActivationPolicy: lazy
```

See Also `BUNDLE_ACTIVATIONPOLICY`, `Bundle.start(int)`, `Bundle.START_ACTIVATION_POLICY`

Since 1.4

10.1.15.2 **public static final String BUNDLE_ACTIVATIONPOLICY = "Bundle-ActivationPolicy"**

Manifest header identifying the bundle's activation policy.

The header value may be retrieved from the `Dictionary` object returned by the `Bundle.getHeaders` method.

See Also `ACTIVATION_LAZY`, `INCLUDE_DIRECTIVE`, `EXCLUDE_DIRECTIVE`

Since 1.4

10.1.15.3 **public static final String BUNDLE_ACTIVATOR = "Bundle-Activator"**

Manifest header identifying the bundle's activator class.

If present, this header specifies the name of the bundle resource class that implements the `Bundle-Activator` interface and whose `start` and `stop` methods are called by the Framework when the bundle is started and stopped, respectively.

The header value may be retrieved from the `Dictionary` object returned by the `Bundle.getHeaders` method.

10.1.15.4 **public static final String BUNDLE_CATEGORY = "Bundle-Category"**

Manifest header identifying the bundle's category.

The header value may be retrieved from the `Dictionary` object returned by the `Bundle.getHeaders` method.

- 10.1.15.5** **public static final String BUNDLE_CLASSPATH = "Bundle-ClassPath"**
Manifest header identifying a list of directories and embedded JAR files, which are bundle resources used to extend the bundle's classpath.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
- 10.1.15.6** **public static final String BUNDLE_CONTACTADDRESS = "Bundle-ContactAddress"**
Manifest header identifying the contact address where problems with the bundle may be reported; for example, an email address.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
- 10.1.15.7** **public static final String BUNDLE_COPYRIGHT = "Bundle-Copyright"**
Manifest header identifying the bundle's copyright information.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
- 10.1.15.8** **public static final String BUNDLE_DESCRIPTION = "Bundle-Description"**
Manifest header containing a brief description of the bundle's functionality.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
- 10.1.15.9** **public static final String BUNDLE_DEVELOPERS = "Bundle-Developers"**
Manifest header identifying the bundle's developers.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
Since 1.9
- 10.1.15.10** **public static final String BUNDLE_DOCURL = "Bundle-DocURL"**
Manifest header identifying the bundle's documentation URL, from which further information about the bundle may be obtained.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
- 10.1.15.11** **public static final String BUNDLE_ICON = "Bundle-Icon"**
Manifest header identifying the bundle's icon URLs.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
Since 1.8
- 10.1.15.12** **public static final String BUNDLE_LICENSE = "Bundle-License"**
Manifest header identifying the bundle's license information.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
Since 1.8
- 10.1.15.13** **public static final String BUNDLE_LOCALIZATION = "Bundle-Localization"**
Manifest header identifying the base name of the bundle's localization entries.

The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.

See Also BUNDLE_LOCALIZATION_DEFAULT_BASENAME

Since 1.3

10.1.15.14 **public static final String BUNDLE_LOCALIZATION_DEFAULT_BASENAME = "OSGI-INF/1on/bundle"**

Default value for the Bundle-Localization manifest header.

See Also BUNDLE_LOCALIZATION

Since 1.3

10.1.15.15 **public static final String BUNDLE_MANIFESTVERSION = "Bundle-ManifestVersion"**

Manifest header identifying the bundle manifest version. A bundle manifest may express the version of the syntax in which it is written by specifying a bundle manifest version. Bundles exploiting OSGi Release 4, or later, syntax must specify a bundle manifest version.

The bundle manifest version defined by OSGi Release 4 or, more specifically, by version 1.3 of the OSGi Core Specification is "2".

The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.

Since 1.3

10.1.15.16 **public static final String BUNDLE_NAME = "Bundle-Name"**

Manifest header identifying the bundle's name.

The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.

10.1.15.17 **public static final String BUNDLE_NATIVECODE = "Bundle-NativeCode"**

Manifest header identifying a number of hardware environments and the native language code libraries that the bundle is carrying for each of these environments.

The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.

10.1.15.18 **public static final String BUNDLE_NATIVECODE_LANGUAGE = "language"**

Manifest header attribute identifying the language in which the native bundle code is written specified in the Bundle-NativeCode manifest header. See ISO 639 for possible values.

The attribute value is encoded in the Bundle-NativeCode manifest header like:

```
Bundle-NativeCode: http.so ; language=nl_be ...
```

See Also BUNDLE_NATIVECODE

10.1.15.19 **public static final String BUNDLE_NATIVECODE_OSNAME = "osname"**

Manifest header attribute identifying the operating system required to run native bundle code specified in the Bundle-NativeCode manifest header).

The attribute value is encoded in the Bundle-NativeCode manifest header like:

```
Bundle-NativeCode: http.so ; osname=Linux ...
```

See Also BUNDLE_NATIVECODE

10.1.15.20 **public static final String BUNDLE_NATIVECODE_OSVERSION = "osversion"**

Manifest header attribute identifying the operating system version required to run native bundle code specified in the Bundle-NativeCode manifest header).

The attribute value is encoded in the Bundle-NativeCode manifest header like:

```
Bundle-NativeCode: http.so ; osversion="2.34" ...
```

See Also BUNDLE_NATIVECODE

10.1.15.21 **public static final String BUNDLE_NATIVECODE_PROCESSOR = "processor"**

Manifest header attribute identifying the processor required to run native bundle code specified in the Bundle-NativeCode manifest header).

The attribute value is encoded in the Bundle-NativeCode manifest header like:

```
Bundle-NativeCode: http.so ; processor=x86 ...
```

See Also BUNDLE_NATIVECODE

10.1.15.22 **public static final String BUNDLE_REQUIREDEXECUTIONENVIRONMENT = "Bundle-RequiredExecutionEnvironment"**

Manifest header identifying the required execution environment for the bundle. The service platform may run this bundle if any of the execution environments named in this header matches one of the execution environments it implements.

The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.2

Deprecated As of 1.6. Replaced by the osgi.ee capability.

10.1.15.23 **public static final String BUNDLE_SCM = "Bundle-SCM"**

Manifest header identifying the bundle's software configuration management system.

The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.9

10.1.15.24 **public static final String BUNDLE_SYMBOLICNAME = "Bundle-SymbolicName"**

Manifest header identifying the bundle's symbolic name.

The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.3

10.1.15.25 **public static final String BUNDLE_SYMBOLICNAME_ATTRIBUTE = "bundle-symbolic-name"**

Manifest header attribute identifying the symbolic name of a bundle that exports a package specified in the Import-Package manifest header.

The attribute value is encoded in the Import-Package manifest header like:

```
Import-Package: org.osgi.framework;  
bundle-symbolic-name="com.acme.module.test"
```

See Also IMPORT_PACKAGE

Since 1.3

- 10.1.15.26** **public static final String BUNDLE_UPDATELOCATION = "Bundle-UpdateLocation"**
- Manifest header identifying the location from which a new bundle version is obtained during a bundle update operation.
- The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.
- 10.1.15.27** **public static final String BUNDLE_VENDOR = "Bundle-Vendor"**
- Manifest header identifying the bundle's vendor.
- The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.
- 10.1.15.28** **public static final String BUNDLE_VERSION = "Bundle-Version"**
- Manifest header identifying the bundle's version.
- The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.
- 10.1.15.29** **public static final String BUNDLE_VERSION_ATTRIBUTE = "bundle-version"**
- Manifest header attribute identifying a range of versions for a bundle specified in the `Require-Bundle` or `Fragment-Host` manifest headers. The default value is `o.o.o`.
- The attribute value is encoded in the `Require-Bundle` manifest header like:
- ```
Require-Bundle: com.acme.module.test; bundle-version="1.1"
Require-Bundle: com.acme.module.test; bundle-version="[1.0,2.0)"
```
- The `bundle-version` attribute value uses a mathematical interval notation to specify a range of bundle versions. A `bundle-version` attribute value specified as a single version means a version range that includes any bundle version greater than or equal to the specified version.
- See Also* `REQUIRE_BUNDLE`
- Since* 1.3
- 10.1.15.30**      **public static final String DYNAMICIMPORT\_PACKAGE = "DynamicImport-Package"**
- Manifest header identifying the packages that the bundle may dynamically import during execution.
- The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.
- Since* 1.2
- 10.1.15.31**      **public static final String EFFECTIVE\_ACTIVE = "active"**
- Manifest header directive value identifying a capability that is effective at active time. Capabilities with an effective time of active are ignored by the resolver.
- The directive value is encoded in the `Provide-Capability` manifest header like:
- ```
Provide-Capability: com.acme.capability; effective:="active"
```
- See Also* `EFFECTIVE_DIRECTIVE`
- Since* 1.6
- 10.1.15.32** **public static final String EFFECTIVE_DIRECTIVE = "effective"**
- Manifest header directive identifying the effective time of the provided capability. The default value is `resolve`.

The directive value is encoded in the Provide-Capability manifest header like:

```
Provide-Capability: com.acme.capability; effective:="resolve"
```

See Also PROVIDE_CAPABILITY, EFFECTIVE_RESOLVE, EFFECTIVE_ACTIVE

Since 1.6

10.1.15.33 **public static final String EFFECTIVE_RESOLVE = "resolve"**

Manifest header directive value identifying a capability that is effective at resolve time. Capabilities with an effective time of resolve are the only capabilities which are processed by the resolver.

The directive value is encoded in the Provide-Capability manifest header like:

```
Provide-Capability: com.acme.capability; effective:="resolve"
```

See Also EFFECTIVE_DIRECTIVE

Since 1.6

10.1.15.34 **public static final String EXCLUDE_DIRECTIVE = "exclude"**

Manifest header directive identifying a list of classes to exclude in the exported package..

This directive is used by the Export-Package manifest header to identify a list of classes of the specified package which must not be allowed to be exported. The directive value is encoded in the Export-Package manifest header like:

```
Export-Package: org.osgi.framework; exclude:="*Impl"
```

This directive is also used by the Bundle-ActivationPolicy manifest header to identify the packages from which class loads will not trigger lazy activation. The directive value is encoded in the Bundle-ActivationPolicy manifest header like:

```
Bundle-ActivationPolicy: lazy; exclude:="org.osgi.framework"
```

See Also EXPORT_PACKAGE, BUNDLE_ACTIVATIONPOLICY

Since 1.3

10.1.15.35 **public static final String EXPORT_PACKAGE = "Export-Package"**

Manifest header identifying the packages that the bundle offers to the Framework for export.

The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

10.1.15.36 **public static final String EXPORT_SERVICE = "Export-Service"**

Manifest header identifying the fully qualified class names of the services that the bundle may register (used for informational purposes only).

The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Deprecated As of 1.2.

10.1.15.37 **public static final String EXTENSION_BOOTCLASSPATH = "bootclasspath"**

Manifest header directive value identifying the type of extension fragment. An extension fragment type of bootclasspath indicates that the extension fragment is to be loaded by the boot class loader.

The directive value is encoded in the Fragment-Host manifest header like:

```
Fragment-Host: system.bundle; extension="bootclasspath"
```

See Also EXTENSION_DIRECTIVE

Since 1.3

Deprecated As of 1.9.

10.1.15.38 **public static final String EXTENSION_BUNDLE_ACTIVATOR = "ExtensionBundle-Activator"**

Manifest header identifying the extension bundle's activator class.

If present, this header specifies the name of the extension bundle resource class that implements the BundleActivator interface and whose start and stop methods are called by the Framework when the Framework is initialized and shutdown, respectively.

Since 1.8

10.1.15.39 **public static final String EXTENSION_DIRECTIVE = "extension"**

Manifest header directive identifying the type of the extension fragment.

The directive value is encoded in the Fragment-Host manifest header like:

```
Fragment-Host: system.bundle; extension="framework"
```

The default value is framework.

See Also FRAGMENT_HOST, EXTENSION_FRAMEWORK

Since 1.3

10.1.15.40 **public static final String EXTENSION_FRAMEWORK = "framework"**

Manifest header directive value identifying the type of extension fragment. An extension fragment type of framework indicates that the extension fragment is to be loaded by the framework's class loader.

The directive value is encoded in the Fragment-Host manifest header like:

```
Fragment-Host: system.bundle; extension="framework"
```

See Also EXTENSION_DIRECTIVE

Since 1.3

10.1.15.41 **public static final String FILTER_DIRECTIVE = "filter"**

Manifest header directive identifying the capability filter specified in the Require-Capability manifest header.

The directive value is encoded in the Require-Capability manifest header like:

```
Require-Capability: com.acme.capability; filter="(someattr=somevalue)"
```

See Also REQUIRE_CAPABILITY

Since 1.6

10.1.15.42 **public static final String FRAGMENT_ATTACHMENT_ALWAYS = "always"**

Manifest header directive value identifying a fragment attachment type of always. A fragment attachment type of always indicates that fragments are allowed to attach to the host bundle at any time (while the host is resolved or during the process of resolving the host bundle).

The directive value is encoded in the Bundle-SymbolicName manifest header like:

```
Bundle-SymbolicName: com.acme.module.test; fragment-attachment:="always"
```

See Also FRAGMENT_ATTACHMENT_DIRECTIVE

Since 1.3

10.1.15.43 **public static final String FRAGMENT_ATTACHMENT_DIRECTIVE = "fragment-attachment"**

Manifest header directive identifying if and when a fragment may attach to a host bundle. The default value is always.

The directive value is encoded in the Bundle-SymbolicName manifest header like:

```
Bundle-SymbolicName: com.acme.module.test; fragment-attachment:="never"
```

See Also BUNDLE_SYMBOLICNAME, FRAGMENT_ATTACHMENT_ALWAYS,
FRAGMENT_ATTACHMENT_RESOLVETIME, FRAGMENT_ATTACHMENT_NEVER

Since 1.3

10.1.15.44 **public static final String FRAGMENT_ATTACHMENT_NEVER = "never"**

Manifest header directive value identifying a fragment attachment type of never. A fragment attachment type of never indicates that no fragments are allowed to attach to the host bundle at any time.

The directive value is encoded in the Bundle-SymbolicName manifest header like:

```
Bundle-SymbolicName: com.acme.module.test; fragment-attachment:="never"
```

See Also FRAGMENT_ATTACHMENT_DIRECTIVE

Since 1.3

10.1.15.45 **public static final String FRAGMENT_ATTACHMENT_RESOLVETIME = "resolve-time"**

Manifest header directive value identifying a fragment attachment type of resolve-time. A fragment attachment type of resolve-time indicates that fragments are allowed to attach to the host bundle only during the process of resolving the host bundle.

The directive value is encoded in the Bundle-SymbolicName manifest header like:

```
Bundle-SymbolicName: com.acme.module.test;  
fragment-attachment:="resolve-time"
```

See Also FRAGMENT_ATTACHMENT_DIRECTIVE

Since 1.3

10.1.15.46 **public static final String FRAGMENT_HOST = "Fragment-Host"**

Manifest header identifying the symbolic name of another bundle for which that the bundle is a fragment.

The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.3

10.1.15.47 **public static final String FRAMEWORK_BEGINNING_STARTLEVEL = "org.osgi.framework.startlevel.beginning"**

Framework launching property specifying the beginning start level of the framework.

See Also Core Specification, Starting the Framework.

Since 1.5

- 10.1.15.48** **public static final String FRAMEWORK_BOOTDELEGATION = "org.osgi.framework.bootdelegation"**
- Framework launching property identifying packages for which the Framework must delegate class loading to the parent class loader of the bundle.
- The value of this property may be retrieved by calling the `BundleContext.getProperty` method.
- See Also* `FRAMEWORK_BUNDLE_PARENT`
- Since* 1.3
- 10.1.15.49** **public static final String FRAMEWORK_BSNVERSION = "org.osgi.framework.bsntversion"**
- Framework launching property specifying whether multiple bundles having the same symbolic name and version may be installed.
- Default value is managed in this release of the specification. This default may change in a future specification release. Therefore, code must not assume the default behavior is managed and should interrogate the value of this property to determine the behavior.
- The value of this property may be retrieved by calling the `BundleContext.getProperty` method.
- See Also* `FRAMEWORK_BSNVERSION_MULTIPLE`, `FRAMEWORK_BSNVERSION_SINGLE`, `FRAMEWORK_BSNVERSION_MANAGED`
- Since* 1.6
- 10.1.15.50** **public static final String FRAMEWORK_BSNVERSION_MANAGED = "managed"**
- Specifies the framework must consult the bundle collision hook services to determine if it will be an error to install a bundle or update a bundle to have the same symbolic name and version as another installed bundle. If no bundle collision hook services are registered, then it will be an error to install a bundle or update a bundle to have the same symbolic name and version as another installed bundle.
- See Also* `FRAMEWORK_BSNVERSION`, `BundleException.DUPLICATE_BUNDLE_ERROR`
- Since* 1.7
- 10.1.15.51** **public static final String FRAMEWORK_BSNVERSION_MULTIPLE = "multiple"**
- Specifies the framework will allow multiple bundles to be installed having the same symbolic name and version.
- See Also* `FRAMEWORK_BSNVERSION`
- Since* 1.6
- 10.1.15.52** **public static final String FRAMEWORK_BSNVERSION_SINGLE = "single"**
- Specifies the framework will only allow a single bundle to be installed for a given symbolic name and version. It will be an error to install a bundle or update a bundle to have the same symbolic name and version as another installed bundle.
- See Also* `FRAMEWORK_BSNVERSION`, `BundleException.DUPLICATE_BUNDLE_ERROR`
- Since* 1.6
- 10.1.15.53** **public static final String FRAMEWORK_BUNDLE_PARENT = "org.osgi.framework.bundle.parent"**
- Framework launching property specifying the parent class loader type for all bundle class loaders. Default value is `boot`.
- See Also* `FRAMEWORK_BUNDLE_PARENT_BOOT`, `FRAMEWORK_BUNDLE_PARENT_EXT`, `FRAMEWORK_BUNDLE_PARENT_APP`, `FRAMEWORK_BUNDLE_PARENT_FRAMEWORK`
- Since* 1.5

- 10.1.15.54** **public static final String FRAMEWORK_BUNDLE_PARENT_APP = "app"**
Specifies to use the application class loader as the parent class loader for all bundle class loaders. Depending on how the framework is launched, this may refer to the same class loader as FRAMEWORK_BUNDLE_PARENT_FRAMEWORK.
See Also FRAMEWORK_BUNDLE_PARENT
Since 1.5
- 10.1.15.55** **public static final String FRAMEWORK_BUNDLE_PARENT_BOOT = "boot"**
Specifies to use of the boot class loader as the parent class loader for all bundle class loaders.
See Also FRAMEWORK_BUNDLE_PARENT
Since 1.5
- 10.1.15.56** **public static final String FRAMEWORK_BUNDLE_PARENT_EXT = "ext"**
Specifies to use the extension class loader as the parent class loader for all bundle class loaders.
See Also FRAMEWORK_BUNDLE_PARENT
Since 1.5
- 10.1.15.57** **public static final String FRAMEWORK_BUNDLE_PARENT_FRAMEWORK = "framework"**
Specifies to use the framework class loader as the parent class loader for all bundle class loaders. The framework class loader is the class loader used to load the framework implementation. Depending on how the framework is launched, this may refer to the same class loader as FRAMEWORK_BUNDLE_PARENT_APP.
See Also FRAMEWORK_BUNDLE_PARENT
Since 1.5
- 10.1.15.58** **public static final String FRAMEWORK_COMMAND_ABSPATH = "abspath"**
Specified the substitution string for the absolute path of a file.
See Also FRAMEWORK_EXECPERMISSION
Since 1.6
- 10.1.15.59** **public static final String FRAMEWORK_EXECPERMISSION = "org.osgi.framework.command.execpermission"**
Framework launching property specifying an optional OS specific command to set file permissions on extracted native code. On some operating systems, it is required that native libraries be set to executable. This optional property allows you to specify the command. For example, on a UNIX style OS, this property could have the following value.

 `chmod +rx ${abspath}`

The `${abspath}` is used by the framework to substitute the actual absolute file path.
Since 1.5
- 10.1.15.60** **public static final String FRAMEWORK_EXECUTIONENVIRONMENT = "org.osgi.framework.executionenvironment"**
Framework launching property identifying execution environments provided by the Framework. The value of this property may be retrieved by calling the BundleContext.getProperty method.
Since 1.2
Deprecated As of 1.6. Replaced by the osgi.ee capability.

- 10.1.15.61** **public static final String FRAMEWORK_LANGUAGE = "org.osgi.framework.language"**
- Framework launching property identifying the Framework implementation language (see ISO 639 for possible values).
- The value of this property may be retrieved by calling the `BundleContext.getProperty` method.
- 10.1.15.62** **public static final String FRAMEWORK_LIBRARY_EXTENSIONS = "org.osgi.framework.library.extensions"**
- Framework launching property specifying a comma separated list of additional library file extensions that must be used when a bundle's class loader is searching for native libraries. If this property is not set, then only the library name returned by `System.mapLibraryName(String)` will be used to search. This is needed for certain operating systems which allow more than one extension for a library. For example, AIX allows library extensions of `.a` and `.so`, but `System.mapLibraryName(String)` will only return names with the `.a` extension.
- Since* 1.5
- 10.1.15.63** **public static final String FRAMEWORK_OS_NAME = "org.osgi.framework.os.name"**
- Framework launching property identifying the Framework host-computer's operating system.
- The value of this property may be retrieved by calling the `BundleContext.getProperty` method.
- 10.1.15.64** **public static final String FRAMEWORK_OS_VERSION = "org.osgi.framework.os.version"**
- Framework launching property identifying the Framework host-computer's operating system version number.
- The value of this property may be retrieved by calling the `BundleContext.getProperty` method.
- 10.1.15.65** **public static final String FRAMEWORK_PROCESSOR = "org.osgi.framework.processor"**
- Framework launching property identifying the Framework host-computer's processor name.
- The value of this property may be retrieved by calling the `BundleContext.getProperty` method.
- 10.1.15.66** **public static final String FRAMEWORK_SECURITY = "org.osgi.framework.security"**
- Framework launching property specifying the type of security manager the framework must use. If not specified then the framework will not set the VM security manager.
- See Also* `FRAMEWORK_SECURITY_OSGI`
- Since* 1.5
- 10.1.15.67** **public static final String FRAMEWORK_SECURITY_OSGI = "osgi"**
- Specifies that a security manager that supports all security aspects of the OSGi core specification including postponed conditions must be installed.
- If this value is specified and there is a security manager already installed, then a `SecurityException` must be thrown when the Framework is initialized.
- See Also* `FRAMEWORK_SECURITY`
- Since* 1.5
- 10.1.15.68** **public static final String FRAMEWORK_STORAGE = "org.osgi.framework.storage"**
- Framework launching property specifying the persistent storage area used by the framework. The value of this property must be a valid file path in the file system to a directory. If the specified directory does not exist then the framework will create the directory. If the specified path exists but is not a directory or if the framework fails to create the storage directory, then framework initialization must fail. The framework is free to use this directory as it sees fit. This area can not be shared with anything else.

If this property is not set, the framework should use a reasonable platform default for the persistent storage area.

Since 1.5

10.1.15.69 **public static final String FRAMEWORK_STORAGE_CLEAN = "org.osgi.framework.storage.clean"**

Framework launching property specifying if and when the persistent storage area for the framework should be cleaned. If this property is not set, then the framework storage area must not be cleaned.

See Also FRAMEWORK_STORAGE_CLEAN_ONFIRSTINIT

Since 1.5

10.1.15.70 **public static final String FRAMEWORK_STORAGE_CLEAN_ONFIRSTINIT = "onFirstInit"**

Specifies that the framework storage area must be cleaned before the framework is initialized for the first time. Subsequent inits, starts or updates of the framework will not result in cleaning the framework storage area.

Since 1.5

10.1.15.71 **public static final String FRAMEWORK_SYSTEMCAPABILITIES = "org.osgi.framework.system.capabilities"**

Framework launching property identifying capabilities which the system bundle must provide.

If this property is not specified then the framework must calculate a reasonable default value for the current execution environment.

The value of this property may be retrieved by calling the `BundleContext.getProperty` method.

Since 1.6

10.1.15.72 **public static final String FRAMEWORK_SYSTEMCAPABILITIES_EXTRA = "org.osgi.framework.system.capabilities.extra"**

Framework launching property identifying extra capabilities which the system bundle must additionally provide.

This property is useful for configuring extra system capabilities in addition to the system capabilities calculated by the framework.

The value of this property may be retrieved by calling the `BundleContext.getProperty` method.

See Also FRAMEWORK_SYSTEMCAPABILITIES

Since 1.6

10.1.15.73 **public static final String FRAMEWORK_SYSTEMPACKAGES = "org.osgi.framework.system.packages"**

Framework launching property identifying packages which the system bundle must export.

If this property is not specified then the framework must calculate a reasonable default value for the current execution environment.

The value of this property may be retrieved by calling the `BundleContext.getProperty` method.

Since 1.3

10.1.15.74 **public static final String FRAMEWORK_SYSTEMPACKAGES_EXTRA = "org.osgi.framework.system.packages.extra"**

Framework launching property identifying extra packages which the system bundle must export from the current execution environment.

This property is useful for configuring extra system packages in addition to the system packages calculated by the framework.

The value of this property may be retrieved by calling the `BundleContext.getProperty` method.

See Also `FRAMEWORK_SYSTEMPACKAGES`

Since 1.5

10.1.15.75 **public static final String FRAMEWORK_TRUST_REPOSITORIES = "org.osgi.framework.trust.repositories"**

Framework launching property specifying the trust repositories used by the framework. The value is a `java.io.File.pathSeparator` separated list of valid file paths to files that contain key stores. Key stores of type JKS must be supported and other key store types may be supported. The framework will use the key stores as trust repositories to authenticate certificates of trusted signers. The key stores are only used as read-only trust repositories to access public keys. No passwords are required to access the key stores' public keys.

Note that framework implementations are allowed to use other trust repositories in addition to the trust repositories specified by this property. How these other trust repositories are configured and populated is implementation specific.

Since 1.5

10.1.15.76 **public static final String FRAMEWORK_UUID = "org.osgi.framework.uuid"**

Framework environment property identifying the Framework's universally unique identifier (UUID). A UUID represents a 128-bit value. A new UUID is generated by the `Framework.init()` method each time a framework is initialized. The value of this property must conform to the UUID string representation specified in RFC 4122 [<http://www.ietf.org/rfc/rfc4122.txt>].

The value of this property may be retrieved by calling the `BundleContext.getProperty` method.

Since 1.6

10.1.15.77 **public static final String FRAMEWORK_VENDOR = "org.osgi.framework.vendor"**

Framework environment property identifying the Framework implementation vendor.

The value of this property may be retrieved by calling the `BundleContext.getProperty` method.

10.1.15.78 **public static final String FRAMEWORK_VERSION = "org.osgi.framework.version"**

Framework environment property identifying the Framework version.

The value of this property may be retrieved by calling the `BundleContext.getProperty` method.

10.1.15.79 **public static final String FRAMEWORK_WINDOWSYSTEM = "org.osgi.framework.windowssystem"**

Framework launching property specifying the current windowing system. The framework should provide a reasonable default if this is not set.

Since 1.5

10.1.15.80 **public static final String IMPORT_PACKAGE = "Import-Package"**

Manifest header identifying the packages on which the bundle depends.

The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.

10.1.15.81 **public static final String IMPORT_SERVICE = "Import-Service"**

Manifest header identifying the fully qualified class names of the services that the bundle requires (used for informational purposes only).

The header value may be retrieved from the Dictionary object returned by the `Bundle.getHeaders` method.

Deprecated As of 1.2.

10.1.15.82 **public static final String INCLUDE_DIRECTIVE = "include"**

Manifest header directive identifying a list of classes to include in the exported package.

This directive is used by the Export-Package manifest header to identify a list of classes of the specified package which must be allowed to be exported. The directive value is encoded in the Export-Package manifest header like:

```
Export-Package: org.osgi.framework; include:="MyClass*"
```

This directive is also used by the Bundle-ActivationPolicy manifest header to identify the packages from which class loads will trigger lazy activation. The directive value is encoded in the Bundle-ActivationPolicy manifest header like:

```
Bundle-ActivationPolicy: lazy; include:="org.osgi.framework"
```

See Also EXPORT_PACKAGE, BUNDLE_ACTIVATIONPOLICY

Since 1.3

10.1.15.83 **public static final String INTENT_ASYNC = "osgi.async"**

Intent supported by Remote Service implementations that support Asynchronous Remote Services as defined for the osgi.async intent.

Since 1.9

10.1.15.84 **public static final String INTENT_BASIC = "osgi.basic"**

Intent supported by Remote Services implementations that support Basic Remote Services as defined for the osgi.basic intent.

Since 1.9

10.1.15.85 **public static final String INTENT_CONFIDENTIAL = "osgi.confidential"**

Intent supported by Remote Service implementation that provide confidential communications as defined for the osgi.confidential intent.

Since 1.9

10.1.15.86 **public static final String INTENT_PRIVATE = "osgi.private"**

Intent supported by Remote Service implementations that provide private communications as defined for the osgi.private intent.

Since 1.9

10.1.15.87 **public static final String MANDATORY_DIRECTIVE = "mandatory"**

Manifest header directive identifying names of matching attributes which must be specified by matching Import-Package statements in the Export-Package manifest header.

The directive value is encoded in the Export-Package manifest header like:

```
Export-Package: org.osgi.framework; mandatory:="bundle-symbolic-name"
```

See Also EXPORT_PACKAGE

Since 1.3

10.1.15.88 **public static final String OBJECTCLASS = "objectClass"**

Service property identifying all of the class names under which a service was registered in the Framework. The value of this property must be of type String[].

This property is set by the Framework when a service is registered.

- 10.1.15.89** **public static final String PACKAGE_SPECIFICATION_VERSION = "specification-version"**
Manifest header attribute identifying the version of a package specified in the Export-Package or Import-Package manifest header.
Deprecated As of 1.3. This has been replaced by VERSION_ATTRIBUTE.
- 10.1.15.90** **public static final String PROVIDE_CAPABILITY = "Provide-Capability"**
Manifest header identifying the capabilities that the bundle offers to provide to other bundles.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
Since 1.6
- 10.1.15.91** **public static final String REMOTE_CONFIGS_SUPPORTED = "remote.configs.supported"**
Service property identifying the configuration types supported by a distribution provider. Registered by the distribution provider on one of its services to indicate the supported configuration types.
The value of this property must be of type String, String[], or Collection of String.
See Also Remote Services Specification
Since 1.6
- 10.1.15.92** **public static final String REMOTE_INTENTS_SUPPORTED = "remote.intents.supported"**
Service property identifying the intents supported by a distribution provider. Registered by the distribution provider on one of its services to indicate the vocabulary of implemented intents.
The value of this property must be of type String, String[], or Collection of String.
See Also Remote Services Specification
Since 1.6
- 10.1.15.93** **public static final String REQUIRE_BUNDLE = "Require-Bundle"**
Manifest header identifying the symbolic names of other bundles required by the bundle.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
Since 1.3
- 10.1.15.94** **public static final String REQUIRE_CAPABILITY = "Require-Capability"**
Manifest header identifying the capabilities on which the bundle depends.
The header value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.
Since 1.6
- 10.1.15.95** **public static final String RESOLUTION_DIRECTIVE = "resolution"**
Manifest header directive identifying the resolution type in the Import-Package, Require-Bundle or Require-Capability manifest header. The default value is mandatory.
The directive value is encoded in the Import-Package, Require-Bundle or Require-Capability manifest header like:

 Import-Package: org.osgi.framework; resolution:="optional"
 Require-Bundle: com.acme.module.test; resolution:="optional"
 Require-Capability: com.acme.capability; resolution:="optional"

See Also IMPORT_PACKAGE, REQUIRE_BUNDLE, REQUIRE_CAPABILITY, RESOLUTION_MANDATORY, RESOLUTION_OPTIONAL

Since 1.3

10.1.15.96 public static final String RESOLUTION_MANDATORY = "mandatory"

Manifest header directive value identifying a mandatory resolution type. A mandatory resolution type indicates that the import package, require bundle or require capability must be resolved when the bundle is resolved. If such an import, require bundle or require capability cannot be resolved, the module fails to resolve.

The directive value is encoded in the Import-Package, Require-Bundle or Require-Capability manifest header like:

```
Import-Package: org.osgi.framework; resolution:="mandatory"  
Require-Bundle: com.acme.module.test; resolution:="mandatory"  
Require-Capability: com.acme.capability; resolution:="mandatory"
```

See Also RESOLUTION_DIRECTIVE

Since 1.3

10.1.15.97 public static final String RESOLUTION_OPTIONAL = "optional"

Manifest header directive value identifying an optional resolution type. An optional resolution type indicates that the import, require bundle or require capability is optional and the bundle may be resolved without the import, require bundle or require capability being resolved. If the import, require bundle or require capability is not resolved when the bundle is resolved, the import, require bundle or require capability may not be resolved until the bundle is refreshed.

The directive value is encoded in the Import-Package, Require-Bundle or Require-Capability manifest header like:

```
Import-Package: org.osgi.framework; resolution:="optional"  
Require-Bundle: com.acme.module.test; resolution:="optional"  
Require-Capability: com.acme.capability; resolution:="optional"
```

See Also RESOLUTION_DIRECTIVE

Since 1.3

10.1.15.98 public static final String SCOPE_BUNDLE = "bundle"

Service scope is bundle. Each bundle using the service receives a customized service object.

See Also SERVICE_SCOPE

Since 1.8

10.1.15.99 public static final String SCOPE_PROTOTYPE = "prototype"

Service scope is prototype. Each bundle using the service receives either a customized service object or can request multiple customized service objects via ServiceObjects.

See Also SERVICE_SCOPE

Since 1.8

10.1.15.100 public static final String SCOPE_SINGLETON = "singleton"

Service scope is singleton. All bundles using the service receive the same service object.

See Also SERVICE_SCOPE

Since 1.8

10.1.15.101 **public static final String SELECTION_FILTER_ATTRIBUTE = "selection-filter"**

Manifest header attribute is used for selection by filtering based upon system properties.

The attribute value is encoded in manifest headers like:

```
Bundle-NativeCode: libgtk.so; selection-filter="(ws=gtk)"; ...
```

See Also BUNDLE_NATIVECODE

Since 1.3

10.1.15.102 **public static final String SERVICE_BUNDLEID = "service.bundleid"**

Service property identifying the bundle id of the bundle registering the service.

This property is set by the Framework when a service is registered. The value of this property must be of type Long.

Since 1.8

10.1.15.103 **public static final String SERVICE_CHANGECOUNT = "service.changecount"**

Service property identifying the monotonically increasing change count of a service.

A service may optional provide this property to indicate there has been a change in some data provided by the service. The change count must be incremented with a positive value every time the data provided by the service is changed. The service announces the modified change count by updating its service properties with the new value for this service property.

The value of this property must be of type Long.

Since 1.9

10.1.15.104 **public static final String SERVICE_DESCRIPTION = "service.description"**

Service property identifying a service's description.

This property may be supplied in the properties Dictionary object passed to the BundleContext.registerService method.

10.1.15.105 **public static final String SERVICE_EXPORTED_CONFIGS = "service.exported.configs"**

Service property identifying the configuration types that should be used to export the service. Each configuration type represents the configuration parameters for an endpoint. A distribution provider should create an endpoint for each configuration type that it supports.

This property may be supplied in the properties Dictionary object passed to the BundleContext.registerService method. The value of this property must be of type String, String[], or Collection of String.

See Also Remote Services Specification

Since 1.6

10.1.15.106 **public static final String SERVICE_EXPORTED_INTENTS = "service.exported.intents"**

Service property identifying the intents that the distribution provider must implement to distribute the service. Intents listed in this property are reserved for intents that are critical for the code to function correctly, for example, ordering of messages. These intents should not be configurable.

This property may be supplied in the properties Dictionary object passed to the BundleContext.registerService method. The value of this property must be of type String, String[], or Collection of String.

See Also Remote Services Specification

Since 1.6

- 10.1.15.107** **public static final String SERVICE_EXPORTED_INTENTS_EXTRA = "service.exported.intents.extra"**
- Service property identifying the extra intents that the distribution provider must implement to distribute the service. This property is merged with the `service.exported.intents` property before the distribution provider interprets the listed intents; it has therefore the same semantics but the property should be configurable so the administrator can choose the intents based on the topology. Bundles should therefore make this property configurable, for example through the Configuration Admin service.
- This property may be supplied in the properties Dictionary object passed to the `BundleContext.registerService` method. The value of this property must be of type `String`, `String[]`, or `Collection of String`.
- See Also* Remote Services Specification
- Since* 1.6
- 10.1.15.108** **public static final String SERVICE_EXPORTED_INTERFACES = "service.exported.interfaces"**
- Service property marking the service for export. It defines the interfaces under which this service can be exported. This list must be a subset of the types under which the service was registered. The single value of an asterisk ('*' \u002A) indicates all the interface types under which the service was registered excluding the non-interface types. It is strongly recommended to only export interface types and not concrete classes due to the complexity of creating proxies for some type of concrete classes.
- This property may be supplied in the properties Dictionary object passed to the `BundleContext.registerService` method. The value of this property must be of type `String`, `String[]`, or `Collection of String`.
- See Also* Remote Services Specification
- Since* 1.6
- 10.1.15.109** **public static final String SERVICE_ID = "service.id"**
- Service property identifying a service's registration number. The value of this property must be of type `Long`.
- The value of this property is assigned by the Framework when a service is registered. The Framework assigns a unique, non-negative value that is larger than all previously assigned values since the Framework was started. These values are NOT persistent across restarts of the Framework.
- 10.1.15.110** **public static final String SERVICE_IMPORTED = "service.imported"**
- Service property identifying the service as imported. This service property must be set by a distribution provider to any value when it registers the endpoint proxy as an imported service. A bundle can use this property to filter out imported services.
- The value of this property may be of any type.
- See Also* Remote Services Specification
- Since* 1.6
- 10.1.15.111** **public static final String SERVICE_IMPORTED_CONFIGS = "service.imported.configs"**
- Service property identifying the configuration types used to import the service. Any associated properties for this configuration types must be properly mapped to the importing system. For example, a URL in these properties must point to a valid resource when used in the importing framework. If multiple configuration types are listed in this property, then they must be synonyms for exactly the same remote endpoint that is used to export this service.
- The value of this property must be of type `String`, `String[]`, or `Collection of String`.

See Also Remote Services Specification, SERVICE_EXPORTED_CONFIGS

Since 1.6

10.1.15.112 **public static final String SERVICE_INTENTS = "service.intents"**

Service property identifying the intents that this service implement. This property has a dual purpose:

- A bundle can use this service property to notify the distribution provider that these intents are already implemented by the exported service object.
- A distribution provider must use this property to convey the combined intents of: the exporting service, the intents that the exporting distribution provider adds, and the intents that the importing distribution provider adds.

To export a service, a distribution provider must expand any qualified intents. Both the exporting and importing distribution providers must recognize all intents before a service can be distributed.

The value of this property must be of type `String`, `String[]`, or `Collection of String`.

See Also Remote Services Specification

Since 1.6

10.1.15.113 **public static final String SERVICE_PID = "service.pid"**

Service property identifying a service's persistent identifier.

This property may be supplied in the `properties Dictionary` object passed to the `BundleContext.registerService` method. The value of this property must be of type `String`, `String[]`, or `Collection of String`.

A service's persistent identifier uniquely identifies the service and persists across multiple Framework invocations.

By convention, every bundle has its own unique namespace, starting with the bundle's identifier (see `Bundle.getId()`) and followed by a dot (`.`). A bundle may use this as the prefix of the persistent identifiers for the services it registers.

10.1.15.114 **public static final String SERVICE_RANKING = "service.ranking"**

Service property identifying a service's ranking number.

This property may be supplied in the `properties Dictionary` object passed to the `BundleContext.registerService` method. The value of this property must be of type `Integer`.

The service ranking is used by the Framework to determine the *natural order* of services, see `ServiceReference.compareTo(Object)`, and the *default* service to be returned from a call to the `BundleContext.getServiceReference(Class)` or `BundleContext.getServiceReference(String)` method.

The default ranking is zero (0). A service with a ranking of `Integer.MAX_VALUE` is very likely to be returned as the default service, whereas a service with a ranking of `Integer.MIN_VALUE` is very unlikely to be returned.

If the supplied property value is not of type `Integer`, it is deemed to have a ranking value of zero.

10.1.15.115 **public static final String SERVICE_SCOPE = "service.scope"**

Service property identifying a service's scope.

This property is set by the Framework when a service is registered. If the registered object implements `PrototypeServiceFactory`, then the value of this service property will be `SCOPE_PROTOTYPE`. Otherwise, if the registered object implements `ServiceFactory`, then the value of this service property will be `SCOPE_BUNDLE`. Otherwise, the value of this service property will be `SCOPE_SINGLETON`.

See Also SCOPE_SINGLETON, SCOPE_BUNDLE, SCOPE_PROTOTYPE

Since 1.8

10.1.15.116 **public static final String SERVICE_VENDOR = "service.vendor"**

Service property identifying a service's vendor.

This property may be supplied in the properties Dictionary object passed to the BundleContext.registerService method.

10.1.15.117 **public static final String SINGLETON_DIRECTIVE = "singleton"**

Manifest header directive identifying whether a bundle is a singleton. The default value is false.

The directive value is encoded in the Bundle-SymbolicName manifest header like:

```
Bundle-SymbolicName: com.acme.module.test; singleton:=true
```

See Also BUNDLE_SYMBOLICNAME

Since 1.3

10.1.15.118 **public static final String SUPPORTS_BOOTCLASSPATH_EXTENSION =
"org.osgi.supports.bootclasspath.extension"**

Framework environment property identifying whether the Framework supports bootclasspath extension bundles.

If the value of this property is true, then the Framework supports bootclasspath extension bundles. The default value is false.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

Since 1.3

10.1.15.119 **public static final String SUPPORTS_FRAMEWORK_EXTENSION = "org.osgi.supports.framework.extension"**

Framework environment property identifying whether the Framework supports framework extension bundles.

As of version 1.4, the value of this property must be true. The Framework must support framework extension bundles.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

Since 1.3

10.1.15.120 **public static final String SUPPORTS_FRAMEWORK_FRAGMENT = "org.osgi.supports.framework.fragment"**

Framework environment property identifying whether the Framework supports fragment bundles.

As of version 1.4, the value of this property must be true. The Framework must support fragment bundles.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

Since 1.3

10.1.15.121 **public static final String SUPPORTS_FRAMEWORK_REQUIREBUNDLE =
"org.osgi.supports.framework.requirebundle"**

Framework environment property identifying whether the Framework supports the Require-Bundle manifest header.

As of version 1.4, the value of this property must be true. The Framework must support the Require-Bundle manifest header.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

Since 1.3

10.1.15.122 **public static final long SYSTEM_BUNDLE_ID = 0L**
Identifier of the OSGi *system bundle*, which is defined to be 0.

Since 1.8

10.1.15.123 **public static final String SYSTEM_BUNDLE_LOCATION = "System Bundle"**
Location identifier of the OSGi *system bundle*, which is defined to be "System Bundle".

10.1.15.124 **public static final String SYSTEM_BUNDLE_SYMBOLICNAME = "system.bundle"**
Alias for the symbolic name of the OSGi *system bundle*. It is defined to be "system.bundle".

Since 1.3

10.1.15.125 **public static final String USES_DIRECTIVE = "uses"**
Manifest header directive identifying a list of packages that an exported package or provided capability uses.

The directive value is encoded in the Export-Package or Provide-Capability manifest header like:

```
Export-Package: org.osgi.util.tracker; uses:="org.osgi.framework"  
Provide-Capability: com.acme.capability; uses:="com.acme.service"
```

See Also EXPORT_PACKAGE, PROVIDE_CAPABILITY

Since 1.3

10.1.15.126 **public static final String VERSION_ATTRIBUTE = "version"**
Manifest header attribute identifying the version of a package specified in the Export-Package or Import-Package manifest header.

The attribute value is encoded in the Export-Package or Import-Package manifest header like:

```
Export-Package: org.osgi.framework; version="1.1"
```

See Also EXPORT_PACKAGE, IMPORT_PACKAGE

Since 1.3

10.1.15.127 **public static final String VISIBILITY_DIRECTIVE = "visibility"**
Manifest header directive identifying the visibility of a required bundle in the Require-Bundle manifest header. The default value is private.

The directive value is encoded in the Require-Bundle manifest header like:

```
Require-Bundle: com.acme.module.test; visibility:="reexport"
```

See Also REQUIRE_BUNDLE, VISIBILITY_PRIVATE, VISIBILITY_REEXPORT

Since 1.3

10.1.15.128 **public static final String VISIBILITY_PRIVATE = "private"**
Manifest header directive value identifying a private visibility type. A private visibility type indicates that any packages that are exported by the required bundle are not made visible on the export signature of the requiring bundle.

The directive value is encoded in the Require-Bundle manifest header like:

```
Require-Bundle: com.acme.module.test; visibility:="private"
```

See Also VISIBILITY_DIRECTIVE

Since 1.3

10.1.15.129 **public static final String VISIBILITY_REEXPORT = "reexport"**

Manifest header directive value identifying a reexport visibility type. A reexport visibility type indicates any packages that are exported by the required bundle are re-exported by the requiring bundle. Any arbitrary matching attributes with which they were exported by the required bundle are deleted.

The directive value is encoded in the Require-Bundle manifest header like:

```
Require-Bundle: com.acme.module.test; visibility:="reexport"
```

See Also VISIBILITY_DIRECTIVE

Since 1.3

10.1.16 **public interface Filter**

An RFC 1960 [<http://www.ietf.org/rfc/rfc1960.txt>]-based Filter.

Filters can be created by calling `BundleContext.createFilter(String)` or `FrameworkUtil.createFilter(String)` with a filter string.

A Filter can be used numerous times to determine if the match argument matches the filter string that was used to create the Filter.

Some examples of LDAP filters are:

```
"(cn=Babs Jensen)"
"! (cn=Tim Howes)"
"&(" + Constants.OBJECTCLASS + "=Person) (| (sn=Jensen) (cn=Babs J*))"
"(o=univ*of*mich*)"
```

See Also Core Specification, Filters, for a description of the filter string syntax.

Since 1.1

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.1.16.1 **public boolean equals(Object obj)**

obj The object to compare against this Filter.

- Compares this Filter to another Filter.

This implementation returns the result of calling `this.toString().equals(obj.toString())`.

Returns If the other object is a Filter object, then returns the result of calling `this.toString().equals(obj.toString())`; false otherwise.

10.1.16.2 **public int hashCode()**

- Returns the hashCode for this Filter.

This implementation returns the result of calling `this.toString().hashCode()`.

Returns The hashCode of this Filter.

10.1.16.3 **public boolean match(ServiceReference<?> reference)**

reference The reference to the service whose properties are used in the match.

- Filter using a service's properties.

This Filter is executed using the keys and values of the referenced service's properties. The keys are looked up in a case insensitive manner.

Returns true if the service's properties match this Filter; false otherwise.

10.1.16.4 **public boolean match(Dictionary<String, ?> dictionary)**

dictionary The Dictionary whose key/value pairs are used in the match.

- Filter using a Dictionary with case insensitive key lookup. This Filter is executed using the specified Dictionary's keys and values. The keys are looked up in a case insensitive manner.

Returns true if the Dictionary's values match this filter; false otherwise.

Throws IllegalArgumentException– If dictionary contains case variants of the same key name.

10.1.16.5 **public boolean matchCase(Dictionary<String, ?> dictionary)**

dictionary The Dictionary whose key/value pairs are used in the match.

- Filter using a Dictionary. This Filter is executed using the specified Dictionary's keys and values. The keys are looked up in a normal manner respecting case.

Returns true if the Dictionary's values match this filter; false otherwise.

Since 1.3

10.1.16.6 **public boolean matches(Map<String, ?> map)**

map The Map whose key/value pairs are used in the match. Maps with null key or values are not supported. A null value is considered not present to the filter.

- Filter using a Map. This Filter is executed using the specified Map's keys and values. The keys are looked up in a normal manner respecting case.

Returns true if the Map's values match this filter; false otherwise.

Since 1.6

10.1.16.7 **public String toString()**

- Returns this Filter's filter string.

The filter string is normalized by removing whitespace which does not affect the meaning of the filter.

Returns This Filter's filter string.

10.1.17 **public class FrameworkEvent extends EventObject**

A general event from the Framework.

FrameworkEvent objects are delivered to FrameworkListeners when a general event occurs within the OSGi environment. A type code is used to identify the event type for future extendability.

OSGi Alliance reserves the right to extend the set of event types.

See Also FrameworkListener

Concurrency Immutable

10.1.17.1 **public static final int ERROR = 2**

An error has occurred.

There was an error associated with a bundle.

10.1.17.2 public static final int INFO = 32

An informational event has occurred.

There was an informational event associated with a bundle.

Since 1.3

10.1.17.3 public static final int PACKAGES_REFRESHED = 4

A FrameworkWiring.refreshBundles operation has completed.

This event is fired when the Framework has completed the refresh bundles operation initiated by a call to the FrameworkWiring.refreshBundles method. The source of this event is the System Bundle.

See Also FrameworkWiring.refreshBundles(java.util.Collection, FrameworkListener...)

Since 1.2

10.1.17.4 public static final int STARTED = 1

The Framework has started.

This event is fired when the Framework has started after all installed bundles that are marked to be started have been started and the Framework has reached the initial start level. The source of this event is the System Bundle.

See Also The Start Level Specification

10.1.17.5 public static final int STARTLEVEL_CHANGED = 8

A FrameworkStartLevel.setStartLevel operation has completed.

This event is fired when the Framework has completed changing the active start level initiated by a call to the StartLevel.setStartLevel method. The source of this event is the System Bundle.

See Also FrameworkStartLevel.setStartLevel(int, FrameworkListener...)

Since 1.2

10.1.17.6 public static final int STOPPED = 64

The Framework has stopped.

This event is fired when the Framework has been stopped because of a stop operation on the system bundle. The source of this event is the System Bundle.

Since 1.5

10.1.17.7 public static final int STOPPED_BOOTCLASSPATH_MODIFIED = 256

The Framework has stopped and the boot class path has changed.

This event is fired when the Framework has been stopped because of a stop operation on the system bundle and a bootclasspath extension bundle has been installed or updated. The source of this event is the System Bundle.

Since 1.5

10.1.17.8 public static final int STOPPED_SYSTEM_REFRESHED = 1024

The Framework has stopped and the framework requires a new class loader to restart.

This event is fired when the Framework has been stopped because of a stop operation on the system bundle and the framework requires a new class loader to be used to restart. For example, if a framework extension bundle has been refreshed. The source of this event is the System Bundle.

Since 1.9

10.1.17.9 public static final int STOPPED_UPDATE = 128

The Framework has stopped during update.

This event is fired when the Framework has been stopped because of an update operation on the system bundle. The Framework will be restarted after this event is fired. The source of this event is the System Bundle.

Since 1.5

10.1.17.10 public static final int WAIT_TIMEOUT = 512

The Framework did not stop before the wait timeout expired.

This event is fired when the Framework did not stop before the wait timeout expired. The source of this event is the System Bundle.

Since 1.5

10.1.17.11 public static final int WARNING = 16

A warning has occurred.

There was a warning associated with a bundle.

Since 1.3

10.1.17.12 public FrameworkEvent(int type, Object source)

type The event type.

source The event source object. This may not be null.

- Creates a Framework event.

Deprecated As of 1.2. This constructor is deprecated in favor of using the other constructor with the System Bundle as the event source.

10.1.17.13 public FrameworkEvent(int type, Bundle bundle, Throwable throwable)

type The event type.

bundle The event source.

throwable The related exception. This argument may be null if there is no related exception.

- Creates a Framework event regarding the specified bundle.

10.1.17.14 public Bundle getBundle()

- Returns the bundle associated with the event. This bundle is also the source of the event.

Returns The bundle associated with the event.

10.1.17.15 public Throwable getThrowable()

- Returns the exception related to this event.

Returns The related exception or null if none.

10.1.17.16 public int getType()

- Returns the type of framework event.

The type values are:

- STARTED
- ERROR

- WARNING
- INFO
- PACKAGES_REFRESHED
- STARTLEVEL_CHANGED
- STOPPED
- STOPPED_BOOTCLASSPATH_MODIFIED
- STOPPED_UPDATE
- WAIT_TIMEDOUT

Returns The type of state change.

10.1.18 **public interface FrameworkListener** **extends EventListener**

A FrameworkEvent listener. FrameworkListener is a listener interface that may be implemented by a bundle developer. When a FrameworkEvent is fired, it is asynchronously delivered to a FrameworkListener. The Framework delivers FrameworkEvent objects to a FrameworkListener in order and must not concurrently call a FrameworkListener.

A FrameworkListener object is registered with the Framework using the BundleContext.addFrameworkListener(FrameworkListener) method. FrameworkListener objects are called with a FrameworkEvent objects when the Framework starts and when asynchronous errors occur.

See Also FrameworkEvent

Concurrency Not Thread-safe

10.1.18.1 **public void frameworkEvent(FrameworkEvent event)**

event The FrameworkEvent object.

- Receives notification of a general FrameworkEvent object.

10.1.19 **public class FrameworkUtil**

Framework Utility class.

This class contains utility methods which access Framework functions that may be useful to bundles.

Since 1.3

Concurrency Thread-safe

10.1.19.1 **public static Filter createFilter(String filter) throws InvalidSyntaxException**

filter The filter string.

- Creates a Filter object. This Filter object may be used to match a ServiceReference object or a Dictionary object.

If the filter cannot be parsed, an InvalidSyntaxException will be thrown with a human readable message where the filter became unparseable.

This method returns a Filter implementation which may not perform as well as the framework implementation-specific Filter implementation returned by BundleContext.createFilter(String).

Returns A Filter object encapsulating the filter string.

Throws InvalidSyntaxException– If filter contains an invalid filter string that cannot be parsed.

NullPointerException– If filter is null.

See Also `Filter`

10.1.19.2 **public static Bundle getBundle(Class<?> classFromBundle)**

classFromBundle A class defined by a bundle class loader.

- Return a Bundle for the specified bundle class. The returned Bundle is the bundle associated with the bundle class loader which defined the specified class.

Returns A Bundle for the specified bundle class or null if the specified class was not defined by a bundle class loader.

Since 1.5

10.1.19.3 **public static boolean matchDistinguishedNameChain(String matchPattern, List<String> dnChain)**

matchPattern The pattern against which to match the DN chain.

dnChain The DN chain to match against the specified pattern. Each element of the chain must be of type String and use the format defined in RFC 2253 [<http://www.ietf.org/rfc/rfc2253.txt>].

- Match a Distinguished Name (DN) chain against a pattern. DNs can be matched using wildcards. A wildcard ('*\u002A) replaces all possible values. Due to the structure of the DN, the comparison is more complicated than string-based wildcard matching.

A wildcard can stand for zero or more DNs in a chain, a number of relative distinguished names (RDNs) within a DN, or the value of a single RDN. The DNs in the chain and the matching pattern are canonicalized before processing. This means, among other things, that spaces must be ignored, except in values.

The format of a wildcard match pattern is:

```
matchPattern ::= dn-match ( ';' dn-match ) *
dn-match     ::= ( '*' | rdn-match ) ( ',' rdn-match ) * | '-'
rdn-match    ::= name '=' value-match
value-match  ::= '*' | value-star
value-star   ::= < value, requires escaped '*' and '-' >
```

The most simple case is a single wildcard; it must match any DN. A wildcard can also replace the first list of RDNs of a DN. The first RDNs are the least significant. Such lists of matched RDNs can be empty.

For example, a match pattern with a wildcard that matches all DNs that end with RDNs of o=ACME and c=US would look like this:

```
*, o=ACME, c=US
```

This match pattern would match the following DNs:

```
cn = Bugs Bunny, o = ACME, c = US
ou = Carrots, cn=Daffy Duck, o=ACME, c=US
street = 9C\, Avenue St. Drézéry, o=ACME, c=US
dc=www, dc=acme, dc=com, o=ACME, c=US
o=ACME, c=US
```

The following DNs would not match:

```
street = 9C\, Avenue St. Drézéry, o=ACME, c=FR
dc=www, dc=acme, dc=com, c=US
```

If a wildcard is used for a value of an RDN, the value must be exactly *. The wildcard must match any value, and no substring matching must be done. For example:

```
cn=*, o=ACME, c=*
```

This match pattern with wildcard must match the following DNs:

```
cn=Bugs Bunny, o=ACME, c=US
cn = Daffy Duck , o = ACME , c = US
cn=Road Runner, o=ACME, c=NL
```

But not:

```
o=ACME, c=NL
dc=acme.com, cn=Bugs Bunny, o=ACME, c=US
```

A match pattern may contain a chain of DN match patterns. The semicolon(';') must be used to separate DN match patterns in a chain. Wildcards can also be used to match against a complete DN within a chain.

The following example matches a certificate signed by Tweety Inc. in the US.

```
* ; ou=S & V, o=Tweety Inc., c=US
```

The wildcard (*) matches zero or one DN in the chain, however, sometimes it is necessary to match a longer chain. The minus sign ('-') represents zero or more DNs, whereas the asterisk only represents a single DN. For example, to match a DN where the Tweety Inc. is in the DN chain, use the following expression:

```
- ; *, o=Tweety Inc., c=US
```

Returns true If the pattern matches the DN chain; otherwise false is returned.

Throws IllegalArgumentException– If the specified match pattern or DN chain is invalid.

Since 1.5

10.1.20 **public class InvalidSyntaxException extends Exception**

A Framework exception used to indicate that a filter string has an invalid syntax.

An InvalidSyntaxException object indicates that a filter string parameter has an invalid syntax and cannot be parsed. See Filter for a description of the filter string syntax.

This exception conforms to the general purpose exception chaining mechanism.

10.1.20.1 **public InvalidSyntaxException(String msg, String filter)**

msg The message.

filter The invalid filter string.

- Creates an exception of type InvalidSyntaxException.

This method creates an InvalidSyntaxException object with the specified message and the filter string which generated the exception.

10.1.20.2 **public InvalidSyntaxException(String msg, String filter, Throwable cause)**

msg The message.

filter The invalid filter string.

cause The cause of this exception.

- Creates an exception of type InvalidSyntaxException.

This method creates an `InvalidSyntaxException` object with the specified message and the filter string which generated the exception.

Since 1.3

10.1.20.3 **public Throwable getCause()**

- Returns the cause of this exception or null if no cause was set.

Returns The cause of this exception or null if no cause was set.

Since 1.3

10.1.20.4 **public String getFilter()**

- Returns the filter string that generated the `InvalidSyntaxException` object.

Returns The invalid filter string.

See Also `BundleContext.getServiceReferences(Class, String)`, `BundleContext.getServiceReferences(String, String)`, `BundleContext.addServiceListener(ServiceListener, String)`

10.1.20.5 **public Throwable initCause(Throwable cause)**

cause The cause of this exception.

- Initializes the cause of this exception to the specified value.

Returns This exception.

Throws `IllegalArgumentException`– If the specified cause is this exception.

`IllegalStateException`– If the cause of this exception has already been set.

Since 1.3

10.1.21 **public final class PackagePermission extends BasicPermission**

A bundle's authority to import or export a package.

A package is a dot-separated string that defines a fully qualified Java package.

For example:

```
org.osgi.service.http
```

`PackagePermission` has three actions: `exportonly`, `import` and `export`. The `export` action, which is deprecated, implies the `import` action.

Concurrency Thread-safe

10.1.21.1 **public static final String EXPORT = "export"**

The action string `export`. The `export` action implies the `import` action.

Deprecated As of 1.5. Use `exportonly` instead.

10.1.21.2 **public static final String EXPORTONLY = "exportonly"**

The action string `exportonly`. The `exportonly` action does not imply the `import` action.

Since 1.5

10.1.21.3 **public static final String IMPORT = "import"**

The action string `import`.

10.1.21.4 public PackagePermission(String name, String actions)

name Package name or filter expression. A filter expression can only be specified if the specified action is import.

actions exportonly,import (canonical order).

- Creates a new PackagePermission object.

The name is specified as a normal Java package name: a dot-separated string. Wildcards may be used.

name ::= <package name> | <package name ending in ".*"> | *

Examples:

```
org.osgi.service.http
javax.servlet.*
*
```

For the import action, the name can also be a filter expression. The filter gives access to the following attributes:

- *signer* - A Distinguished Name chain used to sign the exporting bundle. Wildcards in a DN are not matched according to the filter string rules, but according to the rules defined for a DN chain.
- *location* - The location of the exporting bundle.
- *id* - The bundle ID of the exporting bundle.
- *name* - The symbolic name of the exporting bundle.
- *package.name* - The name of the requested package.

Filter attribute names are processed in a case sensitive manner.

Package Permissions are granted over all possible versions of a package. A bundle that needs to export a package must have the appropriate PackagePermission for that package; similarly, a bundle that needs to import a package must have the appropriate PackagePermission for that package.

Permission is granted for both classes and resources.

Throws IllegalArgumentException – If the specified name is a filter expression and either the specified action is not import or the filter has an invalid syntax.

10.1.21.5 public PackagePermission(String name, Bundle exportingBundle, String actions)

name The name of the requested package to import.

exportingBundle The bundle exporting the requested package.

actions The action import.

- Creates a new requested PackagePermission object to be used by code that must perform checkPermission for the import action. PackagePermission objects created with this constructor cannot be added to a PackagePermission permission collection.

Throws IllegalArgumentException – If the specified action is not import or the name is a filter expression.

Since 1.5

10.1.21.6 public boolean equals(Object obj)

obj The object to test for equality with this PackagePermission object.

- Determines the equality of two PackagePermission objects. This method checks that specified package has the same package name and PackagePermission actions as this PackagePermission object.

Returns true if obj is a PackagePermission, and has the same package name and actions as this PackagePermission object; false otherwise.

10.1.21.7 public String getActions()

- Returns the canonical string representation of the PackagePermission actions.

Always returns present PackagePermission actions in the following order: EXPORTONLY,IMPORT.

Returns Canonical string representation of the PackagePermission actions.

10.1.21.8 public int hashCode()

- Returns the hash code value for this object.

Returns A hash code value for this object.

10.1.21.9 public boolean implies(Permission p)

p The requested permission.

- Determines if the specified permission is implied by this object.

This method checks that the package name of the target is implied by the package name of this object. The list of PackagePermission actions must either match or allow for the list of the target object to imply the target PackagePermission action.

The permission to export a package implies the permission to import the named package.

```
x.y.*, "export" -> x.y.z, "export" is true
*, "import" -> x.y, "import" is true
*, "export" -> x.y, "import" is true
x.y, "export" -> x.y.z, "export" is false
```

Returns true if the specified permission is implied by this object; false otherwise.

10.1.21.10 public PermissionCollection newPermissionCollection()

- Returns a new PermissionCollection object suitable for storing PackagePermission objects.

Returns A new PermissionCollection object.

**10.1.22 public interface PrototypeServiceFactory<S>
extends ServiceFactory<S>**

<S> Type of Service

A factory for prototype scope services. The factory can provide multiple, customized service objects in the OSGi environment.

When registering a service, a PrototypeServiceFactory object can be used instead of a service object, so that the bundle developer can create a customized service object for each caller that is using the service.

When a caller uses a ServiceObjects to request a service object, the framework calls the getService method to return a service object customized for the requesting caller. The caller can release the returned service object and the framework will call the ungetService method with the service object.

When a bundle uses the BundleContext.getService(ServiceReference) method to obtain a service object, the framework must act as if the service has bundle scope. That is, the framework will call the getService method to obtain a bundle-scoped service object which will be cached and have a use count. See ServiceFactory.

A bundle can use both ServiceObjects and BundleContext.getService(ServiceReference) to obtain a service object for a service. ServiceObjects.getService() will always return a service object provided

by a call to `getService(Bundle, ServiceRegistration)` and `BundleContext.getService(ServiceReference)` will always return the bundle-scoped service object.

PrototypeServiceFactory objects are only used by the Framework and are not made available to other bundles in the OSGi environment. The Framework may concurrently call a PrototypeServiceFactory.

See Also `BundleContext.getServiceObjects(ServiceReference)`, `ServiceObjects`

Since 1.8

Concurrency Thread-safe

10.1.22.1 **public S getService(Bundle bundle, ServiceRegistration<S> registration)**

bundle The bundle requesting the service.

registration The ServiceRegistration object for the requested service.

- Returns a service object for a caller.

The Framework invokes this method for each caller requesting a service object using `ServiceObjects.getService()`. The factory can then return a customized service object for the caller.

The Framework must check that the returned service object is valid. If the returned service object is null or is not an instance of all the classes named when the service was registered, a framework event of type `FrameworkEvent.ERROR` is fired containing a service exception of type `ServiceException.FACTORY_ERROR` and null is returned to the caller. If this method throws an exception, a framework event of type `FrameworkEvent.ERROR` is fired containing a service exception of type `ServiceException.FACTORY_EXCEPTION` with the thrown exception as the cause and null is returned to the caller.

Returns A service object that **must** be an instance of all the classes named when the service was registered.

See Also `ServiceObjects.getService()`

10.1.22.2 **public void ungetService(Bundle bundle, ServiceRegistration<S> registration, S service)**

bundle The bundle releasing the service.

registration The ServiceRegistration object for the service being released.

service The service object returned by a previous call to the `getService` method.

- Releases a service object customized for a caller.

The Framework invokes this method when a service has been released by a bundle such as by calling `ServiceObjects.ungetService(Object)`. The service object may then be destroyed.

If this method throws an exception, a framework event of type `FrameworkEvent.ERROR` is fired containing a service exception of type `ServiceException.FACTORY_EXCEPTION` with the thrown exception as the cause.

See Also `ServiceObjects.ungetService(Object)`

10.1.23 **public class ServiceEvent extends EventObject**

An event from the Framework describing a service lifecycle change.

ServiceEvent objects are delivered to `ServiceListeners` and `AllServiceListeners` when a change occurs in this service's lifecycle. A type code is used to identify the event type for future extendability.

OSGi Alliance reserves the right to extend the set of types.

See Also `ServiceListener`, `AllServiceListener`

Concurrency Immutable

10.1.23.1 **public static final int MODIFIED = 2**

The properties of a registered service have been modified.

This event is synchronously delivered **after** the service properties have been modified.

See Also ServiceRegistration.setProperties(Dictionary)

10.1.23.2 **public static final int MODIFIED_ENDMATCH = 8**

The properties of a registered service have been modified and the new properties no longer match the listener's filter.

This event is synchronously delivered **after** the service properties have been modified. This event is only delivered to listeners which were added with a non-null filter where the filter matched the service properties prior to the modification but the filter does not match the modified service properties.

See Also ServiceRegistration.setProperties(Dictionary)

Since 1.5

10.1.23.3 **public static final int REGISTERED = 1**

This service has been registered.

This event is synchronously delivered **after** the service has been registered with the Framework.

See Also BundleContext.registerService(String[],Object,Dictionary)

10.1.23.4 **public static final int UNREGISTERING = 4**

This service is in the process of being unregistered.

This event is synchronously delivered **before** the service has completed unregistering.

If a bundle is using a service that is UNREGISTERING, the bundle should release its use of the service when it receives this event. If the bundle does not release its use of the service when it receives this event, the Framework will automatically release the bundle's use of the service while completing the service unregistration operation.

See Also ServiceRegistration.unregister(), BundleContext.ungetService(ServiceReference)

10.1.23.5 **public ServiceEvent(int type, ServiceReference<?> reference)**

type The event type.

reference A ServiceReference object to the service that had a lifecycle change.

- Creates a new service event object.

10.1.23.6 **public ServiceReference<?> getServiceReference()**

- Returns a reference to the service that had a change occur in its lifecycle.

This reference is the source of the event.

Returns Reference to the service that had a lifecycle change.

10.1.23.7 **public int getType()**

- Returns the type of event. The event type values are:
 - REGISTERED
 - MODIFIED
 - MODIFIED_ENDMATCH

- UNREGISTERING

Returns Type of service lifecycle change.

10.1.24 **public class ServiceException extends RuntimeException**

A service exception used to indicate that a service problem occurred.

A ServiceException object is created by the Framework or service implementation to denote an exception condition in the service. A type code is used to identify the exception type for future extendability. Service implementations may also create subclasses of ServiceException. When subclassing, the subclass should set the type to SUBCLASSED to indicate that ServiceException has been subclassed.

This exception conforms to the general purpose exception chaining mechanism.

Since 1.5

10.1.24.1 **public static final int ASYNC_ERROR = 7**

An asynchronous operation was unable to obtain the service.

Since 1.8

10.1.24.2 **public static final int FACTORY_ERROR = 2**

The service factory produced an invalid service object.

10.1.24.3 **public static final int FACTORY_EXCEPTION = 3**

The service factory threw an exception.

10.1.24.4 **public static final int FACTORY_RECURSION = 6**

The service factory resulted in a recursive call to itself for the requesting bundle.

Since 1.6

10.1.24.5 **public static final int REMOTE = 5**

An error occurred invoking a remote service.

10.1.24.6 **public static final int SUBCLASSED = 4**

The exception is a subclass of ServiceException. The subclass should be examined for the type of the exception.

10.1.24.7 **public static final int UNREGISTERED = 1**

The service has been unregistered.

10.1.24.8 **public static final int UNSPECIFIED = 0**

No exception type is unspecified.

10.1.24.9 **public ServiceException(String msg, Throwable cause)**

msg The associated message.

cause The cause of this exception.

- Creates a ServiceException with the specified message and exception cause.

10.1.24.10 **public ServiceException(String msg)**

msg The message.

- Creates a ServiceException with the specified message.

10.1.24.11 **public ServiceException(String msg, int type, Throwable cause)**

msg The associated message.

type The type for this exception.

cause The cause of this exception.

- Creates a ServiceException with the specified message, type and exception cause.

10.1.24.12 **public ServiceException(String msg, int type)**

msg The message.

type The type for this exception.

- Creates a ServiceException with the specified message and type.

10.1.24.13 **public int getType()**

- Returns the type for this exception or UNSPECIFIED if the type was unspecified or unknown.

Returns The type of this exception.

10.1.25 **public interface ServiceFactory<S>**

<S> Type of Service

A factory for bundle scope services. The factory can provide service objects customized for each bundle in the OSGi environment.

When registering a service, a ServiceFactory object can be used instead of a service object, so that the bundle developer can create a customized service object for each bundle that is using the service.

When a bundle requests the service object, the framework calls the getService method to return a service object customized for the requesting bundle. The returned service object is cached by the Framework for subsequent calls to BundleContext.getService(ServiceReference) until the bundle releases its use of the service.

When the bundle's use count for the service is decremented to zero (including the bundle stopping or the service being unregistered), the framework will call the ungetService method.

ServiceFactory objects are only used by the Framework and are not made available to other bundles in the OSGi environment. The Framework may concurrently call a ServiceFactory.

See Also BundleContext.getService(ServiceReference)

Concurrency Thread-safe

10.1.25.1 **public S getService(Bundle bundle, ServiceRegistration<S> registration)**

bundle The bundle requesting the service.

registration The ServiceRegistration object for the requested service.

- Returns a service object for a bundle.

The Framework invokes this method the first time the specified bundle requests a service object using the BundleContext.getService(ServiceReference) method. The factory can then return a customized service object for each bundle.

The Framework must check that the returned service object is valid. If the returned service object is null or is not an instance of all the classes named when the service was registered, a framework event of type FrameworkEvent.ERROR is fired containing a service exception of type ServiceException.FACTORY_ERROR and null is returned to the bundle. If this method throws an exception, a framework event of type FrameworkEvent.ERROR is fired containing a service exception of type ServiceException.FACTORY_EXCEPTION with the thrown exception as the cause

and null is returned to the bundle. If this method is recursively called for the specified bundle, a framework event of type `FrameworkEvent.ERROR` is fired containing a service exception of type `ServiceException.FACTORY_RECURSION` and null is returned to the bundle.

The Framework caches the valid service object and will return the same service object on any future call to `BundleContext.getService(ServiceReference)` for the specified bundle. This means the Framework must not allow this method to be concurrently called for the specified bundle.

Returns A service object that **must** be an instance of all the classes named when the service was registered.

See Also `BundleContext.getService(ServiceReference)`

10.1.25.2 **public void ungetService(Bundle bundle, ServiceRegistration<S> registration, S service)**

bundle The bundle releasing the service.

registration The `ServiceRegistration` object for the service being released.

service The service object returned by a previous call to the `getService` method.

- Releases a service object customized for a bundle.

The Framework invokes this method when a service has been released by a bundle. The service object may then be destroyed.

If this method throws an exception, a framework event of type `FrameworkEvent.ERROR` is fired containing a service exception of type `ServiceException.FACTORY_EXCEPTION` with the thrown exception as the cause.

See Also `BundleContext.ungetService(ServiceReference)`

10.1.26 **public interface ServiceListener extends EventListener**

A `ServiceEvent` listener. `ServiceListener` is a listener interface that may be implemented by a bundle developer. When a `ServiceEvent` is fired, it is synchronously delivered to a `ServiceListener`. The Framework may deliver `ServiceEvent` objects to a `ServiceListener` out of order and may concurrently call and/or reenter a `ServiceListener`.

A `ServiceListener` object is registered with the Framework using the `BundleContext.addServiceListener` method. `ServiceListener` objects are called with a `ServiceEvent` object when a service is registered, modified, or is in the process of unregistering.

`ServiceEvent` object delivery to `ServiceListener` objects is filtered by the filter specified when the listener was registered. If the Java Runtime Environment supports permissions, then additional filtering is done. `ServiceEvent` objects are only delivered to the listener if the bundle which defines the listener object's class has the appropriate `ServicePermission` to get the service using at least one of the named classes under which the service was registered.

`ServiceEvent` object delivery to `ServiceListener` objects is further filtered according to package sources as defined in `ServiceReference.isAssignableTo(Bundle, String)`.

See Also `ServiceEvent`, `ServicePermission`

Concurrency Thread-safe

10.1.26.1 **public void serviceChanged(ServiceEvent event)**

event The `ServiceEvent` object.

- Receives notification that a service has had a lifecycle change.

10.1.27 **public interface ServiceObjects<S>**

<S> Type of Service

Allows multiple service objects for a service to be obtained.

For services with prototype scope, multiple service objects for the service can be obtained. Since implementations of `PrototypeServiceFactory` can return the same service object repeatedly, the framework must use count the returned service objects to release the service object only when its use count returns to zero.

For services with singleton or bundle scope, only one, use-counted service object is available to a requesting bundle.

Any unreleased service objects obtained from this `ServiceObjects` object are automatically released by the framework when the bundle associated with the `BundleContext` used to create this `ServiceObjects` object is stopped.

See Also `BundleContext.getServiceObjects(ServiceReference)`, `PrototypeServiceFactory`

Since 1.8

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.1.27.1 **public S getService()**

- Returns a service object for the associated service.

This `ServiceObjects` object can be used to obtain multiple service objects for the associated service if the service has prototype scope.

If the associated service has singleton or bundle scope, this method behaves the same as calling the `BundleContext.getService(ServiceReference)` method for the associated service. That is, only one, use-counted service object is available from this `ServiceObjects` object.

This method will always return null when the associated service has been unregistered.

For a prototype scope service, the following steps are required to obtain a service object:

1. If the associated service has been unregistered, null is returned.
2. The `PrototypeServiceFactory.getService(Bundle, ServiceRegistration)` method is called to supply a customized service object for the caller.
3. If the service object returned by the `PrototypeServiceFactory` object is null, not an instance of all the classes named when the service was registered or the `PrototypeServiceFactory` object throws an exception, null is returned and a `FrameworkEvent.ERROR` containing a `ServiceException` describing the error is fired.
4. The use count for the customized service object is incremented by one.
5. The customized service object is returned.

Returns A service object for the associated service or null if the service is not registered, the customized service object returned by a `ServiceFactory` does not implement the classes under which it was registered or the `ServiceFactory` threw an exception.

Throws `IllegalStateException`— If the `BundleContext` used to create this `ServiceObjects` object is no longer valid.

See Also `ungetService(Object)`

10.1.27.2 **public ServiceReference<S> getServiceReference()**

- Returns the `ServiceReference` for the service associated with this `ServiceObjects` object.

Returns The `ServiceReference` for the service associated with this `ServiceObjects` object.

10.1.27.3 **public void ungetService(S service)**

service A service object previously provided by this `ServiceObjects` object.

- Releases a service object for the associated service.

This `ServiceObjects` object can be used to obtain multiple service objects for the associated service if the service has prototype scope. If the associated service has singleton or bundle scope, this method behaves the same as calling the `BundleContext.ungetService(ServiceReference)` method for the associated service. That is, only one, use-counted service object is available from this `ServiceObjects` object.

For a prototype scope service, the following steps are required to release a service object:

1. If the associated service has been unregistered, this method returns without doing anything.
2. The use count for the specified service object is decremented by one.
3. If the use count for the specified service object is now zero, the `PrototypeServiceFactory.ungetService(Bundle, ServiceRegistration, Object)` method is called to release the specified service object.

The specified service object must no longer be used and all references to it should be destroyed after calling this method when the use count has returned to zero.

Throws `IllegalStateException`—If the `BundleContext` used to create this `ServiceObjects` object is no longer valid.

`IllegalArgumentException`—If the specified service object is null or was not provided by a `ServiceObjects` object for the associated service.

See Also `getService()`

10.1.28 **public final class ServicePermission** **extends BasicPermission**

A bundle's authority to register or get a service.

- The register action allows a bundle to register a service on the specified names.
- The get action allows a bundle to detect a service and get it.

Permission to get a service is required in order to detect events regarding the service. Untrusted bundles should not be able to detect the presence of certain services unless they have the appropriate `ServicePermission` to get the specific service.

Concurrency Thread-safe

10.1.28.1 **public static final String GET = "get"**

The action string `get`.

10.1.28.2 **public static final String REGISTER = "register"**

The action string `register`.

10.1.28.3 **public ServicePermission(String name, String actions)**

name The service class name

actions `get,register` (canonical order)

- Create a new `ServicePermission`.

The name of the service is specified as a fully qualified class name. Wildcards may be used.

`name ::= <class name> | <class name ending in ".*"> | *`

Examples:

```
org.osgi.service.http.HttpService
org.osgi.service.http.*
*
```

For the `get` action, the name can also be a filter expression. The filter gives access to the service properties as well as the following attributes:

- `signer` - A Distinguished Name chain used to sign the bundle publishing the service. Wildcards in a DN are not matched according to the filter string rules, but according to the rules defined for a DN chain.
- `location` - The location of the bundle publishing the service.
- `id` - The bundle ID of the bundle publishing the service.
- `name` - The symbolic name of the bundle publishing the service.

Since the above attribute names may conflict with service property names used by a service, you can prefix an attribute name with '@' in the filter expression to match against the service property and not one of the above attributes. Filter attribute names are processed in a case sensitive manner unless the attribute references a service property. Service properties names are case insensitive.

There are two possible actions: `get` and `register`. The `get` permission allows the owner of this permission to obtain a service with this name. The `register` permission allows the bundle to register a service under that name.

Throws `IllegalArgumentException`– If the specified name is a filter expression and either the specified action is not `get` or the filter has an invalid syntax.

10.1.28.4 **public ServicePermission(ServiceReference<?> reference, String actions)**

reference The requested service.

actions The action `get`.

- Creates a new requested `ServicePermission` object to be used by code that must perform `checkPermission` for the `get` action. `ServicePermission` objects created with this constructor cannot be added to a `ServicePermission` permission collection.

Throws `IllegalArgumentException`– If the specified action is not `get` or `reference` is null.

Since 1.5

10.1.28.5 **public boolean equals(Object obj)**

obj The object to test for equality.

- Determines the equality of two `ServicePermission` objects. Checks that specified object has the same class name and action as this `ServicePermission`.

Returns `true` if `obj` is a `ServicePermission`, and has the same class name and actions as this `ServicePermission` object; `false` otherwise.

10.1.28.6 **public String getActions()**

- Returns the canonical string representation of the actions. Always returns present actions in the following order: `get`, `register`.

Returns The canonical string representation of the actions.

10.1.28.7 **public int hashCode()**

- Returns the hash code value for this object.

Returns Hash code value for this object.

10.1.28.8 public boolean implies(Permission p)

p The target permission to check.

- Determines if a ServicePermission object "implies" the specified permission.

Returns true if the specified permission is implied by this object; false otherwise.

10.1.28.9 public PermissionCollection newPermissionCollection()

- Returns a new PermissionCollection object for storing ServicePermission objects.

Returns A new PermissionCollection object suitable for storing ServicePermission objects.

**10.1.29 public interface ServiceReference<S>
extends Comparable<Object>**

<S> Type of Service.

A reference to a service.

The Framework returns ServiceReference objects from the BundleContext.getServiceReference and BundleContext.getServiceReferences methods.

A ServiceReference object may be shared between bundles and can be used to examine the properties of the service and to get the service object.

Every service registered in the Framework has a unique ServiceRegistration object and may have multiple, distinct ServiceReference objects referring to it. ServiceReference objects associated with a ServiceRegistration object have the same hashCode and are considered equal (more specifically, their equals() method will return true when compared).

If the same service object is registered multiple times, ServiceReference objects associated with different ServiceRegistration objects are not equal.

See Also BundleContext.getServiceReference(Class), BundleContext.getServiceReference(String), BundleContext.getServiceReferences(Class, String), BundleContext.getServiceReferences(String, String), BundleContext.getService(ServiceReference), BundleContext.getServiceObjects(ServiceReference)

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.1.29.1 public int compareTo(Object reference)

reference The ServiceReference to be compared.

- Compares this ServiceReference with the specified ServiceReference for order.

If this ServiceReference and the specified ServiceReference have the same service id they are equal. This ServiceReference is less than the specified ServiceReference if it has a lower service ranking and greater if it has a higher service ranking. Otherwise, if this ServiceReference and the specified ServiceReference have the same service ranking, this ServiceReference is less than the specified ServiceReference if it has a higher service id and greater if it has a lower service id.

Returns Returns a negative integer, zero, or a positive integer if this ServiceReference is less than, equal to, or greater than the specified ServiceReference.

Throws IllegalArgumentException– If the specified ServiceReference was not created by the same framework instance as this ServiceReference.

Since 1.4

10.1.29.2 public Bundle getBundle()

- Returns the bundle that registered the service referenced by this ServiceReference object.

This method must return null when the service has been unregistered. This can be used to determine if the service has been unregistered.

Returns The bundle that registered the service referenced by this ServiceReference object; null if that service has already been unregistered.

See Also BundleContext.registerService(String[],Object,Dictionary)

10.1.29.3 public Dictionary<String, Object> getProperties()

- Returns a copy of the properties of the service referenced by this ServiceReference object.

This method will continue to return the properties after the service has been unregistered. This is so references to unregistered services (for example, ServiceReference objects stored in the log) can still be interrogated.

The returned Dictionary object:

- Must map property values by using property keys in a *case-insensitive manner*.
- Must return property keys in a *case-preserving* manner. This means that the keys must have the same case as the corresponding key in the properties Dictionary that was passed to the BundleContext.registerService(String[],Object,Dictionary) or ServiceRegistration.setProperties(Dictionary) methods.
- Is the property of the caller and can be modified by the caller but any changes are not reflected in the properties of the service. ServiceRegistration.setProperties(Dictionary) must be called to modify the properties of the service.

Returns A copy of the properties of the service referenced by this ServiceReference object

Since 1.9

10.1.29.4 public Object getProperty(String key)

key The property key.

- Returns the property value to which the specified property key is mapped in the properties Dictionary object of the service referenced by this ServiceReference object.

Property keys are case-insensitive.

This method must continue to return property values after the service has been unregistered. This is so references to unregistered services (for example, ServiceReference objects stored in the log) can still be interrogated.

Returns The property value to which the key is mapped; null if there is no property named after the key.

10.1.29.5 public String[] getPropertyKeys()

- Returns an array of the keys in the properties Dictionary object of the service referenced by this ServiceReference object.

This method will continue to return the keys after the service has been unregistered. This is so references to unregistered services (for example, ServiceReference objects stored in the log) can still be interrogated.

This method is *case-preserving*; this means that every key in the returned array must have the same case as the corresponding key in the properties Dictionary that was passed to the BundleContext.registerService(String[],Object,Dictionary) or ServiceRegistration.setProperties(Dictionary) methods.

Returns An array of property keys.

10.1.29.6 **public Bundle[] getUsingBundles()**

- Returns the bundles that are using the service referenced by this `ServiceReference` object. Specifically, this method returns the bundles whose usage count for that service is greater than zero.

Returns An array of bundles whose usage count for the service referenced by this `ServiceReference` object is greater than zero; null if no bundles are currently using that service.

Since 1.1

10.1.29.7 **public boolean isAssignableTo(Bundle bundle, String className)**

bundle The `Bundle` object to check.

className The class name to check.

- Tests if the bundle that registered the service referenced by this `ServiceReference` and the specified bundle use the same source for the package of the specified class name.

This method performs the following checks:

1. Get the package name from the specified class name.
2. For the bundle that registered the service referenced by this `ServiceReference` (registrant bundle); find the source for the package. If no source is found then return true if the registrant bundle is equal to the specified bundle; otherwise return false.
3. If the package source of the registrant bundle is equal to the package source of the specified bundle then return true; otherwise return false.

Returns true if the bundle which registered the service referenced by this `ServiceReference` and the specified bundle use the same source for the package of the specified class name. Otherwise false is returned.

Throws `IllegalArgumentException`– If the specified `Bundle` was not created by the same framework instance as this `ServiceReference`.

Since 1.3

10.1.30 **public interface ServiceRegistration<S>**

<S> Type of Service.

A registered service.

The Framework returns a `ServiceRegistration` object when a `BundleContext.registerService` method invocation is successful. The `ServiceRegistration` object is for the private use of the registering bundle and should not be shared with other bundles.

The `ServiceRegistration` object may be used to update the properties of the service or to unregister the service.

See Also `BundleContext.registerService(String[],Object,Dictionary)`

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.1.30.1 **public ServiceReference<S> getReference()**

- Returns a `ServiceReference` object for a service being registered.

The `ServiceReference` object may be shared with other bundles.

Returns `ServiceReference` object.

Throws `IllegalStateException`– If this `ServiceRegistration` object has already been unregistered.

10.1.30.2 public void setProperties(Dictionary<String, ?> properties)

properties The properties for this service. See Constants for a list of standard service property keys. Changes should not be made to this object after calling this method. To update the service's properties this method should be called again.

- Updates the properties associated with a service.

The Constants.OBJECTCLASS, Constants.SERVICE_BUNDLEID, Constants.SERVICE_ID and Constants.SERVICE_SCOPE keys cannot be modified by this method. These values are set by the Framework when the service is registered in the OSGi environment.

The following steps are required to modify service properties:

1. The service's properties are replaced with the provided properties.
2. A service event of type ServiceEvent.MODIFIED is fired.

Throws IllegalStateException– If this ServiceRegistration object has already been unregistered.

IllegalArgumentException– If properties contains case variants of the same key name.

10.1.30.3 public void unregister()

- Unregisters a service. Remove a ServiceRegistration object from the Framework service registry. All ServiceReference objects associated with this ServiceRegistration object can no longer be used to interact with the service once unregistration is complete.

The following steps are required to unregister a service:

1. The service is removed from the Framework service registry so that it can no longer be obtained.
2. A service event of type ServiceEvent.UNREGISTERING is fired so that bundles using this service can release their use of the service. Once delivery of the service event is complete, the ServiceReference objects for the service may no longer be used to get a service object for the service.
3. For each bundle whose use count for this service is greater than zero:
 - The bundle's use count for this service is set to zero.
 - If the service was registered with a ServiceFactory object, the ServiceFactory.ungetService method is called to release the service object for the bundle.

Throws IllegalStateException– If this ServiceRegistration object has already been unregistered.

See Also BundleContext.ungetService(ServiceReference), ServiceFactory.ungetService(Bundle, ServiceRegistration, Object)

10.1.31 public interface SynchronousBundleListener extends BundleListener

A synchronous BundleEvent listener. SynchronousBundleListener is a listener interface that may be implemented by a bundle developer. When a BundleEvent is fired, it is synchronously delivered to a SynchronousBundleListener. The Framework may deliver BundleEvent objects to a SynchronousBundleListener out of order and may concurrently call and/or reenter a SynchronousBundleListener.

For BundleEvent types STARTED and LAZY_ACTIVATION, the Framework must not hold the referenced bundle's "state change" lock when the BundleEvent is delivered to a SynchronousBundleListener. For the other BundleEvent types, the Framework must hold the referenced bundle's "state change" lock when the BundleEvent is delivered to a SynchronousBundleListener. A SynchronousBundleListener cannot directly call life cycle methods on the referenced bundle when the Framework is holding the referenced bundle's "state change" lock.

A SynchronousBundleListener object is registered with the Framework using the BundleContext.addBundleListener(BundleListener) method. SynchronousBundleListener objects

are called with a `BundleEvent` object when a bundle has been installed, resolved, starting, started, stopping, stopped, updated, unresolved, or uninstalled.

Unlike normal `BundleListener` objects, `SynchronousBundleListeners` are synchronously called during bundle lifecycle processing. The bundle lifecycle processing will not proceed until all `SynchronousBundleListeners` have completed. `SynchronousBundleListener` objects will be called prior to `BundleListener` objects.

`AdminPermission[bundle,LISTENER]` is required to add or remove a `SynchronousBundleListener` object.

See Also `BundleEvent`

Since 1.1

Concurrency Thread-safe

10.1.32 **public interface UnfilteredServiceListener extends ServiceListener**

A `ServiceEvent` listener that does *not* filter based upon any filter string specified to `BundleContext.addServiceListener(ServiceListener, String)`. Using an `UnfilteredServiceListener` and specifying a filter string to `BundleContext.addServiceListener(ServiceListener, String)` allows the listener to receive all `ServiceEvent` objects while still advising `ListenerHook` implementation of the service interests in the filter string. For example, an implementation of `Declarative Services` would add an `UnfilteredServiceListener` with a filter string listing all the services referenced by all the service components. The `Declarative Services` implementation would receive all `ServiceEvent` objects for internal processing and a `Remote Services` discovery service implementation can observe the service interests of the service components using a `ListenerHook`. When the set of service components being processed changes, the `Declarative Services` implementation would re-add the `UnfilteredServiceListener` with an updated filter string.

When a `ServiceEvent` is fired, it is synchronously delivered to an `UnfilteredServiceListener`. The Framework may deliver `ServiceEvent` objects to an `UnfilteredServiceListener` out of order and may concurrently call and/or reenter an `UnfilteredServiceListener`.

An `UnfilteredServiceListener` object is registered with the Framework using the `BundleContext.addServiceListener` method. `UnfilteredServiceListener` objects are called with a `ServiceEvent` object when a service is registered, modified, or is in the process of unregistering.

`ServiceEvent` object delivery to `UnfilteredServiceListener` objects are *not* filtered by the filter specified when the listener was registered. If the Java Runtime Environment supports permissions, then some filtering is done. `ServiceEvent` objects are only delivered to the listener if the bundle which defines the listener object's class has the appropriate `ServicePermission` to get the service using at least one of the named classes under which the service was registered.

See Also `ServiceEvent`, `ServicePermission`

Since 1.7

Concurrency Thread-safe

10.1.33 **public class Version implements Comparable<Version>**

Version identifier for capabilities such as bundles and packages.

Version identifiers have four components.

1. Major version. A non-negative integer.
2. Minor version. A non-negative integer.
3. Micro version. A non-negative integer.

4. Qualifier. A text string. See `Version(String)` for the format of the qualifier string.

Version objects are immutable.

Since 1.3

Concurrency Immutable

10.1.33.1 public static final Version emptyVersion

The empty version "0.0.0".

10.1.33.2 public Version(int major, int minor, int micro)

major Major component of the version identifier.

minor Minor component of the version identifier.

micro Micro component of the version identifier.

- Creates a version identifier from the specified numerical components.

The qualifier is set to the empty string.

Throws `IllegalArgumentException`– If the numerical components are negative.

10.1.33.3 public Version(int major, int minor, int micro, String qualifier)

major Major component of the version identifier.

minor Minor component of the version identifier.

micro Micro component of the version identifier.

qualifier Qualifier component of the version identifier. If null is specified, then the qualifier will be set to the empty string.

- Creates a version identifier from the specified components.

Throws `IllegalArgumentException`– If the numerical components are negative or the qualifier string is invalid.

10.1.33.4 public Version(String version)

version String representation of the version identifier. There must be no whitespace in the argument.

- Creates a version identifier from the specified string.

Version string grammar:

```
version ::= major ('.' minor ('.' micro ('.' qualifier)?)?)?
major  ::= digit+
minor  ::= digit+
micro  ::= digit+
qualifier ::= (alpha|digit|'_'|'-')+
digit  ::= [0..9]
alpha  ::= [a..zA..Z]
```

Throws `IllegalArgumentException`– If version is improperly formatted.

10.1.33.5 public int compareTo(Version other)

other The Version object to be compared.

- Compares this Version object to another Version.

A version is considered to be **less than** another version if its major component is less than the other version's major component, or the major components are equal and its minor component is less than the other version's minor component, or the major and minor components are equal and its

micro component is less than the other version's micro component, or the major, minor and micro components are equal and it's qualifier component is less than the other version's qualifier component (using `String.compareTo`).

A version is considered to be **equal to** another version if the major, minor and micro components are equal and the qualifier component is equal (using `String.compareTo`).

Returns A negative integer, zero, or a positive integer if this version is less than, equal to, or greater than the specified Version object.

Throws `ClassCastException`– If the specified object is not a Version object.

10.1.33.6 **public boolean equals(Object object)**

object The Version object to be compared.

- Compares this Version object to another object.

A version is considered to be **equal to** another version if the major, minor and micro components are equal and the qualifier component is equal (using `String.equals`).

Returns true if object is a Version and is equal to this object; false otherwise.

10.1.33.7 **public int getMajor()**

- Returns the major component of this version identifier.

Returns The major component.

10.1.33.8 **public int getMicro()**

- Returns the micro component of this version identifier.

Returns The micro component.

10.1.33.9 **public int getMinor()**

- Returns the minor component of this version identifier.

Returns The minor component.

10.1.33.10 **public String getQualifier()**

- Returns the qualifier component of this version identifier.

Returns The qualifier component.

10.1.33.11 **public int hashCode()**

- Returns a hash code value for the object.

Returns An integer which is a hash code value for this object.

10.1.33.12 **public static Version parseVersion(String version)**

version String representation of the version identifier. Leading and trailing whitespace will be ignored.

- Parses a version identifier from the specified string.

See `Version(String)` for the format of the version string.

Returns A Version object representing the version identifier. If version is null or the empty string then `emptyVersion` will be returned.

Throws `IllegalArgumentException`– If version is improperly formatted.

10.1.33.13 **public String toString()**

- Returns the string representation of this version identifier.

The format of the version string will be `major.minor.micro` if `qualifier` is the empty string or `major.minor.micro.qualifier` otherwise.

Returns The string representation of this version identifier.

10.1.33.14 **public static Version valueOf(String version)**

version String representation of the version identifier. Leading and trailing whitespace will be ignored. Must not be null.

- Returns a `Version` object holding the version identifier in the specified `String`.

See `Version(String)` for the format of the version string.

This method performs a similar function as `parseVersion(String)` but has the static factory `valueOf(String)` method signature.

Returns A `Version` object representing the version identifier. If `version` is the empty string then `emptyVersion` will be returned.

Throws `IllegalArgumentException`– If `version` is improperly formatted.

Since 1.8

10.1.34 **public class VersionRange**

Version range. A version range is an interval describing a set of versions.

A range has a left (lower) endpoint and a right (upper) endpoint. Each endpoint can be open (excluded from the set) or closed (included in the set).

`VersionRange` objects are immutable.

Since 1.7

Concurrency Immutable

10.1.34.1 **public static final char LEFT_CLOSED = 91**

The left endpoint is closed and is included in the range.

The value of `LEFT_CLOSED` is '['.

10.1.34.2 **public static final char LEFT_OPEN = 40**

The left endpoint is open and is excluded from the range.

The value of `LEFT_OPEN` is '('.

10.1.34.3 **public static final char RIGHT_CLOSED = 93**

The right endpoint is closed and is included in the range.

The value of `RIGHT_CLOSED` is ']'.

10.1.34.4 **public static final char RIGHT_OPEN = 41**

The right endpoint is open and is excluded from the range.

The value of `RIGHT_OPEN` is ')'

10.1.34.5 **public VersionRange(char leftType, Version leftEndpoint, Version rightEndpoint, char rightType)**

leftType Must be either `LEFT_CLOSED` or `LEFT_OPEN`.

leftEndpoint Left endpoint of range. Must not be null.

rightEndpoint Right endpoint of range. May be null to indicate the right endpoint is *Infinity*.

rightType Must be either `RIGHT_CLOSED` or `RIGHT_OPEN`.

- Creates a version range from the specified versions.

Throws `IllegalArgumentException`– If the arguments are invalid.

10.1.34.6 **public VersionRange(String range)**

range String representation of the version range. The versions in the range must contain no whitespace. Other whitespace in the range string is ignored. Must not be null.

- Creates a version range from the specified string.

Version range string grammar:

```
range ::= interval | atleast
interval ::= ( '[' | '(' ) left ',' right ( ']' | ')' )
left ::= version
right ::= version
atleast ::= version
```

Throws `IllegalArgumentException`– If range is improperly formatted.

10.1.34.7 **public boolean equals(Object object)**

object The `VersionRange` object to be compared.

- Compares this `VersionRange` object to another object.

A version range is considered to be **equal to** another version range if both the endpoints and their types are equal or if both version ranges are empty.

Returns true if object is a `VersionRange` and is equal to this object; false otherwise.

10.1.34.8 **public Version getLeft()**

- Returns the left endpoint of this version range.

Returns The left endpoint.

10.1.34.9 **public char getLeftType()**

- Returns the type of the left endpoint of this version range.

Returns `LEFT_CLOSED` if the left endpoint is closed or `LEFT_OPEN` if the left endpoint is open.

10.1.34.10 **public Version getRight()**

- Returns the right endpoint of this version range.

Returns The right endpoint. May be null which indicates the right endpoint is *Infinity*.

10.1.34.11 **public char getRightType()**

- Returns the type of the right endpoint of this version range.

Returns `RIGHT_CLOSED` if the right endpoint is closed or `RIGHT_OPEN` if the right endpoint is open.

10.1.34.12 **public int hashCode()**

- Returns a hash code value for the object.

Returns An integer which is a hash code value for this object.

10.1.34.13 **public boolean includes(Version version)**

version The version to test for inclusion in this version range.

- Returns whether this version range includes the specified version.

Returns true if the specified version is included in this version range; false otherwise.

10.1.34.14 **public VersionRange intersection(VersionRange... ranges)**

ranges The version ranges to intersect with this version range.

- Returns the intersection of this version range with the specified version ranges.

Returns A version range representing the intersection of this version range and the specified version ranges. If no version ranges are specified, then this version range is returned.

10.1.34.15 **public boolean isEmpty()**

- Returns whether this version range is empty. A version range is empty if the set of versions defined by the interval is empty.

Returns true if this version range is empty; false otherwise.

10.1.34.16 **public boolean isExact()**

- Returns whether this version range contains only a single version.

Returns true if this version range contains only a single version; false otherwise.

10.1.34.17 **public String toFilterString(String attributeName)**

attributeName The attribute name to use in the returned filter string.

- Returns the filter string for this version range using the specified attribute name.

Returns A filter string for this version range using the specified attribute name.

Throws IllegalArgumentException– If the specified attribute name is not a valid attribute name.

See Also Core Specification, Filters, for a description of the filter string syntax.

10.1.34.18 **public String toString()**

- Returns the string representation of this version range.

The format of the version range string will be a version string if the right end point is *Infinity* (null) or an interval string.

Returns The string representation of this version range.

10.1.34.19 **public static VersionRange valueOf(String range)**

range String representation of the version range. The versions in the range must contain no whitespace. Other whitespace in the range string is ignored. Must not be null.

- Returns a VersionRange object holding the version range in the specified String.

See VersionRange(String) for the format of the version range string.

Returns A VersionRange object representing the version range.

Throws IllegalArgumentException– If range is improperly formatted.

Since 1.8

10.2 org.osgi.framework.launch

Framework Launch Package Version 1.2.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest.

Example import for consumers using the API in this package:

Import-Package: org.osgi.framework.launch; version="[1.2,2.0]"

10.2.1 Summary

- Framework - A Framework instance.
- FrameworkFactory - A factory for creating Framework instances.

10.2.2 public interface Framework extends Bundle

A Framework instance. A Framework is also known as a System Bundle.

Framework instances are created using a FrameworkFactory. The methods of this interface can be used to manage and control the created framework instance.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.2.2.1 public A adapt(Class<A> type)

Type Parameters <A>

<A> The type to which this Framework is to be adapted.

type Class object for the type to which this Framework is to be adapted.

- Adapt this Framework to the specified type.

Adapting this Framework to the specified type may require certain checks, including security checks, to succeed. If a check does not succeed, then this Framework cannot be adapted and null is returned. If this Framework is not initialized, then null is returned if the specified type is one of the OSGi defined types to which a system bundle can be adapted.

Returns The object, of the specified type, to which this Framework has been adapted or null if this Framework cannot be adapted

10.2.2.2 public Enumeration<URL> findEntries(String path, String filePattern, boolean recurse)

path Ignored.

filePattern Ignored.

recurse Ignored.

- Returns null as a framework implementation does not have a proper bundle from which to return entries.

Returns null as a framework implementation does not have a proper bundle from which to return entries.

10.2.2.3 public long getBundleId()

- Returns the Framework unique identifier. This Framework is assigned the unique identifier zero (0) since this Framework is also a System Bundle.

Returns 0.

See Also Bundle.getBundleId()

10.2.2.4 public URL getEntry(String path)

path Ignored.

- Returns null as a framework implementation does not have a proper bundle from which to return an entry.

Returns null as a framework implementation does not have a proper bundle from which to return an entry.

10.2.2.5 **public Enumeration<String> getEntryPaths(String path)**

path Ignored.

- Returns null as a framework implementation does not have a proper bundle from which to return entry paths.

Returns null as a framework implementation does not have a proper bundle from which to return entry paths.

10.2.2.6 **public long getLastModified()**

- Returns the time when the set of bundles in this framework was last modified. The set of bundles is considered to be modified when a bundle is installed, updated or uninstalled.

The time value is the number of milliseconds since January 1, 1970, 00:00:00 UTC.

Returns The time when the set of bundles in this framework was last modified.

10.2.2.7 **public String getLocation()**

- Returns the Framework location identifier. This Framework is assigned the unique location "System Bundle" since this Framework is also a System Bundle.

Returns The string "System Bundle".

Throws `SecurityException`– If the caller does not have the appropriate `AdminPermission[this,METADATA]`, and the Java Runtime Environment supports permissions.

See Also `Bundle.getLocation()`, `Constants.SYSTEM_BUNDLE_LOCATION`

10.2.2.8 **public String getSymbolicName()**

- Returns the symbolic name of this Framework. The symbolic name is unique for the implementation of the framework. However, the symbolic name "system.bundle" must be recognized as an alias to the implementation-defined symbolic name since this Framework is also a System Bundle.

Returns The symbolic name of this Framework.

See Also `Bundle.getSymbolicName()`, `Constants.SYSTEM_BUNDLE_SYMBOLICNAME`

10.2.2.9 **public void init() throws BundleException**

- Initialize this Framework.

This method performs the same function as calling `init(FrameworkListener...)` with no framework listeners.

Throws `BundleException`– If this Framework could not be initialized.

`SecurityException`– If the Java Runtime Environment supports permissions and the caller does not have the appropriate `AdminPermission[this,EXECUTE]` or if there is a security manager already installed and the `Constants.FRAMEWORK_SECURITY` configuration property is set.

See Also `init(FrameworkListener...)`

10.2.2.10 **public void init(FrameworkListener... listeners) throws BundleException**

listeners Zero or more listeners to be notified when framework events occur while initializing the framework. The specified listeners do not need to be otherwise registered with the framework. If a specified listener is registered with the framework, it will be notified twice for each framework event.

- Initialize this Framework. After calling this method, this Framework must:

- Have generated a new framework UUID.
- Be in the STARTING state.
- Have a valid Bundle Context.
- Be at start level 0.
- Have event handling enabled.
- Have reified Bundle objects for all installed bundles.
- Have registered any framework services. For example, ConditionalPermissionAdmin.
- Be adaptable to the OSGi defined types to which a system bundle can be adapted.
- Have called the start method of the extension bundle activator for all resolved extension bundles.

This Framework will not actually be started until start is called.

This method does nothing if called when this Framework is in the STARTING, ACTIVE or STOPPING states.

All framework events fired by this method are also delivered to the specified FrameworkListeners in the order they are specified before returning from this method. After returning from this method the specified listeners are no longer notified of framework events.

Throws BundleException– If this Framework could not be initialized.

SecurityException– If the Java Runtime Environment supports permissions and the caller does not have the appropriate AdminPermission[this,EXECUTE] or if there is a security manager already installed and the Constants.FRAMEWORK_SECURITY configuration property is set.

Since 1.2

10.2.2.11 **public void start() throws BundleException**

- Start this Framework.

The following steps are taken to start this Framework:

1. If this Framework is not in the STARTING state, initialize this Framework.
2. All installed bundles must be started in accordance with each bundle's persistent *autostart setting*. This means some bundles will not be started, some will be started with *eager activation* and some will be started with their *declared activation* policy. The start level of this Framework is moved to the start level specified by the beginning start level framework property, as described in the *Start Level Specification*. If this framework property is not specified, then the start level of this Framework is moved to start level one (1). Any exceptions that occur during bundle starting must be wrapped in a BundleException and then published as a framework event of type FrameworkEvent.ERROR
3. This Framework's state is set to ACTIVE.
4. A framework event of type FrameworkEvent.STARTED is fired

Throws BundleException– If this Framework could not be started.

SecurityException– If the caller does not have the appropriate AdminPermission[this,EXECUTE], and the Java Runtime Environment supports permissions.

See Also Start Level Specification

10.2.2.12 **public void start(int options) throws BundleException**

options Ignored. There are no start options for the Framework.

- Start this Framework.

Calling this method is the same as calling start(). There are no start options for the Framework.

Throws BundleException– If this Framework could not be started.
SecurityException– If the caller does not have the appropriate AdminPermission[this,EXECUTE], and the Java Runtime Environment supports permissions.

See Also start()

10.2.2.13 **public void stop() throws BundleException**

- Stop this Framework.

The method returns immediately to the caller after initiating the following steps to be taken on another thread.

1. This Framework's state is set to STOPPING.
2. All installed bundles must be stopped without changing each bundle's persistent *autostart setting*. The start level of this Framework is moved to start level zero (0), as described in the *Start Level Specification*. Any exceptions that occur during bundle stopping must be wrapped in a BundleException and then published as a framework event of type FrameworkEvent.ERROR
3. Unregister all services registered by this Framework.
4. Event handling is disabled.
5. This Framework's state is set to RESOLVED.
6. All resources held by this Framework are released. This includes threads, bundle class loaders, open files, etc.
7. Notify all threads that are waiting at waitForStop that the stop operation has completed.

After being stopped, this Framework may be discarded, initialized or started.

Throws BundleException– If stopping this Framework could not be initiated.

SecurityException– If the caller does not have the appropriate AdminPermission[this,EXECUTE], and the Java Runtime Environment supports permissions.

See Also Start Level Specification

10.2.2.14 **public void stop(int options) throws BundleException**

options Ignored. There are no stop options for the Framework.

- Stop this Framework.

Calling this method is the same as calling stop(). There are no stop options for the Framework.

Throws BundleException– If stopping this Framework could not be initiated.

SecurityException– If the caller does not have the appropriate AdminPermission[this,EXECUTE], and the Java Runtime Environment supports permissions.

See Also stop()

10.2.2.15 **public void uninstall() throws BundleException**

- The Framework cannot be uninstalled.

This method always throws a BundleException.

Throws BundleException– This Framework cannot be uninstalled.

SecurityException– If the caller does not have the appropriate AdminPermission[this,LIFECYCLE], and the Java Runtime Environment supports permissions.

10.2.2.16 **public void update() throws BundleException**

- Stop and restart this Framework.

The method returns immediately to the caller after initiating the following steps to be taken on another thread.

1. Perform the steps in the stop() method to stop this Framework.
2. Perform the steps in the start() method to start this Framework.

Throws BundleException– If stopping and restarting this Framework could not be initiated.

SecurityException– If the caller does not have the appropriate AdminPermission[this,LIFECYCLE], and the Java Runtime Environment supports permissions.

10.2.2.17 **public void update(InputStream in) throws BundleException**

in Any provided InputStream is immediately closed before returning from this method and otherwise ignored.

- Stop and restart this Framework.

Calling this method is the same as calling update() except that any provided InputStream is immediately closed.

Throws BundleException– If stopping and restarting this Framework could not be initiated.

SecurityException– If the caller does not have the appropriate AdminPermission[this,LIFECYCLE], and the Java Runtime Environment supports permissions.

10.2.2.18 **public FrameworkEvent waitForStop(long timeout) throws InterruptedException**

timeout Maximum number of milliseconds to wait until this Framework has completely stopped. A value of zero will wait indefinitely.

- Wait until this Framework has completely stopped. The stop and update methods on a Framework performs an asynchronous stop of the Framework. This method can be used to wait until the asynchronous stop of this Framework has completed. This method will only wait if called when this Framework is in the STARTING, ACTIVE, or STOPPING states. Otherwise it will return immediately. A Framework Event is returned to indicate why this Framework has stopped.

Returns A Framework Event indicating the reason this method returned. The following FrameworkEvent types may be returned by this method.

- STOPPED - This Framework has been stopped.
- STOPPED_UPDATE - This Framework has been updated which has shutdown and will now restart.
- STOPPED_BOOTCLASSPATH_MODIFIED - This Framework has been stopped and a bootclass-path extension bundle has been installed or updated. The VM must be restarted in order for the changed boot class path to take effect.
- ERROR - The Framework encountered an error while shutting down or an error has occurred which forced the framework to shutdown.
- WAIT_TIMEDOUT - This method has timed out and returned before this Framework has stopped.

Throws InterruptedException– If another thread interrupted the current thread before or while the current thread was waiting for this Framework to completely stop. The *interrupted status* of the current thread is cleared when this exception is thrown.

IllegalArgumentException– If the value of timeout is negative.

10.2.3 **public interface FrameworkFactory**

A factory for creating Framework instances.

A framework implementation jar must contain the following resource:

```
/META-INF/services/org.osgi.framework.launch.FrameworkFactory
```

This UTF-8 encoded resource must contain the name of the framework implementation's FrameworkFactory implementation class. Space and tab characters, including blank lines, in the resource must be ignored. The number sign ('#\u0023') and all characters following it on each line are a comment and must be ignored.

Launchers can find the name of the FrameworkFactory implementation class in the resource and then load and construct a FrameworkFactory object for the framework implementation. The FrameworkFactory implementation class must have a public, no-argument constructor. Java™ SE 6 introduced the ServiceLoader class which can create a FrameworkFactory instance from the resource.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.2.3.1 **public Framework newFramework(Map<String, String> configuration)**

configuration The framework properties to configure the new framework instance. If framework properties are not provided by the configuration argument, the created framework instance must use some reasonable default configuration appropriate for the current VM. For example, the system packages for the current execution environment should be properly exported. The specified configuration argument may be null. The created framework instance must copy any information needed from the specified configuration argument since the configuration argument can be changed after the framework instance has been created.

- Create a new Framework instance.

Returns A new, configured Framework instance. The framework instance must be in the Bundle.INSTALLED state.

Throws SecurityException—If the caller does not have AllPermission, and the Java Runtime Environment supports permissions.

10.3 org.osgi.resource

Resource Package Version 1.0.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest. For example:

```
Import-Package: org.osgi.resource; version="[1.0,2.0]"
```

10.3.1 Summary

- Capability - A capability that has been declared from a Resource.
- Namespace - Capability and Requirement Namespaces base class.
- Requirement - A requirement that has been declared from a Resource .
- Resource - A resource is the representation of a uniquely identified and typed data.
- Wire - A wire connecting a Capability to a Requirement.
- Wiring - A wiring for a resource.

10.3.2 **public interface Capability**

A capability that has been declared from a Resource.

Instances of this type must be *effectively immutable*. That is, for a given instance of this interface, the methods defined by this interface must always return the same result.

Concurrency Thread-safe

10.3.2.1 **public boolean equals(Object obj)**

obj The object to compare against this Capability.

- Compares this Capability to another Capability.

This Capability is equal to another Capability if they have the same namespace, directives and attributes and are declared by the same resource.

Returns true if this Capability is equal to the other object; false otherwise.

10.3.2.2 **public Map<String, Object> getAttributes()**

- Returns the attributes of this capability.

Returns An unmodifiable map of attribute names to attribute values for this capability, or an empty map if this capability has no attributes.

10.3.2.3 **public Map<String, String> getDirectives()**

- Returns the directives of this capability.

Returns An unmodifiable map of directive names to directive values for this capability, or an empty map if this capability has no directives.

10.3.2.4 **public String getNamespace()**

- Returns the namespace of this capability.

Returns The namespace of this capability.

10.3.2.5 **public Resource getResource()**

- Returns the resource declaring this capability.

Returns The resource declaring this capability.

10.3.2.6 **public int hashCode()**

- Returns the hashCode of this Capability.

Returns The hashCode of this Capability.

10.3.3 **public abstract class Namespace**

Capability and Requirement Namespaces base class.

This class is the common class shared by all OSGi defined namespaces. It defines the names for the common attributes and directives for the OSGi specified namespaces.

The OSGi Alliance reserves the right to extend the set of directives and attributes which have specified semantics for all of the specified namespaces.

The values associated with these keys are of type String, unless otherwise indicated.

Concurrency Immutable

10.3.3.1 **public static final String CAPABILITY_EFFECTIVE_DIRECTIVE = "effective"**

The capability directive used to specify the effective time for the capability. The default value is resolve.

See Also resolve, active

10.3.3.2 **public static final String CAPABILITY_USES_DIRECTIVE = "uses"**

The capability directive used to specify the comma separated list of package names used by a capability.

10.3.3.3 **public static final String CARDINALITY_MULTIPLE = "multiple"**

The directive value identifying a multiple cardinality type.

See Also REQUIREMENT_CARDINALITY_DIRECTIVE

10.3.3.4 **public static final String CARDINALITY_SINGLE = "single"**

The directive value identifying a cardinality type of single.

See Also REQUIREMENT_CARDINALITY_DIRECTIVE

10.3.3.5 **public static final String EFFECTIVE_ACTIVE = "active"**

The directive value identifying a capability or requirement that is effective at active time. Capabilities and requirements with an effective time of active are ignored while resolving a resource.

See Also REQUIREMENT_EFFECTIVE_DIRECTIVE, CAPABILITY_EFFECTIVE_DIRECTIVE

10.3.3.6 **public static final String EFFECTIVE_RESOLVE = "resolve"**

The directive value identifying a capability or requirement that is effective at resolve time. Capabilities and requirements with an effective time of resolve are the only capabilities which are processed while resolving a resource.

See Also REQUIREMENT_EFFECTIVE_DIRECTIVE, CAPABILITY_EFFECTIVE_DIRECTIVE

10.3.3.7 **public static final String REQUIREMENT_CARDINALITY_DIRECTIVE = "cardinality"**

The requirement directive used to specify the cardinality for a requirement. The default value is single.

See Also multiple, single

10.3.3.8 **public static final String REQUIREMENT_EFFECTIVE_DIRECTIVE = "effective"**

The requirement directive used to specify the effective time for the requirement. The default value is resolve.

See Also resolve, active

10.3.3.9 **public static final String REQUIREMENT_FILTER_DIRECTIVE = "filter"**

The requirement directive used to specify a capability filter. This filter is used to match against a capability's attributes.

10.3.3.10 **public static final String REQUIREMENT_RESOLUTION_DIRECTIVE = "resolution"**

The requirement directive used to specify the resolution type for a requirement. The default value is mandatory .

See Also mandatory, optional

10.3.3.11 **public static final String RESOLUTION_MANDATORY = "mandatory"**

The directive value identifying a mandatory requirement resolution type. A mandatory resolution type indicates that the requirement must be resolved when the resource is resolved. If such a requirement cannot be resolved, the resource fails to resolve.

See Also REQUIREMENT_RESOLUTION_DIRECTIVE

10.3.3.12 **public static final String RESOLUTION_OPTIONAL = "optional"**

The directive value identifying an optional requirement resolution type. An optional resolution type indicates that the requirement is optional and the resource may be resolved without the requirement being resolved.

See Also REQUIREMENT_RESOLUTION_DIRECTIVE

10.3.3.13 **protected Namespace()**

- Protected constructor for Namespace sub-types.

10.3.4 **public interface Requirement**

A requirement that has been declared from a Resource .

Instances of this type must be *effectively immutable*. That is, for a given instance of this interface, the methods defined by this interface must always return the same result.

Concurrency Thread-safe

10.3.4.1 **public boolean equals(Object obj)**

obj The object to compare against this Requirement .

- Compares this Requirement to another Requirement .

This Requirement is equal to another Requirement if they have the same namespace, directives and attributes and are declared by the same resource.

Returns true if this Requirement is equal to the other object; false otherwise.

10.3.4.2 **public Map<String, Object> getAttributes()**

- Returns the attributes of this requirement.

Requirement attributes have no specified semantics and are considered extra user defined information.

Returns An unmodifiable map of attribute names to attribute values for this requirement, or an empty map if this requirement has no attributes.

10.3.4.3 **public Map<String, String> getDirectives()**

- Returns the directives of this requirement.

Returns An unmodifiable map of directive names to directive values for this requirement, or an empty map if this requirement has no directives.

10.3.4.4 **public String getNamespace()**

- Returns the namespace of this requirement.

Returns The namespace of this requirement.

10.3.4.5 **public Resource getResource()**

- Returns the resource declaring this requirement.

Returns The resource declaring this requirement. This can be null if this requirement is synthesized.

10.3.4.6 **public int hashCode()**

- Returns the hashCode of this Requirement .

Returns The hashCode of this Requirement .

10.3.5 public interface Resource

A resource is the representation of a uniquely identified and typed data. A resource declares requirements that need to be satisfied by capabilities before it can provide its capabilities.

Instances of this type must be *effectively immutable*. That is, for a given instance of this interface, the methods defined by this interface must always return the same result.

Concurrency Thread-safe

10.3.5.1 public boolean equals(Object obj)

obj The object to compare against this Resource.

- Compares this Resource to another Resource.

This Resource is equal to another Resource if both have the same content and come from the same location. Location may be defined as the bundle location if the resource is an installed bundle or the repository location if the resource is in a repository.

Returns true if this Resource is equal to the other object; false otherwise.

10.3.5.2 public List<Capability> getCapabilities(String namespace)

namespace The namespace of the declared capabilities to return or null to return the declared capabilities from all namespaces.

- Returns the capabilities declared by this resource.

Returns An unmodifiable list containing the declared Capabilities from the specified namespace. The returned list will be empty if this resource declares no capabilities in the specified namespace.

10.3.5.3 public List<Requirement> getRequirements(String namespace)

namespace The namespace of the declared requirements to return or null to return the declared requirements from all namespaces.

- Returns the requirements declared by this bundle resource.

Returns An unmodifiable list containing the declared Requirement s from the specified namespace. The returned list will be empty if this resource declares no requirements in the specified namespace.

10.3.5.4 public int hashCode()

- Returns the hashCode of this Resource.

Returns The hashCode of this Resource.

10.3.6 public interface Wire

A wire connecting a Capability to a Requirement.

Instances of this type must be *effectively immutable*. That is, for a given instance of this interface, the methods defined by this interface must always return the same result.

Concurrency Thread-safe

10.3.6.1 public boolean equals(Object obj)

obj The object to compare against this Wire.

- Compares this Wire to another Wire.

This Wire is equal to another Wire if they have the same capability, requirement, provider and requirer.

Returns true if this Wire is equal to the other object; false otherwise.

10.3.6.2 public Capability getCapability()

- Returns the Capability for this wire.

Returns The Capability for this wire.

10.3.6.3 public Resource getProvider()

- Returns the resource providing the capability.

The returned resource may differ from the resource referenced by the capability.

Returns The resource providing the capability.

10.3.6.4 public Requirement getRequirement()

- Returns the Requirement for this wire.

Returns The Requirement for this wire.

10.3.6.5 public Resource getRequirer()

- Returns the resource who requires the capability.

The returned resource may differ from the resource referenced by the requirement.

Returns The resource who requires the capability.

10.3.6.6 public int hashCode()

- Returns the hashCode of this Wire.

Returns The hashCode of this Wire.

10.3.7 public interface Wiring

A wiring for a resource. A wiring is associated with a resource and represents the dependencies with other wirings.

Instances of this type must be *effectively immutable*. That is, for a given instance of this interface, the methods defined by this interface must always return the same result.

Concurrency Thread-safe

10.3.7.1 public List<Wire> getProvidedResourceWires(String namespace)

namespace The namespace of the capabilities for which to return wires or null to return the wires for the capabilities in all namespaces.

- Returns the Wires to the provided capabilities of this wiring.

Returns A list containing a snapshot of the Wires for the capabilities of this wiring, or an empty list if this wiring has no capabilities in the specified namespace. For a given namespace, the list contains the wires in the order the capabilities were specified in the manifests of the resource and the attached fragment resources of this wiring. There is no ordering defined between capabilities in different namespaces.

10.3.7.2 public List<Wire> getRequiredResourceWires(String namespace)

namespace The namespace of the requirements for which to return wires or null to return the wires for the requirements in all namespaces.

- Returns the Wires to the requirements in use by this wiring.

Returns A list containing a snapshot of the Wires for the requirements of this wiring, or an empty list if this wiring has no requirements in the specified namespace. For a given namespace, the list contains the wires in the order the requirements were specified in the manifests of the resource and the attached

fragment resources of this wiring. There is no ordering defined between requirements in different namespaces.

10.3.7.3 **public Resource getResource()**

- Returns the resource associated with this wiring.

Returns The resource associated with this wiring.

10.3.7.4 **public List<Capability> getResourceCapabilities(String namespace)**

namespace The namespace of the capabilities to return or null to return the capabilities from all namespaces.

- Returns the capabilities provided by this wiring.

Only capabilities considered by the resolver are returned. For example, capabilities with effective directive not equal to resolve are not returned.

A capability may not be required by any wiring and thus there may be no wires for the capability.

A wiring for a non-fragment resource provides a subset of the declared capabilities from the resource and all attached fragment resources[†]. Not all declared capabilities may be provided since some may be discarded. For example, if a package is declared to be both exported and imported, only one is selected and the other is discarded.

A wiring for a fragment resource with a symbolic name must provide exactly one `osgi.identity` capability.

[†] The `osgi.identity` capability provided by attached fragment resource must not be included in the capabilities of the host wiring.

Returns A list containing a snapshot of the Capabilities, or an empty list if this wiring provides no capabilities in the specified namespace. For a given namespace, the list contains the capabilities in the order the capabilities were specified in the manifests of the resource and the attached fragment resources[†] of this wiring. There is no ordering defined between capabilities in different namespaces.

10.3.7.5 **public List<Requirement> getResourceRequirements(String namespace)**

namespace The namespace of the requirements to return or null to return the requirements from all namespaces.

- Returns the requirements of this wiring.

Only requirements considered by the resolver are returned. For example, requirements with effective directive not equal to resolve are not returned.

A wiring for a non-fragment resource has a subset of the declared requirements from the resource and all attached fragment resources. Not all declared requirements may be present since some may be discarded. For example, if a package is declared to be both exported and imported, only one is selected and the other is discarded.

Returns A list containing a snapshot of the Requirements, or an empty list if this wiring uses no requirements in the specified namespace. For a given namespace, the list contains the requirements in the order the requirements were specified in the manifests of the resource and the attached fragment resources of this wiring. There is no ordering defined between requirements in different namespaces.

10.4 **org.osgi.framework.wiring**

Framework Wiring Package Version 1.2.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest. For example:

```
Import-Package: org.osgi.framework.wiring; version="[1.2,2.0) "
```

10.4.1 Summary

- `BundleCapability` - A capability that has been declared from a bundle revision.
- `BundleRequirement` - A requirement that has been declared from a bundle revision.
- `BundleRevision` - Bundle Revision.
- `BundleRevisions` - The bundle revisions of a bundle.
- `BundleWire` - A wire connecting a `BundleCapability` to a `BundleRequirement`.
- `BundleWiring` - A wiring for a bundle.
- `FrameworkWiring` - Query and modify wiring information for the framework.

10.4.2 **public interface BundleCapability** **extends Capability**

A capability that has been declared from a bundle revision.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.4.2.1 **public Map<String, Object> getAttributes()**

- Returns the attributes of this capability.

Returns An unmodifiable map of attribute names to attribute values for this capability, or an empty map if this capability has no attributes.

10.4.2.2 **public Map<String, String> getDirectives()**

- Returns the directives of this capability.

All capability directives not specified by the wiring namespaces have no specified semantics and are considered extra user defined information.

Returns An unmodifiable map of directive names to directive values for this capability, or an empty map if this capability has no directives.

10.4.2.3 **public String getNamespace()**

- Returns the namespace of this capability.

Returns The namespace of this capability.

10.4.2.4 **public BundleRevision getResource()**

- Returns the resource declaring this capability.

This method returns the same value as `getRevision()`.

Returns The resource declaring this capability.

Since 1.1

10.4.2.5 **public BundleRevision getRevision()**

- Returns the bundle revision declaring this capability.

Returns The bundle revision declaring this capability.

10.4.3 **public interface BundleRequirement extends Requirement**

A requirement that has been declared from a bundle revision.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.4.3.1 **public Map<String, Object> getAttributes()**

- Returns the attributes of this requirement.

Requirement attributes have no specified semantics and are considered extra user defined information.

Returns An unmodifiable map of attribute names to attribute values for this requirement, or an empty map if this requirement has no attributes.

10.4.3.2 **public Map<String, String> getDirectives()**

- Returns the directives of this requirement.

All requirement directives not specified by the wiring namespaces have no specified semantics and are considered extra user defined information.

Returns An unmodifiable map of directive names to directive values for this requirement, or an empty map if this requirement has no directives.

10.4.3.3 **public String getNamespace()**

- Returns the namespace of this requirement.

Returns The namespace of this requirement.

10.4.3.4 **public BundleRevision getResource()**

- Returns the resource declaring this requirement.

This method returns the same value as `getRevision()`.

Returns The resource declaring this requirement. This can be null if this requirement is synthesized.

Since 1.1

10.4.3.5 **public BundleRevision getRevision()**

- Returns the bundle revision declaring this requirement.

Returns The bundle revision declaring this requirement.

10.4.3.6 **public boolean matches(BundleCapability capability)**

capability The capability to match to this requirement.

- Returns whether the specified capability matches this requirement.

Returns true if the specified capability has the same namespace as this requirement and the filter for this requirement matches the attributes of the specified capability; false otherwise.

10.4.4 **public interface BundleRevision extends BundleReference, Resource**

Bundle Revision. When a bundle is installed and each time a bundle is updated, a new bundle revision of the bundle is created. Since a bundle update can change the entries in a bundle, different bundle wirings for the same bundle can be associated with different bundle revisions.

For a bundle that has not been uninstalled, the most recent bundle revision is defined to be the current bundle revision. A bundle in the UNINSTALLED state does not have a current revision. The current bundle revision for a bundle can be obtained by calling `bundle.adapt(BundleRevision.class)`. Since a bundle in the UNINSTALLED state does not have a current revision, adapting such a bundle returns null.

The framework defines namespaces for package, bundle and host capabilities and requirements. These namespaces are defined only to express wiring information by the framework. They must not be used in Provide-Capability and Require-Capability manifest headers.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.4.4.1 **public static final String BUNDLE_NAMESPACE = "osgi.wiring.bundle"**

Namespace for bundle capabilities and requirements.

The bundle symbolic name of the bundle is stored in the capability attribute of the same name as this namespace (`osgi.wiring.bundle`). The other directives and attributes of the bundle, from the Bundle-SymbolicName manifest header, can be found in the capability's directives and attributes. The bundle-version capability attribute must contain the Version of the bundle from the Bundle-Version manifest header if one is specified or `Version.emptyVersion` if not specified.

A non-fragment revision declares exactly one[†] bundle capability (that is, the bundle can be required by another bundle). A fragment revision must not declare a bundle capability.

A bundle wiring for a non-fragment revision provides exactly one[†] bundle capability (that is, the bundle can be required by another bundle) and requires zero or more bundle capabilities (that is, requires other bundles).

[†] A bundle with no bundle symbolic name (that is, a bundle with Bundle-ManifestVersion < 2) must not provide a bundle capability.

See Also BundleNamespace

10.4.4.2 **public static final String HOST_NAMESPACE = "osgi.wiring.host"**

Namespace for host capabilities and requirements.

The bundle symbolic name of the bundle is stored in the capability attribute of the same name as this namespace (`osgi.wiring.host`). The other directives and attributes of the bundle, from the Bundle-SymbolicName manifest header, can be found in the capability's directives and attributes. The bundle-version capability attribute must contain the Version of the bundle from the Bundle-Version manifest header if one is specified or `Version.emptyVersion` if not specified.

A non-fragment revision declares zero or one[†] host capability if the bundle allows fragments to be attached. A fragment revision must declare exactly one host requirement.

A bundle wiring for a non-fragment revision provides zero or one[†] host capability if the bundle allows fragments to be attached. A bundle wiring for a fragment revision requires a host capability for each host to which it is attached.

[†] A bundle with no bundle symbolic name (that is, a bundle with Bundle-ManifestVersion < 2) must not provide a host capability.

See Also HostNamespace

10.4.4.3 **public static final String PACKAGE_NAMESPACE = "osgi.wiring.package"**

Namespace for package capabilities and requirements.

The name of the package is stored in the capability attribute of the same name as this namespace (`osgi.wiring.package`). The other directives and attributes of the package, from the Export-Package manifest header, can be found in the capability's directives and attributes. The version capability at-

tribute must contain the Version of the package if one is specified or Version.emptyVersion if not specified. The bundle-symbolic-name capability attribute must contain the symbolic name of the provider if one is specified. The bundle-version capability attribute must contain the version of the provider if one is specified or Version.emptyVersion if not specified.

The package capabilities provided by the system bundle, that is the bundle with id zero, must include the package specified by the Constants.FRAMEWORK_SYSTEMPACKAGES and Constants.FRAMEWORK_SYSTEMPACKAGES_EXTRA framework properties as well as any other package exported by the framework implementation.

A bundle revision declares zero or more package capabilities (this is, exported packages) and declares zero or more package requirements.

A bundle wiring provides zero or more resolved package capabilities (that is, exported packages) and requires zero or more resolved package requirements (that is, imported packages). The number of package wires required by a bundle wiring may change as the bundle wiring may dynamically import additional packages.

See Also PackageNamespace

10.4.4.4 **public static final int TYPE_FRAGMENT = 1**

Bundle revision type indicating the bundle revision is a fragment.

See Also getTypes()

10.4.4.5 **public List<Capability> getCapabilities(String namespace)**

namespace The namespace of the declared capabilities to return or null to return the declared capabilities from all namespaces.

- Returns the capabilities declared by this resource.

This method returns the same value as getDeclaredCapabilities(String).

Returns An unmodifiable list containing the declared Capabilities from the specified namespace. The returned list will be empty if this resource declares no capabilities in the specified namespace.

Since 1.1

10.4.4.6 **public List<BundleCapability> getDeclaredCapabilities(String namespace)**

namespace The namespace of the declared capabilities to return or null to return the declared capabilities from all namespaces.

- Returns the capabilities declared by this bundle revision.

Returns An unmodifiable list containing the declared BundleCapabilities from the specified namespace. The returned list will be empty if this bundle revision declares no capabilities in the specified namespace. The list contains the declared capabilities in the order they are specified in the manifest.

10.4.4.7 **public List<BundleRequirement> getDeclaredRequirements(String namespace)**

namespace The namespace of the declared requirements to return or null to return the declared requirements from all namespaces.

- Returns the requirements declared by this bundle revision.

Returns An unmodifiable list containing the declared BundleRequirements from the specified namespace. The returned list will be empty if this bundle revision declares no requirements in the specified namespace. The list contains the declared requirements in the order they are specified in the manifest.

10.4.4.8 **public List<Requirement> getRequirements(String namespace)**

namespace The namespace of the declared requirements to return or null to return the declared requirements from all namespaces.

- Returns the requirements declared by this bundle resource.

This method returns the same value as `getDeclaredRequirements(String)`.

Returns An unmodifiable list containing the declared `Requirement`s from the specified namespace. The returned list will be empty if this resource declares no requirements in the specified namespace.

Since 1.1

10.4.4.9 **public String getSymbolicName()**

- Returns the symbolic name for this bundle revision.

Returns The symbolic name for this bundle revision.

See Also `Bundle.getSymbolicName()`

10.4.4.10 **public int getTypes()**

- Returns the special types of this bundle revision. The bundle revision type values are:

- `TYPE_FRAGMENT`

A bundle revision may be more than one type at a time. A type code is used to identify the bundle revision type for future extendability.

If this bundle revision is not one or more of the defined types then 0 is returned.

Returns The special types of this bundle revision. The type values are ORed together.

10.4.4.11 **public Version getVersion()**

- Returns the version for this bundle revision.

Returns The version for this bundle revision, or `Version.emptyVersion` if this bundle revision has no version information.

See Also `Bundle.getVersion()`

10.4.4.12 **public BundleWiring getWiring()**

- Returns the bundle wiring which is using this bundle revision.

Returns The bundle wiring which is using this bundle revision or null if no bundle wiring is using this bundle revision.

See Also `BundleWiring.getRevision()`

10.4.5 **public interface BundleRevisions
extends BundleReference**

The bundle revisions of a bundle. When a bundle is installed and each time a bundle is updated, a new bundle revision of the bundle is created. For a bundle that has not been uninstalled, the most recent bundle revision is defined to be the current bundle revision. A bundle in the UNINSTALLED state does not have a current revision. An in use bundle revision is associated with an in use `BundleWiring`. The current bundle revision, if there is one, and all in use bundle revisions are returned.

The bundle revisions for a bundle can be obtained by calling `bundle.adapt(BundleRevisions.class).getRevisions()` on the bundle.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.4.5.1 **public List<BundleRevision> getRevisions()**

- Return the bundle revisions for the referenced bundle.

The result is a list containing the current bundle revision, if there is one, and all in use bundle revisions. The list may also contain intermediate bundle revisions which are not in use.

The list is ordered in reverse chronological order such that the first item is the most recent bundle revision and last item is the oldest bundle revision.

Generally the list will have at least one bundle revision for the bundle: the current bundle revision. However, for an uninstalled bundle with no in use bundle revisions, the list may be empty.

Returns A list containing a snapshot of the BundleRevisions for the referenced bundle.

10.4.6 **public interface BundleWire extends Wire**

A wire connecting a BundleCapability to a BundleRequirement.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.4.6.1 **public BundleCapability getCapability()**

- Returns the BundleCapability for this wire.

Returns The BundleCapability for this wire.

10.4.6.2 **public BundleRevision getProvider()**

- Returns the resource providing the capability.

The returned resource may differ from the resource referenced by the capability.

This method returns the same value as `getProviderWiring().getRevision()`.

Returns The resource providing the capability.

Since 1.1

10.4.6.3 **public BundleWiring getProviderWiring()**

- Returns the bundle wiring providing the capability.

The bundle revision referenced by the returned bundle wiring may differ from the bundle revision referenced by the capability.

Returns The bundle wiring providing the capability. If the bundle wiring providing the capability is not in use, null will be returned.

10.4.6.4 **public BundleRequirement getRequirement()**

- Return the BundleRequirement for this wire.

Returns The BundleRequirement for this wire.

10.4.6.5 **public BundleRevision getRequirer()**

- Returns the resource who requires the capability.

The returned resource may differ from the resource referenced by the requirement.

This method returns the same value as `getRequirerWiring().getRevision()`.

Returns The resource who requires the capability.

Since 1.1

10.4.6.6 **public BundleWiring getRequirerWiring()**

- Returns the bundle wiring who requires the capability.

The bundle revision referenced by the returned bundle wiring may differ from the bundle revision referenced by the requirement.

Returns The bundle wiring whose requirement is wired to the capability. If the bundle wiring requiring the capability is not in use, null will be returned.

10.4.7 **public interface BundleWiring extends BundleReference, Wiring**

A wiring for a bundle. Each time a bundle is resolved, a new bundle wiring for the bundle is created. A bundle wiring is associated with a bundle revision and represents the dependencies with other bundle wirings.

The bundle wiring for a bundle is the current bundle wiring if it is the most recent bundle wiring for the current bundle revision. A bundle wiring is in use if it is the current bundle wiring or if some other in use bundle wiring is dependent upon it. For example, another bundle wiring is wired to a capability provided by the bundle wiring. An in use bundle wiring for a non-fragment bundle has a class loader. All bundles with non-current, in use bundle wirings are considered removal pending. Once a bundle wiring is no longer in use, it is considered stale and is discarded by the framework.

The current bundle wiring for a bundle can be obtained by calling `bundle.adapt(BundleWiring.class)`. A bundle in the INSTALLED or UNINSTALLED state does not have a current wiring, adapting such a bundle returns null.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.4.7.1 **public static final int FINDENTRIES_RECURSE = 1**

The find entries operation must recurse into subdirectories.

This bit may be set when calling `findEntries(String, String, int)` to specify the result must include the matching entries from the specified path and its subdirectories. If this bit is not set, then the result must only include matching entries from the specified path.

See Also `findEntries(String, String, int)`

10.4.7.2 **public static final int LISTRESOURCES_LOCAL = 2**

The list resource names operation must limit the result to the names of matching resources contained in this bundle wiring's bundle revision and its attached fragment revisions. The result must not include resource names for resources in package names which are imported by this wiring.

This bit may be set when calling `listResources(String, String, int)` to specify the result must only include the names of matching resources contained in this bundle wiring's bundle revision and its attached fragment revisions. If this bit is not set, then the result must include the names of matching resources reachable from this bundle wiring's class loader which may include the names of matching resources contained in imported packages and required bundles.

See Also `listResources(String, String, int)`

10.4.7.3 **public static final int LISTRESOURCES_RECURSE = 1**

The list resource names operation must recurse into subdirectories.

This bit may be set when calling `listResources(String, String, int)` to specify the result must include the names of matching resources from the specified path and its subdirectories. If this bit is not set, then the result must only include names of matching resources from the specified path.

See Also `listResources(String, String, int)`

10.4.7.4 **public List<URL> findEntries(String path, String filePattern, int options)**

path The path name in which to look. The path is always relative to the root of this bundle wiring and may begin with "/". A path value of "/" indicates the root of this bundle wiring.

filePattern The file name pattern for selecting entries in the specified path. The pattern is only matched against the last element of the entry path. If the entry is a directory then the trailing "/" is not used for pattern matching. Substring matching is supported, as specified in the Filter specification, using the wildcard character ("*"). If null is specified, this is equivalent to "*" and matches all files.

options The options for listing resource names. See `FINDENTRIES_RECURSE`. The method must ignore unrecognized options.

- Returns entries in this bundle wiring's bundle revision and its attached fragment revisions. This bundle wiring's class loader is not used to search for entries. Only the contents of this bundle wiring's bundle revision and its attached fragment revisions are searched for the specified entries.

This method takes into account that the "contents" of this bundle wiring can have attached fragments. This "bundle space" is not a namespace with unique members; the same entry name can be present multiple times. This method therefore returns a list of URL objects. These URLs can come from different JARs but have the same path name. This method can either return only entries in the specified path or recurse into subdirectories returning entries in the directory tree beginning at the specified path.

URLs for directory entries must have their path end with "/".

Note: Jar and zip files are not required to include directory entries. URLs to directory entries will not be returned if the bundle contents do not contain directory entries.

Returns An unmodifiable list of URL objects for each matching entry, or an empty list if no matching entry could be found, if this bundle wiring is for a fragment revision or if the caller does not have the appropriate `AdminPermission[bundle,RESOURCE]` and the Java Runtime Environment supports permissions. The list is ordered such that entries from the bundle revision are returned first followed by the entries from attached fragment revisions in attachment order. If this bundle wiring is not in use, null must be returned.

See Also `Bundle.findEntries(String, String, boolean)`

10.4.7.5 **public List<BundleCapability> getCapabilities(String namespace)**

namespace The namespace of the capabilities to return or null to return the capabilities from all namespaces.

- Returns the capabilities provided by this bundle wiring.

Only capabilities considered by the resolver are returned. For example, capabilities with effective directive not equal to resolve are not returned.

A capability may not be required by any bundle wiring and thus there may be no wires for the capability.

A bundle wiring for a non-fragment revision provides a subset of the declared capabilities from the bundle revision and all attached fragment revisions[†]. Not all declared capabilities may be provided since some may be discarded. For example, if a package is declared to be both exported and imported, only one is selected and the other is discarded.

A bundle wiring for a fragment revision with a symbolic name must provide exactly one identity capability.

† The identity capability provided by attached fragment revisions must not be included in the capabilities of the host bundle wiring.

Returns A list containing a snapshot of the BundleCapabilities, or an empty list if this bundle wiring provides no capabilities in the specified namespace. If this bundle wiring is not in use, null will be returned. For a given namespace, the list contains the capabilities in the order the capabilities were specified in the manifests of the bundle revision and the attached fragments[†] of this bundle wiring. There is no ordering defined between capabilities in different namespaces.

10.4.7.6 **public ClassLoader getClassLoader()**

- Returns the class loader for this bundle wiring. Since a bundle refresh creates a new bundle wiring for a bundle, different bundle wirings for the same bundle will have different class loaders.

Returns The class loader for this bundle wiring. If this bundle wiring is not in use or this bundle wiring is for a fragment revision, null will be returned.

Throws SecurityException– If the caller does not have the appropriate RuntimePermission("getClassLoader"), and the Java Runtime Environment supports permissions.

10.4.7.7 **public List<Wire> getProvidedResourceWires(String namespace)**

namespace The namespace of the capabilities for which to return wires or null to return the wires for the capabilities in all namespaces.

- Returns the Wires to the provided capabilities of this wiring.

This method returns the same value as `getProvidedWires(String)`.

Returns A list containing a snapshot of the Wires for the capabilities of this wiring, or an empty list if this wiring has no capabilities in the specified namespace. For a given namespace, the list contains the wires in the order the capabilities were specified in the manifests of the resource and the attached fragment resources of this wiring. There is no ordering defined between capabilities in different namespaces.

Since 1.1

10.4.7.8 **public List<BundleWire> getProvidedWires(String namespace)**

namespace The namespace of the capabilities for which to return wires or null to return the wires for the capabilities in all namespaces.

- Returns the BundleWires to the provided capabilities of this bundle wiring.

Returns A list containing a snapshot of the BundleWires for the capabilities of this bundle wiring, or an empty list if this bundle wiring has no capabilities in the specified namespace. If this bundle wiring is not in use, null will be returned. For a given namespace, the list contains the wires in the order the capabilities were specified in the manifests of the bundle revision and the attached fragments of this bundle wiring. There is no ordering defined between capabilities in different namespaces.

10.4.7.9 **public List<Wire> getRequiredResourceWires(String namespace)**

namespace The namespace of the requirements for which to return wires or null to return the wires for the requirements in all namespaces.

- Returns the Wires to the requirements in use by this wiring.

This method returns the same value as `getRequiredWires(String)`.

Returns A list containing a snapshot of the Wires for the requirements of this wiring, or an empty list if this wiring has no requirements in the specified namespace. For a given namespace, the list contains the wires in the order the requirements were specified in the manifests of the resource and the attached fragment resources of this wiring. There is no ordering defined between requirements in different namespaces.

Since 1.1

10.4.7.10 **public List<BundleWire> getRequiredWires(String namespace)**

namespace The namespace of the requirements for which to return wires or null to return the wires for the requirements in all namespaces.

- Returns the BundleWires to the requirements in use by this bundle wiring.

This method may return different results if this bundle wiring establishes additional wires to more requirements. For example, dynamically importing a package will establish a new wire to the dynamically imported package.

Returns A list containing a snapshot of the BundleWires for the requirements of this bundle wiring, or an empty list if this bundle wiring has no requirements in the specified namespace. If this bundle wiring is not in use, null will be returned. For a given namespace, the list contains the wires in the order the requirements were specified in the manifests of the bundle revision and the attached fragments of this bundle wiring followed by dynamically established wires, if any, in the order they were established. There is no ordering defined between requirements in different namespaces.

10.4.7.11 **public List<BundleRequirement> getRequirements(String namespace)**

namespace The namespace of the requirements to return or null to return the requirements from all namespaces.

- Returns the requirements of this bundle wiring.

Only requirements considered by the resolver are returned. For example, requirements with effective directive not equal to resolve are not returned.

A bundle wiring for a non-fragment revision has a subset of the declared requirements from the bundle revision and all attached fragment revisions. Not all declared requirements may be present since some may be discarded. For example, if a package is declared to be both exported and imported, only one is selected and the other is discarded.

Returns A list containing a snapshot of the BundleRequirements, or an empty list if this bundle wiring uses no requirements in the specified namespace. If this bundle wiring is not in use, null will be returned. For a given namespace, the list contains the requirements in the order the requirements were specified in the manifests of the bundle revision and the attached fragments of this bundle wiring. There is no ordering defined between requirements in different namespaces.

10.4.7.12 **public BundleRevision getResource()**

- Returns the resource associated with this wiring.

This method returns the same value as `getRevision()`.

Returns The resource associated with this wiring.

Since 1.1

10.4.7.13 **public List<Capability> getResourceCapabilities(String namespace)**

namespace The namespace of the capabilities to return or null to return the capabilities from all namespaces.

- Returns the capabilities provided by this wiring.

Only capabilities considered by the resolver are returned. For example, capabilities with effective directive not equal to resolve are not returned.

A capability may not be required by any wiring and thus there may be no wires for the capability.

A wiring for a non-fragment resource provides a subset of the declared capabilities from the resource and all attached fragment resources[†]. Not all declared capabilities may be provided since

some may be discarded. For example, if a package is declared to be both exported and imported, only one is selected and the other is discarded.

A wiring for a fragment resource with a symbolic name must provide exactly one `osgi.identity` capability.

† The `osgi.identity` capability provided by attached fragment resource must not be included in the capabilities of the host wiring.

This method returns the same value as `getCapabilities(String)`.

Returns A list containing a snapshot of the `Capabilities`, or an empty list if this wiring provides no capabilities in the specified namespace. For a given namespace, the list contains the capabilities in the order the capabilities were specified in the manifests of the resource and the attached fragment resources[†] of this wiring. There is no ordering defined between capabilities in different namespaces.

Since 1.1

10.4.7.14 **public List<Requirement> getResourceRequirements(String namespace)**

namespace The namespace of the requirements to return or null to return the requirements from all namespaces.

- Returns the requirements of this wiring.

Only requirements considered by the resolver are returned. For example, requirements with effective directive not equal to `resolve` are not returned.

A wiring for a non-fragment resource has a subset of the declared requirements from the resource and all attached fragment resources. Not all declared requirements may be present since some may be discarded. For example, if a package is declared to be optionally imported and is not actually imported, the requirement must be discarded.

This method returns the same value as `getRequirements(String)`.

Returns A list containing a snapshot of the `Requirements`, or an empty list if this wiring uses no requirements in the specified namespace. For a given namespace, the list contains the requirements in the order the requirements were specified in the manifests of the resource and the attached fragment resources of this wiring. There is no ordering defined between requirements in different namespaces.

Since 1.1

10.4.7.15 **public BundleRevision getRevision()**

- Returns the bundle revision for the bundle in this bundle wiring. Since a bundle update can change the entries in a bundle, different bundle wirings for the same bundle can have different bundle revisions.

The bundle object referenced by the returned `BundleRevision` may return different information than the returned `BundleRevision` since the returned `BundleRevision` may refer to an older revision of the bundle.

Returns The bundle revision for this bundle wiring.

See Also `BundleRevision.getWiring()`

10.4.7.16 **public boolean isCurrent()**

- Returns true if this bundle wiring is the current bundle wiring. The bundle wiring for a bundle is the current bundle wiring if it is the most recent bundle wiring for the current bundle revision. All bundles with non-current, in use bundle wirings are considered removal pending.

Returns true if this bundle wiring is the current bundle wiring; false otherwise.

10.4.7.17 **public boolean isInUse()**

- Returns true if this bundle wiring is in use. A bundle wiring is in use if it is the current wiring or if some other in use bundle wiring is dependent upon it. Once a bundle wiring is no longer in use, it is considered stale and is discarded by the framework.

Returns true if this bundle wiring is in use; false otherwise.

10.4.7.18 **public Collection<String> listResources(String path, String filePattern, int options)**

path The path name in which to look. The path is always relative to the root of this bundle wiring's class loader and may begin with "/". A path value of "/" indicates the root of this bundle wiring's class loader.

filePattern The file name pattern for selecting resource names in the specified path. The pattern is only matched against the last element of the resource path. If the resource is a directory then the trailing "/" is not used for pattern matching. Substring matching is supported, as specified in the Filter specification, using the wildcard character ("*"). If null is specified, this is equivalent to "*" and matches all files.

options The options for listing resource names. See LISTRESOURCES_LOCAL and LISTRESOURCES_RECURSE. This method must ignore unrecognized options.

- Returns the names of resources visible to this bundle wiring's class loader. The returned names can be used to access the resources via this bundle wiring's class loader.
 - Only the resource names for resources in bundle wirings will be returned. The names of resources visible to a bundle wiring's parent class loader, such as the bootstrap class loader, must not be included in the result.
 - Only established wires will be examined for resources. This method must not cause new wires for dynamic imports to be established.

Returns An unmodifiable collection of resource names for each matching resource, or an empty collection if no matching resource could be found, if this bundle wiring is for a fragment revision or if the caller does not have the appropriate AdminPermission[bundle,RESOURCE] and the Java Runtime Environment supports permissions. The collection is unordered and must contain no duplicate resource names. If this bundle wiring is not in use, null must be returned.

10.4.8 **public interface FrameworkWiring
extends BundleReference**

Query and modify wiring information for the framework. The framework wiring object for the framework can be obtained by calling bundle.adapt(FrameworkWiring.class) on the system bundle. Only the system bundle can be adapted to a FrameworkWiring object.

The system bundle associated with this FrameworkWiring object can be obtained by calling BundleReference.getBundle().

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.4.8.1 **public Collection<BundleCapability> findProviders(Requirement requirement)**

requirement The requirement to find matching bundle capabilities. Must not be null.

- Find bundle capabilities that match the given requirement.

The returned collection contains BundleCapability objects where the revision must be the declaring revision of the capability and the revision must either be the current bundle revision or an in use bundle revision.

Each returned capability must match the given requirement. This means that the filter in the requirement must match as well as any namespace specific directives. For example, the mandatory attributes for the `osgi.wiring.package` namespace.

The returned collection has not been filtered to remove capabilities that are non-effective, substituted or for which the providing bundle does not have permission to provide. No resolve hooks are called to filter matching capabilities.

Returns A collection of `BundleCapability` objects that match the specified requirement.

Since 1.2

10.4.8.2 **public Collection<Bundle> getDependencyClosure(Collection<Bundle> bundles)**

bundles The initial bundles for which to generate the dependency closure.

- Returns the dependency closure for the specified bundles.

A graph of bundles is computed starting with the specified bundles. The graph is expanded by adding any bundle that is either wired to a package that is currently exported by a bundle in the graph or requires a bundle in the graph. The graph is fully constructed when there is no bundle outside the graph that is wired to a bundle in the graph. The graph may contain UNINSTALLED bundles that are removal pending.

Returns A collection containing a snapshot of the dependency closure of the specified bundles, or an empty collection if there were no specified bundles.

Throws `IllegalArgumentException`– If the specified Bundles were not created by the same framework instance associated with this `FrameworkWiring`.

10.4.8.3 **public Collection<Bundle> getRemovalPendingBundles()**

- Returns the bundles that have non-current, in use bundle wirings. This is typically the bundles which have been updated or uninstalled since the last call to `refreshBundles(Collection, FrameworkListener...)`.

Returns A collection containing a snapshot of the Bundles which have non-current, in use `BundleWirings`, or an empty collection if there are no such bundles.

10.4.8.4 **public void refreshBundles(Collection<Bundle> bundles, FrameworkListener... listeners)**

bundles The bundles to be refreshed, or null to refresh the removal pending bundles.

listeners Zero or more listeners to be notified when the bundle refresh has been completed. The specified listeners do not need to be otherwise registered with the framework. If a specified listener is already registered with the framework, it will be notified twice.

- Refreshes the specified bundles. This forces the update (replacement) or removal of packages exported by the specified bundles.

The technique by which the framework refreshes bundles may vary among different framework implementations. A permissible implementation is to stop and restart the framework.

This method returns to the caller immediately and then performs the following steps on a separate thread:

1. Compute the dependency closure of the specified bundles. If no bundles are specified, compute the dependency closure of the removal pending bundles.
2. Each bundle in the dependency closure that is in the ACTIVE state will be stopped as described in the `Bundle.stop` method.
3. Each bundle in the dependency closure that is in the RESOLVED state is unresolved and thus moved to the INSTALLED state. The effect of this step is that bundles in the dependency closure are no longer RESOLVED.

4. Each bundle in the dependency closure that is in the UNINSTALLED state is removed from the dependency closure and is now completely removed from the Framework.
5. Each bundle in the dependency closure that was in the ACTIVE state prior to Step 2 is started as described in the Bundle.start method, causing all bundles required for the restart to be resolved. It is possible that, as a result of the previous steps, packages that were previously exported no longer are. Therefore, some bundles may be unresolvable until bundles satisfying the dependencies have been installed in the Framework.

For any exceptions that are thrown during any of these steps, a framework event of type FrameworkEvent.ERROR is fired containing the exception. The source bundle for these events should be the specific bundle to which the exception is related. If no specific bundle can be associated with the exception then the System Bundle must be used as the source bundle for the event. All framework events fired by this method are also delivered to the specified FrameworkListeners in the order they are specified.

When this process completes after the bundles are refreshed, the Framework will fire a Framework event of type FrameworkEvent.PACKAGES_REFRESHED to announce it has completed the bundle refresh. The specified FrameworkListeners are notified in the order specified. Each specified FrameworkListener will be called with a Framework event of type FrameworkEvent.PACKAGES_REFRESHED.

Throws IllegalArgumentException— If the specified Bundles were not created by the same framework instance associated with this FrameworkWiring.

SecurityException— If the caller does not have AdminPermission[System Bundle,RESOLVE] and the Java runtime environment supports permissions.

10.4.8.5 **public boolean resolveBundles(Collection<Bundle> bundles)**

bundles The bundles to resolve or null to resolve all unresolved bundles installed in the Framework.

- Resolves the specified bundles. The Framework must attempt to resolve the specified bundles that are unresolved. Additional bundles that are not included in the specified bundles may be resolved as a result of calling this method. A permissible implementation of this method is to attempt to resolve all unresolved bundles installed in the framework.

If no bundles are specified, then the Framework will attempt to resolve all unresolved bundles. This method must not cause any bundle to be refreshed, stopped, or started. This method will not return until the operation has completed.

Returns true if all specified bundles are resolved; false otherwise.

Throws IllegalArgumentException— If the specified Bundles were not created by the same framework instance associated with this FrameworkWiring.

SecurityException— If the caller does not have AdminPermission[System Bundle,RESOLVE] and the Java runtime environment supports permissions.

10.5 **org.osgi.framework.startlevel**

Framework Start Level Package Version 1.0.

The Framework Start Level package allows management agents to manage a start level assigned to each bundle and the active start level of the Framework. This package is a replacement for the now deprecated org.osgi.service.startlevel package.

A start level is defined to be a state of execution in which the Framework exists. Start level values are defined as unsigned integers with 0 (zero) being the state where the Framework is not launched.

Progressively higher integral values represent progressively higher start levels. For example, 2 is a higher start level than 1.

AdminPermission is required to modify start level information.

Start Level support in the Framework includes the ability to modify the active start level of the Framework and to assign a specific start level to a bundle. The beginning start level of a Framework is specified via the `org.osgi.framework.Constants.FRAMEWORK_BEGINNING_STARTLEVEL` framework property when configuring a framework.

When the Framework is first started it must be at start level zero. In this state, no bundles are running. This is the initial state of the Framework before it is launched. When the Framework is launched, the Framework will enter start level one and all bundles which are assigned to start level one and whose autostart setting indicates the bundle should be started are started as described in the `org.osgi.framework.Bundle.start(int)` method. The Framework will continue to increase the start level, starting bundles at each start level, until the Framework has reached a beginning start level. At this point the Framework has completed starting bundles and will then fire a Framework event of type `org.osgi.framework.FrameworkEvent.STARTED` to announce it has completed its launch.

Within a start level, bundles may be started in an order defined by the Framework implementation. This may be something like ascending `org.osgi.framework.Bundle.getId()` order or an order based upon dependencies between bundles. A similar but reversed order may be used when stopping bundles within a start level.

The Framework Start Level package can be used by management bundles to alter the active start level of the framework.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest. For example:

```
Import-Package: org.osgi.framework.startlevel; version="[1.0,2.0) "
```

10.5.1 Summary

- BundleStartLevel - Query and modify the start level information for a bundle.
- FrameworkStartLevel - Query and modify the start level information for the framework.

10.5.2 public interface BundleStartLevel extends BundleReference

Query and modify the start level information for a bundle. The start level object for a bundle can be obtained by calling `bundle.adapt(BundleStartLevel.class)` on the bundle.

The bundle associated with this BundleStartLevel object can be obtained by calling `BundleReference.getBundle()`.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.5.2.1 public int getStartLevel()

- Return the assigned start level value for the bundle.

Returns The start level value of the bundle.

Throws IllegalStateException – If the bundle has been uninstalled.

See Also `setStartLevel(int)`

10.5.2.2 public boolean isActivationPolicyUsed()

- Returns whether the bundle's autostart setting indicates that the activation policy declared in the bundle manifest must be used.

The autostart setting of a bundle indicates whether the bundle's declared activation policy is to be used when the bundle is started.

Returns true if the bundle's autostart setting indicates the activation policy declared in the manifest must be used. false if the bundle must be eagerly activated.

Throws `IllegalStateException`– If the bundle has been uninstalled.

See Also `Bundle.START_ACTIVATION_POLICY`

10.5.2.3 **public boolean isPersistentlyStarted()**

- Returns whether the bundle's autostart setting indicates it must be started.

The autostart setting of a bundle indicates whether the bundle is to be started when its start level is reached.

Returns true if the autostart setting of the bundle indicates it is to be started. false otherwise.

Throws `IllegalStateException`– If this bundle has been uninstalled.

See Also `Bundle.START_TRANSIENT`

10.5.2.4 **public void setStartLevel(int startlevel)**

startlevel The new start level for the bundle.

- Assign a start level value to the bundle.

The bundle will be assigned the specified start level. The start level value assigned to the bundle will be persistently recorded by the Framework.

If the new start level for the bundle is lower than or equal to the active start level of the Framework and the bundle's autostart setting indicates this bundle must be started, the Framework will start the bundle as described in the `Bundle.start(int)` method using the `Bundle.START_TRANSIENT` option. The `Bundle.START_ACTIVATION_POLICY` option must also be used if `isActivationPolicyUsed()` returns true. The actual starting of the bundle must occur asynchronously.

If the new start level for the bundle is higher than the active start level of the Framework, the Framework will stop the bundle as described in the `Bundle.stop(int)` method using the `Bundle.STOP_TRANSIENT` option. The actual stopping of the bundle must occur asynchronously.

Throws `IllegalArgumentException`– If the specified start level is less than or equal to zero, or if the bundle is the system bundle.

`IllegalStateException`– If the bundle has been uninstalled.

`SecurityException`– If the caller does not have `AdminPermission[bundle,EXECUTE]` and the Java runtime environment supports permissions.

10.5.3 **public interface FrameworkStartLevel extends BundleReference**

Query and modify the start level information for the framework. The start level object for the framework can be obtained by calling `bundle.adapt(FrameworkStartLevel.class)` on the system bundle. Only the system bundle can be adapted to a `FrameworkStartLevel` object.

The system bundle associated with this `FrameworkStartLevel` object can be obtained by calling `BundleReference.getBundle()`.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

10.5.3.1 **public int getInitialBundleStartLevel()**

- Return the initial start level value that is assigned to a `Bundle` when it is first installed.

Returns The initial start level value for Bundles.

See Also `setInitialBundleStartLevel(int)`

10.5.3.2 **public int getStartLevel()**

- Return the active start level value of the Framework. If the Framework is in the process of changing the start level this method must return the active start level if this differs from the requested start level.

Returns The active start level value of the Framework.

10.5.3.3 **public void setInitialBundleStartLevel(int startlevel)**

startlevel The initial start level for newly installed bundles.

- Set the initial start level value that is assigned to a Bundle when it is first installed.

The initial bundle start level will be set to the specified start level. The initial bundle start level value will be persistently recorded by the Framework.

When a Bundle is installed via `BundleContext.installBundle`, it is assigned the initial bundle start level value.

The default initial bundle start level value is 1 unless this method has been called to assign a different initial bundle start level value.

This method does not change the start level values of installed bundles.

Throws `IllegalArgumentException`– If the specified start level is less than or equal to zero.

`SecurityException`– If the caller does not have `AdminPermission[System Bundle,STARTLEVEL]` and the Java runtime environment supports permissions.

10.5.3.4 **public void setStartLevel(int startlevel, FrameworkListener... listeners)**

startlevel The requested start level for the Framework.

listeners Zero or more listeners to be notified when the start level change has been completed. The specified listeners do not need to be otherwise registered with the framework. If a specified listener is already registered with the framework, it will be notified twice.

- Modify the active start level of the Framework and notify when complete.

The Framework will move to the requested start level. This method will return immediately to the caller and the start level change will occur asynchronously on another thread. The specified `FrameworkListeners` are notified, in the order specified, when the start level change is complete. When the start level change completes normally, each specified `FrameworkListener` will be called with a Framework event of type `FrameworkEvent.STARTLEVEL_CHANGED`. If the start level change does not complete normally, each specified `FrameworkListener` will be called with a Framework event of type `FrameworkEvent.ERROR`.

If the specified start level is higher than the active start level, the Framework will continue to increase the start level until the Framework has reached the specified start level. At each intermediate start level value on the way to and including the target start level, the Framework must:

1. Change the active start level to the intermediate start level value.
2. Start bundles at the intermediate start level whose `autostart` setting indicate they must be started. They are started as described in the `Bundle.start(int)` method using the `Bundle.START_TRANSIENT` option. The `Bundle.START_ACTIVATION_POLICY` option must also be used if `BundleStartLevel.isActivationPolicyUsed()` returns true for the bundle.

When this process completes after the specified start level is reached, the Framework will fire a Framework event of type `FrameworkEvent.STARTLEVEL_CHANGED` to announce it has moved to the specified start level.

If the specified start level is lower than the active start level, the Framework will continue to decrease the start level until the Framework has reached the specified start level. At each intermediate start level value on the way to and including the specified start level, the framework must:

1. Stop bundles at the intermediate start level as described in the `Bundle.stop(int)` method using the `Bundle.STOP_TRANSIENT` option.
2. Change the active start level to the intermediate start level value.

When this process completes after the specified start level is reached, the Framework will fire a Framework event of type `FrameworkEvent.STARTLEVEL_CHANGED` to announce it has moved to the specified start level.

If the specified start level is equal to the active start level, then no bundles are started or stopped, however, the Framework must fire a Framework event of type `FrameworkEvent.STARTLEVEL_CHANGED` to announce it has finished moving to the specified start level. This event may arrive before this method returns.

Throws `IllegalArgumentException`– If the specified start level is less than or equal to zero.

`SecurityException`– If the caller does not have `AdminPermission[System Bundle,STARTLEVEL]` and the Java runtime environment supports permissions.

10.6 org.osgi.framework.namespace

Namespace Package Version 1.1.

Bundles should not need to import this package at runtime since all the types in this package just contain constants for capability and requirement namespaces specified by the OSGi Alliance.

10.6.1 Summary

- `AbstractWiringNamespace` - Wiring Capability and Requirement Namespaces base class.
- `BundleNamespace` - Bundle Capability and Requirement Namespace.
- `ExecutionEnvironmentNamespace` - Execution Environment Capability and Requirement Namespace.
- `HostNamespace` - Host Capability and Requirement Namespace.
- `IdentityNamespace` - Identity Capability and Requirement Namespace.
- `NativeNamespace` - Native Capability and Requirement Namespace.
- `PackageNamespace` - Package Capability and Requirement Namespace.

10.6.2 **public abstract class AbstractWiringNamespace extends Namespace**

Wiring Capability and Requirement Namespaces base class.

This class is the common class shared by all OSGi defined wiring namespaces. It defines the names for the common attributes and directives for the OSGi specified wiring namespaces.

The values associated with these keys are of type `String`, unless otherwise indicated.

Concurrency Immutable

Provider Type Consumers of this API must not implement this type

10.6.2.1 **public static final String CAPABILITY_BUNDLE_VERSION_ATTRIBUTE = "bundle-version"**

The capability attribute contains the Version of the resource providing the capability if one is specified or `0.0.0` if not specified. The value of this attribute must be of type `Version`.

10.6.2.2 **public static final String CAPABILITY_MANDATORY_DIRECTIVE = "mandatory"**

The capability directive used to specify the comma separated list of mandatory attributes which must be specified in the filter of a requirement in order for the capability to match the requirement.

10.6.3 **public final class BundleNamespace
extends AbstractWiringNamespace**

Bundle Capability and Requirement Namespace.

This class defines the names for the attributes and directives for this namespace. All unspecified capability attributes are of type String and are used as arbitrary matching attributes for the capability. The values associated with the specified directive and attribute keys are of type String, unless otherwise indicated.

Unless otherwise noted, all directives specified on the Bundle-SymbolicName header are visible in the capability and all directives specified on the Require-Bundle header are visible in the requirement.

- The uses directive must be ignored. A uses directive specified on the Bundle-SymbolicName header must be ignored. A uses directive must not be present in the capability.
- The effective directives must be ignored. This namespace is only effective at resolve time. An effective directive specified on the Bundle-SymbolicName or Require-Bundle headers must be ignored. An effective directive must not be present in a capability or requirement.
- The cardinality directive must be ignored. A cardinality directive specified on the Require-Bundle header must be ignored. A cardinality directive must not be present in a requirement.

A non-fragment resource with the `osgi.bundle` type identity provides exactly one[†] bundle capability (that is, the bundle can be required by another bundle). A fragment resource with the `osgi.fragment` type identity must not declare a bundle capability. A resource requires zero or more bundle requirements (that is, required bundles).

[†] A resource with no symbolic name must not provide a bundle capability.

Concurrency Immutable

10.6.3.1 **public static final String BUNDLE_NAMESPACE = "osgi.wiring.bundle"**

Namespace name for bundle capabilities and requirements.

Also, the capability attribute used to specify the symbolic name of the bundle.

10.6.3.2 **public static final String CAPABILITY_FRAGMENT_ATTACHMENT_DIRECTIVE = "fragment-attachment"**

The capability directive identifying if and when a fragment may attach to a host bundle.

This directive should be examined using the host namespace.

See Also `HostNamespace.CAPABILITY_FRAGMENT_ATTACHMENT_DIRECTIVE`

10.6.3.3 **public static final String CAPABILITY_SINGLETON_DIRECTIVE = "singleton"**

The capability directive identifying if the resource is a singleton. A String value of "true" indicates the resource is a singleton; any other value or null indicates the resource is not a singleton.

This directive should be examined using the identity namespace.

See Also `IdentityNamespace.CAPABILITY_SINGLETON_DIRECTIVE`

10.6.3.4 **public static final String REQUIREMENT_EXTENSION_DIRECTIVE = "extension"**

The requirement directive used to specify the type of the extension fragment.

This directive should be examined using the host namespace.

See Also HostNamespace.REQUIREMENT_EXTENSION_DIRECTIVE

10.6.3.5 **public static final String REQUIREMENT_VISIBILITY_DIRECTIVE = "visibility"**

The requirement directive used to specify the visibility type for a requirement. The default value is private.

See Also private, reexport

10.6.3.6 **public static final String VISIBILITY_PRIVATE = "private"**

The directive value identifying a private visibility type. A private visibility type indicates that any packages that are exported by the required bundle are not made visible on the export signature of the requiring bundle. .

See Also REQUIREMENT_VISIBILITY_DIRECTIVE

10.6.3.7 **public static final String VISIBILITY_REEXPORT = "reexport"**

The directive value identifying a reexport visibility type. A reexport visibility type indicates any packages that are exported by the required bundle are re-exported by the requiring bundle.

See Also REQUIREMENT_VISIBILITY_DIRECTIVE

10.6.4 **public final class ExecutionEnvironmentNamespace extends Namespace**

Execution Environment Capability and Requirement Namespace.

This class defines the names for the attributes and directives for this namespace. All unspecified capability attributes are of type String and are used as arbitrary matching attributes for the capability. The values associated with the specified directive and attribute keys are of type String, unless otherwise indicated.

Concurrency Immutable

10.6.4.1 **public static final String CAPABILITY_VERSION_ATTRIBUTE = "version"**

The capability attribute contains the versions of the execution environment. The value of this attribute must be of type List<Version>.

10.6.4.2 **public static final String EXECUTION_ENVIRONMENT_NAMESPACE = "osgi.ee"**

Namespace name for execution environment capabilities and requirements.

Also, the capability attribute used to specify the name of the execution environment.

10.6.5 **public final class HostNamespace extends AbstractWiringNamespace**

Host Capability and Requirement Namespace.

This class defines the names for the attributes and directives for this namespace. All unspecified capability attributes are of type String and are used as arbitrary matching attributes for the capability. The values associated with the specified directive and attribute keys are of type String, unless otherwise indicated.

Unless otherwise noted, all directives specified on the Bundle-SymbolicName header are visible in the capability and all directives specified on the Fragment-Host header are visible in the requirement.

- The uses directive must be ignored. A uses directive specified on the Bundle-SymbolicName header must be ignored. A uses directive must not be present in the capability.

- The effective directives must be ignored. This namespace is only effective at resolve time. An effective directive specified on the Bundle-SymbolicName or Fragment-Host headers must be ignored. An effective directive must not be present in a capability or requirement.
- The cardinality directive has limited applicability to this namespace. A cardinality directive specified on the Fragment-Host header must be ignored. All requirements must have the cardinality directive set to multiple.

A non-fragment resource with the with the `osgi.bundle` type identity provides zero or one[†] host capabilities. A fragment resource with the `osgi.fragment` type identity must not declare a host capability and must declare exactly one host requirement.

[†] A resource with no bundle symbolic name must not provide a host capability.

Concurrency Immutable

10.6.5.1 **public static final String CAPABILITY_FRAGMENT_ATTACHMENT_DIRECTIVE = "fragment-attachment"**

The capability directive identifying if and when a fragment may attach to a host bundle. The default value is always.

See Also FRAGMENT_ATTACHMENT_ALWAYS, FRAGMENT_ATTACHMENT_RESOLVETIME, FRAGMENT_ATTACHMENT_NEVER

10.6.5.2 **public static final String CAPABILITY_SINGLETON_DIRECTIVE = "singleton"**

The capability directive identifying if the resource is a singleton. A String value of "true" indicates the resource is a singleton; any other value or null indicates the resource is not a singleton.

This directive should be examined using the identity namespace.

See Also IdentityNamespace.CAPABILITY_SINGLETON_DIRECTIVE

10.6.5.3 **public static final String EXTENSION_BOOTCLASSPATH = "bootclasspath"**

The directive value indicating that the extension fragment is to be loaded by the boot class loader.

See Also REQUIREMENT_EXTENSION_DIRECTIVE

10.6.5.4 **public static final String EXTENSION_FRAMEWORK = "framework"**

The directive value indicating that the extension fragment is to be loaded by the framework's class loader.

See Also REQUIREMENT_EXTENSION_DIRECTIVE

10.6.5.5 **public static final String FRAGMENT_ATTACHMENT_ALWAYS = "always"**

The directive value indicating that fragments are allowed to attach to the host bundle at any time (while the host is resolved or during the process of resolving the host bundle).

See Also CAPABILITY_FRAGMENT_ATTACHMENT_DIRECTIVE

10.6.5.6 **public static final String FRAGMENT_ATTACHMENT_NEVER = "never"**

The directive value indicating that no fragments are allowed to attach to the host bundle at any time.

See Also CAPABILITY_FRAGMENT_ATTACHMENT_DIRECTIVE

10.6.5.7 **public static final String FRAGMENT_ATTACHMENT_RESOLVETIME = "resolve-time"**

The directive value indicating that fragments are allowed to attach to the host bundle only during the process of resolving the host bundle.

See Also CAPABILITY_FRAGMENT_ATTACHMENT_DIRECTIVE

- 10.6.5.8** **public static final String HOST_NAMESPACE = "osgi.wiring.host"**
Namespace name for host capabilities and requirements.
Also, the capability attribute used to specify the symbolic name of the host.
- 10.6.5.9** **public static final String REQUIREMENT_EXTENSION_DIRECTIVE = "extension"**
The requirement directive used to specify the type of the extension fragment. The default value is framework.
See Also EXTENSION_FRAMEWORK, EXTENSION_BOOTCLASSPATH
- 10.6.5.10** **public static final String REQUIREMENT_VISIBILITY_DIRECTIVE = "visibility"**
The requirement directive used to specify the visibility type for a requirement.
This directive should be examined using the bundle namespace.
See Also BundleNamespace.REQUIREMENT_VISIBILITY_DIRECTIVE
- 10.6.6** **public final class IdentityNamespace**
extends Namespace
Identity Capability and Requirement Namespace.
This class defines the names for the attributes and directives for this namespace. All unspecified capability attributes are of type String and are used as arbitrary matching attributes for the capability. The values associated with the specified directive and attribute keys are of type String, unless otherwise indicated.
Each resource provides exactly one[†] identity capability that can be used to identify the resource.
The bundle wiring for the bundle revision provides exactly one[†] identity capability.
[†] A resource with no symbolic name must not provide an identity capability.
- Concurrency* Immutable
- 10.6.6.1** **public static final String CAPABILITY_COPYRIGHT_ATTRIBUTE = "copyright"**
The capability attribute that contains a human readable copyright notice for the resource. See the Bundle-Copyright manifest header.
- 10.6.6.2** **public static final String CAPABILITY_DESCRIPTION_ATTRIBUTE = "description"**
The capability attribute that contains a human readable description for the resource. See the Bundle-Description manifest header.
- 10.6.6.3** **public static final String CAPABILITY_DOCUMENTATION_ATTRIBUTE = "documentation"**
The capability attribute that contains the URL to documentation for the resource. See the Bundle-DocURL manifest header.
- 10.6.6.4** **public static final String CAPABILITY_LICENSE_ATTRIBUTE = "license"**
The capability attribute that contains the URL to the license for the resource. See the name portion of the Bundle-License manifest header.
- 10.6.6.5** **public static final String CAPABILITY_SINGLETON_DIRECTIVE = "singleton"**
The capability directive identifying if the resource is a singleton. A String value of "true" indicates the resource is a singleton; any other value or null indicates the resource is not a singleton.
- 10.6.6.6** **public static final String CAPABILITY_TYPE_ATTRIBUTE = "type"**
The capability attribute identifying the resource type. If the resource has no type then the value unknown must be used for the attribute.

See Also TYPE_BUNDLE, TYPE_FRAGMENT, TYPE_UNKNOWN

10.6.6.7 **public static final String CAPABILITY_VERSION_ATTRIBUTE = "version"**

The capability attribute identifying the Version of the resource if one is specified or o.o.o if not specified. The value of this attribute must be of type Version.

10.6.6.8 **public static final String CLASSIFIER_JAVADOC = "javadoc"**

The attribute value identifying the resource classifier as an archive containing the javadoc in the same directory layout as the resource.

See Also REQUIREMENT_CLASSIFIER_DIRECTIVE

10.6.6.9 **public static final String CLASSIFIER_SOURCES = "sources"**

The attribute value identifying the resource classifier as an archive containing the source code in the same directory layout as the resource.

See Also REQUIREMENT_CLASSIFIER_DIRECTIVE

10.6.6.10 **public static final String IDENTITY_NAMESPACE = "osgi.identity"**

Namespace name for identity capabilities and requirements.

Also, the capability attribute used to specify the symbolic name of the resource.

10.6.6.11 **public static final String REQUIREMENT_CLASSIFIER_DIRECTIVE = "classifier"**

The requirement directive that classifies the relationship with another resource.

See Also CLASSIFIER_SOURCES, CLASSIFIER_JAVADOC

10.6.6.12 **public static final String TYPE_BUNDLE = "osgi.bundle"**

The attribute value identifying the resource type as an OSGi bundle.

See Also CAPABILITY_TYPE_ATTRIBUTE

10.6.6.13 **public static final String TYPE_FRAGMENT = "osgi.fragment"**

The attribute value identifying the resource type as an OSGi fragment.

See Also CAPABILITY_TYPE_ATTRIBUTE

10.6.6.14 **public static final String TYPE_UNKNOWN = "unknown"**

The attribute value identifying the resource type as unknown.

See Also CAPABILITY_TYPE_ATTRIBUTE

10.6.7 **public final class NativeNamespace
extends Namespace**

Native Capability and Requirement Namespace.

This class defines the names for the attributes and directives for this namespace. All unspecified capability attributes are of type String and are used as arbitrary matching attributes for the capability. The values associated with the specified directive and attribute keys are of type String, unless otherwise indicated.

Since 1.1

Concurrency Immutable

10.6.7.1 **public static final String CAPABILITY_LANGUAGE_ATTRIBUTE = "osgi.native.language"**

The capability attribute contains the org.osgi.framework.language launching property value. The value of this attribute must be of type String.

10.6.7.2 **public static final String CAPABILITY_OSNAME_ATTRIBUTE = "osgi.native.osname"**

The capability attribute contains alias values of the org.osgi.framework.os.name launching property value according to the OSGi Specification References [<https://www.osgi.org/developer/specifications/reference/>]. The value of this attribute must be of type List<String>.

10.6.7.3 **public static final String CAPABILITY_OSVERSION_ATTRIBUTE = "osgi.native.osversion"**

The capability attribute contains a Version parsed from the org.osgi.framework.os.version launching property value. The value of this attribute must be of type Version.

10.6.7.4 **public static final String CAPABILITY_PROCESSOR_ATTRIBUTE = "osgi.native.processor"**

The capability attribute contains alias values of the org.osgi.framework.processor launching property value according to the OSGi Specification References [<https://www.osgi.org/developer/specifications/reference/>]. The value of this attribute must be of type List<String>.

10.6.7.5 **public static final String NATIVE_NAMESPACE = "osgi.native"**

Namespace name for native capabilities and requirements.

10.6.8 **public final class PackageNamespace
extends AbstractWiringNamespace**

Package Capability and Requirement Namespace.

A resource provides zero or more package capabilities (this is, exported packages) and requires zero or more package requirements (that is, imported packages).

This class defines the names for the attributes and directives for this namespace. All unspecified capability attributes are of type String and are used as arbitrary matching attributes for the capability. The values associated with the specified directive and attribute keys are of type String, unless otherwise indicated.

Unless otherwise noted, all directives specified on the Export-Package header are visible in the capability and all directives specified on the Import-Package and DynamicImport-Package headers are visible in the requirement.

- The effective directives must be ignored. This namespace is only effective at resolve time. An effective directive specified on the Export-Package, Import-Package or DynamicImport-Package headers must be ignored. An effective directive must not be present in a capability or requirement.
- The cardinality directive has limited applicability to this namespace. A cardinality directive specified on the Import-Package or DynamicImport-Package headers must be ignored. Only requirements with resolution set to dynamic and the package name contains a wildcard must have the cardinality directive set to multiple. Otherwise, a cardinality directive must not be present in a requirement.

Concurrency Immutable

10.6.8.1 **public static final String CAPABILITY_BUNDLE_SYMBOLICNAME_ATTRIBUTE = "bundle-symbolic-name"**

The capability attribute contains the symbolic name of the resource providing the package.

10.6.8.2 **public static final String CAPABILITY_EXCLUDE_DIRECTIVE = "exclude"**

The capability directive used to specify the comma separated list of classes which must not be allowed to be exported.

- 10.6.8.3** **public static final String CAPABILITY_INCLUDE_DIRECTIVE = "include"**
The capability directive used to specify the comma separated list of classes which must be allowed to be exported.
- 10.6.8.4** **public static final String CAPABILITY_VERSION_ATTRIBUTE = "version"**
The capability attribute contains the Version of the package if one is specified or o.o.o if not specified. The value of this attribute must be of type Version.
- 10.6.8.5** **public static final String PACKAGE_NAMESPACE = "osgi.wiring.package"**
Namespace name for package capabilities and requirements.
Also, the capability attribute used to specify the name of the package.
- 10.6.8.6** **public static final String RESOLUTION_DYNAMIC = "dynamic"**
The directive value identifying a dynamic requirement resolution type. A dynamic resolution type indicates that the requirement is resolved dynamically at runtime (such as a dynamically imported package) and the resource will be resolved without the requirement being resolved.
- See Also* Namespace.REQUIREMENT_RESOLUTION_DIRECTIVE

10.7 **org.osgi.annotation.versioning**

OSGi Versioning Annotations Package Version 1.1.

This package is not used at runtime.

See Also Semantic Versioning [<https://www.osgi.org/wp-content/uploads/SemanticVersioning1.pdf>]

10.7.1 **Summary**

- ConsumerType - A type implemented by, or extended by, the Consumer Role.
- ProviderType - A type implemented by, or extended by, the Provider Role.
- Version - Specify the version of a package.

10.7.2 **@ConsumerType**

A type implemented by, or extended by, the Consumer Role.

A non-binary-compatible change to a consumer type or a binary-compatible change to a consumer type affecting an abstract method normally requires incrementing the major version of the type's package. This change will require all providers and all consumers to be updated to handle the change since consumers that implement or extend the consumer type and all providers must understand the change in the consumer type.

A binary-compatible change to a consumer type not affecting an abstract method normally requires incrementing the minor version of the type's package. This change will require all providers to be updated to handle the change, but consumers will not require changes since no abstract methods requiring implementation by the consumer are affected.

A type can be marked ConsumerType or ProviderType but not both. A type is assumed to be ConsumerType if it is not marked either ConsumerType or ProviderType.

A package can be marked ProviderType. In this case, all types in the package are considered to be a provider type regardless of whether they are marked ConsumerType or ProviderType.

This annotation is not retained at runtime. It is for use by tools to understand the semantic version of a package. When a bundle implements a consumer type from an imported package, then the

bundle's import range for that package must require the exact major version and a minor version greater than or equal to the package's version.

See Also Semantic Versioning [<https://www.osgi.org/wp-content/uploads/SemanticVersioning1.pdf>]

Retention CLASS

Target TYPE

10.7.3 **@ProviderType**

A type implemented by, or extended by, the Provider Role.

A non-binary-compatible change to a provider type normally requires incrementing the major version of the type's package. This change will require all providers and all consumers to be updated to handle the change. However, a non-binary-compatible change affecting a protected access member only requires incrementing the minor version of the type's package. This change will require all providers to be updated to handle the change, but consumers will not require changes since they only use, and do not extend, the provider type and thus could not access protected access members of the provider type.

A binary-compatible change to a provider type normally requires incrementing the minor version of the type's package. This change will require all providers to be updated to handle the change, but consumers will not require changes since they only use, and do not implement or extend, the provider type.

A type can be marked `ConsumerType` or `ProviderType` but not both. A type is assumed to be `ConsumerType` if it is not marked either `ConsumerType` or `ProviderType`.

A package can be marked `ProviderType`. In this case, all types in the package are considered to be a provider type regardless of whether they are marked `ConsumerType` or `ProviderType`.

This annotation is not retained at runtime. It is for use by tools to understand the semantic version of a package. When a bundle implements a provider type from an imported package, then the bundle's import range for that package must require the package's exact major and minor version.

See Also Semantic Versioning [<https://www.osgi.org/wp-content/uploads/SemanticVersioning1.pdf>]

Retention CLASS

Target TYPE, PACKAGE

10.7.4 **@Version**

Specify the version of a package.

This annotation is not retained at runtime. It is for use by tools to generate bundle manifests or otherwise process the version of a package.

See Also Semantic Versioning [<https://www.osgi.org/wp-content/uploads/SemanticVersioning1.pdf>]

Retention CLASS

Target PACKAGE

10.7.4.1 **String value**

- The version of the annotated package.
The version must be a valid OSGi version string.

10.8 **org.osgi.annotation.bundle**

OSGi Bundle Annotations Package Version 1.0.

This package is not used at runtime.

10.8.1 Summary

- Attribute - Mark an annotation element as an attribute.
- Capabilities - Container annotation for repeated Capability annotations.
- Capability - Define a capability for a bundle.
- Directive - Mark an annotation element as a directive.
- Export - Mark a package to be exported from its bundle.
- Export.Substitution - Substitution policy for this package.
- Header - Define a manifest header for a bundle.
- Headers - Container annotation for repeated Header annotations.
- Requirement - Define a requirement for a bundle.
- Requirement.Cardinality - Cardinality for this requirement.
- Requirement.Resolution - Resolution for this requirement.
- Requirements - Container annotation for repeated Requirement annotations.

10.8.2 @Attribute

Mark an annotation element as an attribute.

This is used when applying Capability or Requirement as a meta annotation to an annotation declaration. The value of the annotation element annotated with Attribute is used as the value of an attribute in the generated capability or requirement clause. For example:

```
@Capability(namespace = "my.namespace")
public @interface MyCapability {
    @Attribute("attr")
    String value() default "";
}
```

```
@MyCapability("foo")
public MyClass {}
```

The use of the MyCapability annotation, which is meta annotated with the Capability and Attribute annotations, will result in a capability in the namespace my.namespace with the attribute attr=foo.

If the element annotated with Attribute is unspecified when applied, then the attribute must not be generated in the generated capability or requirement clause. For example:

```
@MyCapability
public MyClass {}
```

will not have the attr attribute in the generated capability.

This annotation is not retained at runtime. It is for use by tools to generate bundle manifests.

Retention CLASS

Target METHOD

10.8.2.1 String value default ""

- The name of the attribute.

If not specified, the name of the annotated element is used as the name of the attribute.

10.8.3 @Capabilities

Container annotation for repeated Capability annotations.

Retention CLASS

Target TYPE, PACKAGE

10.8.3.1 **Capability[] value**

- Repeated Capability annotations.

10.8.4 **@Capability**

Define a capability for a bundle.

For example:

```
@Capability(namespace=ExtenderNamespace.EXTENDER_NAMESPACE,
            name="osgi.component", version="1.3.0")
```

This annotation is not retained at runtime. It is for use by tools to generate bundle manifests or otherwise process the type or package.

This annotation can be used to annotate an annotation. If the meta-annotated annotation declares an element of the same name as an element in this annotation, the element is considered to override the element in this annotation.

Retention CLASS

Target TYPE, PACKAGE

10.8.4.1 **String namespace**

- The namespace of this capability.

10.8.4.2 **String name default ""**

- The name of this capability within the namespace.

If specified, adds an attribute with the name of the namespace and the value of the specified name to the capability clause.

10.8.4.3 **String version default ""**

- The version of this capability.

If specified, adds an attribute with the name and type of `version:Version` and the value of the specified version to the capability clause.

The specified version must be a valid OSGi version string.

10.8.4.4 **Class<?>[] uses default {}**

- A list of classes whose packages are inspected to calculate the uses directive for this capability.

If not specified, the uses directive is omitted from the capability clause.

10.8.4.5 **String effective default "resolve"**

- The effective time of this capability.

Specifies the time the capability is available. The OSGi framework resolver only considers capabilities without an effective directive or `effective:=resolve`. Capabilities with other values for the effective directive can be considered by an external agent.

If not specified, the effective directive is omitted from the capability clause.

10.8.4.6 **String[] attribute default {}**

- A list of attribute or directive names and values.

Each string should be specified in the form:

- "name=value" for attributes.
- "name:type=value" for typed attributes.
- "name:=value" for directives.

These are added, separated by semicolons, to the export package clause.

10.8.5 @Directive

Mark an annotation element as a directive.

This is used when applying Capability or Requirement as a meta annotation to an annotation declaration. The value of the annotation element annotated with Directive is used as the value of a directive in the generated capability or requirement clause. For example:

```
@Capability(namespace = "my.namespace")
public @interface MyCapability {
    @Directive("resource")
    String value() default "";
}

@MyCapability("foo")
public MyClass {}
```

The use of the MyCapability annotation, which is meta annotated with the Capability and Directive annotations, will result in a capability in the namespace my.namespace with the directive resource:=foo.

If the element annotated with Directive is unspecified when applied, then the directive must not be generated in the generated capability or requirement clause. For example:

```
@MyCapability
public MyClass {}
```

will not have the resource directive in the generated capability.

This annotation is not retained at runtime. It is for use by tools to generate bundle manifests.

Retention CLASS

Target METHOD

10.8.5.1 String value default ""

- The name of the directive.

If not specified, the name of the annotated element is used as the name of the directive.

10.8.6 @Export

Mark a package to be exported from its bundle.

The package must also be annotation with the Version annotation to specify the export version of the package.

This annotation is not retained at runtime. It is for use by tools to generate bundle manifests or otherwise process the package.

Retention CLASS

Target PACKAGE

10.8.6.1 String[] uses default {}

- A list of package names that are used by this package.

If the uses directive must be omitted from the export package clause for this package, the empty value {} must be specified.

If not specified, the uses directive for the export package clause is calculated by inspection of the classes in this package.

10.8.6.2 String[] attribute default {}

- A list of attribute or directive names and values.

Each string should be specified in the form:

- "name=value" for attributes.
- "name:type=value" for typed attributes.
- "name:=value" for directives.

These are added, separated by semicolons, to the export package clause.

10.8.6.3 Export.Substitution substitution default CALCULATED

- Specify the policy for substitutably importing this package.

Bundles that collaborate require the same class loader for types used in the collaboration. If multiple bundles export packages with collaboration types then they will have to be placed in disjoint class spaces, making collaboration impossible. Collaboration is significantly improved when bundles are willing to import exported packages; these imports will allow a framework to substitute exports for imports.

If not specified, the Substitution.CALCULATED substitution policy is used for this package.

10.8.7 enum Export.Substitution

Substitution policy for this package.

10.8.7.1 CONSUMER

Use a consumer type version range for the import package clause when substitutably importing a package.

See Also ConsumerType

10.8.7.2 PROVIDER

Use a provider type version range for the import package clause when substitutably importing a package.

See Also ProviderType

10.8.7.3 NOIMPORT

The package must not be substitutably imported.

10.8.7.4 CALCULATED

The policy value is calculated by inspection of the classes in the package.

10.8.8 @Header

Define a manifest header for a bundle.

For example:

```
@Header (name=Constants.BUNDLE_CATEGORY, value="osgi")
```

This annotation is not retained at runtime. It is for use by tools to generate bundle manifests.

Retention CLASS

Target TYPE, PACKAGE

10.8.8.1 **String name**

- The name of this header.

10.8.8.2 **String value**

- The value of this header.

10.8.9 **@Headers**

Container annotation for repeated Header annotations.

Retention CLASS

Target TYPE, PACKAGE

10.8.9.1 **Header[] value**

- Repeated Header annotations.

10.8.10 **@Requirement**

Define a requirement for a bundle.

For example:

```
@Requirement (namespace=ExtenderNamespace.EXTENDER_NAMESPACE,
              name="osgi.component", version="1.3.0")
```

This annotation is not retained at runtime. It is for use by tools to generate bundle manifests or otherwise process the a package.

This annotation can be used to annotate an annotation. If the meta-annotated annotation declares an element of the same name as an element in this annotation, the element is considered to override the element in this annotation.

Retention CLASS

Target TYPE, PACKAGE

10.8.10.1 **String namespace**

- The namespace of this requirement.

10.8.10.2 **String name default ""**

- The name of this requirement within the namespace.

If specified, adds an expression, using the & operator with any specified filter(), to the requirement's filter directive to test that an attribute with the name of the namespace is equal to the value of the specified name.

10.8.10.3 **String version default ""**

- The floor version of the version range for this requirement.

If specified, adds a version range expression, using the & operator with any specified filter(), to the requirement's filter directive. The ceiling version of the version range is the next major version from

the floor version. For example, if the specified version is 1.3, then the version range expression is `(&(version>=1.3)(!(version>=2.0)))`.

The specified version must be a valid OSGi version string.

10.8.10.4 **String filter default ""**

- The filter expression of this requirement, if any.

10.8.10.5 **String effective default "resolve"**

- The effective time of this requirement.

Specifies the time the requirement is available. The OSGi framework resolver only considers requirement without an effective directive or `effective:=resolve`. Requirements with other values for the effective directive can be considered by an external agent.

If not specified, the effective directive is omitted from the requirement clause.

10.8.10.6 **String[] attribute default {}**

- A list of attribute or directive names and values.

Each string should be specified in the form:

- "name=value" for attributes.
- "name:type=value" for typed attributes.
- "name:=value" for directives.

These are added, separated by semicolons, to the export package clause.

10.8.10.7 **Requirement.Cardinality cardinality default SINGLE**

- The cardinality of this requirement.

Indicates if this requirement can be wired a single time or multiple times.

If not specified, the cardinality directive is omitted from the requirement clause.

10.8.10.8 **Requirement.Resolution resolution default MANDATORY**

- The resolution policy of this requirement.

A mandatory requirement forbids the bundle to resolve when this requirement is not satisfied; an optional requirement allows a bundle to resolve even if this requirement is not satisfied.

If not specified, the resolution directive is omitted from the requirement clause.

10.8.11 **enum Requirement.Cardinality**

Cardinality for this requirement.

10.8.11.1 **SINGLE**

Indicates if the requirement can only be wired a single time.

10.8.11.2 **MULTIPLE**

Indicates if the requirement can be wired multiple times.

10.8.12 **enum Requirement.Resolution**

Resolution for this requirement.

10.8.12.1 **MANDATORY**

A mandatory requirement forbids the bundle to resolve when the requirement is not satisfied.

10.8.12.2**OPTIONAL**

An optional requirement allows a bundle to resolve even if the requirement is not satisfied.

10.8.13**@Requirements**

Container annotation for repeated Requirement annotations.

Retention CLASS

Target TYPE, PACKAGE

10.8.13.1**Requirement[] value**

- Repeated Requirement annotations.

50 Conditional Permission Admin Service Specification

Version 1.1

50.1 Introduction

The OSGi security model is based on the powerful and flexible Java security architecture, specifically the permission model. This specification adds several new features to the Java model to adapt it to the typical use cases of OSGi deployments.

Key aspects of this security management API is the use of policies. Policies contain a set of permissions that are applicable when the related conditions are met. A policy can both allow (the Java model) as well as deny access when the permissions are implied. Deny permissions can significantly simplify security management. The real time management of Conditional Permission Admin enables management applications to control the permissions of other applications with immediate effect; no restart is required.

Policies are based on the very general concept of *conditions*. Conditions guard access to the policy's permissions. If they are not satisfied, then the permissions are not applicable. Conditions can be based on the bundle signer, the bundle location, as well as on user-defined conditions. The advantage of this model is that groups of permissions can be shared based on signers or locations. Conditions can also be used to enable or disable a group of permissions when an external condition is true, for example, an inserted SIM card, an online connection to the management system is established, a specific roaming area, or a user has approved a permission after prompting. This model allows an operator to create and enforce a dynamic security policies for its devices.

This specification defines a Conditional Permission Admin that supersedes the Permission Admin (albeit its relation to Permission Admin is well-defined in this specification).

50.1.1 Essentials

- *Policies* - Provide a security policy system where conditions control the actual permissions that bundles have at a certain moment in time to be allowed or denied access.
- *Java Security* - Provide full compatibility with the existing Java security model, existing applications must not require modifications.
- *Delegation* - Support a management delegation model where an Operator can delegate part of the management of a device to another party in a secure way.
- *Digital Signatures* - Support the use of digital signatures in a bundle's policy decisions.
- *Real Time* - Changes in the environment must be reflected immediately in the bundle's permissions.
- *Operator Specific Conditions* - It must be possible for operators, manufacturers, selected developers, and others to provide custom conditions.
- *User Confirmation* - The policy model must support end user prompting and confirmations.
- *Allow/Deny Policies* - It must be possible to both allow access as well as specifically deny access.
- *Ordering* - Policies must be ordered in a table and evaluated in the given order, which is from index 0 upwards.

- *Backward Compatibility* - The model must be backward compatible with the Permission Admin of earlier releases.

50.1.2 Entities

- *Conditional Permission Admin* - The administrative service that provides the functions to manipulate the *policy table*.
- *Policy* - Provides the information to allow or deny access to a resource. A policy contains a name, an access type, a set of conditions that must all be satisfied and a set of permissions of which at least one should be implied to specifically allow or deny access. A policy is encoded in a Conditional Permission Info.
- *Policy Table* - A conceptual table containing all the Conditional Permission Infos.
- *Conditional Permission Info* - The encoded form of a Policy.
- *Conditional Permission Update* - Holds a temporary copy of the Policy Table so that a number of changes can be committed as a whole.
- *Permission Info* - Holds a string based encoding of a Permission object.
- *Condition Info* - Holds a string based encoding of a Condition object.
- *Condition* - A Condition object is associated with a single Bundle Protection Domain. It abstracts an external condition that can be evaluated. A condition can be mutable or immutable as well as immediate or postponed.
- *Bundle Location Condition* - An immutable Condition object that is satisfied when the associated bundle has the given location.
- *Bundle Signer Condition* - An immutable Condition object that is satisfied when the associated bundle is signed by a certificate that matched the given DN.
- *Permission* - An object that defines a certain permission type. Same as the Java Security model.
- *Bundle Protection Domain* - The class that implements the Protection Domain of a bundle, this specification does not define an interface for this class, but it plays an important role in this specification.

50.2 Permission Management Model

The Conditional Permission Admin provides a flexible security model for bundles. However, the price of this flexibility is additional complexity. The amount of configuration necessary to setup a working system can easily become overwhelming. It is therefore necessary to be very careful implementing a deployment security model. This section defines a series of possible deployment security models while simultaneously defining the terminology that is used in later sections.

50.2.1 Local Permissions

A good working principle is to minimize permissions as much as possible, as early as possible. This principle is embodied with the *local permissions* of a bundle. Local permissions are defined by a Bundle Permission Resource that is contained in the bundle; this resource defines a set of *permissions*. These permissions must be enforced by the Framework for the given bundle. That is, a bundle can get less permissions than the local permissions but it can never get more permissions. If no such permission resource is present then the local permissions must be All Permission. The Bundle Permission Resource is defined in *Bundle Permission Resource* on page 347.

For example, if the local permissions do not imply `ServicePermission[org.osgi.service.log.LogService,GET]`, then the bundle can never get the `LogService` object, regardless of any other security setup in the device.

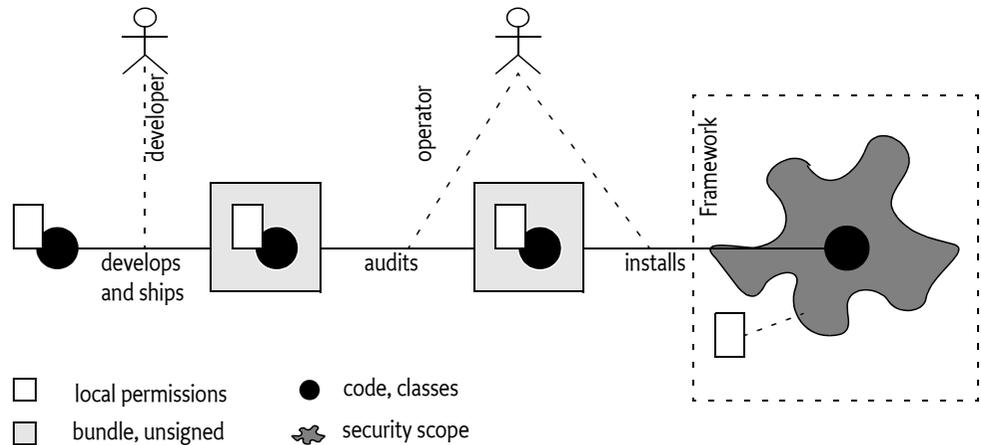
The fine-grained permissions allowed by the OSGi framework are very effective with the local permissions because they can be defined by the developer instead of the deployer. The developer knows exactly what services are needed, what packages the bundle requires, and what network hosts are accessed. Tools can be used that analyze bundles and provide the appropriate local permissions to simplify the task of the developer. However, without detailed knowledge of the bundle's intrinsic, it is very difficult to create the local permissions due to their fine-grained granularity.

At first sight, it can seem odd that a bundle carries its own permissions. However, the local permissions define the *maximum* permissions that the bundle needs, providing more permissions to the bundle is irrelevant because the Framework must not allow the bundle to use them. The purpose of the local permissions is therefore *auditing* by the deployer. Analyzing a bundle's byte codes for its security requirements is cumbersome, if not impossible. Auditing a bundle's permission resource is (relatively) straightforward. For example, if the local permissions request permission to access the Internet, it is clear that the bundle has the potential to access the network. By inspecting the local permissions, the Operator can quickly see the security impact of the bundle. It can trust this audit because it must be enforced by the Framework when the bundle is executed.

An Operator that runs a fully closed system can use the local permissions to run third party applications that are not trusted to run unchecked, thereby mitigating risks. The Framework guarantees that a bundle is never granted a permission that is not implied by its local permissions. A simple audit of the application's local permissions will reveal any potential threats.

This scenario is depicted in Figure 50.2. A developer creates a bundle with local permissions, the operator verifies the local permissions, and if it matches the expectations, it is deployed to the device where the Framework verifies that the local permissions are never exceeded.

Figure 50.2 Local permissions and Deployment



Summarizing, the benefits of local permissions are:

- *Fine-grained* - The developer has the knowledge to provide the fine-grained permissions that are necessary to minimize the sandbox of the bundle without constraining it.
- *Auditable* - The Operator has a relatively small and readable file that shows the required sandbox. It can therefore assess the risk of running a bundle.
- *Sandboxed* - The Operator has the guarantee from the Framework that a bundle cannot escape its local permissions.

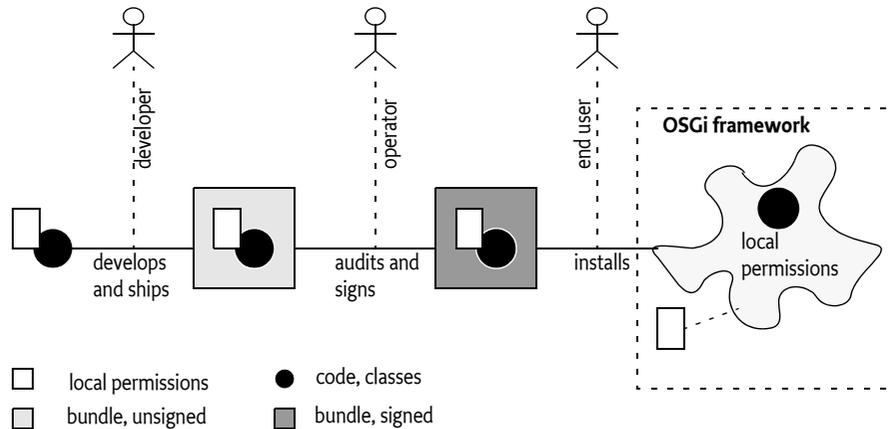
50.2.2 Open Deployment Channels

From a business perspective it is sometimes too restrictive to maintain a fully closed system. There are many use cases where users should be able to deploy bundles from a CD, via a PC, or from an Internet web sites. In those scenarios, relying on the local permissions is not sufficient because the Framework cannot verify that the local permissions have not been tampered with.

The de facto solution to tampering is to *digitally sign* the bundles. The rules for OSGi signing are defined in *Digitally Signed JAR Files* on page 20. A digital signing algorithm detects modifications of the JAR as well as provide the means for authenticating the signer. A Framework therefore must refuse to run a bundle when a signature does not match the contents or it does not recognize the signer. Signing makes it possible to use an untrusted deployment channel and still rely on the enforcement of the local permissions.

For example, an Operator can provision its applications via the Internet. When such an application is downloaded from an untrusted site, the Framework verifies the signature. It should install the application only when the signature is trusted or when it has default permissions for untrusted bundles.

Figure 50.3 with signing

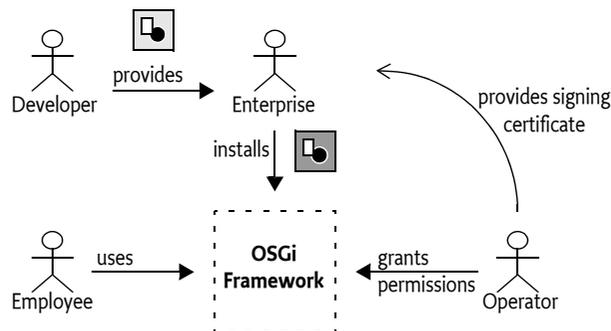


50.2.3 Delegation

A model where the local permissions are secured with a signature works for an Operator that fully controls a device. The operator must sign all bundles before they are provisioned. In this case, the Operator acts as a gatekeeper, no authority is delegated.

This can become expensive when there are third parties involved. For example, an Enterprise could provide applications to its employees on a mobile phone that is managed by an Operator. This model is depicted in Figure 50.4. If the Enterprise always has to contact the Operator before it can provision a new version, bottlenecks quickly arise.

Figure 50.4 Delegation model



This bottleneck problem can also be solved with signing. Signing does not only provide tamper detection, it can also provide an authenticated *principal*. The principal can be authenticated with a certificate chain. The device contains a set of trusted certificates (depending on implementation) that are used to authenticate the certificate of the signer.

The operator can therefore safely associate a principal with a set of permissions. These permissions are called the *system permissions*. Bundles signed by that principal are then automatically granted those system permissions.

In this model, the Operator is still fully in control. At any moment in time, the Operator can change the system permissions associated with the principal and thereby immediately deny access to all bundles of that principal, while they are running. Alternatively, the Operator can add additional system permissions to the principal if a new service has become available to the signer's applications. For example, if the Operator installs a `org.tourist.PointOfInterest` service, it can grant the `ServicePermission[org.tourist.PointOfInterest,GET]` and `PackagePermission[org.tourist,IMPORT]`

to all principals that are allowed to use this service. The Operator can inform the involved parties after the fact, if at all. This model therefore does not create a bottleneck.

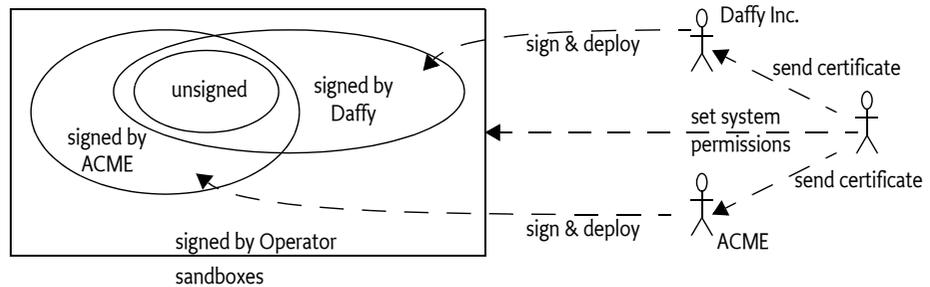
Using digital signing to assign system permissions can therefore *delegate* the responsibility of provisioning to other parties. The Operator completely defines the limits of the permissions of the principal, but the signing and deployment can be done by the other parties.

For example, an Operator can define that the ACME company can provision bundles without any intervention of the Operator. The Operator has to provide ACME once with a signing certificate and the Operator must associate the ACME principal with the appropriate system permissions on the device.

The key advantage of this model is the reduced communication between ACME and the Operator: The Operator can modify the system permissions of ACME applications and be in control at any moment in time. The ACME company can develop new applications without the need to coordinate these efforts in any way with the Operator. This model is depicted in Figure 50.5, which also shows the possible sandboxes for Daffy Inc. and unsigned bundles.

Figure 50.5

Typical Delegation model



The local permissions can still play an important role in the delegation model because it provides the signer the possibility to mitigate its risk, just as it did for the Operator. Signers can verify the local permissions before they sign a bundle. Like the Operator in the earlier scenario, the signer can quickly verify the security requirements of a bundle. For example, if a game bundle requests Admin-Permission[*,*], it is unlikely that the bundle will pass the security audit of the signer. However, in the unlikely case it did, it will not be granted this permission unless the Operator gave such a permission to the signer's principal on the device.

50.2.4 Grouping

The grouping model is traditionally used because it minimizes the administration of the security setup. For example, an operator can define the following security levels:

- *Untrusted* - Applications that are not trusted. These applications must run in a very limited security scope. They could be unsigned.
- *Trusted* - Applications that are trusted but that are not allowed to manage the device or provide system services.
- *System* - Applications that provide system services.
- *Manage* - Applications that manage the device.

The operator signs the bundle with an appropriate certificate before it is deployed, when the bundle is installed, it will be automatically be assigned to the appropriate security scope.

However, the behavior can also be obtained using the local permissions of a bundle.

50.2.5 Typical Example

This example provides a simple setup for a delegation model. The example is intended for readability, certain concepts will be explained later. The basic syntax for the policies is:

```

policy      ::= access '{' conditions permissions '}' name?
access      ::= 'ALLOW' | 'DENY'           // case insensitive
conditions  ::= ( '[' qname quoted-string* ']' ) *
permissions ::= ( '(' qname (quoted-string
                        quoted-string)? ')' ) +
name        ::= quoted-string

```

For readability, package prefixes that can be guessed are replaced with "..".

The following policy has a condition that limits the permissions to bundles that are signed by ACME. The permissions given are related to managing other bundles.

```

ALLOW {
  [ ..BundleSignerCondition "*" ; o=ACME" ]

  ( ..AdminPermission "(signer=\* ; o=ACME)" "*" )
  ( ..ServicePermission "..ManagedService" "register" )
  ( ..ServicePermission "..ManagedServiceFactory" "register" )
} "1"

```

The next permission policy is for bundles signed by the operator. The operator bundles get full managing capabilities as well as permissions to provide any service.

```

ALLOW {
  [ ..BundleSignerCondition "*; o=Operator" ]
  ( ..AdminPermission "*" "*" )
  ( ..ServicePermission "*" "get,register" )
  ( ..PackagePermission "*" "import,exportonly" )
} "2"

```

The following block indicates that all bundles not signed by ACME will not have access to the `com.acme.secret` package, nor can they provide it. In this case, only bundles that are signed by ACME may use the `com.acme.secret.*` packages. Instead of explicitly specifying all allowed packages for bundles not signed by ACME, it is easier to deny them the protected packages. The exclamation mark (! '\u0021) is a parameter for the Bundle Signer Condition to reverse its normal answer. This facility is also available in the Bundle Location Condition.

That is, the following policy specifies that bundles *not* signed by ACME will be denied permission to package `com.acme.secret.*`.

```

DENY {
  [ ..BundleSignerCondition "*" ; o=ACME" !" ]
  ( ..PackagePermission "com.acme.secret.*"
    "import,exportonly" )
} "3"

```

Basic permissions define the permissions that are available to all bundles. The basic permissions therefore have no conditions associated with them so all bundles will be able to use these permissions. All bundles may use the Log Service as well as use any package that was not yet denied earlier.

```

ALLOW {
  ( ..ServicePermission "..LogService" "get" )
  ( ..PackagePermission "*" "import" )
} "4"

```

The resulting permissions are summarized in Table 50.1. The + indicates allow, the - means deny. The number is the deciding policy.

Table 50.1 Assigned Permissions. + indicates allow, - deny.

		Unsigned	ACME	Operator
..LogService	get	+4	+4	+2
..ManagedService*	register	-	+1	+2
..ManagedService*	get	-	-	+2
com.acme.FooService	get	-	-	+2
com.acme.secret	import	-3	+4	+2
com.acme.secret.bar	exportonly	-3	-	+2
com.acme.foo	import	+4	+4	+2
bundle signed by ACME	start	-	+1	+2
bundle signed by Operator	start	-	-	+2

50.3 Effective Permissions

Once a bundle is installed, it gets Java *permissions* associated from the framework. Some of these permissions are *implied*. Implied permissions are given by the framework because they are required for normal operation, for example every bundle has the File Permission to read and write the bundle data area. See *Implied Permissions* on page 29.

A framework can also provide an administrative service to associate a set of permissions with a bundle. The set of permissions given by such an administrative agent to a bundle are called the *system permissions*. For example, the Permission Admin service and the Conditional Permission Admin service can be used by a managing application to define the *system permissions*. Additionally, a bundle can carry its own permissions; these are called the *local permissions*. All these permission sets interact in a non-trivial way to give the *effective permissions*.

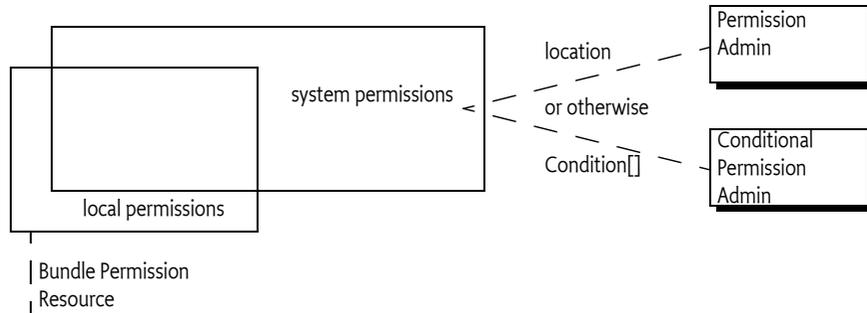
The purpose of the local permissions is to mitigate the bundle signer's risk. The Framework guarantees that a bundle's effective permissions are always smaller or equal than the local permissions because the effective permissions are the intersection of the local permissions with the system permissions, except for the implied permissions that are always granted.

$$\text{Effective} = (\text{Local} \cap \text{System}) \cup \text{Implied}$$

The system permissions have two possible sources. The system permissions can be bound via the Permission Admin service to a location. This mechanism is provided for backward compatibility only. New management applications should use the Conditional Permission Admin service if possible.

If the Permission Admin location is not bound, all the *conditional permissions* from Conditional Permission Admin act as the system permissions. The relationship between the system permissions and local permissions is depicted in Figure 50.6.

Figure 50.6 System, Local and Security permissions



50.4 Conditional Permissions

The conditional permissions provide a very general model that is related to the Java Security model. The Java Security model assigns a set of permissions to a code base or signer. During the permission check, this set is consulted for permissions that imply the checked permissions. If the checked permission is implied, access is granted.

The Conditional Permission Admin service model assumes a more general approach. It conceptually has a system wide *policy table*, that is shared between all bundles.

A policy consists of:

- An access type (ALLOW or DENY)
- A set of conditions
- A set of permissions
- A name

During a permission check, the table is traversed in ascending index order and each policy is evaluated. The first policy that is *matching* controls the outcome of the permission check as given by its access type. A policy is only matching a permission P when:

- All of the policy's conditions are satisfied
- At least one of its permissions implies P, as defined by Java security.

For example, assume the following setup for bundle A:

```
ALLOW {
  [ ...BundleSignerCondition "cn=*, o=ACME, c=US" ]
  [ com.acme.Online ]
  (...AdminPermission "*" "*")
}
```

In the example, both the BundleSignerCondition must be satisfied as well as the com.acme.Online condition before Admin Permission is granted.

Deny policies significantly simplify the security configuration setup because they handle the common case of an exception to a general rule. For example, a bundle that is allowed to use all package imports and exports *except* packages in the com.acme.secret.* namespace. The set of all possible packages is impossible to enumerate because it is an infinite set. In this case, * cannot be used because the com.acme.secret.* should not be included. With a deny policy it is possible to first deny access to com.acme.secret.* for all bundles bar the exception, and then later allow * for everybody. The policies for this look like:

```

DENY {
    [...BundleSignerCondition "cn=*, o=ACME" "!" ]
    (...PackagePermission "com.acme.secret.*"
        "import,exportonly" )
}
ALLOW {
    (...PackagePermission "*" "*" )
}

```

50.4.1 Encoding versus Instantiation

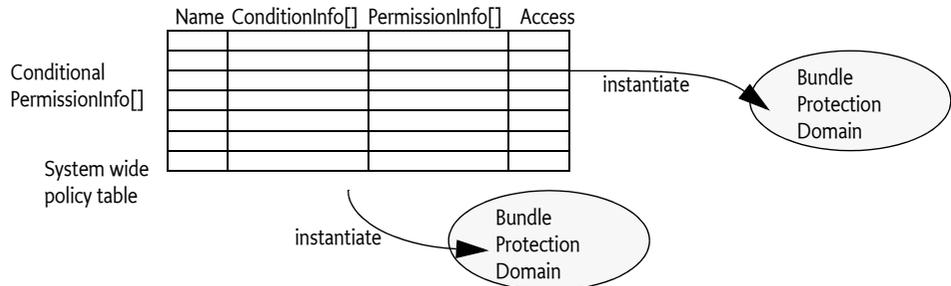
The system wide policy table does not contain instances, it contains *encoded forms* of the permissions and conditions. The policy table acts as a *template* for each Bundle Protection Domain; the Bundle Protection Domain creates instances with the associated bundle as their context.

It is a dynamic template because a Bundle Protection Domain must track the changes to the framework's policy table immediately and update any instances from the new encoded forms. Once the atomic `commit()` method of the update object has successfully returned, all subsequent use of Bundle Protection Domains must be based on the new configuration. See *Permission Management* on page 343 for more information of how to manage this table.

The conditions and permissions of the policy table must be instantiated before the conditions can be checked. This instantiation can happen, when a Bundle Protection Domain is created, or the first time when the conditional permissions are needed because of a permission check. Figure 50.7 shows the central table and its instantiation for different Bundle Protection Domains.

Figure 50.7

Instantiation of the policy table



Condition objects must always belong to a single Bundle Protection Domain and must never be shared.

50.5 Conditions

The purpose of a Condition is to decide if a policy is applicable or not. That is, it acts as a guard for the permissions. The conditions must therefore be evaluated when a Permission object is checked against the effective permissions of a bundle.

The state of a Condition object can be obtained with its `isSatisfied()` method. A condition that returns true to this method is called to be *satisfied*. If the method throws an Exception, this should be logged and treated as if the condition is not satisfied.

Certain Condition objects could optimize their evaluations if they are activated multiple times in the same permission check. For example, a user prompt could appear several times in a permission check but the prompt should only be given once to the user. These conditions are called *postponed conditions*, conditions that can be verified immediately are called *immediate conditions*. The `isPostponed()` method can inform if the condition is immediate or postponed. A Condition must always return the same value for the `isPostponed` method so that the Conditional Permission Admin can

cache this value. If this method returns false, the `isSatisfied()` method must be quick and can be called during the permission check, otherwise the decision must be postponed until the end of the permission check because it is potentially expensive to evaluate. Postponed conditions must always be postponed the first time they are evaluated.

For example, a condition could verify that a mobile phone is *roaming*. This information is readily available in memory and therefore the `isPostponed()` method could always return false. Alternatively, a Condition object that gets an authorization over the network should only be evaluated at most once during a permission check to minimize the delay caused by the network latency. Such a Condition object should return true for the `isPostponed` method so all the Condition objects are evaluated together at the end of the permission check.

Condition objects only need to be evaluated multiple times when the answer can change. A Condition object that can vary its satisfiability is called *mutable*, it can be checked with the `isMutable()` method. If the condition is *immutable*, the Condition object must always return the same result for the `isSatisfied()` method. The `isMutable()` method answers the mutability of the next `isSatisfied()` method. The answer of the next call to the `isSatisfied` method could still differ from the previous call, even if the `isMutable` method returns true.

A mutable Condition can become immutable over time but it cannot go from immutable to mutable. Optimizations can take advantage of the immutability by, for example, caching the result of the `isSatisfied()` method.

Except for immediate conditions, the `isSatisfied` method must only be called inside a permission check.

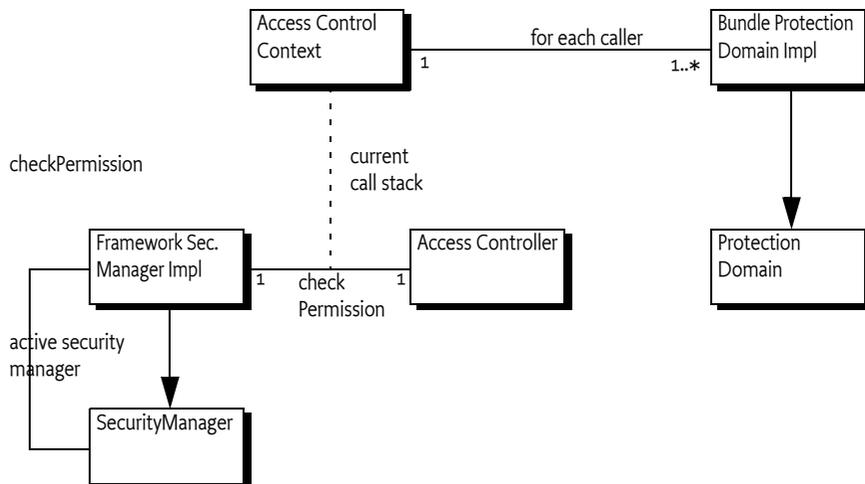
For example, the Bundle Protection Domain can prune any policy from its view of the policy table that contains a Condition object that is immutable and not satisfied. The Bundle Signer Condition and Bundle Location Condition are examples of immutable conditions that can easily be discarded when they do not match the context bundle when the policy table is instantiated. See *Optimizing Immutable Conditions* on page 349 for more information about optimizing immutable conditions.

50.6 The Permission Check

The Java security model has both a Security Manager and an Access Controller to perform a permission check. The core functionality is located in the `AccessController` and the `AccessControlContext` classes that cooperate with `ProtectionDomain` objects to detect if a permission is allowed or denied. In the OSGi Framework, each bundle must have a single Bundle Protection Domain that holds the instantiated policy table.

The Access Controller provides the full functionality for checking a permission. However, all permission checks should be tunneled through the `SecurityManager` `checkPermission` methods. The Security Manager can be replaced by a custom implementation, unlike the Access Controller (it is a final class). This model is depicted in Figure 50.8.

Figure 50.8 in OSGi bundles



50.6.1 Security Manager checkPermission Method

A permission check starts when the Security Manager `checkPermission` method is called with permission *P* as argument. The current Security Manager must be implemented by the Framework and is therefore called the Framework Security Manager; it must be fully integrated with the Conditional Permission Admin service.

The Framework Security Manager must get the Access Control Context in effect. It must call the `AccessController.getContext()` method to get the default context if it is not passed a specific context.

The `AccessControlContext.checkPermission` method must then be called, which causes the call stack to be traversed. At each stack level the Bundle Protection Domain of the calling class is evaluated for the permission *P* using the `ProtectionDomain.implies` method. The complete evaluation must take place on the same thread.

50.6.2 Bundle Protection Domain implies Method

Permission *P* must be implied by the local permissions of the Bundle Protection Domain. If this is not the case, the complete check must immediately end with a failure. Local permissions are described in *Local Permissions* on page 328 and *Bundle Permission Resource* on page 347.

The permission check now depends on the instantiated policy table, called *Ts*. During the Bundle Protection Domain `implies` method, the goal is to decide if the permission *P* is denied, or can progress because it is potentially allowed. Potentially, because the table can contain postponed conditions that need to be executed after all protection domains are checked.

The policy table must therefore be traversed in ascending index order until the first policy is matching that can give an immediate access type. If this access type is DENY, the `implies` method fails and aborts the check. If an ALLOW is found, the next domain must be checked. To ensure that there is at least one immediate matching policy in the table, a virtual DENY { (AllPermission) } is added at the end of the table. This virtual policy has the effect of making the default policy DENY when no matching entries are found.

During the traversal, an optimized policy list per bundle is constructed containing the postponed conditions and at the end a matching policy. This list is evaluated after all the protection domains are checked and none of them failed.

Therefore, the following definitions begin the Bundle Protection Domain `implies` method's algorithm:

```
Ts = instantiated policy table + DENY {(AllPermission)}
PL = {}
```

PL will be copied from Ts until the first policy that *matches*. A matching policy has all of its conditions immediately satisfied and one of the permissions implies permission P. If a policy can never be matched because it has an immediate condition that cannot be satisfied, then it is not copied to PL. At the end, PL contains zero or more postponed policies followed by exactly one matching policy.

In pseudo code:

```
policy:
for each policy T in Ts
  for each condition C in T conditions
    if C is immediate and C is not satisfied
      continue policy

  found = false
  for permission X in T permissions
    found |= X implies P

  if not found
    continue policy

  add T to PL

  if T has no postponed conditions
    break
```

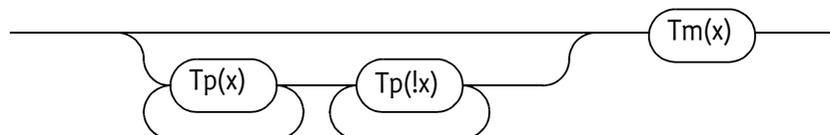
PL must now be optimized to remove superfluous policies. A postponed policy can be removed if it cannot change the outcome from the last (which is an immediate) policy. That is, if the immediate policy at the end has the same access type as the previous policy in PL, then it can be ignored. The following pseudo code removes these superfluous postponed conditions.

```
while PL length > 1
  if PL[PL length -2] access = PL[PL length -1] access
    remove PL[PL length -2]
  else
    break
```

After discarding these superfluous postponed conditions, the contents of PL has the structure outline in Figure 50.9, where $Tp(x)$ is a postponed policy with a access type x , and Tm is a matching policy, $!$ is the not operator for the condition.

Figure 50.9

Structure of Postponed List PL



If PL contains only one policy and it is a DENY policy, then the Bundle Protection Domain can directly answer false from the implies method, which will abort the complete permission check evaluation. In all other cases, it must remember the postponed list PL for the given bundle, and return true.

```
if PL = {DENY{...}}
  return false
Bundle.pl = PL
```

```
return true
```

50.6.2.1 Example Bundle Protection Domain Check

This example demonstrated the per bundle evaluation aspect of the Bundle Protection Domain's `implies` method. Assume the following policies are active:

```
DENY {
  [ BundleSignerCondition "cn=ACME" "!" ]
  ( FilePermission "/tmp/acme/-" "READ,WRITE" )
} "0"
ALLOW {
  ( FilePermission "/tmp/-" "READ,WRITE" )
} "1"
ALLOW {
  [ PromptCondition "Allowed to Read?" ]
  ( FilePermission "*" "READ" )
} "2"
DENY {
  [ PromptCondition "Deny Writing?" ]
  ( FilePermission "*" "READ,WRITE" )
} "3"
```

This setup reserves unconditionally the `/tmp/acme/-` file system for bundles signed by ACME because the first line denies any bundle not signed by ACME access to this part of the file system. Reading and writing of the remainder of the `/tmp` file tree is allowed for all. For the rest of the file system, read access is prompted to allow, and write access is prompted to deny.

Assume that a bundle signed by ACME wants to read `/etc/passwd`. Policy 0, and 1 do not match because the File Permission in these policies are not applicable. Policy 2 has a permission that implies this file and its condition is postponed, so it will be postponed and policy 3 will also be included. There is no matching policy, so a virtual matching DENY policy (D) will be included as the last entry. This makes PL: 2, 3, and D.

```
Tp(ALLOW)      # 2
Tp(DENY)       # 3
Tm(DENY)       # virtual (D)
```

In this case, there is a superfluous `Tp(DENY) #3` because it can not change the final answer of the last matching DENY. It is therefore removed. The list is thus:

```
Tp(ALLOW)      # 2
Tm(DENY)       # virtual
```

This list must be saved for later evaluation when all the Bundle Protection Domains have finished successfully.

50.6.3 Postponed Evaluation

If all protection domains have been checked and none has denied the permission by returning false, then *each* checked Bundle Protection Domain has a postponed list.

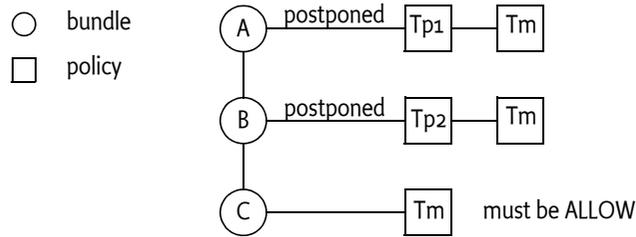
This per bundle postponed list contains one or more policies that must now be evaluated in sequence. The first policy in the list that can satisfy all its postponed conditions decides the access. If this policy has an access type of ALLOW, the list of the next domain is evaluated otherwise the evaluation fails.

The evaluation always ends because the last entry in each of the postponed lists is guaranteed to be a matching policy. As a special case, a postponed list with one entry indicates success. This must be a matching ALLOW because an immediate DENY would have failed earlier.

For example, if bundle A postponed policy Tp1 and bundle B postponed policy Tp2, and bundle C was immediately satisfied for ALLOW, then the constellation would like Figure 50.10.

Figure 50.10

Evaluation of postponed policies



The Conditional Permission Admin provides a type specific Dictionary object to all evaluations of the same postponed Condition implementation class during a single permission check. It is the responsibility of the Condition implementer to use this Dictionary to maintain states between invocations. The condition is evaluated with a method that takes an array and a Dictionary object: `isSatisfied(Condition[], Dictionary)`. The array always contains a single element that is the receiver. An array is used because an earlier version of this specification could verify multiple conditions simultaneously.

The Dictionary object has the following qualities:

- It is specific to a Condition implementation class, different implementation classes will not share this Dictionary object.
- It is created before the `isSatisfied(Condition[], Dictionary)` is called for the first time during this permission check.
- It is only valid during the invocation of a single checkPermission session. That is, it is not maintained between checkPermission invocations.
- It is shared between invocations of `isSatisfied(Condition[], Dictionary)` method for different Bundle Protection Domains.

The algorithm for the postponed processing can now be explained with the following pseudo code:

```

bundle:
for each bundle B
  policy:
  for each policy T in B.pl
    for C in T conditions
      if C is postponed and
        C is not satisfied with Dictionary
        continue policy

    if T access = DENY
      return false
    else
      continue bundle
  assert false // can not reach

return true
  
```

50.6.4 Example

A permission P is checked while bundle A, B, and C are on the call stack. Their security setup is as follows:

- IC = a condition that is immediately evaluated,

- PC is a postponed condition,
- P, Q, and R are permissions.

The situation for C is as follows:

```
ALLOW {           (Q)    } "C1"
ALLOW { [IC0]     (P)    } "C2"
ALLOW { [PC2]     (P)    } "C3"
```

First, the Bundle Protection Domain of bundle C is asked if it implies permission P. Bundle C has three policies. Policy C1 has no conditions, only a permission that does not imply permission P, it is therefore ignored. The second policy has an immediate condition IC0, which is not satisfied. Therefore, the policy's permissions are not even considered. The last policy contains a mutable postponed condition PC2. The permission P is implied by the related permissions. However, it is not possible to make the decision at this moment in time, therefore the evaluation of policy C3 is postponed. The postponed list for bundle C is therefore:

```
ALLOW {[PC2]}           "C3"
DENY {(AllPermission)}
```

This list can not be optimized because the final access type differs from the earlier access types.

The setup for bundle B is as follows:

```
ALLOW { [IC1] [PC2] [PC1] (P) (R) } "B1"
ALLOW { [PC2]              (P) (R) } "B2"
DENY  {                    (P)     } "B3"
ALLOW {                    (Q)     } "B4"
```

Bundle B is considered, its first policy has an immediate Condition object that is IC1. This condition turns out to be satisfied. This policy is a potential candidate because it has two postponed conditions left. It is a possibility because its permissions imply permission P. The policy is therefore placed on the postponed list.

Policy B2 is similar, it must also be placed on the postponed list because it implies permission P and it has a postponed condition PC2.

Policy B3 matches, it is therefore placed on the postponed list and the evaluation is stopped because there is an immediate decision, therefore it is not necessary to look at policy B4.

There are 2 policies postponed, the bundle is potentially permitted. Bundle's B postponed list therefore looks like:

```
ALLOW {[PC2] [PC1]}    "B1"
ALLOW {[PC2]}         "B2"
DENY  { }
```

This list cannot be optimized because the final access type differs from the earlier postponed conditions.

Last and least, bundle A.

```
A: ALLOW { [IC1] [PC1] (P) (Q) } "A1"
    ALLOW { [IC2]      (P) (R) } "A2"
    ALLOW {           (S)     } "A3"
```

Bundle A's IC1 is evaluated first and it is satisfied. Permission P is implied by the policy A1's permissions, therefore this policy is postponed for evaluation.

Policy A2 is also satisfied and it directly implies permission P. This policy is therefore also placed on the postponed list and further evaluation is no longer necessary because it is the first matching policy. That is, policy A3 is ignored. The postponed list looks like:

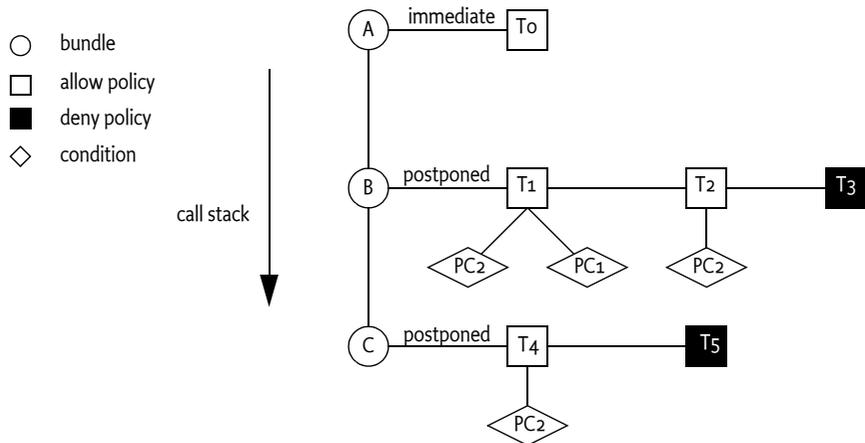
```
ALLOW { [PC1] } "A1"
ALLOW { } "A2"
```

This list is optimized to:

```
ALLOW {} "A2"
```

After the checkPermission method of the Access Control Context method returns, the Framework Security Manager must evaluate the postponed lists of all the bundles. The list of postponed policies looks like Figure 50.10.

Figure 50.11 Evaluation of postponed policies



The Framework Security Manager must now evaluate the postponed lists for each bundle. In this example, postponed condition PC2 occurs 3 times. All these evaluations of PC2 get the same Dictionary object. If PC2 prompts the users with a specific question, then it should not ask the same question again when another PC2 is evaluated later. The Dictionary object can be used to maintain this state.

Both PC1 and PC2 prompt the user. PC1 will be rejected in this example, and PC2 will be affirmed.

First the postponed list of bundle A is evaluated. This is the trivial case of ALLOW {}, and the postponed list for bundle A succeeds with ALLOW.

For bundle B, policy T1 must prompt for PC2 and PC1. PC2 records the answer in the Dictionary that is specific for PC2. Because PC1 fails, T1 is not applicable and policy T2 must be evaluated. PC2 had recorded its answer so it does not prompt but returns true immediately. Policy T2 is an ALLOW policy and bundle B therefore ends positively.

Last, bundle C requires evaluation of policy T4. PC2 retrieves its answer from the given Dictionary object and succeeds. Policy T4 has an access type of ALLOW and this concludes the complete permission check positively.

50.6.5 Using the Access Control Context Directly

Bundle programmers should always use the Java Security Manager to do security checks. When the Access Controller is used directly (or the Access Control Context) to do the security check instead, then the evaluation cannot handle postponed conditions. Therefore, the postponed conditions must be treated as immediate conditions by the Bundle Protection Domain when the permissions check does not go through the Framework's security manager. The implication of this is that the result of checking a permission can depend on the way the check is initiated.

For example, a bundle on the stack has the needed permission P tied to a User Prompt Condition and another bundle on the stack does not have the Permission P. The check would fail if the Security

Manager was called and the user would never be prompted because the failure was detected before the conditional permissions could be evaluated. However, if the Access Control Context was called directly, the user would be prompted and fail even if the user acknowledged the request.

50.7 Permission Management

The policy model provided by the Conditional Permission Admin service requires that the policies in the policy table are ordered. This requires a management interface that allows easy manipulation of the ordered table. The List interface fulfills this requirement, but an OSGi Framework is a dynamic environment and there can be other parties editing the same policy table. Therefore, the Conditional Permission Admin service uses an indirection. If a bundle wants to edit the table, it can get the table in a ConditionalPermissionUpdate object with the `newConditionalPermissionUpdate()` method from the Conditional Permission Admin service. This method creates a copy of the policy table in the returned `update` object. This update object provides access to a List object with ConditionalPermissionInfo objects, which are the encoded form of the policies.

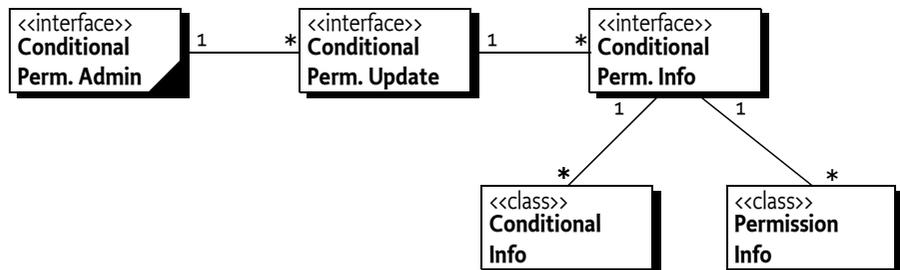
New objects can be created with the `newConditionalPermissionInfo(String,ConditionInfo[],PermissionInfo[],String)` method on the Conditional Permission Admin service, and then added to this list. The method requires a name, an array of ConditionInfo objects, an array of PermissionInfo objects, and the access decision. The name parameter can be null. Each ConditionalPermissionInfo object has a name to distinguish it from others, as well as identifying it to a management server. If the name is null, the Conditional Permission Admin service will automatically create a unique name. Though it is possible to create policies with the same name, during the commit the names will be verified for uniqueness. If a duplicate name appears, an exception will be thrown.

Conditional Permission Infos can also be removed from this list. Modifications like `remove`, do not change or influence the running system, they only affect the update object.

All changes are effectuated when the `commit` method is called. If there had been a change in the underlying policy table since the update object was created, the `commit` method will abort and return false. Otherwise, the actual policy table is atomically updated and true is returned. There is no obligation to ever call `commit`; a canceled update can just be forgotten.

The data structures of the update model are depicted in Figure 50.12.

Figure 50.12 Structure of the Info objects.



Both the ConditionalInfo and PermissionInfo objects can be constructed from encoded strings. The syntax for these strings are:

```

conditions ::= ( '[' qname quoted-string* ']' ) *
permissions ::= ( '(' qname (quoted-string
                    quoted-string?)? ')' ) +
  
```

The strings are converted by getting the class with the `qname`, and then creating an instance through a constructor that takes the given number of arguments. The exclamation mark is conven-

tion for a negated condition, it indicates that the condition should reverse its result. Deny policies often require the negation of the conditions. For example, often a bundle should *not* be signed by a specific signer to exclude it from a resource.

Both the `PermissionInfo` and `ConditionInfo` are concrete classes with appropriate methods to construct them from their encoded form. The encoded form given to a `Condition` implementation constructor must not contain the exclamation mark for negation.

A policy is specified with the following syntax:

```
policy    ::= access '{' conditions permissions '}' name?
access    ::= 'ALLOW' | 'DENY' // case insensitive
name      ::= quoted-string
```

The `ConditionalPermissionAdmin` provides a convenience method to create a `ConditionalPermissionInfo` object with the `newConditionalPermissionInfo(String)` method.

The following example is a code snippet that reads a stream with conditional permissions using the encoded form. The method parses the file line by line. Each line is scanned and split with regular expressions. The following example shows how a text string can be parsed and added to the update object.

```
static Pattern CP_MATCHER = Pattern.compile(...);
public void manage(ConditionalPermissionAdmin admin,
    String text) {
    ConditionalPermissionUpdate update = admin
        .newConditionalPermissionUpdate();
    List list = update.getConditionalPermissionInfos();
    list.clear();

    Matcher m = CP_MATCHER.matcher(text);
    int n = 1;
    while (m.find()) {
        String policy = m.group(1);
        ConditionalPermissionInfo info =
            admin.newConditionalPermissionInfo( policy );

        list.add(info);
    }
    if ( !update.commit() )
        throw new ConcurrentModificationException(
            "Conditional Permission Admin was updated concurrently");
}
```

50.7.1 Default Permissions

`ConditionalPermissionAdmin` does not have a specific concept of default permissions. Default permissions are derived from the policies that do not have any `Condition` objects. These policies are applied to all bundles, effectively making them default permissions. This is different from `PermissionAdmin`; in `PermissionAdmin` default permissions only apply when there are no specific permissions set.

50.8 Implementing Conditions

`Condition` objects are constructed from `ConditionInfo` objects when the policy table is instantiated for a `BundleProtectionDomain`. The `ConditionInfo` object supports a variable number of arguments.

The Conditional Permission Admin must use reflection to find a public static `getCondition` method on the Condition implementation class that takes a `Bundle` object and a `ConditionInfo` object as arguments. This method must return a object that implements the `Condition` interface.

However, this does not have to be a new object, the `getCondition` method can reuse objects if it so desires. For example, a `Bundle Location Condition` is immutable, it therefore maintains only 2 instances: One for bundles that match the given location and one for the others. In the `getCondition` method it can verify the bundle's location with argument and return either instance.

This is such a common pattern that the `Condition` interface provides two such immutable instances:

- `TRUE` - A condition object that will always evaluate to true and that is never postponed.
- `FALSE` - A condition object that will always evaluate to false and that is never postponed.

If no static `getCondition` method can be found, the Conditional Permission Admin service must try to find a public constructor that takes a `Bundle` object and a `ConditionInfo` object as arguments. For the `com.acme.AcmeCondition`, the Conditional Permission Admin must look for:

```
public static Condition com.acme.AcmeCondition.getCondition(
    Bundle, ConditionInfo )
public com.acme.AcmeCondition( Bundle, ConditionInfo )
```

If it is not possible to create a condition object, the given condition must be treated as a `Condition.FALSE` object and an error should be logged.

A `Condition` object will be unique to a `Bundle Protection Domain` as explained in *Encoding versus Instantiation* on page 335. Thus, any queries made on a `Condition` object will be with the given `Bundle` object as context.

The cheapest `Condition` objects are immutable; they have almost no overhead. If a `Condition` object is immutable directly after it is created, then the `Framework Security Manager` can immediately shortcut future evaluations. That is, if an immutable `Condition` object is not satisfied, its parent policy can be immediately be discarded; it is not even necessary to instantiate any further `Condition` or `Permission` objects for that policy.

Mutable `Condition` objects must be evaluated during a permission check. Permission checks are common and the evaluation of a permission should therefore be highly optimized and preferably not cause additional security checks on the same thread. A mutable condition is system code, it must be designed to work in a constrained environment. The `isSatisfied()` method should be designed to quickly return. It should normally base its decision on variables and limit its side effects.

However, side effects are sometimes necessary; a key example is user prompting. As discussed in *Security Manager checkPermission Method* on page 337, the evaluation can be postponed towards the end of the check, where a special version of `isSatisfied` method is called. The `Condition` object must always return true for the `isPostponed()` method to be postponed and it must always return the same value.

Mutable postponed conditions must optimize their evaluation by implementing an instance method `isSatisfied(Condition[], Dictionary)`. This method must only be called with a single element in the array; this element is unrelated to the given instance (except that the class is the same).

The following is the code for a condition that verifies that an action is granted by a network server. This is a postponed condition that groups all requests before it asks the host for authorization. The network code is abstracted in a `Host` class that is not shown here.

```
public class HostCondition implements Condition{
    String          action;

    public HostCondition( Bundle, ConditionInfo info ) {
        action = info.getArgs() [0];
    }
}
```

```

    }

    public boolean isSatisfied() { return false; }
    public boolean isPostponed() { return true; }
    public boolean isMutable() { return false; }

    static Host          host = new Host();

    public synchronized boolean isSatisfied(
        Condition[] conditions, Dictionary state ) {
        Set          granted = (Set) state.get("granted");
        if ( granted == null ) {
            granted = new TreeSet();
            state.put("granted", granted );
        }
        Set          pending = new TreeSet();
        // There will only be one condition
        for ( int i=0; i<conditions.length; i++ ) {
            String a = ((HostCondition)conditions[i]).action;
            if ( ! granted.contains(a) )
                pending.add( a );
        }
        if ( pending.isEmpty() )
            return true;

        if ( ! host.permits( pending ) )
            return false;

        granted.addAll( pending );
        return true;
    }
}

```

The Host Condition has the following Condition Info representation:

```
[ HostCondition "payment" ]
```

The majority of the code is in the `isSatisfied` method which takes an array of `Condition`. The constructor only stores the action.

This `isSatisfied` method first gets the set of granted permissions. The first time the method is called this set does not exist. It is then created and stored in the state dictionary for use in later invocations.

Next, a temporary set `pending` is created to hold all the actions of the conditions that are checked, minus any conditions that were already granted during this invocation of the Security Manager `checkPermission` method. If the pending list turns out to be empty because all actions were already granted, the method returns true. Otherwise it asks the host. If the host allows the actions, the pending actions are added to the granted set in the state dictionary.

50.9 Standard Conditions

This specification provides a number of standard conditions. These conditions are explained in the following sections.

50.9.1 Bundle Signer Condition

A Bundle Signer Condition is satisfied when the related bundle is signed with a certificate that matches its argument. That is, this condition can be used to assign permissions to bundles that are signed by certain principals.

The Bundle Signer Condition must be created through its static `getCondition(Bundle,ConditionInfo)` method. The first string argument is a matching Distinguished Name as defined in *Certificate Matching* on page 27. The second argument is optional, if used, it must be an exclamation mark (`!' \u0021`). The exclamation mark indicates that the result for this condition must be reversed. For example:

```
[ ...BundleSignerCondition "*" ;cn=S&V,o=Tweety Inc., c=US"]
[ ...BundleSignerCondition "*" ;cn=S&V" !" ]
```

The Bundle Signer Condition is immutable and can be completely evaluated during the `getCondition` method.

50.9.2 Bundle Location Condition

The Bundle Location Condition matches its argument against the location string of the bundle argument. Bundle location matching provides many of the advantages of signing without the overhead. However, using locations as the authenticator requires that the download locations are secured and cannot be spoofed. For example, an Operator could permit Enterprises by forcing them to download their bundles from specific locations. To make this reasonable secure, at least the HTTPS protocol should be used. The Operator can then use the location to assign permissions.

```
https://www.acme.com/download/*      Appsfrom ACME
https://www.operator.com/download/*  Operatorapps
```

The Bundle Location Condition must be created through its static `getCondition(Bundle,ConditionInfo)` method. The first string argument is a location string with possible wildcard asterisks (`*' \u002A`). Wildcards are matched using Filter string matching. The second argument is optional, if used, it must be an exclamation mark (`!' \u0021`). The exclamation mark indicates that the result for this condition must be reversed. For example:

```
..BundleLocationCondition "http://www.acme.com/*"
..BundleLocationCondition "*://www.acme.com/*"
```

The Bundle Location Condition is satisfied when its argument can be matched with the actual location.

The Bundle Location Condition is immutable and can be completely evaluated during the `getCondition` method.

50.10 Bundle Permission Resource

Bundles can convey their local permissions using the file `OSGI-INF/permissions.perm`. This must be a UTF-8 encoded file. The format of the file is line based; lines are not limited in length but must be readable with the `BufferedReader readLine` method:

```
permissions.perm ::= line *
line             ::= ( comment | pinfo ) ( '\r\n' | '\n' )
comment         ::= ( '#' | '/' )
pinfo           ::= '(' qname ( quoted-string
                          ( quoted-string )? )? ')'
```

// See 1.3.2

Each permission must be listed on its own line using the encoded form of Permission Info. Comment lines are allowed. They consist of lines starting with a # or //, where leading spaces must be ignored. Multiple spaces outside quotes must be treated as a single space.

For example (.. must be replaced with the appropriate package prefix.):

```
# Friday, Feb 24 2005
# ACME, chess game
( ..ServicePermission "..log.LogService" "GET" )
( ..PackagePermission "..log" "IMPORT" )
( ..ServicePermission "..cm.ManagedService" "REGISTER" )
( ..PackagePermission "..cm" "IMPORT" )
( ..ServicePermission "..useradmin.UserAdmin" "GET" )
( ..PackagePermission "com.acme.chess" "IMPORT,EXPORTONLY" )
( ..PackagePermission "com.acme.score" "IMPORT" )
```

If this resource is present in the Bundle JAR, it will set the local permissions. If it is not present, the local permissions must be All Permission.

50.10.1 Removing the Bundle Permission Resource

An attacker could circumvent the local permission by simply removing the permissions.perm file from the bundle. This would remove any local permissions that were required by a signer of the bundle. To prevent this type of attack the Conditional Permission Admin must detect that the permissions.perm resource was signed, that is, present in the Manifest, but that it is not in the JAR. If the bundle is being installed when this condition is detected, the install must fail with a Bundle Exception.

50.11 Relation to Permission Admin

If the framework provides a Conditional Permission Admin service and a Permission Admin service then a bundle A will receive its permissions according to the following steps:

1. If the Permission Admin defines the permissions for bundle A (location is set), then these permissions override any Conditional Permission Admin information.
2. If the Conditional Permission Admin has a non-empty table, then this table is used to calculate the permissions for bundle A.
3. If the default permissions are set in Permission Admin, then these are given to bundle A.
4. All Permission is given to bundle A.

The Permission Admin defines a concept of *Default Permissions*, which is not supported by Conditional Permission Admin. Default permissions are now modeled with an empty set of conditions. Empty sets of conditions apply to *all bundles*, this in addition to any more specific conditions. This is very different from the Permission Admin service where the default permissions only apply when there is no location bound permission for that bundle. The default conditions of Permission Admin are therefore never used when Conditional Permission Admin is present and its table is non-empty.

New applications should use the Conditional Permission Admin service. The Permission Admin service will be deprecated in a future release.

50.12 Implementation Issues

50.12.1 Optimizing Immutable Conditions

There is a subtle interaction between mutability and postponement. An immutable postponed condition must be treated as a postponed conditions. This first result can then be cached. The following table shows the interaction between mutability and postponement. The *Direct* column indicates the steps during the permission check, the *After* column indicates the step when all the permissions are checked and found to allow the requested action.

isMutable	isPostponed	Direct	After
false	false	isSatisfied() / cache	
false	true	use cache if exists	isSatisfied(Condition[], Dictionary) / cache
true	false	isSatisfied()	
true	true	postpone	isSatisfied(Condition[], Dictionary) (grouped)

This significant optimization is leveraged by the provided `BundleLocationCondition` and `BundleSignerCondition` classes. The Protection Domain will never have to consider conditional permissions that do not match the protection domain's bundle. However, a `Condition` object can also start as a mutable condition and later become immutable. For example, a user prompt could have the following states:

- *Prompt* - The user must be prompted to get the answer, the Conditional Permission Admin will evaluate the answer to detect if it is satisfied.
- *Blanket* - The user, during an earlier prompt, has indicated it approves or denies access for that remainder of the lifetime of the bundle. In this state, the `Condition` object has become immutable.

This specification provides a number of condition classes to bind permission sets to specific bundles. However, custom code can also provide conditions. See *Implementing Conditions* on page 344 for more information about custom conditions.

50.12.2 Optimizing the Permission Check

Theoretically, every `checkPermission` method must evaluate every condition for every bundle on the call stack. That is, the Framework Security Manager must iterate through all bundles on the stack, run through the instantiated policy table of that bundle, evaluate all the conditions, test the permissions, until it finds a permission that is implied. This model would be prohibitively expensive.

Implementations are therefore urged to optimize the evaluation of the permission checks as much as possible. They are free to change the algorithms described in this specification as long as the external effect remains the same.

One optimization is pruning the instantiated policy table. A `Condition` object can be pruned if it is immutable.

If an immutable `Condition` object is satisfied, it can be removed from the policy's `Condition` objects because it cannot influence the evaluation anymore. If it is not satisfied, the corresponding policy can be completely discarded because one of the `Condition` objects is not satisfied, making it impossible for the policy to be used.

For example, assume the following policy table:

```
ALLOW {
```

```

    [ ...BundleLocationCondition
      "http://www.acme.com/*" ]
    ( ...SocketPermission "www.acme.com" "connect,accept" )
  }
ALLOW {
  [ ...BundleLocationCondition
    "http://www.et.com/*" ]
  [ ...Prompt "Phone home?" ]
  ( ...SocketPermission "www.et.com" "connect,accept" )
}

```

Assume this table is instantiated for a bundle with a location of `http://www.acme.com/bundle.jar`. The first policy's permissions can be placed in a the special Permission Collection because the Bundle Location condition is immutable and in this case satisfied.

The second policy can be discarded for this bundle because it is immutable and not satisfied for the bundle's location. Any condition that is not satisfied and immutable makes the policy ignorable.

50.12.3 Using Permission Checks in Conditions

If there is a chance that permissions will be checked in code being called by `isSatisfied`, the implementer of the Condition should use the `AccessController.doPrivileged` to ensure needed permissions. For example, a User Prompt Condition has the potential to cause many permission checks as it interacts with the UI.

However, the same Condition object must not be evaluated recursively. The Framework must detect the recursive evaluation of a Condition object and act as if the second invocation returns an unsatisfied, not postponed Condition object.

For example, if a User Prompt Condition is evaluated and this evaluation accesses the UI, which in its turn checks a permission that causes the evaluation of the same User Prompt Condition, then this second evaluation must not take place and be treated as not postponed and false.

50.12.4 Concurrency

A Condition implementation is guaranteed that all evaluations necessary for a single `checkPermission` invocation are carried out on the same thread. However, multiple permission checks can take place on different threads. It is the responsibility of the Condition class implementers to handle these synchronization issues.

50.12.5 Class Loading

All conditions must come from the boot class path or from the Framework class loader. This is due to security reasons as well as to prevent the case that there are multiple versions of the implementation packages present. Conditions can still be downloaded with bundles by using a Framework extension bundle, see *Extension Bundles* on page 90.

50.12.6 Condition Life Cycle

Condition objects will get instantiated when the framework is restarted or the Bundle Protection Domain is created. Framework implementations can also use optimizations that cause Condition objects to be created and destroyed multiple times within the lifetime of an instance of a Bundle Protection Domain. An implementation of a Condition class must not make any assumptions about its creation or dereferencing.

50.13 Security

50.13.1 Service Registry Security

50.13.1.1 Conditional Permission Admin Service

The Conditional Permission Admin service should be part of the Framework and therefore has All Permission.

50.13.1.2 Client

```
ServicePermission    ..ConditionalPermissionAdmin  GET
PackagePermission   ..condpermadmin              IMPORT
AllPermission
```

Clients of the Conditional Permission Admin service that set permissions must themselves have All Permission because they can give All Permission to any bundle.

50.14 org.osgi.service.condpermadmin

Conditional Permission Admin Package Version 1.1.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.service.condpermadmin; version="[1.1,2.0]"
```

50.14.1 Summary

- BundleLocationCondition - Condition to test if the location of a bundle matches or does not match a pattern.
- BundleSignerCondition - Condition to test if the signer of a bundle matches or does not match a pattern.
- Condition - The interface implemented by a Condition.
- ConditionalPermissionAdmin - Framework service to administer Conditional Permissions.
- ConditionalPermissionInfo - A list of Permissions guarded by a list of conditions with an access decision.
- ConditionalPermissionUpdate - Update the Conditional Permission Table.
- ConditionInfo - Condition representation used by the Conditional Permission Admin service.

50.14.2 public class BundleLocationCondition

Condition to test if the location of a bundle matches or does not match a pattern. Since the bundle's location cannot be changed, this condition is immutable.

Pattern matching is done according to the filter string matching rules.

Concurrency Thread-safe

50.14.2.1 public static Condition getCondition(Bundle bundle, ConditionInfo info)

bundle The Bundle being evaluated.

info The ConditionInfo from which to construct the condition. The ConditionInfo must specify one or two arguments. The first argument of the ConditionInfo specifies the location pattern against

which to match the bundle location. Matching is done according to the filter string matching rules. Any '*' characters in the first argument are used as wildcards when matching bundle locations unless they are escaped with a '\' character. The Condition is satisfied if the bundle location matches the pattern. The second argument of the ConditionInfo is optional. If a second argument is present and equal to "!", then the satisfaction of the Condition is negated. That is, the Condition is satisfied if the bundle location does NOT match the pattern. If the second argument is present but does not equal "!", then the second argument is ignored.

- Constructs a condition that tries to match the passed Bundle's location to the location pattern.

Returns Condition object for the requested condition.

50.14.3 public class BundleSignerCondition

Condition to test if the signer of a bundle matches or does not match a pattern. Since the bundle's signer can only change when the bundle is updated, this condition is immutable.

The condition expressed using a single String that specifies a Distinguished Name (DN) chain to match bundle signers against. DN's are encoded using IETF RFC 2253. Usually signers use certificates that are issued by certificate authorities, which also have a corresponding DN and certificate. The certificate authorities can form a chain of trust where the last DN and certificate is known by the framework. The signer of a bundle is expressed as signers DN followed by the DN of its issuer followed by the DN of the next issuer until the DN of the root certificate authority. Each DN is separated by a semicolon.

A bundle can satisfy this condition if one of its signers has a DN chain that matches the DN chain used to construct this condition. Wildcards (*) can be used to allow greater flexibility in specifying the DN chains. Wildcards can be used in place of DNs, RDNs, or the value in an RDN. If a wildcard is used for a value of an RDN, the value must be exactly "*" and will match any value for the corresponding type in that RDN. If a wildcard is used for a RDN, it must be the first RDN and will match any number of RDNs (including zero RDNs).

Concurrency Thread-safe

50.14.3.1 public static Condition getCondition(Bundle bundle, ConditionInfo info)

bundle The Bundle being evaluated.

info The ConditionInfo from which to construct the condition. The ConditionInfo must specify one or two arguments. The first argument of the ConditionInfo specifies the chain of distinguished names pattern to match against the signer of the bundle. The Condition is satisfied if the signer of the bundle matches the pattern. The second argument of the ConditionInfo is optional. If a second argument is present and equal to "!", then the satisfaction of the Condition is negated. That is, the Condition is satisfied if the signer of the bundle does NOT match the pattern. If the second argument is present but does not equal "!", then the second argument is ignored.

- Constructs a Condition that tries to match the passed Bundle's location to the location pattern.

Returns A Condition which checks the signers of the specified bundle.

50.14.4 public interface Condition

The interface implemented by a Condition. Conditions are bound to Permissions using Conditional Permission Info. The Permissions of a ConditionalPermission Info can only be used if the associated Conditions are satisfied.

Concurrency Thread-safe

50.14.4.1 public static final Condition FALSE

A Condition object that will always evaluate to false and that is never postponed.

50.14.4.2 public static final Condition TRUE

A Condition object that will always evaluate to true and that is never postponed.

50.14.4.3 public boolean isMutable()

- Returns whether the Condition is mutable. A Condition can go from mutable (true) to immutable (false) over time but never from immutable (false) to mutable (true).

Returns true if `isSatisfied()` can change. Otherwise, false if the value returned by `isSatisfied()` will not change for this condition.

50.14.4.4 public boolean isPostponed()

- Returns whether the evaluation must be postponed until the end of the permission check. If this method returns false (or this Condition is immutable), then this Condition must be able to directly answer the `isSatisfied()` method. In other words, `isSatisfied()` will return very quickly since no external sources, such as for example users or networks, need to be consulted.

This method must always return the same value whenever it is called so that the Conditional Permission Admin can cache its result.

Returns true to indicate the evaluation must be postponed. Otherwise, false if the evaluation can be performed immediately.

50.14.4.5 public boolean isSatisfied()

- Returns whether the Condition is satisfied. This method is only called for immediate Condition objects or immutable postponed conditions, and must always be called inside a permission check. Mutable postponed Condition objects will be called with the grouped version `isSatisfied(Condition[], Dictionary)` at the end of the permission check.

Returns true to indicate the Condition is satisfied. Otherwise, false if the Condition is not satisfied.

50.14.4.6 public boolean isSatisfied(Condition[] conditions, Dictionary<Object, Object> context)

conditions The array of Condition objects, which must all be of the same class and mutable. The receiver must be one of those Condition objects.

context A Dictionary object that implementors can use to track state. If this method is invoked multiple times in the same permission check, the same Dictionary will be passed multiple times. The SecurityManager treats this Dictionary as an opaque object and simply creates an empty dictionary and passes it to subsequent invocations if multiple invocations are needed.

- Returns whether the specified set of Condition objects are satisfied. Although this method is not static, it must be implemented as if it were static. All of the passed Condition objects will be of the same type and will correspond to the class type of the object on which this method is invoked. This method must be called inside a permission check only.

Returns true if all the Condition objects are satisfied. Otherwise, false if one of the Condition objects is not satisfied.

50.14.5 public interface ConditionalPermissionAdmin

Framework service to administer Conditional Permissions. Conditional Permissions can be added to, retrieved from, and removed from the framework. Conditional Permissions are conceptually managed in an ordered table called the Conditional Permission Table.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

- 50.14.5.1** **public ConditionalPermissionInfo addConditionalPermissionInfo(ConditionInfo[] conditions, PermissionInfo[] permissions)**
- conditions* The conditions that need to be satisfied to enable the specified permissions. This argument can be null or an empty array indicating the specified permissions are not guarded by any conditions.
- permissions* The permissions that are enabled when the specified conditions, if any, are satisfied. This argument must not be null and must specify at least one permission.
- Create a new Conditional Permission Info in the Conditional Permission Table.
The Conditional Permission Info will be given a unique, never reused name. This entry will be added at the beginning of the Conditional Permission Table with an access decision of ALLOW.
Since this method changes the Conditional Permission Table any ConditionalPermissionUpdates that were created prior to calling this method can no longer be committed.
- Returns* The ConditionalPermissionInfo for the specified Conditions and Permissions.
- Throws* IllegalArgumentException– If no permissions are specified.
SecurityException– If the caller does not have AllPermission.
- Deprecated* As of 1.1. Use newConditionalPermissionUpdate() instead.
- 50.14.5.2** **public AccessControlContext getAccessControlContext(String[] signers)**
- signers* The signers for which to return an Access Control Context.
- Returns the Access Control Context that corresponds to the specified signers. The returned Access Control Context must act as if its protection domain came from a bundle that has the following characteristics:
 - It is signed by all of the given signers
 - It has a bundle id of -1
 - Its location is the empty string
 - Its state is UNINSTALLED
 - It has no headers
 - It has the empty version (0.0.0)
 - Its last modified time=0
 - Many methods will throw IllegalStateException because the state is UNINSTALLED
 - All other methods return a null
- Returns* An AccessControlContext that has the Permissions associated with the signer.
- 50.14.5.3** **public ConditionalPermissionInfo getConditionalPermissionInfo(String name)**
- name* The name of the Conditional Permission Info to be returned.
- Return the Conditional Permission Info with the specified name.
- Returns* The Conditional Permission Info with the specified name or null if no Conditional Permission Info with the specified name exists in the Conditional Permission Table.
- Deprecated* As of 1.1. Use newConditionalPermissionUpdate() instead.
- 50.14.5.4** **public Enumeration<ConditionalPermissionInfo> getConditionalPermissionInfos()**
- Returns the Conditional Permission Infos from the Conditional Permission Table.
The returned Enumeration will return elements in the order they are kept in the Conditional Permission Table.

The Enumeration returned is based on a copy of the Conditional Permission Table and therefore will not throw exceptions if the Conditional Permission Table is changed during the course of reading elements from the Enumeration.

Returns An enumeration of the Conditional Permission Infos that are currently in the Conditional Permission Table.

Deprecated As of 1.1. Use `newConditionalPermissionUpdate()` instead.

50.14.5.5 **public ConditionalPermissionInfo newConditionalPermissionInfo(String name, ConditionInfo[] conditions, PermissionInfo[] permissions, String access)**

name The name of the created ConditionalPermissionInfo or null to have a unique name generated when the returned ConditionalPermissionInfo is committed in an update to the Conditional Permission Table.

conditions The conditions that need to be satisfied to enable the specified permissions. This argument can be null or an empty array indicating the specified permissions are not guarded by any conditions.

permissions The permissions that are enabled when the specified conditions, if any, are satisfied. This argument must not be null and must specify at least one permission.

access Access decision. Must be one of the following values:

- allow
- deny

The specified access decision value must be evaluated case insensitively.

- Creates a new ConditionalPermissionInfo with the specified fields suitable for insertion into a ConditionalPermissionUpdate. The delete method on ConditionalPermissionInfo objects created with this method must throw UnsupportedOperationException.

Returns A ConditionalPermissionInfo object suitable for insertion into a ConditionalPermissionUpdate.

Throws IllegalArgumentException– If no permissions are specified or if the specified access decision is not a valid value.

Since 1.1

50.14.5.6 **public ConditionalPermissionInfo newConditionalPermissionInfo(String encodedConditionalPermissionInfo)**

encodedConditionalPermissionInfo The encoded ConditionalPermissionInfo. White space in the encoded ConditionalPermissionInfo is ignored. The access decision value in the encoded ConditionalPermissionInfo must be evaluated case insensitively. If the encoded ConditionalPermissionInfo does not contain the optional name, null must be used for the name and a unique name will be generated when the returned ConditionalPermissionInfo is committed in an update to the Conditional Permission Table.

- Creates a new ConditionalPermissionInfo from the specified encoded ConditionalPermissionInfo string suitable for insertion into a ConditionalPermissionUpdate. The delete method on ConditionalPermissionInfo objects created with this method must throw UnsupportedOperationException.

Returns A ConditionalPermissionInfo object suitable for insertion into a ConditionalPermissionUpdate.

Throws IllegalArgumentException– If the specified encodedConditionalPermissionInfo is not properly formatted.

See Also ConditionalPermissionInfo.getEncoded()

Since 1.1

50.14.5.7 **public ConditionalPermissionUpdate newConditionalPermissionUpdate()**

- Creates a new update for the Conditional Permission Table. The update is a working copy of the current Conditional Permission Table. If the running Conditional Permission Table is modified before

commit is called on the returned update, then the call to commit on the returned update will fail. That is, the commit method will return false and no change will be made to the running Conditional Permission Table. There is no requirement that commit is eventually called on the returned update.

Returns A new update for the Conditional Permission Table.

Since 1.1

50.14.5.8 **public ConditionalPermissionInfo setConditionalPermissionInfo(String name, ConditionInfo[] conditions, PermissionInfo[] permissions)**

name The name of the Conditional Permission Info, or null.

conditions The conditions that need to be satisfied to enable the specified permissions. This argument can be null or an empty array indicating the specified permissions are not guarded by any conditions.

permissions The permissions that are enabled when the specified conditions, if any, are satisfied. This argument must not be null and must specify at least one permission.

- Set or create a Conditional Permission Info with a specified name in the Conditional Permission Table.

If the specified name is null, a new Conditional Permission Info must be created and will be given a unique, never reused name. If there is currently no Conditional Permission Info with the specified name, a new Conditional Permission Info must be created with the specified name. Otherwise, the Conditional Permission Info with the specified name must be updated with the specified Conditions and Permissions. If a new entry was created in the Conditional Permission Table it will be added at the beginning of the table with an access decision of ALLOW.

Since this method changes the underlying permission table any ConditionalPermissionUpdates that were created prior to calling this method can no longer be committed.

Returns The ConditionalPermissionInfo for the specified name, Conditions and Permissions.

Throws IllegalArgumentException– If no permissions are specified.

SecurityException– If the caller does not have AllPermission.

Deprecated As of 1.1. Use newConditionalPermissionUpdate() instead.

50.14.6 **public interface ConditionalPermissionInfo**

A list of Permissions guarded by a list of conditions with an access decision. Instances of this interface are obtained from the Conditional Permission Admin service.

Concurrency Immutable

Provider Type Consumers of this API must not implement this type

50.14.6.1 **public static final String ALLOW = "allow"**

This string is used to indicate that a row in the Conditional Permission Table should return an access decision of "allow" if the conditions are all satisfied and at least one of the permissions is implied.

Since 1.1

50.14.6.2 **public static final String DENY = "deny"**

This string is used to indicate that a row in the Conditional Permission Table should return an access decision of "deny" if the conditions are all satisfied and at least one of the permissions is implied.

Since 1.1

50.14.6.3 public void delete()

- Removes this Conditional Permission Info from the Conditional Permission Table.

Since this method changes the underlying permission table, any ConditionalPermissionUpdates that were created prior to calling this method can no longer be committed.

Throws UnsupportedOperationException– If this object was created by ConditionalPermissionAdmin.newConditionalPermissionInfo(String) or ConditionalPermissionAdmin.newConditionalPermissionInfo(String, ConditionInfo[], PermissionInfo[], String) or obtained from a ConditionalPermissionUpdate. This method only functions if this object was obtained from one of the ConditionalPermissionAdmin methods deprecated in version 1.1.

SecurityException– If the caller does not have AllPermission.

Deprecated As of 1.1. Use ConditionalPermissionAdmin.newConditionalPermissionUpdate() instead to manage the Conditional Permissions.

50.14.6.4 public boolean equals(Object obj)

obj The object to test for equality with this ConditionalPermissionInfo object.

- Determines the equality of two ConditionalPermissionInfo objects. This method checks that specified object has the same access decision, conditions, permissions and name as this ConditionalPermissionInfo object.

Returns true if obj is a ConditionalPermissionInfo, and has the same access decision, conditions, permissions and name as this ConditionalPermissionInfo object; false otherwise.

Since 1.1

50.14.6.5 public String getAccessDecision()

- Returns the access decision for this Conditional Permission Info.

Returns One of the following values:

- allow - The access decision is "allow".
- deny - The access decision is "deny".

Since 1.1

50.14.6.6 public ConditionInfo[] getConditionInfos()

- Returns the Condition Infos for the Conditions that must be satisfied to enable the Permissions.

Returns The Condition Infos for the Conditions in this Conditional Permission Info.

50.14.6.7 public String getEncoded()

- Returns the string encoding of this ConditionalPermissionInfo in a form suitable for restoring this ConditionalPermissionInfo.

The encoded format is:

```
access {conditions permissions} name
```

where *access* is the access decision, *conditions* is zero or more encoded conditions, *permissions* is one or more encoded permissions and *name* is the name of the ConditionalPermissionInfo.

name is optional. If *name* is present in the encoded string, it must be quoted, beginning and ending with ". The *name* value must be encoded for proper parsing. Specifically, the ", \, carriage return, and line feed characters must be escaped using \", \\, \r, and \n, respectively.

The encoded string contains no leading or trailing whitespace characters. A single space character is used between *access* and { and between } and *name*, if *name* is present. All encoded conditions and permissions are separated by a single space character.

Returns The string encoding of this ConditionalPermissionInfo.

Since 1.1

50.14.6.8 **public String getName()**

- Returns the name of this Conditional Permission Info.

Returns The name of this Conditional Permission Info. This can be null if this Conditional Permission Info was created without a name.

50.14.6.9 **public PermissionInfo[] getPermissionInfos()**

- Returns the Permission Infos for the Permissions in this Conditional Permission Info.

Returns The Permission Infos for the Permissions in this Conditional Permission Info.

50.14.6.10 **public int hashCode()**

- Returns the hash code value for this object.

Returns A hash code value for this object.

Since 1.1

50.14.6.11 **public String toString()**

- Returns the string representation of this ConditionalPermissionInfo. The string is created by calling the getEncoded method on this ConditionalPermissionInfo.

Returns The string representation of this ConditionalPermissionInfo.

Since 1.1

50.14.7 **public interface ConditionalPermissionUpdate**

Update the Conditional Permission Table. There may be many update objects in the system at one time. If commit is called and the Conditional Permission Table has been modified since this update was created, then the call to commit will fail and this object should be discarded.

Since 1.1

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

50.14.7.1 **public boolean commit()**

- Commit this update. If no changes have been made to the Conditional Permission Table since this update was created, then this method will replace the Conditional Permission Table with this update's Conditional Permissions. This method may only be successfully called once on this object.

If any of the ConditionalPermissionInfos in the update list has null as a name it will be replaced with a new ConditionalPermissionInfo object that has a generated name which is unique within the list.

No two entries in this update's Conditional Permissions may have the same name. Other consistency checks may also be performed. If this update's Conditional Permissions are determined to be inconsistent in some way then an IllegalStateException will be thrown.

This method returns false if the commit did not occur because the Conditional Permission Table has been modified since the creation of this update.

Returns true if the commit was successful. false if the commit did not occur because the Conditional Permission Table has been modified since the creation of this update.

Throws SecurityException– If the caller does not have AllPermission.

IllegalStateException– If this update's Conditional Permissions are not valid or inconsistent. For example, this update has two Conditional Permissions in it with the same name.

50.14.7.2 **public List<ConditionalPermissionInfo> getConditionalPermissionInfos()**

- This method returns the list of ConditionalPermissionInfos for this update. This list is originally based on the Conditional Permission Table at the time this update was created. The list returned by this method will be replace the Conditional Permission Table if commit is called and is successful.

The delete() method of the ConditionalPermissionInfos in the list must throw UnsupportedOperationException.

The list returned by this method is ordered and the most significant table entry is the first entry in the list.

Returns A List of the ConditionalPermissionInfos which represent the Conditional Permissions maintained by this update. Modifications to this list will not affect the Conditional Permission Table until successfully committed. The list may be empty if the Conditional Permission Table was empty when this update was created.

50.14.8 **public class ConditionInfo**

Condition representation used by the Conditional Permission Admin service.

This class encapsulates two pieces of information: a Condition *type* (class name), which must implement Condition, and the arguments passed to its constructor.

In order for a Condition represented by a ConditionInfo to be instantiated and considered during a permission check, its Condition class must be available from the system classpath.

The Condition class must either:

- Declare a public static getCondition method that takes a Bundle object and a ConditionInfo object as arguments. That method must return an object that implements the Condition interface.
- Implement the Condition interface and define a public constructor that takes a Bundle object and a ConditionInfo object as arguments.

Concurrency Immutable

50.14.8.1 **public ConditionInfo(String type, String[] args)**

type The fully qualified class name of the Condition represented by this ConditionInfo.

args The arguments for the Condition. These arguments are available to the newly created Condition by calling the getArgs() method.

- Constructs a ConditionInfo from the specified type and args.

Throws NullPointerException– If type is null.

50.14.8.2 **public ConditionInfo(String encodedCondition)**

encodedCondition The encoded ConditionInfo.

- Constructs a ConditionInfo object from the specified encoded ConditionInfo string. White space in the encoded ConditionInfo string is ignored.

Throws IllegalArgumentException– If the specified encodedCondition is not properly formatted.

See Also getEncoded()

50.14.8.3 public boolean equals(Object obj)

obj The object to test for equality with this ConditionInfo object.

- Determines the equality of two ConditionInfo objects. This method checks that specified object has the same type and args as this ConditionInfo object.

Returns true if *obj* is a ConditionInfo, and has the same type and args as this ConditionInfo object; false otherwise.

50.14.8.4 public final String[] getArgs()

- Returns arguments of this ConditionInfo.

Returns The arguments of this ConditionInfo. An empty array is returned if the ConditionInfo has no arguments.

50.14.8.5 public final String getEncoded()

- Returns the string encoding of this ConditionInfo in a form suitable for restoring this ConditionInfo. The encoded format is:

```
[type "arg0" "arg1" ...]
```

where *argN* are strings that must be encoded for proper parsing. Specifically, the ", \, carriage return, and line feed characters must be escaped using "\", "\\", "\r", and "\n", respectively.

The encoded string contains no leading or trailing whitespace characters. A single space character is used between type and "*arg0*" and between the arguments.

Returns The string encoding of this ConditionInfo.

50.14.8.6 public final String getType()

- Returns the fully qualified class name of the condition represented by this ConditionInfo.

Returns The fully qualified class name of the condition represented by this ConditionInfo.

50.14.8.7 public int hashCode()

- Returns the hash code value for this object.

Returns A hash code value for this object.

50.14.8.8 public String toString()

- Returns the string representation of this ConditionInfo. The string is created by calling the `getEncoded` method on this ConditionInfo.

Returns The string representation of this ConditionInfo.

51 Permission Admin Service Specification

Version 1.2

51.1 Introduction

Note: The Permission Admin has been superseded by the Conditional Permission Admin. See *Conditional Permission Admin Service Specification* on page 325.

In the Framework, a bundle can have a single set of permissions. These permissions are used to verify that a bundle is authorized to execute privileged code. For example, a `FilePermission` defines what files can be used and in what way.

The policy of providing the permissions to the bundle should be delegated to a Management Agent. For this reason, the Framework provides the Permission Admin service so that a Management Agent can administrate the permissions of a bundle and provide defaults for all bundles.

Related mechanisms of the Framework are discussed in *Security Overview* on page 19.

51.1.1 Essentials

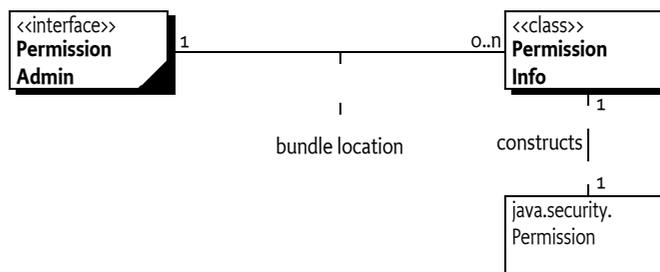
- *Status information* - The Permission Admin Service must provide status information about the current permissions of a bundle.
- *Administrative* - The Permission Admin Service must allow a Management Agent to set the permissions before, during, or after a bundle is installed.
- *Defaults* - The Permission Admin Service must provide control over default permissions. These are the permissions for a bundle with no specific permissions set.

51.1.2 Entities

- *PermissionAdmin* - The service that provides access to the permission repository of the Framework.
- *PermissionInfo* - An object that holds the information needed to construct a `Permission` object.
- *Bundle location* - The string that specifies the bundle location. This is described in *Bundle Identifiers* on page 113.

Figure 51.1

org.osgi.service.permissionadmin package



51.1.3 Operation

The Framework maintains a repository of permissions. These permissions are stored under the bundle location string. Using the bundle location allows the permissions to be set *before* a bundle is downloaded. The Framework must consult this repository when it needs the permissions of a bundle. When no specific permissions are set, the bundle must use the default permissions. If no default is set, the bundle must use `java.security.AllPermission`. If the default permissions are changed, a bundle with no specific permissions must immediately start using the new default permissions.

The Permission Admin service is registered by the Framework's system bundle under the `org.osgi.service.permissionadmin.PermissionAdmin` interface. This is an optional singleton service, so at most one Permission Admin service is registered at any moment in time.

The Permission Admin service provides access to the permission repository. A Management Agent can get, set, update, and delete permissions from this repository. A Management Agent can also use a `SynchronousBundleListener` object to set the permissions during the installation or updating of a bundle.

51.2 Permission Admin service

The Permission Admin service needs to manipulate the default permissions and the permissions associated with a specific bundle. The default permissions and the bundle-specific permissions are stored persistently. It is possible to set a bundle's permissions before the bundle is installed in the Framework because the bundle's location is used to set the bundle's permissions.

The manipulation of a bundle's permissions, however, may also be done in real time when a bundle is downloaded or just before the bundle is downloaded. To support this flexibility, a `SynchronousBundleListener` object may be used by a Management Agent to detect the installation or update of a bundle, and set the required permissions before the installation completes.

Permissions are activated before the first time a permission check for a bundle is performed. This means that if a bundle has opened a file, this file must remain usable even if the permission to open that file is removed at a later time.

Permission information is *not* specified using `java.security.Permission` objects. The reason for this approach is the relationship between the required persistence of the information across the Framework restarts and the concept of class loaders in the Framework. Actual `Permission` classes must be subclasses of `Permission` and may be exported from any bundle. The Framework can access these permissions as long as they are exported, but the Management Agent would have to import all possible packages that contain permissions. This requirement would severely limit permission types. Therefore, the Permission Admin service uses the `PermissionInfo` class to specify permission information. Objects of this class are used by the Framework to create `Permission` objects.

`PermissionInfo` objects restrict the possible `Permission` objects that can be used. A `Permission` subclass can only be described by a `PermissionInfo` object when it has the following characteristics:

- It must be a subclass of `java.security.Permission`.
- It must use the two-argument public constructor `type(name,actions)`.
- The class must be available to the Framework code from the system class path or from any exported package so it can be loaded by the Framework.
- The class must be public.

If any of these conditions is not met, the `PermissionInfo` object must be ignored and an error message should be logged.

The permissions are always set as an array of `PermissionInfo` objects to make the assignment of all permissions atomic.

The PermissionAdmin interface provides the following methods:

- `getLocations()` - Returns a list of locations that have permissions assigned to them. This method allows a Management Agent to examine the current set of permissions.
- `getPermissions(String)` - Returns a list of PermissionInfo objects that are set for that location, or returns null if no permissions are set.
- `setPermissions(String,PermissionInfo[])` - Associates permissions with a specific location, or returns null when the permissions should be removed.
- `getDefaultPermissions()` - This method returns the list of default permissions.
- `setDefaultPermissions(PermissionInfo[])` - This method sets the default permissions.

51.2.1 File Permission for Relative Path Names

A `java.io.FilePermission` assigned to a bundle via the `setPermissions` method must receive special treatment if the path argument for the `FilePermission` is a relative path name. A relative path name is one that is not absolute. See the `java.io.File.isAbsolute` method for more information on absolute path names.

When a bundle is assigned a `FilePermission` for a relative path name, the path name is taken to be relative to the bundle's persistent storage area. This allows additional permissions, such as `execute`, to be assigned to files in the bundle's persistent storage area. For example:

```
java.io.FilePermission "-" "execute"
```

can be used to allow a bundle to execute any file in the bundle's persistent storage area.

This only applies to `FilePermission` objects assigned to a bundle via the `setPermission` method. This does not apply to default permissions. A `FilePermission` for a relative path name assigned via the `setDefaultPermission` method must be ignored.

51.3 Security

The Permission Admin service is a system service that can be abused. A bundle that can access and use the Permission Admin service has full control over the OSGi framework. However, many bundles can have `ServicePermission[PermissionAdmin,GET]` because all methods that change the state of the Framework require `AdminPermission`.

No bundle must have `ServicePermission[PermissionAdmin,REGISTER]` for this service because only the Framework should provide this service.

51.4 org.osgi.service.permissionadmin

Permission Admin Package Version 1.2.

Bundles wishing to use this package must list the package in the `Import-Package` header of the bundle's manifest.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.service.permissionadmin; version="[1.2,2.0)"
```

51.4.1 Summary

- `PermissionAdmin` - The Permission Admin service allows management agents to manage the permissions of bundles.

- `PermissionInfo` - Permission representation used by the Permission Admin service.

51.4.2 public interface `PermissionAdmin`

The Permission Admin service allows management agents to manage the permissions of bundles. There is at most one Permission Admin service present in the OSGi environment.

Access to the Permission Admin service is protected by corresponding `ServicePermission`. In addition `AdminPermission` is required to actually set permissions.

Bundle permissions are managed using a permission table. A bundle's location serves as the key into this permission table. The value of a table entry is the set of permissions (of type `PermissionInfo`) granted to the bundle named by the given location. A bundle may have an entry in the permission table prior to being installed in the Framework.

The permissions specified in `setDefaultPermissions` are used as the default permissions which are granted to all bundles that do not have an entry in the permission table.

Any changes to a bundle's permissions in the permission table will take effect no later than when bundle's `java.security.ProtectionDomain` is next involved in a permission check, and will be made persistent.

Only permission classes on the system classpath or from an exported package are considered during a permission check. Additionally, only permission classes that are subclasses of `java.security.Permission` and define a 2-argument constructor that takes a *name* string and an *actions* string can be used.

Permissions implicitly granted by the Framework (for example, a bundle's permission to access its persistent storage area) cannot be changed, and are not reflected in the permissions returned by `getPermissions` and `getDefaultPermissions`.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

51.4.2.1 public `PermissionInfo[] getDefaultPermissions()`

- Gets the default permissions.

These are the permissions granted to any bundle that does not have permissions assigned to its location.

Returns The default permissions, or null if no default permissions are set.

51.4.2.2 public `String[] getLocations()`

- Returns the bundle locations that have permissions assigned to them, that is, bundle locations for which an entry exists in the permission table.

Returns The locations of bundles that have been assigned any permissions, or null if the permission table is empty.

51.4.2.3 public `PermissionInfo[] getPermissions(String location)`

location The location of the bundle whose permissions are to be returned.

- Gets the permissions assigned to the bundle with the specified location.

Returns The permissions assigned to the bundle with the specified location, or null if that bundle has not been assigned any permissions.

51.4.2.4 public void `setDefaultPermissions(PermissionInfo[] permissions)`

permissions The default permissions, or null if the default permissions are to be removed from the permission table.

- Sets the default permissions.

These are the permissions granted to any bundle that does not have permissions assigned to its location.

Throws `SecurityException`—If the caller does not have `AllPermission`.

51.4.2.5 **public void setPermissions(String location, PermissionInfo[] permissions)**

location The location of the bundle that will be assigned the permissions.

permissions The permissions to be assigned, or null if the specified location is to be removed from the permission table.

- Assigns the specified permissions to the bundle with the specified location.

Throws `SecurityException`—If the caller does not have `AllPermission`.

51.4.3 **public class PermissionInfo**

Permission representation used by the Permission Admin service.

This class encapsulates three pieces of information: a *Permission type* (class name), which must be a subclass of `java.security.Permission`, and the *name* and *actions* arguments passed to its constructor.

In order for a permission represented by a `PermissionInfo` to be instantiated and considered during a permission check, its `Permission` class must be available from the system classpath or an exported package. This means that the instantiation of a permission represented by a `PermissionInfo` may be delayed until the package containing its `Permission` class has been exported by a bundle.

Concurrency Immutable

51.4.3.1 **public PermissionInfo(String type, String name, String actions)**

type The fully qualified class name of the permission represented by this `PermissionInfo`. The class must be a subclass of `java.security.Permission` and must define a 2-argument constructor that takes a *name* string and an *actions* string.

name The permission name that will be passed as the first argument to the constructor of the `Permission` class identified by *type*.

actions The permission actions that will be passed as the second argument to the constructor of the `Permission` class identified by *type*.

- Constructs a `PermissionInfo` from the specified *type*, *name*, and *actions*.

Throws `NullPointerException`—If *type* is null.

`IllegalArgumentException`—If *action* is not null and *name* is null.

51.4.3.2 **public PermissionInfo(String encodedPermission)**

encodedPermission The encoded `PermissionInfo`.

- Constructs a `PermissionInfo` object from the specified encoded `PermissionInfo` string. White space in the encoded `PermissionInfo` string is ignored.

Throws `IllegalArgumentException`—If the specified *encodedPermission* is not properly formatted.

See Also `getEncoded()`

51.4.3.3 **public boolean equals(Object obj)**

obj The object to test for equality with this `PermissionInfo` object.

- Determines the equality of two `PermissionInfo` objects. This method checks that specified object has the same *type*, *name* and *actions* as this `PermissionInfo` object.

Returns true if obj is a PermissionInfo, and has the same type, name and actions as this PermissionInfo object; false otherwise.

51.4.3.4 **public final String getActions()**

- Returns the actions of the permission represented by this PermissionInfo.

Returns The actions of the permission represented by this PermissionInfo, or null if the permission does not have any actions associated with it.

51.4.3.5 **public final String getEncoded()**

- Returns the string encoding of this PermissionInfo in a form suitable for restoring this PermissionInfo.

The encoded format is:

(type)

or

(type "name")

or

(type "name" "actions")

where *name* and *actions* are strings that must be encoded for proper parsing. Specifically, the "\, carriage return, and line feed characters must be escaped using "\", "\r, and "\n, respectively.

The encoded string contains no leading or trailing whitespace characters. A single space character is used between *type* and "*name*" and between "*name*" and "*actions*".

Returns The string encoding of this PermissionInfo.

51.4.3.6 **public final String getName()**

- Returns the name of the permission represented by this PermissionInfo.

Returns The name of the permission represented by this PermissionInfo, or null if the permission does not have a name.

51.4.3.7 **public final String getType()**

- Returns the fully qualified class name of the permission represented by this PermissionInfo.

Returns The fully qualified class name of the permission represented by this PermissionInfo.

51.4.3.8 **public int hashCode()**

- Returns the hash code value for this object.

Returns A hash code value for this object.

51.4.3.9 **public String toString()**

- Returns the string representation of this PermissionInfo. The string is created by calling the getEncoded method on this PermissionInfo.

Returns The string representation of this PermissionInfo.

52 URL Handlers Service Specification

Version 1.0

52.1 Introduction

This specification standardizes the mechanism to extend the Java run-time with new URL schemes and content handlers through bundles. Dynamically extending the URL schemes that are supported in an OSGi framework is a powerful concept.

This specification is necessary because the standard Java mechanisms for extending the URL class with new schemes and different content types is not compatible with the dynamic aspects of an OSGi framework. The registration of a new scheme or content type is a one time only action in Java, and once registered, a scheme or content type can never be revoked. This singleton approach to registration makes the provided mechanism impossible to use by different, independent bundles. Therefore, it is necessary for OSGi Framework implementations to hide this mechanism and provide an alternative mechanism that can be used.

52.1.1 Essentials

- *Multiple Access* - Multiple bundles should be allowed to register ContentHandler objects and URLStreamHandler objects.
- *Existing Schemes Availability* - Existing schemes in an OSGi framework should not be overridden.
- *life cycle Monitored* - The life cycle of bundles must be supported. Scheme handlers and content type handlers must become unavailable when the registering bundle is stopped.
- *Simplicity* - Minimal effort should be required for a bundle to provide a new URL scheme or content type handler.

52.1.2 Entities

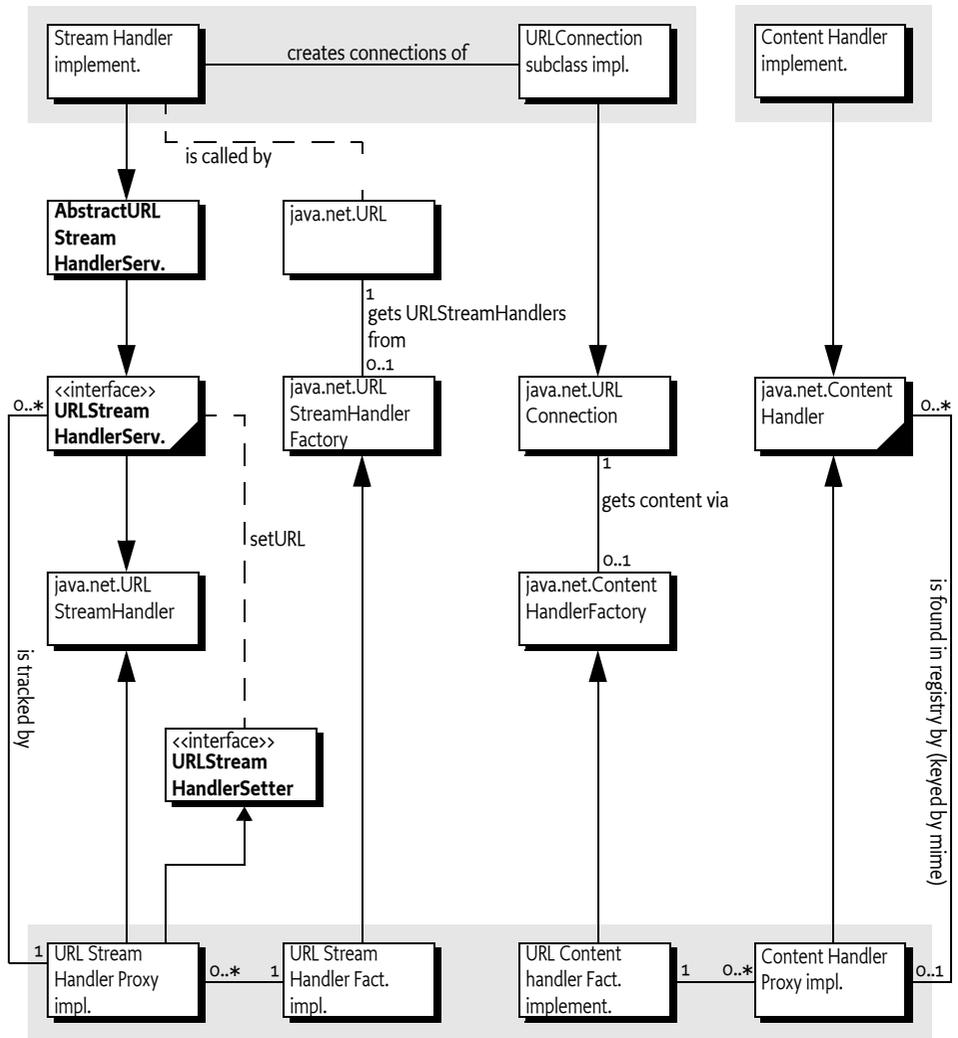
- *Scheme* - An identifier for a specific protocol. For example, "http" is a scheme for the Hyper Text Transfer Protocol. A scheme is implemented in a `java.net.URLStreamHandler` sub-class.
- *Content Type* - An identifier for the type of the content. Content types are usually referred to as MIME types. A content type handler is implemented as a `java.net.ContentHandler` sub-class.
- *Uniform Resource Locator (URL)* - An instance of the `java.net.URL` class that holds the name of a scheme with enough parameters to identify a resource for that scheme.
- *Factory* - An object that creates other objects. The purpose is to hide the implementation types (that may vary) from the caller. The created objects are a subclass/implementation of a specific type.
- *Proxy* - The object that is registered with Java and that forwards all calls to the real implementation that is registered with the service registry.
- *java.net.URLStreamHandler* - An instance of the `java.net.URLStreamHandler` class that can create URLConnection objects that represent a connection for a specific protocol.
- *Singleton Operation* - An operation that can only be executed once.
- *URLStreamHandlerService* - An OSGi service interface that contains the methods of the URLStreamHandler class with public visibility so they can be called from the Framework.
- *AbstractURLStreamHandlerService* - An implementation of the URLStreamHandlerService interface that implements the interface's methods by calling the implementation of the super class

(`java.net.url.URLStreamHandler`). This class also handles the setting of the `java.net.URL` object via the `java.net.URLStreamHandlerSetter` interface.

- *URLStreamHandlerSetter* - An interface needed to abstract the setting of the `java.net.URL` object. This interface is related to the use of a proxy and security checking.
- *java.net.URLStreamHandlerFactory* - A factory, registered with the `java.net.URL` class, that is used to find `java.net.URLStreamHandler` objects implementing schemes that are not implemented by the Java environment. Only one `java.net.URLStreamHandlerFactory` object can be registered with Java.
- *java.net.URLConnection* - A connection for a specific, scheme-based protocol. A `java.net.URLConnection` object is created by a `java.net.URLStreamHandler` object when the `java.net.URL.openConnection` method is invoked.
- *java.net.ContentHandler* - An object that can convert a stream of bytes to a Java object. The class of this Java object depends on the MIME type of the byte stream.
- *java.net.ContentHandlerFactory* - A factory that can extend the set of `java.net.ContentHandler` objects provided by the `java.net.URLConnection` class, by creating new ones on demand. Only one `java.net.ContentHandlerFactory` object can be registered with the `java.net.URLConnection` class.
- *MIME Type* - A namespace for byte stream formats. See [2] *MIME Multipurpose Internet Mail Extension*.

The following class diagram is surprisingly complex due to the complicated strategy that Java uses to implement extendable stream handlers and content handlers.

Figure 52.1 Class Diagram, java.net (URL and associated classes)



52.1.3 Operation

A bundle that can implement a new URL scheme should register a service object under the `URLStreamHandlerService` interface with the OSGi Framework. This interface contains public versions of the `java.net.URLStreamHandler` class methods, so that these methods can be called by the *proxy* (the object that is actually registered with the Java run-time).

The OSGi Framework implementation must make this service object available to the underlying `java.net` implementation. This must be supported by the OSGi Framework implementation because the `java.net.URL.setStreamHandlerFactory` method can only be called *once*, making it impossible to use by bundles that come and go.

Bundles that can convert a content-typed stream should register a service object under the name `java.net.ContentHandler`. These objects should be made available by the OSGi Framework to the `java.net.URLConnection` class.

52.2 Factories in java.net

Java provides the `java.net.URL` class which is used by the OSGi Framework and many of the bundles that run on the OSGi framework. A key benefit of using the `URL` class is the ease with which a `URL` string is translated into a request for a resource.

The extensibility of the `java.net.URL` class allows new schemes (protocols) and content types to be added dynamically using `java.net.URLStreamHandlerFactory` objects. These new handlers allow existing applications to use new schemes and content types in the same way as the handlers provided by the Java run-time environment. This mechanism is described in the Javadoc for the `URLStreamHandler` and `ContentHandler` class.

For example, the `URL` `http://www.osgi.org/sample.txt` addresses a file on the OSGi web server that is obtained with the `HTTP` scheme (usually a scheme provided by the Java run-time). A `URL` such as `rsh://www.acme.com/agent.zip` is addressing a `ZIP` file that can be obtained with the non-built-in `RSH` scheme. A `java.net.URLStreamHandlerFactory` object must be registered with the `java.net.URL` class prior to the successful use of an `RSH` scheme.

There are several problems with using only the existing Java facilities for extending the handlers used by the `java.net.URL` class:

- *Factories Are Singleton Operations* - One `java.net.URLStreamHandlerFactory` object can be registered *once* with the `java.net.URL` class. Similarly, one `java.net.ContentHandlerFactory` object can be registered once with the `java.net.URLConnection` class. It is impossible to undo the registration of a factory or register a replacement factory.
- *Caching Of Schemes* - When a previously unused scheme is first used by the `java.net.URL` class, the `java.net.URL` class requests a `java.net.URLStreamHandler` object for that specific scheme from the currently registered `java.net.URLStreamHandlerFactory` object. A returned `java.net.URLStreamHandler` object is cached and subsequent requests for that scheme use the same `java.net.URLStreamHandler` object. This means that once a handler has been constructed for a specific scheme, this handler can no longer be removed, nor replaced, by a new handler for that scheme. This caching is likewise done for `java.net.ContentHandler` objects.

Both problems impact the OSGi operating model, which allows a bundle to go through different life cycle stages that involve exposing services, removing services, updating code, replacing services provided by one bundle with services from another, etc. The existing Java mechanisms are not compatible when used by bundles.

52.3 Framework Procedures

The OSGi Framework must register a `java.net.URLStreamHandlerFactory` object and a `java.net.ContentHandlerFactory` object with the `java.net.URL.setURLStreamHandlerFactory` and `java.net.URLConnection.setContentHandlerFactory` methods, respectively.

When these two factories are registered, the OSGi Framework service registry must be tracked for the registration of `URLStreamHandlerService` services and `java.net.ContentHandler` services.

A `URL Stream Handler Service` must be associated with a service registration property named `URL_HANDLER_PROTOCOL`. The value of this `url.handler.protocol` property must be an array of scheme names (`String[]` or `String`).

A `Content Handler service` must be associated with a service registration property named `URL_CONTENT_MIMETYPE`. The value of the `URL_CONTENT_MIMETYPE` property must be an array of MIME types names (`String[]` or `String`) in the form `type/subtype`. See [2] *MIME Multipurpose Internet Mail Extension*.

52.3.1 Constructing a Proxy and Handler

When a URL is used with a previously unused scheme, it must query the registered `java.net.URLStreamHandlerFactory` object (that should have been registered by the OSGi Framework). The OSGi Framework must then search the service registry for services that are registered under `URLStreamHandlerService` and that match the requested scheme.

If one or more service objects are found, a proxy object must be constructed. A proxy object is necessary because the service object that provides the implementation of the `java.net.URLStreamHandler` object can become unregistered and Java does not provide a mechanism to withdraw a `java.net.URLStreamHandler` object once it is returned from a `java.net.URLStreamHandlerFactory` object.

Once the proxy is created, it must track the service registry for registrations and unregistrations of services matching its associated scheme. The proxy must be associated with the service that matches the scheme and has the highest value for the `org.osgi.framework.Constants.SERVICE_RANKING` service registration property (see *Service Properties* on page 137) at any moment in time. If a proxy is associated with a URL Stream Handler Service, it must change the associated handler to a newly registered service when that service has a higher value for the ranking property.

The proxy object must forward all method requests to the associated URL Stream Handler Service until this service object becomes unregistered.

Once a proxy is created, it cannot be withdrawn because it is cached by the Java run-time. However, service objects can be withdrawn and it is possible for a proxy to exist without an associated `URLStreamHandlerService/java.net.ContentHandler` object.

In this case, the proxy must handle subsequent requests until another appropriate service is registered. When this happens, the proxy class must handle the error.

In the case of a URL Stream Handler proxy, it must throw a `java.net.MalformedURLException` exception if the signature of a method allows throwing this exception. Otherwise, a `java.lang.IllegalStateException` exception is thrown.

In the case of a Content Handler proxy, it must return `InputStream` to the data.

Bundles must ensure that their `URLStreamHandlerService` or `java.net.ContentHandler` service objects throw these exceptions also when they have become unregistered.

Proxies for Content Handler services operate slightly differently from URL Stream Handler Service proxies. In the case that null is returned from the registered `ContentHandlerFactory` object, the factory will not get another chance to provide a `ContentHandler` object for that content-type. Thus, if there is no built-in handler, nor a registered handler for this content-type, a `ContentHandler` proxy must be constructed that returns the `InputStream` object from the `URLConnection` object as the content object until a handler is registered.

52.3.2 Built-in Handlers

Implementations of Java provide a number of sub-classes of `java.net.URLStreamHandler` classes that can handle protocols like HTTP, FTP, NEWS etc. Most Java implementations provide a mechanism to add new handlers that can be found on the class path through class name construction.

If a registered `java.net.URLStreamHandlerFactory` object returns null for a built-in handler (or one that is available through the class name construction mechanism), it will never be called again for that specific scheme because the Java implementation will use its built-in handler or uses the class name construction.

As a result, even though it is not forbidden for URL Handlers Service implementations to override built-in handlers, it is not possible to guarantee that a registered `URLStreamHandlerService` object will be used when it is overriding a built-in handler. For consistency reasons, it is therefore recommended to never override built-in handlers.

The Content Handler Factory is implemented using a similar technique and has therefore the same problems.

To facilitate the discovery of built-in handlers that are available through the name construction, the method described in the next section must be used by the Framework before any handlers are searched for in the service registry.

52.3.3 Finding Built-in Handlers

If the system properties `java.protocol.handler.pkgs` or `java.content.handler.pkgs` are defined, they must be used to locate built-in handlers. Each property must be defined as a list of package names that are separated by a vertical line (`'|' \u007C`) and that are searched in the left-to-right order (the names must *not* end in a full stop (`'.' \u002E`)). For example:

```
org.osgi.impl.handlers | com.acme.url
```

The package names are the prefixes that are put in front of a scheme or content type to form a class name that can handle the scheme or content-type.

A URL Stream Handler name for a scheme is formed by appending the string `".Handler"` to the scheme name. Using the packages in the previous example, the `rsh` scheme handler class is searched by the following names:

```
org.osgi.impl.handlers.rsh.Handler
com.acme.url.rsh.Handler
```

MIME type names contain the solidus (`'/' \u002F`) character and can contain other characters that must not be part of a Java class name. A MIME type name must be processed as follows before it can be converted to a class name:

1. First, all solidi in the MIME name must be converted to a full stop (`'.' \u002E`). All other characters that are not allowed in a Java class name must be converted to an underscore (`'_' \u005F`).

```
application/zip    application.zip
text/uri-list      text.uri_list
image/vnd.dwg      image.vnd_dwg
```

2. After this conversion, the name is appended to the list of packages specified in `java.content.handler.pkgs`. For example, if the content type is `application/zip`, and the packages are defined as in the previous example, then the following classes are searched:

```
org.osgi.impl.handlers.application.zip
com.acme.url.application.zip
```

The Java run-time specific packages should be listed in the appropriate properties so that implementations of the URL Stream Handler Factory and Content Handler Factory can be made aware of these packages.

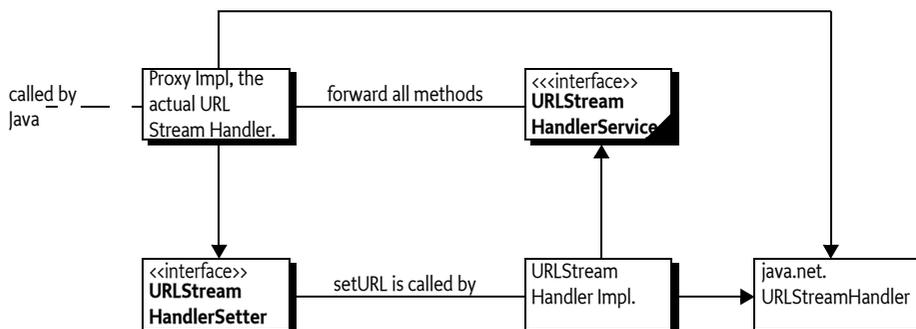
52.3.4 Protected Methods and Proxy

Implementations of `java.net.URLStreamHandler` class cannot be registered in the service registry for use by the proxy because the methods of the `URLStreamHandler` class are protected and thus not available to the proxy implementation. Also, the `URLStreamHandler` class checks that only the `URLStreamHandler` object that was returned from the `URLStreamHandlerFactory` object can invoke the `setURL` method. This means that `URLStreamHandler` objects in the service registry would be unable to invoke the `setURL` method. Invoking this method is necessary when implementing the `parseURL` method.

Therefore, the `URLStreamHandlerService` and `URLStreamHandlerSetter` interfaces were created. The `URLStreamHandlerService` interface provides public versions of the `URLStreamHandler` methods, except that the `setURL` method is missing and the `parseURL` method has a new first argument of type `URLStreamHandlerSetter`. In general, sub-classes of the `URLStreamHandler` class can be converted to `URLStreamHandlerService` classes with minimal code changes. Apart from making the relevant methods public, the `parseURL` method needs to be changed to invoke the `setURL` method on the `URLStreamHandlerSetter` object that the `URLStreamHandlerService` object was passed, rather than the `setURL` method of `URLStreamHandler` class.

Figure 52.2

Proxy Issues



To aid in the conversion of `URLStreamHandler` implementation classes, the `AbstractURLStreamHandlerService` has been provided. Apart from making the relevant methods public, the `AbstractURLStreamHandlerService` stores the `URLStreamHandlerSetter` object in a private variable. To make the `setURL` method work properly, it overrides the `setURL` method to invoke the `setURL` method on the saved `URLStreamHandlerSetter` object rather than the `URLStreamHandler.setURL` method. This means that a subclass of `URLStreamHandler` should be changed to become a sub-class of the `AbstractURLStreamHandlerService` class and be recompiled.

Normally, the `parseURL` method will have the following form:

```

class URLStreamHandlerImpl {
    ...
    protected URLStreamHandlerSetter realHandler;
    ...
    public void parseURL(
        URLStreamHandlerSetter realHandler,
        URL u, String spec, int start, int limit) {
        this.realHandler = realHandler;
        parseURL(u, spec, start, limit);
    }
    protected void setURL(URL u,
        String protocol, String host,
        int port, String authority,
        String userInfo, String path,
        String query, String ref) {
        realHandler.setURL(u, protocol, host,
            port, authority, userInfo, path,
            query, ref);
    }
    ...
}
  
```

The `URLConnectionHandler.parseURL` method will call the `setURL` method which must be invoked on the proxy rather than this. That is why the `setURL` method is overridden to delegate to the `URLConnectionHandlerSetter` object in `realHandler` as opposed to `super`.

52.3.5 Stream Handlers that use `java.net.Proxy`

Java 1.5 introduced a new method on the `URLConnectionHandler` class: `URLConnectionHandler.openConnection(URL,Proxy)`. Adding this method to the URL Stream Handler service poses the following problems:

- It would have broken all existing implementations.
- The references to the `java.net.Proxy` class would make the API dependent on Java 1.5

Therefore, scheme providers can optionally implement the `URLConnectionHandler.openConnection(URL,Proxy)` method as a public method. If the scheme provider implements this method, then the framework must call it (using reflection). If this method is not implemented in the URL Stream Handler service an `UnsupportedOperationException` must be thrown.

Framework implementations should be careful not to create unwanted dependencies on Java 1.5. This will require two different implementation classes for the `URLConnectionHandler` class that is used to proxy the URL Stream Handler services.

52.4 Providing a New Scheme

The following example provides a scheme that returns the path part of the URL. The first class that is implemented is the `URLConnectionHandlerService`. When it is started, it registers itself with the OSGi Framework. The OSGi Framework calls the `URLConnectionHandlerService.openConnection` method when a new `java.net.URLConnection` must be created. In this example, a `DataConnection` object is returned.

```
public class DataProtocol
    extends AbstractURLConnectionHandlerService
    implements BundleActivator {
    public void start( BundleContext context ) {
        Hashtable properties = new Hashtable();
        properties.put( URLConstants.URL_HANDLER_PROTOCOL,
            new String[] { "data" } );
        context.registerService(
            URLStreamHandlerService.class.getName(),
            this, properties );
    }
    public void stop( BundleContext context ) {}

    public URLConnection openConnection( URL url ) {
        return new DataConnection(url);
    }
}
```

The following example `DataConnection` class extends `java.net.URLConnection` and overrides the constructor so that it can provide the URL object to the super class, the `connect` method, and the `getInputStream` method. This last method returns the path part of the URL as an `java.io.InputStream` object.

```
class DataConnection extends java.net.URLConnection{
    DataConnection( URL url ) {super(url);}
    public void connect() {}
}
```

```
public InputStream getInputStream() throws IOException {
    String s = getURL().getPath();
    byte [] buf = s.getBytes();
    return new ByteArrayInputStream(buf,1,buf.length-1);
}
public String getContentType() {
    return "text/plain";
}
}
```

52.5 Providing a Content Handler

A Content Handler should extend the `java.net.ContentHandler` class and implement the `getContent` method. This method must get the `InputStream` object from the `java.net.URLConnection` parameter object and convert the bytes from this stream to the applicable type. In this example, the MIME type is `text/plain` and the return object is a `String` object.

```
public class TextPlainHandler extends ContentHandler
    implements BundleActivator {

    public void start( BundleContext context ) {
        Hashtable properties = new Hashtable();
        properties.put( URLConstants.URL_CONTENT_MIMETYPE,
            new String[] { "text/plain" } );
        context.registerService(
            ContentHandler.class.getName(),
            this, properties );
    }
    public void stop( BundleContext context ) {}

    public Object getContent( URLConnection conn )
        throws IOException {
        InputStream in = conn.getInputStream();
        InputStreamReader r = new InputStreamReader( in );
        StringBuffer sb = new StringBuffer();
        int c;
        while ( (c=r.read()) >= 0 )
            sb.append( (char) c );
        r.close(); in.close();
        return sb.toString();
    }
}
```

52.6 Security Considerations

The ability to specify a protocol and add content handlers makes it possible to directly affect the behavior of a core Java VM class. The `java.net.URL` class is widely used by network applications and can be used by the OSGi Framework itself.

Therefore, care must be taken when providing the ability to register handlers. The two types of supported handlers are `URLStreamHandlerService` and `java.net.ContentHandler`. Only trusted bundles should be allowed to register these services and have

ServicePermission[URLStreamHandlerService|ContentHandler, REGISTER] for these classes. Since these services are made available to other bundles through the java.net.URL class and java.net.URLConnection class, it is advisable to deny the use of these services (ServicePermission[<name>, GET]) to all, so that only the Framework can get them. This prevents the circumvention of the permission checks done by the java.net.URL class by using the URLStreamHandlerServices service objects directly.

52.7 org.osgi.service.url

URL Stream and Content Handlers Package Version 1.0.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.service.url; version="[1.0,2.0]"
```

52.7.1 Summary

- AbstractURLStreamHandlerService - Abstract implementation of the URLStreamHandlerService interface.
- URLConstants - Defines standard names for property keys associated with URLStreamHandlerService and java.net.ContentHandler services.
- URLStreamHandlerService - Service interface with public versions of the protected java.net.URLStreamHandler methods.
- URLStreamHandlerSetter - Interface used by URLStreamHandlerService objects to call the setURL method on the proxy URLStreamHandler object.

52.7.2 public abstract class AbstractURLStreamHandlerService extends URLStreamHandler implements URLStreamHandlerService

Abstract implementation of the URLStreamHandlerService interface. All the methods simply invoke the corresponding methods on java.net.URLStreamHandler except for parseURL and setURL, which use the URLStreamHandlerSetter parameter. Subclasses of this abstract class should not need to override the setURL and parseURL(URLStreamHandlerSetter,...) methods.

Concurrency Thread-safe

52.7.2.1 protected volatile URLStreamHandlerSetter realHandler

The URLStreamHandlerSetter object passed to the parseURL method.

52.7.2.2 public AbstractURLStreamHandlerService()

52.7.2.3 public boolean equals(URL u1, URL u2)

- This method calls super.equals(URL,URL).

See Also java.net.URLStreamHandler.equals(URL,URL)

52.7.2.4 public int getDefaultPort()

- This method calls super.getDefaultPort.

See Also java.net.URLStreamHandler.getDefaultPort

52.7.2.5 **public InetAddress getHostAddress(URL u)**

- This method calls `super.getHostAddress`.

See Also `java.net.URLStreamHandler.getHostAddress`

52.7.2.6 **public int hashCode(URL u)**

- This method calls `super.hashCode(URL)`.

See Also `java.net.URLStreamHandler.hashCode(URL)`

52.7.2.7 **public boolean hostsEqual(URL u1, URL u2)**

- This method calls `super.hostsEqual`.

See Also `java.net.URLStreamHandler.hostsEqual`

52.7.2.8 **public abstract URLConnection openConnection(URL u) throws IOException**

See Also `java.net.URLStreamHandler.openConnection`

52.7.2.9 **public void parseURL(URLStreamHandlerSetter realHandler, URL u, String spec, int start, int limit)**

realHandler The object on which the `setURL` method must be invoked for the specified URL.

- Parse a URL using the `URLStreamHandlerSetter` object. This method sets the `realHandler` field with the specified `URLStreamHandlerSetter` object and then calls `parseURL(URL,String,int,int)`.

See Also `java.net.URLStreamHandler.parseURL`

52.7.2.10 **public boolean sameFile(URL u1, URL u2)**

- This method calls `super.sameFile`.

See Also `java.net.URLStreamHandler.sameFile`

52.7.2.11 **protected void setURL(URL u, String proto, String host, int port, String file, String ref)**

- This method calls `realHandler.setURL(URL,String,String,int,String,String)`.

See Also `java.net.URLStreamHandler.setURL(URL,String,String,int,String,String)`

Deprecated This method is only for compatibility with handlers written for JDK 1.1.

52.7.2.12 **protected void setURL(URL u, String proto, String host, int port, String auth, String user, String path, String query, String ref)**

- This method calls `realHandler.setURL(URL,String,String,int,String,String,String,String)`.

See Also `java.net.URLStreamHandler.setURL(URL,String,String,int,String,String,String,String)`

52.7.2.13 **public String toExternalForm(URL u)**

- This method calls `super.toExternalForm`.

See Also `java.net.URLStreamHandler.toExternalForm`

52.7.3 **public interface URLConstants**

Defines standard names for property keys associated with `URLStreamHandlerService` and `java.net.ContentHandler` services.

The values associated with these keys are of type `java.lang.String[]` or `java.lang.String`, unless otherwise indicated.

Provider Type Consumers of this API must not implement this type

52.7.3.1 **public static final String URL_CONTENT_MIMETYPE = "url.content.mimetype"**

Service property naming the MIME types serviced by a `java.net.ContentHandler`. The property's value is a MIME type or an array of MIME types.

52.7.3.2 **public static final String URL_HANDLER_PROTOCOL = "url.handler.protocol"**

Service property naming the protocols serviced by a `URLStreamHandlerService`. The property's value is a protocol name or an array of protocol names.

52.7.4 **public interface URLStreamHandlerService**

Service interface with public versions of the protected `java.net.URLStreamHandler` methods.

The important differences between this interface and the `URLStreamHandler` class are that the `setURL` method is absent and the `parseURL` method takes a `URLStreamHandlerSetter` object as the first argument. Classes implementing this interface must call the `setURL` method on the `URLStreamHandlerSetter` object received in the `parseURL` method instead of `URLStreamHandler.setURL` to avoid a `SecurityException`.

See Also `AbstractURLStreamHandlerService`

Concurrency Thread-safe

52.7.4.1 **public boolean equals(URL u1, URL u2)**

See Also `java.net.URLStreamHandler.equals(URL, URL)`

52.7.4.2 **public int getDefaultPort()**

See Also `java.net.URLStreamHandler.getDefaultPort`

52.7.4.3 **public InetAddress getHostAddress(URL u)**

See Also `java.net.URLStreamHandler.getHostAddress`

52.7.4.4 **public int hashCode(URL u)**

See Also `java.net.URLStreamHandler.hashCode(URL)`

52.7.4.5 **public boolean hostsEqual(URL u1, URL u2)**

See Also `java.net.URLStreamHandler.hostsEqual`

52.7.4.6 **public URLConnection openConnection(URL u) throws IOException**

See Also `java.net.URLStreamHandler.openConnection`

52.7.4.7 **public void parseURL(URLStreamHandlerSetter realHandler, URL u, String spec, int start, int limit)**

realHandler The object on which `setURL` must be invoked for this URL.

- Parse a URL. This method is called by the `URLStreamHandler` proxy, instead of `java.net.URLStreamHandler.parseURL`, passing a `URLStreamHandlerSetter` object.

See Also `java.net.URLStreamHandler.parseURL`

52.7.4.8 **public boolean sameFile(URL u1, URL u2)**

See Also `java.net.URLStreamHandler.sameFile`

52.7.4.9 public String toExternalForm(URL u)

See Also `java.net.URLStreamHandler.toExternalForm`

52.7.5 public interface URLStreamHandlerSetter

Interface used by `URLStreamHandlerService` objects to call the `setURL` method on the proxy `URLStreamHandler` object.

Objects of this type are passed to the `URLStreamHandlerService.parseURL(URLStreamHandlerSetter, URL, String, int, int)` method. Invoking the `setURL` method on the `URLStreamHandlerSetter` object will invoke the `setURL` method on the proxy `URLStreamHandler` object that is actually registered with `java.net.URL` for the protocol.

Concurrency Thread-safe

52.7.5.1 public void setURL(URL u, String protocol, String host, int port, String file, String ref)

See Also `java.net.URLStreamHandler.setURL(URL,String,String,int,String,String)`

Deprecated This method is only for compatibility with handlers written for JDK 1.1.

52.7.5.2 public void setURL(URL u, String protocol, String host, int port, String authority, String userInfo, String path, String query, String ref)

See Also `java.net.URLStreamHandler.setURL(URL,String,String,int,String,String,String,String,String)`

52.8 References

- [1] *URLs*
<http://www.ietf.org/rfc/rfc1738.txt>
- [2] *MIME Multipurpose Internet Mail Extension*
<http://www.nacs.uci.edu/indiv/ehood/MIME/MIME.html>
- [3] *Assigned MIME Media Types*
<http://www.iana.org/assignments/media-types>

53 Resolver Hook Service Specification

Version 1.0

53.1 Introduction

The module layer is responsible for the resolve operation that wires requirements (Import-Package, Require-Bundle etc.) to capabilities (Export-Package, Bundle-SymbolicName/Bundle-Version etc.). The resolve operation is designed to work stand-alone but in certain use cases it is important to be able to influence the resolver's decisions. This specification defines a Resolver Hook Factory service that allows third party bundles to influence the resolve operation. Primary use cases for this hook are scoping of groups of bundles. However, the hooks also allows bundle to find out about, and control, the resolve operation for other purposes.

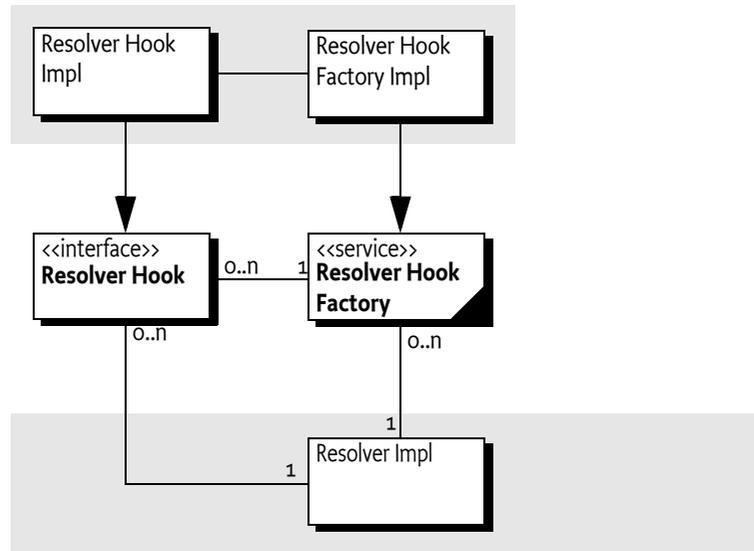
53.1.1 Essentials

- *Reduction* - Allow third party bundles to remove capabilities from a set of capabilities that matches a requirement.
- *Complete* - Support all built-in namespaces as well as the generic capability and requirement headers.
- *Singletons* - Allow third party bundles to remove candidates from a set of singleton capabilities before the resolver selects one.
- *Secure* - Support full security but allow operation without security present.

53.1.2 Entities

- *Resolver Hook Factory* - The service registered by a bundle that wants to control the resolve operation. This service is used to create an instance of the Resolver Hook for each resolve operation.
- *Resolver Hook* - Is created by the Resolver Hook Factory service for each resolver process. Is consulted to reduce candidate capabilities for resolving and selecting singletons.
- *Client* - A bundle that is considered during the resolve operation.
- *Handler* - A bundle that registers a Resolver Hook Factory service for influencing the resolve operation.
- *Bundle Capability* - A capability represents a feature of a bundle described with attributes and directives defined in a namespace. Some namespaces are built-in to the OSGi framework, others are generic.
- *Bundle Requirement* - A requirement represents a need from a bundle described as a filter on the attributes of a Bundle Capability.
- *Provider* - A bundle that provides a Bundle Capability.
- *Consumer* - A bundle that requires a Bundle Capability
- *Resolver* - The internal framework machinery that resolves requirements to providers with matching capabilities.

Figure 53.1 Resolver Hooks Entities



53.1.3 Synopsis

A handler bundle that needs to manage the wiring between bundles must register a Resolver Hook Factory service. For each resolve operation the Resolver needs to perform, the framework asks each Resolver Hook Factory service for a new Resolver Hook specific for the operation. During the resolve operation, the Resolver will allow the Resolver Hooks to remove candidate solutions and assist in selecting singletons.

53.2 Resolve Operation

53.2.1 Trigger Bundles

The Resolver is triggered by activity in the OSGi framework. Calling certain methods on a bundle when a bundle is in the INSTALLED state will cause the framework to begin a *resolve operation* in order to resolve the bundle. Other API can also trigger a resolver. Frameworks can resolve on a per bundle basis or they can resolve a number of bundles atomically in one operation. The bundles that trigger a resolve operation are called the *trigger bundles*. The trigger bundles can be defined by the following cases:

- *Root Bundle* - Calling certain methods on a bundle when a bundle is in the INSTALLED state will cause the framework to begin a *resolve operation* in order to resolve the bundle. In general, a bundle needs to be resolved when its class loader is needed. The following Bundle methods will start a resolve operation when the subject is not yet resolved:
 - start
 - loadClass
 - findEntries
 - getResource
 - getResources
- *Resolve Bundles* - The set of bundle revisions of the unresolved bundles given as argument, or their default when null is used, to the Framework Wiring resolveBundles method. See *Using the Wiring API* on page 158.

- *Refresh Bundles* - A refresh operation will have to re-resolve the bundles that will be unresolved in the refresh. The trigger bundles are then the bundle revisions of the dependency closure, which is described in *Refreshing* on page 167.
- *Dynamic Import* - A Dynamic Import can require the framework to start a resolve operation.
- *Other* - The Resolver Hook is a service so other parties can to start a resolver operation to run what-if scenarios or for other purposes.

53.2.2 Resolving Types

Various types of resolve operations can be initiated:

- *Static* - A static bundle resolve operation. This resolve operation is necessary any time one or more bundles transitions from the INSTALLED state to the RESOLVED state. During this resolve operation the framework attempts to resolve static requirements specified by the bundles being resolved.
- *Dynamic* - A dynamic import must be resolved.

The resolve operation is not limited to the trigger bundles only, they just provide the root bundles that must be resolved. The Resolver is free to consider any present bundle to provide the required capabilities. If such bundles are in the INSTALLED state then they can also become a candidate to be resolved. The resolver is also free to use bundles that are actually not installed in the framework, for example for what-if scenarios.

53.2.3 Preparing Handlers

Once the resolver is triggered, it must prepare the *Handlers* to participate in the resolve operation. A Handler is an active bundle that needs to participate in the resolve operation, there can be multiple Handlers in a framework. A Handler must register a Resolver Hook Factory service. This service is the interface between a *Handler* bundle, a bundle that will handle some aspects of the resolve operation, and the Resolver.

To prepare the Handlers, the Resolver must request a new Resolver Hook from each of the registered Resolver Hook Factory services with the `begin(Collection)` method. The parameter is the set of trigger bundles. The Handler is expected to create a new `ResolverHook` object for each call. If null is returned then the Handler abstains from participation. A Resolver Hook Factory must be thread-safe and allow the creation of independent Resolver Hook objects that can be active on multiple threads.

A Resolver Hook is created for a single atomic resolve operation and does not have to be thread safe. The Resolver must ensure that access to the Resolver Hook is serialized, that is, the can only be active from a single thread. The `ResolverHook` object is called multiple times during a resolve operation to influence the outcome of a resolve operation. The following operations are provided:

- `filterResolvable(Collection)` - Removes bundles that are candidates for resolving so they do not resolve in the current operation. Provides an easy way to exclude bundles.
- `filterMatches(BundleRequirement,Collection)` - Remove matching capabilities from the candidate capabilities. This effectively hides capabilities for certain requirers.
- `filterSingletonCollisions(BundleCapability,Collection)` - Remove potentially conflicting singletons from the collection. This provides the possibility to resolve a singleton multiple times in different groups.

A Resolver Hook can influence the outcome of a resolve operation by removing entries from *shrinkable* collections. A shrinkable collection is a collection that can only shrink. The Handler can remove entries from the collection but it cannot add an entry to it. Any attempt to add to the collection must result in throwing an `UnsupportedOperationException`. All collections in the Resolver Hook API are shrinkable collections.

The Resolver Hook Factory services `begin(Collection)` method is called in the ranking order, see *Service Ranking Order* on page 139. This is the same order used for calling the resulting Resolver Hooks.

The Resolver Hook `end()` method notifies the Handler that the resolve operation has finished. The framework must not hold on to this Resolver Hook instance after the `end()` method has been called.

53.2.4 Limiting the Set of Resolvable Bundles

There are use cases where a bundle that is being installed should not be allowed to resolve until some activity has taken place. Sometimes certain bundles should never resolve. For example, there are byte code weaving scenarios where a bundle is used as the source but a synthetic bundle with the woven code provides the actual classes. The source bundle should then not resolve. The `filterResolvable(Collection)` method can be used to ensure that certain bundles are never resolved. All the given Bundle Revisions are unresolved. The Handler can look at the given collection and remove any bundles it wants to prevent being resolved in this resolve operation.

The set of bundles passed will contain the trigger bundles. If a Handler removes one of the trigger bundles the resolve of the removed bundle will not succeed and fail the call to the method that triggered the resolve operation.

The framework can pass an empty collection of resolvable bundle revisions, this could for example happen while resolving a dynamic import. An empty collection indicates that the framework will not cause any bundles to transition from `INSTALLED` to `RESOLVED` during a dynamic import package resolving.

For example, a Handler wants to ensure certain bundles are not resolved, then it can do:

```
public class UnresolveHandler implements ResolverHook{
    Set<BundleRevision> neverResolve = ... ;

    public void filterResolvable(
        Collection<BundleRevision> toBeResolved ) {
        toBeResolved.removeAll( neverResolve );
    }

    ... other methods
}
```

53.2.5 Hiding Capabilities

The `filterMatches(BundleRequirement,Collection)` method is used to remove capabilities for consideration for a specific requirer. The Handler receives the Bundle Requirement and the set of candidates that already match the requirement. The Handler can now remove any candidates that are not suitable. Removing the capability will prevent the requirement from getting wired to the capability. If the Bundle Requirement is declared in a fragment then the host is not knowable.

For example, a Handler wants to ensure that a set of bundles in a group are only wired to a limited set of infra-structure bundles and each other. This could be implemented as follows:

```
public class GroupHandler implements ResolverHook{
    Map<Bundle,Set<Bundle>> groups = ...;
    Set<Bundle> system = ... ;

    public void filterMatches( BundleRequirement r,
        Collection<BundleCapability> candidates ) {
        Set<Bundle> group = groups.get(r.getRevision()).getBundle();
        if ( group == null )
            return; // not in a group

        for ( Iterator<BundleCapability> i = candidates.iterator();
            i.hasNext(); ) {
            BundleCapability candidate = i.next();
```

```

        Bundle other = candidate.getRevision().getBundle();

        if ( group.contains(other) ||
            system.contains(other) )
            continue;

        i.remove(); // not system, not in the same group
    }
}

... other methods
}

```

53.2.6 Effect of Singleton Capabilities

Certain namespaces provide a singleton directive. For example, the `osgi.wiring.bundle` namespace defines that a bundle can be singleton, meaning that only one such bundle with a given symbolic name can be resolved. The purpose is to ensure that a bundle that needs exclusiveness gets this.

In certain scenarios it is necessary to limit the singleton constraint to a group of bundles instead of the whole framework. One of the primary use cases of the Resolver Hooks is to allow scoping of bundles. Some Handlers can interpret the singleton constraints as to apply to the group, not the whole framework. For this purpose, the Resolver Hook API allows the Handler to influence which bundle revision is selected for the singleton with the [filterSingletonCollisions\(BundleCapability,Collection\)](#) method.

The first parameter is the capability that is under consideration by the resolver, called the *viewpoint* capability. The resolver needs to find out what other capabilities can *collide* with the viewpoint. A collision takes place when multiple bundles with the same symbolic name and singleton directive set to true can potentially be resolved at the same time. For example, a Handler implements a grouping model. A singleton is therefore only valid for the bundles in this group. A Handler must therefore be able to indicate which bundles can collide. This model is asymmetric. If a group has for example outer and inner bundles, then inner bundles can collide with outer bundles but not vice versa.

The second parameters of the [filterSingletonCollisions\(BundleCapability,Collection\)](#) method is a set of capabilities called the *candidates*. The Handler can shrink this collection by removing capabilities. Removing a capability from the list of collision candidates will effectively hide the collision candidate from the target singleton bundle. This will allow the target singleton bundle to resolve regardless of the resolving state of the collision candidate.

If S is the group of infrastructure bundles (acting as an outer bundles) and a non-infrastructure group is A, then the following cases exist:

```

S S    collide, leave in set
A A    collide, leave in set
A !A  remove from set, not visible
A S    collide, leave in set
S A    do not collide, remove from set

```

The following example implements this strategy:

```

public class GroupHandler implements ResolverHook{
    Map<Bundle,Set<Bundle>> groups = ...;

    public void filterSingletonCollisions( BundleCapability c,
        Collection<BundleCapability> candidates ) {
        Set<Bundle> group = groups.get(c.getRevision().getBundle());
    }
}

```

```

    for ( Iterator<BundleCapability> i = candidates.iterator();
          i.hasNext(); ) {
        BundleCapability candidate = i.next();
        Bundle other = candidate.getRevision().getBundle();
        Set<Bundle> otherGroup = groups.get(other);

        if ( group == otherGroup || otherGroup == null ) // Samegroup
            continue;

        i.remove(); // not system, not in the same group
    }
}
... other methods
}

```

The framework can call this method multiple times for the same singleton capability. For example, as a first pass a framework may want to determine if a singleton bundle is resolvable first based on the presence of other already resolved singleton capabilities. Later the framework may call this method again to determine which singleton capabilities from unresolved bundles to allow to resolve.

53.3 The Resolve Operation

The following steps outline the way a framework uses the resolver hooks during a resolve operation. Any callbacks to the hook services must be done in a privileged block, see *Privileged Callbacks* on page 131.

1. Collect a snapshot of registered Resolver Hook Factory services that will be called during the current resolve operation. If a Resolver Hook Factory contained in the snapshot unregisters then the resolve must fail, see *Failures* on page 388. Each registered Resolver Hook Factory service in the snapshot will be obtained by the framework through the system's bundle context.
2. For each Resolver Hook Factory in the snapshot, in ranking order, call the [begin\(Collection\)](#) method to inform the Handler about the begin of a new resolve operation. This method must return a Resolver Hook. If this hook is not null, must be added to list H. If a corresponding Resolver Hook Factory service is unregistered then the Resolver Hook must be removed from H.
3. Determine the collection of unresolved bundle revisions that may be considered for resolving during the current resolve operation and place each of the bundle revisions in a shrinkable collection U(nresolved).
 - For each active Resolver Hook in H(ooks), call the [filterResolvable\(Collection\)](#) method with U. The Handler can remove any candidate that should not be resolved.

U now contains all the unresolved bundle revisions that potentially could be resolved during this resolve operation. Any bundle revisions that were removed by Handlers must not resolve in this operation.

This step can be repeated multiple times interspersed with other calls except to the begin and end methods.

4. $S = \{\}$
5. For each bundle revision B in U that represents a singleton capability:
 - Determine the collection of available capabilities that have a namespace of `osgi.wiring.bundle`, are singletons, and have the same symbolic name as the singleton bundle revision B and place each of the matching capabilities into a shrinkable collection S.

- Remove the `osgi.wiring.bundle` capability provided by the bundle revision B from S. A singleton bundle cannot collide with itself.
- For each resolver hook call the `filterSingletonCollisions(BundleCapability,Collection)` method with the `osgi.wiring.bundle` capability provided by bundle revision B and S.

S now contains all the singleton `osgi.wiring.bundle` capabilities that can influence the ability of bundle revision B to resolve.

This step can be repeated multiple times interspersed with other calls except to the begin and end methods.

6. During a resolve operation the Resolver can resolve any or all bundles contained in U. For each bundle revision B in U which the Resolver attempts to resolve the following steps must be followed:
 - For each requirement R(equirement) specified by bundle revision B, determine the collection of capabilities that satisfy the requirement R and place each matching capability into a shrinkable collection C(apabilities). A capability is considered to satisfy a particular requirement if its attributes match the requirement's filter and the requirer bundle has permission to access the capability.
 - For each Resolver Hook in H, call the `filterMatches(BundleRequirement,Collection)` method with the Bundle Requirement R and the shrinkable collection C.

C now contains all the capabilities that can be used to satisfy the requirement R. Any other capabilities that got removed from C must not be used to satisfy requirement R.

This step can be repeated multiple times interspersed with other calls except begin and end.

7. For each Resolver Hook in H
 - Call the end method to inform the Handler about a resolve operation ending.
8. For each Resolve Hook still in H, ensure that the Resolver Hook is no longer referenced.

In cases where the a shrinkable collection becomes empty the framework must continue calling the remaining hooks because these hooks can also be used to trace progress.

The above steps are meant to illustrate how the Resolve Hooks are used by the Resolver, they are not normative. The nature of the resolve operation and the Resolver algorithm can require back tracking by the Resolver implementation. It is therefore acceptable for the Resolver to call the Resolver Hook multiple times with similar or identical parameters during a single resolve operation. This is true for all methods except the begin and end methods that are only called once during a resolve operation.

A Resolver Hook must always return the same answer for the same set of inputs, that is, it must be *stable*.

53.3.1 Resolver Hook Limitations

Resolver hooks are system level components. Handlers must be careful not to create an unresolvable state which is very hard for a developer or a provisioner to diagnose. Resolver Hooks also must not be allowed to start another resolve operation, for example by starting a bundle or resolving bundles. The framework must detect this and throw an Illegal State Exception.

In cases where a Bundle Exception can be thrown, such as the Bundle start method, the Illegal State Exception must be the cause of the Bundle Exception and the Bundle Exception must be of type `RESOLVE_ERROR`. In cases where an exception cannot be propagated to a caller, for example during dynamic import resolving, a Framework Event of type `ERROR` must be published.

All hooks are treated as ordinary services, they can be used by the system bundle or other bundles.

53-3-2 Failures

If during the resolving anything goes wrong then the Resolver must abort the resolve operation, clean up and report an error.

If the `begin(Collection)` method successfully returns a `ResolverHook`, then the `end()` method must be called on that hook if it is still valid (its `ResolverHookFactory` is still registered) at the end of the Resolve. A `ResolverHook` can therefore safely allocate resources in the `begin(Collection)` method because it is guaranteed that it can deallocate them in the `end()` method.

The following are potential failures:

- A Resolver Hook Factory used in a resolve operation is unregistered
- A Resolver Hook throws an exception.

If the Resolver fails, it must throw a Bundle Exception to the caller if possible. Otherwise it must publish a Framework Event of type ERROR.

53.4 Security

The Resolver Hook Factory service described in this specification is a highly complex facility that requires great care in their implementation to maintain the Framework invariants. It is therefore important that in a secure system the permission to register these hooks is only given to privileged bundles.

In this case, the user of the Resolver Hook Factory service is the framework. Therefore, there is never a need to provide this service. Implementers of these hooks must have:

- `ServicePermission[..ResolverHookFactory,REGISTER]` for Event Listener Hook services.

53.5 org.osgi.framework.hooks.resolver

Framework Resolver Hooks Package Version 1.0.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.framework.hooks.resolver; version="[1.0,2.0]"
```

53.5.1 Summary

- `ResolverHook` - OSGi Framework Resolver Hook instances are obtained from the OSGi Framework Resolver Hook Factory service.
- `ResolverHookFactory` - OSGi Framework Resolver Hook Factory Service.

53.5.2 public interface ResolverHook

OSGi Framework Resolver Hook instances are obtained from the OSGi Framework Resolver Hook Factory service.

A Resolver Hook instance is called by the framework during a resolve process. A resolver hook may influence the outcome of a resolve process by removing entries from shrinkable collections that are passed to the hook during a resolve process. A shrinkable collection is a `Collection` that supports all remove operations. Any other attempts to modify a shrinkable collection will result in an `UnsupportedOperationException` being thrown.

The following steps outline the way a framework uses the resolver hooks during a resolve process.

1. Collect a snapshot of registered resolver hook factories that will be called during the current resolve process. Any hook factories registered after the snapshot is taken must not be called during the current resolve process. A resolver hook factory contained in the snapshot may become unregistered during the resolve process. The framework should handle this and stop calling the resolver hook instance provided by the unregistered hook factory and the current resolve process must fail. If possible, an exception must be thrown to the caller of the API which triggered the resolve process. In cases where the caller is not available a framework event of type error should be fired.
2. For each registered hook factory call the `ResolverHookFactory.begin(Collection)` method to inform the hooks about a resolve process beginning and to obtain a Resolver Hook instance that will be used for the duration of the resolve process.
3. Determine the collection of unresolved bundle revisions that may be considered for resolution during the current resolution process and place each of the bundle revisions in a shrinkable collection `Resolvable`. For each resolver hook call the `filterResolvable(Collection)` method with the shrinkable collection `Resolvable`.
4. The shrinkable collection `Resolvable` now contains all the unresolved bundle revisions that may end up as resolved at the end of the current resolve process. Any other bundle revisions that got removed from the shrinkable collection `Resolvable` must not end up as resolved at the end of the current resolve process.
5. For each bundle revision `B` left in the shrinkable collection `Resolvable` and any bundle revision `B` which is currently resolved that represents a singleton bundle do the following:
 - Determine the collection of available capabilities that have a namespace of `osgi.identity`, are singletons, and have the same symbolic name as the singleton bundle revision `B` and place each of the matching capabilities into a shrinkable collection `Collisions`.
 - Remove the `osgi.identity` capability provided by bundle revision `B` from shrinkable collection `Collisions`. A singleton bundle cannot collide with itself.
 - For each resolver hook call the `filterSingletonCollisions(BundleCapability, Collection)` with the `osgi.identity` capability provided by bundle revision `B` and the shrinkable collection `Collisions`
 - The shrinkable collection `Collisions` now contains all singleton `osgi.identity` capabilities that can influence the ability of bundle revision `B` to resolve.
 - If the bundle revision `B` is already resolved then any resolvable bundle revision contained in the collection `Collisions` is not allowed to resolve.
6. During a resolve process a framework is free to attempt to resolve any or all bundles contained in shrinkable collection `Resolvable`. For each bundle revision `B` left in the shrinkable collection `Resolvable` which the framework attempts to resolve the following steps must be followed:
 - For each requirement `R` specified by bundle revision `B` determine the collection of capabilities that satisfy (or match) the requirement and place each matching capability into a shrinkable collection `Candidates`. A capability is considered to match a particular requirement if its attributes satisfy a specified requirement and the requirer bundle has permission to access the capability.
 - For each resolver hook call the `filterMatches(BundleRequirement, Collection)` with the requirement `R` and the shrinkable collection `Candidates`.
 - The shrinkable collection `Candidates` now contains all the capabilities that may be used to satisfy the requirement `R`. Any other capabilities that got removed from the shrinkable collection `Candidates` must not be used to satisfy requirement `R`.
7. For each resolver hook call the `end()` method to inform the hooks about a resolve process ending.

In all cases, the order in which the resolver hooks are called is the reverse `compareTo` ordering of their Service References. That is, the service with the highest ranking number must be called first. In

cases where a shrinkable collection becomes empty the framework is required to call the remaining registered hooks.

Resolver hooks are low level. Implementations of the resolver hook must be careful not to create an unresolvable state which is very hard for a developer or a provisioner to diagnose. Resolver hooks also must not be allowed to start another synchronous resolve process (e.g. by calling `Bundle.start()` or `FrameworkWiring.resolveBundles(Collection)`). The framework must detect this and throw an `IllegalStateException`.

See Also `ResolverHookFactory`

Concurrency Not Thread-safe

53.5.2.1 **public void end()**

- This method is called once at the end of the resolve process. After the end method is called the resolve process has ended. The framework must not hold onto this resolver hook instance after end has been called.

53.5.2.2 **public void filterMatches(BundleRequirement requirement, Collection<BundleCapability> candidates)**

requirement the requirement to filter candidates for

candidates a collection of candidates that match the requirement

- Filter matches hook method. This method is called during the resolve process for the specified requirement. The collection of candidates match the specified requirement. This method can filter the collection of matching candidates by removing candidates from the collection. Removing a candidate will prevent the resolve process from choosing the removed candidate to satisfy the requirement.

All of the candidates will have the same namespace and will match the specified requirement.

If the Java Runtime Environment supports permissions then the collection of candidates will only contain candidates for which the requirer has permission to access.

53.5.2.3 **public void filterResolvable(Collection<BundleRevision> candidates)**

candidates the collection of resolvable candidates available during a resolve process.

- Filter resolvable candidates hook method. This method may be called multiple times during a single resolve process. This method can filter the collection of candidates by removing potential candidates. Removing a candidate will prevent the candidate from resolving during the current resolve process.

53.5.2.4 **public void filterSingletonCollisions(BundleCapability singleton, Collection<BundleCapability> collisionCandidates)**

singleton the singleton involved in a resolve process

collisionCandidates a collection of singleton collision candidates

- Filter singleton collisions hook method. This method is called during the resolve process for the specified singleton. The specified singleton represents a singleton capability and the specified collection represent a collection of singleton capabilities which are considered collision candidates. The singleton capability and the collection of collision candidates must all use the same namespace.

Currently only capabilities with the namespace of `osgi.wiring.bundle` and `osgi.identity` can be singletons. The collision candidates will all have the same namespace, be singletons, and have the same symbolic name as the specified singleton capability.

In the future, capabilities in other namespaces may support the singleton concept. Hook implementations should be prepared to receive calls to this method for capabilities in namespaces other than `osgi.wiring.bundle` or `osgi.identity`.

This method can filter the list of collision candidates by removing potential collisions. Removing a collision candidate will allow the specified singleton to resolve regardless of the resolution state of the removed collision candidate.

53-5-3 **public interface ResolverHookFactory**

OSGi Framework Resolver Hook Factory Service.

Bundles registering this service will be called by the framework during a bundle resolver process to obtain a resolver hook instance which will be used for the duration of a resolve process.

See Also ResolverHook

Concurrency Thread-safe

53-5-3.1 **public ResolverHook begin(Collection<BundleRevision> triggers)**

triggers an unmodifiable collection of bundles which triggered the resolve process. This collection may be empty if the collection of trigger bundles cannot be determined.

- This method is called by the framework each time a resolve process begins to obtain a resolver hook instance. This resolver hook instance will be used for the duration of the resolve process. At the end of the resolve process the method `ResolverHook.end()` must be called by the framework and the framework must not hold any references of the resolver hook instance.

The triggers represent the collection of bundles which triggered the resolve process. This collection may be empty if the triggers cannot be determined by the framework. In most cases the triggers can easily be determined. Calling certain methods on bundle when a bundle is in the INSTALLED state will cause the framework to begin a resolve process in order to resolve the bundle. The following methods will start a resolve process in this case:

- `start`
- `loadClass`
- `findEntries`
- `getResource`
- `getResources`

In such cases the collection will contain the single bundle which the framework is trying to resolve. Other cases will cause multiple bundles to be included in the trigger bundles collection. When `resolveBundles` is called the collection of triggers must include all the current bundle revisions for bundles passed to `resolveBundles` which are in the INSTALLED state.

When `FrameworkWiring.refreshBundles(Collection, org.osgi.framework.FrameworkListener...)` is called the collection of triggers is determined with the following steps:

- If the collection of bundles passed is null then `FrameworkWiring.getRemovalPendingBundles()` is called to get the initial collection of bundles.
- The equivalent of calling `FrameworkWiring.getDependencyClosure(Collection)` is called with the initial collection of bundles to get the dependency closure collection of the bundles being refreshed.
- Remove any non-active bundles from the dependency closure collection.
- For each bundle remaining in the dependency closure collection get the current bundle revision and add it to the collection of triggers.

As described above, a resolve process is typically initiated as a result of calling API that causes the framework to attempt to resolve one or more bundles. The framework is free to start a resolve process at any time for reasons other than calls to framework API. For example, a resolve process may be used by the framework for diagnostic purposes and result in no bundles actually becoming resolved at the end of the process. Resolver hook implementations must be prepared for resolve processes that are initiated for other reasons besides calls to framework API.

Returns a resolver hook instance to be used for the duration of the resolve process. A null value may be returned which indicates this resolver hook factory abstains from the resolve process.

54 Bundle Hook Service Specification

Version 1.1

54.1 Introduction

The basic framework provides complete visibility for any bundle to any other bundle. In certain use cases it can be important to provide the impression to application bundles that they are part of a limited group of bundles. Bundle Hook services allow Handlers to hide bundles from other bundles by filtering the Bundle Events and return values of methods that return bundles.

Though Bundle Hooks can effectively control bundle visibility of other bundles by filtering some of the key Bundle Context methods as well as event delivery, it does not provide proper isolation. Bundles that use other API will be able to see bundles even if they are hidden by the Bundle Hooks.

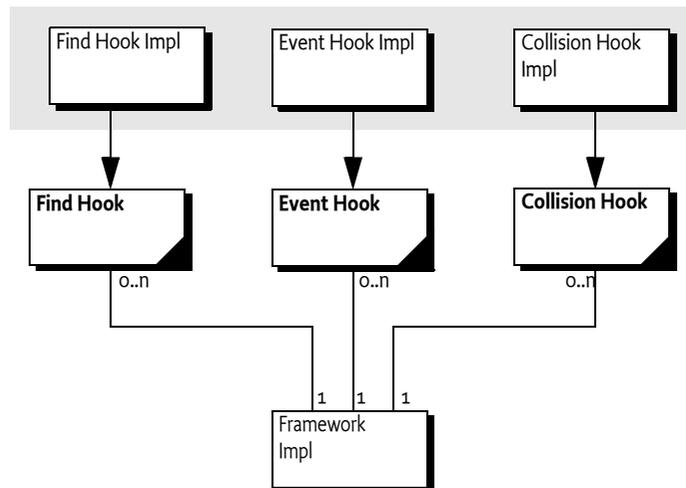
54.1.1 Essentials

- *Filtering* - Remove bundles from the view of specific bundles.

54.1.2 Entities

- *Find Hook* - A service used by the framework to filter methods that return bundles.
- *Event Hook* - A service used by the framework to filter Bundle Events before they are delivered to their listeners.
- *Collision Hook* - A service used by the framework to filter colliding bundles during an install or update operation when the `org.osgi.framework.bsntversion` is set to managed.
- *Collision* - Two bundles collide when they have the same version and bundle symbolic name.
- *Client* - The bundle that finds bundles or receives events about bundles.
- *Handler* - The bundle that registers a hook service.
- *Target* - The bundle performing the install or update operation.

Figure 54.1 Bundle Hooks, `org.osgi.framework.hooks.bundle` package



54.1.3 Synopsis

A Handler registers Bundle Hook services to filter the view on the bundles stored in the framework. Whenever the framework has to deliver Bundle events to one or more bundles the Event Hook services are asked to look at the target bundles and remove any targets from the collection. Removed bundles are then not notified.

If a bundle calls a method that returns a bundle like the Bundle Context `getBundles` method or the `getBundle` method, the Find Hook is called. The Find Hook can then look at the bundles that will be returned to the caller and filter that list accordingly.

If the Framework installs or updates a bundle it is possible that the new bundle symbolic name/version pair collides with an existing bundle. The `org.osgi.framework.bsnversion` property controls the property in this case. The Collision Hook is used to control this policy when the property is set to managed.

There can be multiple Bundle Hook services registered by different Handlers, multiple Bundle Hook services are called in service ranking order.

54.2 About the Hooks

The Bundle hooks provide a basic mechanism to hide bundles from each other as well as control *bundle collisions*. The Bundle *Event Hook* allows a *Handler* to hide Bundle Events from bundles, the Bundle *Find Hook* allows a Handler to alter the result of framework methods that return bundles. The Collision Hook is used for providing a policy when bundles collide. A collision takes place when there is an attempt to install or update a bundle and the situation arises that there are two bundles with the same bundle symbolic name and version.

A Find Hook or an Event Hook can influence the outcome of a number of operations that retrieve a bundle or show a bundle related event by removing entries from *shrinkable* collections. A shrinkable collection is a collection that can only remove entries, not add to it. Any attempt to add to the collection must result in throwing an `UnsupportedOperationException`. All collections in the Find Hook and Event Hook API are shrinkable collections.

The framework must call the hooks in a privileged block, see *Privileged Callbacks* on page 131. Hooks are always called in service ranking order, *Service Ranking Order* on page 139.

54.3 Bundle Event Hook

Handlers must ensure that Client bundles continue to see a consistent set of Bundle Events that strictly follow the transitions defined by the OSGi specifications because Bundle events can be used in a state machine that depends on these transitions. Such state machines can get confused if some Bundle Events are missed.

For example, if a Bundle Tracker sees a `STARTED` event but the corresponding `STOPPED` event is removed for that Client then the tracker will still assume the associated bundle is active.

A simple solution is to stop the Client bundle when the Handler decides to start filtering the Bundle Events. The Client bundle should then be started after the filter is in place. This model ensures that the Handler can assume the Client has no knowledge of any hidden bundles.

However, when the bundle that implements the bundle event hook is stopped, it will of course no longer be able to filter events and the target bundle might see bundle events for bundles it was not aware of.

As a best practice a Handler should not hide a Bundle from itself. That is, its own events should always be received and if it gets the bundles from the framework its own Bundle object should be included.

A Handler must register a bundle Event Hook service to intercept and filter events before they are delivered to bundles. The framework must call the `event(BundleEvent,Collection)` method on all registered hooks in service ranking order to filter the events before they are delivered to any of the registered bundle listeners. The Handler can remove any BundleContext objects from the given shrinkable collection it wants shield from the event's Bundle.

The event method must be called once for each Bundle Event, this includes Bundle Events that are generated when there are no Bundle Listeners registered.

The `event(BundleEvent,Collection)` method must be called on the same thread that is performing the action which generated the specified event. The shrinkable collection includes BundleContext objects with all Bundle Listeners registered with them.

A Bundle Event Hook must receive all Bundle Events:

- INSTALLED
- RESOLVED
- STARTING
- STARTED
- STOPPING
- STOPPED
- UNRESOLVED
- UPDATED
- UNINSTALLED
- Other if new events are defined in later versions

54.3.1 System Bundle Listeners

Bundle Listeners may be registered with the system bundle's BundleContext. If at least one Bundle Listener is registered with the system bundle's BundleContext then the system bundle's BundleContext must be contained in the shrinkable collection passed to the `event(BundleEvent,Collection)` bundle event hook method. Just like other BundleContext objects contained in the shrinkable collection, the system bundle's BundleContext may be removed. If the system bundle's BundleContext is removed by a bundle Event Hook then the BundleContext will not be contained in the collection for the remaining bundle Event Hooks called. Unlike other BundleContext objects, if the system bundle's BundleContext is removed from the shrinkable collection then the bundle event is still delivered to the Bundle Listeners added to the system bundle's BundleContext.

54.4 Bundle Find Hook

The purpose of the Bundle Find Hook, is to limit the visibility of bundles to selected Client bundles. The Find Hook service is called with the `find(BundleContext,Collection)` method on all Handler Hook services in service ranking order when a Client bundle tries to get bundles from the framework. A registered Find Hook service gets a chance to inspect the candidate set of bundles and can remove any bundle that must be hidden from the receiver.

The Bundle Find Hook can filter the result of the following methods:

- `getBundle(long)`
- `getBundles()`

The Find Hook is not called for:

- `getBundle(String)` - If the caller knows the name then it is not necessary to hide the bundle.

The Bundle Find Hook is also used during an install operation when the to be installed bundle is already installed at a given location. Normally, the install returns the Bundle object of the existing bundle but this can cause confusion for the installer when this bundle is hidden by the Find Hook. Therefore, the `REJECTED_BY_HOOK` Bundle Exception is thrown when the `find(BundleContext,Collection)` method determines that the Bundle Context has no visibility of the conflicting bundle.

54.4.1 System Bundle Context

When the `getBundle(long)` or `getBundles()` methods are called using the system bundle's BundleContext then the bundle Find Hooks are called in the same way the hooks are called when a normal BundleContext is used. The system bundle's BundleContext along with the shrinkable candidate bundles collection is passed to the `find(BundleContext,Collection)` method. Bundle Find Hooks may remove bundles from the shrinkable collection. If a bundle is removed by a bundle Find Hook then the bundle will not be contained in the collection for the remaining bundle Find Hooks called. Unlike other BundleContext objects, if the system bundle's BundleContext is used to find bundles then the Framework ignores the bundle removals performed by the bundle Find Hooks and allows the bundles removed to remain visible in the find results.

The bundle Find Hook is also used during an install operation. When the system bundle's BundleContext is used to install a bundle then the bundle Find Hooks are called in the same way the hooks are called when a normal BundleContext is used. Unlike other BundleContext objects, if the system bundle's BundleContext is used to install bundles then the Framework ignores the bundle removals performed by the bundle Find Hooks. This implies that if the system bundle's BundleContext is used to install a bundle at a location where an existing bundle is installed then the existing bundle is always returned.

54.5 Bundle Collision Hook

Two bundles *collide* when they have the same bundle symbolic name and version, although there location must always be different. The `org.osgi.framework.bsnversion` launching property (see *Launching Properties* on page 102) defines the policy when a collision is about to take place during install or update operations. The launching property can have the following values:

- `single` - Collisions are not allowed, attempting to install/update a bundle that will cause a collision is rejected and all bundles can assume there are no collisions between installed bundles.
- `multiple` - Collisions are allowed and bundles must assume that there are collisions in the set of installed bundles.
- `managed` - Collisions are *managed* via a Collision Hook service, specified in the remainder of this section.

There are two *types* of operation that can *create* a new *bundle revision*: Install and Update. During this creation the framework has to consider its `bsnversion` policy as defined by the launching property. For each creation, there are a number of *candidates* to collide with. In `single` mode, any candidate that exists will fail the creation. In `multiple` mode, any number of candidates are allowed. In `managed` mode, no candidates are allowed, like the `single` mode, but the Collision Hook services can prune the list of candidates before the framework makes the decision. If the Collision Hook services have emptied the list of candidates then the installation will succeed, if any bundle remains in this list then the operation fails. In `managed` mode, creations are treated as in `single` mode but bundles must assume as if the system operates in `multiple` mode.

The purpose of the Collision Hook is to delegate the decision of bundle collisions to a management agent. For example, using this and other hooks a management agent can create regions of bundles that have limited visibility of each other. Since these bundles do not have visibility of all other bun-

dles a global collision does not necessarily translate into a collision inside a region. Using the Collision Hook the management agent can allow these collisions globally but restrict their impact locally.

In managed mode the framework must call all registered Collision Hook services for each bundle install and update operation. The calling order of the hooks is defined by ranking order, see *Service Ranking Order* on page 139. The Collision Hook service is only called in managed mode and there exists one or more candidates during the creation phase of an install/update operation.

The `CollisionHook` interface has a single method:

- `filterCollisions(int, Bundle, Collection)` - An install or update operation is in progress that will result in a possible bundle collision. The implementer of this method can optionally shrink the given collection of any collision candidates if it can decide that a collision cannot harm.

The `filterCollisions(int, Bundle, Collection)` method takes a type of operation value that must be one of the following two values that indicate the operation that caused the Collision Hook to be called:

- `INSTALLING`
- `UPDATING`

54.5.1 System Bundle Context

When the system bundle's `BundleContext` is used to install a bundle then the Collision Hooks are called in the same way the hooks are called when a normal `BundleContext` is used. The system bundle along with the shrinkable candidate bundles collection is passed to the `filterCollisions(int, Bundle, Collection)` method. Bundle Collision Hooks may remove bundles from the shrinkable collection. If a bundle is removed by a bundle Collision Hook then the bundle will not be contained in the collection for the remaining bundle Collision Hooks called. Unlike the other bundle and service hooks, if the system bundle's `BundleContext` is used to install a bundle then the Framework must not ignore the bundle removals performed by the bundle Collision Hooks. This implies that the system bundle's `BundleContext` can be used to install the same bundle multiple times when the `org.osgi.framework.bsnversion` launching property is set to managed.

54.6 Security

All hooks described in this specification are highly complex facilities that require great care in their implementation to maintain the Framework invariants. It is therefore important that in a secure system the permission to register these hooks is only given to privileged bundles.

In this case, the user of the hook services is the framework. Therefore, there is never a need to provide:

- `ServicePermission[..EventHook,GET]`, or
- `ServicePermission[..FindHook,GET]`, or
- `ServicePermission[..CollisionHook,GET]`

Implementers of these hooks must have:

- `ServicePermission[..EventHook,REGISTER]` for Event Hook services.
- `ServicePermission[..FindHook,REGISTER]` for Find Hook services
- `ServicePermission[..CollisionHook,REGISTER]` for Collision Hook services

54.7 org.osgi.framework.hooks.bundle

Framework Bundle Hooks Package Version 1.1.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.framework.hooks.bundle; version="[1.1,2.0)"
```

54.7.1 Summary

- CollisionHook - OSGi Framework Bundle Collision Hook Service.
- EventHook - OSGi Framework Bundle Event Hook Service.
- FindHook - OSGi Framework Bundle Context Hook Service.

54.7.2 public interface CollisionHook

OSGi Framework Bundle Collision Hook Service.

If the framework was launched with the org.osgi.framework.bsnversion framework launching property set to managed, then all registered collision hook services will be called during framework bundle install and update operations to determine if an install or update operation will result in a bundle symbolic name and version collision.

Concurrency Thread-safe

54.7.2.1 public static final int INSTALLING = 1

Specifies a bundle install operation is being performed.

54.7.2.2 public static final int UPDATING = 2

Specifies a bundle update operation is being performed.

54.7.2.3 public void filterCollisions(int operationType, Bundle target, Collection<Bundle> collisionCandidates)

operationType The operation type. Must be the value of installing or updating.

target The target bundle used to determine what collision candidates to filter.

collisionCandidates The collection of collision candidates. The collection supports all the optional Collection operations except add and addAll. Attempting to add to the collection will result in an UnsupportedOperationException. The collection is not synchronized.

- Filter bundle collisions hook method. This method is called during the install or update operation. The operation type will be installing or updating. Depending on the operation type the target bundle and the collision candidate collection are the following:
 - installing - The target is the bundle associated with the BundleContext used to call one of the install methods. The collision candidate collection contains the existing bundles installed which have the same symbolic name and version as the bundle being installed.
 - updating - The target is the bundle used to call one of the update methods. The collision candidate collection contains the existing bundles installed which have the same symbolic name and version as the content the target bundle is being updated to.

This method can filter the collection of collision candidates by removing potential collisions. For the specified operation to succeed, the collection of collision candidates must be empty after all registered collision hook services have been called.

54.7.3 public interface EventHook

OSGi Framework Bundle Event Hook Service.

Bundles registering this service will be called during framework lifecycle (install, start, stop, update, and uninstall bundle) operations.

Concurrency Thread-safe

54-7.3.1 **public void event(BundleEvent event, Collection<BundleContext> contexts)**

event The bundle event to be delivered

contexts A collection of Bundle Contexts for bundles which have listeners to which the specified event will be delivered. The implementation of this method may remove bundle contexts from the collection to prevent the event from being delivered to the associated bundles. The collection supports all the optional Collection operations except add and addAll. Attempting to add to the collection will result in an UnsupportedOperationException. The collection is not synchronized.

- Bundle event hook method. This method is called prior to bundle event delivery when a bundle is installed, resolved, started, stopped, unresolved, or uninstalled. This method can filter the bundles which receive the event.

This method must be called by the framework one and only one time for each bundle event generated, this included bundle events which are generated when there are no bundle listeners registered. This method must be called on the same thread that is performing the action which generated the specified event. The specified collection includes bundle contexts with synchronous and asynchronous bundle listeners registered with them.

54-7.4 **public interface FindHook**

OSGi Framework Bundle Context Hook Service.

Bundles registering this service will be called during framework bundle find (get bundles) operations.

Concurrency Thread-safe

54-7.4.1 **public void find(BundleContext context, Collection<Bundle> bundles)**

context The bundle context of the bundle performing the find operation.

bundles A collection of Bundles to be returned as a result of the find operation. The implementation of this method may remove bundles from the collection to prevent the bundles from being returned to the bundle performing the find operation. The collection supports all the optional Collection operations except add and addAll. Attempting to add to the collection will result in an UnsupportedOperationException. The collection is not synchronized.

- Find hook method. This method is called for the following:
 - Bundle find operations using BundleContext.getBundle(long) and BundleContext.getBundles() methods. The find method can filter the result of the find operation. Note that a find operation using the BundleContext.getBundle(String) method does not cause the find method to be called.
 - Bundle install operations when an existing bundle is already installed at a given location. In this case, the find method is called to determine if the context performing the install operation is able to find the bundle. If the context cannot find the existing bundle then the install operation must fail with a BundleException.REJECTED_BY_HOOK exception.

55 Service Hook Service Specification

Version 1.1

55.1 Introduction

The OSGi framework has built-in support for the normal service primitives: *publish*, *find*, and *bind*. Despite their simplicity, these primitives are surprisingly powerful and have become quite popular. However, these primitives operate on information that is not completely visible to the bundles. For example, it is impossible to find out what services are being waited upon by other bundles. This information can be useful to provide a service just in time to that bundle. Additionally, it is also not possible to allow bundles functionality that interacts with the service engine. For example, a bundle could proxy another service but to do this transparently, it is required to hide the original service and offer the proxy only to a specific bundle. With the current primitives this is also not possible.

Therefore, this service hook specification provides a number of new mechanisms that closely interact with the service engine. These interactions are *not* intended for use by application bundles. The service primitives appear simple but require surprisingly complex code to make them appear simple to the bundle developer. Modifying the behavior of the service engine requires developers to closely follow the semantics of the OSGi service model and this is often hard, requiring a significant amount of code.

However, the service hooks provide a more symmetric model for service based programming that can act as a multiplier for the framework. The basic framework provides a powerful service engine and this specification allows a bundle to interact with this service engine

55.1.1 Essentials

- *Robust* - The service primitives are very simple and work reliably in many scenarios. The specified hooks interact with this robust service engine. This interaction must not cause disruption of the normal operations.
- *Find listeners* - Provide information about the services specific bundles are interested in.
- *Control visibility* - Provide a mechanism to hide the visibility of a service to one or more bundles.
- *Intercept finds* - Provide a mechanism to detect the searches of a bundle in the service registry and restrict the set of found service references.
- *Whiteboard based* - Use the [1] *Whiteboard Pattern* to simplify the writing of the interceptors.

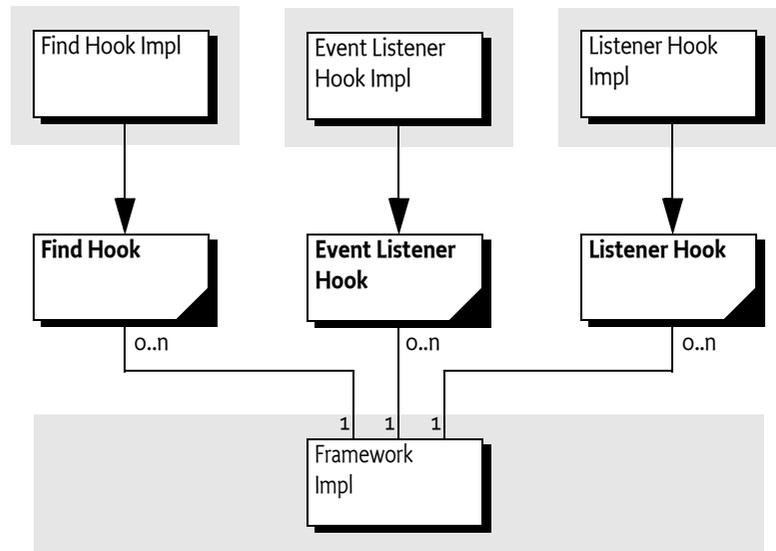
55.1.2 Entities

- *Client* - The bundle that finds services, gets services, and/or receives events about services.
- *Handler* - The bundle that registers a hook service and uses this to view or modify the state.
- *Target* - A client bundle being targeted by a Handler.
- *Publisher* - A client bundle that publishes services.
- *Consumer* - A client bundle that consumes services.
- *Service Engine* - The internal framework machinery that makes the service registry work.
- *Event Listener Hook* - An Event Listener Hook intercepts service events before they are delivered to the client. The hook can select to remove events for specific bundles, which effectively allows the hook to hide service events from a bundle.

- *Find Hook* - A find hook intercepts the `getServiceReference(s)` call just before it returns the result to the client. The result can be influenced by removing service entries. The find hook can be used to hide specific services for specific bundles.
- *Listener Hook* - The listener hook provides insight into what services are being waited for in the system. It gets updated as service listeners are added and removed from the service registry.

Figure 55.1

Service Hooks, `org.osgi.framework.hooks.service` package



55.1.3

Synopsis

A bundle that needs to hide service references from other bundles, or wants to be informed about the service events another bundle sees, can register a *Find* and *Event Listener* hook by registering a *Find Hook* service and an *Event Listener Hook* service with the framework. If a service event is generated, it will pass this event to the hook. The *Event Listener Hook* method can then inspect the arguments and optionally remove bundles from the event delivery list.

When a bundle uses the *Bundle Context* `getServiceReference` or `getServiceReferences` method, the *Find Hook* is notified with the list of discovered services. The hook can then remove any service references it wants to hide for the target bundle.

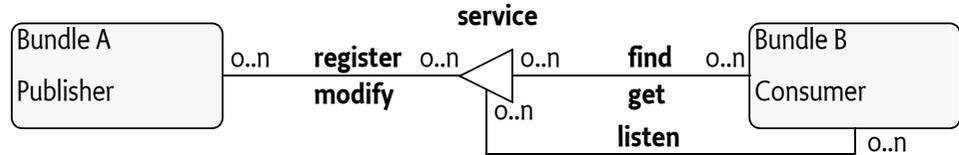
A bundle that wants to be aware of the services bundles are waiting for to be registered can register a *Listener Hook*. The framework will notify such hooks of all existing listeners as well as any changes in this list. The interceptor can use the filter information registered with the listener to detect the services that are being listened for.

55.2 Service Hooks

Service hooks provide an interaction with the service engine. This service engine provides the following primitives to the bundle:

- Register a service under an interface/class name with a set of properties
- Modify the set of properties of a service
- Unregister a service
- Find services based on their interface class name and/or property values
- Listen for the life cycle events of a service

Figure 55.2 Service Primitives



These primitives provide the cornerstone for *service oriented programming*. Service oriented programming consists of a code base that is de-coupled from the outside world through *services*. It can provide services to other bundles and it can consume services from other bundles. In the OSGi variation of service oriented programming, a service is a plain Java object that can be registered and unregistered at runtime.

The dynamics of OSGi services forces bundles to consider the absence, presence, and arrival of services. The cause of these dynamics can be external events, the result of an update, a bundle that is stopped, or the disappearance of a dependent service. A number of support libraries have been developed to minimize the amount of work for the developer that these dynamics can bring. The dynamic nature of services have made them an excellent tool to handle a wide array of dependency scenarios. Services can easily model a real world concept that a bundle depends upon. The features of the service model combined with support libraries like iPOJO, Declarative Services, Spring DM, and others have made the OSGi service model easy to use and very powerful.

A key aspect of the service model is the centrality of the OSGi framework. The service model acts as a guard between bundles. All service primitives pass through the framework and bundles can not intercept the result of other bundles interacting with the service registry. This design was intentional because it creates a boundary between bundles that increases robustness and security. However, the success of the service model also means that it becomes very attractive to interact with the service engine because all inter-bundle communication runs through this engine.

For complexity reasons, this specification does not introduce any ordering dependencies between the handlers and the client bundles.

All Service Hooks must be called in a privileged block, see *Privileged Callbacks* on page 131.

55.3 Usage Scenarios

The service hooks are general mechanisms but they were designed for some specific use cases. The following sections detail some of those use cases.

55.3.1 Proxying

In an OSGi system, all communication is normally tunneled through services. This makes it a very interesting place for a handler to intercept the service communications. These handlers can provide facilities like proxying, extra security, authentication, and other functions completely transparent to the parties that interact through services.

Proxying an existing service for a specific bundle requires the following steps:

- Hide the existing service X
- Register a proxy X' with the same properties as X

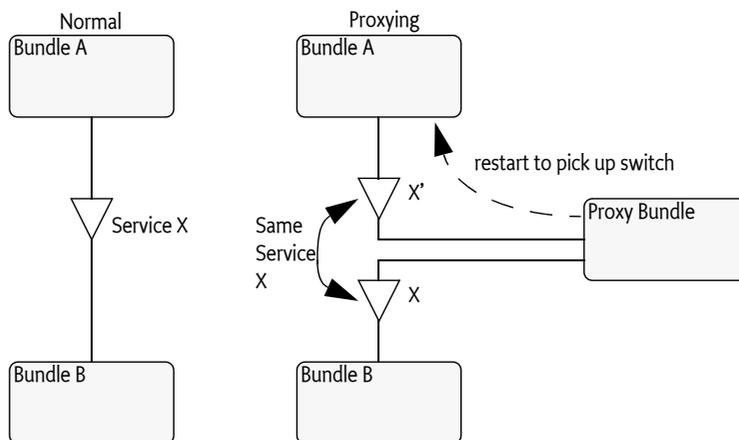
Registering a proxy service X' is trivial with the OSGi API, there are no special requirements on the service. As long as it implements the listed interfaces and provides the same attributes then it can pose as service X.

Hiding service X can be implemented with a combination of the Event Listener Hook and the Find Hook. The Event Listener Hook can be used to hide any service events from the target bundle and

the Find Hook can be used to remove X from the delivered results of the `getServiceReference(s)` methods.

In the following figure the difference between a normal service interaction and a proxied interaction is depicted. In the normal case, Bundle A directly uses Service X, in the proxying case, the Proxy Bundle hides the original and provides an alternative.

Figure 55.3 Normal and proxied service interaction



However, there is one complication with the service hiding: what is the observing state of the target bundle when proxying begins? The Event Listener Hook must be registered to act as a filter on the service events. Just after this registration it can not determine what events have been seen by the target bundle. If it has already checked out X, the hook has no possibility to make the target bundle unget the service. A solution is to transiently stop the target bundle before the hook is registered and then transiently started it again, if the bundle is active. It is usually not advised to start/stop other bundles but this seems to be the only reliable solution. The problem can be alleviated when the start level is used to start the proxying handler bundle before the target bundles, in that case the target bundle is not started when the proxy is created. Though this optimizes the normal case, stopping the target bundle remains necessary because any of the bundles can be updated or stopped at any moment in time.

The following example shows how to hide a specific Service Reference from a specific bundle.

```
public class Hide implements EventListenerHook, FindHook {
    final Bundle bundle;
    final ServiceReference reference;
    final BundleContext context;
    ServiceRegistration reg;

    Hide(BundleContext context,
         ServiceReference reference,
         Bundle bundle) {
        this.context = context;
        this.bundle = bundle;
        this.reference = reference;
    }

    void open() {
        boolean active =
            bundle.getBundleState() == Bundle.ACTIVE;
        if ( active )
```

```

        bundle.stop(Bundle.STOP_TRANSIENTLY);
    reg = context.registerService(
        new String[] {
            FindHook.class.getName(),
            EventListenerHook.class.getName() }, this, null);
    if ( active )
        bundle.start(Bundle.START_TRANSIENTLY);
}

public void close() { reg.unregister();}

```

The Hide class registers a Event Listener Hook and Find Hook service in the open method. Once registered, these services will receive their event callbacks. In the find hook, the target Service Reference is removed from the results if the bundle that called the getServiceReference(s) method is the target bundle.

```

public void find(BundleContext ctx,
    String name, String filter,
    boolean allServices, Collection refs) {
    if (ctx.getBundle() == bundle) {
        refs.remove(reference);
    }
}

```

The event method is the opposite of the find method. In this method, the target bundle is removed from the event destinations if the related Service Reference is the target Service Reference.

```

public void event(ServiceEvent event,
    Collection bundles) {
    if (event.getServiceReference().equals(
        reference))
        bundles.remove(bundle);
}
}

```

Once the Hide class is working, a proxy can be registered. For example:

```

void startProxy(ServiceReference ref, Bundle for,
    Object proxy ) {
    Hide hide = new Hide(ctx, ref, for);
    hide.open();
    ServiceRegistration reg = ctx.registerService(
        (String[]) ref.getProperty("objectClass"),
        proxy,
        makeProperties(ref) // copy the properties
    );
}
...

```

55.3.2 Providing a Service on Demand

The Listener Hook provides information about services that bundles are listening for. This makes it possible to look outside the OSGi framework to see if a listened for service could be provided in another way. For example, this service could come from Jini, SLP, or through some other means.

A Listener Hook receives events every time a bundle adds or removes a Service Listener. The Listener Hook is called with an added and removed method that take a collection of ListenerInfo objects.

These objects provide the identity of the bundle that added a Service Listener and the optional filter string. The Listener Hook can use this filter string to look for specific properties, for example the `objectClass` property to determine the type that is being sought. Extracting the property from this filter string is non-trivial though regular expressions can in general be used to extract the needed information.

The following class uses an unexplained `Track` object to do the low level details. The example only shows how the Listener Hook can interact with these track objects.

```
public class OnDemand implements ListenerHook{
    final BundleContext context;
    final Map        tracked = HashMap();
    ServiceRegistration reg;
```

The constructor saves the Bundle Context. The registration is done in an open method.

```
public OnDemand(BundleContext context) {
    this.context = context; }
public void open() {
    reg = context.registerService(
        ListenerHook.class.getName(), this, null); }
```

The Listener Hook has added and removed methods that take collections. It is easier to handle the concurrency per object.

```
public void added(Collection listeners) {
    for (Iterator i=listeners.iterator(); i.hasNext();) {
        add((ListenerHook.ListenerInfo) i.next());
    } }
public void removed(Collection listeners) {
    for (Iterator i=listeners.iterator(); i.hasNext();) {
        remove((ListenerHook.ListenerInfo) i.next());
    } }
```

In the add hook, a `ListenerInfo` object provides the information about the Service Listener. In this example, a `Track` object is created for each active listener and associated with the given info object. This requires proper synchronization and should handle the rare case that the events are delivered out of order. The `ListenerInfo` object contains an `isRemoved` method that provides this information. If it is true, the corresponding removed event has already been called or will be called very soon. In that case, it is safe to discard the added event. For proper cleanup, the `reg` field is tested to see if it is set, if not, this call is during closing and should be ignored.

```
synchronized void add(ListenerHook.ListenerInfoinfo) {
    if ( reg == null || info.isRemoved() )
        return;

    Track t = new Track(info);
    tracked.put(info, t);
    t.open();
}
```

To remove a `Track` object it is necessary to consult the tracked map. If the track object is in the map, it must be closed. If not, there is an out of order delivery and this event can be ignored, the add method will ignore the corresponding `ListenerInfo` object because the `isRemoved` flag will be set. For proper closing, the `reg` field is tested for null.

```
synchronized void remove(ListenerHook.ListenerInfoinfo) {
```

```

    if ( reg == null )
        return;
    Track t = tracked.remove(info);
    if ( t != null )
        t.close();
}

```

The close method is straightforward. The hook services are unregistered and all the remaining Track objects are closed. The reg field is used to make sure the event methods are ignoring any outstanding calls by setting it to null. After the synchronized block, any incoming event is ignored.

```

public void close() {
    reg.unregister();
    synchronized(this) { reg = null; }
    for ( Track t : tracked.values() ) { t.close(); }
    tracked.clear(); } }

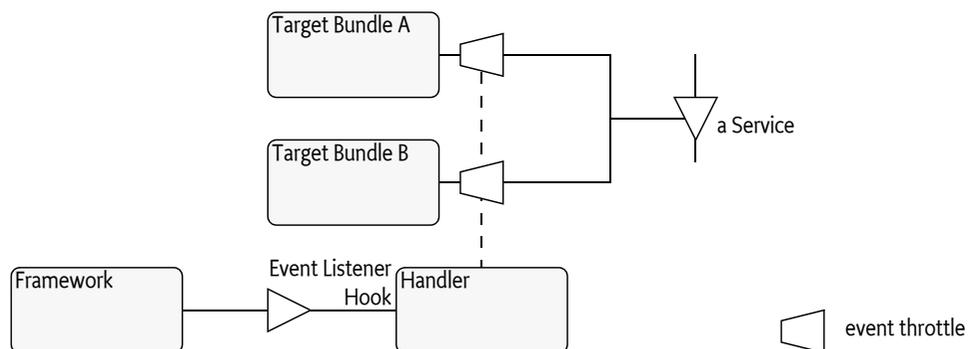
```

55.4 Event Listener Hook

To intercept events being delivered to bundles, a handler must register an [EventListenerHook](#) object as a service with the framework. The framework must then send a service events to all the registered hooks. The calling order of the hooks is defined by the reversed compareTo ordering of their Service Reference objects. That is, the service with the highest ranking number is called first. Event Listener Hooks are called *after* the event is generated but *before* they are filtered by the optional filter expressions of the service listeners. Before the return, the handler can remove bundles from the given list. This allows an Event Listener Hook to hide service events for specific bundles.

The model is depicted in the Figure 55.4. A target bundle listens for service events but these events can be filtered by the handler because it has registered an Event Listener Hook service that is accepted by the Framework.

Figure 55.4 Event Listener Hook Interaction



An Event Listener Hook receives all events, REGISTERED, MODIFIED, UNREGISTERING, and MODIFIED_ENDMATCH, that are to be delivered to all Service Listener objects registered with the framework, regardless of the presence of a service listener filter.

The [EventListenerHook](#) class has a single method:

- [event\(ServiceEvent,Map\)](#) - A service event has been generated. The implementer of this method can optionally shrink the given map of target bundles to service listeners.

One of the parameters of the event method is a map of target bundles to a collection of `ListenerInfo` objects. The handler can shrink this map by removing bundles as well as specific service listeners from the collection of `ListenerHook.ListenerInfo` objects. Both the map and the collection must therefore implement the appropriate remove methods.

Removing a bundle from the list of target bundles will effectively hide the service event from the target bundle. The target bundle can still get the service, though the Find Hook can be used to block this access to the service.

Implementers of the Event Listener Hook must ensure that target bundles continue to see a consistent set of service events. Service events are normally used in a state machine. Such state machines can get confused if some events are missed. For example, if a Service Tracker sees a `REGISTERED` event but is hidden from the corresponding `UNREGISTERING` event then the service will never be released. A simple solution is to stop the target bundle when the filter is put in place. However, when the bundle that implements the Event Listener Hook is stopped, it will of course no longer be able to filter events and the target bundle might see a service events for services it was not aware of.

55.4.1 System Service Listeners

Service Listeners may be registered with the system bundle's `BundleContext`. If at least one Service Listener is registered with the system bundle's `BundleContext` then the system bundle's `BundleContext` must be contained in the keys of the shrinkable map passed to the `event(ServiceEvent,Map)` method. Just like other `BundleContext` keys contained in the shrinkable map, the system bundle's `BundleContext` may be removed. If the system bundle's `BundleContext` is removed by a service Event Listener Hook then the `BundleContext` will not be contained in the map for the remaining service Event Listener Hooks called. Unlike other `BundleContext` objects, if the system bundle's `BundleContext` is removed from the shrinkable map then the service event is still delivered to the Service Listeners added to the system bundle's `BundleContext`.

55.5 Find Hook

The Find Hook is called when a target bundle searches the service registry with the `getServiceReference` or `getServiceReferences` methods. A registered Find Hook service gets a chance to inspect the returned set of service references and can optionally shrink the set of returned services. The order in which the find hooks are called is the reverse `compareTo` ordering of their `ServiceReferences`. That is, the service with the highest ranking number must be called first.

- `find(BundleContext,String,String,boolean,Collection)` - The callback when a bundle calls the `getServiceReference`, `getServiceReferences`, or `getAllServiceReferences` method. As parameters, it gets the bundle context of the calling bundle, the service name, the filter name, the flag that indicates that all services are considered or only the ones that are class compatible with the target bundle. The last parameter is the set of service references that will be returned. This list can be shortened by removing service references from the given list.

The purpose of the Find Hook is to limit the visibility of services to selected target bundles. For this reason, the hook implementation can remove selected service references from the result collection.

55.5.1 System Bundle Context

When one of the `getServiceReference` or `getServiceReferences` methods is called using the system bundle's `BundleContext` then the service Find Hooks are called in the same way the hooks are called when a normal `BundleContext` is used. The system bundle's `BundleContext` along with the shrinkable candidate service references collection is passed to the `find(BundleContext,String,String,boolean,Collection)` method. Service Find Hooks may remove service references from the shrinkable collection. If a service reference is removed by a service Find Hook then the service reference will not be contained in the collection for the remaining service

find hooks called. Unlike other BundleContext objects, if the system bundle's BundleContext is used to find services then the Framework ignores the service reference removals performed by the service Find Hooks and allows the service references removed to remain visible in the find results.

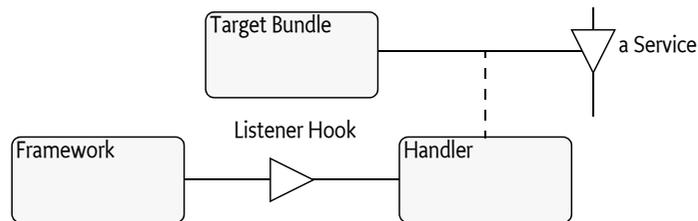
55.6 Listener Hook

The Framework API provides extensive insight in the registration, modification, and unregistration of services. However, it does not provide the information about what services bundles are waiting for. It is a common pattern that a bundle waits for a service to arrive before it is able to perform its function, having the knowledge what bundles are waiting for, allows a number of interesting scenarios.

The Listener Hook is a [1] *Whiteboard Pattern* service that is informed about the coming and going of all service listeners. When a Listener Hook service is registered with the Framework, the Framework will inform this service of all existing listeners and keep it updated of all removed and newly registered service listeners. The events are dispatched in order of the Listener Hook service registration.

In the following figure, it is depicted how the interceptor can find out about target bundles listening for services. It *listens* to registration and unregistration of Service Listeners.

Figure 55.5 Listener Hook Interaction



The ListenerHook interface is composed of the following methods:

- [added\(Collection\)](#) - Inform the hook of the registered listeners. The collection is immutable and contains ListenerInfo objects. These objects identify a unique ServiceListener object registration with the framework. They provide the registering bundle as well as the optional filter. The ListenerInfo class is nested class of the ListenerHook class.
- [removed\(Collection\)](#) - Inform the hook of listeners that have been removed because the bundle is stopped or the bundle implementation has unregistered a listener. The ListenerInfo objects are equal to their corresponding Info Listener object during the addition.

The ListenerHook.ListenerInfo class provides the following methods:

- [getBundleContext\(\)](#) - The Bundle Context of the bundle that registered the service listener.
- [getFilter\(\)](#) - The filter used in the registration.
- [isRemoved\(\)](#) - Provides information if this Listener Info is still valid.

A ListenerInfo object is related to the registration of a ServiceListener with the Framework. The Framework maintains only one registration for a specific, identity based, Service Listener object. That is, registering the same object again, even with a different filter, will automatically unregister the previous registration. This will be visible as a removed - added pair of calls.

The equality and hashCode method of a ListenerInfo object must guarantee that the hook can place the Listener Info objects in hashed collections, such that an ListenerInfo object received in the added method's collection parameter matches its corresponding ListenerInfo object in the removed

method's collection parameter. This is trivially met by the identity equals and hashCode methods if the same objects are used in both methods.

The reason the Listener Hook provides methods that take collection instead of a single ListenerInfo object is because of performance optimization. When a Listener Hook service gets registered, there can already be a large number of Service Listeners available. Similarly, when a bundle gets stopped, it could have registered a number of service listeners that then need to be unregistered. Being able to provide all changes in a batch improves performance.

The framework must report each registration of a Service Listener with the Bundle Context with a new ListenerInfo object that is unequal to any other ListenerInfo object. If the same Service Listener object is registered multiple times, each previous registration must be removed before the listener is added again.

The event method in a Listener Hook is called synchronously with the registration of the Service Listener to minimize the overhead for the framework. However, this does not imply that delivery is always ordered. There are rare cases where a removal is reported before the corresponding addition. Handling this case is simplified by the isRemoved method. If the removed and added methods are synchronized, then the isRemoved method can be used in the added method to detect the out of order delivery. A simple strategy is to ignore removed events without corresponding added events and ignore added events where the ListenerInfo object is already removed.

The following code shows a skeleton of how the Listener Hook methods can be implemented.

```
final HashMap tracked = new HashMap();

public void added( Collection lis ) {
    for ( Iterator li = lis.iterator(); li.hasNext(); ) {
        ListenerHook.ListenerInfo li =
            (ListenerHook.ListenerInfo) li.next();
        synchronized(tracked) {
            if ( li.isRemoved() )
                return;
            ... create some object t
            tracked.put( li, t );
        }
    }
}

public void removed( Collection lis ) {
    for ( Iterator li = lis.iterator(); li.hasNext(); ) {
        ListenerHook.ListenerInfo li =
            (ListenerHook.ListenerInfo) li.next();
        synchronized(tracked) {
            Object t = tracked.remove( li );
            if ( t != null )
                ... dispose object t
        }
    }
}
```

55.6.1 Filter

A key concept in the Listener Hook is the filter. When a bundle is interested in a specific set of services, it registers a service listener with a filter. This filter is an indication of what services are interesting to the target bundle. The objectclass property holds the names of the interfaces and classes. However, just searching for this property with a regular expression is not guaranteed to return a usable value. The form of the sub-expressions can make the property part of an and or even negate. For

example, looking for the objectclass in the following expression gives a result that is the opposite of what is searched.

```
(!(objectclass=org.osgi.service.cm.ConfigurationAdmin))
```

However, understanding a full filter expression is quite difficult. An acceptable strategy is to look for the object classes in the filter string with a regular expression but evaluate the filter against any conclusions that are being drawn. That is, testing a Configuration Admin service against the filter in the previous example will not match.

Realistically, many scenarios that are enabled by the Listener Hook will require the filters to have a simple structure.

55.7 Architectural Notes

55.7.1 Remove Only

The Event Listener Hook and Find Hook both allow the interceptor to remove elements from a collection and not add elements. The reason is that adding almost inevitably violates framework invariants that can trip the receivers. These invariants are very important to keep the programming model for the bundle developers simple.

55.7.2 Ordinary Services

All service hooks are treated as ordinary services. If the framework uses them, their Service References will show that the system bundle is using them, and if a hook is a Service Factory, then the actual instance will be properly created.

The only special treatment of the service hooks is that the framework must not use them for the hooks themselves. That is, the Event and Find Hooks can not be used to hide the services from the framework.

55.7.3 Ordering

The hooks are very sensitive to ordering because they modify the basic behavior of the OSGi Framework. Before a hook is registered, a client bundle interacts with the framework directly. However, ordering in an OSGi Framework can never be relied upon from a programmer's perspective. It is bad practice to rely on start level ordering in a program because updates and other disturbances will inevitably break this ordering. Start level ordering is a tool for deployers to smoothen initialization problems, not to handle ordering dependencies.

Implementers of the hooks must therefore be intricately aware that they can be started before or after their target bundles are started.

55.7.4 Providing the Service Object

Many scenarios for the hooks specified here could be simplified by being able to intercept the getService call of the target bundle. This design was investigated and rejected because it created a dependency graph (registering bundle, proxying bundle, and target bundle) that could not be properly managed in a dynamic OSGi system. For example, if a proxying bundle provides an alternative implementation for a service, how does the receiving bundle know that it should stop using this service? It has no knowledge that the proxying bundle even exists. Instead of creating a much more complex service registry, it was decided to keep the model simple and reuse the existing primitives. This puts the complexity at implementing the hooks, but leaves the overall service model simple.

55-7-5 Multi Threading

All hooks in this specification must be thread safe because the hooks can be called any time. All hook methods must be re-entrant, the framework can enter them at any time, and in rare cases in the wrong order. Most methods will be called synchronously with framework activities. It is fully allowed to call the framework from any of the hook methods. However, even more than usual, it is highly recommended to not hold any locks while calling the framework.

55.8 Security

All hooks described in this specification are highly complex facilities that require great care in their implementation to maintain the Framework invariants concerning the service registry. It is therefore important that in a secure system the permission to register these hooks is only given to privileged bundles.

In this case, the user of the hook services is the framework. Therefore, there is never a need to provide:

- ServicePermission[..EventListenerHook,GET],
- ServicePermission[..FindHook,GET], or
- ServicePermission[..ListenerHook,GET]

Implementers of these hooks must have:

- ServicePermission[..EventListenerHook,REGISTER] for Event Listener Hook services.
- ServicePermission[..FindHook,REGISTER] for Find Hook services
- ServicePermission[..ListenerHook,REGISTER] for Listener Hook services

55.9 org.osgi.framework.hooks.service

Framework Service Hooks Package Version 1.1.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.framework.hooks.service; version="[1.1,2.0)"
```

55.9.1 Summary

- EventHook - OSGi Framework Service Event Hook Service.
- EventListenerHook - OSGi Framework Service Event Listener Hook Service.
- FindHook - OSGi Framework Service Find Hook Service.
- ListenerHook - OSGi Framework Service Listener Hook Service.
- ListenerHook.ListenerInfo - Information about a Service Listener.

55.9.2 public interface EventHook

OSGi Framework Service Event Hook Service.

Bundles registering this service will be called during framework service (register, modify, and unregister service) operations.

Deprecated As of 1.1. Replaced by EventListenerHook.

Concurrency Thread-safe

55.9.2.1 **public void event(ServiceEvent event, Collection<BundleContext> contexts)**

event The service event to be delivered.

contexts A collection of Bundle Contexts for bundles which have listeners to which the specified event will be delivered. The implementation of this method may remove bundle contexts from the collection to prevent the event from being delivered to the associated bundles. The collection supports all the optional Collection operations except add and addAll. Attempting to add to the collection will result in an UnsupportedOperationException. The collection is not synchronized.

- Event hook method. This method is called prior to service event delivery when a publishing bundle registers, modifies or unregisters a service. This method can filter the bundles which receive the event.

55.9.3 **public interface EventListenerHook**

OSGi Framework Service Event Listener Hook Service.

Bundles registering this service will be called during framework service (register, modify, and unregister service) operations.

Since 1.1

Concurrency Thread-safe

55.9.3.1 **public void event(ServiceEvent event, Map<BundleContext, Collection<ListenerHook.ListenerInfo>> listeners)**

event The service event to be delivered.

listeners A map of Bundle Contexts to a collection of Listener Infos for the bundle's listeners to which the specified event will be delivered. The implementation of this method may remove bundle contexts from the map and listener infos from the collection values to prevent the event from being delivered to the associated listeners. The map supports all the optional Map operations except put and putAll. Attempting to add to the map will result in an UnsupportedOperationException. The collection values in the map supports all the optional Collection operations except add and addAll. Attempting to add to a collection will result in an UnsupportedOperationException. The map and the collections are not synchronized.

- Event listener hook method. This method is called prior to service event delivery when a publishing bundle registers, modifies or unregisters a service. This method can filter the listeners which receive the event.

55.9.4 **public interface FindHook**

OSGi Framework Service Find Hook Service.

Bundles registering this service will be called during framework service find (get service references) operations.

Concurrency Thread-safe

55.9.4.1 **public void find(BundleContext context, String name, String filter, boolean allServices, Collection<ServiceReference<?>> references)**

context The bundle context of the bundle performing the find operation.

name The class name of the services to find or null to find all services.

filter The filter criteria of the services to find or null for no filter criteria.

allServices true if the find operation is the result of a call to BundleContext.getAllServiceReferences(String, String)

references A collection of Service References to be returned as a result of the find operation. The implementation of this method may remove service references from the collection to prevent the references from being returned to the bundle performing the find operation. The collection supports all the optional Collection operations except add and addAll. Attempting to add to the collection will result in an UnsupportedOperationException. The collection is not synchronized.

- Find hook method. This method is called during the service find operation (for example, BundleContext.getServiceReferences(String, String)). This method can filter the result of the find operation.

55.9.5 public interface ListenerHook

OSGi Framework Service Listener Hook Service.

Bundles registering this service will be called during service listener addition and removal.

Concurrency Thread-safe

55.9.5.1 public void added(Collection<ListenerHook.ListenerInfo> listeners)

listeners A collection of ListenerInfos for newly added service listeners which are now listening to service events. Attempting to add to or remove from the collection will result in an UnsupportedOperationException. The collection is not synchronized.

- Added listeners hook method. This method is called to provide the hook implementation with information on newly added service listeners. This method will be called as service listeners are added while this hook is registered. Also, immediately after registration of this hook, this method will be called to provide the current collection of service listeners which had been added prior to the hook being registered.

55.9.5.2 public void removed(Collection<ListenerHook.ListenerInfo> listeners)

listeners A collection of ListenerInfos for newly removed service listeners which are no longer listening to service events. Attempting to add to or remove from the collection will result in an UnsupportedOperationException. The collection is not synchronized.

- Removed listeners hook method. This method is called to provide the hook implementation with information on newly removed service listeners. This method will be called as service listeners are removed while this hook is registered.

55.9.6 public static interface ListenerHook.ListenerInfo

Information about a Service Listener. This interface describes the bundle which added the Service Listener and the filter with which it was added.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

55.9.6.1 public boolean equals(Object obj)

obj The object to compare against this ListenerInfo.

- Compares this ListenerInfo to another ListenerInfo. Two ListenerInfos are equals if they refer to the same listener for a given addition and removal life cycle. If the same listener is added again, it must have a different ListenerInfo which is not equal to this ListenerInfo.

Returns true if the other object is a ListenerInfo object and both objects refer to the same listener for a given addition and removal life cycle.

55.9.6.2 public BundleContext getBundleContext()

- Return the context of the bundle which added the listener.

Returns The context of the bundle which added the listener.

55.9.6.3 **public String getFilter()**

- Return the filter string with which the listener was added.

Returns The filter string with which the listener was added. This may be null if the listener was added without a filter.

55.9.6.4 **public int hashCode()**

- Returns the hash code for this ListenerInfo.

Returns The hash code of this ListenerInfo.

55.9.6.5 **public boolean isRemoved()**

- Return the state of the listener for this addition and removal life cycle. Initially this method will return false indicating the listener has been added but has not been removed. After the listener has been removed, this method must always return true.

There is an extremely rare case in which removed notification to ListenerHooks can be made before added notification if two threads are racing to add and remove the same service listener. Because ListenerHooks are called synchronously during service listener addition and removal, the Framework cannot guarantee in-order delivery of added and removed notification for a given service listener. This method can be used to detect this rare occurrence.

Returns false if the listener has not been removed, true otherwise.

55.10 References

- [1] *Whiteboard Pattern*
<https://www.osgi.org/wp-content/uploads/whiteboard1.pdf>

56 Weaving Hook Service Specification

Version 1.1

56.1 Introduction

Bytecode weaving is a popular technique that transforms class files to provide additional functionality. This is a powerful technique that, when used with care, can significantly reduce the coding effort for mundane programming chores.

This specification provides a means for a handler bundle to intercept any bundle class loading calls in the framework, transform the byte codes, and add new dynamic imports. A means for observing the final weaving results, both before and after they take effect, is also provided.

56.1.1 Essentials

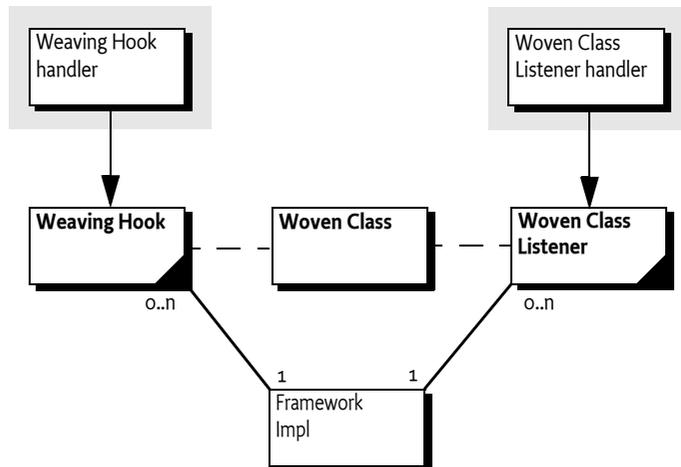
- *Ordering* - Allow a weaver to weave a bundle before it is loaded and used.
- *Dynamic Imports* - Support additional imports.
- *Strategy* - Support both Static and Dynamic Weaving strategies.
- *No Metadata* - Allow standard bundles, without any specific metadata, to be woven.
- *Java API* - Use the existing Java byte code transformation APIs where possible.
- *Multiple* - Allow for multiple weavers per bundle in a defined order.
- *Observation* - Allow woven class state transitions to be observed.

56.1.2 Entities

- *Weaving Hook* - A service registered by a bundle that wants to weave other bundles.
- *Woven Class* - An object representing the class to be woven.
- *Woven Class Listener* - A service registered by a bundle that wants to observe woven class state transitions.

Figure 56.1

Byte Code Weaving



56.2 Usage

56.2.1 Tracing

For tracing purposes, a bundle can weave a trace entry and exit message around each method. This can be done with byte code weaving by inserting a call to a service at the beginning and end of a method. In this example, a service is created that has two methods:

- `trace(Bundle)` - Byte code weave the given bundle with trace entry and exit methods.
- `untrace(Bundle)` - Remove any weavings.

The strategy chosen here is simple. The weaver registers a Weaving Hook service so it receives all class loads. Any such class load is checked against a set of bundles that needs tracing, any class from a traced bundle is then woven with the trace information. If a bundle is to be traced, the set is updated and the bundle is refreshed to ensure all classes are loaded anew so the tracing code can be woven in.

```

public class TracingWeaver implements WeavingHook {
    final Set<Bundle> bundles = new HashSet<Bundle>();
    final List<String> imports = Arrays.asList(
        "com.acme.trace;version=\"[1,2)\"");
    BundleContext context;
}
  
```

The `weave` method is the service method of the Weaving Hook service. It receives a `WovenClass` object that provides the information about the class to be woven. In this case, the `bundles` field contains the bundles to be woven, so this is checked first. If the to-be-loaded class is in one of the traced bundles, the byte codes are changed to provide trace information. Otherwise the no change is made.

In general, weaving code will require new imports for the to-be-woven bundle. These imports can be added by adding Dynamic Import Package clauses to the list received from the `getDynamicImports()` method. This is a list of String objects, the syntax of each string is equal to a clause in the DynamicImport-Package header. See *Dynamic Import Package* on page 69 for the proper syntax.

```

public void weave(WovenClass classInfo) {
    BundleWiring bw = classInfo.getBundleWiring();
    Bundle b = bw.getBundle();
    if (bundles.contains(b)) {
}
  
```

```

        byte [] woven = weaveTracing(classInfo.getBytes());
        if (!classInfo.getDynamicImports().containsAll(imports))
            classInfo.getDynamicImports().addAll(imports);
        classInfo.setBytes(woven);
    }
}

```

The following trace method is called when a bundle must be traced. It ignores the request if the bundle is already traced. Otherwise, it will add the bundle to the set of traced bundles and refresh the bundle.

```

public void trace(Bundle b) {
    if (bundles.add(b))
        refresh(b);
}

```

The untrace method is the reverse:

```

public void untrace(Bundle b) {
    if (bundles.remove(b))
        refresh(b);
}

```

The refresh method uses the Bundle Wiring API to refresh a bundle. Refreshing a bundle will throw away its class loader so that all used classes are reloaded when needed.

```

private void refresh(Bundle b) {
    Bundle fwb = context.getBundle(0);
    FrameworkWiring fw = fwb.adapt(FrameworkWiring.class);
    fw.refreshBundles(Arrays.asList(b));
}

```

The trace method that does the final weaving is left as an exercise to the reader:

```

byte[] weaveTracing(byte[] bytes) {
    ..
}
}

```

56.2.2 Isolation

The *Resolver Hook Service Specification* on page 381 allows bundles to be separated into various regions isolated by sharing policies. The dynamic imports added in the tracing example will need to be taken into account by the sharing policies of regions containing bundles whose classes were woven in order for the bundles to resolve. This can be accomplished using a Woven Class Listener. Using a Weaving Hook would not be appropriate since there is no guarantee that a Weaving Hook observes the final list of dynamic imports.

The region registers a Woven Class Listener service so it receives notifications of Woven Class state transitions. The sharing policy of the region containing the bundle whose class was woven is updated with the dynamic imports, if any. This action occurs while the Woven Class is in the **TRANSFORMED** state to ensure the region is prepared to accept the imports before the bundle wiring is updated upon entering the **DEFINED** state. The region is initialized with the set of bundles composing it and a static sharing policy consisting of namespaces mapped to sets of filters indicating the allowed capabilities.

```

public class Region implements WovenClassListener, ResolverHook {
    final Set<Bundle> bundles;
}

```

```
final Map<String, Set<Filter>> policy;
```

The modified method is the service method of the Woven Class Listener service. It receives a Woven Class object that provides the information about the woven class that underwent a state transition. If the current state is [TRANSFORMED](#), and the associated bundle is part of the region, the sharing policy is updated with the additional dynamic imports, if any.

```
public void modified(WovenClass wovenClass) {
    if ((wovenClass.getState() & WovenClass.TRANSFORMED) == 0)
        return;
    Bundle bundle = wovenClass.getBundleWiring().getBundle();
    if (!bundles.contains(bundle))
        return;
    Set<Filter> filters = policy.get(PackageNamespace.PACKAGE_NAMESPACE);
    for (String dynamicImport : wovenClass.getDynamicImports())
        filters.add(toFilter(dynamicImport));
}
```

The region also implements ResolverHook. When the filterMatches method is called, the requirement is inspected to see if its matching capabilities are allowed into the region. If not, the list of candidates is cleared.

```
public void filterMatches(BundleRequirement requirement,
    Collection<BundleCapability> candidates) {
    Bundle bundle = requirement.getRevision().getBundle();
    if (!bundles.contains(bundle))
        return;
    String namespace = requirement.getNamespace();
    if (!policy.containsKey(namespace))
        return;
    Map<String, String> directives = requirement.getDirectives();
    String filter = directives.get(
        PackageNamespace.REQUIREMENT_FILTER_DIRECTIVE);
    Set<Filter> filters = policy.get(namespace);
    if (!filters.contains(toFilter(filter)))
        candidates.clear();
}
```

The toFilter method responsible for converting the requirement filters and dynamic import package clauses into a Filter is left as an exercise to the reader.

```
private Filter toFilter(String s) {
    ...
}
}
```

56.3 Weaving Hook

The Weaving Hook service is a [1] *Whiteboard Pattern* service. Any party that wants to participate in weaving classes can register such a service. The framework obtains the Weaving Hook services and calls their [weave\(WovenClass\)](#) method for each class that must be loaded. The Weaving Hook services must be called in the service ranking order. See *Service Ranking Order* on page 139.

The Weaving Hook weave method is called with a [WovenClass](#) object that represents the class to be woven. This class is similar to the Java ClassFileTransformer class but adds bundle wiring informa-

tion and can be made available in environments prior to Java 5. The methods must all be called in privileged blocks. See *Privileged Callbacks* on page 131.

The `WovenClass` object provides access to:

- `getClassName()` - The name of the class being loaded,
- `getBundleWiring()` - The bundle wiring, which provides access to the bundle, the bundle class loaders and the capabilities.
- `getProtectionDomain()` - The protection domain it is being defined in, and
- `getBytes()` - The class bytes to be defined.

A Weaving Hook service can use the `WovenClass` object to decide to weave or not to weave. This decision can be based on the bundle wiring, the class name, the protection domain, or the bytes. For example, the following code checks if the class comes from a specific bundle:

```
if (wovenClass.getBundleWiring().getBundle().equals(mybundle))  
    ...
```

If the Weaving Hook service decides to weave the class, it must calculate new bytes for the provided `WovenClass`, these bytes can be set with the `setBytes(byte[])` method. This implies that ordering is relevant. Weaving Hook services that are lower in ranking (called later) will weave any of the changes of higher ranking Weaving Hook services. Not all combinations of Weaving Hook services will therefore work as expected.

Weaving a class can create new dependencies that are unknown to the woven class. In the trace example, the entry and exit traces require access to the tracing subsystem, a dependency the original class did not have. The `WovenClass` object allows these extra imports to be added as new dynamic import package clauses. The current set of dynamic imports for the `WovenClass` is available from the `WovenClass` `getDynamicImports()` method. This method returns a mutable list of `String` during the weave method, the Weaving Hook service can add new dynamic import package clauses to this list while the weave method is active. The syntax of the strings is defined by the `DynamicImportPackage` header, see *Dynamic Import Package* on page 69. The dynamic imports must have a valid syntax, otherwise an `IllegalArgument` Exception must be thrown. These dynamically added dependencies are made visible through the *Bundle Wiring API Specification* on page 157 as new requirements. The `getRevision` method of these requirements must return the `BundleRevision` of the bundle that is woven; that revision will not include these synthetic requirements in the `getDeclaredRequirements` method.

Dynamic imports are the last resort for the framework to find a provider when the normal imports fail. The woven class dynamic imports are consulted after the dynamic imports specified in the bundle's manifest. Frameworks must append all additional dynamic imports in the given order but are expected to filter out duplicates for performance reasons.

The management of the dynamic import is error prone and should be handled with care because dynamic imports use wildcards. Wildcards make the ordering of the imports important. In the pathological case, a full wildcard in the beginning (for example in the manifest) will void any more specific clauses that were added by Handlers. Handlers should be as specific as possible when adding dynamic import clauses.

In many cases the additional imports must refer to classes that the Handler is already resolved to. In an OSGi framework, the same package can be present multiple times. A Handler should therefore ensure that the woven bundle gets wired to the correct bundle. One way to achieve this is to include the `bundle-version` and `bundle-symbolic-name` synthetic attributes that are available on every exported package.

```
com.acme.weavesupport.core;version=1.2;bundle-version=3.2; «  
    bundle-symbolic-name=com.acme.weavesupport
```

After calling the last Weaving Hook service, the WovenClass object is made *complete*. The framework must make the WovenClass object immutable when it is complete. After the Woven Class is complete, the current bytes are then used to define the new class. Attempts to modify it, or any of its properties, must throw an Exception. After completion, the `getBytes()` method must return a copy of the byte array that was used to define the class.

56.3.1 Concurrency

Class loads can occur at any time and Weaving Hook services must be able to handle concurrent as well as re-entrant calls to the weave method. The framework should not hold any locks when calling the Weaving Hook services, and Weaving Hook service implementations must be thread-safe. Furthermore Weaving Hook services may be re-entrant, and should be careful to avoid cycles when weaving.

For example when a class is being woven, the Weaving Hook may implicitly load a class by having a reference to it or the Weaving Hook can explicitly load a class. This new class load will also pass through the Weaving Hook service, so care must be taken to avoid infinite looping.

56.3.2 Error Handling

Weaving hooks are very low level and care must be taken by the Weaving Hook services to not disrupt normal class loading. In the case that a weaving hook throws an unexpected exception the framework must do the following:

1. If the exception is not a Weaving Exception:
 - The framework must blacklist the weaving hook registration and never call that Weaving Hook service again as long as it is registered. This Weaving Hook service is considered *blacklisted*.
2. A framework event of type ERROR should be published that must include the Exception thrown by the Weaving Hook service. The source must be the bundle registering the Weaving Hook service.
3. The WovenClass object must be marked as complete. All remaining Weaving Hook services must be skipped.
4. The bundle class loader must throw a ClassFormatError with the cause being the exception thrown by the Weaving Hook service.

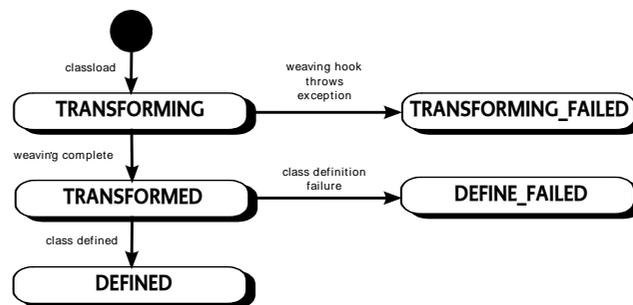
56.4 Woven Class Listener

The Woven Class Listener service is a [1] *Whiteboard Pattern* service. Any party that wants to receive notifications of woven class state transitions can register such a service. The framework obtains the Woven Class Listener services and calls their `modified(WovenClass)` method whenever a Woven Class undergoes a state transition. The framework must not obtain Woven Class Listener services if there are no Weaving Hook services registered. In this case, if the party needs to receive notifications of woven class state transitions then a no-op Weaving Hook service implementation can be registered to ensure Woven Class Listener services are called.

The Woven Class Listener `modified` method is called with a `WovenClass` object that represents the woven class that underwent a state transition. The method must be called in a privileged block. See *Privileged Callbacks* on page 131.

The following diagram depicts the state transitions of a Woven Class.

Figure 56.2 Woven Class State Diagram



Woven Class Listeners are not notified of the **TRANSFORMING** state because the Woven Class is mutable and listeners are not permitted to mutate the Woven Class. For all states observed by Woven Class Listeners, the Woven Class is effectively immutable. The first notification received for a given Woven Class is either the **TRANSFORMED** or **TRANSFORMING_FAILED** state. The **TRANSFORMED** state occurs after all Weaving Hooks have been notified but before the class has been defined or the bundle wiring has been updated for any additional dynamic imports. The **TRANSFORMING_FAILED** state occurs if any Weaving Hook throws an exception. After the **TRANSFORMED** state, a Woven Class can transition to either the **DEFINED** state or the **DEFINE_FAILED** state. The **DEFINED** state occurs when the class was defined successfully and after the bundle wiring has been updated. The **DEFINE_FAILED** state occurs if a class definition error occurred.

Table 56.1 describes the states of a Woven Class in more detail.

Table 56.1 Woven Class State Table

State	Description
TRANSFORMING	<p>A bundle class load request was made.</p> <ul style="list-style-type: none"> Weaving is incomplete. The class is undefined. The Woven Class is mutable. Weaving Hooks are notified but Woven Class Listeners are not.
TRANSFORMED	<p>All Weaving Hooks have been notified.</p> <ul style="list-style-type: none"> Weaving is complete. The class is undefined. The Woven Class is effectively immutable. Woven Class Listeners are notified.
TRANSFORMING_FAILED	<p>A Weaving Hook threw an exception.</p> <ul style="list-style-type: none"> Weaving is incomplete. The class is undefined. The Woven Class is effectively immutable. Woven Class Listeners are notified.

State	Description
DEFINED	<p>All Woven Class Listeners have been notified. The class has been defined.</p> <ul style="list-style-type: none"> • Weaving is complete. • The class is defined. • The Woven Class is effectively immutable. • Woven Class Listeners are notified.
DEFINE_FAILED	<p>All Weaving Hooks have been notified. A class definition failure occurred.</p> <ul style="list-style-type: none"> • Weaving is complete. • The class is undefined. • The Woven Class is effectively immutable. • Woven Class Listeners are notified.

56.4.1 Concurrency

Class loads can occur at any time, and Woven Class Listeners must be able to handle concurrent calls to the modified method. The framework should not hold any locks when calling Woven Class Listeners, and Woven Class Listener implementations must be thread-safe. Woven Class Listeners must be synchronously called by the framework when a Woven Class completes a state transition. The woven class processing will not proceed until all Woven Class Listeners are done.

56.4.2 Error Handling

Woven Class Listeners must not cause the weaving process to fail. If a Woven Class Listener throws an exception, the framework should log the exception but otherwise ignore it.

56.5 Security

56.5.1 Weaving Hooks

All hooks described in this specification are highly complex facilities that require great care in their implementation to maintain the Framework invariants. It is therefore important that in a secure system the permission to register these hooks is only given to privileged bundles.

In this case, the user of the hook services is the framework. Therefore, there is never a need to provide:

- `ServicePermission[..WeavingHook,GET]`

Implementers of these hooks must have:

- `ServicePermission[..WeavingHook,REGISTER]` for Weaving Hook services.

In addition, a Weaving Hook must have Admin Permission with the `WEAVE` action to be able to use the methods on the `WovenClass` object that mutate the state like `setBytes(byte[])`, `getBytes()`, and the mutating methods on the list returned by `getDynamicImports()`. Moreover, a Weaving Hook must have Package Permission with the `IMPORT` action in order to add or replace dynamic imports.

56.5.2 Woven Bundles

The Framework must grant implied `PackagePermission[somePkg, IMPORT]` permissions to bundles whose classes are being woven with additional dynamic imports, assuming the weaver has a match-

ing package import permission. The permission check for the weaver must occur during any call to the list that results in the addition or setting of a dynamic import. If the check fails, a `SecurityException` must be thrown. If it succeeds, the implied permission must be granted to the woven bundle immediately before defining the class.

56.5.3 Woven Class Listeners

Implementers of these listeners must have:

- `ServicePermission[.WovenClassListener,REGISTER]` for Woven Class Listener services.

56.6 org.osgi.framework.hooks.weaving

Framework Weaving Hooks Package Version 1.1.

Bundles wishing to use this package must list the package in the `Import-Package` header of the bundle's manifest.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.framework.hooks.weaving; version="[1.1,2.0)"
```

56.6.1 Summary

- `WeavingException` - A weaving exception used to indicate that the class load should be failed but the weaving hook must not be blacklisted by the framework.
- `WeavingHook` - OSGi Framework Weaving Hook Service.
- `WovenClass` - A class being woven.
- `WovenClassListener` - Woven Class Listener Service.

56.6.2 public class `WeavingException` extends `RuntimeException`

A weaving exception used to indicate that the class load should be failed but the weaving hook must not be blacklisted by the framework.

This exception conforms to the general purpose exception chaining mechanism.

56.6.2.1 public `WeavingException(String msg, Throwable cause)`

msg The associated message.

cause The cause of this exception.

- Creates a `WeavingException` with the specified message and exception cause.

56.6.2.2 public `WeavingException(String msg)`

msg The message.

- Creates a `WeavingException` with the specified message.

56.6.3 public interface `WeavingHook`

OSGi Framework Weaving Hook Service.

Bundles registering this service will be called during framework class loading operations. Weaving hook services are called when a class is being loaded by the framework and have an opportunity to transform the class file bytes that represents the class being loaded. Weaving hooks may also ask the framework to wire in additional dynamic imports to the bundle.

When a class is being loaded, the framework will create a `WovenClass` object for the class and pass it to each registered weaving hook service for possible modification. The first weaving hook called will see the original class file bytes. Subsequently called weaving hooks will see the class file bytes as modified by previously called weaving hooks.

Concurrency Thread-safe

56.6.3.1 **public void weave(WovenClass wovenClass)**

wovenClass The `WovenClass` object that represents the data that will be used to define the class.

- Weaving hook method. This method can modify the specified woven class object to weave the class being defined.

If this method throws any exception, the framework must log the exception and fail the class load in progress. This weaving hook service must be blacklisted by the framework and must not be called again. The blacklisting of this weaving hook service must expire when this weaving hook service is unregistered. However, this method can throw a `WeavingException` to deliberately fail the class load in progress without being blacklisted by the framework.

Throws `WeavingException`— If this weaving hook wants to deliberately fail the class load in progress without being blacklisted by the framework

56.6.4 **public interface WovenClass**

A class being woven. This object represents a class being woven and is passed to each `WeavingHook` for possible modification. It allows access to the most recently transformed class file bytes and to any additional packages that should be added to the bundle as dynamic imports.

Upon entering one of the terminal states, this object becomes effectively immutable.

Concurrency Not Thread-safe

Provider Type Consumers of this API must not implement this type

56.6.4.1 **public static final int DEFINE_FAILED = 16**

The woven class failed to define.

The woven class is in this state when a failure occurs while defining the class. The woven class cannot be further transformed or defined. This is a terminal state. Upon entering this state, this object is effectively immutable.

Since 1.1

56.6.4.2 **public static final int DEFINED = 4**

The woven class has been defined.

The woven class is in this state after the class is defined. The woven class cannot be further transformed. This is a terminal state. Upon entering this state, this object is effectively immutable, the bundle wiring has been updated with the dynamic import requirements and the class has been defined.

Since 1.1

56.6.4.3 **public static final int TRANSFORMED = 2**

The woven class has been transformed.

The woven class is in this state after weaving hooks have been called and before the class is defined. The woven class cannot be further transformed. The woven class is in this state while defining the class. If a failure occurs while defining the class, the state transitions to `DEFINE_FAILED`. Otherwise, after the class has been defined, the state transitions to `DEFINED`.

Since 1.1

56.6.4.4 public static final int TRANSFORMING = 1

The woven class is being transformed.

The woven class is in this state while weaving hooks are being called. The woven class is mutable so the class bytes may be modified and dynamic imports may be added. If a weaving hook throws an exception the state transitions to TRANSFORMING_FAILED. Otherwise, after the last weaving hook has been successfully called, the state transitions to TRANSFORMED.

Since 1.1

56.6.4.5 public static final int TRANSFORMING_FAILED = 8

The woven class failed to transform.

The woven class is in this state if a weaving hook threw an exception. The woven class cannot be further transformed or defined. This is a terminal state. Upon entering this state, this object is effectively immutable.

Since 1.1

56.6.4.6 public BundleWiring getBundleWiring()

- Returns the bundle wiring whose class loader will define the woven class.

Returns The bundle wiring whose class loader will define the woven class.

56.6.4.7 public byte[] getBytes()

- Returns the class file bytes to be used to define the named class.

While in the TRANSFORMING state, this method returns a reference to the class files byte array contained in this object. After leaving the TRANSFORMING state, this woven class can no longer be transformed and a copy of the class file byte array is returned.

Returns The bytes to be used to define the named class.

Throws SecurityException – If the caller does not have AdminPermission[bundle,WEAVE] and the Java runtime environment supports permissions.

56.6.4.8 public String getClassName()

- Returns the fully qualified name of the class being woven.

Returns The fully qualified name of the class being woven.

56.6.4.9 public Class<?> getDefinedClass()

- Returns the class defined by this woven class. During weaving, this method will return null. Once weaving is complete, this method will return the class object if this woven class was used to define the class.

Returns The class associated with this woven class, or null if weaving is not complete, the class definition failed or this woven class was not used to define the class.

56.6.4.10 public List<String> getDynamicImports()

- Returns the list of dynamic import package descriptions to add to the bundle wiring for this woven class. Changes made to the returned list will be visible to later weaving hooks called with this object. The returned list must not be modified outside invocations of the weave method by the framework.

After leaving the TRANSFORMING state, this woven class can no longer be transformed and the returned list will be unmodifiable.

If the Java runtime environment supports permissions, any modification to the returned list requires `AdminPermission[bundle,WEAVE]`. Additionally, any add or set modification requires `PackagePermission[package,IMPORT]`.

Returns A list containing zero or more dynamic import package descriptions to add to the bundle wiring for this woven class. This list must throw `IllegalArgumentException` if a malformed dynamic import package description is added.

See Also Core Specification, Dynamic Import Package, for the syntax of a dynamic import package description.

56.6.4.11 **public ProtectionDomain getProtectionDomain()**

- Returns the protection domain to which the woven class will be assigned when it is defined.

Returns The protection domain to which the woven class will be assigned when it is defined, or null if no protection domain will be assigned.

56.6.4.12 **public int getState()**

- Returns the current state of this woven class.

A woven class can be in only one state at any time.

Returns Either `TRANSFORMING`, `TRANSFORMED`, `DEFINED`, `TRANSFORMING_FAILED` or `DEFINE_FAILED`.

Since 1.1

56.6.4.13 **public boolean isWeavingComplete()**

- Returns whether weaving is complete in this woven class. Weaving is complete after the class is defined.

Returns true if state is `DEFINED`, `TRANSFORMING_FAILED` or `DEFINE_FAILED`; false otherwise.

56.6.4.14 **public void setBytes(byte[] newBytes)**

newBytes The new classfile that will be used to define the named class. The specified array is retained by this object and the caller must not modify the specified array.

- Set the class file bytes to be used to define the named class. This method must not be called outside invocations of the `weave` method by the framework.

While in the `TRANSFORMING` state, this method replaces the reference to the array contained in this object with the specified array. After leaving the `TRANSFORMING` state, this woven class can no longer be transformed and this method will throw an `IllegalStateException`.

Throws `NullPointerException`– If `newBytes` is null.

`IllegalStateException`– If state is `TRANSFORMED`, `DEFINED`, `TRANSFORMING_FAILED` or `DEFINE_FAILED`.

`SecurityException`– If the caller does not have `AdminPermission[bundle,WEAVE]` and the Java runtime environment supports permissions.

56.6.5 **public interface WovenClassListener**

Woven Class Listener Service.

Bundles registering this service will receive notifications whenever a woven class completes a state transition. Woven Class Listeners are not able to modify the woven class in contrast with weaving hooks.

Receiving a woven class in the TRANSFORMED state allows listeners to observe the modified byte codes before the class has been DEFINED as well as the additional dynamic imports before the bundle wiring has been updated.

Woven class listeners are synchronously called when a woven class completes a state transition. The woven class processing will not proceed until all woven class listeners are done.

If the Java runtime environment supports permissions, the caller must have `ServicePermission[WovenClassListener,REGISTER]` in order to register a listener.

Since 1.1

Concurrency Thread-safe

56.6.5.1 **public void modified(WovenClass wovenClass)**

wovenClass The woven class that completed a state transition.

- Receives notification that a woven class has completed a state transition.

The listener will be notified when a woven class has entered the TRANSFORMED, DEFINED, TRANSFORMING_FAILED and DEFINE_FAILED states.

If this method throws any exception, the Framework must log the exception but otherwise ignore it.

56.7 References

- [1] *Whiteboard Pattern*
<https://www.osgi.org/wp-content/uploads/whiteboard1.pdf>

57 Data Transfer Objects Specification

Version 1.1

57.1 Introduction

The OSGi API is rich and introspective supporting the local management of bundles, services and other items. Since the API has a lot of behavior and is not designed for serialization, any management model must design its own representation of the relevant OSGi objects for communication with remote management systems. We see this in the Management Model Specification for JMX™ Technology, the Dmt Admin Service Specification and Residential Device Management Tree Specification: the Management Model Specification for JMX™ Technology must define the MBeans and the Residential Device Management Tree Specification must define the tree representation.

The OSGi API continues to evolve and at each update of the OSGi API, the management models will all need to update their representations of the OSGi objects. Having standard, simple, easy to serialize and deserialize objects which represent the relevant OSGi objects will make it easier for the management model to keep up with changes in the OSGi API. Therefore, this specification defines Data Transfer Objects for OSGi in general and well as specific Data Transfer Objects for the Core specification. Other OSGi specifications may be updated over time to define Data Transfer Objects specific to their domain.

57.1.1 Essentials

- *Easy Serialization/Deserialization* - Must be easily serializable. That is, no special serialization/deserialization logic must be required. Serialization must be possible simply by introspection and object graphs must be a tree.
- *No Behavior* - Must have no behavior. That is, no methods other than the default public constructor.
- *Public* - Must have only public fields. That is, no private implementation detail.
- *Limited Field Types* - Must only use a limited selection of field types.
- *Extendable* - May extend other Data Transfer Object types.
- *Snapshot* - Does not track changes to represented runtime object.
- *Not Thread Safe* - External synchronization is needed.
- *Instantiation* - A means is provided to create Data Transfer Objects for the runtime objects they represent.

57.1.2 Entities

- *Data Transfer Object (DTO)* - An object for carrying data between processes. A Data Transfer Object does not have any behavior. See [1] *Data Transfer Object*.
- *Runtime Object* - A runtime object being represented by a Data Transfer Object. The runtime object can have complex behavior.

57.2 Data Transfer Object

A Data Transfer Object is used to represent the state of a related runtime object in a form suitable for easy transfer to some receiver. The receiver can be in the same Java VM but is more likely in another process or on another system that is remote. All Data Transfer Objects are easily serializable having only public fields of a limited set of type. These types are:

- Primitive types
- Wrapper classes for the primitive types
- String
- enum
- [Version](#)
- Data Transfer Objects
- List
- Set
- Map
- array

The List, Set, Map and array aggregates must only hold objects of the listed types.

Data Transfer Objects are public classes with no methods, other than the compiler supplied default constructor, having only public fields limited to the easily serializable types mentioned above. The org.osgi.dto package defines the basic rules and the abstract base [DTO](#) class which Data Transfer Objects must extend.

A Data Transfer Object is a representation of a runtime object at the point in time the Data Transfer Object was created. Data Transfer Objects do not track state changes in the represented runtime object. Since Data Transfer Objects are simply fields with no method behavior, modifications to Data Transfer Object are inherently not thread safe. Care must be taken to safely publish Data Transfer Objects for use by other threads as well as proper synchronization if a Data Transfer Object is mutated by one of the threads.

The object graph from a Data Transfer Object must be a tree to simplify serialization and deserialization.

57.2.1 Naming Conventions

Data Transfer Objects should follow a naming convention for the package containing the Data Transfer Object as well as the Data Transfer Object type. For the package name, we start with the package name containing the runtime type for which the Data Transfer Object is a representation. A `dto` segment is suffixed to the package name. For example, a Data Transfer Object representing a runtime type in the `org.osgi.service.foo` package will be in the Data Transfer Object package name is `org.osgi.service.foo.dto`.

The name of the Data Transfer Object type should be the name of the runtime type for which the Data Transfer Object is a representation followed by `DTO`. So for a type `Widget`, the Data Transfer Object for that type should be `WidgetDTO`. Sometimes the entity for which the Data Transfer Object provides a representation does not exist as a runtime type. In this case, the name of entity with a `DTO` suffix should be used. For example, `EntityDTO`.

Putting both the package and type Data Transfer Object naming conventions together, the fully qualified name for the Data Transfer Object representing the runtime type `org.osgi.service.foo.Widget` would be `org.osgi.service.foo.dto.WidgetDTO`.

57.3 Core Data Transfer Objects

Data Transfer Objects are defined for several important Core specification objects including Bundle, the Framework, and ServiceReference as well as the Resource API types, Start Level API types and Bundle Wiring API types.

57.3.1 Framework Data Transfer Objects

A [BundleDTO](#) represents information about a single bundle such as the id of the bundle, the current state of the bundle and the symbolic name and version of the bundle.

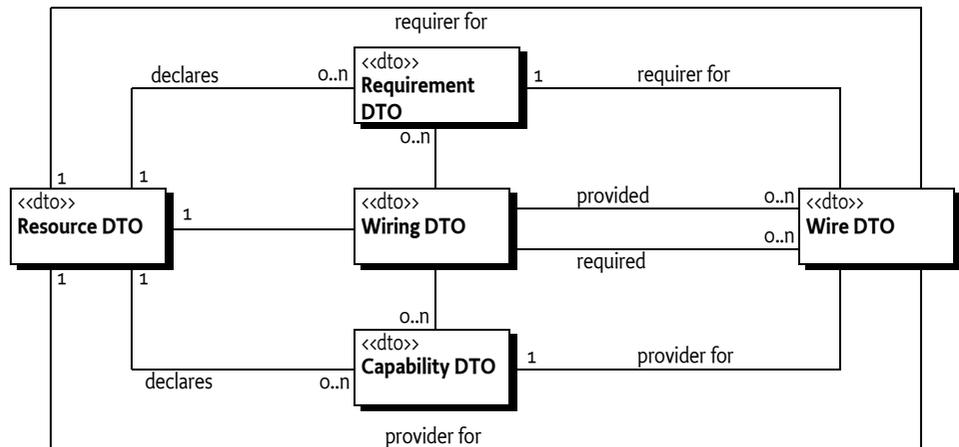
A [ServiceReferenceDTO](#) represents information about a single registered service such as the service properties, the bundle which registered the service and the bundles using the service.

A [FrameworkDTO](#) represents information about the Framework such as the list of installed bundles, the registered services and the launch properties of the framework.

57.3.2 Resource API Data Transfer Objects

[CapabilityDTO](#), [RequirementDTO](#), [ResourceDTO](#), [WiringDTO](#) and [WireDTO](#) represent the capabilities and requirements wiring information of the Resource API. The following figure shows the effective relationship between these Data Transfer Object types. Since the graph of Data Transfer Objects must be a tree, some references are indirect.

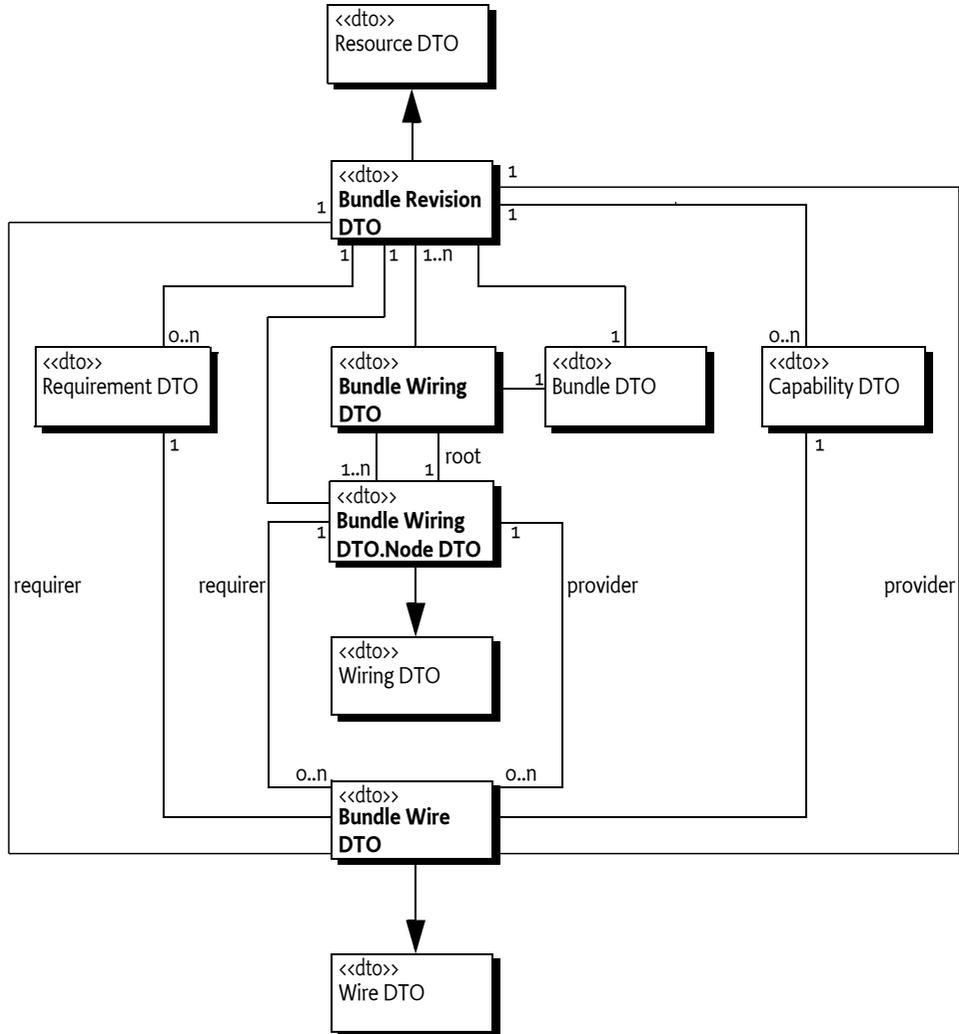
Figure 57.1 Resource API Data Transfer Objects



57.3.3 Bundle Wiring API Data Transfer Objects

[BundleRevisionDTO](#), [BundleWiringDTO](#), and [BundleWireDTO](#) represent the capabilities and requirements wiring information of the Bundle Wiring API. The following figure shows the effective relationship between these Data Transfer Object types. Since the graph of Data Transfer Objects must be a tree, some references are indirect.

Figure 57.2 Bundle Wiring API Data Transfer Objects



[FrameworkWiringDTO](#) represents the complete capabilities and requirements wiring information for all the bundles in the framework.

57.3.4 Start Level API Data Transfer Objects

A [BundleStartLevelDTO](#) represents information about the start level information of a bundle such as the assigned start level, the activation policy used and the whether the bundle is persistently started.

A [FrameworkStartLevelDTO](#) provides the start level information about the Framework such as the active start level and the initial bundle start level assigned to newly installed bundles.

57.4 Obtaining Core Data Transfer Objects

The [adapt\(Class\)](#) method allows the Bundle to be adapted to different types. The adapt method is used to obtain the Core Data Transfer Objects. For example, the adapt method can be used to adapt a Bundle object to the current BundleDTO object. The adapt method can be used as follows:

```
// DTO for the bundle
BundleDTO bundleDTO = bundle.adapt(BundleDTO.class);

// DTO for the current bundle wiring
BundleWiringDTO bundleWiringDTO = bundle.adapt(BundleWiringDTO.class);

// DTO for the current bundle revision
BundleRevisionDTO bundleRevisionDTO = bundle.adapt(BundleRevisionDTO.class);
```

The following table shows the Core Data Transfer Objects that can be obtained via the adapt method.

Table 57.1 *Data Transfer Objects that can be adapted from Bundle*

Class	Description
BundleDTO	The Bundle Data Transfer Object for the bundle.
ServiceReferenceDTO []	An array of Service Reference Data Transfer Objects for the registered services of the bundle. If the bundle has no registered services, the result is an empty array. If the bundle does not have a valid bundle context, the result is null.
BundleRevisionDTO	The Bundle Revision Data Transfer Object for the bundle. If the bundle is uninstalled or otherwise does not have a bundle revision, the result is null.
BundleRevisionDTO []	The Bundle Revision Data Transfer Objects for the bundle. The first revision is the current revision. If the bundle is uninstalled, the result is null.
BundleWiringDTO	The Bundle Wiring Data Transfer Object for the bundle. If the bundle is unresolved or otherwise does not have a bundle wiring, the result is null.
BundleWiringDTO []	The Bundle Wiring Data Transfer Objects for the bundle. The first wiring is the current wiring. If the bundle is uninstalled, the result is null.
BundleStartLevelDTO	The Bundle Start Level Data Transfer Object for the bundle. If the bundle is uninstalled, the result is null.
FrameworkStartLevelDTO	The Framework Start Level Data Transfer Object if the bundle is the System Bundle. If the bundle is not the System Bundle, the result is null.
FrameworkDTO	The Framework Data Transfer Object if the bundle is the System Bundle. If the bundle is not the System Bundle, the result is null.
FrameworkWiringDTO	The Framework Wiring Data Transfer Object if the bundle is the System Bundle. If the bundle is not the System Bundle, the result is null.

57.5 Security

Data Transfer Objects have no behavior by definition and thus no permissions are applicable to their use. To obtain Data Transfer Objects from a Bundle object via the adapt method, `AdaptPermission[<dtype>,ADAPT]` is required for the desired Data Transfer Object type.

57.6 org.osgi.dto

OSGi Data Transfer Object Package Version 1.1.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest. This package has two types of users: the consumers that use the API in this package and the providers that implement the API in this package.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.dto; version="[1.1,2.0]"
```

Example import for providers implementing the API in this package:

```
Import-Package: org.osgi.dto; version="[1.1,1.2]"
```

57.6.1 Summary

- DTO - Super type for Data Transfer Objects.

57.6.2 public abstract class DTO

Super type for Data Transfer Objects.

A Data Transfer Object (DTO) is easily serializable having only public fields of primitive types and their wrapper classes, Strings, enums, Version, and DTOs. List, Set, Map, and array aggregates may also be used. The aggregates must only hold objects of the listed types or aggregates.

The object graph from a Data Transfer Object must be a tree to simplify serialization and deserialization.

Concurrency Not Thread-safe

57.6.2.1 public DTO()

57.6.2.2 public String toString()

- Return a string representation of this DTO suitable for use when debugging.
- The format of the string representation is not specified and subject to change.

Returns A string representation of this DTO suitable for use when debugging.

57.7 org.osgi.framework.dto

OSGi Data Transfer Object Framework Package Version 1.8.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest. This package has two types of users: the consumers that use the API in this package and the providers that implement the API in this package.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.framework.dto; version="[1.8,2.0]"
```

Example import for providers implementing the API in this package:

```
Import-Package: org.osgi.framework.dto; version="[1.8,1.9]"
```

57.7.1 Summary

- BundleDTO - Data Transfer Object for a Bundle.
- FrameworkDTO - Data Transfer Object for a Framework.
- ServiceReferenceDTO - Data Transfer Object for a ServiceReference.

57-7.2 **public class BundleDTO** **extends DTO**

Data Transfer Object for a Bundle.

A Bundle can be adapted to provide a BundleDTO for the Bundle.

Concurrency Not Thread-safe

57-7.2.1 **public long id**

The bundle's unique identifier.

See Also Bundle.getId()

57-7.2.2 **public long lastModified**

The time when the bundle was last modified.

See Also Bundle.getLastModified()

57-7.2.3 **public int state**

The bundle's state.

See Also Bundle.getState()

57-7.2.4 **public String symbolicName**

The bundle's symbolic name.

See Also Bundle.getSymbolicName()

57-7.2.5 **public String version**

The bundle's version.

See Also Bundle.getVersion()

57-7.2.6 **public BundleDTO()**

57-7.3 **public class FrameworkDTO** **extends DTO**

Data Transfer Object for a Framework.

The System Bundle can be adapted to provide a FrameworkDTO for the framework of the system bundle. A FrameworkDTO obtained from a framework will contain only the launch properties of the framework. These properties will not include the System properties.

Concurrency Not Thread-safe

57-7.3.1 **public List<BundleDTO> bundles**

The bundles that are installed in the framework.

See Also BundleContext.getBundles()

57-7.3.2 **public Map<String, Object> properties**

The launch properties of the framework. The value type must be a numerical type, Boolean, String, DTO or an array of any of the former.

See Also BundleContext.getProperty(String)

57-7.3.3 **public List<ServiceReferenceDTO> services**

The services that are registered in the framework.

See Also BundleContext.getServiceReferences(String, String)

57-7-3-4 **public FrameworkDTO()**

57-7.4 **public class ServiceReferenceDTO extends DTO**

Data Transfer Object for a ServiceReference.

ServiceReferenceDTOs for all registered services can be obtained from a FrameworkDTO. A started Bundle can be adapted to provide a ServiceReferenceDTO[] of the services registered by the Bundle. A ServiceReferenceDTO obtained from a framework must convert service property values which are not valid value types for DTOs to type String using String.valueOf(Object).

Concurrency Not Thread-safe

57-7.4.1 **public long bundle**

The id of the bundle that registered the service.

See Also ServiceReference.getBundle()

57-7.4.2 **public long id**

The id of the service.

See Also Constants.SERVICE_ID

57-7.4.3 **public Map<String, Object> properties**

The properties for the service. The value type must be a numerical type, Boolean, String, DTO or an array of any of the former.

See Also ServiceReference.getProperty(String)

57-7.4.4 **public long[] usingBundles**

The ids of the bundles that are using the service.

See Also ServiceReference.getUsingBundles()

57-7.4.5 **public ServiceReferenceDTO()**

57.8 **org.osgi.framework.startlevel.dto**

OSGi Data Transfer Object Framework Start Level Package Version 1.0.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest. This package has two types of users: the consumers that use the API in this package and the providers that implement the API in this package.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.framework.startlevel.dto; version="[1.0,2.0)"
```

Example import for providers implementing the API in this package:

```
Import-Package: org.osgi.framework.startlevel.dto; version="[1.0,1.1)"
```

57.8.1 **Summary**

- BundleStartLevelDTO - Data Transfer Object for a BundleStartLevel.

- FrameworkStartLevelDTO - Data Transfer Object for a FrameworkStartLevel.

57.8.2 **public class BundleStartLevelDTO extends DTO**

Data Transfer Object for a BundleStartLevel.

An installed Bundle can be adapted to provide a BundleStartLevelDTO for the Bundle.

Concurrency Not Thread-safe

57.8.2.1 **public boolean activationPolicyUsed**

The bundle's autostart setting indicates that the activation policy declared in the bundle manifest must be used.

See Also BundleStartLevel.isActivationPolicyUsed()

57.8.2.2 **public long bundle**

The id of the bundle associated with this start level.

See Also BundleStartLevel.getBundle()

57.8.2.3 **public boolean persistentlyStarted**

The bundle's autostart setting indicates it must be started.

See Also BundleStartLevel.isPersistentlyStarted()

57.8.2.4 **public int startLevel**

The assigned start level value for the bundle.

See Also BundleStartLevel.getStartLevel()

57.8.2.5 **public BundleStartLevelDTO()**

57.8.3 **public class FrameworkStartLevelDTO extends DTO**

Data Transfer Object for a FrameworkStartLevel.

The System Bundle can be adapted to provide a FrameworkStartLevelDTO for the framework of the Bundle.

Concurrency Not Thread-safe

57.8.3.1 **public int initialBundleStartLevel**

The initial start level value that is assigned to a bundle when it is first installed.

See Also FrameworkStartLevel.getInitialBundleStartLevel()

57.8.3.2 **public int startLevel**

The active start level value for the framework.

See Also FrameworkStartLevel.getStartLevel()

57.8.3.3 **public FrameworkStartLevelDTO()**

57.9 **org.osgi.framework.wiring.dto**

OSGi Data Transfer Object Framework Wiring Package Version 1.3.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest. This package has two types of users: the consumers that use the API in this package and the providers that implement the API in this package.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.framework.wiring.dto; version="[1.3,2.0)"
```

Example import for providers implementing the API in this package:

```
Import-Package: org.osgi.framework.wiring.dto; version="[1.3,1.4)"
```

57.9.1 Summary

- BundleRevisionDTO - Data Transfer Object for a BundleRevision.
- BundleWireDTO - Data Transfer Object for a BundleWire.
- BundleWiringDTO - Data Transfer Object for a BundleWiring graph.
- BundleWiringDTO.NodeDTO - Data Transfer Object for a BundleWiring node.
- FrameworkWiringDTO - Data Transfer Object for the wiring graph of the framework.

57.9.2 public class BundleRevisionDTO extends ResourceDTO

Data Transfer Object for a BundleRevision.

An installed Bundle can be adapted to provide a BundleRevisionDTO for the current revision of the Bundle. BundleRevisionDTO objects for all in use revisions of the Bundle can be obtained by adapting the bundle to BundleRevisionDTO[.].

Concurrency Not Thread-safe

57.9.2.1 public long bundle

The id of the bundle associated with the bundle revision.

See Also BundleRevision.getBundle()

57.9.2.2 public String symbolicName

The symbolic name of the bundle revision.

See Also BundleRevision.getSymbolicName()

57.9.2.3 public int type

The type of the bundle revision.

See Also BundleRevision.getTypes()

57.9.2.4 public String version

The version of the bundle revision.

See Also BundleRevision.getVersion()

57.9.2.5 public BundleRevisionDTO()

57.9.3 public class BundleWireDTO extends WireDTO

Data Transfer Object for a BundleWire.

BundleWireDTOs are referenced BundleWiringDTO.NodeDTOs.

Concurrency Not Thread-safe

57-9-3.1 **public int providerWiring**

The identifier of the provider wiring for the bundle wire.

See Also WiringDTO.id, BundleWire.getProviderWiring()

57-9-3.2 **public int requirerWiring**

The identifier of the requiring wiring for the bundle wire.

See Also WiringDTO.id, BundleWire.getRequirerWiring()

57-9-3.3 **public BundleWireDTO()**

57-9.4 **public class BundleWiringDTO extends DTO**

Data Transfer Object for a BundleWiring graph.

An installed Bundle can be adapted to provide a BundleWiringDTO for the current wiring Bundle. BundleWiringDTO objects for all in use wirings of the Bundle can be obtained by adapting the bundle to BundleWiringDTO[].

Concurrency Not Thread-safe

57-9.4.1 **public long bundle**

The id of the bundle associated with the bundle wiring graph.

See Also BundleWiring.getBundle()

57-9.4.2 **public Set<BundleWiringDTO.NodeDTO> nodes**

The set of wiring nodes referenced by the wiring graph.

All wiring nodes referenced by wiring node identifiers in the wiring graph are contained in this set.

57-9.4.3 **public Set<BundleRevisionDTO> resources**

The set of resources referenced by the wiring graph.

All resources referenced by resource identifiers in the wiring graph are contained in this set.

57-9.4.4 **public int root**

The identifier of the root wiring node of the bundle wiring graph.

See Also WiringDTO.id

57-9.4.5 **public BundleWiringDTO()**

57-9.5 **public static class BundleWiringDTO.NodeDTO extends WiringDTO**

Data Transfer Object for a BundleWiring node.

The providedWires field must contain an array of BundleWireDTOs. The requiredWires field must contain an array of BundleWireDTOs.

Concurrency Not Thread-safe

57.9.5.1 public boolean current

The current state of the bundle wiring. The bundle wiring's current setting indicates that the bundle wiring is the current bundle wiring for the bundle.

See Also BundleWiring.isCurrent()

57.9.5.2 public boolean inUse

The bundle wiring's in use setting indicates that the bundle wiring is in use.

See Also BundleWiring.isInUse()

57.9.5.3 public NodeDTO()**57.9.6 public class FrameworkWiringDTO extends DTO**

Data Transfer Object for the wiring graph of the framework.

The system bundle can be adapted to provide the FrameworkWiringDTO. Only the system bundle can be adapted to a FrameworkWiringDTO object

Since 1.3

Concurrency Not Thread-safe

57.9.6.1 public Set<BundleRevisionDTO> resources

The set of resources referenced by the wiring graph of the framework.

All resources referenced by resource identifiers in the wiring graph are contained in this set.

57.9.6.2 public Set<BundleWiringDTO.NodeDTO> wirings

The set of wiring nodes referenced by the wiring graph of the framework.

All wiring nodes referenced by wiring node identifiers in the wiring graph are contained in this set.

57.9.6.3 public FrameworkWiringDTO()**57.10 org.osgi.resource.dto**

OSGi Data Transfer Object Resource Package Version 1.0.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest. This package has two types of users: the consumers that use the API in this package and the providers that implement the API in this package.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.resource.dto; version="[1.0,2.0]"
```

Example import for providers implementing the API in this package:

```
Import-Package: org.osgi.resource.dto; version="[1.0,1.1]"
```

57.10.1 Summary

- CapabilityDTO - Data Transfer Object for a Capability.
- CapabilityRefDTO - Data Transfer Object for a reference to a Capability.
- RequirementDTO - Data Transfer Object for a Requirement.

- RequirementRefDTO - Data Transfer Object for a reference to a Requirement.
- ResourceDTO - Data Transfer Object for a Resource.
- WireDTO - Data Transfer Object for a Wire.
- WiringDTO - Data Transfer Object for a Wiring node.

57.10.2 **public class CapabilityDTO** **extends DTO**

Data Transfer Object for a Capability.

Concurrency Not Thread-safe

57.10.2.1 **public Map<String, Object> attributes**

The attributes for the capability.

The value type must be a numerical type, Boolean, String, DTO or an array of any of the former.

See Also Capability.getAttributes()

57.10.2.2 **public Map<String, String> directives**

The directives for the capability.

See Also Capability.getDirectives()

57.10.2.3 **public int id**

The unique identifier of the capability.

This identifier is transiently assigned and may vary across restarts.

57.10.2.4 **public String namespace**

The namespace for the capability.

See Also Capability.getNamespace()

57.10.2.5 **public int resource**

The identifier of the resource declaring the capability.

See Also ResourceDTO.id, Capability.getResource()

57.10.2.6 **public CapabilityDTO()**

57.10.3 **public class CapabilityRefDTO** **extends DTO**

Data Transfer Object for a reference to a Capability.

Concurrency Not Thread-safe

57.10.3.1 **public int capability**

The identifier of the capability in the resource.

See Also CapabilityDTO.id

57.10.3.2 **public int resource**

The identifier of the resource declaring the capability.

See Also ResourceDTO.id

57.10.3.3 **public CapabilityRefDTO()**

57.10.4 **public class RequirementDTO** **extends DTO**

Data Transfer Object for a Requirement.

Concurrency Not Thread-safe

57.10.4.1 **public Map<String, Object> attributes**

The attributes for the requirement.

The value type must be a numerical type, Boolean, String, DTO or an array of any of the former.

See Also Requirement.getAttributes()

57.10.4.2 **public Map<String, String> directives**

The directives for the requirement.

See Also Requirement.getDirectives()

57.10.4.3 **public int id**

The unique identifier of the requirement.

This identifier is transiently assigned and may vary across restarts.

57.10.4.4 **public String namespace**

The namespace for the requirement.

See Also Requirement.getNamespace()

57.10.4.5 **public int resource**

The identifier of the resource declaring the requirement.

See Also ResourceDTO.id, Requirement.getResource()

57.10.4.6 **public RequirementDTO()**

57.10.5 **public class RequirementRefDTO** **extends DTO**

Data Transfer Object for a reference to a Requirement.

Concurrency Not Thread-safe

57.10.5.1 **public int requirement**

The identifier of the requirement in the resource.

See Also RequirementDTO.id

57.10.5.2 **public int resource**

The identifier of the resource declaring the requirement.

See Also ResourceDTO.id

57.10.5.3 **public RequirementRefDTO()**

57.10.6 **public class ResourceDTO** **extends DTO**

Data Transfer Object for a Resource.

Concurrency Not Thread-safe

57.10.6.1 **public List<CapabilityDTO> capabilities**

The capabilities of the resource.

See Also Resource.getCapabilities(String)

57.10.6.2 **public int id**

The unique identifier of the resource.

This identifier is transiently assigned and may vary across restarts.

57.10.6.3 **public List<RequirementDTO> requirements**

The requirements of the resource.

See Also Resource.getRequirements(String)

57.10.6.4 **public ResourceDTO()**

57.10.7 **public class WireDTO
extends DTO**

Data Transfer Object for a Wire.

Concurrency Not Thread-safe

57.10.7.1 **public CapabilityRefDTO capability**

Reference to the Capability for the wire.

See Also Wire.getCapability()

57.10.7.2 **public int provider**

The identifier of the provider resource for the wire.

See Also ResourceDTO.id, Wire.getProvider()

57.10.7.3 **public RequirementRefDTO requirement**

Reference to the Requirement for the wire.

See Also Wire.getRequirement()

57.10.7.4 **public int requirer**

The identifier of the requiring resource for the wire.

See Also ResourceDTO.id, Wire.getRequirer()

57.10.7.5 **public WireDTO()**

57.10.8 **public class WiringDTO
extends DTO**

Data Transfer Object for a Wiring node.

Concurrency Not Thread-safe

57.10.8.1 **public List<CapabilityRefDTO> capabilities**

The references to the capabilities for the wiring node.

See Also `Wiring.getResourceCapabilities(String)`

57.10.8.2

public int id

The unique identifier of the wiring node.

This identifier is transiently assigned and may vary across restarts.

57.10.8.3

public List<WireDTO> providedWires

The provided wires for the wiring node.

See Also `Wiring.getProvidedResourceWires(String)`

57.10.8.4

public List<WireDTO> requiredWires

The required wires for the wiring node.

See Also `Wiring.getRequiredResourceWires(String)`

57.10.8.5

public List<RequirementRefDTO> requirements

The references to the requirements for the wiring node.

See Also `Wiring.getResourceRequirements(String)`

57.10.8.6

public int resource

The identifier of the resource associated with the wiring node.

See Also `ResourceDTO.id`, `Wiring.getResource()`

57.10.8.7

public WiringDTO()

57.11 References

- [1] *Data Transfer Object*
https://en.wikipedia.org/wiki/Data_transfer_object

57.12 Changes

- Added support for enums and Version fields in DTOs.
- A new DTO for the complete framework wiring, `FrameworkWiringDTO`, is added.

58 Resolver Service Specification

Version 1.1

58.1 Introduction

Today very few applications are self contained, the predominant development model is that applications are built from (external) components, which are often open source. Application developers add business logic, glue code, and assemble the diverse components into a resource that provides the desired capabilities when installed in an environment. Designing the assembly has long been a manual and error prone process, partly due to the complexity of external dependencies. Although the direct dependencies are often given, the largest number of dependencies are usually the transitive dependencies: the dependencies of the dependencies. Modern applications can end up with hundreds to thousands of external dependencies. Numbers that make tooling inevitable.

The OSGi framework is the first specification that provides a foundation for automating a significant part of this assembly process. The Requirement-Capability model defined in *Resource API Specification* on page 151 provides a dependency model that allows resources to express dependencies, constraints, and capabilities. If a resource's constraints are met it provides capabilities that can satisfy further requirements. The OSGi dependency model is fully generic and is not limited to bundles. Resources can be bundles but also certificates, plugged in devices, etc.

Resolving transitive dependencies is a non-trivial process that requires careful design to achieve the required performance since the underlying problem is NP-complete. OSGi frameworks have always included such resolvers but these were built into the frameworks. They were not usable outside the framework for tooling, for example automatically finding the dependencies of a bundle that needs to be installed.

The number of dependencies is rapidly reaching a threshold where manual methods no longer can provide reliable results. This specification therefore provides the *Resolver service*, a service that can be the base for provisioning, deployment, build, and diagnostic tooling. The service can take a requirement and resolve it to a wiring of resources. For example, with cloud computing a new requirement can be translated into a new OSGi framework instance being started on a node and provisioned with the set of bundles that satisfy the given requirement. The OSGi Resolver service is intended to be a corner stone of such an auto-provisioning tool.

However, the OSGi Resolver service is not limited to these higher end schemes. Build tools can use the Resolver to find components for the build path and/or run time environment and predict the results of installing a set of bundles on a target environment. The OSGi Resolver service is an essential part of a software model where applications are built out of independent components.

This specification is based on the concepts and API defined in the *Resource API Specification* on page 151, *Bundle Wiring API Specification* on page 157, and the *Module Layer* on page 33. These specifications are required reading for understanding this specification. This specification is for highly specialized use, it is not intended to be used in applications, the Resolver API is a low level service intended for system developers with deep knowledge of the OSGi module layer.

58.1.1 Essentials

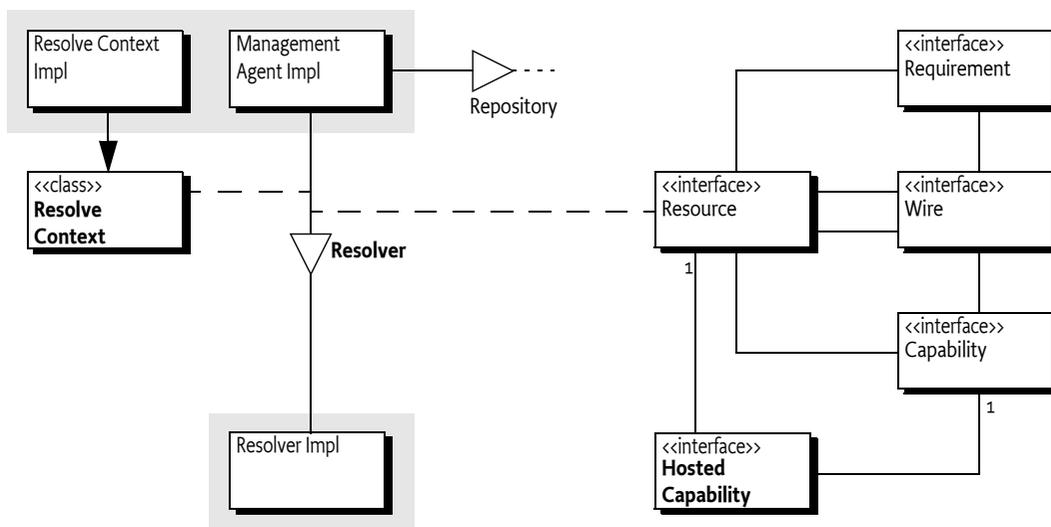
- *Transitive* - From a requirement, find a consistent set of resources that satisfy that requirement.
- *Diagnostics* - Provide diagnostic information when no resolution can be found.

- *Scoped Repositories* - Allow the environment to control the repositories to use.
- *Build Tools* - Must be useful in establishing build and run time class paths.
- *Provisioning* - Must be useful to find a set of bundles that can be installed in a system without running into unresolved dependencies.
- *OSGi* - Provide the semantics of all the OSGi namespaces, including the uses constraints.
- *API* - The API for the Resolver must provide the base for the Framework Bundle Wiring API.
- *Performant* - Enable highly performant implementations.
- *Frameworks* - Allow Frameworks to provide their resolver as a service.
- *Scalable* - Allow access to, and use of, very large repositories.

58.1.2 Entities

- *Environment* - A container or framework that can install resources and uses a Resolver to wire these resources.
- *Resolve Context* - An interface implemented by the management agent to provide the context of the resolution.
- *Wiring* - Represents the state of a resource's wires, requirements, and capabilities in an environment.
- *Resolver* - A service that can find a set of wires that can be applied to an existing wiring state where a set of initial resources have all their mandatory requirements satisfied.
- *Wire* - Links requirement to a capability.
- *Resource* - An artifact with requirements that need to be provisioned and resolved to provide its capabilities.
- *Requirement* - A necessity for a given resource before it can provide its capabilities; expressed as a filter expression on the attributes of a capability in a given namespace.
- *Capability* - A set of attributes and directives defined by a namespace, describes what a resource provides when resolved.
- *Hosted Capability* - Pairs a resource with a capability to model hosting capabilities in another resource.
- *Namespace* - The type for a capability and requirement.
- *Resolution* - The result of a resolve operation.

Figure 58.1 Class and Service overview



58.1.3 Synopsis

The Resolver service can find a complete and consistent set of transitive dependencies starting with an initial set of mandatory and optional resources. Such a set can be used to install resources in the environment from local or remote repositories. To use the Resolver service, the client must provide a [ResolveContext](#) object. This complex object represents the context of a resolution; it provides the initial resources (optional and mandatory), defines a number of namespaces specific policies, and provides the state of the environment.

A resolution can be based on an existing wiring in the environment, for example the current framework state. For the framework, the Resolve Context can find this existing state via the *Bundle Wiring API Specification* on page 157. The Resolver must then satisfy all the requirements of the mandatory resources. The Resolver must always ask the Resolve Context to find additional capabilities for the unsatisfied requirements. A capability is always associated with a resource, which is subsequently associated with additional requirements. The final resolution must contain a set of resources that include the initial set of mandatory resources, has no unsatisfied mandatory requirements, and is consistent with the implied constraints. Otherwise it fails.

The Requirement-Capability model is fully generic but provides special semantics through the use of namespaces. The Resolver must implement the standard OSGi namespaces as described in *Bundle Wiring API Specification* on page 157, which includes the uses constraints. Part of the semantics of the OSGi namespaces are delegated to the Resolve Context so that it can implement different policies. Singletons, ordering of capabilities, and matching are the responsibility of the Resolve Context; the Resolver never matches a requirement to a capability.

Requirements have an effective directive that indicates in what situations the requirement must be resolved. Also here, the Resolve Context decides if a particular requirement is effective or not. Only effective requirements are wired in the resolution.

Since capabilities are declared by resources that have additional requirements, the Resolver must create a set of resources where all transitive requirements are satisfied or fail with a Resolution Exception. This Resolution Exception can provide additional details why the resolution failed, if possible.

At the end of a successful resolve operation the Resolver returns a `Map<Resource,List<Wire>>`. These wires are a delta on the existing state, if any. The wires can then be used to provision missing resources or to provide diagnostic feedback.

58.2 The Resolve Context

Provisioning is the process of providing a framework with the necessary resources to allow it to operate according to set goals. In OSGi terms, this consists of installing bundles and ensuring that the configuration is set up correctly. With OSGi, bundles explicitly describe their capabilities and requirements as manifest headers. This can range from `Export-Package` (a capability) to a generic `Provide-Capability` header.

OSGi Frameworks have a *resolving* stage that ensures requirements are satisfied before a bundle is allowed to provide code to the shared space. As long as the requirements are not met, the bundle remains in the `INSTALLED` state and is thus prohibited from contributing capabilities. Once all the mandatory requirements are met, the bundle becomes `RESOLVED`. That is, a framework combines two decisions when it resolves bundles:

- Find a resolution based on the existing set of installed bundles.
- Move the bundles that have all their mandatory requirements satisfied to the `RESOLVED` state.

The *Resolver service* separates these two stages and thus allows a third party, the *management agent*, to define the *environment* of the resolution. A management agent can interact with the Resolver service

while it is searching for a resolution because the Resolver service calls back the management agent through a [ResolveContext](#) object. The Resolver service will therefore allow the management agent to handle more scenarios, better diagnostics, etc.

The Resolve Context is provided by the management agent, it is an abstract base class and must therefore be extended. It is a non-trivial class to implement since it is tightly coupled to the rules of the environment; it represents the policies of the management agent for that environment. For OSGi framework resolvers, the Resolve Context must understand and implement a part of the OSGi framework namespaces.

With the Resolver service, a management agent can try out resolutions before any bundle can see the result of such a resolution but it can also include extra bundles or other resources on demand. The Resolver service will also allow resolutions to be calculated for other frameworks.

For example, a management agent could use a Resolver service to find missing dependencies and install them on demand from a local directory with bundles. Such a Provisioner could have the following skeleton:

```
public class Provisioner {
    File bundles = ...;
    Map<String,Resource> resources = ...;
    Resolver resolver = ...;
    BundleContext context = ...;

    public void install(String location) {
        Resource resource = resources.get( location );
        if ( resource == null ) error(...);

        try {
            ResolveContextImpl rc = ...
            rc.addMandatory( resource );
            Set<Resource> provision = resolver.resolve( rc ).keySet();

            for ( Resource rb : provision ) {
                String location = getLocation( rb );

                Bundle bundle = context.installBundle( location );
                if ( !isFragment( bundle ) )
                    bundle.start();
            }
        } catch(ResolutionException re) {
            ... // diagnostics
        } catch(BundleException be) {
            ... // diagnostics
        }
    }
}
```

58.2.1 Mandatory and Optional Resources

The Resolve Context provides all the parameters for the resolve operation, the Resolver does not maintain any state between invocations. The Resolve Context must therefore provide the mandatory and optional resources, which are essentially the input parameters to the resolve operation. The resolver must find a solution that includes at least the initial mandatory resources and should include the optional resources.

58.2.2 Finding Capabilities

The Resolve Context's `findProviders(Requirement)` method must be implemented in such a way that it returns an ordered list of capabilities. The Resolver will treat the order of the capabilities as preferences, the first element is more preferred than a later element. The Resolver cannot guarantee that the wiring obeys this preference since there can be other constraints. However, a Resolver must use this preference order for simple cases and try to use it in more constrained situations.

The Resolver does not make any assumptions, this means that the `findProviders(Requirement)` method must do all the matching. Even though the Resolver gets the mandatory and optional resources it will not search these for capabilities to satisfy requirements. If the `findProviders(Requirement)` method does not search these resources then their capabilities will not be used. The same is true for the existing wiring state used.

Since this section describes the Resolver with respect to a provisioning agent, the set of resources is not limited to the installed set. That is, normally when a framework is resolved the Resolver only has to include installed resources. However, for a provisioning agent it is possible to retrieve external resources. The [1] *Repository Service Specification* provides access to resource repositories but a management agent is free to find capabilities by any alternative means.

For resolving an OSGi framework the specifications outlines a number of heuristics that guide the order of wiring bundles and packages:

1. A resource that is already resolved, that is, it is already wired
2. The highest version
3. The lowest bundle id

The Resolver can, and likely will, use the returned list to maintain its internal state during the resolve operation while trying out different potential solutions. It can add and remove capabilities at will. The returned list must therefore be mutable and not reused, after it is returned; it becomes owned by the Resolver. However, the Resolver can call back later with the `insertHostedCapability(List,HostedCapability)` method, giving back the returned list as the first parameter, see *Insert Hosted Capabilities* on page 454.

For example, assume that all possible resources in the previous example can be gotten with the `getSortedResources` method in the preferred resource order. This list contains all installed resources as well as any potentially installable resources. This list is sorted once on the given ordering criteria, this only has to be done once and not for each `findProviders(Requirement)` method invocation. The following code, which does not order by capability versions, could then be a simple skeleton for the `findProviders(Requirement)` method on the `ResolveContextImpl` inner class:

```
public List<Capability> findProviders(Requirement requirement) {
    List<Capability> result = new ArrayList<Capability>();

    for ( Resource r : getSortedResources() )
        for ( Capability c : r.getCapabilities( null ) )
            if ( match( requirement, c ) )
                result.add( c );

    return result;
}
```

58.2.3 Matching

The `findProviders(Requirement)` method is responsible for only returning the capabilities that the management agent wants to be considered by the Resolver. Since the Resolver must never match any requirements to capabilities it allows the management agent to fully control the matching. However, in an OSGi environment the following matching behavior is expected:

- Requirements and capabilities must be in the same namespace.
- Only requirements and capabilities that have no effective directive or have the directive set to resolve should be considered.
- The requirement's filter must match the capability's attributes.
- If the namespace is an `osgi.wiring.*` namespace then the mandatory directive on the capability must be supported. Mandatory attributes are defined with a mandatory directive on a capability, they contain a list of attribute names. Each of these attributes must be used in the filter. Since the filter must be constructed from the corresponding manifest header it is sufficient to search the filter string with a regular expression that detects the usage of an attribute name.

The following example shows a skeleton match method that provides OSGi semantics:

```
boolean match(Requirement r, Capability c){
    if ( !r.getNamespace().equals( c.getNamespace() ) )
        return false;

    String effective = c.getDirectives().get("effective");
    if ( !(effective == null || effective.equals( "resolve" ) ) )
        return false;

    String f = r.getDirectives().get( "filter" );
    if ( f != null ) {
        Filter filter = context.createFilter( f );
        if ( !filter.matches( c.getAttributes() ) )
            return false;
    }

    if ( !c.getNamespace().startsWith( "osgi.wiring." ) )
        return true;

    String mandatory = c.getDirectives().get("mandatory");
    if ( mandatory == null )
        return true;

    List<String> attrs =
        Arrays.asList( mandatory.toLowerCase().split( "\\s*,\\s*" ) );

    Matcher m = FILTER_ASSERT_PATTERN.matcher( f == null ? "" : f );
    while( m.find() )
        attrs.remove(m.group(1)); // the attribute name

    return mandatory.isEmpty();
}
```

58.2.4 Repositories

Resolving to provision a framework is different than a framework resolving itself. During provisioning remote repositories can be consulted to find external resources while the framework only resolves a limited set (the installed bundles). These repositories generally contain magnitudes more bundles than what is installed in a framework.

Repositories do not implement any namespace specific semantics and therefore do not understand any directives. Repositories only verify the requirement's filter (if any) against the capability's attributes. The Resolver expects the Resolve Context to do the namespace specific matching. The [1] *Repository Service Specification* provides the details for a service that abstracts a Requirement-Capability aware repository.

With such a repository service the `findProviders(Requirement)` method can be implemented as follows:

```
List<Repository> repositories = new CopyOnWriteArrayList<Repository>();

void addRepository( Repository repository) { repositories.add(repository);}
void removeRepository(Repository repository){ repositories.remove(repository);}

public List<Capability> findProviders( Requirement requirement) {
    List<Capability> result = new ArrayList<Capability>();

    // previous findProviders that searches the initial resources

    for ( Repository repository : repositories ) {
        Collection<Capability> capabilities = repository.findProviders(
            Collections.singleton( requirement ) ).get( requirement);
        for ( Capability c : capabilities )
            if ( match( requirement, c ) )
                result.add( c );
    }
    return result;
}
```

58.2.5 Existing Wiring State

The Resolver service always creates a list of wires that should be added to an existing state. To get the existing state, the `ResolveContext` interface specifies the `getWirings()` method. This method must return the existing state as a `Map<Resource,Wiring>`. A `Wiring` is an object that reflects the wired state of a resource in the environment. From this object, all declared and hosted capabilities and requirements can be found, including their wires if any. The Resolver needs this existing state to create a consistent resolution. For example, uses constraints require access to the existing state.

The Resolver service API is based on the generic Requirement-Capability model. This API is implemented by the OSGi framework to reflect its internal wiring, see *Bundle Wiring API Specification* on page 157. When the Resolver service is used for an OSGi framework then the Resolve Context can provide the existing wiring state based on the Framework Wiring API. The interfaces used in the `org.osgi.framework.wiring` package all extend their counterpart in the `org.osgi.resource` package (the generic model). For example, the `BundleCapability` interface extends the `Capability` interface.

The framework wiring API models all the power and complexities of the OSGi framework. One of those aspects is *removal pending*. Each installed bundle is represented by one or more bundle revisions. Each bundle revision is a `Resource` object but only one is the current bundle revision. During a resolve operation a framework can actually wire to the current bundle revision but is not forbidden to also select the pending removal bundle revisions. The Resolve Context must therefore decide if it provides only the current bundle revisions or all. The best policy solution in this case is to always refresh after a (batch) of install operations and only resolve when there are no pending-removal bundle revisions. However, certain management agents attempt to manage a system that is in this half-way state and will then be required to include the pending-removal revisions.

The following example code shows a possible implementation of the `getWirings()` method. It only uses the current wiring and ignores removal pending bundle revisions:

```
public Map<Resource,Wiring> getWirings(){
    Map<Resource,Wiring> wirings = new HashMap<Resource,Wiring>();

    for ( Bundle b : context.getBundles() ) {
        BundleRevision revision = b.adapt( BundleRevision.class);
        if ( revision != null ) {
```

```

        Wiring wiring = revision.getWiring();
        if ( wiring != null )
            wirings.put( revision, wiring );
    }
}
return wirings;
}

```

A wiring for a resource may also have a subset of required wires which substitute capabilities provided by the resource or one of its attached fragment resources. The [getSubstitutionWires\(Wiring\)](#) method is called by the resolver in order to find the wires that substitute capabilities of the wiring. For example, when a wiring provides a `osgi.wiring.bundle` capability that is used to resolve one or more `osgi.wiring.bundle` requirements. In this case the resolver needs to discover which capabilities have been substituted in order to ensure a consistent class space (see *Requiring Bundles* on page 84). In order to get the capabilities which have been substituted, the resolver asks the resolve context to return the substitution wires for the wiring.

Note that the default implementation of this method searches all the `osgi.wiring.package` capabilities which are declared as provided by the resource associated with the wiring and fragment resources wired to the wiring with the `osgi.wiring.host` namespace. The provided capabilities are compared against the required package wires to determine which wires are substitution wires. Subclasses of `ResolveContext` should provide a more efficient implementation of this method.

58.2.6 Effective

The Resolver service is designed to work with OSGi frameworks but the scope is broader; its design allows many alternative usages. The effective directive on the capabilities and requirements is meant to allow requirements and capabilities to be effective in different phases. The default is resolve, the value for an OSGi framework resolving process. Bundles and other OSGi defined artifacts must declare their capabilities and requirements in the resolve effective time to be considered by an OSGi resolver.

However, Resolvers can use the effective directive to run the Resolver at other times than the standard OSGi framework resolve. For example, it could be possible to define an *active time* to resolve the service dependencies.

For this reason, the Resolver is designed to be agnostic for this directive, it will always ask the [ResolveContext](#) if a requirement is effective. It does this with the [isEffective\(Requirement\)](#) method. Since the Resolver service never matches requirements to capabilities it is also up to the Resolve Context to decide how to treat the effective directive. For an OSGi resolve operation, capabilities should also have an effective time value of resolve (or not set since resolve is the default).

To make requirements effective during the resolving of bundles it will be necessary to implement the [isEffective\(Requirement\)](#) method similar to:

```

public boolean isEffective( Requirement requirement ) {
    String e = requirement.getDirectives().get( "effective" );
    return e==null || "resolve".equals( e );
}

```

58.2.7 Insert Hosted Capabilities

One of the complex aspects of resolving for an OSGi framework is handling fragments. For fragments, the declared capabilities are going to be hosted by their hosts. The Requirement and Capability objects have a `getResource` method that returns the associated resource. For hosted capabilities and requirements this must be the hosting resource and for others the declaring resource.

The [HostedCapability](#) interface defines the interface for allowing the hosting resource to be returned instead of the declaring resource. Since the Resolver service creates these Hosted

Capabilities the Resolver needs a way to add them to the lists of capabilities returned from [findProviders\(Requirement\)](#). The Resolver service cannot add them itself since this list has a preference order, the Resolver service must therefore ask the Resolve Context to insert this new capability to allow the Resolve Context to maintain the desired order.

The Resolve Context must therefore implement an [insertHostedCapability\(List,HostedCapability\)](#) method. The given list must have been returned earlier from a [findProviders\(Requirement\)](#) method invocation. The Resolve Context must find the appropriate position to insert the [HostedCapability](#) object, insert it, and return the index of the inserted object.

It is the responsibility of the Resolve Context to find the proper position. In *Finding Capabilities* on page 451 it was discussed how the [findProviders\(Requirement\)](#) method must return an ordered list. The [insertHostedCapability\(List,HostedCapability\)](#) has that same responsibility.

The following example shows how the Hosted Capability is inserted based on the index of the hosted resource's index in the sorted list of resources the management agent maintained. The example iterates through the capabilities and compares the index of sorted resources to indicate preference. If it finds a capability from a resource that was later in the list of sorted resources then it inserts it at that position. A real implementation should also take the version of the capability into account.

```
public int insertHostedCapability(
    List<Capability> caps, HostedCapability hc ) {

    List<Resource> resources = getSortedResources();
    int index = resources.indexOf( hc.getResource() );

    for ( int i =0; i < caps.size(); i++ ) {
        Capability c = caps.get( i );
        int otherIndex = resources.indexOf( c.getResource() );
        if ( otherIndex > index ) {
            caps.add( i, hc );
            return i;
        }
    }
    caps.add( hc );
    return caps.size()-1;
}
```

58.2.8 Fragments

Fragments are resources that have an `osgi.wiring.host` requirement that must match a capability from one or more host bundles. However, for example an `Export-Package` in a fragment must be merged with its attached hosts. These capabilities and requirements from namespaces that appear as if they come from the host bundle are called *hosted*.

When resolving a set of resources it must be possible to pull in any available fragments which may attach to the resource. Since fragments are not required by the host bundle, there will be no resource requiring the fragment bundles. However, fragments will require their hosts. A Resolver should attach any fragments available in a resolution to suitable hosts.

In order to discover additional fragments which may be attached to the resources in a resolution the [findRelatedResources\(Resource\)](#) method is called by the resolver. The resolver attempts to also resolve the related resources during the current resolve operation. Failing to resolve one of the related resources must not result in a resolution exception unless the related resource is also considered a mandatory resource.

A resolve context may consider a fragment to be a related resource for the hosts it can attach to. In order for the resolver to pull the fragments into the resolve operation the resolve context is asked to return the related resources of each host bundle which is to be resolved. The resolve context may

decide if the fragments of the host needs to be resolved along with the host. Note that fragments are used as an example of a related resource. The resolve context is free to use any type of resource as a related resource.

Fragments can of course also be found by the normal finding of capabilities.

58.2.9 Singleton Capabilities

A resource can be marked as a *singleton*. A singleton resource has the singleton directive set to true on the `osgi.identity` capability. A singleton resource *conflicts* with another singleton resource if:

- They have the same `osgi.identity`, and
- They have the same type, and
- They have a different or identical version.

This constraint is not enforced by the Resolver service to give more flexibility to management agents. The Resolve Context must ensure that it does not return capabilities from conflicting singleton resources from the `findProviders(Requirement)` method. When the Resolver is used with a limited set of resources then it is possible to enumerate all singletons ahead of time and use permutations. However, when repositories are used an incremental method works better because the scope is so much larger.

When the `findProviders(Requirement)` method is called for a requirement that selects a capability declared in a singleton then it is likely that repositories will return multiple versions of this singleton including the resource with the highest available version for conflicting resources. It is therefore possible to maintain a white list of singletons incrementally.

Once the `findProviders(Requirement)` method has created a result list, it is possible to prune this list of conflicting singletons. This can be an incremental process, the first time a singleton is encountered in such a list of capabilities the highest version can be *selected* as the singleton. Other singletons that are in that list or come in other invocations of `findProviders(Requirement)` can then no longer provide capabilities. For example:

```
Map<String,Resource> whitelist = new HashMap<String,Resource>();

void prune( List<Capability> list ) {
    Map<String,Resource> singletons = new HashMap<String,Resource>();

    for ( Capability c : list ) {
        Resource r = c.getResource();
        Version now = getVersion( r );
        String identity = getIdentity( r );

        if ( isSingleton( r ) && !whitelist.containsKey(identity) ) {
            Resource selected = singletons.get( identity );
            if ( selected == null )
                singletons.put( identity, r );
            else {
                Version old = getVersion( selected );
                if ( now.compareTo( old ) > 0 )
                    singletons.put( identity, r );
            }
        }
    }

    this.whitelist.putAll( singletons );
}
```

```

        for ( Iterator<Capability> i=list.iterator(); i.hasNext(); ) {
            Capability c = i.next();
            Resource r = c.getResource();
            String identity = getIdentity( r );
            Resource selected = this.whitelist.get( identity );
            if ( selected != null && !selected.equals( r ))
                i.remove();
        }
    }
}

```

58.2.10 Diagnostics

The Resolver service throws a [ResolutionException](#) when the resolve operation cannot find a solution. This Exception provides the standard human readable message. However, there is also the [getUnresolvedRequirements\(\)](#) method. With this method it is possible to find what requirements could not be matched. Though this is very useful in many cases it must be realized that resolving is a complicated process. It is not possible to establish the exact set of missing requirements because any unresolved resolution can have many, different, sets of unresolved requirements. This is an intrinsic part of the resolution problem. There is also no guarantee that providing capabilities that satisfy these requirements will give a successful resolution. There could still be other constraints that cannot be satisfied. In general, the Resolve Context can already detect any unresolved mandatory requirements when it cannot find a matching capability in the [findProviders\(Requirement\)](#) method.

That said, the [getUnresolvedRequirements\(\)](#) can often point to a potential solution.

58.2.11 Cancel

Some resolution operations can be long running, and therefore a resolve context may want to cancel the currently running resolve operation. The resolver must register a single runnable callback with the resolve context that is associated with the currently running resolve operation. The [onCancel\(Runnable\)](#) method must be invoked by the resolver implementation before any other method on the resolve context is invoked. The resolve context invokes the callback to cancel the currently running resolve operation that appears to be running endlessly or at risk of running out of resources. The resolve context may give up on the resolve operation or attempt to try another resolve operation with a smaller set of resources which may allow the resolve operation to complete normally.

58.2.12 Complexity

Implementing a Resolve Context is a non-trivial task that requires extensive knowledge of the OSGi framework, especially the module layer. Though this section contains numerous code examples, they are not sufficient to implement a real Resolve Context since this would require too much code for a specification.

58.3 Resolver Service

The *Resolver* service is an interface to a generic constraint solver based on the *Require-Capability* model defined in *Resource API Specification* on page 151. This model defines a constraint-solving language that is used by the Framework, see *Module Layer* on page 33, to create the mesh of class loaders. However, the Resolver service has been designed to be useful in solving other types of constraint problems.

The task of the Resolver is to find a *resolution*. The resolve method returns a *delta* on an *existing wiring state*. The total of existing wiring state and the applied delta is the resolution. The delta is a set of wires between requirements and capabilities.

58.3.1

Variables

The `resolve(ResolveContext)` method uses a Resolve Context to provide the context and parameters of the resolution. During the resolution process the Resolver service can callback the Resolve Context to retrieve the following information:

R_m	Collection<Resource>	<code>getMandatoryResources()</code>
R_o	Collection<Resource>	<code>getOptionalResources()</code>
C_{env}	Map<Requirement,List<Capability>>	Combined answers from the <code>findProviders(Requirement)</code> method
Q_{eff}	Collection<Requirement>	Set of effective requirements as defined by the <code>isEffective(Requirement)</code> method
X	Map<Resource,Wiring>	An existing Wiring state, <code>getWirings()</code>
S	Map<Wiring,List<Wire>>	The substitution wires of an existing Wiring state, <code>getSubstitutionWires(Wiring)</code>

The Resolver service returns the following:

D	Map<Resource,List<Wire>>	The resolution, a delta on the existing state
---	--------------------------	---

The `resolve(ResolveContext)` method returns a resolution D that is a delta on the existing Wiring state X. It is up to the Resolve Context to ensure that the delta D is installed. In for example the OSGi framework the framework hooks can be used to guide the framework's resolving process.

58.3.2

Resolving

The goal of the Resolver is to provide a set of wires between a set of *resolved* resources. A resource is resolved when all its *mandatory* and *effective* requirements are satisfied by capabilities from resolved resources. A Resolver must not return wires between resources that have unsatisfied mandatory requirements.

A *mandatory* requirement has a resolution directive that is not set or that is set to mandatory. The *effectiveness* of a requirement is defined by the Resolve Context, a Resolver service must call the `isEffective(Requirement)` method to establish if a requirement is effective for a given resolve operation. A Resolver must never create a wire from a requirement that is not effective.

To find a resolution, the Resolver must use the Resolve Context to find *candidate* capabilities for the requirements declared in the resources that it needs to resolve. A candidate capability is a capability that *satisfies* the requirement. From the perspective of the Resolver service, a requirement is satisfied by a capability when that capability is returned from the `findProviders(Requirement)` method. A Resolver has no alternative way to find out if a requirement is satisfied by a capability and must therefore not make any assumptions about matching. Any matching rules like for example the `osgi.wiring.* mandatory` directive must be implemented by the Resolve Context. A Resolve Context must always return the same capabilities during a resolving operation when given the same requirement.

Since the resolver cannot match requirements and capabilities the Resolve Context must return capabilities for all possible resources, this must include:

- The given mandatory resources R_m
- The given optional resources R_o
- The existing Wiring state X

It can include additional resources that were indirectly returned through the `findProviders(Requirement)` method.

The existing wiring X and its substitution wires S provides an existing set of constraints that the Resolver service must abide by. It can get this state with the `getWirings()` and `getSubstitutionWires(Wiring)` methods. The purpose of the existing state is to ensure that any wires

are compatible with existing wiring. For an OSGi framework it is crucial that the uses constraints are maintained for the resolution, see *Module Layer* on page 33.

The Resolver service can wire new requirements to existing capabilities but it can never create wires for an existing requirement from the existing wiring unless the resolve process is for a dynamic resolve, see *Dynamic Resolving* on page 459.

If the Resolver service attaches a hosted resource like a fragment, and thereby needs to add new [HostedCapability](#) objects to a previously returned list from [findProviders\(Requirement\)](#) then it must call the Resolve Context's [insertHostedCapability\(List,HostedCapability\)](#) method.

Fragments can be attached to resolved resources or to resources that declare the capabilities returned from [findProviders\(Requirement\)](#), that is, C_{env} . Additional resources are also pulled into the resolve operation by invoking the [findRelatedResources\(Resource\)](#) method on the resolve context. As part of the related resources the resolve context can include fragments to be considered as part of the resolve operation. This allows the available fragments to be resolved when the host is being resolved.

This specification does not define the detailed rules and constraints associated with resolving; these rules are defined in their namespaces. An OSGi Resolver service must support at least all namespaces defined in *Framework Namespaces Specification* on page 171 except for the following directives:

- **mandatory** - Mandatory attributes on the `osgi.wiring.*` namespaces must be implemented by the Resolve Context. The Resolve Context should not return capabilities from [findProviders\(Requirement\)](#) unless the rules of the OSGi mandatory directive are followed.
- **singleton** - Singletons are not implemented by the Resolver, the Resolve Context must not return capabilities from [findProviders\(Requirement\)](#) from conflicting singleton resources.
- **effective** - The Resolve Context decides what requirements are effective in the [isEffective\(Requirement\)](#) method.

A Resolver service must support the uses constraints and any applicable rule defined in the *Module Layer* on page 33 for the `osgi.wiring.*` namespaces.

The Resolver must return a delta wiring to the existing state (potentially empty) or throw an Exception. The resolution:

- Must contain all mandatory resources R_m as provided by [getMandatoryResources\(\)](#).
- Must have all resources resolved.
- Must have no wired capabilities that are declared or hosted in resources that are not resolved.
- Should include optional resources R_o as provided by [getOptionalResources\(\)](#).

58.3.3 Dynamic Resolving

The [resolveDynamic\(ResolveContext,Wiring,Requirement\)](#) method is used to resolve a dynamic requirement for an existing host wiring. For example, this method can be used to resolve dynamic package imports as specified by the DynamicImport-Package manifest header. This method may resolve additional resources in order to resolve the dynamic requirement. Dynamic resolving must return a resolution D that is a delta on the existing Wiring state X or throw a [ResolutionException](#) if the dynamic requirement cannot be resolved.

The delta must contain the host resource of the host wiring as a key. The list of wires for the host resource entry will contain a single wire that resolves the dynamic requirement to a valid capability. The delta wiring may also contain additional resources that are necessary to resolve the dynamic requirement.

To find a dynamic resolution D , the Resolver must use the Resolve Context in the same way as normal resolving except the Resolve Context is not asked for mandatory or optional resources as provided by [getMandatoryResources\(\)](#) and [getOptionalResources\(\)](#). The Resolve Context is asked to find providers for the dynamic requirement as provided by [findProviders\(Requirement\)](#).

The Resolver assumes the following about the host wiring and the dynamic requirement:

- The requirement uses the `osgi.wiring.package` namespace.
- The requirement has a resolution directive of `dynamic`.
- The requirement is hosted by the host wiring.
- A requirement that has a cardinality directive of `single` is not used by an existing required wire of the host wiring.

The Resolver is not required to validate these assumptions. If these assumptions are not true then the result of the dynamic resolution is not specified.

The Resolver uses the dynamic requirement to call `findProviders(Requirement)` in order to find valid matching capabilities. In order for a matching capability to be considered as valid it must satisfy the following rules:

- The capability must use the `osgi.wiring.package` namespace.
- The wiring must not provide an `osgi.wiring.package` capability that has the same package name as the matching capability. In other words, the resolved bundle must not already export the package name.
- The wiring must not have a required wire that wires to an `osgi.wiring.package` capability that has the same package name as the matching capability. In other words, the resolved bundle must not already import the package name.

The Resolver assumes the matching capabilities are valid. If invalid capabilities are returned by the Resolve Context then the result of the dynamic resolution is not specified.

At this point the dynamic resolution continues on as a normal resolution where the host wiring resource is considered a mandatory resource and the dynamic requirement is considered a mandatory requirement. The resources providing the matching capabilities to the dynamic requirement are then resolved as in a normal resolution operation.

58.3.4 Resolution Exception

If the Resolver cannot find a solution or it runs into problems then it must throw a Resolution Exception, which is a Runtime Exception.

The `ResolutionException` provides the `getUnresolvedRequirements()` method. If the resolution failed then it is possible that this was caused because it failed to find matches for certain requirements. The information in this method can be very helpful to find a solution that will work, however, there are a number of caveats.

Resolving is an NP-complete problem. For these problems there exists no algorithm that can infer a solution from the desired outcome. Therefore, the Resolver tries a potential solution and if that solution does not match the constraints it will backtrack and attempt another solution. An unavoidable aspect of such solutions is that it is impossible to pin-point a single failure point if the algorithm fails to find a solution, in general the algorithm gives up after having exhausted its search space. However, during its search it might have been very close to a solution, for example it only missed a single requirement, but its final failure missed many requirements.

The implication is that the reported missing requirements neither give a guarantee for a resolution when satisfied nor indicate that this is the smallest set of missing requirements.

Therefore, `getUnresolvedRequirements()` is intended for human consumption and not for automated solutions.

58.4 Security

58.4.1 Resolving

The Resolver service is a pure function that has no state. The Resolve Context maintains the state and is therefore the actor that requires most permissions. In general, it will require access to the Wiring API and Repositories.

Since the Resolver requires no external access it does not have to be a trusted service. Resolve Contexts that support security must ensure that the callbacks are executed in a privileged block.

58.4.2 Minimum Implementation Permissions

```
PackagePermission[org.osgi.service.resolver, IMPORT]
ServicePermission[...Resolver, REGISTER ]
```

58.4.3 Minimum Using Permissions

```
PackagePermission[org.osgi.service.repository, IMPORT]
PackagePermission[org.osgi.service.resolver, IMPORT]
PackagePermission[org.osgi.resource, IMPORT]
PackagePermission[org.osgi.framework.wiring, IMPORT]
PackagePermission[org.osgi.framework.namespaces, IMPORT]
ServicePermission[...Resolver, GET ]
... likely needs AdaptPermissions and ServicePermission[...Repository, GET]
```

58.5 org.osgi.service.resolver

Resolver Service Package Version 1.1.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest. This package has two types of users: the consumers that use the API in this package and the providers that implement the API in this package.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.service.resolver; version="[1.1,2.0)"
```

Example import for providers implementing the API in this package:

```
Import-Package: org.osgi.service.resolver; version="[1.1,1.2)"
```

58.5.1 Summary

- `HostedCapability` - A capability hosted by a resource.
- `ResolutionException` - Indicates failure to resolve a set of requirements.
- `ResolveContext` - A resolve context provides resources, options and constraints to the potential solution of a resolve operation.
- `Resolver` - A resolver service resolves the specified resources in the context supplied by the caller.

58.5.2 public interface `HostedCapability` extends `Capability`

A capability hosted by a resource.

A `HostedCapability` is a `Capability` where the `getResource()` method returns a `Resource` that hosts this `Capability` instead of declaring it. This is necessary for cases where the declaring `Resource` of a `Capability` does not match the runtime state. For example, this is the case for fragments attached to a host. Most fragment declared capabilities and requirements become hosted by the host resource. Since a fragment can attach to multiple hosts, a single capability can actually be hosted multiple times.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

58.5.2.1 **public Capability getDeclaredCapability()**

- Return the `Capability` hosted by the `Resource`.

Returns The `Capability` hosted by the `Resource`.

58.5.2.2 **public Resource getResource()**

- Return the `Resource` that hosts this `Capability`.

Returns The `Resource` that hosts this `Capability`.

58.5.3 **public class ResolutionException extends Exception**

Indicates failure to resolve a set of requirements.

If a resolution failure is caused by a missing mandatory dependency a resolver may include any requirements it has considered in the resolution exception. Clients may access this set of dependencies via the `getUnresolvedRequirements()` method.

Resolver implementations may extend this class to provide extra state information about the reason for the resolution failure.

58.5.3.1 **public ResolutionException(String message, Throwable cause, Collection<Requirement> unresolvedRequirements)**

message The message.

cause The cause of this exception.

unresolvedRequirements The unresolved mandatory requirements from mandatory resources or null if no unresolved requirements information is provided.

- Create a `ResolutionException` with the specified message, cause and unresolved requirements.

58.5.3.2 **public ResolutionException(String message)**

message The message.

- Create a `ResolutionException` with the specified message.

58.5.3.3 **public ResolutionException(Throwable cause)**

cause The cause of this exception.

- Create a `ResolutionException` with the specified cause.

58.5.3.4 **public Collection<Requirement> getUnresolvedRequirements()**

- Return the unresolved requirements, if any, for this exception.

The unresolved requirements are provided for informational purposes and the specific set of unresolved requirements that are provided after a resolve failure is not defined.

Returns A collection of the unresolved requirements for this exception. The returned collection may be empty if no unresolved requirements information is available.

58.5.4 public abstract class ResolveContext

A resolve context provides resources, options and constraints to the potential solution of a resolve operation.

Resolve Contexts:

- Specify the mandatory and optional resources to resolve. The mandatory and optional resources must be consistent and correct. For example, they must not violate the singleton policy of the implementer.
- Provide capabilities that the Resolver can use to satisfy requirements via the `findProviders(Requirement)` method
- Constrain solutions via the `getWirings()` method. A wiring consists of a map of existing resources to wiring.
- Filter requirements that are part of a resolve operation via the `isEffective(Requirement)`.

A resolver may call the methods on the resolve context any number of times during a resolve operation using any thread. Implementors should ensure that this class is properly thread safe.

Except for `insertHostedCapability(List, HostedCapability)` and `onCancel(Runnable)`, the resolve context methods must be *idempotent*. This means that resources must have constant capabilities and requirements and the resolve context must return a consistent set of capabilities, wires and effective requirements.

Concurrency Thread-safe

58.5.4.1 public ResolveContext()

58.5.4.2 public abstract List<Capability> findProviders(Requirement requirement)

requirement The requirement that a resolver is attempting to satisfy. Must not be null.

- Find Capabilities that match the given Requirement.

The returned list contains Capability objects where the Resource must be the declared Resource of the Capability. The Resolver can then add additional HostedCapability objects with the `insertHostedCapability(List, HostedCapability)` method when it, for example, attaches fragments. Those HostedCapability objects will then use the host's Resource which likely differs from the declared Resource of the corresponding Capability.

The returned list is in priority order such that the Capabilities with a lower index have a preference over those with a higher index. The resolver must use the `insertHostedCapability(List, HostedCapability)` method to add additional Capabilities to maintain priority order. In general, this is necessary when the Resolver uses Capabilities declared in a Resource but that must originate from an attached host.

Each returned Capability must match the given Requirement. This means that the filter in the Requirement must match as well as any namespace specific directives. For example, the mandatory attributes for the `osgi.wiring.package` namespace.

Returns A list of Capability objects that match the specified requirement.

58.5.4.3 public Collection<Resource> findRelatedResources(Resource resource)

resource The Resource that a resolver is attempting to find related resources for. Must not be null.

- Find resources that are related to the given resource.

The resolver attempts to resolve related resources during the current resolve operation. Failing to resolve one of the related resources will not result in a resolution exception unless the related resource is also a mandatory resource.

The resolve context is asked to return related resources for each resource that is pulled into a resolve operation. This includes the mandatory and optional resources and each related resource returned by this method.

For example, a fragment can be considered a related resource for a host bundle. When a host is being resolved the resolve context will be asked if any related resources should be added to the resolve operation. The resolve context may decide that the potential fragments of the host should be resolved along with the host.

Returns A collection of the resources that the resolver should attempt to resolve for this resolve context. May be empty if there are no related resources. The returned collection may be unmodifiable.

Since 1.1

58.5.4.4 **public Collection<Resource> getMandatoryResources()**

- Return the resources that must be resolved for this resolve context.

The default implementation returns an empty collection.

Returns A collection of the resources that must be resolved for this resolve context. May be empty if there are no mandatory resources. The returned collection may be unmodifiable.

58.5.4.5 **public Collection<Resource> getOptionalResources()**

- Return the resources that the resolver should attempt to resolve for this resolve context. Inability to resolve one of the specified resources will not result in a resolution exception.

The default implementation returns an empty collection.

Returns A collection of the resources that the resolver should attempt to resolve for this resolve context. May be empty if there are no optional resources. The returned collection may be unmodifiable.

58.5.4.6 **public List<Wire> getSubstitutionWires(Wiring wiring)**

wiring the wiring to get the substitution wires for. Must not be null.

- Returns the subset of required wires that provide wires to capabilities which substitute capabilities of the wiring. For example, when a package name is both provided and required by the same resource. If the package requirement is resolved to a capability provided by a different wiring then the package capability is considered to be substituted.

The resolver asks the resolve context to return substitution wires for each wiring that provides a bundle namespace capability that is used to resolve one or more bundle requirements.

Note that this method searches all the package capabilities declared as provided by the resource associated with the wiring and fragment resources wired to the wiring with the host namespace. The provided package names are compared against the required package wires to determine which wires are substitution wires. Subclasses of ResolveContext should provide a more efficient implementation of this method.

Returns A list containing a snapshot of the substitution Wires for the requirements of the wiring, or an empty list if the wiring has no substitution wires. The list contains the wires in the order they are found in the required wires of the wiring.

Since 1.1

58.5.4.7 **public abstract Map<Resource, Wiring> getWirings()**

- Returns the wirings for existing resolved resources.

For example, if this resolve context is for an OSGi framework, then the result would contain all the currently resolved bundles with each bundle's current wiring.

Multiple calls to this method for this resolve context must return the same result.

Returns The wirings for existing resolved resources. The returned map is unmodifiable.

58.5.4.8 **public abstract int insertHostedCapability(List<Capability> capabilities, HostedCapability hostedCapability)**

capabilities The list returned from findProviders(Requirement). Must not be null.

hostedCapability The HostedCapability to insert in the specified list. Must not be null.

- Add a HostedCapability to the list of capabilities returned from findProviders(Requirement).

This method is used by the Resolver to add Capabilities that are hosted by another Resource to the list of Capabilities returned from findProviders(Requirement). This function is necessary to allow fragments to attach to hosts, thereby changing the origin of a Capability. This method must insert the specified HostedCapability in a place that makes the list maintain the preference order. It must return the index in the list of the inserted HostedCapability.

Returns The index in the list of the inserted HostedCapability.

58.5.4.9 **public abstract boolean isEffective(Requirement requirement)**

requirement The Requirement to test. Must not be null.

- Test if a given requirement should be wired in the resolve operation. If this method returns false, then the resolver should ignore this requirement during the resolve operation.

The primary use case for this is to test the effective directive on the requirement, though implementations are free to use any effective test.

Returns true if the requirement should be considered as part of the resolve operation.

58.5.4.10 **public void onCancel(Runnable callback)**

callback the callback to execute in order to cancel the resolve operation. Must not be null.

- Registers a callback with the resolve context that is associated with the currently running resolve operation. The callback can be executed in order to cancel the currently running resolve operation.

When a resolve operation begins, the resolver must call this method once and only once for the duration of the resolve operation and that call must happen before calling any other method on this resolve context. If the specified callback is executed then the resolver must cancel the currently running resolve operation and throw a ResolutionException with a cause of type CancellationException.

The callback allows a resolve context to cancel a long running resolve operation that appears to be running endlessly or at risk of running out of resources. The resolve context may then decide to give up on resolve operation or attempt to try another resolve operation with a smaller set of resources which may allow the resolve operation to complete normally.

Throws IllegalStateException– if the resolver attempts to register more than one callback for a resolve operation

Since 1.1

58.5.5 **public interface Resolver**

A resolver service resolves the specified resources in the context supplied by the caller.

Concurrency Thread-safe

Provider Type Consumers of this API must not implement this type

58.5.5.1 public Map<Resource, List<Wire>> resolve(ResolveContext context) throws ResolutionException

context The resolve context for the resolve operation. Must not be null.

- Resolve the specified resolve context and return any new resources and wires to the caller.

The resolver considers two groups of resources:

- Mandatory - any resource in the mandatory group must be resolved. A failure to satisfy any mandatory requirement for these resources will result in throwing a ResolutionException
- Optional - any resource in the optional group may be resolved. A failure to satisfy a mandatory requirement for a resource in this group will not fail the overall resolution but no resources or wires will be returned for that resource.

The resolve method returns the delta between the start state defined by `ResolveContext.getWirings()` and the end resolved state. That is, only new resources and wires are included.

The behavior of the resolver is not defined if the specified resolve context supplies inconsistent information.

Returns The new resources and wires required to satisfy the specified resolve context. The returned map is the property of the caller and can be modified by the caller.

Throws ResolutionException– If the resolution cannot be satisfied.

58.5.5.2 public Map<Resource, List<Wire>> resolveDynamic(ResolveContext context, Wiring hostWiring, Requirement dynamicRequirement) throws ResolutionException

context The resolve context for the resolve operation. Must not be null.

hostWiring The wiring with the dynamic requirement. Must not be null.

dynamicRequirement The dynamic requirement. Must not be null.

- Resolves a given requirement dynamically for the given host wiring using the given resolve context and return any new resources and wires to the caller.

The requirement must be a requirement of the wiring and must use the package namespace with a resolution of type dynamic.

The resolve context is not asked for mandatory resources or for optional resources. The resolve context is asked to find providers for the given requirement. The matching package capabilities returned by the resolve context must not have a `osgi.wiring.package` attribute equal to a package capability already wired to by the wiring or equal a package capability provided by the wiring. The resolve context may be requested to find providers for other requirements in order to resolve the resources that provide the matching capabilities to the given requirement.

If the requirement cardinality is not multiple then no new wire must be created if the wires of the wiring already contain a wire that uses the requirement

This operation may resolve additional resources in order to resolve the dynamic requirement. The returned map will contain entries for each resource that got resolved in addition to the specified wiring resource. The wire list for the wiring resource will only contain one wire which is for the dynamic requirement.

Returns The new resources and wires required to satisfy the specified dynamic requirement. The returned map is the property of the caller and can be modified by the caller. If no new wires were created then a ResolutionException is thrown.

Throws ResolutionException– if the dynamic requirement cannot be resolved

58.6 References

- [1] *Repository Service Specification*
OSGi Compendium, Chapter 132 Repository Service Specification

58.7 Changes

- Added new methods: `findRelatedResources`, `onCancel`, `getSubstitutionWires`, and `resolveDynamic`.

701 Tracker Specification

Version 1.5

701.1 Introduction

The Framework provides a powerful and very dynamic programming environment: Bundles are installed, started, stopped, updated, and uninstalled without shutting down the Framework. Dependencies between bundles are monitored by the Framework, but bundles *must* cooperate in handling these dependencies correctly. Two important *dynamic* aspects of the Framework are the service registry and the set of installed bundles.

Bundle developers must be careful not to use service objects that have been unregistered and are therefore stale. The dynamic nature of the Framework service registry makes it necessary to track the service objects as they are registered and unregistered to prevent problems. It is easy to overlook race conditions or boundary conditions that will lead to random errors. Similar problems exist when tracking the set of installed bundles and their state.

This specification defines two utility classes, `ServiceTracker` and `BundleTracker`, that make tracking services and bundles easier. A `ServiceTracker` class can be customized by implementing the `ServiceTrackerCustomizer` interface or by sub-classing the `ServiceTracker` class. Similarly, a `BundleTracker` class can be customized by sub-classing or implementing the `BundleTrackerCustomizer` interface.

These utility classes significantly reduce the complexity of tracking services in the service registry and the set of installed bundles.

701.1.1 Essentials

- *Simplify* - Make it simple to tracking services or bundles.
- *Customizable* - Allow a default implementation to be customized so that bundle developers can start simply and later extend the implementation to meet their needs.
- *Small* - Every Framework implementation should have this utility implemented. It should therefore be very small because some Framework implementations target minimal OSGi frameworks.
- *Services* - Track a set of services, optionally filtered, or track a single service.
- *Bundles* - Track bundles based on their state.
- *Cleanup* - Properly clean up when tracking is no longer necessary
- *Generified* - Generics are used to promote type safety.

701.1.2 Operation

The fundamental tasks of a tracker are:

- To create an initial list of *targets* (service or bundle).
- To listen to the appropriate events so that the targets are properly tracked.
- To allow the client to customize the tracking process through programmatic selection of the services/bundles to be tracked, as well as to perform client code when a service/bundle is added or removed.

A `ServiceTracker` object is populated with a set of services that match given search criteria, and then listens to `ServiceEvent` objects which correspond to those services. A `Bundle Tracker` is populated

with the set of installed bundles and then listens to `BundleEvent` objects to notify the customizer of changes in the state of the bundles.

701.1.3 Entities

Figure 701.1

Class diagram of `org.osgi.util.tracker`



701.2 Tracking

The OSGi Framework is a dynamic multi-threaded environment. In such an environments callbacks can occur on different threads at the same time. This dynamism causes many complexities. One of the surprisingly hard aspects of this environment is to reliably track services and bundles (called *targets* from now on).

The complexity is caused by the fact that the `BundleListener` and `ServiceListener` interfaces are only providing access to the *changed* state, not to the existing state when the listener is registered. This leaves the programmer with the problem to merge the set of existing targets with the changes to the state as signified by the events, without unwantedly duplicating a target or missing a remove event that would leave a target in the tracked map while it is in reality gone. These problems are caused by the multi-threaded nature of OSGi.

The problem is illustrated with the following (quite popular) code:

```

// Bad Example! Do not do this!
Bundle[] bundles = context.getBundles();
for ( Bundle bundle : bundles ) {
    map.put(bundle.getLocation(), bundle );
}

context.addBundleListener( new BundleListener() {
    public void bundleChanged(BundleEvent event) {
        Bundle bundle = event.getBundle();
        switch(event.getType()) {
            case BundleEvent.INSTALLED:
                map.put(bundle.getLocation(), bundle );
                break;

            case BundleEvent.UNINSTALLED:
                map.remove(bundle.getLocation());
                break;

            default:
                // ignore
        }
    }
});

```

Assume the code runs the first part, getting the existing targets. If during this time a targets state changes, for example bundle is installed or uninstalled, then the event is missed and the map will miss a bundle or it will contain a bundle that is already gone. An easy solution seems to be to first register the listener and then get the existing targets. This solves the earlier problem but will be introduce other problems. In this case, an uninstall event can occur before the bundle has been discovered.

Proper locking can alleviate the problem but it turns out that this easily create solutions that are very prone to deadlocks. Solving this tracking problem is surprisingly hard. For this reason, the OSGi specifications contain a *bundle tracker* and a *service tracker* that are properly implemented. These classes significantly reduce the complexity of the dynamics in an OSGi framework.

701.2.1 Usage

Trackers can be used with the following patterns:

- *As-is* - Each tracker can be used without further customizing. A tracker actively tracks a map of targets and this map can be consulted with a number of methods when the information is needed. This is especially useful for the Service Tracker because it provides convenience methods to wait for services to arrive.
- *Callback object* - Each tracker provides a call back interface that can be implemented by the client code.
- *Sub-classing* - The trackers are designed to be sub-classed. Sub-classes have access to the bundle context and only have to override the callback methods they need.

701.2.2 General API

A tracker hides the mechanisms in the way the targets are stored and evented. From a high level, a tracker maintains a *map* of targets to *wrapper* objects. The wrapper object can be defined by the client, though the Bundle Tracker uses the Bundle object and the Service Tracker uses the service object as default wrapper. The tracker notifies the client of any changes in the state of the target.

A tracker must be constructed with a Bundle Context. This context is used to register listeners and obtain the initial list of targets during the call to the open method. At the end of the life of a tracker it must be closed to release any remaining objects. It is advised to properly close all trackers in the bundle activator's stop method.

A tracker provides a uniform callback interface, which has 3 different methods.

- *Adding* - Provide a new object, obtained from the store or from an event and return the wrapper or a related object. The adding method can decide not to track the target by returning a null object. When null is returned, no modified or remove methods are further called. However, it is possible that the adding method is called again for the same target.
- *Modified* - The target is modified. For example, the service properties have changed or the bundle has changed state. This callback provides a mechanism for the client to update its internal structures. The callback provides the wrapper object.
- *Removing* - The target is no longer tracked. This callback is provided the wrapper object returned from the adding method. This allows for simplified cleanup if the client maintains state about the target.

Each tracker is associated with a callback interface, which it implements itself. That is, a Service Tracker implements the ServiceTrackerCustomizer interface. By implementing this customizer, the tracker can also be sub-classed, this can be quite useful in many cases. Sub-classing can override only one or two of the methods instead of having to implement all methods. When overriding the callback methods, it must be ensured that the wrapper object is treated accordingly to the base implementation in all methods. For example, the Service Tracker's default implementation for the adding method checks out the service and therefore the remove method must unget this same ser-

vice. Changing the wrapper object type to something else can therefore clash with the default implementations.

Trackers can provide all the objects that are tracked, return the mapped wrapper from the target, and deliver the number of tracked targets.

701.2.3 Tracking Count

The tracker also maintains a count that is updated each time that an object is added, modified, or removed, that is any change to the implied map. This tracking count makes it straightforward to verify that a tracker has changed; just store the tracking count and compare it later to see if it has changed.

701.2.4 Multi Threading

The dynamic environment of OSGi requires that tracker are thread safe. However, the tracker closely interacts with the client through a callback interface. The tracker implementation must provide the following guarantees:

- The tracker code calling a callback must not hold any locks

Clients must be aware that their callbacks are reentrant though the tracker implementations guarantee that the add/modified/remove methods can only called in this order for a specific target. A tracker must not call these methods out of order.

701.2.5 Synchronous

Trackers use *synchronous* listeners; the callbacks are called on the same thread as that of the initiating event. Care should be taken to not linger in the callback and perform non-trivial work. Callbacks should return immediately and move substantial work to other threads.

701.3 Service Tracker

The purpose of a Service Tracker is to track *service references*, that is, the target is the ServiceReference object. The Service Tracker uses generics to provide a type safe interface. It has two type arguments:

- S - The service type.
- T - The type used by the program. T can differ from S if the program creates a wrapper around the service object, a common pattern.

The ServiceTracker interface defines three constructors to create ServiceTracker objects, each providing different search criteria:

- `ServiceTracker(BundleContext,String,ServiceTrackerCustomizer)` - This constructor takes a service interface name as the search criterion. The ServiceTracker object must then track all services that are registered under the specified service interface name.
- `ServiceTracker(BundleContext,Filter,ServiceTrackerCustomizer)` - This constructor uses a Filter object to specify the services to be tracked. The ServiceTracker must then track all services that match the specified filter.
- `ServiceTracker(BundleContext,ServiceReference,ServiceTrackerCustomizer)` - This constructor takes a ServiceReference object as the search criterion. The ServiceTracker must then track only the service that corresponds to the specified ServiceReference. Using this constructor, no more than one service must ever be tracked, because a ServiceReference refers to a specific service.
- `ServiceTracker(BundleContext,Class,ServiceTrackerCustomizer)` - This constructor takes a class as argument. The tracker must only track services registered with this name. This is in general the most convenient way to use the Service Tracker.

Each of the ServiceTracker constructors takes a BundleContext object as a parameter. This BundleContext object must be used by a ServiceTracker object to track, get, and unget services.

A new ServiceTracker object must not begin tracking services until its open method is called. There are 2 versions of the open method:

- `open()` - This method is identical to `open(false)`. It is provided for backward compatibility reasons.
- `open(boolean)` - The tracker must start tracking the services as were specified in its constructor. If the boolean parameter is true, it must track all services, regardless if they are compatible with the bundle that created the Service Tracker or not. See *Multiple Version Export Considerations* on page 148 for a description of the compatibility issues when multiple variations of the same package can exist. If the parameter is false, the Service Tracker must only track compatible versions.

701.3.1 Using a Service Tracker

Once a ServiceTracker object is opened, it begins tracking services immediately. A number of methods are available to the bundle developer to monitor the services that are being tracked, including the ones that are in the service registry at that time. The ServiceTracker class defines these methods:

- `getService()` - Returns one of the services being tracked or null if there are no active services being tracked.
- `getServices()` - Returns an array of all the tracked services. The number of tracked services is returned by the size method.
- `getServices(T[])` - Like `getServices()` but provides a convenient way to get these services into a correctly typed array.
- `getServiceReference()` - Returns a ServiceReference object for one of the services being tracked. The service object for this service may be returned by calling the ServiceTracker object's `getService()` method.
- `getServiceReferences()` - Returns a list of the ServiceReference objects for services being tracked. The service object for a specific tracked service may be returned by calling the ServiceTracker object's `getService(ServiceReference)` method.
- `waitForService(long)` - Allows the caller to wait until at least one instance of a service is tracked or until the time-out expires. If the time-out is zero, the caller must wait until at least one instance of a service is tracked. `waitForService` must not be used within the BundleActivator methods, as these methods are expected to complete in a short period of time. A Framework could wait for the start method to complete before starting the bundle that registers the service for which the caller is waiting, creating a deadlock situation.
- `remove(ServiceReference)` - This method may be used to remove a specific service from being tracked by the ServiceTracker object, causing `removedService` to be called for that service.
- `close()` - This method must remove all services being tracked by the ServiceTracker object, causing `removedService` to be called for all tracked services.
- `getTrackingCount()` - A Service Tracker can have services added, modified, or removed at any moment in time. The `getTrackingCount` method is intended to efficiently detect changes in a Service Tracker. Every time the Service Tracker is changed, it must increase the tracking count.
- `isEmpty()` - To detect that the tracker has no tracked services.
- `getTracked()` - Return the tracked objects.

701.3.2 Customizing the Service Tracker class

The behavior of the ServiceTracker class can be customized either by providing a ServiceTrackerCustomizer object, implementing the desired behavior when the ServiceTracker object is constructed, or by sub-classing the ServiceTracker class and overriding the ServiceTrackerCustomizer methods.

The ServiceTrackerCustomizer interface defines these methods:

- `addingService(ServiceReference)` - Called whenever a service is being added to the `ServiceTracker` object.
- `modifiedService(ServiceReference,T)` - Called whenever a tracked service is modified.
- `removedService(ServiceReference,T)` - Called whenever a tracked service is removed from the `ServiceTracker` object.

When a service is being added to the `ServiceTracker` object or when a tracked service is modified or removed from the `ServiceTracker` object, it must call `addingService`, `modifiedService`, or `removedService`, respectively, on the `ServiceTrackerCustomizer` object (if specified when the `ServiceTracker` object was created); otherwise it must call these methods on itself.

A bundle developer may customize the action when a service is tracked. Another reason for customizing the `ServiceTracker` class is to programmatically select which services are tracked. A filter may not sufficiently specify the services that the bundle developer is interested in tracking. By implementing `addingService`, the bundle developer can use additional runtime information to determine if the service should be tracked. If null is returned by the `addingService` method, the service must not be tracked.

Finally, the bundle developer can return a specialized object from `addingService` that differs from the service object. This specialized object could contain the service object and any associated information. This returned object is then tracked instead of the service object. When the `removedService` method is called, the object that is passed along with the `ServiceReference` object is the one that was returned from the earlier call to the `addingService` method.

701.3.3 Customizing Example

An example of customizing the action taken when a service is tracked might be registering a `MyServlet` object with each `Http Service` that is tracked. This customization could be done by subclassing the `ServiceTracker` class and overriding the `addingService` and `removedService` methods as follows:

```
new ServiceTracker<HttpService,MyServlet>(context,HttpService.class,null){
    public MyServlet addingService( ServiceReference<HttpService>reference) {
        HttpService svc = context.getService(reference);
        MyServlet ms = new MyServlet(scv);    return ms;
    }
    public void removedService( ServiceReference<HttpService>reference,
        MyServlet ms) {
        ms.close();
        context.ungetService(reference);
    }
}
```

In this example, the service type is the `HttpService` class and the wrapper type is the `servlet`.

701.4 Bundle Tracker

The purpose of the `Bundle Tracker` is to simplify tracking bundles. A popular example where bundles need to be tracked is the *extender* pattern. An extender uses information in other bundles to provide its function. For example, a `Declarative Services` implementation reads the component XML file from the bundle to learn of the presence of any components in that bundle.

There are, however, other places where it is necessary to track bundles. The `Bundle Tracker` significantly simplifies this task.

701.4.1 Bundle States

The state diagram of a Bundle is significantly more complex than that of a service. However, the interface is simpler because there is only a need to specify for which states the bundle tracker should track a service.

Bundle states are defined as a bit in an integer, allowing the specifications of multiple states by setting multiple bits. The Bundle Tracker therefore uses a *bit mask* to specify which states are of interest. For example, if a client is interested in active and resolved bundles, it is possible to specify the Bundle ACTIVE | RESOLVED | STARTING states in the mask.

The Bundle Tracker tracks bundles whose state matches the mask. That is, when a bundle is not tracked it adds that bundle to the tracked map when its state matches the mask. If the bundle reaches a new state that is not listed in the mask, the bundle will be removed from the tracked map. If the state changes but the bundle should still be tracked, then the bundle is considered to be modified.

701.4.2 Constructor

The BundleTracker interface defines the following constructors to create BundleTracker objects:

- `BundleTracker(BundleContext,int,BundleTrackerCustomizer)` - Create a Bundle Tracker that tracks the bundles which state is listed in the mask. The customizer may be null, in that case the callbacks can be implemented in a subclass.

A new BundleTracker object must not begin tracking services until its open method is called.

- `open()` - Start tracking the bundles, callbacks can occur before this method is called.

701.4.3 Using a Bundle Tracker

Once a BundleTracker object is opened, it begins tracking bundles immediately. A number of methods are available to the bundle developer to monitor the bundles that are being tracked. The BundleTracker class defines the following methods:

- `getBundles()` - Returns an array of all the tracked bundles.
- `getObject(Bundle)` - Returns the wrapper object that was returned from the addingBundle method.
- `remove(Bundle)` - Removes the bundle from the tracked bundles. The removedBundle method is called when the bundle is not in the tracked map.
- `size()` - Returns the number of bundles being tracked.
- `getTrackingCount()` - A Bundle Tracker can have bundles added, modified, or removed at any moment in time. The getTrackingCount method is intended to efficiently detect changes in a Bundle Tracker. Every time the Bundle Tracker is changed, it must increase the tracking count.
- `isEmpty()` - To detect that the tracker has no tracked bundles.
- `getTracked()` - Return the tracked objects.

701.4.4 Customizing the Bundle Tracker class

The behavior of the BundleTracker class can be customized either by providing a BundleTrackerCustomizer object when the BundleTracker object is constructed, or by sub-classing the BundleTracker class and overriding the BundleTrackerCustomizer methods on the BundleTracker class.

The BundleTrackerCustomizer interface defines these methods:

- `addingBundle(Bundle,BundleEvent)` - Called whenever a bundle is being added to the BundleTracker object. This method should return a wrapper object, which can be the Bundle object itself. If null is returned, the Bundle must not be further tracked.

- `modifiedBundle(Bundle, BundleEvent, T)` - Called whenever a tracked bundle is modified. The object that is passed is the object returned from the `addingBundle` method, the wrapper object.
- `removedBundle(Bundle, BundleEvent, T)` - Called whenever a tracked bundle is removed from the `BundleTracker` object. The passed object is the wrapper returned from the `addingBundle` method.

The `BundleEvent` object in the previous methods can be null.

When a bundle is being added the OSGi Framework, or when a tracked bundle is modified or uninstalled from the OSGi Framework, the `Bundle Tracker` must call `addingBundle`, `modifiedBundle`, or `removedBundle`, respectively, on the `BundleTrackerCustomizer` object (if specified when the `BundleTracker` object was created); otherwise it must call these methods on itself, allowing them to be overridden in a subclass.

The bundle developer can return a specialized object from `addingBundle` that differs from the `Bundle` object. This wrapper object could contain the `Bundle` object and any associated client specific information. This returned object is then used as the wrapper instead of the `Bundle` object. When the `removedBundle` method is called, the wrapper is passed as an argument.

701.4.5 Extender Model

The `Bundle Tracker` allows the implementation of extenders with surprisingly little effort. The following example checks a manifest header (`Http-Mapper`) in all active bundles to see if the bundle has resources that need to be mapped to the HTTP service. This extender enables bundles that have no code, just content.

This example is implemented with a `BundleTrackerCustomizer` implementation, though sub-classing the `BundleTracker` class is slightly simpler because the `open/close` methods would be inherited, the `tracker` field is not necessary and it is not necessary to provide a dummy implementation of `modifiedBundle` method. However, the `Service Tracker` example already showed how to use inheritance.

The `Extender` class must implement the customizer and declare fields for the `Http Service` and a `Bundle Tracker`.

```
public class Extender implements BundleTrackerCustomizer<ExtenderContext>{
    final HttpService http;
    final BundleTracker<ExtenderContext> tracker;
```

It is necessary to parse the `Http-Mapper` header. Regular expression allow this to be done very concise.

```
final static Pattern HTTPMAPPER =
    Pattern.compile(
        "\\s*([-/\\w.]+)\\s*=\\s*([-/\\w.]+)\\s*");
```

The `Bundle Tracker` requires a specialized constructor. This example only works for *active* bundles. This implies that a bundle only provides contents when it is started, enabling an administrator to control the availability.

```
Extender(BundleContext context, HttpService http) {
    tracker = new BundleTracker<ExtenderContext>(
        context, Bundle.ACTIVE, this );
    this.http = http;
}
```

The following method implements the callback from the `Bundle Tracker` when a new bundle is discovered. In this method a specialized `HttpContext` object is created that knows how to retrieve its resources from the bundle that was just discovered. This context is registered with the `Http Service`. If no header is found null is returned so that non-participating bundles are no longer tracked.

```

public ExtenderContext addingBundle(Bundlebundle,
    BundleEvent event) {
    String header = bundle.getHeaders()
        .get("Http-Mapper") + "";
    Matcher match = HTTPMAPPER.matcher(header);
    if (match.matches()) {
        try {
            ExtenderContext wrapper =
                new ExtenderContext(bundle, match.group(1));
            http.registerResources(
                match.group(1), // alias
                match.group(2), // resource path
                wrapper         // the http context
            );
            return wrapper;
        } catch (NamespaceException nspe) {
            // error is handled in the fall through
        }
    }
    System.err.println(
        "Invalid header for Http-Mapper: " + header);
    return null;
}

```

The `modifiedBundle` method does not have to be implemented because this example is not interested in state changes because the only state of interest is the ACTIVE state. Therefore, the remaining method left to implement is the `removedBundle` method. If the wrapper object is non-null then we need to unregister the alias to prevent collisions in the http namespace when the bundle is reinstalled or updated.

```

public void removedBundle(
    Bundle bundle, BundleEvent event,
    ExtenderContext wrapper) {
    http.unregister(wrapper.alias);
}

```

The remaining methods would be unnecessary if the `Extender` class had extended the `BundleTracker` class. The `BundleTrackerCustomizer` interface requires a dummy implementation of the `modifiedBundle` method:

```

public void modifiedBundle(
    Bundle bundle, BundleEvent event, ExtenderContext object){
    // Nothing to do
}

```

It is usually not a good idea to start a tracker in a constructor because opening a service tracker will immediately cause a number of callbacks for the existing bundles. If the `Extender` class was subclassed, then this could call back the uninitialized sub class methods. It is therefore better to separate the initialization from the opening. There is therefore a need for an open and close method.

```

public void close() {
    tracker.close();
}
public void open() {
    tracker.open();
}

```

```
}
```

The previous example uses an `HttpContext` subclass that can retrieve resources from the target bundle:

```
public class ExtenderContext implements HttpContext{
    final Bundle bundle;
    final String alias;

    ExtenderContext(Bundle bundle, String alias) {
        this.bundle = bundle;
        this.alias = alias;
    }
    public boolean handleSecurity(
        HttpServletRequest rq, HttpServletResponse rsp) {
        return true;
    }
    public String getMimeType(String name) {
        return null;
    }
    public URL getResource(String name) {
        return bundle.getResource(name);
    }
}
```

701.5 Security

A tracker contains a `BundleContext` instance variable that is accessible to the methods in a subclass. A `BundleContext` object should never be given to other bundles because it is a *capability*. The framework makes allocations based on the bundle context with respect to security and resource management.

The tracker implementations do not have a method to get the `BundleContext` object, however, subclasses should be careful not to provide such a method if the tracker is given to other bundles.

The services that are being tracked are available via a `ServiceTracker`. These services are dependent on the `BundleContext` as well. It is therefore necessary to do a careful security analysis when `ServiceTracker` objects are given to other bundles. The same counts for the `BundleTracker`. It is strongly advised to not pass trackers to other bundles.

701.5.1 Synchronous Bundle Listener

The `BundleTracker` uses the synchronous bundle listener because it is impossible to provide some of the guarantees the `BundleTracker` provides without handling the events synchronously. Synchronous events can block the complete system, therefore `Synchronous Bundle Listeners` require `AdminPermission[*,LISTENER]`. The wildcard `*` can be replaced with a specifier for the bundles that should be visible to the `BundleTracker`. See *Admin Permission* on page 129 for more information.

Code that calls the open and close methods of `BundleTrackers` must therefore have the appropriate `Admin Permission`.

701.6 org.osgi.util.tracker

Tracker Package Version 1.5.

Bundles wishing to use this package must list the package in the Import-Package header of the bundle's manifest.

Example import for consumers using the API in this package:

```
Import-Package: org.osgi.util.tracker; version="[1.5,2.0]"
```

701.6.1

Summary

- **BundleTracker** - The BundleTracker class simplifies tracking bundles much like the ServiceTracker simplifies tracking services.
- **BundleTrackerCustomizer** - The BundleTrackerCustomizer interface allows a BundleTracker to customize the Bundles that are tracked.
- **ServiceTracker** - The ServiceTracker class simplifies using services from the Framework's service registry.
- **ServiceTrackerCustomizer** - The ServiceTrackerCustomizer interface allows a ServiceTracker to customize the service objects that are tracked.

701.6.2

public class BundleTracker<T> implements BundleTrackerCustomizer<T>

<T> The type of the tracked object.

The BundleTracker class simplifies tracking bundles much like the ServiceTracker simplifies tracking services.

A BundleTracker is constructed with state criteria and a BundleTrackerCustomizer object. A BundleTracker can use the BundleTrackerCustomizer to select which bundles are tracked and to create a customized object to be tracked with the bundle. The BundleTracker can then be opened to begin tracking all bundles whose state matches the specified state criteria.

The getBundles method can be called to get the Bundle objects of the bundles being tracked. The getObject method can be called to get the customized object for a tracked bundle.

The BundleTracker class is thread-safe. It does not call a BundleTrackerCustomizer while holding any locks. BundleTrackerCustomizer implementations must also be thread-safe.

Since 1.4

Concurrency Thread-safe

701.6.2.1

protected final BundleContext context

The Bundle Context used by this BundleTracker.

701.6.2.2

public BundleTracker(BundleContext context, int stateMask, BundleTrackerCustomizer<T> customizer)

context The BundleContext against which the tracking is done.

stateMask The bit mask of the ORing of the bundle states to be tracked.

customizer The customizer object to call when bundles are added, modified, or removed in this BundleTracker. If customizer is null, then this BundleTracker will be used as the BundleTrackerCustomizer and this BundleTracker will call the BundleTrackerCustomizer methods on itself.

- Create a BundleTracker for bundles whose state is present in the specified state mask.

Bundles whose state is present on the specified state mask will be tracked by this BundleTracker.

See Also Bundle.getState()

701.6.2.3

public T addingBundle(Bundle bundle, BundleEvent event)

bundle The Bundle being added to this BundleTracker object.

event The bundle event which caused this customizer method to be called or null if there is no bundle event associated with the call to this method.

- Default implementation of the BundleTrackerCustomizer.addingBundle method.

This method is only called when this BundleTracker has been constructed with a null BundleTrackerCustomizer argument.

This implementation simply returns the specified Bundle.

This method can be overridden in a subclass to customize the object to be tracked for the bundle being added.

Returns The specified bundle.

See Also BundleTrackerCustomizer.addingBundle(Bundle, BundleEvent)

701.6.2.4 **public void close()**

- Close this BundleTracker.

This method should be called when this BundleTracker should end the tracking of bundles.

This implementation calls getBundles() to get the list of tracked bundles to remove.

701.6.2.5 **public Bundle[] getBundles()**

- Return an array of Bundles for all bundles being tracked by this BundleTracker.

Returns An array of Bundles or null if no bundles are being tracked.

701.6.2.6 **public T getObject(Bundle bundle)**

bundle The Bundle being tracked.

- Returns the customized object for the specified Bundle if the specified bundle is being tracked by this BundleTracker.

Returns The customized object for the specified Bundle or null if the specified Bundle is not being tracked.

701.6.2.7 **public Map<Bundle, T> getTracked()**

- Return a Map with the Bundles and customized objects for all bundles being tracked by this BundleTracker.

Returns A Map with the Bundles and customized objects for all services being tracked by this BundleTracker. If no bundles are being tracked, then the returned map is empty.

Since 1.5

701.6.2.8 **public int getTrackingCount()**

- Returns the tracking count for this BundleTracker. The tracking count is initialized to 0 when this BundleTracker is opened. Every time a bundle is added, modified or removed from this BundleTracker the tracking count is incremented.

The tracking count can be used to determine if this BundleTracker has added, modified or removed a bundle by comparing a tracking count value previously collected with the current tracking count value. If the value has not changed, then no bundle has been added, modified or removed from this BundleTracker since the previous tracking count was collected.

Returns The tracking count for this BundleTracker or -1 if this BundleTracker is not open.

701.6.2.9 **public boolean isEmpty()**

- Return if this BundleTracker is empty.

Returns true if this BundleTracker is not tracking any bundles.

Since 1.5

701.6.2.10 public void modifiedBundle(Bundle bundle, BundleEvent event, T object)

bundle The Bundle whose state has been modified.

event The bundle event which caused this customizer method to be called or null if there is no bundle event associated with the call to this method.

object The customized object for the specified Bundle.

- Default implementation of the BundleTrackerCustomizer.modifiedBundle method.

This method is only called when this BundleTracker has been constructed with a null BundleTrackerCustomizer argument.

This implementation does nothing.

See Also BundleTrackerCustomizer.modifiedBundle(Bundle, BundleEvent, Object)

701.6.2.11 public void open()

- Open this BundleTracker and begin tracking bundles.

Bundle which match the state criteria specified when this BundleTracker was created are now tracked by this BundleTracker.

Throws IllegalStateException— If the BundleContext with which this BundleTracker was created is no longer valid.

SecurityException— If the caller and this class do not have the appropriate AdminPermission[context bundle, LISTENER], and the Java Runtime Environment supports permissions.

701.6.2.12 public void remove(Bundle bundle)

bundle The Bundle to be removed.

- Remove a bundle from this BundleTracker. The specified bundle will be removed from this BundleTracker. If the specified bundle was being tracked then the BundleTrackerCustomizer.removedBundle method will be called for that bundle.

701.6.2.13 public void removedBundle(Bundle bundle, BundleEvent event, T object)

bundle The Bundle being removed.

event The bundle event which caused this customizer method to be called or null if there is no bundle event associated with the call to this method.

object The customized object for the specified bundle.

- Default implementation of the BundleTrackerCustomizer.removedBundle method.

This method is only called when this BundleTracker has been constructed with a null BundleTrackerCustomizer argument.

This implementation does nothing.

See Also BundleTrackerCustomizer.removedBundle(Bundle, BundleEvent, Object)

701.6.2.14 public int size()

- Return the number of bundles being tracked by this BundleTracker.

Returns The number of bundles being tracked.

701.6.3 **public interface BundleTrackerCustomizer<T>**

<T> The type of the tracked object.

The BundleTrackerCustomizer interface allows a BundleTracker to customize the Bundles that are tracked. A BundleTrackerCustomizer is called when a bundle is being added to a BundleTracker. The BundleTrackerCustomizer can then return an object for the tracked bundle. A BundleTrackerCustomizer is also called when a tracked bundle is modified or has been removed from a BundleTracker.

The methods in this interface may be called as the result of a BundleEvent being received by a BundleTracker. Since BundleEvents are received synchronously by the BundleTracker, it is highly recommended that implementations of these methods do not alter bundle states while being synchronized on any object.

The BundleTracker class is thread-safe. It does not call a BundleTrackerCustomizer while holding any locks. BundleTrackerCustomizer implementations must also be thread-safe.

Since 1.4

Concurrency Thread-safe

701.6.3.1 **public T addingBundle(Bundle bundle, BundleEvent event)**

bundle The Bundle being added to the BundleTracker.

event The bundle event which caused this customizer method to be called or null if there is no bundle event associated with the call to this method.

- A bundle is being added to the BundleTracker.

This method is called before a bundle which matched the search parameters of the BundleTracker is added to the BundleTracker. This method should return the object to be tracked for the specified Bundle. The returned object is stored in the BundleTracker and is available from the getObject method.

Returns The object to be tracked for the specified Bundle object or null if the specified Bundle object should not be tracked.

701.6.3.2 **public void modifiedBundle(Bundle bundle, BundleEvent event, T object)**

bundle The Bundle whose state has been modified.

event The bundle event which caused this customizer method to be called or null if there is no bundle event associated with the call to this method.

object The tracked object for the specified bundle.

- A bundle tracked by the BundleTracker has been modified.

This method is called when a bundle being tracked by the BundleTracker has had its state modified.

701.6.3.3 **public void removedBundle(Bundle bundle, BundleEvent event, T object)**

bundle The Bundle that has been removed.

event The bundle event which caused this customizer method to be called or null if there is no bundle event associated with the call to this method.

object The tracked object for the specified bundle.

- A bundle tracked by the BundleTracker has been removed.

This method is called after a bundle is no longer being tracked by the BundleTracker.

701.6.4 **public class ServiceTracker<S, T> implements ServiceTrackerCustomizer<S, T>**

<S> The type of the service being tracked.

<T> The type of the tracked object.

The ServiceTracker class simplifies using services from the Framework's service registry.

A ServiceTracker object is constructed with search criteria and a ServiceTrackerCustomizer object. A ServiceTracker can use a ServiceTrackerCustomizer to customize the service objects to be tracked. The ServiceTracker can then be opened to begin tracking all services in the Framework's service registry that match the specified search criteria. The ServiceTracker correctly handles all of the details of listening to ServiceEvents and getting and ungetting services.

The getServiceReferences method can be called to get references to the services being tracked. The getService and getServices methods can be called to get the service objects for the tracked service.

The ServiceTracker class is thread-safe. It does not call a ServiceTrackerCustomizer while holding any locks. ServiceTrackerCustomizer implementations must also be thread-safe.

Concurrency Thread-safe

701.6.4.1 **protected final BundleContext context**

The Bundle Context used by this ServiceTracker.

701.6.4.2 **protected final Filter filter**

The Filter used by this ServiceTracker which specifies the search criteria for the services to track.

Since 1.1

701.6.4.3 **public ServiceTracker(BundleContext context, ServiceReference<S> reference, ServiceTrackerCustomizer<S, T> customizer)**

context The BundleContext against which the tracking is done.

reference The ServiceReference for the service to be tracked.

customizer The customizer object to call when services are added, modified, or removed in this ServiceTracker. If customizer is null, then this ServiceTracker will be used as the ServiceTrackerCustomizer and this ServiceTracker will call the ServiceTrackerCustomizer methods on itself.

- Create a ServiceTracker on the specified ServiceReference .

The service referenced by the specified ServiceReference will be tracked by this ServiceTracker.

701.6.4.4 **public ServiceTracker(BundleContext context, String clazz, ServiceTrackerCustomizer<S, T> customizer)**

context The BundleContext against which the tracking is done.

clazz The class name of the services to be tracked.

customizer The customizer object to call when services are added, modified, or removed in this ServiceTracker. If customizer is null, then this ServiceTracker will be used as the ServiceTrackerCustomizer and this ServiceTracker will call the ServiceTrackerCustomizer methods on itself.

- Create a ServiceTracker on the specified class name.

Services registered under the specified class name will be tracked by this ServiceTracker.

701.6.4.5 **public ServiceTracker(BundleContext context, Filter filter, ServiceTrackerCustomizer<S, T> customizer)**

context The BundleContext against which the tracking is done.

filter The Filter to select the services to be tracked.

customizer The customizer object to call when services are added, modified, or removed in this ServiceTracker. If customizer is null, then this ServiceTracker will be used as the ServiceTrackerCustomizer and this ServiceTracker will call the ServiceTrackerCustomizer methods on itself.

- Create a ServiceTracker on the specified Filter object.

Services which match the specified Filter object will be tracked by this ServiceTracker.

Since 1.1

701.6.4.6 public ServiceTracker(BundleContext context, Class<S> clazz, ServiceTrackerCustomizer<S, T> customizer)

context The BundleContext against which the tracking is done.

clazz The class of the services to be tracked.

customizer The customizer object to call when services are added, modified, or removed in this ServiceTracker. If customizer is null, then this ServiceTracker will be used as the ServiceTrackerCustomizer and this ServiceTracker will call the ServiceTrackerCustomizer methods on itself.

- Create a ServiceTracker on the specified class.

Services registered under the name of the specified class will be tracked by this ServiceTracker.

Since 1.5

701.6.4.7 public T addingService(ServiceReference<S> reference)

reference The reference to the service being added to this ServiceTracker.

- Default implementation of the ServiceTrackerCustomizer.addingService method.

This method is only called when this ServiceTracker has been constructed with a null ServiceTrackerCustomizer argument.

This implementation returns the result of calling getService, on the BundleContext with which this ServiceTracker was created, passing the specified ServiceReference.

This method can be overridden in a subclass to customize the service object to be tracked for the service being added. In that case, take care not to rely on the default implementation of removedService to unget the service.

Returns The service object to be tracked for the service added to this ServiceTracker.

See Also ServiceTrackerCustomizer.addingService(ServiceReference)

701.6.4.8 public void close()

- Close this ServiceTracker.

This method should be called when this ServiceTracker should end the tracking of services.

This implementation calls getServiceReferences() to get the list of tracked services to remove.

701.6.4.9 public T getService(ServiceReference<S> reference)

reference The reference to the desired service.

- Returns the service object for the specified ServiceReference if the specified referenced service is being tracked by this ServiceTracker.

Returns A service object or null if the service referenced by the specified ServiceReference is not being tracked.

701.6.4.10 public T getService()

- Returns a service object for one of the services being tracked by this ServiceTracker.

If any services are being tracked, this implementation returns the result of calling `getService(getServiceReference())`.

Returns A service object or null if no services are being tracked.

701.6.4.11 **public ServiceReference<S> getServiceReference()**

- Returns a `ServiceReference` for one of the services being tracked by this `ServiceTracker`.

If multiple services are being tracked, the service with the highest ranking (as specified in its `service.ranking` property) is returned. If there is a tie in ranking, the service with the lowest service id (as specified in its `service.id` property); that is, the service that was registered first is returned. This is the same algorithm used by `BundleContext.getServiceReference`.

This implementation calls `getServiceReferences()` to get the list of references for the tracked services.

Returns A `ServiceReference` or null if no services are being tracked.

Since 1.1

701.6.4.12 **public ServiceReference<S>[] getServiceReferences()**

- Return an array of `ServiceReferences` for all services being tracked by this `ServiceTracker`.

Returns Array of `ServiceReferences` or null if no services are being tracked.

701.6.4.13 **public Object[] getServices()**

- Return an array of service objects for all services being tracked by this `ServiceTracker`.

This implementation calls `getServiceReferences()` to get the list of references for the tracked services and then calls `getService(ServiceReference)` for each reference to get the tracked service object.

Returns An array of service objects or null if no services are being tracked.

701.6.4.14 **public T[] getServices(T[] array)**

array An array into which the tracked service objects will be stored, if the array is large enough.

- Return an array of service objects for all services being tracked by this `ServiceTracker`. The runtime type of the returned array is that of the specified array.

This implementation calls `getServiceReferences()` to get the list of references for the tracked services and then calls `getService(ServiceReference)` for each reference to get the tracked service object.

Returns An array of service objects being tracked. If the specified array is large enough to hold the result, then the specified array is returned. If the specified array is longer than necessary to hold the result, the array element after the last service object is set to null. If the specified array is not large enough to hold the result, a new array is created and returned.

Since 1.5

701.6.4.15 **public SortedMap<ServiceReference<S>, T> getTracked()**

- Return a `SortedMap` of the `ServiceReferences` and service objects for all services being tracked by this `ServiceTracker`. The map is sorted in reverse natural order of `ServiceReference`. That is, the first entry is the service with the highest ranking and the lowest service id.

Returns A `SortedMap` with the `ServiceReferences` and service objects for all services being tracked by this `ServiceTracker`. If no services are being tracked, then the returned map is empty.

Since 1.5

701.6.4.16 public int getTrackingCount()

- Returns the tracking count for this ServiceTracker. The tracking count is initialized to 0 when this ServiceTracker is opened. Every time a service is added, modified or removed from this ServiceTracker, the tracking count is incremented.

The tracking count can be used to determine if this ServiceTracker has added, modified or removed a service by comparing a tracking count value previously collected with the current tracking count value. If the value has not changed, then no service has been added, modified or removed from this ServiceTracker since the previous tracking count was collected.

Returns The tracking count for this ServiceTracker or -1 if this ServiceTracker is not open.

Since 1.2

701.6.4.17 public boolean isEmpty()

- Return if this ServiceTracker is empty.

Returns true if this ServiceTracker is not tracking any services.

Since 1.5

701.6.4.18 public void modifiedService(ServiceReference<S> reference, T service)

reference The reference to modified service.

service The service object for the modified service.

- Default implementation of the ServiceTrackerCustomizer.modifiedService method.

This method is only called when this ServiceTracker has been constructed with a null ServiceTrackerCustomizer argument.

This implementation does nothing.

See Also ServiceTrackerCustomizer.modifiedService(ServiceReference, Object)

701.6.4.19 public void open()

- Open this ServiceTracker and begin tracking services.

This implementation calls open(false).

Throws IllegalStateException– If the BundleContext with which this ServiceTracker was created is no longer valid.

See Also open(boolean)

701.6.4.20 public void open(boolean trackAllServices)

trackAllServices If true, then this ServiceTracker will track all matching services regardless of class loader accessibility. If false, then this ServiceTracker will only track matching services which are class loader accessible to the bundle whose BundleContext is used by this ServiceTracker.

- Open this ServiceTracker and begin tracking services.

Services which match the search criteria specified when this ServiceTracker was created are now tracked by this ServiceTracker.

Throws IllegalStateException– If the BundleContext with which this ServiceTracker was created is no longer valid.

Since 1.3

701.6.4.21 public void remove(ServiceReference<S> reference)

reference The reference to the service to be removed.

- Remove a service from this ServiceTracker. The specified service will be removed from this ServiceTracker. If the specified service was being tracked then the ServiceTrackerCustomizer.removedService method will be called for that service.

701.6.4.22 **public void removedService(ServiceReference<S> reference, T service)**

reference The reference to removed service.

service The service object for the removed service.

- Default implementation of the ServiceTrackerCustomizer.removedService method.

This method is only called when this ServiceTracker has been constructed with a null ServiceTrackerCustomizer argument.

This implementation calls ungetService, on the BundleContext with which this ServiceTracker was created, passing the specified ServiceReference.

This method can be overridden in a subclass. If the default implementation of addingService method was used, this method must unget the service.

See Also ServiceTrackerCustomizer.removedService(ServiceReference, Object)

701.6.4.23 **public int size()**

- Return the number of services being tracked by this ServiceTracker.

Returns The number of services being tracked.

701.6.4.24 **public T waitForService(long timeout) throws InterruptedException**

timeout The time interval in milliseconds to wait. If zero, the method will wait indefinitely.

- Wait for at least one service to be tracked by this ServiceTracker. This method will also return when this ServiceTracker is closed.

It is strongly recommended that waitForService is not used during the calling of the BundleActivator methods. BundleActivator methods are expected to complete in a short period of time.

This implementation calls getService() to determine if a service is being tracked.

Returns Returns the result of getService().

Throws InterruptedException– If another thread has interrupted the current thread.

IllegalArgumentException– If the value of timeout is negative.

701.6.5 **public interface ServiceTrackerCustomizer<S, T>**

<S> The type of the service being tracked.

<T> The type of the tracked object.

The ServiceTrackerCustomizer interface allows a ServiceTracker to customize the service objects that are tracked. A ServiceTrackerCustomizer is called when a service is being added to a ServiceTracker. The ServiceTrackerCustomizer can then return an object for the tracked service. A ServiceTrackerCustomizer is also called when a tracked service is modified or has been removed from a ServiceTracker.

The methods in this interface may be called as the result of a ServiceEvent being received by a ServiceTracker. Since ServiceEvents are synchronously delivered by the Framework, it is highly recommended that implementations of these methods do not register (BundleContext.registerService), modify (ServiceRegistration.setProperties) or unregister (ServiceRegistration.unregister) a service while being synchronized on any object.

The ServiceTracker class is thread-safe. It does not call a ServiceTrackerCustomizer while holding any locks. ServiceTrackerCustomizer implementations must also be thread-safe.

Concurrency Thread-safe

701.6.5.1 public T addingService(ServiceReference<S> reference)

reference The reference to the service being added to the ServiceTracker.

- A service is being added to the ServiceTracker.

This method is called before a service which matched the search parameters of the ServiceTracker is added to the ServiceTracker. This method should return the service object to be tracked for the specified ServiceReference. The returned service object is stored in the ServiceTracker and is available from the getService and getServices methods.

Returns The service object to be tracked for the specified referenced service or null if the specified referenced service should not be tracked.

701.6.5.2 public void modifiedService(ServiceReference<S> reference, T service)

reference The reference to the service that has been modified.

service The service object for the specified referenced service.

- A service tracked by the ServiceTracker has been modified.

This method is called when a service being tracked by the ServiceTracker has had its properties modified.

701.6.5.3 public void removedService(ServiceReference<S> reference, T service)

reference The reference to the service that has been removed.

service The service object for the specified referenced service.

- A service tracked by the ServiceTracker has been removed.

This method is called after a service is no longer being tracked by the ServiceTracker.

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