OSGi Service Platform Core Specification

The OSGi Alliance

Release 4, Version 4.1
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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 Service Platform 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 fourth release of the OSGi Service Platform specification developed by representatives from OSGi member companies. The OSGi Service Platform Release 4 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 4 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 Service Platform 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.

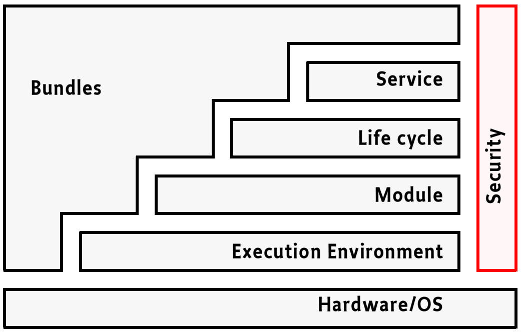
It provides the bundle developer with the resources necessary to take advantage of Java's platform independence and dynamic code-loading capability in order to easily develop services for small-memory devices that can be deployed on a large scale.

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.

Figure 1 *Layering*



The Security Layer is based on Java 2 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 2 security layer. The Security Layer is described in *Security Layer* on page 11.

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 25.

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 service platform. 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 79

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.

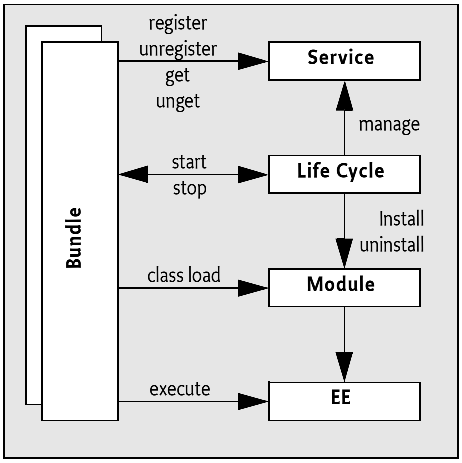
A consistent programming model helps bundle developers cope with scalability issues in many different dimensions – critical because the Framework is intended to run on a variety of devices whose differing hardware characteristics may affect many aspects of a service implementation. Consistent interfaces 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 107.

The interactions between the layers is depicted in Figure 2.

Figure 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 2 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
```

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

```
digit       ::= [0..9]
alpha       ::= [a..zA..Z]
alphanum    ::= alpha | digit
token       ::= ( alphanum | '_' | '-' )+
number      ::= digit+
jletter     ::= <see [5] Lexical Structure Java Language for
                  JavaLetter>
```

```
jletterordigit::=  <See [5] Lexical Structure Java Language for
                   JavaLetterOrDigit >

qname          ::= /* See [5] Lexical Structure Java Language for
                   fully qualified class names */
identifier     ::= jletter jletterordigit *
quoted-string::= '"' ( [^"\#x0D#x0A#x00] | '\"'|'\\')* '"'
argument       ::= token | quoted-string
parameter      ::= directive | attribute
directive      ::= token ':=' argument
attribute      ::= token '=' argument

unique-name    ::= identifier ( '.' identifier )*
symbolic-name :: = token('.'token)*
package-name  ::= unique-name

path           ::= path-unquoted | ('"' path-unquoted '"')
path-unquoted::= path-sep | path-sep? path-element
                     (path-sep path-element)*
path-element ::= [^/"\#x0D#x0A#x00]+
path-sep      ::= '/'
```

Whitespaces in the previous definitions are only allowed when the values are quoted.

The isJavaIdentifierStart and isJavaIdentifierPart methods of the Character class are not included in the Minimum Execution Environment. This can make it difficult or expensive for an embedded device to conform to this specification. Therefore, it is allowed to assume that any character having a code of more than \u00FF is a jletterordigit or jletter.

Any value that contains a space, a comma, semi-colon, 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.

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 Security Exception" and to "to have File Permission" is more readable then "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".

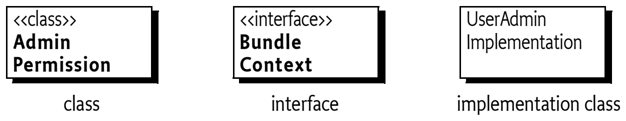
Service objects are registered with the OSGi Framework. Registration consists of the service object, a set of properties, and a list of classes and interfaces implemented by this service object. The classes and interfaces are used for type safety *and* naming. Therefore, it is said that a service object 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.

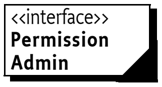
Classes or interfaces are depicted as rectangles, as in Figure 3. Interfaces are indicated with the qualifier <<interface>> as the first line. The name of the class/interface is indicated in bold when it is part of the specification. Implementation classes are sometimes shown to demonstrate a possible 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 period.

Figure 3 *Class and interface symbol*



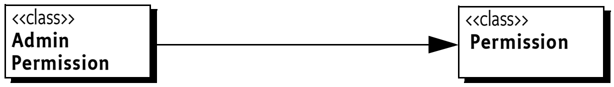
If an interface or class is used as a service object, it will have a black triangle in the bottom right corner.

Figure 4 *Service symbol*



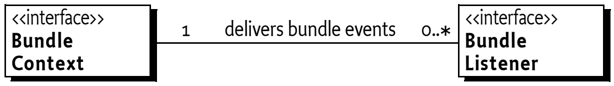
Inheritance (the extends or implements keyword in Java class definitions) is indicated with an arrow. Figure 5 shows that the AdminPermission class implements or extends the Permission class.

Figure 5 *Inheritance (implements or extends) symbol*



Relations are depicted with a line. The cardinality of the relation is given explicitly when relevant. Figure 6 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."

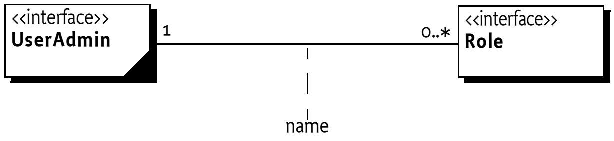
Figure 6 *Relations symbol*



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.

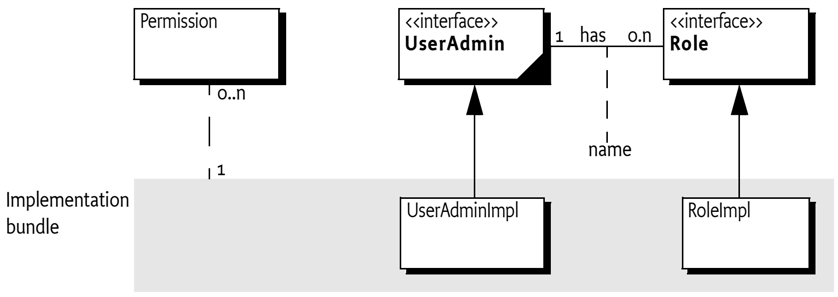
When a relationship is qualified by a name or an object, it is indicated by drawing a dotted line perpendicular to the relation and connecting this line to a class box or a description. Figure 7 shows that the relationship between a UserAdmin class and a Role class is qualified by a name. Such an association is usually implemented with a Dictionary or Map object.

Figure 7 *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 8.

Figure 8 *Bundles*



1.3.5 Key Words

This specification consistently uses the words *may*, *should*, and *must*. Their meaning is well-defined in [1] *Bradner, S., Key words for use in RFCs to Indicate Requirement Levels*. A summary follows.

- *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.

1.4 Version Information

This document specifies OSGi Service Platform Core Specification, Release 4. This specification is backward compatible to releases 1, 2, and 3.

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 *Packages and versions OSGi Service Platform, Release 4, Version 4.1*

Item	Package	Version
Framework Specification (all layers)	org.osgi.framework	Version 1.4
9 Conditional Permission Admin Specification	org.osgi.service.condpermissionadmin	Version 1.0
7 Package Admin Service Specification	org.osgi.service.packageadmin	Version 1.2
10 Permission Admin Service Specification	org.osgi.service.permissionadmin	Version 1.2
8 Start Level Service Specification	org.osgi.service.startlevel	Version 1.1
11 URL Handlers Service Specification	org.osgi.service.url	Version 1.0

1.5 References

[1] *Bradner, S., Key words for use in RFCs to Indicate Requirement Levels* http://www.ietf.org/rfc/rfc2119.txt, March 1997.

[2] *OSGi Service Gateway Specification 1.0, May 2000* http://www.osgi.org/resources/spec_download.asp

[3] *OSGi Service Platform, Release 2, October 2001* http://www.osgi.org/resources/spec_download.asp

[4] *OSGi Service Platform, Release 3, March 2003* http://www.osgi.org/resources/spec_download.asp

[5] *Lexical Structure Java Language* http://java.sun.com/docs/books/jls/second_edition/html/lexical.doc.html

2 Security Layer

Version 1.4

2.1 Introduction

The OSGi Security Layer is an optional layer that underlies the OSGi Service Platform. The layer is based on the Java 2 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 2 specification. If security checks are performed, they must be done according to [8] *Java 2 Security Architecture*. It is assumed that the reader is familiar with this specification. The security layer is optional, see *Optional Security* on page 12.

2.2.1 Code Authentication

The OSGi Service Platform 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 12.

2.2.2 Optional Security

The Java platform on which the Framework runs must provide the Java Security APIs necessary for Java 2 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.

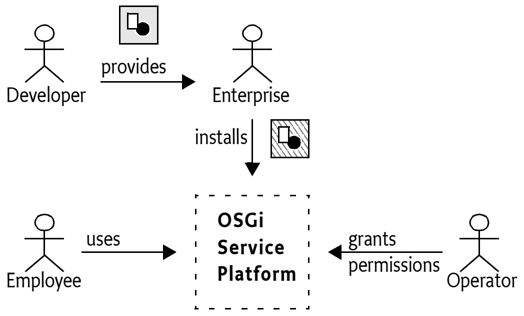
In an OSGi Framework, the principals that signed a JAR become associated with that JAR. This association is then used to:

- 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 16).

The digital signing process used is based on Java 2 JAR signing. The process of signing is repeated, restricted and augmented here to improve the interoperability of OSGi bundles.

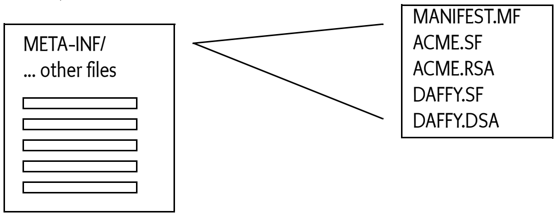
2.3.1 JAR Structure and Manifest

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 [16] *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 `SHA1-Digest`. It is recommended that OSGi Framework implementations support the following digest algorithms.

- *MD5* – Message Digest 5, an improved version of MD4. It generates a 128-bit hash. It is described at page 436 in [12] *RFC 1321 The MD5 Message-Digest Algorithm*.
- *SHA1* – An improved version of SHA, delivers a 160 bit hash. It is defined in [11] *Secure Hash Algorithm 1*.

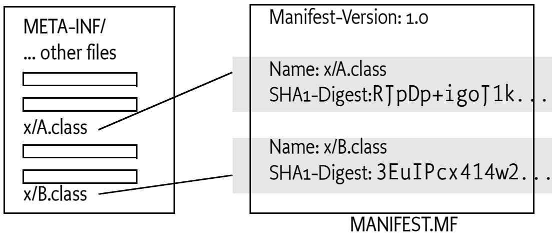
The hash must be encoded with a Base 64 encoding. Base 64 encoding is defined in [13] *RFC 1421 Privacy Enhancement for Internet Electronic Mail*.

For example, a manifest could look like:

```
Manifest-Version: 1.0
Bundle-Name: DisplayManifest
↵
Name: x/A.class
SHA1-Digest: RJpDp+igoJ1kxs8CSFeDtMbMq78=
↵
Name: x/B.class
SHA1-Digest: 3EuIPcx414w2QfFSXSZEBfLgKYA=
↵
```

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 jar-signer 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. SHA1) followed by -Digest-Manifest. For example:

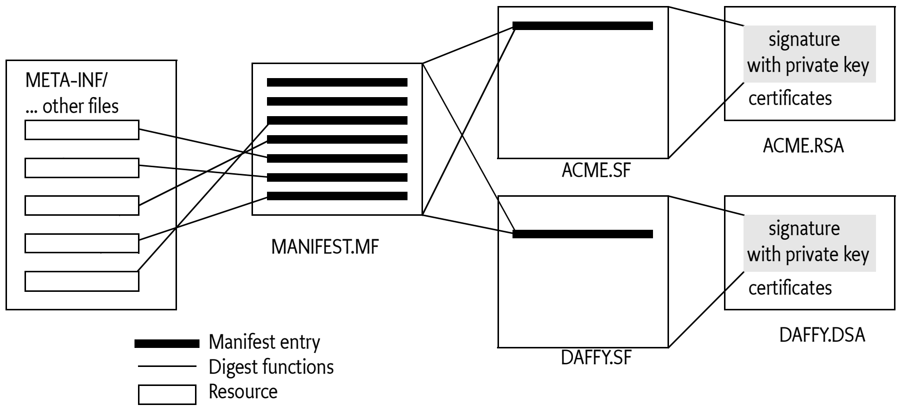
```
Signature-Version: 1.0
SHA1-Digest-Manifest: RJpDp+igoJ1kxs8CSFeDtMbMq78=
MD5-Digest-Manifest: IIsI6HranRNHMY27SK8M5qMunR4=
```

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 except the resources in the META-INF directory.
- The name sections in the signature files are ignored. Only the Manifest digest is used.

2.3.3 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 [14] *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 [15] *RSA*. The extension of the signature resource name must be `.RSA`.

The signature files for RSA and DSA are stored in a PCKS#7 format. This is a format that has a structure as defined in [16] *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.

2.3.4 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 [7] *X.509 Certificates*.

An X.509 certificate contains the following elements:

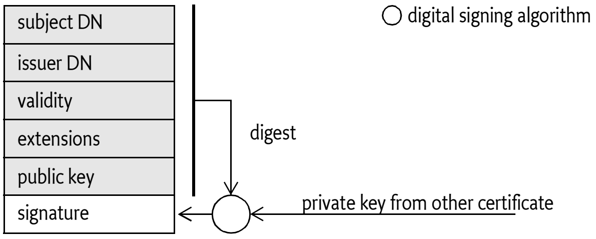
- *Subject Name* – The subject name is a unique identifier for the object being certified. In the case of a person this might include the name, nationality and e-mail address, the organization, and the department within that organization. This identifier is a Distinguished Name, which is defined in *Distinguished Names* on page 18.
- *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*

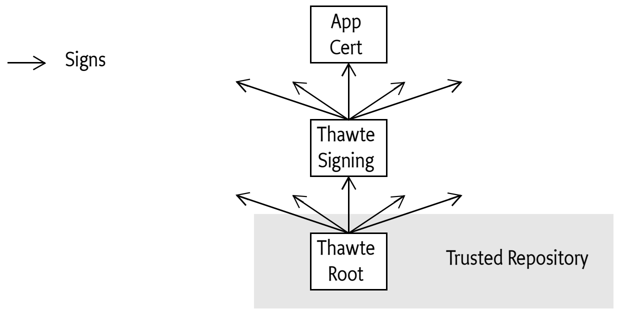


Certificates can be freely dispersed; they do not contain any secret information. Therefore, the PKCS#7 resource contains the signing certificate. It cannot be trusted at face value because the certificate is carried in the bundle itself. A perpetrator can easily create its own certificate with any content. 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



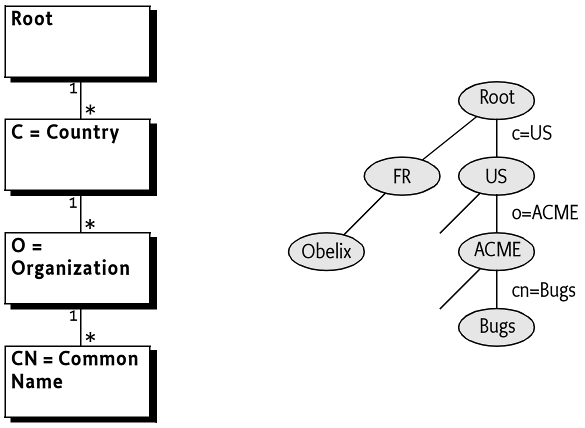
This specification does not specify access to the trusted repository. It is implementation specific how this repository is populated and maintained.

2.3.5 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 name space. The DN concept was developed for the X.500 directory service which envisioned a world wide name space managed by PTTs. Today, the DN is used as an identifier in a local name space, as in a name space designed by an Operator. For example, given a name space 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 name space.



The traversal of the name space 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 [6] *RFC 2253* 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 characters ('*' \u002A) are not allowed in a value part. The following characters must be escaped with a back slash:

```
comma        ','   \u002C
plus         '+'   \u002B
double quote '"'   \u0022
back slash   '\'   \u005C
less then    '<'   \u003C
greater then '>'   \u003E
semicolon    ';'   \u003B
```

Backslashes must already be escaped in Java strings, requiring 2 backslashes 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):

commonName	cn	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 [18] *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=Bug Bunny+title=Manager, o=ACME, c=US"
```

2.3.6 Certificate Matching

Certificates are matched by their Subject DN. Before matching, DNs, 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 ('*' \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. DNs 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 18, 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 16. 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 References

[6] *RFC 2253*
http://www.ietf.org/rfc/rfc2253.txt

[7] *X.509 Certificates*
http://www.ietf.org/rfc/rfc2459.txt

[8] *Java 2 Security Architecture*
Version 1.2, Sun Microsystems, March 2002

[9] *The Java 2 Package Versioning Specification*
http://java.sun.com/j2se/1.4/docs/guide/versioning/index.html

[10] *Manifest Format*
http://java.sun.com/j2se/1.4/docs/guide/jar/jar.html#JAR%20Manifest

[11] *Secure Hash Algorithm 1*
http://csrc.nist.gov/publications/fips/fips180-2/fips180-2withchangenotice.pdf

[12] *RFC 1321 The MD5 Message-Digest Algorithm*
http://www.ietf.org/rfc/rfc1321.txt

[13] *RFC 1421 Privacy Enhancement for Internet Electronic Mail*
http://www.ietf.org/rfc/rfc1421.txt

[14] *DSA*
http://www.itl.nist.gov/fipspubs/fip186.htm

[15] *RSA*
http://www.ietf.org/rfc/rfc2313.txt which is superseded by
http://www.ietf.org/rfc/rfc2437.txt

[16] *Public Key Cryptography Standard #7*
http://www.rsasecurity.com/rsalabs/node.asp?id=2129

[17] *Unicode Normalization UAX # 15*
http://www.unicode.org/reports/tr15/

[18] *Understanding and Deploying LDAP Directory Services*
ISBN 1-57870-070-1

3 Module Layer

Version 1.4

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 Service Platform, 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 [27] *Zip File Format.*

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 Service Platform.

Once a bundle is started, its functionality is provided and services are exposed to other bundles installed in the OSGi Service Platform.

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 [28] *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 85.

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 83.

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 period ('.') specifies the root directory of the bundle's JAR. The period is also the default. See *Bundle Class Path* on page 49.

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-DocURL: http:/www.acme.com/Firewall/doc

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

3.2.1.9 Bundle-Localization: OSGI-INF/l10n/bundle

The Bundle-Localization header contains the location in the bundle where localization files can be found. The default value is OSGI-INF/l10n/bundle. Translations are by default therefore OSGI-INF/l10n/bundle_de.properties, OSGI-INF/l10n/bundle_nl.properties, etc. See *Manifest Localization* on page 63.

3.2.1.10 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 Service Platform can define higher numbers for this header.

3.2.1.11 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.

3.2.1.12 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 57.

3.2.1.13 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 Service Platform. See *Execution Environment* on page 31.

3.2.1.14 Bundle-SymbolicName: com.acme.daffy

The Bundle-SymbolicName header specifies a unique, non-localizable name for this bundle. This name should be based on the reverse domain name convention, see *Bundle-SymbolicName* on page 35. This header must be set.

3.2.1.15 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.

3.2.1.16 Bundle-Vendor: OSGi Alliance

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

3.2.1.17 Bundle-Version: 1.1

The Bundle-Version header specifies the version of this bundle. See *Version* on page 28. The default value is 0.0.0

3.2.1.18 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 51.

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

The Export-Package header contains a declaration of exported packages. See *Export-Package* on page 37.

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

Deprecated.

3.2.1.21 **Fragment-Host: org.eclipse.swt; bundle-version="[3.0.0,4.0.0)"**
The Fragment-Host header defines the host bundle for this fragment. See *Fragment-Host* on page 69

3.2.1.22 **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 Header* on page 36.

3.2.1.23 **Import-Service: org.osgi.service.log.LogService**
Deprecated

3.2.1.24 **Require-Bundle: com.acme.chess**
The Require-Bundle header specifies the required exports from another bundle. *Require-Bundle* on page 65

3.2.2 Header Value Syntax

Each Manifest header has its own syntax. In all descriptions, the syntax is defined with [29] *W3C EBNF*. These following sections define a number of commonly used tokens.

3.2.3 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.

3.2.4 Version

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

```
version   ::=
  major( '.' minor ( '.' micro ( '.' qualifier )? )? )?
major     ::= number                    // See 1.3.2
minor     ::= number
micro     ::= number
qualifier ::= ( alphanum | ’_’ | '-' )+
```

A version token must not contain any white space. The default value for a version is 0.0.0.

3.2.5 Version Ranges

A version range describes a range of versions using a mathematical interval notation. See [31] *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 [0.0.0,∞).

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

3.2.6 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 [23] *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 | less
equal        ::=  '='
approx       ::=  '~='
greater      ::=  '>='
less         ::=  '<='
present      ::=  attr '=*'
substring    ::=  attr '=' initial any final
inital       ::=  () | value
```

```
any          ::=  '*' star-value
star-value   ::=  () | value '*' star-value
final        ::=  () | value
value         ::=  <see text>
```

attr is a string representing an attribute, or key, in the properties. 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 '\', '*', '(' or ')', then these characters should be preceded with the backslash ('\') 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 may 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 must always be String objects so that a case insensitive attr can be used to obtain the property value.

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

```
type       ::=  scalar  | primitive | 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
- *Boolean objects* – Use comparison defined by Boolean.valueOf(v).booleanValue().
- *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, and the type has a constructor taking a single `String` argument, then the Framework must construct an object to compare with the property value by passing `value` to the single `String` argument constructor 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)`.

3.3 Execution Environment

A bundle that is restricted to one or more execution environments must carry a header in its manifest file to indicate this dependency. This header is Bundle-RequiredExecutionEnvironment. The syntax of this header is a list of comma-separated names of execution environments.

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

ee-name ::= <defined execution environment name>
```

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.

3.3.1 Naming of Execution Environments

Execution environments require a proper name so that:

- A bundle can require that a Framework provides a certain execution environment before it is installed
- To provide information about which execution environments a Framework provides.

Execution environment names consist of any set of characters except white space characters and the comma character (' ,', or `\u002C`). The OSGi Alliance has defined a number of execution environments.

The naming scheme further uses J2ME configuration and profile names. There is no clear definition for this naming scheme but similar names are used in different specifications.

The J2ME scheme uses a configuration and a profile name to designate an execution environment. The OSGi Alliance naming combines those two names into a single execution environment name.

There already exist a number of Execution Environments from J2ME that are likely available in Service Platform Servers. The value for the execution environment header must be compatible with these specifications.

A J2ME execution environment name is a combination of a configuration and a profile name. In J2ME, these are two different system properties. These properties are:

```
microedition.configuration
microedition.profiles
```

For example, Foundation Profile has an execution environment name of `CDC-1.0/Foundation-1.0`. The structure of the name obeys the following rules:

```
ee-name = [ <configuration> '-' <version> '/' ]
          <profile> '-' <version>
```

Configuration and profile names are defined by the JCP or OSGi Alliance. If an execution environment does not have a configuration or profile, the profile part is the name identifying the execution environment. These guidelines are not normative.

Table 3.2 on page 32, contains a number of examples of the most common execution environments.

Table 3.2 Sample EE names

Name	Description
CDC-1.0/Foundation-1.0	Equal to J2ME Foundation Profile
OSGi/Minimum-1.1	OSGi EE that is a minimal set that allows the implementation of an OSGi Framework.
JRE-1.1	Java 1.1.x
J2SE-1.2	Java 2 SE 1.2.x
J2SE-1.3	Java 2 SE 1.3.x
J2SE-1.4	Java 2 SE 1.4.x
J2SE-1.5	Java 2 SE 1.5.x
JavaSE-1.6	Java SE 1.6.x
PersonalJava-1.1	Personal Java 1.1
PersonalJava-1.2	Personal Java 1.2
CDC-1.0/PersonalBasis-1.0	J2ME Personal Basis Profile
CDC-1.0/PersonalJava-1.0	J2ME Personal Java Profile

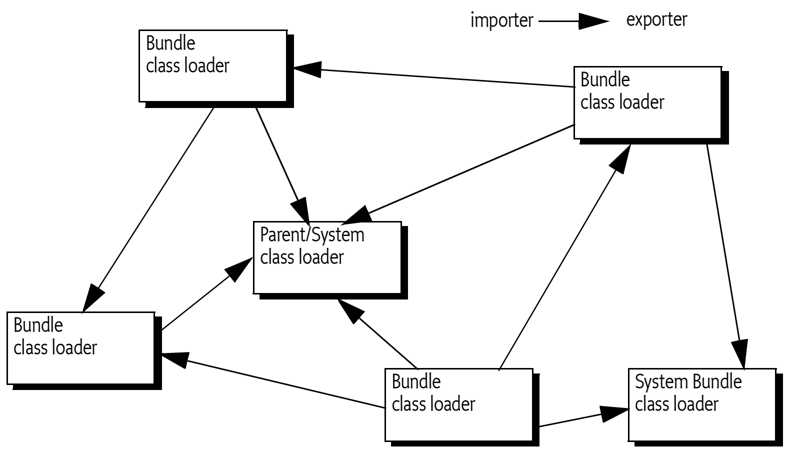
The org.osgi.framework.executionenvironment property from BundleContext.getProperty(String) must contain a comma-separated list of execution environment names implemented by the Framework. This property is defined as *volatile*. A Framework implementation must not cache this information because bundles may change this system property at any time. The purpose of this volatility is testing and possible extension of the execution environments at run-time.

3.4 Class Loading Architecture

Many bundles can share a single virtual machine (VM). 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 sub-set 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 3.8.

Figure 3.8 Class Loader 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 68.

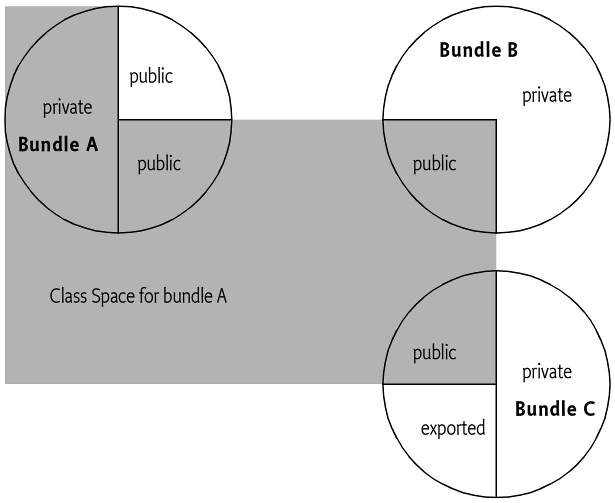
A *class space* is then all classes reachable from a given bundle's class loader. Thus, a class space for a given bundle can contain classes from:

- 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 3.9 *Class Space*



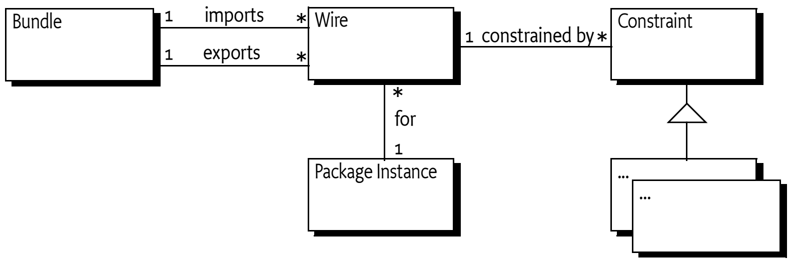
The Framework therefore has a number of responsibilities related to class loading. Before a bundle is used, it must resolve the constraints that a set of bundles place on the sharing of packages. Then select the best possibilities to create a *wiring*. See *Resolving Process* on page 48 for further information. The runtime aspects are described in *Runtime Class Loading* on page 49.

3.4.1 Resolving

The Framework must *resolve* bundles. Resolving is the process where importers are *wired* to exporters. Resolving is a process of satisfying constraints. This 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 3.10 depicts the class structure of the wiring model.

Figure 3.10 *Example class structure of wiring*



3.5 Resolving Metadata

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

3.5.1 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 version 1.3 (or later) 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 since this version header has a default value.

3.5.2 Bundle-SymbolicName

The Bundle-SymbolicName manifest header is a mandatory header. The bundle symbolic name and bundle version allow a bundle to be uniquely identified in the Framework. That is, a bundle with a given symbolic name and version is treated as equal to another bundle with the same (case sensitive) symbolic name and exact version.

The installation of a bundle with a Bundle-SymbolicName and Bundle-Version identical to an existing bundle must fail.

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. 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 68. The following values are valid for this directive:
  - always – 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.

For example:

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

3.5.3 Bundle-Version

Bundle-Version is an optional header; the default value is 0.0.0.

```
Bundle-Version ::= version  // See 3.2.4
```

If the minor or micro version components are not specified, they have a default value of 0. 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
```

3.5.4 Import-Package Header

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 42.

The developer can specify arbitrary matching attributes. See *Attribute Matching* on page 45. 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 28. For more information on version selection, see *Version Matching* on page 41. If this attribute is not specified, it is assumed to be [0.0.0, ∞).
- 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 [0.0.0, ∞). See *Version Matching* on page 41. In the case of a Fragment bundle, the version is from the host bundle.

In order to be allowed to import a package (except for packages starting with java.), 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.

Example of a correct definition:

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

3.5.5 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.

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 43.
- `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 45.
- `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 46.
- `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 46.

The following attribute is part of this specification:

- `version` – The version of the named packages with syntax as defined in *Version* on page 28. It defines the version of the associated packages. The default value is `0.0.0`.
- `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 45.

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>, EXPORT]`.

Example:

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

3.5.6 Exporting and Importing a Package

Exporting a package does not imply the import of that same package (in Release 3, an export did imply an import). The reason for this separation is that it enables a bundle to provide a package to other bundles without having to take into account that the exported package could be *substituted* by the resolver with the same package from another bundle. This is a common case when an application consists of a set of closely intertwined bundles where implementation packages are provided to other bundles.

The substitution of packages is crucial for the inter-operability of bundles. In Java, bundles can only inter-operate when they use the same class loaders for the same classes. Therefore, two bundles that both export the same package, but do not import it, cannot share objects from that package. This is very important for a collaboration mechanism like the Service Layer. Bundles can only use the same service objects if their classes and interfaces come from the same class loaders.

Bundles should import exported packages, allowing the resolver to substitute packages that contain interfaces and other shared types. This substitution allows bundles to inter-operate through the service registry and other mechanisms. Additionally, the import should be as unconstrained as possible to allow the resolver maximum flexibility.

3.5.7 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 given 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.

3.6 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.

3.6.1 Diagrams and Syntax

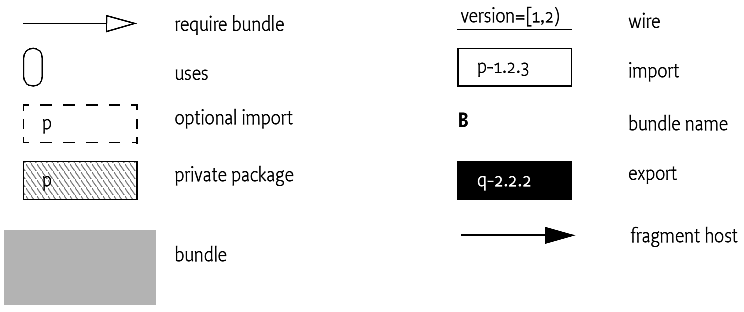
Wires create a graph of nodes. Both the wires as well as nodes (bundles) carry a significant amount of information. In the next sections, the following conventions are used to explain the many details.

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 3.11 Legend of wiring instance diagrams, and example

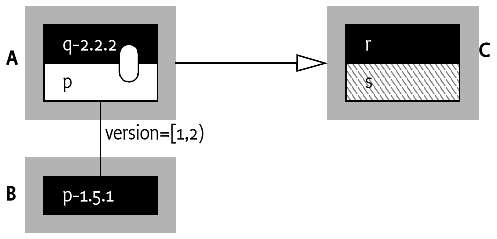


For example:

```
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 3.12 shows the same setup graphically.

Figure 3.12 *Example bundle diagram*



3.6.2 Version Matching

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

Version ranges encode the assumptions about compatibility. This specification does not define any compatibility policy; the policy decision is left to the importer that specifies a version range. A version range embeds such a policy.

However, the most common version compatibility policies are:

- `major` – An incompatible update
- `minor` – A backward compatible update
- `micro` – A change that does not affect the interface: for example, a bug fix

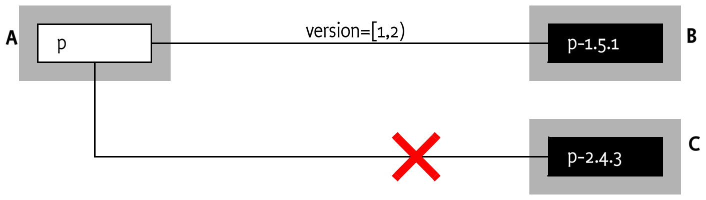
An import definition must specify a version range as the value for its version attribute, and the exporter must specify a version as the value for its version attribute. Matching is done with the rules for version range matches as described in *Version Ranges* on page 28.

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 3.13 graphically shows how a constraint can exclude an exporter.

Figure 3.13 *Version Constrained*



3.6.3 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.

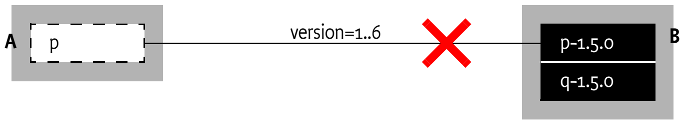
The resolution directive of the import definition can take the value mandatory or optional.

- 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.

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 3.14 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.

3.6.4 Package Constraints

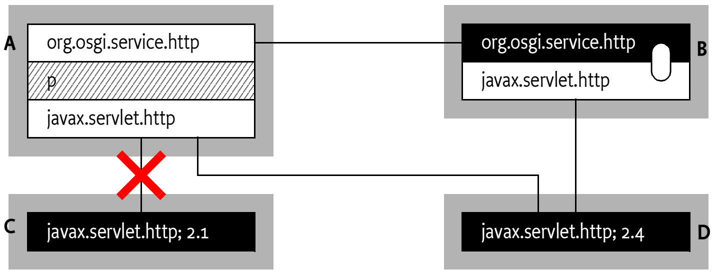
Classes can depend on classes in other packages. For example, when they extend classes from another package, or these other classes appear in method signatures. It can therefore be said that a package *use*s other packages. These inter-package dependencies are modeled with the `uses` directive on the 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 is bound to happen. This is depicted in Figure 3.15.

Figure 3.15 Uses directive in B, forces A to use javax.servlet from D



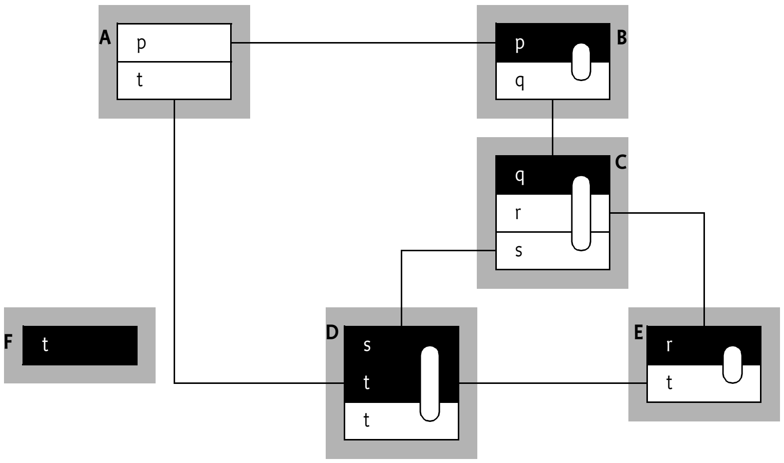
If a bundle imports a package from an exporter then the export definition of that package can imply constraints on a number of other packages through the `uses` directive. The `uses` directive lists the packages that the exporter depends upon and therefore constrains the resolver for imports. These constraints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

When an importer imports a package with implied constraints, the resolver must wire the import to the exporter implied by the 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 resolved.

For example, in Figure 3.16, 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 3.16 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 ClassCastExceptions. Alternatively, if all bundles are wired to F.t, then the problem also goes away.

Another scenario with this case is depicted in Figure 3.15. 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"
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.

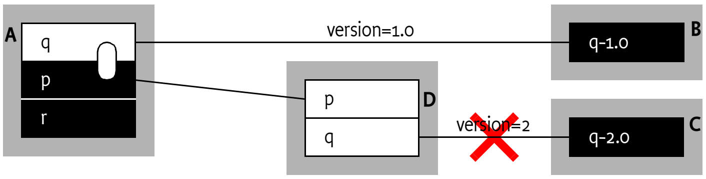
Adding a bundle D will now not be possible:

```
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 3.17.

Figure 3.17 *Uses directive and resolving*



3.6.5 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 information specified in the DynamicImport-Package is ignored during the resolve phase.

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.

3.6.6 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
```

3.6.7 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 wildcards ('*').

The default for the include directive is'*' (wildcard matching all names), and for the exclude directive, so that no classes or resources 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 or resources that were not filtered out by the earlier version. In addition, when modularizing existing code, filtering out classes or resources 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
```

3.6.8 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 exporter. 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 28. 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 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.

3.7 Resolving Process

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

- 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 65.
- Fragments, which provide their contents and definitions to the host as defined in *Fragment Bundles* on page 68

Before a bundle is resolved, all its Fragments must be attached. 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.

If a module 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 module, then the overlapping import definition in this module is discarded.
- *Unresolved* – There is no matching export definition. This is however a developer error because it means the overlapping export definition of the bundle is not compatible with the overlapping import definition.

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

- 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 *Version Matching* on page 41.

- The importer specifies all mandatory attributes from the exporter. See *Mandatory Attributes* on page 45.
- All the importer's attributes match the attributes of the corresponding exporter. See *Attribute Matching* on page 45
- Implied packages referring to the same package as the wire are wired to the same exporter. See *Package Constraints* on page 43.
- 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 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 name space, 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.

3.8.1 Bundle Class Path

Intra bundle class path dependencies are declared in the Bundle-Classpath manifest header. This declaration allows a bundle to declare its *embedded* class path using one or more JAR files or directories that are contained in the bundle's JAR file.

The Bundle-Classpath manifest header is a list of comma-separated file names. A file name can be either:

- The dot ('.' \u002E), representing the bundle's JAR file itself, is the default value if no Bundle-Classpath is specified.
- A path to a JAR file contained in the bundle's JAR file.
- A path to a directory contained in the bundle's JAR file.

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 Framework must ignore a target in the Bundle-Classpath header if the target (directory or JAR file) cannot be located when it is needed, which can happen at any time after the bundle is resolved. However, in this case the Framework should publish a Framework Event of type INFO with an appropriate message for each entry that cannot be located.

When locating a class path entry in a bundle, the Framework must attempt to locate the class path entry relative to the root of the bundle's JAR. If a class path entry cannot be located in the bundle, then the Framework must attempt to locate the class path entry in each of the attached fragment bundles. The attached fragment bundles are searched in ascending bundle ID order. This allows a fragment to supply entries that are inserted into the host's Bundle-Classpath

The following example illustrates this:

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

In this example, bundle A has a Bundle-Classpath header with three entries (required.jar, optional.jar, and default.jar). The required.jar class path entry may contain the classes and resources that must be present for the bundle to function. The optional.jar class path entry may contain classes and resources that the bundle will use if present.

The default.jar class path entry may contain classes and resources that the bundle will use if the optional.jar is not available, but the classes and resources from default.jar can be overridden by classes and resources in the optional.jar (from the fragment) class path entries. Bundle A has only the required.jar and default.jar entries packaged with it. This allows a fragment bundle B to be installed that can supply the optional.jar for bundle A.

The fragment bundle B has a Bundle-Classpath with one entry (fragment.jar). When bundle A is resolved and the fragment bundle B is attached then the bundle class path for the bundle A is:

```
required.jar, optional.jar, default.jar, fragment.jar
```

3.8.2 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 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 arbitrary 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 0.0.0.

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.

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 45) 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 42, but differ in the fact that they are handled after the bundle is resolved.

3.8.3 Parent Delegation

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

Certain Java virtual machines, also SUN'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. 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 a SUN 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.

3.8.4 Overall Search Order

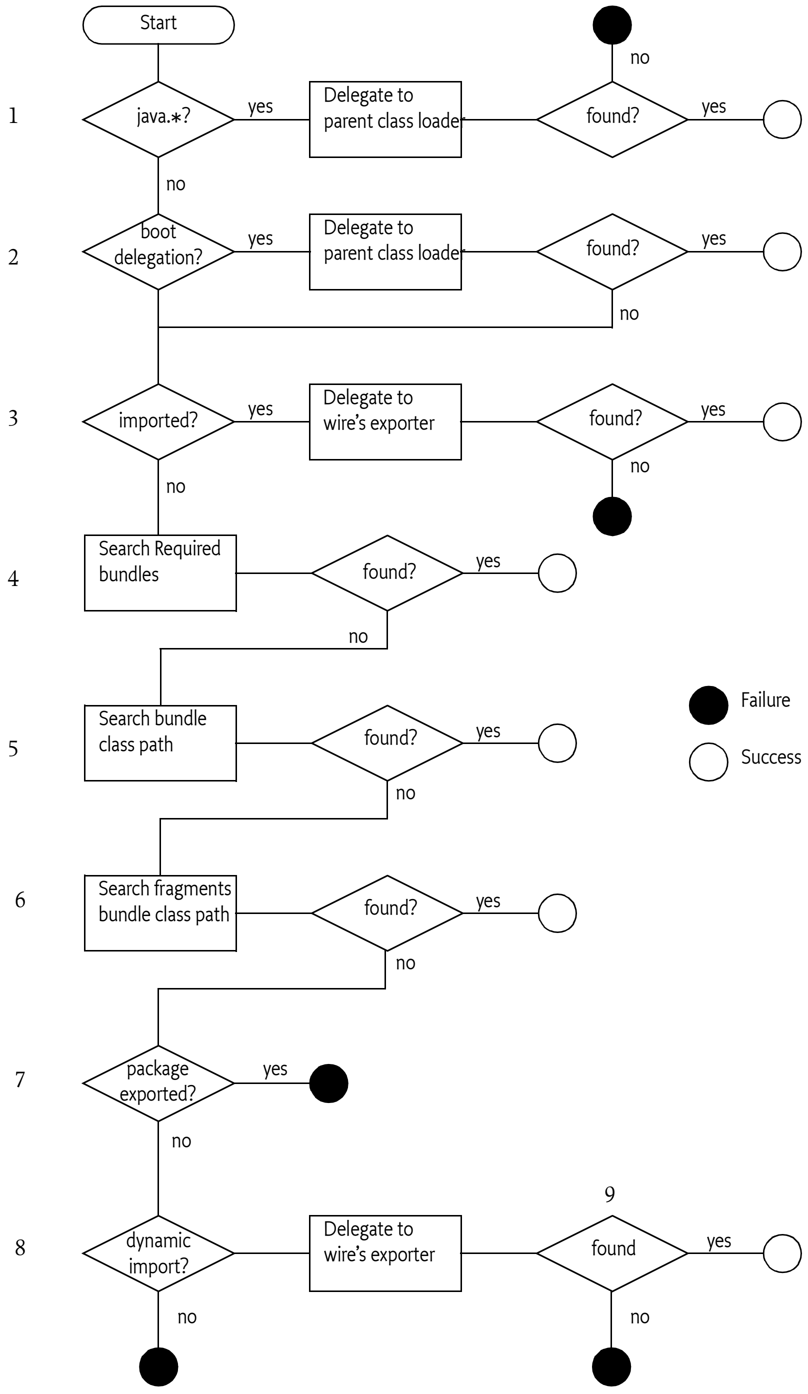
Frameworks must adhere to the following rules for class or resource loading. When a bundle's class loader is requested to load a class or find a resource, the search must be performed in the following order:

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 classpath is used. If the class or resource is not found, then the search continues with the next step.
5 The bundle's own internal bundle class path is searched. If the class or resource is not found, then the search continues with the next step.
6 Each attached fragment's internal bundle class path is searched. The fragments are searched in ascending bundle ID order. If the class or resource is not found, then the search continues with the next step.
7 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.
8 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.
9 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 3.18 Flow chart for class loading (non-normative)



3.8.5 Parent Class Loader

The set of implicitly imported 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 imports or exports for java.* packages; doing so is an error and any such bundle must fail to install. All other packages available 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 implementation specific bundle symbolic name and 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.

3.8.6 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, getEntry or findEntries methods. All these methods return a URL object or an Enumeration object of URL objects. The URLs are called *bundle entry URLs*. The schemes for the URLs returned by these methods can differ and are implementation dependent.

Bundle entry URLs 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 URLs must be hierarchical (See [32] *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 );
   }
   ...
}
```

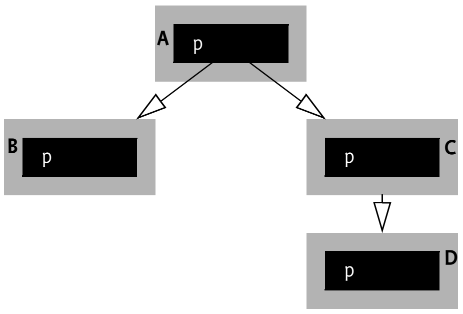
3.8.7 Bundle Cycles

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 3.19.

Figure 3.19 Depth First search with Require Bundle

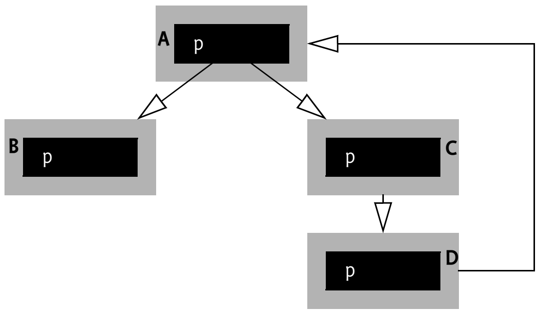


Each of the bundles exports the package p. In this example, bundle A requires bundle B, and bundle C requires bundle D. When bundle A loads a class or resource from package p, then the required bundle search order is the following: B, D, C, A. This is a depth first search order because required bundles are searched before the bundle classpath 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 3.20.

```
D: Require-Bundle: A
```

Figure 3.20 *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 recurs 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.

3.8.8 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 Loading Native Code Libraries

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 Service Platform.

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 *Environment Properties* on page 93.
- osversion – The operating system version. The value of this attribute must be a version range as defined in *Version Ranges* on page 28.
- processor – The processor architecture. The value of this attribute must be the name of the processor architecture upon which the native libraries run. see *Environment Properties* on page 93.
- 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.

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
```

If the optional'*' is specified at the end of the Bundle-NativeCode manifest header, a bundle installation error will not occur 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 ,
      *
```

3.9.1 Native Code Algorithm

In the description of this algorithm, [x] represents the value of the Framework property x 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. (See *Environment Properties* on page 93). If a property is not an alias, or has the wrong value, the Operator should set the appropriate system property to the generic name or to a valid value because Java System properties with this name override the Framework construction of these properties. For example, if the operating system returns version 2.4.2-kwt, the Operator should set the system property org.osgi.framework.os.version to 2.4.2.

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]
   - processor ~= [org.osgi.framework.processor]
   - osversion range includes [org.osgi.framework.os.version] or osversion is not specified
   - language ~= [org.osgi.framework.language] or language is not specified
   - selection-filter evaluates to true when using the values of the system properties or selection-filter is not specified

2 If no native clauses were selected in step 1, this algorithm is terminated and a BundleException is thrown if the optional clause is not present.

3 The selected clauses are now sorted in the following priority order:
   - osversion: floor of the osversion range in descending order, osversion 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 installation must fail with a Bundle Exception. This is true even if the optional clause is specified.

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.

If a selection filter is evaluated and its syntax is invalid, then the bundle installation must fail with a Bundle Exception. If a selection filter is not evaluated (it may be in a native code clause where the osname or processor does not match), then the invalid filter must not cause the bundle installation to fail. This is also true even if the optional clause is specified.

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 3.3 for an example.

Table 3.3 *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)

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

```
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)"
```

3.9.2 Considerations Using Native Libraries

There are some restrictions on loading native libraries due to the nature of class loaders. In order to preserve name space 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.

3.10 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/l10n/bundle_en.properties
OSGI-INF/l10n/bundle_nl_BE.properties
OSGI-INF/l10n/bundle_nl_NL.properties
OSGI-INF/l10n/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/l10n/bundle_en_GB_welsh.properties
OSGI-INF/l10n/bundle_en_GB.properties
OSGI-INF/l10n/bundle_en.properties
OSGI-INF/l10n/bundle.properties
```

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

3.10.1 Finding Localization Entries

Localization entries can be contained in the bundle or delivered in fragments. The Framework must therefore first look in the bundle and then in its attached fragments. Fragment bundles must delegate the search for a localization entry to their host bundle with the lowest bundle ID.

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 dot ('.') is not in the bundle class path.

3.10.2 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.

3.11 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 R3 specification.

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

- Bundle-RequireExecutionEnvironment header does not match the available execution environments.
- Missing Bundle-SymbolicName.
- Duplicate attribute or duplicate directive (except in the Bundle-Native code clause).
- Multiple imports of a given package.
- Export or import of `java.*`.
- Export-Package with a mandatory attribute that is not defined.
- Installing a bundle that has the same symbolic name and version as an already installed bundle.
- Updating a bundle to a bundle that has the same symbolic name and version as another installed bundle.
- 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/permission.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.

3.12 Optional

This specification provides for one optional mechanism: the boot class path extension. The reason to make this mechanism optional is that it is not possible to implement this in a portable way. A compliant framework must set the following property to `true` or `false` depending on the implementation of the boot class path extension:

- `org.osgi.supports.bootclasspath.extension`

If the property is not set or the value is unrecognized, then the value defaults to `false`. A Framework that does not implement the bootclasspath extension must refuse to install or update a bundle that carries this option. It must then throw an exception at install or update time.

Additionally, 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

3.13 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 bundle symbolic names that need to be searched after the imports are searched but before the bundle's class path is searched. Fragment or extension bundles can not be required. Only packages that are marked exported by the required bundles are visible 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 28. The default value is [0.0.0,∞).

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 66. 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 66.

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 consists of a number of 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 designates 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

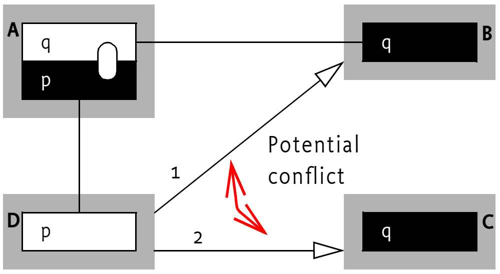
The preferred way of wiring bundles is to use the Import-Package and Export-Package headers because they couple the importer and exporter to a much lesser extent. Bundles can be refactored to have a different package composition without causing other bundles to fail.

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, there is no way 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 increases the number of times that a `ClassNotFoundException` must be thrown which can 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 3.21 *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`.

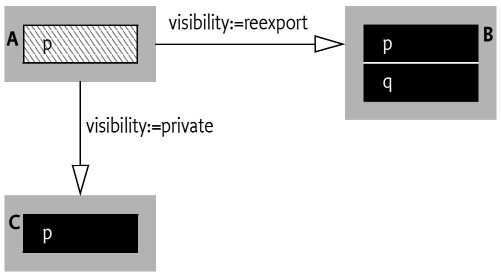
- *Mutable Exports* – The feature of `visibility:=reexport` that the export signature of the requiring bundle can unexpectedly change depending on the export signature of the required bundle.
- *Shadowing* – The classes in the requiring bundle that are shadowed by those in a required bundle depend on 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.)

- *Unexpected Signature Changes* – The Require-Bundle directive visibility:=private (the default) may be unexpectedly overridden in some circumstances as the following example shows.

```
A:                 p     (private, not exposed in manifest)
   Require-Bundle: B;visibility:=reexport,
                   C;visibility:=private
B: Export-Package: p
C: Export-Package: p
```

  The export signature of bundle A will consist of only package p. However, package p is split. The Framework searches for a class in package p in bundle B, then bundle C, and last bundle A.
  So the visibility:=private directive on Require-Bundle C had no effect relative to package p. However, if bundle B was changed to stop exporting package p, then the directive would take effect and package p would drop out of bundle A's export signature. This is depicted in Figure 3.22.

Figure 3.22 Unexpected Signature change



3.14 Fragment Bundles

Fragments are bundles that are *attached* to a *host bundle* 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. Fragments must have their own Protection Domain.

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 bundle is updated, the content of the previous fragment must remain attached to its host bundle. The new content of the updated fragment must not be allowed to attach to the host bundle 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.

In this case, the Package Admin service must return information only for the last version of the supplied bundles. In the previous described case, the getHosts method must return the host bundle of the *new* version of the fragment bundle, and the getFragments method must return the fragment bundles attached to the new version of the host bundle.

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.

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 its 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 70.

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

3.14.1 Fragment-Host

A *fragment* is a bundle that is attached to one other bundle called its *host bundle*. The components of the fragment, like the Bundle-Classpath and other definitions, are added at the end of the related definitions of the host bundle. In the case of the Export-Package header, bundle dependent attributes like bundle-version and bundle-symbolic-name come from the host. All classes and resources within the fragment bundle must be loaded using the class loader of the host bundle.

The Fragment-Host manifest header 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 72. The following values are supported:

- framework - The fragment bundle is a Framework extension bundle.
- 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 bundle that provides the host bundle. See *Version Matching* on page 41. The default value is [0.0.0,∞).

When a fragment bundle becomes resolved, the Framework must attach the fragment bundle to the selected host bundle with the highest version. When a fragment bundle is attached to its host bundle, it logically becomes part of it. All classes and resources within the fragment bundle must be loaded using the class loader of its host bundle. The fragment bundles of a host bundle must be attached to the 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 its 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, a fragment must never have its own class loader. Fragment bundles are treated as if they are an intrinsic part of their host.

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 3.23 Resource/class searching with fragments

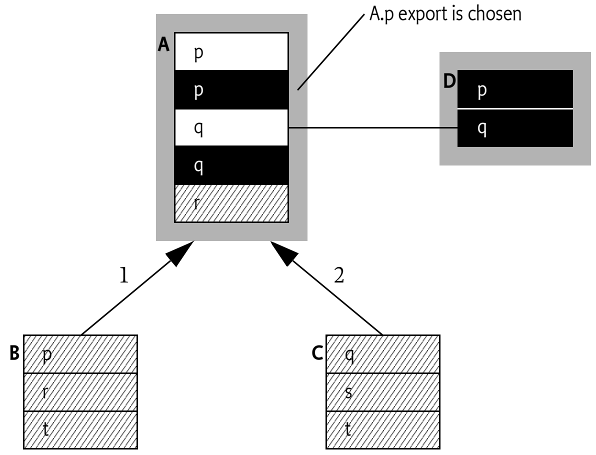


Figure 3.23 shows a setup with two fragments. Bundle B is installed before bundle C and both bundle B and bundle C attach to bundle A. The following table shows where different packages originate in this setup. Note that the order of the append (>) is significant.

Table 3.4 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 as long as the host remains resolved. When a host bundle becomes unresolved, then all 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 bundle
- Reattach the remaining attached fragment bundles.

A Fragment bundle can become unresolved by calling the refreshPackages method or the resolveBundle method on itself or on its host.

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 or provide functionality that must reside on the boot class path. These packages cannot be provided by the normal import/export mechanisms.

Boot class path extensions are necessary because certain package implementations assume that they are on the boot class path or are required to be available to all clients. An example of a boot class path extension is an implementation of java.sql such as JSR 169. Boot class path extensions are not required to be implemented by a compliant framework, see *Optional* on page 64.

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 service 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 a specific Framework implementation.

```
Fragment-Host: com.acme.impl.framework; extension:=framework
```

The following example uses the Fragment-Host manifest header to specify a boot class path extension bundle.

```
Fragment-Host: system.bundle; extension:=bootclasspath
```

The following steps 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, which can require a Framework re-launch.
3 If the extension bundle is refreshed then the Framework must shutdown, the host VM must terminate, and the Framework must be re-launched.
4 If a RESOLVED extension bundle is refreshed then the Framework must shutdown; the host VM must terminate and framework must be re-launched.
5 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; the host VM must terminate and framework must be re-launched.

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 Package Admin service). This must initiate a VM and Framework 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.

- Import-Package
- Require-Bundle
- Bundle-NativeCode
- DynamicImport-Package
- Bundle-Activator

Both boot class path and framework extension bundles are permitted to specify an Export-Package header. Any exported packages specified by a framework extension bundle must be exported by the System Bundle when the extension bundle is resolved.

3.15.2 Class Path Treatment

A boot class path extension bundle's JAR file must be appended to the boot class path of the host VM. A framework extension bundle's JAR is appended to the class path of the Framework.

Extension bundles must be appended to their class path in the order in which the extension bundles are installed: that is, ascending bundle ID order.

How a framework configures itself or the boot class path to append the extension bundle's JAR is implementation specific. In some execution environments, it may be impossible to support extension bundles. In such environments, the Framework must throw a BundleException when such an extension bundle is installed. The resulting Bundle Exception must have a cause of type UnsupportedOperationException.

3.16 Security

3.16.1 Extension Bundles

In an environment that has Java 2 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. It must therefore not be allowed for an extension bundle to be installed unless it already has been granted AllPermissions.

The installer of an extension bundle must have AdminPermission[<extension bundle>,EXTENSIONLIFECYCLE] to install an extension bundle.

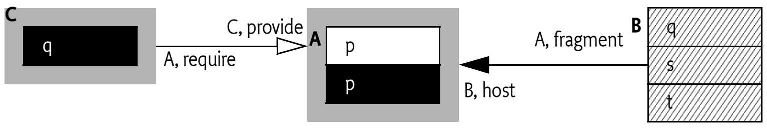
3.16.2 Bundle Permission

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, if fragment bundle A attaches 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 3.24.

Figure 3.24 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 package that may be exported or imported. A wildcard may be used. The granularity of the permission is the package, not the class name.
- The action, either IMPORT or EXPORT. If a bundle has permission to export a package, the Framework must automatically grant it permission to import the package.

A PackagePermission with * and EXPORT as parameters allows the import and export of any package.

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 Security Exception. This will cause a Malformed URL Exception 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 Security Exception if the caller does not have AdminPermission[bundle, RESOURCE] for the bundle referenced by the URL.

3.16.5 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 Changes 4.1

- Class loader delegations was fine tuned from step 3 to step 4 in *Overall Search Order* on page 52
- Minor corrections in the description of the native code header, *Loading Native Code Libraries* on page 57,
- Added clarifications and examples to the Require-Bundle section to illustrate some of the issues with shadowing and split packages. See *Requiring Bundles* on page 65.
- Changed the appropriate section in*Fragment Bundles* on page 68. The export definitions of a Fragment bundle must be appended to the export definitions of the host bundle unless the exact definition (directives and attributes must match) is already present in the host.
- Bundle-Name header now accepts embedded spaces in the name.
- Removed optionality of fragments and require bundle. Only boot class path extensions are left optional.
- Clarified that Bundle-SymbolicName is case sensitive.
- Filter escaping, substring comparisons, and boolean check clarified. Also replaced Vector with Collection.

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ISO 639, International Standards Organization
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:

4 Life Cycle Layer

Version 1.4

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.

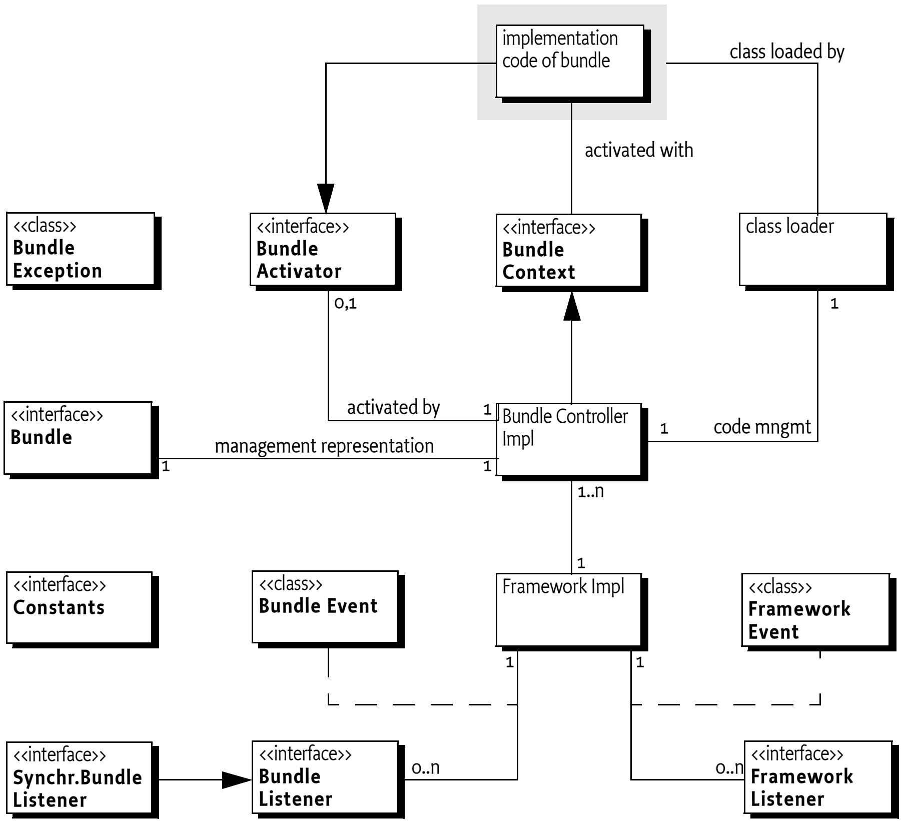
4.1.1 Essentials

- *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 Service Platform remotely.

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.

Figure 4.25 *Class diagram* org.osgi.framework *Life Cycle Layer*


implementation code of bundle
class loaded by
activated with
<<class>> Bundle Exception
<<interface>> Bundle Activator
<<interface>> Bundle Context
class loader
0,1
1
activated by
1
Bundle Controller Impl
1
code mngmt
<<interface>> Bundle
management representation
1
1
1..n
1
<<interface>> Constants
<<class>> Bundle Event
Framework Impl
<<class>> Framework Event
1
1
<<interface>> Synchr.Bundle Listener
<<interface>> Bundle Listener
0..n
0..n
<<interface>> Framework Listener

4.2 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 107.

4.3 The Bundle Object

For each bundle installed in the OSGi Service Platform, 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.

4.3.1 Bundle Identifiers

A bundle is identified by a number of names that vary in their scope:

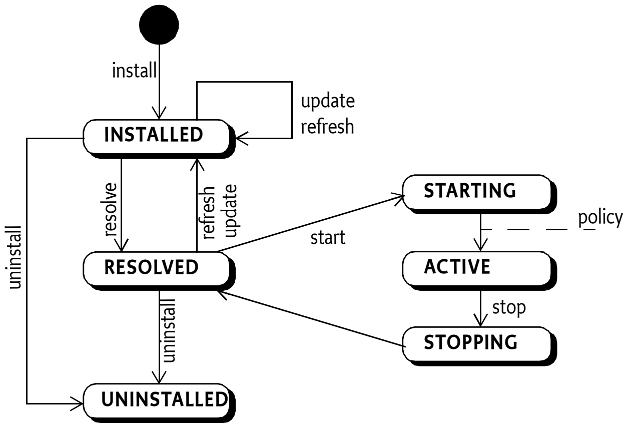
- *Bundle identifier* – A `long` that is a Framework assigned unique identifier for the full lifetime of a bundle, even if it is updated or the Framework is restarted. Its purpose is to distinguish bundles in a Framework. Bundle identifiers are assigned in ascending order to bundles when they are installed. 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* – A name 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.

4.3.2 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 an activation policy, the bundle will remain in the `STARTING` state until the bundle is activated according to its activation policy. See *Activation Policies* on page 85 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 4.26 *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 service influences the actual starting and stopping of bundles. See *Start Level Service Specification* on page 203.

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()
```

4.3.3 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 64.

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 Service Platform 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.

4.3.4 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 48.

4.3.5 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 service is used, then the bundle's start level is met.

Once a bundle is started, a bundle must be *activated*, see *Activation* on page 84, 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 85.

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.

The start() method calls start(0).

The optional Start Level service influences the actual order of starting and stopping of bundles. See *Start Level Service Specification* on page 203. The Start Level service can also be used to query the autostart setting:

- isBundlePersistentlyStarted(Bundle) – false if the bundle's autostart setting indicates *Stopped*, otherwise true.
- isBundleActivationPolicyUsed(Bundle) – true if the bundle's autostart setting indicates that the activation policy declared in the manifest must be used. false if the bundle must be eagerly activated.

Fragment bundles can not be started and must cause a Bundle Exception when there is an attempt to start them.

4.3.6 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 Bundle Activator stop(BundleContext) method.
- 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.

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.

4.3.7 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.

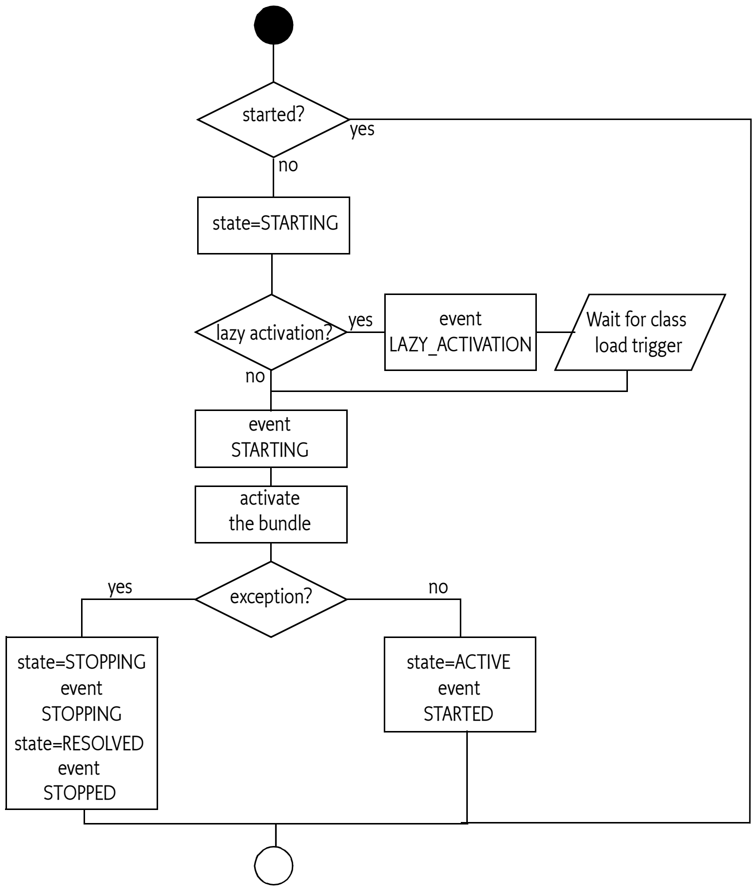
4.3.7.1 Lazy Activation Policy

A lazy activation policy indicates that the bundle, once started, must not be activated until a class is loaded from it; either during normal class loading or via the Bundle loadClass method. Resource loading does not trigger the activation. 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 4.27. This flow chart also shows the difference in activation policy of the normal eager activation and the lazy activation.

Figure 4.27 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 load 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.

4.3.8 Stopping Bundles

The Bundle interface defines the stop(int) method for stopping a bundle. This stops a bundle 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 service influences the actual order of starting and stopping of bundles. See *Start Level Service Specification* on page 203.

Attempting to stop a Fragment bundle must result in a Bundle Exception.

4.3.9 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 during its lifetime, then the Framework must automatically unregister all registered services when the bundle is stopped. It is therefore unnecessary to unregister any services 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.

4.3.10 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 version of a bundle to a newer version of the same bundle. The exports of an updated bundle must be immediately available to the Framework. If none of the old exports are used, then the old exports must be removed. Otherwise, all old exports must remain available for existing bundles and future resolves until the refreshPackages method is called or the Framework is restarted.

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 101.

4.3.11 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.

Once this method returns, the state of the OSGi Service Platform must be the same as if the bundle had never been installed, unless:

- The uninstalled bundle has exported any packages (via its Export-Package manifest header)
- The uninstalled bundle was selected by the Framework as the exporter of these packages.

If none of the old exports are used, then the old exports must be removed. Otherwise, all old exports must remain available for existing bundles and future resolves until the refreshPackages method is called or the Framework is restarted.

4.3.12 Detecting Bundle Changes

The Bundle object provides a convenient way to detect changes in a bundle. The Framework must keep the time that a bundle is changed by any of the life cycle operations. The getLastModified() method will return the last time the bundle was installed, updated, or uninstalled. 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 change must always result in a higher value than the previous last modified time of any bundle.

The getLastModified() is very useful when a bundle is caching resources from another bundle and needs to refresh the cache when the bundle changes. This life cycle change of the target bundle can happen while the caching bundle is not active. The last modified time is therefore a convenient way to track these target bundles.

4.3.13 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.

Localization is performed according to the description in *Localization* on page 62. 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.

4.3.14 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.

4.3.15 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 different 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 52. 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. The method provides access to all directories in the associated JAR files.

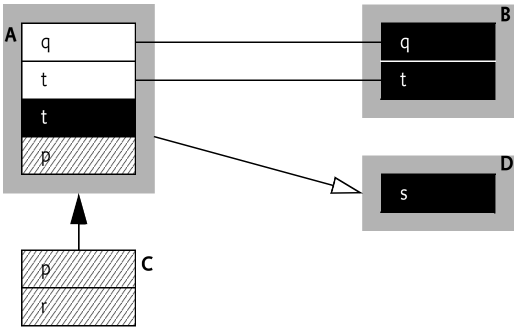
For example, consider the following setup:

```
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 4.28.

Figure 4.28 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	getResource	getEntry	findEntries
q	B.q	null	null
p	A.p > C.p	A.p	A.p > C.p
r	C.r	null	C.r
s	D.s	null	null
t	B.t	A.t	A.t

Table 4.6 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

4.3.16 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.

The parameter type is Object so that the Framework can be implemented on Java platforms that do not support Java 2 based security.

4.3.17 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 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 Service Platform, 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 82.
- Interrogating other bundles installed in the OSGi environment. See *Getting Bundle Information* on page 93.
- Obtaining a persistent storage area. See *Persistent Storage* on page 93.
- Retrieving service objects of registered services. See *Service References* on page 109.
- Registering services in the Framework service. See *Registering Services* on page 110.
- Subscribing or unsubscribing to events broadcast by the Framework. See *Listeners* on page 97.

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.

4.4.1 Getting Bundle Information

The BundleContext interface defines methods to retrieve information about bundles installed in the OSGi Service Platform:

- 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].

4.4.2 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.

4.4.3 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 following Framework properties:

All Framework properties may be defined by the Operator as System properties. If these properties are not defined as System properties, the Framework must construct these properties from relevant standard Java System properties.

Table 4.7 Property Names

Property name	Description
org.osgi.framework.version	The specification version of the Framework, must be 1.3
org.osgi.framework.vendor	The vendor of the Framework implementation.
org.osgi.framework.language	The language being used. See *ISO 639, International Standards Organization* See [41] *Codes for the Representation of Names of Languages* for valid values.
org.osgi.framework. « executionenvironment	A comma-separated list of provided execution environments (EE). All methods of each listed EE must be present on the Service Platform. For example, this property could contain: `CDC-1.0/Foundation-1.0,OSGi/Minimum-1.0` A Service Platform implementation must provide *all* the signatures that are defined in the mentioned EEs. Thus, the execution environment for a specific Service Platform Server must be the combined set of all signatures of all EEs in the org.osgi.framework.executionenvironment property.
org.osgi.framework.processor	Processor name. The following table defines a list of processor names. New processors are made available on the OSGi web site. Names should be matched case insensitive.

Name	Aliases	Description
68k		Motorola 68000
ARM		Intel Strong ARM
Alpha		Compaq (ex DEC)
Ignite	psc1k	PTSC
Mips		SGI
PArisc		Hewlett Packard
PowerPC	power ppc	Motorola/IBM Power PC
Sh4		Hitachi
Sparc		SUN
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

Property name	Description
org.osgi.framework.os.version	The version of the operating system. If the version does not fit the standard x.y.z format (e.g. 2.4.32-kwt), then the Operator should define a System property with this name.
org.osgi.framework.os.name	The name of the operating system (OS) of the host computer. The following table defines a list of OS names. New OS names are made available on the OSGi web site. Names should be matched case insensitive.

Name	Aliases	Description
AIX		IBM
DigitalUnix		Compaq

Table 4.7 Property Names

Property name	Description		
	Embos		Segger Embedded Software Solutions
	Epoc32	SymbianOS	Symbian OS
	FreeBSD		Free BSD
	HPUX		Hewlett Packard
	IRIX		Silicon Graphics
	Linux		Open source
	MacOS		Apple
	NetBSD		Open source
	Netware		Novell
	OpenBSD		Open source
	OS2	OS/2	IBM
	QNX	procnto	QNX
	Solaris		Sun (almost an alias of SunOS)
	SunOS		Sun Microsystems
	VxWorks		WindRiver Systems
	Windows95	Win95 "Windows 95" Win32	Microsoft Windows 95
	Windows98	Win98 "Windows 98" Win32	Microsoft Windows 98
	WindowsNT	WinNT "Windows NT" Win32	Microsoft Windows NT
	WindowsCE	WinCE "Windows CE"	Microsoft Windows CE
	Windows2000	Win2000 "Windows 2000" Win32	Microsoft Windows 2000
	Windows2003	Win2003 "Windows 2003" Win32	Microsoft Windows 2003
	WindowsXP	WinXP "Windows XP" Win32	Microsoft Windows XP
	WindowsVista	WinVista "Windows Vista" Win32	Microsoft Windows Vista
org.osgi.supports.« framework.extension	Support for framework extensions is mandatory, must therefore be set to true, see *Extension Bundles* on page 72.		
org.osgi.supports.« bootclasspath.extension	See *Optional* on page 64.		

Table 4.7 *Property Names*

Property name	Description
org.osgi.supports.« framework.fragment	Support for fragment bundles is mandatory, must therefore be set to true, see *Fragment Bundles* on page 68.
org.osgi.supports.« framework.requirebundle	Support for Require Bundle is mandatory, must therefore be set to true, see *Requiring Bundles* on page 65.
org.osgi.framework.« bootdelegation	See *Parent Delegation* on page 52
org.osgi.framework.« system.packages	See *Parent Class Loader* on page 55

The alias column contains is names that have been reported to be returned by certain versions of the related operating systems. Frameworks should try to convert these aliases to the canonical OS or processor name. The bundle developer should use the canonical name in the Bundle-NativeCode manifest header.

4.5 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 services are the Package Admin and Permission Admin services.

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 *Framework Startup and Shutdown* on page 100 for more information about the starting and stopping of the Framework.
- The system bundle's `Bundle.getHeaders` method returns a `Dictionary` object with implementation-specific manifest headers. For example, the system bundle's manifest file should contain an Export-Package header

declaring which packages are to be exported by the Framework (for example, org.osgi.framework).

4.6 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.

4.6.1 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 Package

  Admin 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 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.
  - WARNING – A warning to the operator that is not crucial but may indicate a potential error situation.

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).

4.6.2 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.

4.6.3 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.

4.7 Framework Startup and Shutdown

A Framework implementation must be started before any services can be provided. How a Framework should be started by the Operator is not detailed in this specification because it can differ for different implementations. Some Framework implementations may provide command line options, and others may read startup information from a configuration file. In all cases, Framework implementations must perform all of the following actions in the given order.

4.7.1 Startup

When the Framework is started, the following actions must occur:

1. Event handling is enabled. Events can now be delivered to listeners. Events are discussed in *Events* on page 97.
2. The system bundle enters the STARTING state. More information about the system bundle can be found in *The System Bundle* on page 96.
3. 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 event of type FrameworkEvent.ERROR. Bundles and their different states are discussed in *The Bundle Object* on page 81. If the Framework implements the optional Start Level specification, this behavior is different. See *Start Level Service Specification* on page 203. Any bundles that specify an activation policy must be treated according to their activation policy, see *Activation Policies* on page 85.
4. The system bundle enters the ACTIVE state.
5. A Framework event of type FrameworkEvent.STARTED is broadcast.

4.7.2 Shutdown

The Framework will also need to be shut down on occasion. Shutdown can also be initiated by stopping the system bundle, covered in *The System Bundle* on page 96. When the Framework is shut down, the following actions must occur in the given order:

1. The system bundle enters the STOPPING state.
2. All ACTIVE bundles are stopped as described in the Bundle.stop method, except that their persistently recorded state indicates that they must be restarted when the Framework is next started 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 is different. See *Start Level Service Specification* on page 203. During the shutdown, bundles with a lazy policy must not be activated even when classes are loaded from them.
3. Event handling is disabled.

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. This is to ensure the fastest execution of the permission check.

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") );
         ...
   }
}
```

When assigning permissions to the bundle via (Conditional) Permission Admin service, it is difficult for the administrator to have a priori knowledge of the bundle ID assigned to a bundle. In order to provide a more flexible way to designate the bundle for an Admin Permission, (Conditional) Permission Admin must provide special support for creating `AdminPermission` objects from a `PermissionInfo` object. When a Permission Info specifies an Admin Permission, the name parameter of the Permission Info must be a *filter* string. This filter has the same syntax as an OSGi filter but has special rules for wildcards in the location and signer attributes.

The filter can contain the following keys:

- *id* – The bundle ID of the designated 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 the *Certificate Matching* on page 21 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 character ('*' or \u002a) must be escaped with a backslash ('\') 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 complete filter can also be a single wildcard character ('*' or \u002a). In that case all bundles must match.

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 table Table 4.8. 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 4.8 Admin Permission actions

Action	Used in
`metadata`	`Bundle.getHeaders` `Bundle.getLocation`

`resource`	`Bundle.getResource`
	`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`
	`StartLevel.setBundleStartLevel`

`listener`	`BundleContext.addBundleListener` for `SynchronousBundleListener`
	`BundleContext.removeBundleListener` for `SynchronousBundleListener`

`extensionLifecycle`	`BundleContext.installBundle` for extension bundles `Bundle.update` for extension bundles `Bundle.uninstall` for extension bundles

Table 4.8 Admin Permission actions

Action	Used in
resolve	PackageAdmin.refreshPackages PackageAdmin.resolveBundles
startlevel	StartLevel.setStartLevel StartLevel.setInitialBundleStartLevel
context	Bundle.getBundleContext

The special action "*" will represent all actions.

Each bundle must be given AdminPermission(<bundle identifier>, "resource,metadata,class") so that it can access its own resources. This is an implicit permission that must be automatically given to all bundles by the Framework.

The actions resolve and startlevel must use the system bundle as target.

The implementation of the AdminPermission class requires close integration with the Framework implementation. However, an AdminPermission class accompanies the specification. Framework implementations can change this class if they so desire. However, the default implementation provided must load a Framework implementation provided class when it is loaded. This class comes from the package named in the following property:

```
org.osgi.vendor.framework
```

The class named AdminPermission in that package must be used to instantiate a new Permission object using the constructor with the same signature to which all the AdminPermission methods must delegate.

4.8.2 Using Signer for the Target

The Admin Permission use the signer of the bundle to select a target. For example, a bundle could be granted the permission to perform life cycle operations on bundles signed by a particular principal.

Using the principal (signer) as target, the maintenance of the permission management can be significantly reduced because it is not necessary to configure for individual bundles: the signer is effectively used as a grouping mechanism. However, one must consider that signatures can be added by any part, thereby causing it to become eligible for management by bundles that have the permission to administrate specific signers.

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 can 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.

4.8.3 Privileged Callbacks

The following interfaces define bundle callbacks that are invoked by the Framework:

- BundleActivator
- ServiceFactory
- Bundle-, Service-, and FrameworkListener.

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.

4.8.4 Lazy Activation

The activation policy, see *Activation Policies* on page 85, 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 Changes 4.1

- Expressly indicated that Fragment bundles can not be started and must not have a Bundle Activator.
- Added a `LAZY_ACTIVATION` event.
- Added a `getBundleContext` method to the Bundle interface in *Access to a Bundle's Bundle Context* on page 92. Added a section for the required Admin Permission
- Added activation policies, see *Activation Policies* on page 85.
- Add properties for Windows Vista and 64 bit processors. See *Environment Properties* on page 93.
- Added a new `start` and `stop` method that take an `int` to specify the start/stop option.
- An option is defined to start bundles transient, that is, starting the bundle but not changing the recorded start state.
- Added text to ensure that events are delivered in order.

4.10 References

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5 Service Layer

Version 1.4

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

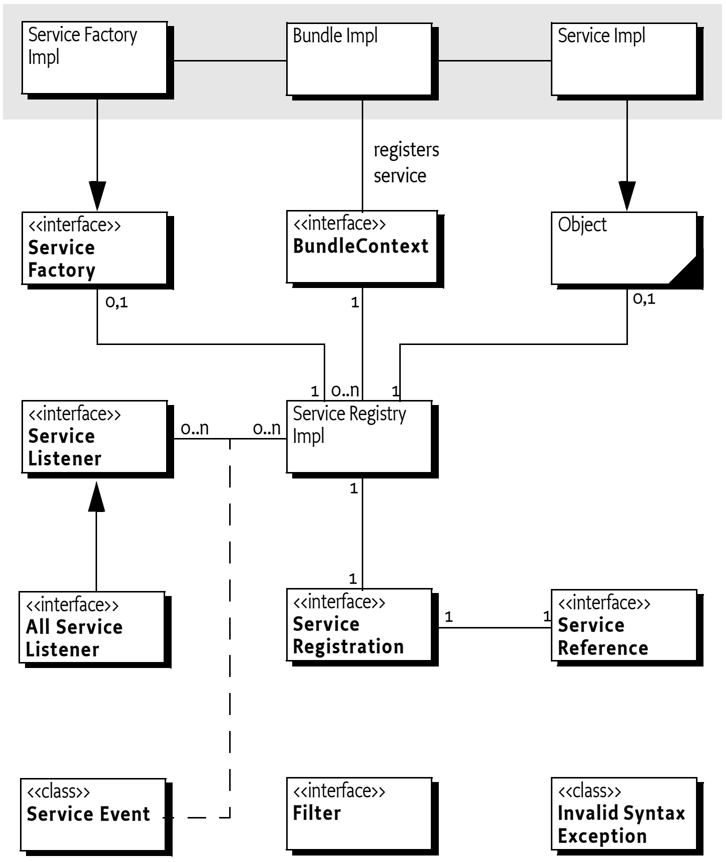
- *Collaborative* – The service layer must provide a mechanism for bundles to publish, find, and bind to each other's services without having a priori knowledge of those bundles.
- *Dynamic* – The service mechanism must be able to handle changes in the outside world and underlying structures directly.
- *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. This object 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 Factory* – A facility to let the registering bundle customize the service object for each using bundle.
- *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 5.29 *Class Diagram* org.osgi.framework *Service Layer*


Service Factory Impl
Bundle Impl
Service Impl
registers service
<<interface>> Service Factory
<<interface>> BundleContext
Object
0,1
1
0,1
1
0..n
1
<<interface>> Service Listener
0..n
0..n
Service Registry Impl
1
1
<<interface>> All Service Listener
<<interface>> Service Registration
1
1
<<interface>> Service Reference
<<class>> Service Event
<<interface>> Filter
<<class>> Invalid Syntax Exception

5.2 Services

In the OSGi Service Platform, 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 provides 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 services 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. When a bundle wishes to use the service, it can be obtained by passing the ServiceReference object to BundleContext.getService(ServiceReference). See *Locating Services* on page 114.

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.

A ServiceReference object may also be obtained from a ServiceRegistration object.

A ServiceReference object is valid only as long as the service object is registered. However, its properties must remain available as long as the ServiceReference object exists.

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 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 object, 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.

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 117.

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 object'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.

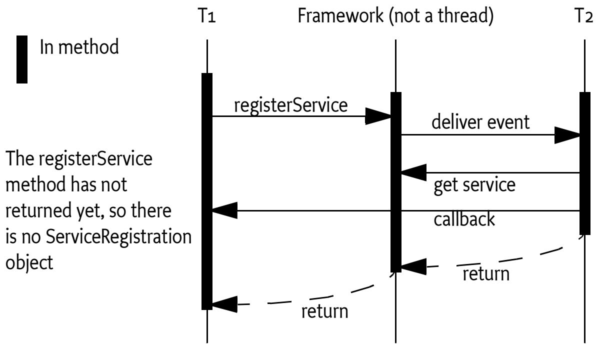
Using the ServiceRegistration object is the only way to reliably change the service object's properties after it has been registered (see setProperties(Dictionary)). Modifying a service object's Dictionary object after the service object is registered may not have any effect on the service's properties.

The process of registering a service object is subject to a permission check. The registering bundle must have ServicePermission[<interface 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 5.30 on page 111 shows such a sequence.

Figure 5.30 Service Registration and registration



In a case as described previously, access to the registration object can be obtained via a ServiceFactory object. If a ServiceFactory object is registered, the Framework must call-back the registering bundle with the ServiceFactory method getService(Bundle,ServiceRegistration). The required ServiceRegistration object is passed as a parameter to this method.

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 116 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 object. 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 service objects. Therefore, all properties share a single name space 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 name space. All properties starting with the prefix service. and the property objectClass are reserved for use by OSGi specifications.

Table 5.9 Standard Service Properties contains a list of pre-defined properties.

Table 5.9 Standard Service Properties

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 BundleContext.getService(ServiceReference), it can be cast to any of the interface names.
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.

Table 5.9 Standard Service Properties

Property Key	Type	Constants	Property Description
service.id	Long	SERVICE_ID	Every registered service object is assigned a unique service.id by the Framework. This number is added to the service object's properties. The Framework assigns a unique 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 *Persistent Identifier (PID)* on page 113.
service.ranking	Integer	SERVICE_RANKING	When registering a service object, a bundle may optionally specify a service.ranking number as one of the service object's properties. If multiple qualifying service interfaces exist, a service with the highest SERVICE_RANKING number, or when equal to the lowest SERVICE_ID, determines which service object is returned by the Framework.
service.vendor	String	SERVICE_VENDOR	This optional property can be used by the bundle registering the service object to indicate the vendor.

5.2.6 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
```

A PID must be unique for each service. A bundle must not register multiple services with the same PID, nor should other bundles use the same PID. If this happens, it is an error condition.

5.2.7 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 two methods a bundle can call to obtain ServiceReference objects from the Framework:

- getServiceReference(String) – This method returns a ServiceReference object to a service object that implements, and was registered under, the name of the service interface specified as String. If multiple such service objects exist, the service object with the highest SERVICE_RANKING is returned. If there is a tie in ranking, the service object with the lowest SERVICE_ID (the service object that was registered first) is returned.
- getServiceReferences(String,String) – This method returns an array of ServiceReference objects that:
  - Implement and were registered under the given service interface.
  - Satisfy the search filter specified. The filter syntax is further explained in *Filters* on page 116.

Both methods must return null if no matching service objects are returned. Otherwise, the caller receives one or more ServiceReference objects. These objects can be used to retrieve properties of the underlying service object, or they can be used to obtain the actual service object via the BundleContext object.

Both methods require that the caller has the required ServicePermission[<name>, GET] to get the service object for the specified service interface names. If the caller lacks the required permission, these methods must return null.

5.2.8 Getting Service Properties

To allow for interrogation of service objects, 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.

5.2.9 Getting Service Objects

The BundleContext object is used to obtain the 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 that registered service object. This dependency is tracked by the BundleContext object used to obtain the service object, and is one reason that it is important to be careful when sharing BundleContext objects with other bundles.

The method BundleContext.getService(ServiceReference) returns an object that implements the interfaces as defined by the objectClass property.

This method has the following characteristics:

- Returns null if the underlying service object has been unregistered.
- Determines if the caller has ServicePermission[<interface name>,GET], to get the service object using at least one of the service interfaces under which the service was registered. This permission check is necessary so that ServiceReference objects can be passed around freely without compromising security.
- Increments the usage count of the service object by one for this BundleContext object.
- If the service object does not implement the ServiceFactory interface, it is returned. Otherwise, if the bundle context's usage count of the service object is one, the object is cast to a ServiceFactory object and the getService method is called to create a customized service object for the calling bundle which is then returned. Otherwise, a cached copy of this customized object is returned. See *Service Factory* on page 117 for more information about ServiceFactory objects.

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 service objects that the bundle has registered with the Framework.
- getServicesInUse() – Returns the service objects that the bundle is using.

5.3 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[<interface name>,GET] for at least one of the interfaces under which the service object is registered.

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.

5.4 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 interface. The methods in the ServiceFactory interface simplify tracking bundles that use their service objects. See *Service Factory* on page 117.
- Use indirection in the service object implementations. Service objects handed out to other bundles should use a pointer to the actual service object implementation. When the service object becomes invalid, the pointer is set to null, effectively removing the reference to the actual service object.

The behavior of a service that becomes unregistered is undefined. Such services may continue to work properly or throw an exception at their discretion. This type of error should be logged.

5.5 Filters

The Framework provides a Filter interface, and uses a filter syntax in the getServiceReferences method that is defined in *Filter Syntax* on page 29. 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.

A Filter object can be used numerous times to determine if the match argument, a ServiceReference 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 a constructor taking a single String object and the class implements the Comparable interface. That is, if the target object is of class Target, the class Target must implement:

- A constructor Target(String)
- Implement the java.lang.Comparable interface

If the target object does not implement java.lang.Comparable, the =, ~=, <= >= operators must return only true when the objects are equal (using the equals(Object) method). The Target class does not need to be a public class.

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.

5.6 Service Factory

A Service Factory allows customization of the service object that is returned when a bundle calls BundleContext.getService(ServiceReference).

Often, the service object that is registered by a bundle is returned directly. If, however, the service object that is registered implements the ServiceFactory interface, the Framework must call methods on this object to create a unique service object for each distinct bundle that gets the service.

When the service object is no longer used by a bundle – for example, when that bundle is stopped – then the Framework must notify the ServiceFactory 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 service, 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 if a call is made to BundleContext.getService and the following are true:
  - The ServiceReference argument to BundleContext.getService refers to a service object that implements the ServiceFactory interface.
  - The bundle's usage count of that service object is zero; that is, the bundle currently does not have any dependencies on the service object.

  The call to BundleContext.getService must be routed by the Framework to this method, passing to it the Bundle object of the caller. The Framework must cache the mapping of the requesting bundle-to-service, and return the cached service object to the bundle on future calls to BundleContext.getService, as long as the requesting bundle's usage count of the service object is greater than zero.
  The Framework must check the 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 caller that called getService. This check must be done as specified in *Registering Services* on page 110.
- ungetService(Bundle,ServiceRegistration,Object) – This method is called by the Framework if a call is made to BundleContext.ungetService and the following are true:
  - The ServiceReference argument to BundleContext.ungetService refers to a service object that implements the ServiceFactory interface.
  - The bundle's usage count for that service object must drop to zero after this call returns; that is, the bundle is about to release its last dependency on the service object.

  The call to BundleContext.ungetService must be routed by the Framework to this method so the ServiceFactory object can release the service object previously created.
  Additionally, the cached copy of the previously created service object must be unreferenced by the Framework so it may be garbage collected.

5.7 Releasing Services

In order for a bundle to release a service object, it must remove the dynamic dependency on the bundle that registered the service object. The Bundle Context interface defines a method to release service objects: ungetService(ServiceReference). A ServiceReference object is passed as the argument of this method.

This method returns a boolean value:

- false if the bundle's usage count of the service object is already zero when the method was called, or the service object has already been unregistered.
- true if the bundle's usage count of the service object was more than zero before this method was called.

5.8 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. The 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 ServiceRegistration.unregister successfully completes, the service object must be:

- Completely removed from the Framework service registry. Therefore, ServiceReference objects obtained for that service object can no longer be used to access the service object. Calling BundleContext.getService method with the ServiceReference 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 object of type ServiceEvent.UNREGISTERING. This event is sent synchronously in order to give bundles the opportunity to release the service object.
  After receiving an event of type ServiceEvent.UNREGISTERING, a bundle should release the service object and release any references it has to this object, so that the service object can be garbage collected by the Java VM.
- Released by all using bundles. For each bundle whose usage count for the service object remains greater than zero after all invoked ServiceListener objects have returned, the Framework must set the usage count to zero and release the service object.

5.9 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.

5.9.1 Service Registry

Bundles must not be exposed to services for which there are conflicting class loaders. A bundle that gets a service 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 was registered and that it can access. No ClassCastExceptions should occur because those interfaces do not come from the same class loader. The service registry must therefore ensure that bundles can only see services that are *not incompatible* with them. A service is not incompatible with the bundle getting the service when that bundle is not wired to another source class loader for this interface package than the bundle registering the service. 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 services. Therefore, the following methods need to filter ServiceReference objects depending on the incompatibility of the interfaces with the calling bundle. The bundle is identified by the used Bundle Context:

- getServiceReference(String) – Only return a Service Reference that is not incompatible with the calling bundle for the specified interface.
- getServiceReferences(String,String) – Only return Service References that are not incompatible with the calling bundle for the specified interface.

The getAllServiceReferences(String,String) provides access to the service registry without any compatibility restrictions. Services acquired through this method can cause Class Cast Exceptions for the correct class names.

The ServiceReference isAssignableTo(Bundle,String) method is also available to test if the bundle that registered the service referenced by this ServiceReference and the specified bundle are both wired to same source for the specified interface.

5.9.2 Service Events

Service events must only be delivered to event listeners that are not incompatible with the Service Reference.

Some bundles need to listen to all service events regardless the compatibility issues. A new type of ServiceListener is therefore added: AllServiceListener. This is a marker interface; it extends ServiceListener. Listeners that use this marker interface indicate to the Framework that they want to see all services, including services that are incompatible with them.

5.10 Security

5.10.1 Service Permission

A ServicePermission has the following parameters.

- *Interface Name* – The interface name may end with a wildcard to match multiple interface names. (See java.security.BasicPermission for a discussion of wildcards.)

- *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 110.

When a ServiceReference object is obtained from the service registry using BundleContext.getServiceReference or BundleContext.getServiceReferences, the calling bundle must have the required ServicePermission[<interface name>, GET] to get the service object with the named class. See *Service References* on page 109.

When a service object is obtained from a ServiceReference object using BundleContext.getService(ServiceReference), the calling code must have the required ServicePermission[<name>, GET] to get the service object for at least one of the classes under which it was registered.

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.

5.11 Changes 4.1

- The ServiceReference interface extends java.lang.Comparable, Service Reference objects are compared for their ranking and id according to the ordering that is used in the getServiceReference(String) method to select a service.

6 Framework API

Version 1.4

6.1 org.osgi.framework

Framework Package Version 1.4.

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;version=1.4
```

6.1.1 Summary

- 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.
- 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-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.
- ServiceEvent - An event from the Framework describing a service lifecycle change.
- ServiceFactory - Allows services to provide customized service objects in the OSGi environment.
- ServiceListener - A ServiceEvent listener.
- 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.

- Version - Version identifier for bundles and packages.

6.1.2 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                 Bundle.loadClass
   execute               Bundle.start
                         Bundle.stop
                         StartLevel.setBundleStartLevel
   extensionLifecycle    BundleContext.installBundle for
extension bundles
                         Bundle.update for extension bundles
                         Bundle.uninstall for extension bundles
   lifecycle             BundleContext.installBundle
                         Bundle.update
                         Bundle.uninstall
   listener              BundleContext.addBundleListener for
SynchronousBundleListener
                         BundleContext.removeBundleListener
for SynchronousBundleListener
   metadata              Bundle.getHeaders
                         Bundle.getLocation
   resolve               PackageAdmin.refreshPackages
                         PackageAdmin.resolveBundles
   resource              Bundle.getResource
                         Bundle.getResources
                         Bundle.getEntry
                         Bundle.getEntryPaths
                         Bundle.findEntries
                         Bundle resource/entry URL creation
   startlevel            StartLevel.setStartLevel
                         StartLevel.setInitialBundleStartLevel
   context               Bundle.getBundleContext
```

The special action "*" will represent all actions.

The name of this permission is a filter expression. The filter gives access to the following parameters:

- 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.

6.1.2.1 public static final String CLASS = "class"

The action string class (Value is "class").

Since 1.3

6.1.2.2 **public static final String CONTEXT = "context"**

The action string context (Value is "context").

Since 1.4

6.1.2.3 **public static final String EXECUTE = "execute"**

The action string execute (Value is "execute").

Since 1.3

6.1.2.4 **public static final String EXTENSIONLIFECYCLE = "extensionLifecycle"**

The action string extensionLifecycle (Value is "extensionLifecycle").

Since 1.3

6.1.2.5 **public static final String LIFECYCLE = "lifecycle"**

The action string lifecycle (Value is "lifecycle").

Since 1.3

6.1.2.6 **public static final String LISTENER = "listener"**

The action string listener (Value is "listener").

Since 1.3

6.1.2.7 **public static final String METADATA = "metadata"**

The action string metadata (Value is "metadata").

Since 1.3

6.1.2.8 **public static final String RESOLVE = "resolve"**

The action string resolve (Value is "resolve").

Since 1.3

6.1.2.9 **public static final String RESOURCE = "resource"**

The action string resource (Value is "resource").

Since 1.3

6.1.2.10 **public static final String STARTLEVEL = "startlevel"**

The action string startlevel (Value is "startlevel").

Since 1.3

6.1.2.11 **public AdminPermission( )**

□ Creates a new AdminPermission object that matches all bundles and has all actions. Equivalent to AdminPermission("*","*");

6.1.2.12 **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.

actions class, execute, extensionLifecycle, lifecycle, listener, metadata, resolve, resource, startlevel or context. 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 "*".

6.1.2.13 public AdminPermission(Bundle bundle, String actions)

bundle A bundle

actions class, execute, extensionLifecycle, lifecycle, listener, metadata, resolve, resource, startlevel, context.

□ Creates a new AdminPermission object to be used by the code that must check a Permission object.

Since 1.3

6.1.2.14 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.

6.1.2.15 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.

Returns Canonical string representation of the AdminPermission actions.

6.1.2.16 public int hashCode( )

□ Returns the hash code value for this object.

Returns Hash code value for this object.

6.1.2.17 public boolean implies(Permission p)

p The permission to interrogate.

□ 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.

Throws `RuntimeException` – if specified permission was not constructed with a bundle or "*"

6.1.2.18 public PermissionCollection newPermissionCollection( )

□ Returns a new PermissionCollection object suitable for storing AdminPermissions.

Returns A new PermissionCollection object.

6.1.3 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

6.1.4 public interface 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 reinstalling 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 execute code 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.

6.1.4.1 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.

6.1.4.2 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.

6.1.4.3 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.

6.1.4.4 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

6.1.4.5 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

6.1.4.6 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 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.

6.1.4.7 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

6.1.4.8 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` 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.

6.1.4.9 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.

6.1.4.10 public Enumeration 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 and it supports substring matching, 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 classloader 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();
```

Returns An enumeration of URL objects for each matching entry, or null if an entry could not 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 ascending bundle id order. If this bundle is a fragment, then only matching entries in this fragment are returned.

Since 1.3

6.1.4.11 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

6.1.4.12 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.

6.1.4.13 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 classloader 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.

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

6.1.4.14 public Enumeration 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 classloader 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 "/".

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

6.1.4.15 public Dictionary 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.

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 A 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`

6.1.4.16 public Dictionary 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.

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 A 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

6.1.4.17 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 GMT.

Returns The time when this bundle was last modified.

Since 1.3

6.1.4.18 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.

6.1.4.19 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`

6.1.4.20 public URL getResource(String name)

name The name of the resource. See java.lang.ClassLoader.getResource for a description of the format of a resource name.

□ Find the specified resource from this bundle. 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.

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`, `findEntries`

Since 1.1

6.1.4.21 public Enumeration getResources(String name) throws IOException

name The name of the resource. See java.lang.ClassLoader.getResources for a description of the format of a resource name.

□ Find the specified resources from this bundle. 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 resolved, 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.

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

6.1.4.22 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 its use count for that service is greater than zero.

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`

6.1.4.23 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.

6.1.4.24 public String getSymbolicName( )

□ Returns the symbolic name of this bundle as specified by its Bundle-SymbolicName manifest header. The name must be unique, it is recommended to use a reverse domain name naming convention like that used for java packages. If this bundle does not have a specified symbolic name then null is returned.

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.

Since 1.3

6.1.4.25 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 instanceofjava.security.Permission.

Throws `IllegalStateException` – If this bundle has been uninstalled.

6.1.4.26 public Class loadClass(String name) throws ClassNotFoundException

name The name of the class to load.

□ Loads the specified class using this bundle's classloader.

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

6.1.4.27 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 Framework implements the optional Start Level service and 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 this bundle's state is ACTIVE then this method returns immediately.
3. 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.
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` 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 If this bundle's state is UNINSTALLED, because this bundle was uninstalled while the BundleActivator.start method was running, a BundleException is thrown.
10 This bundle's state is set to ACTIVE.
11 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. This could be because a code dependency could not be resolved or the specified BundleActivator could not be loaded or threw an exception or this bundle is a fragment.

`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

6.1.4.28 public void start( ) throws BundleException

□ Starts this bundle with no options.

This method calls start(0).

Throws `BundleException` – If this bundle could not be started. This could be because a code dependency could not be resolved or the specified BundleActivator could not be loaded or threw an exception or this bundle is a fragment.

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)

6.1.4.29 public void stop(int options) throws BundleException

options The options for stoping 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 then set this bundle's persistent autostart setting to 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 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 The BundleActivator.stop 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. 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` – If this bundle's BundleActivator threw an exception or this bundle is a fragment.

`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

6.1.4.30 public void stop( ) throws BundleException

☐ Stops this bundle with no options.

This method calls stop(0).

Throws `BundleException` – If this bundle's BundleActivator threw an exception or this bundle is a fragment.

`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)`

6.1.4.31 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 PackageAdmin.refreshPackages 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.

`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()`

6.1.4.32 public void update( ) throws BundleException

□ Updates this bundle.

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, these packages must not be updated. Instead, the previous package version must remain exported until the PackageAdmin.refreshPackages method has been 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 download location of the new version of this bundle is determined from either this bundle's `Constants.BUNDLE_UPDATELOCATION` Manifest header (if available) or this bundle's original location.
4. The location is interpreted in an implementation dependent manner, typically as a URL, and the new version of this bundle is obtained from this location.
5. The new version of this bundle is installed. If the Framework is unable to install the new 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.
6. If this bundle has declared an Bundle-RequiredExecutionEnvironment header, then the listed execution environments must be verified against the installed execution environments. If they do not all match, the original version of this bundle must be restored and a BundleException must be thrown after completion of the remaining steps.
7. This bundle's state is set to INSTALLED.

8 If the new version of this bundle was successfully installed, a bundle event of type `BundleEvent.UPDATED` is fired.
9 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 the update fails.

`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()`

6.1.4.33 public void update(InputStream in) throws BundleException

in The InputStream from which to read the new bundle.

□ Updates this bundle from an InputStream.

This method performs all the steps listed in Bundle.update(), except the new version of this bundle must be read from the supplied InputStream, rather than a URL.

This method must always close the InputStream when it is done, even if an exception is thrown.

Throws `BundleException` – If the provided stream cannot be read or the update fails.

`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()`

6.1.5 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().

6.1.5.1 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.

6.1.5.2 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.

6.1.6 public interface BundleContext

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 and provided to the bundle associated with this context when it is started using the `BundleActivator.start` method. The same BundleContext object will be passed to the bundle associated with this context when it is stopped using the `BundleActivator.stop` method. 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 Bundle object associated with a BundleContext object is called the context bundle.

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. If the BundleContext object is used subsequently, an IllegalStateException must be thrown. The BundleContext object must never be reused after its context bundle is stopped.

The Framework is the only entity that can create BundleContext objects and they are only valid within the Framework that created them.

6.1.6.1 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`

6.1.6.2 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`

6.1.6.3 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 ServiceEvents 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`

6.1.6.4 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)`

6.1.6.5 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 unparsable.

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

6.1.6.6 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 criteria.

□ 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 criteria.

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 anytime.

filter is used to select the registered service whose properties objects contain keys and values which satisfy the filter. See `Filter` for a description of the filter string syntax.

If filter is null, all registered services are considered to match the filter. If filter cannot be parsed, an `InvalidSyntaxException` will be thrown with a human readable message where the filter became unparsable.

The following steps are required to select a set of ServiceReference objects:

1 If the filter string is not null, the filter string is parsed and the set ServiceReference objects of registered services that satisfy the filter is produced. If the filter string is null, then all registered services are considered to satisfy the filter.
2 If the Java Runtime Environment supports permissions, the set of ServiceReference objects produced by the previous step is reduced by checking that the caller has the ServicePermission to get at least one of the class names under which the service was registered. If the caller does not have the correct permission for a particular ServiceReference object, then it is removed from the set.
3 If clazz is not null, the set is further reduced to those services that are an instanceof and were registered under the specified class. The complete list of classes of which a service is an instance and which were specified when the service was registered is available from the service's `Constants.OBJECTCLASS` property.
4 An array of the remaining ServiceReference objects is returned.

Returns An array of ServiceReference objects or null if no services are registered which satisfy the search.

Throws `InvalidSyntaxException` – If filter contains an invalid filter string that cannot be parsed.

`IllegalStateException` – If this BundleContext is no longer valid.

Since 1.3

6.1.6.7 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.

6.1.6.8 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.

6.1.6.9 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.

6.1.6.10 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.

6.1.6.11 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.

The Framework defines the following standard property keys:

- `Constants.FRAMEWORK_VERSION` - The OSGi Framework version.
- `Constants.FRAMEWORK_VENDOR` - The Framework implementation vendor.
- `Constants.FRAMEWORK_LANGUAGE` - The language being used. See ISO 639 for possible values.
- `Constants.FRAMEWORK_OS_NAME` - The host computer operating system.
- `Constants.FRAMEWORK_OS_VERSION` - The host computer operating system version number.
- `Constants.FRAMEWORK_PROCESSOR` - The host computer processor name.

All bundles must have permission to read these properties.

Note: The last four standard properties are used by the `Constants.BUNDLE_NATIVECODE`Manifest header's matching algorithm for selecting native language code.

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.

6.1.6.12 public Object getService(ServiceReference reference)

reference A reference to the service.

□ Returns the specified service object for a service.

A bundle's use of a service is tracked by the bundle's use count of that service. Each time a service's service object is returned by `getService(ServiceReference)` the context bundle's use count for that service is incremented by one. Each time the service is released by `ungetService(ServiceReference)` the context bundle's use count for that service is decremented by one.

When a bundle's use count for a service drops to zero, the bundle should no longer use that service.

This method will always return null when the service associated with this 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 The context bundle's use count for this service is incremented by one.
3 If the context bundle's use count for the service is currently one and the service was registered with an object implementing the ServiceFactory interface, the `ServiceFactory.getService(Bundle, ServiceRegistration)` method is called to create a service object for the context bundle. This 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 services's service object for the context bundle will return the cached service object.

If the service object returned by the ServiceFactory object is not an instanceof all the classes named when the service was registered or the ServiceFactory object throws an exception, null is returned and a Framework event of type `FrameworkEvent.ERROR` is fired.

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 or does not implement the classes under which it was registered in the case of a ServiceFactory.

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.

See Also `ungetService(ServiceReference)`, `ServiceFactory`

6.1.6.13 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.

This 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 anytime.

This method is the same as calling `BundleContext.getServiceReferences(String, String)` with a null filter string. 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 named class.

Throws `IllegalStateException` – If this BundleContext is no longer valid.

See Also `getServiceReferences(String, String)`

6.1.6.14 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 criteria.

□ 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 criteria, 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 anytime.

filter is used to select the registered service whose properties objects contain keys and values which satisfy the filter. See `Filter` for a description of the filter string syntax.

If filter is null, all registered services are considered to match the filter. If filter cannot be parsed, an `InvalidSyntaxException` will be thrown with a human readable message where the filter became unparsable.

The following steps are required to select a set of ServiceReference objects:

1. If the filter string is not null, the filter string is parsed and the set ServiceReference objects of registered services that satisfy the filter is produced. If the filter string is null, then all registered services are considered to satisfy the filter.
2. If the Java Runtime Environment supports permissions, the set of ServiceReference objects produced by the previous step is reduced by checking that the caller has the ServicePermission to get at least one of the class names under which the service was registered. If the caller does not have the correct permission for a particular ServiceReference object, then it is removed from the set.
3. If clazz is not null, the set is further reduced to those services that are an instanceof and were registered under the specified class. The complete list of classes of which a service is an instance and which were specified when the service was registered is available from the service's `Constants.OBJECTCLASS` property.
4. The set is reduced one final time by cycling through each ServiceReference object and calling `ServiceReference.isAssignableTo(Bundle, String)` with the context bundle and each class name under which the ServiceReference object was registered. For any given ServiceReference object, if any call to `ServiceReference.isAssignableTo(Bundle, String)` returns false, then it is removed from the set of ServiceReference objects.
5. An array of the remaining ServiceReference objects is returned.

Returns An array of ServiceReference objects or null if no services are registered which satisfy the search.

Throws `InvalidSyntaxException` – If filter contains an invalid filter string that cannot be parsed.

`IllegalStateException` – If this BundleContext is no longer valid.

6.1.6.15 public Bundle installBundle(String location) throws BundleException

location The location identifier of the bundle to install.

□ Installs a bundle from the specified location string. A bundle is obtained from location as interpreted by the Framework in an implementation dependent manner.

Every installed bundle is uniquely identified by its location string, typically in the form of a URL.

The following steps are required to install a bundle:

1. If a bundle containing the same location string is already installed, the Bundle object for that bundle is returned.
2. The bundle's content is read from the location string. If this fails, a `BundleException` is thrown.
3. The bundle's Bundle-NativeCode dependencies are resolved. If this fails, a BundleException is thrown.
4. 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.
5. If the bundle has declared an Bundle-RequiredExecutionEnvironment header, then the listed execution environments must be verified against the installed execution environments. If none of the listed execution environments match an installed execution environment, a BundleException must be thrown.
6. The bundle's state is set to INSTALLED.
7. A bundle event of type `BundleEvent.INSTALLED` is fired.
8. 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 and no trace of the bundle exists.

Returns The Bundle object of the installed bundle.

Throws `BundleException` – If the installation failed.

`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.

6.1.6.16 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.

□ Installs a bundle from the specified InputStream object.

This method performs all of the steps listed in BundleContext.installBundle(String location), except that the bundle's content will be read from the InputStream object. The location identifier string specified will be used as the identity of the bundle.

This method must always close the InputStream object, even if an exception is thrown.

Returns The Bundle object of the installed bundle.

Throws `BundleException` – If the provided stream cannot be read or the installation failed.

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(java.lang.String)

6.1.6.17 public ServiceRegistration registerService(String[] clazzes, Object service, Dictionary 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 a ServiceFactory object.

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 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 either the getServiceReferences or getServiceReference method.

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 is not a ServiceFactory, an IllegalArgumentException is thrown if service is not an instanceof all the classes named.
2 The Framework adds these service properties to the specified Dictionary (which may be null): a property named Constants.SERVICE_ID identifying the registration number of the service and a property named Constants.OBJECTCLASS containing all the specified classes. If any of these properties have already been specified by the registering bundle, their values will be overwritten by the Framework.
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 is not a ServiceFactory object and is not an instance of all the named classes in clazzes.
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, ServiceFactory

6.1.6.18 public ServiceRegistration registerService(String clazz, Object service, Dictionary properties)

clazz The class name under which the service can be located.

service The service object or a ServiceFactory object.

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(java.lang.String[], java.lang.Object, java.util.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 strings, 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(java.lang.String[], java.lang.Object, java.util.Dictionary)

6.1.6.19 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.

6.1.6.20 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.

6.1.6.21 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.

6.1.6.22 public boolean ungetService(ServiceReference reference)

reference A reference to the service to be released.

☐ Releases the service object 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's service object should 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 unget 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 this service is decremented by one.
3. If the context bundle's use count for the service is currently zero and the service was registered with a ServiceFactory object, 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.

See Also `getService`, `ServiceFactory`

6.1.7 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 extendability.

OSGi Alliance reserves the right to extend the set of types.

See Also `BundleListener`, `SynchronousBundleListener`

Concurrency Immutable

6.1.7.1 public static final int INSTALLED = 1

The bundle has been installed.

The value of INSTALLED is 0x00000001.

See Also `BundleContext.installBundle(String)`

6.1.7.2 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.

The value of LAZY_ACTIVATION is 0x00000200.

Since 1.4

6.1.7.3 public static final int RESOLVED = 32

The bundle has been resolved.

The value of RESOLVED is 0x00000020.

See Also `Bundle.RESOLVED`

Since 1.3

6.1.7.4 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.

The value of STARTED is 0x00000002.

See Also `Bundle.start()`

6.1.7.5 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.

The value of STARTING is 0x00000080.

See Also `Bundle.start()`

Since 1.3

6.1.7.6 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.

The value of STOPPED is 0x00000004.

See Also `Bundle.stop()`

6.1.7.7 public static final int STOPPING = 256

The bundle is about to 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 SynchronousBundleListeners. It is not delivered to BundleListeners.

The value of STOPPING is 0x00000100.

See Also `Bundle.stop()`

Since 1.3

6.1.7.8 public static final int UNINSTALLED = 16

The bundle has been uninstalled.

The value of UNINSTALLED is 0x00000010.

See Also `Bundle.uninstall`

6.1.7.9 public static final int UNRESOLVED = 64

The bundle has been unresolved.

The value of UNRESOLVED is 0x00000040.

See Also `Bundle.INSTALLED`

Since 1.3

6.1.7.10 public static final int UPDATED = 8

The bundle has been updated.

The value of UPDATED is 0x00000008.

See Also `Bundle.update()`

6.1.7.11 public BundleEvent(int type, Bundle bundle)

type The event type.

bundle The bundle which had a lifecycle change.

□ Creates a bundle event of the specified type.

6.1.7.12 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.

6.1.7.13 public int getType( )

□ Returns the type of lifecyle event. The type values are:

- INSTALLED
- RESOLVED
- LAZY_ACTIVATION
- STARTING
- STARTED
- STOPPING
- STOPPED
- UPDATED
- UNRESOLVED
- UNINSTALLED

Returns The type of lifecycle event.

6.1.8 public class BundleException extends Exception

A Framework exception used to indicate that a bundle lifecycle problem occurred.

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.

This exception is updated to conform to the general purpose exception chaining mechanism.

6.1.8.1 public BundleException(String msg, Throwable cause)

msg The associated message.

cause The cause of this exception.

□ Creates a BundleException that wraps another exception.

6.1.8.2 public BundleException(String msg)

msg The message.

□ Creates a BundleException object with the specified message.

6.1.8.3 public Throwable getCause( )

□ Returns the cause of this exception or null if no cause was specified when this exception was created.

Returns The cause of this exception or null if no cause was specified.

Since 1.3

6.1.8.4 public Throwable getNestedException( )

□ Returns any nested exceptions included in this exception.

This method predates the general purpose exception chaining mechanism. The `getCause()` method is now the preferred means of obtaining this information.

Returns The nested exception; null if there is no nested exception.

6.1.8.5 public Throwable initCause(Throwable cause)

cause Cause of the exception.

□ The cause of this exception can only be set when constructed.

Returns This object.

Throws `IllegalStateException` – This method will always throw an IllegalStateException since the cause of this exception can only be set when constructed.

Since 1.3

6.1.9 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` method. BundleListeners are called with a BundleEvent object when a bundle has been installed, resolved, started, stopped, updated, unresolved, or uninstalled.

See Also `BundleEvent`

6.1.9.1 public void bundleChanged(BundleEvent event)

event The BundleEvent.

□ Receives notification that a bundle has had a lifecycle change.

6.1.10 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.

For example:

org.osgi.example.bundle

BundlePermission has four actions: PROVIDE, REQUIRE,HOST, and FRAGMENT. The PROVIDE action implies the REQUIRE action.

Since 1.3

6.1.10.1 public static final String FRAGMENT = "fragment"

The action string fragment.

6.1.10.2 public static final String HOST = "host"

The action string host.

6.1.10.3 public static final String PROVIDE = "provide"

The action string provide.

6.1.10.4 public static final String REQUIRE = "require"

The action string require.

6.1.10.5 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 BundlePermssion for that symbolic name; a bundle that specifies a fragment host must have the appropriate BundlePermission for that symbolic name.

6.1.10.6 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.

6.1.10.7 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.

6.1.10.8 public int hashCode( )

□ Returns the hash code value for this object.

Returns A hash code value for this object.

6.1.10.9 public boolean implies(Permission p)

p The target permission to interrogate.

□ 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.

6.1.10.10 public PermissionCollection newPermissionCollection( )

□ Returns a new PermissionCollection object suitable for storing BundlePermission objects.

Returns A new PermissionCollection object.

6.1.11 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 instanceof Configurable.

Deprecated As of 1.2. Please use Configuration Admin service.

6.1.11.1 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.

6.1.12 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 java.lang.String, unless otherwise indicated.

Since 1.1

6.1.12.1 public static final String ACTIVATION_LAZY = "lazy"

Bundle activation policy (named "lazy") 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 requestor.

The activation policy value is specified as in the Bundle-ActivationPolicy manifest header like:

```
Bundle-ActivationPolicy: lazy
```

See Also `Constants.BUNDLE_ACTIVATIONPOLICY`, `Bundle.start(int)`, `Bundle.START_ACTIVATION_POLICY`

Since 1.4

6.1.12.2 public static final String BUNDLE_ACTIVATIONPOLICY = "Bundle-ActivationPolicy"

Manifest header (named "Bundle-ActivationPolicy") identifying the bundle's activation policy.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

See Also `Constants.ACTIVATION_LAZY`, `Constants.INCLUDE_DIRECTIVE`, `Constants.EXCLUDE_DIRECTIVE`

Since 1.4

6.1.12.3 public static final String BUNDLE_ACTIVATOR = “Bundle-Activator”

Manifest header attribute (named “Bundle-Activator”) identifying the bundle’s activator class.

If present, this header specifies the name of the bundle resource class that implements the BundleActivator interface and whose start and stop methods are called by the Framework when the bundle is started and stopped, respectively.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.4 public static final String BUNDLE_CATEGORY = “Bundle-Category”

Manifest header (named “Bundle-Category”) identifying the bundle’s category.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.5 public static final String BUNDLE_CLASSPATH = “Bundle-ClassPath”

Manifest header (named “Bundle-ClassPath”) identifying a list of directories and embedded JAR files, which are bundle resources used to extend the bundle’s classpath.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.6 public static final String BUNDLE_CONTACTADDRESS = “Bundle-ContactAddress”

Manifest header (named “Bundle-ContactAddress”) identifying the contact address where problems with the bundle may be reported; for example, an email address.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.7 public static final String BUNDLE_COPYRIGHT = “Bundle-Copyright”

Manifest header (named “Bundle-Copyright”) identifying the bundle’s copyright information.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.8 public static final String BUNDLE_DESCRIPTION = “Bundle-Description”

Manifest header (named “Bundle-Description”) containing a brief description of the bundle’s functionality.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.9 public static final String BUNDLE_DOCURL = "Bundle-DocURL"

Manifest header (named "Bundle-DocURL") identifying the bundle's documentation URL, from which further information about the bundle may be obtained.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.10 public static final String BUNDLE_LOCALIZATION = "Bundle-Localization"

Manifest header (named "Bundle-Localization") identifying the base name of the bundle's localization entries.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

See Also `BUNDLE_LOCALIZATION_DEFAULT_BASENAME`

Since 1.3

6.1.12.11 public static final String BUNDLE_LOCALIZATION_DEFAULT_BASENAME = "OSGI-INF/l10n/bundle"

Default value for the Bundle-Localization manifest header.

See Also `BUNDLE_LOCALIZATION`

Since 1.3

6.1.12.12 public static final String BUNDLE_MANIFESTVERSION = "Bundle-ManifestVersion"

Manifest header (named "Bundle-ManifestVersion") 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 R4, or later, syntax must specify a bundle manifest version.

The bundle manifest version defined by OSGi R4 or, more specifically, by V1.3 of the OSGi Framework Specification is "2".

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.3

6.1.12.13 public static final String BUNDLE_NAME = "Bundle-Name"

Manifest header (named "Bundle-Name") identifying the bundle's name.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.14 public static final String BUNDLE_NATIVECODE = "Bundle-NativeCode"

Manifest header (named "Bundle-NativeCode") identifying a number of hardware environments and the native language code libraries that the bundle is carrying for each of these environments.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.15 public static final String BUNDLE_NATIVECODE_LANGUAGE = “language”

Manifest header attribute (named “language”) 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 ...
```

6.1.12.16 public static final String BUNDLE_NATIVECODE_OSNAME = “osname”

Manifest header attribute (named “osname”) 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 ...
```

6.1.12.17 public static final String BUNDLE_NATIVECODE_OSVERSION = “osversion”

Manifest header attribute (named “osversion”) 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” ...
```

6.1.12.18 public static final String BUNDLE_NATIVECODE_PROCESSOR = “processor”

Manifest header attribute (named “processor”) 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 ...
```

6.1.12.19 public static final String BUNDLE_REQUIREDEXECUTIONENVIRONMENT = “Bundle-RequiredExecutionEnvironment”

Manifest header (named “Bundle-RequiredExecutionEnvironment”) 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 attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.2

6.1.12.20 public static final String BUNDLE_SYMBOLICNAME = “Bundle-SymbolicName”

Manifest header (named “Bundle-SymbolicName”) identifying the bundle’s symbolic name.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.3

6.1.12.21 public static final String BUNDLE_SYMBOLICNAME_ATTRIBUTE = "bundle-symbolic-name"

Manifest header attribute (named "bundle-symbolic-name") 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"
```

Since 1.3

6.1.12.22 public static final String BUNDLE_UPDATELOCATION = "Bundle-UpdateLocation"

Manifest header (named "Bundle-UpdateLocation") identifying the location from which a new bundle version is obtained during a bundle update operation.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.23 public static final String BUNDLE_VENDOR = "Bundle-Vendor"

Manifest header (named "Bundle-Vendor") identifying the bundle's vendor.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.24 public static final String BUNDLE_VERSION = "Bundle-Version"

Manifest header (named "Bundle-Version") identifying the bundle's version.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.25 public static final String BUNDLE_VERSION_ATTRIBUTE = "bundle-version"

Manifest header attribute (named "bundle-version") identifying a range of versions for a bundle specified in the Require-Bundle or Fragment-Host manifest headers. The default value is 0.0.0.

The attribute value is encoded in the Require-Bundle manifest header like:

```
     Require-Bundle: com.acme.module.test; bundle-ver-
sion="1.1"
     Require-Bundle: com.acme.module.test; bundle-ver-
sion="[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.

Since 1.3

6.1.12.26 public static final String DYNAMICIMPORT_PACKAGE = "DynamicImport-Package"

Manifest header (named "DynamicImport-Package") identifying the packages that the bundle may dynamically import during execution.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.2

6.1.12.27 public static final String EXCLUDE_DIRECTIVE = "exclude"

Manifest header directive (named "exclude").

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.frame-
work"
```

Since 1.3

6.1.12.28 public static final String EXPORT_PACKAGE = "Export-Package"

Manifest header (named "Export-Package") identifying the packages that the bundle offers to the Framework for export.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.29 public static final String EXPORT_SERVICE = "Export-Service"

Manifest header (named "Export-Service") identifying the fully qualified class names of the services that the bundle may register (used for informational purposes only).

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Deprecated As of 1.2.

6.1.12.30 public static final String EXTENSION_BOOTCLASSPATH = "bootclasspath"

Manifest header directive value (named "bootclasspath") 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 `Constants.EXTENSION_DIRECTIVE`

Since 1.3

6.1.12.31 public static final String EXTENSION_DIRECTIVE = "extension"

Manifest header directive (named "extension") 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"
```

See Also `Constants.EXTENSION_FRAMEWORK`, `Constants.EXTENSION_BOOTCLASSPATH`

Since 1.3

6.1.12.32 public static final String EXTENSION_FRAMEWORK = "framework"

Manifest header directive value (named "framework") 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 `Constants.EXTENSION_DIRECTIVE`

Since 1.3

6.1.12.33 public static final String FRAGMENT_ATTACHMENT_ALWAYS = "always"

Manifest header directive value (named "always") 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-at-
tachment:="always"
```

See Also `Constants.FRAGMENT_ATTACHMENT_DIRECTIVE`

Since 1.3

6.1.12.34 public static final String FRAGMENT_ATTACHMENT_DIRECTIVE = "fragment-attachment"

Manifest header directive (named "fragment-attachment") 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-at-
tachment:="never"
```

See Also `Constants.FRAGMENT_ATTACHMENT_ALWAYS`, `Constants.FRAGMENT_ATTACHMENT_RESOLVETIME`, `Constants.FRAGMENT_ATTACHMENT_NEVER`

Since 1.3

6.1.12.35 public static final String FRAGMENT_ATTACHMENT_NEVER = "never"

Manifest header directive value (named "never") 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-at-
tachment:="never"
```

See Also `Constants.FRAGMENT_ATTACHMENT_DIRECTIVE`

Since 1.3

6.1.12.36 public static final String FRAGMENT_ATTACHMENT_RESOLVETIME = "resolve-time"

Manifest header directive value (named "resolve-time") 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-at-
tachment:="resolve-time"
```

See Also `Constants.FRAGMENT_ATTACHMENT_DIRECTIVE`

Since 1.3

6.1.12.37 public static final String FRAGMENT_HOST = "Fragment-Host"

Manifest header (named "Fragment-Host") identifying the symbolic name of another bundle for which that the bundle is a fragment.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.3

6.1.12.38 public static final String FRAMEWORK_BOOTDELEGATION = "org.osgi.framework.bootdelegation"

Framework environment property (named "org.osgi.framework.bootdelegation") identifying packages for which the Framework must delegate class loading to the boot class path.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

Since 1.3

6.1.12.39 public static final String FRAMEWORK_EXECUTIONENVIRONMENT = "org.osgi.framework.executionenvironment"

Framework environment property (named "org.osgi.framework.executionenvironment") identifying execution environments provided by the Framework.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

Since 1.2

6.1.12.40 public static final String FRAMEWORK_LANGUAGE = "org.osgi.framework.language"

Framework environment property (named "org.osgi.framework.language") 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.

6.1.12.41 public static final String FRAMEWORK_OS_NAME = "org.osgi.framework.os.name"

Framework environment property (named "org.osgi.framework.os.name") identifying the Framework host-computer's operating system.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

6.1.12.42 public static final String FRAMEWORK_OS_VERSION = "org.osgi.framework.os.version"

Framework environment property (named "org.osgi.framework.os.version") identifying the Framework host-computer's operating system version number.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

6.1.12.43 public static final String FRAMEWORK_PROCESSOR = "org.osgi.framework.processor"

Framework environment property (named "org.osgi.framework.processor") identifying the Framework host-computer's processor name.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

6.1.12.44 public static final String FRAMEWORK_SYSTEMPACKAGES = "org.osgi.framework.system.packages"

Framework environment property (named "org.osgi.framework.system.packages") identifying package which the system bundle must export.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

Since 1.3

6.1.12.45 public static final String FRAMEWORK_VENDOR = "org.osgi.framework.vendor"

Framework environment property (named "org.osgi.framework.vendor") identifying the Framework implementation vendor.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

6.1.12.46 public static final String FRAMEWORK_VERSION = "org.osgi.framework.version"

Framework environment property (named "org.osgi.framework.version") identifying the Framework version.

The value of this property may be retrieved by calling the BundleContext.getProperty method.

6.1.12.47 public static final String IMPORT_PACKAGE = "Import-Package"

Manifest header (named "Import-Package") identifying the packages on which the bundle depends.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

6.1.12.48 public static final String IMPORT_SERVICE = "Import-Service"

Manifest header (named "Import-Service") identifying the fully qualified class names of the services that the bundle requires (used for informational purposes only).

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Deprecated As of 1.2.

6.1.12.49 public static final String INCLUDE_DIRECTIVE = "include"

Manifest header directive (named "include").

This directive is used by the Import-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 Import-Package manifest header like:

```
    Import-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.frame-
work"
```

Since 1.3

6.1.12.50 public static final String MANDATORY_DIRECTIVE = "mandatory"

Manifest header directive (named "mandatory") 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"
```

Since 1.3

6.1.12.51 public static final String OBJECTCLASS = "objectClass"

Service property (named "objectClass") identifying all of the class names under which a service was registered in the Framework (of type java.lang.String[]).

This property is set by the Framework when a service is registered.

6.1.12.52 public static final String PACKAGE_SPECIFICATION_VERSION = "specification-version"

Manifest header attribute (named "specification-version") 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`.

6.1.12.53 public static final String REQUIRE_BUNDLE = "Require-Bundle"

Manifest header (named "Require-Bundle") identifying the symbolic names of other bundles required by the bundle.

The attribute value may be retrieved from the Dictionary object returned by the Bundle.getHeaders method.

Since 1.3

6.1.12.54 public static final String RESOLUTION_DIRECTIVE = "resolution"

Manifest header directive (named "resolution") identifying the resolution type in the Import-Package or Require-Bundle manifest header.

The directive value is encoded in the Import-Package or Require-Bundle manifest header like:

```
    Import-Package: org.osgi.framework; resolution:="option-
al"
    Require-Bundle: com.acme.module.test; resolution:="op-
tional"
```

See Also `Constants.RESOLUTION_MANDATORY`, `Constants.RESOLUTION_OPTIONAL`

Since 1.3

6.1.12.55 public static final String RESOLUTION_MANDATORY = "mandatory"

Manifest header directive value (named "mandatory") identifying a mandatory resolution type. A mandatory resolution type indicates that the import package or require bundle must be resolved when the bundle is resolved. If such an import or require bundle cannot be resolved, the module fails to resolve.

The directive value is encoded in the Import-Package or Require-Bundle manifest header like:

```
    Import-Package: org.osgi.framework; resolution:="mandito-
ry"
    Require-Bundle: com.acme.module.test; resolution:="mandi-
tory"
```

See Also `Constants.RESOLUTION_DIRECTIVE`

Since 1.3

6.1.12.56 public static final String RESOLUTION_OPTIONAL = "optional"

Manifest header directive value (named "optional") identifying an optional resolution type. An optional resolution type indicates that the import or require bundle is optional and the bundle may be resolved without the import or require bundle being resolved. If the import or require bundle is not resolved when the bundle is resolved, the import or require bundle may not be resolved before the bundle is refreshed.

The directive value is encoded in the Import-Package or Require-Bundle manifest header like:

```
    Import-Package: org.osgi.framework; resolution:="option-
al"
    Require-Bundle: com.acme.module.test; resolution:="op-
tional"
```

See Also Constants.RESOLUTION_DIRECTIVE

Since 1.3

6.1.12.57 public static final String SELECTION_FILTER_ATTRIBUTE = "selection-filter"

Manifest header attribute (named "selection-filter") 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)"; ...
```

Since 1.3

6.1.12.58 public static final String SERVICE_DESCRIPTION = "service.description"

Service property (named "service.description") identifying a service's description.

This property may be supplied in the properties Dictionary object passed to the BundleContext.registerService method.

6.1.12.59 public static final String SERVICE_ID = "service.id"

Service property (named "service.id") identifying a service's registration number (of type java.lang.Long).

The value of this property is assigned by the Framework when a service is registered. The Framework assigns a unique value that is larger than all previously assigned values since the Framework was started. These values are NOT persistent across restarts of the Framework.

6.1.12.60 public static final String SERVICE_PID = "service.pid"

Service property (named "service.pid") identifying a service's persistent identifier.

This property may be supplied in the propertiesDictionary object passed to the BundleContext.registerService method.

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.getBundleId`) and followed by a dot (.). A bundle may use this as the prefix of the persistent identifiers for the services it registers.

6.1.12.61 public static final String SERVICE_RANKING = "service.ranking"

Service property (named "service.ranking") identifying a service's ranking number (of type java.lang.Integer).

This property may be supplied in the properties Dictionary object passed to the BundleContext.registerService method.

The service ranking is used by the Framework to determine the *default* service to be returned from a call to the `BundleContext.getServiceReference` method: If more than one service implements the specified class, the ServiceReference object with the highest ranking is returned.

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 java.lang.Integer, it is deemed to have a ranking value of zero.

6.1.12.62 public static final String SERVICE_VENDOR = "service.vendor"

Service property (named "service.vendor") identifying a service's vendor.

This property may be supplied in the properties Dictionary object passed to the BundleContext.registerService method.

6.1.12.63 public static final String SINGLETON_DIRECTIVE = "singleton"

Manifest header directive (named "singleton") 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; single-
ton:=true
```

Since 1.3

6.1.12.64 public static final String SUPPORTS_BOOTCLASSPATH_EXTENSION = "org.osgi.supports.bootclasspath.extension"

Framework environment property (named "org.osgi.supports.bootclasspath.extension") 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

6.1.12.65 public static final String SUPPORTS_FRAMEWORK_EXTENSION =

"org.osgi.supports.framework.extension"

Framework environment property (named "org.osgi.supports.framework.extension") 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

6.1.12.66 public static final String SUPPORTS_FRAMEWORK_FRAGMENT = "org.osgi.supports.framework.fragment"

Framework environment property (named "org.osgi.supports.framework.fragment") 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

6.1.12.67 public static final String SUPPORTS_FRAMEWORK_REQUIREBUNDLE = "org.osgi.supports.framework.requirebundle"

Framework environment property (named "org.osgi.supports.framework.requirebundle") 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

6.1.12.68 public static final String SYSTEM_BUNDLE_LOCATION = "System Bundle"

Location identifier of the OSGi *system bundle* , which is defined to be "System Bundle".

6.1.12.69 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

6.1.12.70 public static final String USES_DIRECTIVE = "uses"

Manifest header directive (named "uses") identifying a list of packages that an exported package uses.

The directive value is encoded in the Export-Package manifest header like:

```
    Export-Package: org.osgi.util.tracker; uses:="org.os-
gi.framework"
```

Since 1.3

6.1.12.71 public static final String VERSION_ATTRIBUTE = “version”

Manifest header attribute (named “version”) 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:

```
    Import-Package: org.osgi.framework; version=”1.1”
```

Since 1.3

6.1.12.72 public static final String VISIBILITY_DIRECTIVE = “visibility”

Manifest header directive (named “visibility”) identifying the visibility of a reqiured bundle in the Require-Bundle manifest header.

The directive value is encoded in the Require-Bundle manifest header like:

```
    Require-Bundle: com.acme.module.test; visibility:=”reex-
port”
```

See Also `Constants.VISIBILITY_PRIVATE`, `Constants.VISIBILITY_REEXPORT`

Since 1.3

6.1.12.73 public static final String VISIBILITY_PRIVATE = “private”

Manifest header directive value (named “private”) 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:=”pri-
vate”
```

See Also `Constants.VISIBILITY_DIRECTIVE`

Since 1.3

6.1.12.74 public static final String VISIBILITY_REEXPORT = “reexport”

Manifest header directive value (named “reexport”) 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 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:=”reex-
port”
```

See Also `Constants.VISIBILITY_DIRECTIVE`

Since 1.3

6.1.13 public interface Filter

An RFC 1960-based Filter.

Filter objects can be created by calling `BundleContext.createFilter` with the chosen filter string.

A Filter object can be used numerous times to determine if the match argument matches the filter string that was used to create the Filter object.

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, section 5.5, for a description of the filter string syntax.`

Since 1.1

6.1.13.1 public boolean equals(Object obj)

obj The object to compare against this Filter object.

□ Compares this Filter object to another object.

Returns If the other object is a Filter object, then returns this.toString().equals(obj.toString();false otherwise.

6.1.13.2 public int hashCode( )

□ Returns the hashCode for this Filter object.

Returns The hashCode of the filter string; that is, this.toString().hashCode().

6.1.13.3 public boolean match(ServiceReference reference)

reference The reference to the service whose properties are used in the match.

□ Filter using a service's properties.

The filter is executed using the keys and values of the referenced service's properties. The keys are case insensitively matched with the filter.

Returns true if the service's properties match this filter; false otherwise.

6.1.13.4 public boolean match(Dictionary dictionary)

dictionary The Dictionary object whose keys are used in the match.

□ Filter using a Dictionary object. The Filter is executed using the Dictionary object's keys and values. The keys are case insensitively matched with the filter.

Returns true if the Dictionary object's keys and values match this filter; false otherwise.

Throws `IllegalArgumentException` – If dictionary contains case variants of the same key name.

6.1.13.5 public boolean matchCase(Dictionary dictionary)

dictionary The Dictionary object whose keys are used in the match.

□ Filter with case sensitivity using a Dictionary object. The Filter is executed using the Dictionary object's keys and values. The keys are case sensitively matched with the filter.

Returns true if the Dictionary object's keys and values match this filter; false otherwise.

Since 1.3

6.1.13.6 public String toString( )

□ Returns this Filter object's filter string.

The filter string is normalized by removing whitespace which does not affect the meaning of the filter.

Returns Filter string.

6.1.14 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

6.1.14.1 public static final int ERROR = 2

An error has occurred.

There was an error associated with a bundle.

The value of ERROR is 0x00000002.

6.1.14.2 public static final int INFO = 32

An informational event has occurred.

There was an informational event associated with a bundle.

The value of INFO is 0x00000020.

Since 1.3

6.1.14.3 public static final int PACKAGES_REFRESHED = 4

A PackageAdmin.refreshPackage operation has completed.

This event is fired when the Framework has completed the refresh packages operation initiated by a call to the PackageAdmin.refreshPackages method.

The value of PACKAGES_REFRESHED is 0x00000004.

See Also `PackageAdmin.refreshPackages`

Since 1.2

6.1.14.4 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 intitial start level.

The value of STARTED is 0x00000001.

See Also StartLevel

6.1.14.5 public static final int STARTLEVEL_CHANGED = 8

A StartLevel.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 value of STARTLEVEL_CHANGED is 0x00000008.

See Also StartLevel

Since 1.2

6.1.14.6 public static final int WARNING = 16

A warning has occurred.

There was a warning associated with a bundle.

The value of WARNING is 0x00000010.

Since 1.3

6.1.14.7 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.

6.1.14.8 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.

6.1.14.9 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.

6.1.14.10 public Throwable getThrowable( )

□ Returns the exception related to this event.

Returns The related exception or null if none.

6.1.14.11 public int getType( )

□ Returns the type of framework event.

The type values are:

- STARTED
- ERROR
- WARNING

- INFO
- PACKAGES_REFRESHED
- STARTLEVEL_CHANGED

Returns The type of state change.

6.1.15 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` method. FrameworkListener objects are called with a FrameworkEvent objects when the Framework starts and when asynchronous errors occur.

See Also `FrameworkEvent`

6.1.15.1 public void frameworkEvent(FrameworkEvent event)

event The FrameworkEvent object.

□ Receives notification of a general FrameworkEvent object.

6.1.16 public class FrameworkUtil

Framework Utility class.

This class contains utility methods which access Framework functions that may be useful to bundles.

Since 1.3

6.1.16.1 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 unparsable.

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`

6.1.17 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 is updated to conform to the general purpose exception chaining mechanism.

6.1.17.1 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.

6.1.17.2 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

6.1.17.3 public Throwable getCause( )

□ Returns the cause of this exception or null if no cause was specified when this exception was created.

Returns The cause of this exception or null if no cause was specified.

Since 1.3

6.1.17.4 public String getFilter( )

□ Returns the filter string that generated the InvalidSyntaxException object.

Returns The invalid filter string.

See Also `BundleContext.getServiceReferences`, `BundleContext.addServiceListener(ServiceListener,String)`

6.1.17.5 public Throwable initCause(Throwable cause)

cause Cause of the exception.

□ The cause of this exception can only be set when constructed.

Returns This object.

Throws `IllegalStateException` – This method will always throw an IllegalStateException since the cause of this exception can only be set when constructed.

Since 1.3

6.1.18 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 two actions: EXPORT and IMPORT. The EXPORT action implies the IMPORT action.

6.1.18.1 public static final String EXPORT = "export"

The action string export.

6.1.18.2 public static final String IMPORT = "import"

The action string import.

6.1.18.3 public PackagePermission(String name, String actions)

name Package name.

actions EXPORT,IMPORT (canonical order).

□ Defines the authority to import and/or export a package within the OSGi environment.

The name is specified as a normal Java package name: a dot-separated string. Wildcards may be used. For example:

```
org.osgi.service.http
javax.servlet.*
*
```

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 PackagePermssion for that package.

Permission is granted for both classes and resources.

6.1.18.4 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.

6.1.18.5 public String getActions( )

☐ Returns the canonical string representation of the PackagePermission actions.

Always returns present PackagePermission actions in the following order: EXPORT,IMPORT.

Returns Canonical string representation of the PackagePermission actions.

6.1.18.6 public int hashCode( )

☐ Returns the hash code value for this object.

Returns A hash code value for this object.

6.1.18.7 public boolean implies(Permission p)

p The target permission to interrogate.

☐ 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 PackagePermission action is implied by this object; false otherwise.

6.1.18.8 public PermissionCollection newPermissionCollection( )

☐ Returns a new PermissionCollection object suitable for storing PackagePermission objects.

Returns A new PermissionCollection object.

6.1.19 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

6.1.19.1 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.

The value of MODIFIED is 0x00000002.

See Also `ServiceRegistration.setProperties`

6.1.19.2 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.

The value of REGISTERED is 0x00000001.

See Also `BundleContext.registerService(String[],Object, java.util.Dictionary)`

6.1.19.3 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.

The value of UNREGISTERING is 0x00000004.

See Also `ServiceRegistration.unregister`, `BundleContext.ungetService`

6.1.19.4 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.

6.1.19.5 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.

6.1.19.6 public int getType( )

□ Returns the type of event. The event type values are:

- REGISTERED
- MODIFIED
- UNREGISTERING

Returns Type of service lifecycle change.

6.1.20 public interface ServiceFactory

Allows services to provide customized service objects 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 gain control of the specific service object granted to a bundle that is using the service.

When this happens, the BundleContext.getService(ServiceReference) method calls the ServiceFactory.getService method to create a service object specifically for the requesting bundle. The service object returned by the ServiceFactory is cached by the Framework until the bundle releases its use of the service.

When the bundle's use count for the service equals zero (including the bundle stopping or the service being unregistered), the ServiceFactory.ungetService method is called.

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`

Concurrency Thread-safe

6.1.20.1 public Object getService(Bundle bundle, ServiceRegistration registration)

bundle The bundle using the service.

registration The ServiceRegistration object for the service.

□ Creates a new service object.

The Framework invokes this method the first time the specified bundle requests a service object using the BundleContext.getService(ServiceReference) method. The service factory can then return a specific service object for each bundle.

The Framework caches the value returned (unless it is null), and will return the same service object on any future call to BundleContext.getService from the same bundle.

The Framework will check if the returned service object is an instance of all the classes named when the service was registered. If not, then null is returned to the bundle.

Returns A service object that must be an instance of all the classes named when the service was registered.

See Also `BundleContext.getService`

6.1.20.2 public void ungetService(Bundle bundle, ServiceRegistration registration, Object service)

bundle The bundle releasing the service.

registration The ServiceRegistration object for the service.

service The service object returned by a previous call to the ServiceFactory.getService method.

□ Releases a service object.

The Framework invokes this method when a service has been released by a bundle. The service object may then be destroyed.

See Also `BundleContext.ungetService`

6.1.21 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

6.1.21.1 public void serviceChanged(ServiceEvent event)

event The ServiceEvent object.

□ Receives notification that a service has had a lifecycle change.

6.1.22 public final class ServicePermission extends BasicPermission

A bundle's authority to register or get a service.

- The ServicePermission.REGISTER action allows a bundle to register a service on the specified names.
- The ServicePermission.GET action allows a bundle to detect a service and get it.

ServicePermission to get the specific service.

6.1.22.1 public static final String GET = "get"

The action string get (Value is "get").

6.1.22.2 public static final String REGISTER = "register"

The action string register (Value is "register").

6.1.22.3 public ServicePermission(String name, String actions)

name class name

actions get,register (canonical order)

□ Create a new ServicePermission.

The name of the service is specified as a fully qualified class name.

```
ClassName ::= <class name> | <class name ending in ".*">
```

Examples:

```
org.osgi.service.http.HttpService
org.osgi.service.http.*
org.osgi.service.snmp.*
```

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.

6.1.22.4 public boolean equals(Object obj)

obj The object to test for equality.

□ Determines the equalty 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.

6.1.22.5 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.

6.1.22.6 public int hashCode( )

□ Returns the hash code value for this object.

Returns Hash code value for this object.

6.1.22.7 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.

6.1.22.8 public PermissionCollection newPermissionCollection( )

□ Returns a new PermissionCollection object for storing ServicePermission objects.

Returns A new PermissionCollection object suitable for storing ServicePermission objects.

6.1.23 public interface ServiceReference extends Comparable

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`, `BundleContext.getServiceReferences`, `BundleContext.getService`

6.1.23.1 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.

Since 1.4

6.1.23.2 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, java.util.Dictionary)`

6.1.23.3 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.

6.1.23.4 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,java.util.Dictionary)` or `ServiceRegistration.setProperties` methods.

Returns An array of property keys.

6.1.23.5 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

6.1.23.6 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.

Since 1.3

6.1.24 public interface ServiceRegistration

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)`

6.1.24.1 public ServiceReference 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.

6.1.24.2 public void setProperties(Dictionary 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` and `Constants.SERVICE_ID` 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.

6.1.24.3 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.

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 used. ServiceReference objects for the service may no longer be used to get a service object for the service.
2 A service event of type `ServiceEvent.UNREGISTERING` is fired so that bundles using this service can release their use of it.

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`, `ServiceFactory.ungetService`

6.1.25 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.

A SynchronousBundleListener object is registered with the Framework using the `BundleContext.addBundleListener` 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

6.1.26 public class Version implements Comparable

Version identifier for 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

6.1.26.1 public static final Version emptyVersion

The empty version "0.0.0". Equivalent to calling new Version(0,0,0).

6.1.26.2 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.

6.1.26.3 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 specifed components.

Throws `IllegalArgumentException` – If the numerical components are negative or the qualifier string is invalid.

6.1.26.4 public Version(String version)

version String representation of the version identifier.

□ Created a version identifier from the specified string.

Here is the grammar for version strings.

```
version ::= major('.'minor('.'micro('.'qualifier)?)?)?
major ::= digit+
minor ::= digit+
micro ::= digit+
qualifier ::= (alpha|digit|'_'|'-')+
digit ::= [0..9]
alpha ::= [a..zA..Z]
```

There must be no whitespace in version.

Throws `IllegalArgumentException` – If version is improperly formatted.

6.1.26.5 public int compareTo(Object object)

object The Version object to be compared.

□ Compares this Version object to another object.

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 object is less than, equal to, or greater than the specified Version object.

Throws `ClassCastException` – If the specified object is not a Version.

6.1.26.6 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.

6.1.26.7 public int getMajor( )

□ Returns the major component of this version identifier.

Returns The major component.

6.1.26.8 public int getMicro( )

□ Returns the micro component of this version identifier.

Returns The micro component.

6.1.26.9 public int getMinor( )

□ Returns the minor component of this version identifier.

Returns The minor component.

6.1.26.10 public String getQualifier( )

□ Returns the qualifier component of this version identifier.

Returns The qualifier component.

6.1.26.11 public int hashCode( )

□ Returns a hash code value for the object.

Returns An integer which is a hash code value for this object.

6.1.26.12 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.

6.1.26.13 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.

7 Package Admin Service Specification

Version 1.2

7.1 Introduction

Bundles can export packages to other bundles. This exporting creates a dependency between the bundle exporting a package and the bundle using the package. When the exporting bundle is uninstalled or updated, a decision must be taken regarding any shared packages.

The Package Admin service provides an interface to let the Management Agent make this decision.

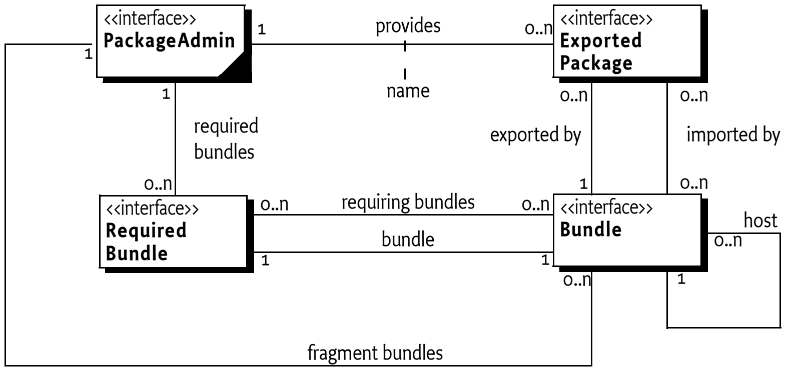
7.1.1 Essentials

- *Information* – The Package Admin service must provide the sharing status of all packages. This should include information about the importing bundles and exporting bundle.
- *Policy* – The Package Admin service must allow a management agent to provide a policy for package sharing when bundles are updated and uninstalled.
- *Minimal update* – Only bundles that depend on the package that needs to be resolved should have to be restarted when packages are forced to be refreshed.

7.1.2 Entities

- PackageAdmin – The interface that provides access to the internal Framework package sharing mechanism.
- ExportedPackage – The interface provides package information and its sharing status.
- RequiredBundle – The interfaces provides information about the bindings of required bundles.
- *Management Agent* – A bundle that is provided by the Operator to implement an Operator specific policy.

Figure 7.31 Class Diagram org.osgi.service.packageadmin



7.1.3 Operation

The Framework's system bundle should provide a Package Admin service for the Management Agent. The Package Admin service must be registered under the org.osgi.service.packageadmin.PackageAdmin interface by the system bundle. It provides access to the internal structures of the Framework related to package sharing, fragments and required bundles. This is an optional singleton service, so at most one Package Admin service must be registered at any moment in time.

The Framework must always leave the package sharing intact for packages exported by a bundle that is uninstalled or updated. A Management Agent can then choose to force the framework to refresh these packages using the Package Admin service. A policy of always using the most current packages exported by installed bundles can be implemented with a Management Agent that watches Framework events for bundles being uninstalled or updated, and then refreshes the packages of those bundles using the Package Admin service.

7.2 Package Admin

The Package Admin service is intended to allow a Management Agent to define the policy for managing package sharing. It provides methods for examining the status of the shared packages. It also allows the Management Agent to refresh the packages and stop and restart bundles as necessary.

7.2.1 Package Sharing

The PackageAdmin class provides the following methods:

- getExportedPackage(String) – Returns an ExportedPackage object that provides information about the requested package. This information can be used to make the decision to refresh the package.
- getExportedPackages(Bundle) – Returns a list of ExportedPackage objects for each package that the given bundle exports.
- refreshPackages(Bundle[]) – The management agent may call this method to refresh the exported packages of the specified bundles. The

actual work must happen asynchronously. The Framework must send a Framework.PACKAGES_REFRESHED when all packages have been refreshed.
- resolveBundles(Bundle[]) – The Framework must attempt to resolve the given bundles.

7.2.2 Bundle Information

There is only the Bundle interface in the Framework API while bundles can perform different roles in the Framework. The Package Admin service provides access to this structural information.

- getBundle(Class) – Answer the bundle with the class loader that loaded the given class.
- getBundles(String,String)– Find a the set of bundles with the given bundle symbolic name and that fall within the given version. If the version is null, all bundles with the given bundle symbolic name are returned.
- getBundleType(Bundle) – Answer the type of the bundle. This is a bitmap of the different types. The following type is defined:
  - BUNDLE_TYPE_FRAGMENT– The bundle is a fragment.

7.2.3 Fragments and Required Bundles

The Package Admin service provides access to the network that is created by by requiring bundles and hosting fragments.

- getFragments(Bundle) – Return an array of bundles that currently act as fragment to the given bundle. If there are no fragments attached, null must be returned.
- getHosts(Bundle) – Return the bundle that acts as host to this fragment bundle. The given bundle should be an attached fragment bundle, otherwise null is returned.
- getRequiredBundles(String) – Return an array of RequiredBundle objects that match the given name (or all of the given name is null). The RequiredBundle object provides structural information about a required bundle.

7.2.4 Exported Package

Information about the shared packages is provided by the ExportedPackage objects. These objects provide detailed information about the bundles that import and export the package. This information can be used by a Management Agent to guide its decisions.

7.2.5 Refreshing Packages and Start Level Service

Bundles may be stopped and later started when the refreshPackages(Bundle[]) method is called. If the Start Level Service is present, the stopping and starting of bundles must not violate the start level constraints. This implies that bundles with a higher start level must be stopped before bundles with a lower start level are stopped. Vice versa, bundles should not be started before all the bundles with a lower start level are started. See *Startup Sequence* on page 207.

7.3 Security

The Package Admin service is a *system service* that can easily be abused because it provides access to the internal data structures of the Framework. Many bundles may have the ServicePermission[org.osgi.service.packageadmin.PackageAdmin, GET] because AdminPermission[System Bundle, RESOLVE] is required for calling any of the methods that modify the environment. No bundle must have ServicePermission[org.osgi.service.packageadmin.PackageAdmin, REGISTER], because only the Framework itself should register such a system service.

This service is intended for use by a Management Agent.

7.4 org.osgi.service.packageadmin

Package 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. For example:

```
Import-Package: org.osgi.service.packageadmin; version=1.2
```

7.4.1 Summary

- ExportedPackage - An exported package.
- PackageAdmin - Framework service which allows bundle programmers to inspect the package wiring state of bundles in the Framework as well as other functions related to the class loader network among bundles.
- RequiredBundle - A required bundle.

7.4.2 public interface ExportedPackage

An exported package. Objects implementing this interface are created by the Package Admin service.

The term *exported package* refers to a package that has been exported from a resolved bundle. This package may or may not be currently wired to other bundles.

The information about an exported package provided by this object may change. An ExportedPackage object becomes stale if the package it references has been updated or removed as a result of calling PackageAdmin.refreshPackages(). If this object becomes stale, its getName() and getVersion() methods continue to return their original values, isRemovalPending() returns true, and getExportingBundle() and getImportingBundles() return null.

7.4.2.1 public Bundle getExportingBundle( )

□ Returns the bundle exporting the package associated with this exported package.

Returns The exporting bundle, or null if this ExportedPackage object has become stale.

7.4.2.2 public Bundle[] getImportingBundles( )

□ Returns the resolved bundles that are currently wired to this exported package.

Bundles which require the exporting bundle associated with this exported package are considered to be wired to this exported package are included in the returned array. See `RequiredBundle.getRequiringBundles()`.

Returns The array of resolved bundles currently wired to this exported package, or null if this ExportedPackage object has become stale.

7.4.2.3 public String getName( )

□ Returns the name of the package associated with this exported package.

Returns The name of this exported package.

7.4.2.4 public String getSpecificationVersion( )

□ Returns the version of this exported package.

Returns The version of this exported package, or null if no version information is available.

Deprecated As of 1.2, replaced by `getVersion`.

7.4.2.5 public Version getVersion( )

□ Returns the version of this exported package.

Returns The version of this exported package, or `Version.emptyVersion` if no version information is available.

Since 1.2

7.4.2.6 public boolean isRemovalPending( )

□ Returns true if the package associated with this ExportedPackage object has been exported by a bundle that has been updated or uninstalled.

Returns true if the associated package is being exported by a bundle that has been updated or uninstalled, or if this ExportedPackage object has become stale; false otherwise.

7.4.3 public interface PackageAdmin

Framework service which allows bundle programmers to inspect the package wiring state of bundles in the Framework as well as other functions related to the class loader network among bundles.

If present, there will only be a single instance of this service registered with the Framework.

See Also `org.osgi.service.packageadmin.ExportedPackage`, `org.osgi.service.packageadmin.RequiredBundle`

7.4.3.1 public static final int BUNDLE_TYPE_FRAGMENT = 1

Bundle type indicating the bundle is a fragment bundle.

The value of BUNDLE_TYPE_FRAGMENT is 0x00000001.

Since 1.2

7.4.3.2 public Bundle getBundle(Class clazz)

clazz The class object from which to locate the bundle.

□ Returns the bundle from which the specified class is loaded. The class loader of the returned bundle must have been used to load the specified class. If the class was not loaded by a bundle class loader then null is returned.

Returns The bundle from which the specified class is loaded or null if the class was not loaded by a bundle class loader.

Since 1.2

7.4.3.3 public Bundle[] getBundles(String symbolicName, String versionRange)

symbolicName The symbolic name of the desired bundles.

versionRange The version range of the desired bundles, or null if all versions are desired.

□ Returns the bundles with the specified symbolic name whose bundle version is within the specified version range. If no bundles are installed that have the specified symbolic name, then null is returned. If a version range is specified, then only the bundles that have the specified symbolic name and whose bundle versions belong to the specified version range are returned. The returned bundles are ordered by version in descending version order so that the first element of the array contains the bundle with the highest version.

Returns An array of bundles with the specified name belonging to the specified version range ordered in descending version order, or null if no bundles are found.

See Also `org.osgi.framework.Constants.BUNDLE_VERSION_ATTRIBUTE`

Since 1.2

7.4.3.4 public int getBundleType(Bundle bundle)

bundle The bundle for which to return the special type.

□ Returns the special type of the specified bundle. The bundle type values are:

- `BUNDLE_TYPE_FRAGMENT`

If a bundle is not one or more of the defined types then 0x00000000 is returned.

Returns The special type of the bundle.

Since 1.2

7.4.3.5 public ExportedPackage getExportedPackage(String name)

name The name of the exported package to be returned.

□ Gets the exported package for the specified package name.

If there are multiple exported packages with specified name, the exported package with the highest version will be returned.

Returns The exported package, or null if no exported package with the specified name exists.

See Also `getExportedPackages(String)`

7.4.3.6 public ExportedPackage[] getExportedPackages(Bundle bundle)

bundle The bundle whose exported packages are to be returned, or null if all exported packages are to be returned. If the specified bundle is the system bundle (that is, the bundle with id zero), this method returns all the packages known to be exported by the system bundle. This will include the package specified by the org.osgi.framework.system.packages system property as well as any other package exported by the framework implementation.

□ Gets the exported packages for the specified bundle.

Returns An array of exported packages, or null if the specified bundle has no exported packages.

7.4.3.7 public ExportedPackage[] getExportedPackages(String name)

name The name of the exported packages to be returned.

□ Gets the exported packages for the specified package name.

Returns An array of the exported packages, or null if no exported packages with the specified name exists.

Since 1.2

7.4.3.8 public Bundle[] getFragments(Bundle bundle)

bundle The bundle whose attached fragment bundles are to be returned.

□ Returns an array of attached fragment bundles for the specified bundle. If the specified bundle is a fragment then null is returned. If no fragments are attached to the specified bundle then null is returned.

This method does not attempt to resolve the specified bundle. If the specified bundle is not resolved then null is returned.

Returns An array of fragment bundles or null if the bundle does not have any attached fragment bundles or the bundle is not resolved.

Since 1.2

7.4.3.9 public Bundle[] getHosts(Bundle bundle)

bundle The bundle whose host bundle is to be returned.

□ Returns an array containing the host bundle to which the specified fragment bundle is attached or null if the specified bundle is not attached to a host or is not a fragment bundle. A fragment may only be attached to a single host bundle.

Returns An array containing the host bundle or null if the bundle does not have a host bundle.

Since 1.2

7.4.3.10 public RequiredBundle[] getRequiredBundles(String symbolicName)

symbolicName The bundle symbolic name or null for all required bundles.

□ Returns an array of required bundles having the specified symbolic name.

If null is specified, then all required bundles will be returned.

Returns An array of required bundles or null if no required bundles exist for the specified symbolic name.

Since 1.2

7.4.3.11 public void refreshPackages(Bundle[] bundles)

bundles The bundles whose exported packages are to be updated or removed, or null for all bundles updated or uninstalled since the last call to this method.

□ Forces the update (replacement) or removal of packages exported by the specified bundles.

If no bundles are specified, this method will update or remove any packages exported by any bundles that were previously updated or uninstalled since the last call to this method. The technique by which this is accomplished may vary among different Framework implementations. One 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 a graph of bundles starting with the specified bundles. If no bundles are specified, compute a graph of bundles starting with bundle updated or uninstalled since the last call to this method. Add to the graph any bundle that is wired to a package that is currently exported by 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 currently still exporting packages.
2 Each bundle in the graph that is in the ACTIVE state will be stopped as described in the Bundle.stop method.
3 Each bundle in the graph 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 graph are no longer RESOLVED.
4 Each bundle in the graph that is in the UNINSTALLED state is removed from the graph and is now completely removed from the Framework.
5 Each bundle in the graph 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 another bundle offering a compatible package for export has been installed in the Framework.
6 A framework event of type FrameworkEvent.PACKAGES_REFRESHED is fired.

For any exceptions that are thrown during any of these steps, a FrameworkEvent of type 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.

Throws `SecurityException` – If the caller does not have AdminPermission[System Bundle,RESOLVE] and the Java runtime environment supports permissions.

7.4.3.12 public boolean resolveBundles(Bundle[] bundles)

bundles The bundles to resolve or null to resolve all unresolved bundles installed in the Framework.

□ Resolve 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 null is 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;

Throws `SecurityException` – If the caller does not have AdminPermission[System Bundle,RESOLVE] and the Java runtime environment supports permissions.

Since 1.2

7.4.4 public interface RequiredBundle

A required bundle. Objects implementing this interface are created by the Package Admin service.

The term *required bundle* refers to a resolved bundle that has a bundle symbolic name and is not a fragment. That is, a bundle that may be required by other bundles. This bundle may or may not be currently required by other bundles.

The information about a required bundle provided by this object may change. A RequiredBundle object becomes stale if an exported package of the bundle it references has been updated or removed as a result of calling PackageAdmin.refreshPackages()). If this object becomes stale, its getSymbolicName() and getVersion() methods continue to return their original values, isRemovalPending() returns true, and getBundle() and getRequiringBundles() return null.

Since 1.2

7.4.4.1 public Bundle getBundle( )

□ Returns the bundle associated with this required bundle.

Returns The bundle, or null if this RequiredBundle object has become stale.

7.4.4.2 public Bundle[] getRequiringBundles( )

□ Returns the bundles that currently require this required bundle.

If this required bundle is required and then re-exported by another bundle then all the requiring bundles of the re-exporting bundle are included in the returned array.

Returns An array of bundles currently requiring this required bundle, or null if this RequiredBundle object has become stale.

7.4.4.3 public String getSymbolicName( )

□ Returns the symbolic name of this required bundle.

Returns The symbolic name of this required bundle.

7.4.4.4 public Version getVersion( )

☐ Returns the version of this required bundle.

Returns The version of this required bundle, or Version.emptyVersion if no version information is available.

7.4.4.5 public boolean isRemovalPending( )

☐ Returns true if the bundle associated with this RequiredBundle object has been updated or uninstalled.

Returns true if the reqiured bundle has been updated or uninstalled, or if the RequiredBundle object has become stale; false otherwise.

8 Start Level Service Specification

Version 1.1

8.1 Introduction

This specification describes how to enable a Management Agent to control the relative starting and stopping order of bundles in an OSGi Service Platform.

The Start Level service assigns each bundle a *start level*. The Management Agent can modify 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 service is to allow the Management Agent to control, in detail, what bundles will be started and stopped and when this occurs.

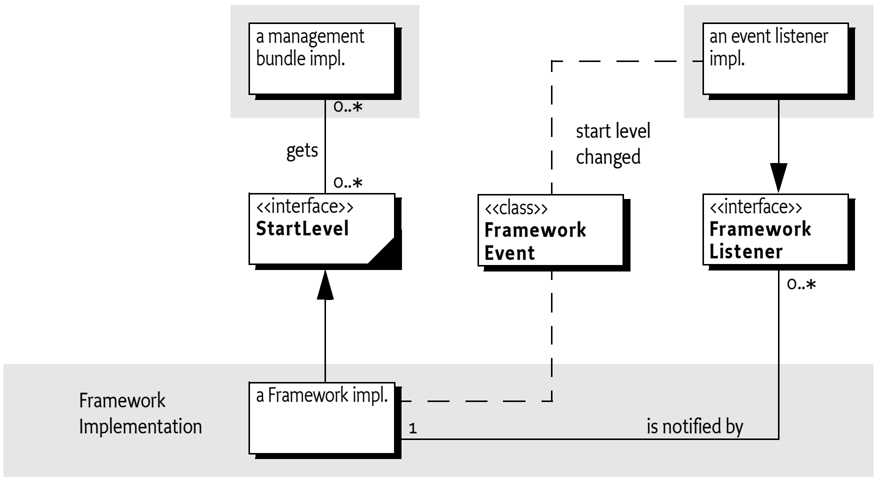
8.1.1 Essentials

- *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.
- *Backward compatible* – The model for start levels should be compatible with the OSGi Service Platform Release 2 specifications.

8.1.2 Entities

- *Start Level Service* – The service that is used by a Management Agent to order the startup and shutdown sequences of bundles.
- *Management Agent* – See page 32.
- *Framework Event* – See page 97.
- *Framework Listener* – See page 97.

Figure 8.32 Class Diagram org.osgi.service.startlevel package



8.2 Start Level Service

The Start Level Service 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.

8.2.1 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 considered 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 setBundleStartLevel(Bundle,int) method. When a bundle is installed, it is initially assigned the bundle start level returned by getInitialBundleStartLevel(). 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.

8.2.2 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.

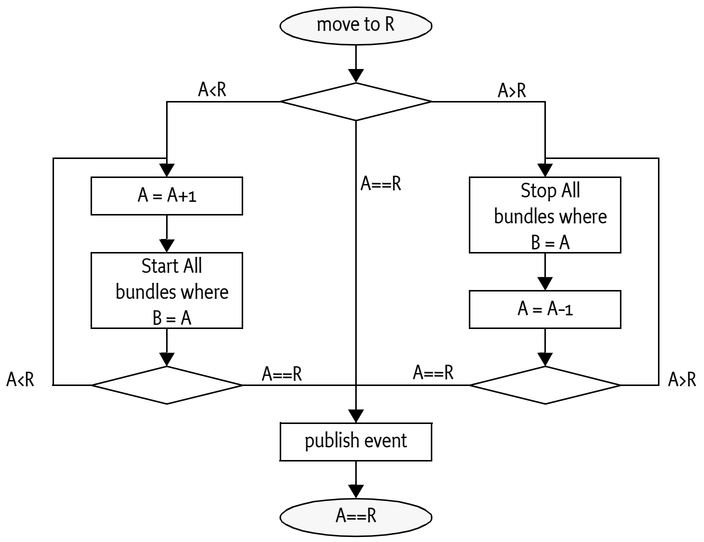
When the requested start level is reached and all bundles satisfy the condition that their bundle start level <= active start level in order to be started, then the FrameworkEvent.STARTLEVEL_CHANGED event must be sent to all registered FrameworkListener objects. If the requested start level and active 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 8.33.

Figure 8.33 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.

8.2.3 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 205 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 initial start level is reached.

8.2.4 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 205 to make the active start level equal to zero.

8.2.5 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. 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 setBundleStartLevel(Bundle,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.

8.2.6 Starting a Bundle

If a bundle is started by calling the Bundle.startmethod, 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.

8.2.7 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.

8.2.8 System Bundle

The System Bundle is defined to have a start level of zero. The start level of the System Bundle cannot be changed. An IllegalArgumentException must be thrown if an attempt is made to change the start level of the System Bundle.

8.3 Compatibility Mode

Compatibility mode consists of a single start level for all bundles. All bundles are assigned a bundle start level of 1. In compatibility mode, the OSGi Framework is started and launched with an argument specifying a beginning start level of 1. The Framework then starts all bundles that are persistently marked to be started. When start level 1 is reached, all bundles have been started and the FrameworkEvent.STARTED event is published. This is considered compatible with prior OSGi Framework versions because all bundles are started and there is no control over the start order. Framework implementations must support compatibility mode.

8.4 Example Applications

The Start Level service allows a Management Agent to implement many different startup schemes. The following sections show some examples.

8.4.1 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 isBundlePersistentlyStarted(Bundle) method of the Start Level service.

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 Service Platform 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.

8.4.2 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 service 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() { ... }
}
```

8.5 Security

When the Start Level service is available, it is crucial to protect its usage from non-trusted bundles. A malicious bundle that can control start levels can control the whole service platform.

The Start Level service is for use by a Management Agent. This means that bundles that use this service must have AdminPermission[bundle, EXECUTE] to be able to modify a bundle's start level or AdminPermission[System Bundle,STARTLEVEL] to modify the Framework's active start level. Bundles that need only read access to this service should have ServicePermission[StartLevel, GET].

The Start Level service must be registered by the Framework so there is no reason for any bundle to have ServicePermission[StartLevel, REGISTER].

8.6 Changes 4.1

- Added isBundleActivationPolicyUsed(Bundle) to find out if a bundle was started eagerly or had an activation policy set.
- Removed the requirement for bundle id based ordering for start and stop.

8.7 org.osgi.service.startlevel

Start Level Package Version 1.1.

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.service.startlevel; version=1.1
```

8.7.1 public interface StartLevel

The StartLevel service allows management agents to manage a start level assigned to each bundle and the active start level of the Framework. There is at most one StartLevel service present in the OSGi environment.

A start level is defined to be a state of execution in which the Framework exists. StartLevel 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. e.g. 2 is a higher start level than 1.

Access to the StartLevel service is protected by corresponding ServicePermission. In addition AdminPermission is required to actually modify start level information.

Start Level support in the Framework includes the ability to control the beginning start level of the Framework, to modify the active start level of the Framework and to assign a specific start level to a bundle. How the beginning start level of a Framework is specified is implementation dependent. It may be a command line argument when invoking the Framework implementation.

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 Bundle.start 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 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 Bundle.getBundleId 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 StartLevel service can be used by management bundles to alter the active start level of the framework.

8.7.1.1 public int getBundleStartLevel(Bundle bundle)

bundle The target bundle.

□ Return the assigned start level value for the specified Bundle.

Returns The start level value of the specified Bundle.

Throws `IllegalArgumentException` – If the specified bundle has been uninstalled.

8.7.1.2 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`

8.7.1.3 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.

8.7.1.4 public boolean isBundleActivationPolicyUsed(Bundle bundle)

bundle The bundle whose autostart setting is to be examined.

□ Returns whether the specified bundle's autostart setting indicates that the activation policy declared in the bundle's 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 `IllegalArgumentException` – If the specified bundle has been uninstalled.

See Also `Bundle.START_ACTIVATION_POLICY`

Since 1.1

8.7.1.5 public boolean isBundlePersistentlyStarted(Bundle bundle)

bundle The bundle whose autostart setting is to be examined.

□ Returns whether the specified bundle's autostart setting indicates the bundle 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 the bundle is to be started. false otherwise.

Throws `IllegalArgumentException` – If the specified bundle has been uninstalled.

See Also `Bundle.START_TRANSIENT`

8.7.1.6 public void setBundleStartLevel(Bundle bundle, int startlevel)

bundle The target bundle.

startlevel The new start level for the specified Bundle.

□ Assign a start level value to the specified Bundle.

The specified 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 the bundle must be started, the Framework will start the specified 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 `isBundleActivationPolicyUsed(Bundle)` returns true for the bundle. The actual starting of this 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 specified bundle as described in the `Bundle.stop(int)` method using the `Bundle.STOP_TRANSIENT` option. The actual stopping of this bundle must occur asynchronously.

Throws `IllegalArgumentException` – If the specified bundle has been uninstalled or if the specified start level is less than or equal to zero, or the specified bundle is the system bundle.

`SecurityException` – If the caller does not have AdminPermission[bundle, EXECUTE] and the Java runtime environment supports permissions.

8.7.1.7 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.

Thie 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.

8.7.1.8 public void setStartLevel(int startlevel)

startlevel The requested start level for the Framework.

□ Modify the active start level of the Framework.

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.

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 `isBundleActivationPolicyUsed(Bundle)` returns true for the bundle.

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.

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 return.

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.

9 Conditional Permission Admin Specification

Version 1.0

9.1 Introduction

The OSGi security model is based on the powerful and flexible Java 2 security architecture, specifically the permission model. This specification adds the several new features to the Java 2 model to adapt it to the typical use cases of OSGi deployments.

In contrast with other Java execution models, the OSGi Framework specification provides a well-defined API to manage permissions. Other execution models tend to leave the permission management up to implementations.

A key aspect of this security management API is the real time management of the permissions. This enables management applications to control the permissions of other applications with immediate effect; no restart is required.

Permission Management is based on the very general mode of *conditional permissions*. Conditional permissions match permissions to bundles using OSGi Alliance or user-defined conditions. The advantage of this model is that groups of permissions can be shared based on signers and locations. Conditions can also be used to enable 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, or a user has approved a permission after prompting. This model allows an operator to create and enforce a dynamic security policy 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). It provides a security model based on conditional permissions where the conditions define the selection of the bundles that these permissions apply to.

9.1.1 Essentials

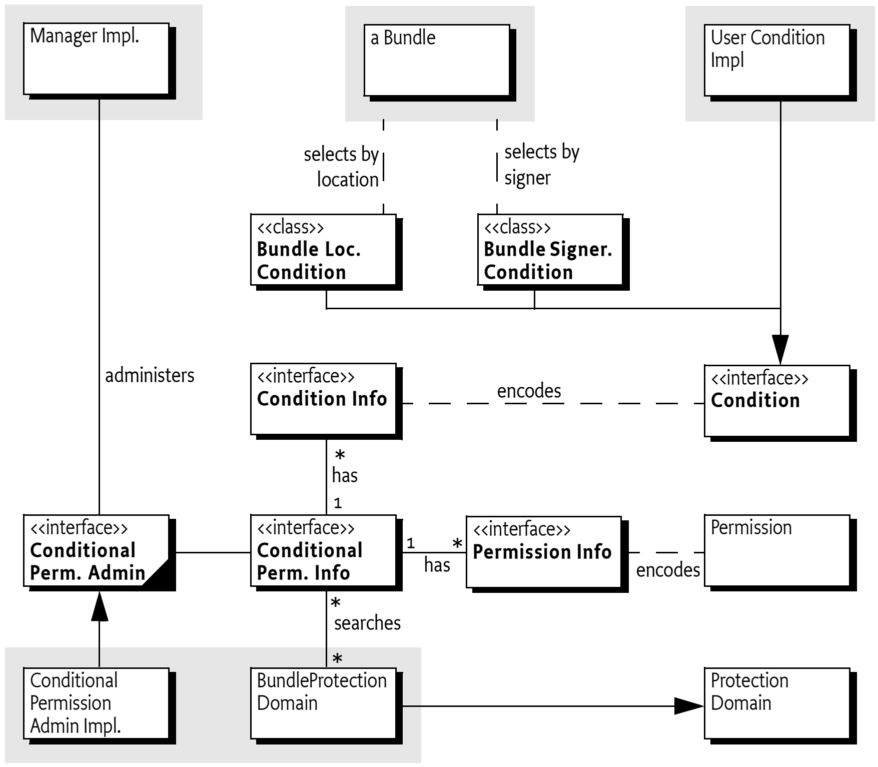
- *Policies* – Provide a security policy system where external conditions control the actual permissions that bundles have at a certain moment in time.
- *Java 2 Security* – Provide full compatibility with the existing Java 2 security model, existing applications must not require modifications.
- *Delegation* – Support a management delegation model where an Operator can delegate securely part of the management of a device to another party.

- *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.
- *Backward Compatibility* – The model must be backward compatible with the Permission Admin of earlier releases.

9.1.2 Entities

- *Conditional Permission Admin* – The administrative service that provides the functions to manipulate the *permission table*.
- *Permission Table* – A conceptual table containing all the Conditional Permission Info tuples.
- *Conditional Permission Info* – A tuple of a set of ConditionInfo objects and a set of PermissionInfo objects.
- *Permission Info* – Holds a string based encoding of a Permission object.
- *Condition Info* – Holds a string based encoding of a Condition object.
- *Condition* – Condition objects is associated with a Bundle Protection Domain and abstract an external condition that can be evaluated at any time.
- *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.
- *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.

Figure 9.34 org.osgi.service.condpermadmin package


Manager Impl.
a Bundle
User Condition Impl
selects by location
selects by signer
<<class>> Bundle Loc. Condition
<<class>> Bundle Signer. Condition
administers
<<interface>> Condition Info
encodes
<<interface>> Condition
*
has
1
<<interface>> Conditional Perm. Admin
<<interface>> Conditional Perm. Info
1
*
has
<<interface>> Permission Info
encodes
Permission
*
searches
*
Conditional Permission Admin Impl.
BundleProtection Domain
Protection Domain

9.1.3 Synopsis

A Conditional Permission Admin service maintains a system wide table of ConditionalPermissionInfo objects, which are an encoded form of conditions and permissions. A manager can enumerate, delete, and add new tuples to this table.

When a bundle is created, it creates a single Bundle Protection Domain. This protection domain calculates the system permissions for that bundle by instantiating the conditions and permissions defined in the permission table, potentially pruning any entries that can never apply to that bundle and optimizing entries that always apply.

A bundle can have local permissions defined in a Bundle Permission Resource. These are the actual permissions needed by this bundle to operate. A bundle's effective permissions are the intersection of the local permissions and the system permissions. During the permission check of the Java Security Manager, each Protection Domain is first checked for the local permissions, if this fails, the check fails.

Otherwise, the Bundle Protection Domains of the calling bundles are consulted to see if they imply the requested permission. To imply the requested permission, the Bundle Protection Domain must find a tuple in its permission table where all conditions are satisfied and where the tuple's permissions imply the requested permission. However, certain conditions must postpone their evaluation so that their evaluation can be grouped. For example, a user prompt must be postponed to remove any redundant questions to the end user. Such conditions are only postponed when their related permissions imply the requested permission and the request cannot be satisfied immediately.

At the end of the permission check, the postponed conditions are evaluated grouped by their class.

9.1.4 What to Read

9.1.4.1 Architects

- *Permission Management Model* on page 218
- *Conditional Permissions* on page 225
- *Conditions* on page 238
- *Digitally Signed JAR Files* on page 12

9.1.4.2 Application Programmers

- *Digitally Signed JAR Files* on page 12

9.1.4.3 Management Programmers

- *Permission Management Model* on page 218
- *Conditional Permissions* on page 225
- *Conditions* on page 238
- *Conditional Permissions* on page 225
- *Permission Management* on page 236
- *Digitally Signed JAR Files* on page 12
- *Standard Conditions* on page 242

9.2 Permission Management Model

The Conditional Permission Admin provides an extremely flexible security model for bundles. However, the price of this flexibility is additional complexity. In this case, the amount of configuration necessary to setup a working system can easily overwhelm anybody. 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 that explain the available mechanisms in detail.

9.2.1 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 embodied in the bundle; it 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 resource is present then the local permissions must be All Permission. The Bundle Permission Resource is defined in *Bundle Permission Resource* on page 243.

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.

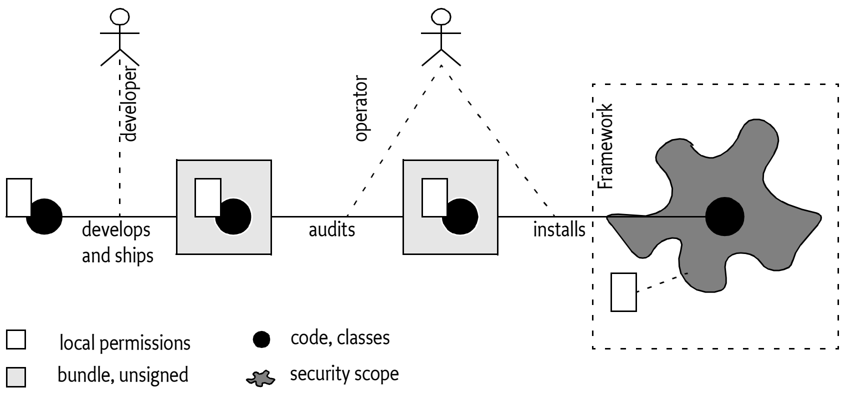
The fine-grained permissions allowed by the OSGi Service Platform are very effective with the local permissions because they can be defined by the developer instead of the deployer. The developer knows exactly what services are needed, what packages the bundle requires, and what network hosts are accessed. 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 intrinsics, 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 scope 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 9.35. 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 9.35 *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 asses the risk of running a bundle.
- *Sandboxed* – The Operator has the guarantee from the Framework that a bundle cannot escape its local permissions.

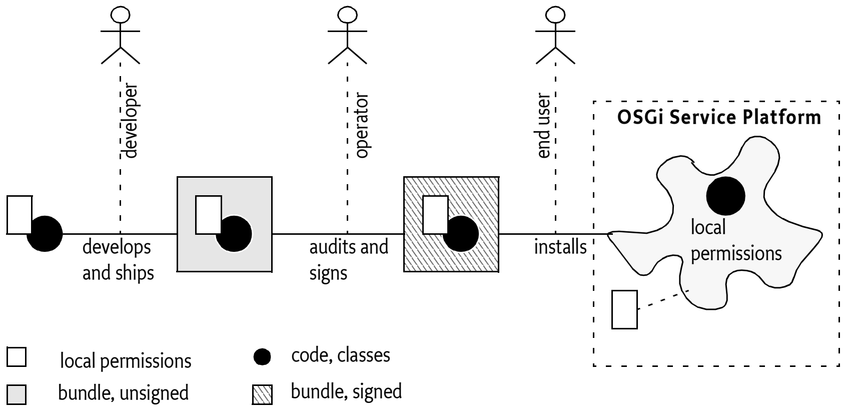
9.2.2 Open Deployment Channels

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 12. A digital signing algorithm detects modifications of the JAR as well as 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 therefore 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 9.36 Local Scope and Deployment with signing

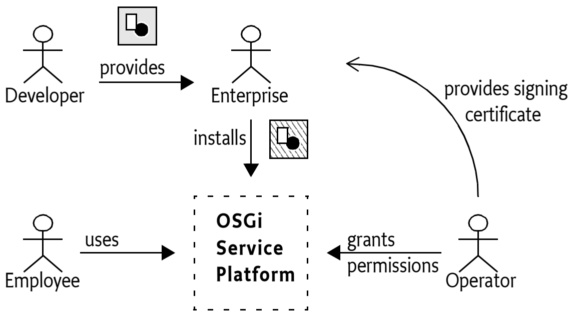


9.2.3 Delegation

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 9.37. If the Enterprise always has to contact the Operator before it can provision a new version, bottlenecks quickly arise.

Figure 9.37 Delegation model



This bottleneck problem can also be solved with signing. Signing does not only provide tamper detection, it also provides an authenticated *principal*. The principal is 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.

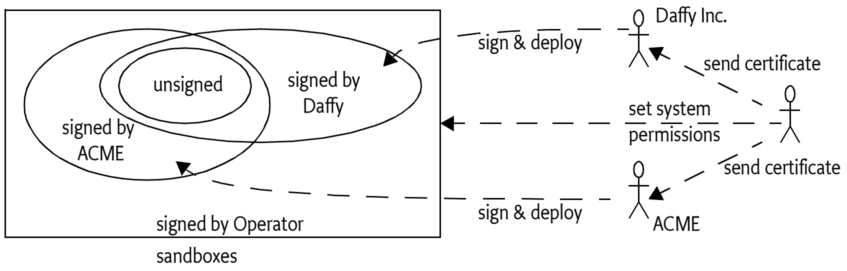
In this model, the Operator is still fully in control. At any moment in time, the Operator can change the system permissions associated with the principal and thereby immediately deny access to all bundles of that principal, while they are running. Alternatively, the Operator can add additional system 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. This model is depicted in Figure 9.38, which also shows the possible sandboxes for Daffy Inc. and unsigned bundles.

Figure 9.38 *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 `AdminPermission[*,*]`, it is likely that the bundle will not 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.

9.2.4 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.

9.2.5 Typical Example

This example provides a simple setup for a delegation model. The example is intended for readability, certain concepts will be explained later. Also for readability, package prefixes that can be guessed are replaced with ....

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:

```
{
   (..ServicePermission "..LogService" "get" )
   (..PackagePermission "..log "import" )
   (..PackagePermission "..framework" "import" )
}
```

The next permission tuple has a condition that limits the permissions to bundles that are signed by ACME. ACME signed bundles are given the permission to manage other ACME bundles. Conditions are encapsulated in square brackets ('[]').

```
{
    [ ..BundleSignerCondition "* ; o=ACME" ]
   ( ..AdminPermission "(signer=\* ; o=ACME)" "*" )
   ( ..ServicePermission "..ManagedService" "register" )
   ( ..ServicePermission "..ManagedServiceFactory"
"register" )
   ( ..PackagePermission "..cm" "import" )
}
```

The last permission tuple is for bundles signed by the operator. The operator bundles get full managing capabilities as well as permissions to provide system services.

```
{
   [ ..BundleSignerCondition "*; o=Operator" ]
   ( ..AdminPermission "*" "*" )
   ( ..ServicePermission "*" "get,register" )
   ( ..PackagePermission "*" "import,export" )
}
```

The resulting permissions are summarized in Table 9.10 on page 223.

Table 9.10 Assigned Permission, implied by another permission, x=direct, i=implied by another permission

Signed by:			**Unsigned**	**ACME**	**Operator**
Service Permission	..LogService	GET	x	x	x/i
	..ManagedService*	REGISTER		x	i
		GET			i
	*	*			x
PackagePermission	..log	IMPORT	x	x	x/i
	..cm	IMPORT		x	i

Table 9.10 Assigned Permission, implied by another permission, x=direct, i=implied by another permission

Signed by:			Unsigned	ACME	Operator
	..framework	IMPORT	x	x	x/i
	*	*			x
AdminPermission	(signer=*;o=ACME)	*		x	i
	*	*			x

9.3 Effective Permissions

Once a bundle is installed, it has Java 2 *permissions* associated with it. This set is called the *effective permissions*. The effective permissions are consulted when the checkPermission method of the Security Manager is called.

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.

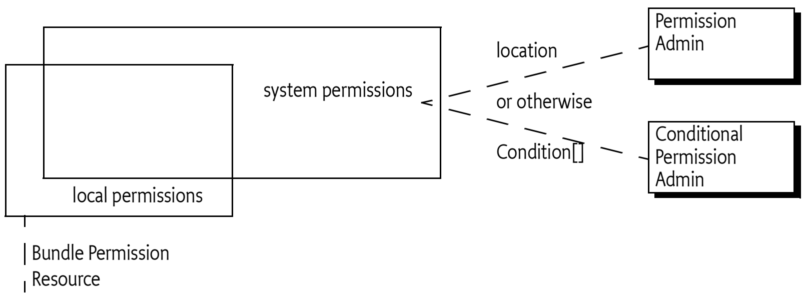
The purpose of the local permissions is to mitigate the bundle signer's risk. The Framework guarantees that a bundle's effective permissions are always smaller or equal than the local permissions because the effective permissions are the intersection of the local permissions with the system permissions.

$$Effective = Local \cap System$$

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 9.39.

Figure 9.39 System, Local and Security permissions



9.4 Conditional Permissions

The conditional permissions provide a very general model that is related to, but different from the Java 2 Policy model. The Java 2 Policy model assigns a set of permissions to a code base or signer.

The Conditional Permission Admin service model assumes a more general approach. It conceptually has a system wide *permission table.* Each entry in this table is applicable for *any* bundle if it fulfills the right conditions.

The *tuples* of this table consist of:

- A set of conditions
- A set of permissions

The permissions of a tuple are only applicable when all conditions in the set of conditions are satisfied at the time of the permission check. Certain condition types are provided by this specification, other conditions can be provided by user code. For example, the Bundle Signer Condition is satisfied when the associated bundle is signed by a specific principal. If the bundle is not signed by that principal, the tuple's permissions must not apply during the check.

An instantiated condition is represented by the `Condition` interface; it represents an expression that can be evaluated to `true` or `false` during permission checking. The condition set must be treated as an `AND` operation. Only if all conditions are satisfied, then the tuple is said to *match* and its permissions apply. That is, a permission `P` is implied by a tuple (`conditions`, `permissions`) when

- All of its `conditions` are satisfied
- At least one of its `permissions` implies `P`, as defined by Java 2 security.

An additional feature of the Condition objects is that they can *postpone* their evaluation until the end of a permission check. Postponing allows a Condition type to group the evaluation of the same conditions. This is, for example, important for prompting a user. An immediate condition is evaluated directly. This is further discussed in *Condition Life Cycle* on page 242.

For example, assume the following setup for bundle `A`:

```
{
  [ ...BundleSignerCondition "cn=*, o=ACME, c=US" ]
  [ com.acme.Online ]
   (...AdminPermission "*", "lifecycle")
}
```

The curly brackets `{}` delimit a single tuple. Conditions are delimited by square brackets `[]` and the permissions are delimited by parentheses `()`. As usual, package prefixes are left out for brevity. This syntax is used in the remainder of the document.

The example shows that both the condition `org.osgi.service.condpermadmin.BundleSignerCondition` must be satisfied as well as the `com.acme.Online` condition, before Admin Permission is granted to perform a life cycle operation on any bundle.

Binding conditional permissions to bundles is very common, though not obligatory. Therefore, a number of Condition classes are provided to define the system permissions of a bundle. This association can depend on a bundle's:

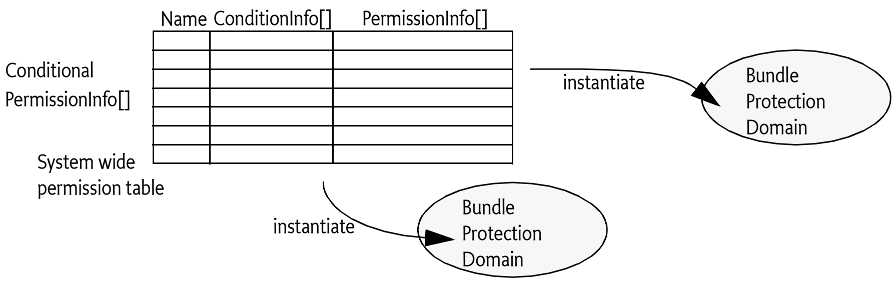
- *Signer* – Implemented with the BundleSignerCondition class.
- *Location* – Implemented with the BundleLocationCondition class

The system permissions of a bundle are dynamic and volatile, the answer to an implies method call depends therefore on the conditions that are satisfied when a permission is checked. In principle, any of the tuples in the system wide permission table can match.

9.4.1 Encoding versus Instantiation

The system wide permission table is maintained with the addConditionalPermissionInfo(ConditionInfo[],PermissionInfo[]) or setConditionalPermissionInfo(String,ConditionInfo[],PermissionInfo[])method. These methods use an encoded form of the conditions and the permissions. This encoded form is stored in the permission table. The permission table acts as a dynamic *template* for the Bundle Protection Domain, the Bundle Protection Domain creates instances with the associated bundle as their context. It is dynamic because a Bundle Protection Domain must track the changes to the permission table immediately and update any instances from the new encoded forms. Once the addConditionalPermissionInfo(ConditionInfo[], PermissionInfo[]) or setConditionalPermissionInfo(String,ConditionInfo[],PermissionInfo[]) method has returned, all subsequent use of Bundle Protection Domains must be based on the new constellation.

Figure 9.40 Instantiation of the permission table



The arguments to the addConditionalPermissionInfo method are ConditionInfo and PermissionInfo (from the org.osgi.service.permissionadmin package) objects. The purpose of these objects is to encode the Condition and Permission objects without instantiating them. The return value of the addConditionalPermission method is also an object that encodes the conditions and permissions: a ConditionalPermissionInfo object.

The conditions and permissions of the permission 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.

Therefore, Condition objects must always belong to a single Bundle Protection Domain and must never be shared. In contrast, Permission objects must be context free and their instances can potentially be shared between different Bundle Protection Domains.

9.5 The Permission Check

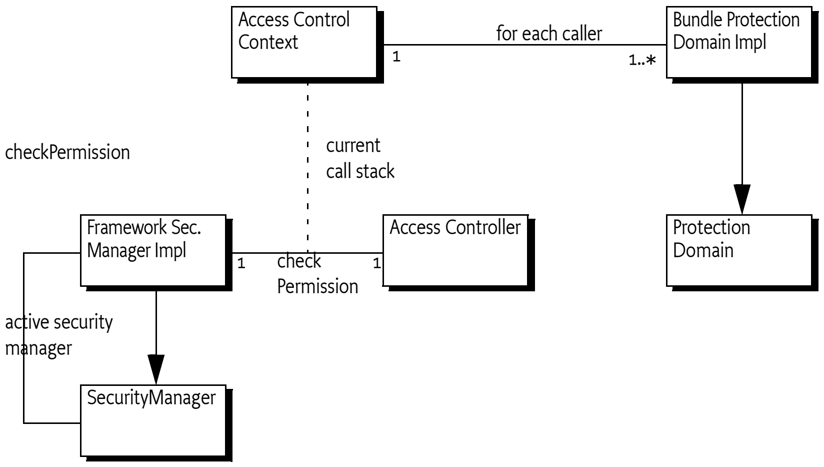
The Java 2 security model has both a Security Manager and an Access Controller to perform a permission check. The core functionality is located in the AccessController and the AccessControlContext classes that cooperate with ProtectionDomain objects and Permission objects to detect if a permission is granted. ProtectionDomain objects hold the permissions for a number of classes. In the OSGi Framework, a bundle must have a single Bundle Protection Domain.

The Access Controller provides the full functionality for checking a permission. However, for backward compatibility, all system checks are 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 9.41

The Conditional Permission Admin guards permissions with a set of conditions. A tuple's permission must only be granted if all its conditions are satisfied. Conditions can require user interaction and cause other side effects. One of the consequences of this processing model is that the execution of conditions must be highly optimized. This requires that the Framework must take over the responsibility for the permission check. Therefore, the Framework must replace the Security Manager to implement the Conditional Permission Admin in a compliant implementation.

If a Framework implementation is not able to take over the Security Manager because another part already has set it, then not all features of this specification can be implemented.

Figure 9.41 Java 2 Permission checking in OSGi bundles



9.5.1 Check Permission Algorithm

A permission check starts when the Security Manager checkPermission method is called with permission P as argument. This 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. This complete evaluation must take place on the same thread.

P must be implied by the local permissions of the Bundle Protection Domain. If this is not the case, the check must end with a failure. Local permissions are described in *Local Permissions* on page 218 and *Bundle Permission Resource* on page 243.

The Bundle Protection Domain must now decide which tuples in its instantiated permission table are applicable and imply P.

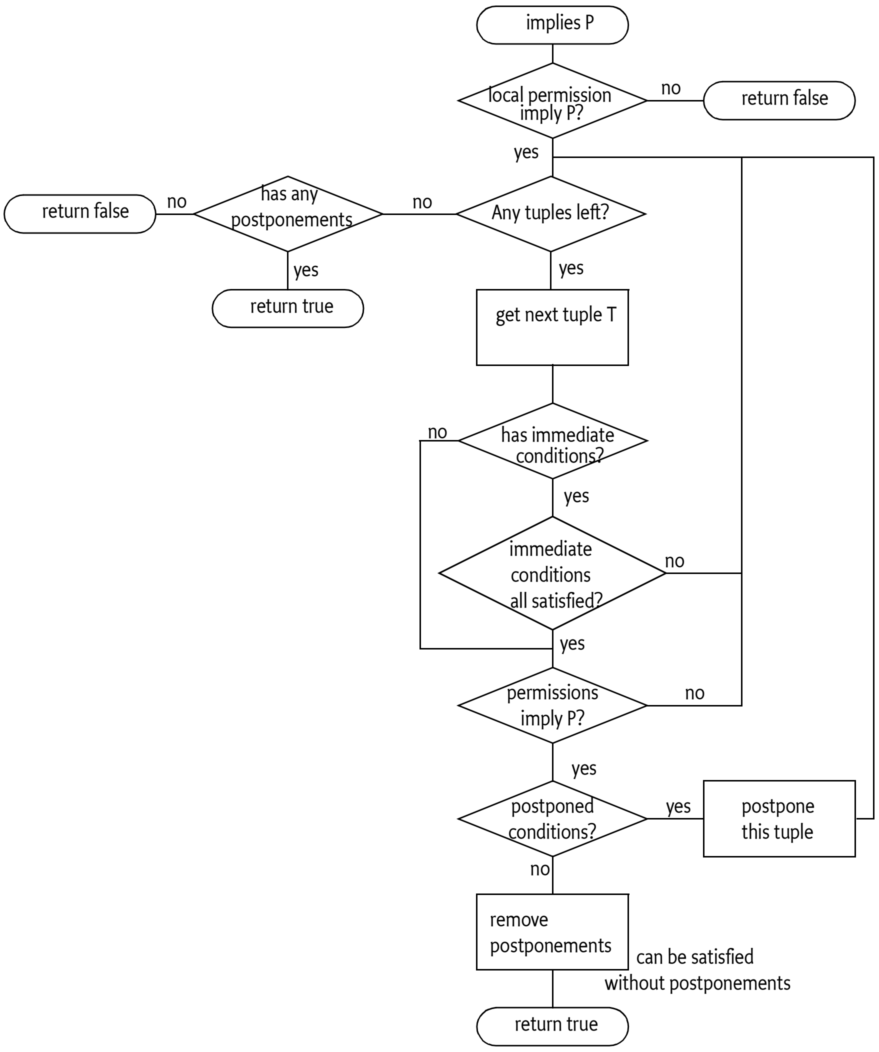
It must therefore execute the following instructions or reach the same result in an alternative way:

- For each tuple T in the instantiated permission table:
  - If T has immediate conditions, evaluate all these immediate Condition objects. If any of these objects is not satisfied, continue with next tuple.
  - If T's permission do no imply P, continue with the next tuple.
  - If T contains postponed Condition objects then postpone the evaluation of T and continue with the next tuple.
  - Otherwise, remove any postponements and return true

- After all tuples have been processed
  - If there were any postponements, then return true. Otherwise, return false.

This algorithm is visualized in a flow chart in Figure 9.42.

Figure 9.42 Flow chart for Bundle Protection Domain implies method



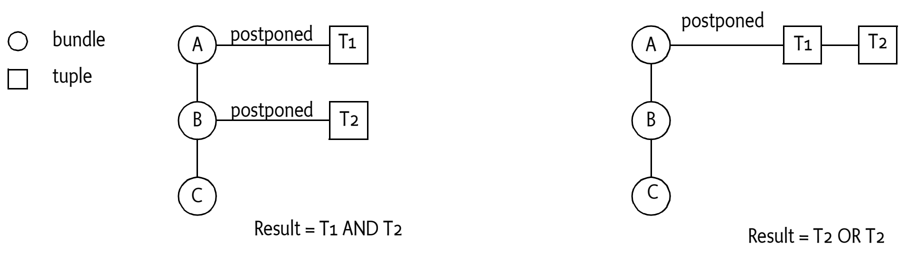
After the Framework Security Manager has called the `checkPermission` method of the Access Control Context, it must decide to fail or handle the postponed tuples. If this method returns `false`, then the Framework Security Manager's `checkPermission` method fails.

If it returns `true`, there could still be a set of postponed tuples. Each of these tuples already imply permission `P`, otherwise they must not have been placed on the postponed list. However, their `Condition` objects still need to be satisfied before `true` can be returned from the Framework Security Manager's `checkPermission` method.

The list of postponed tuples is not a linear list. A number of Bundle Protection Domains can have contributed to this list. Each Bundle Protection Domain must imply the required permissions, therefore, the Framework Security Manager must find at least one tuple per Bundle Protection Domain it can satisfy before it can return true from the Framework Security Manager checkPermission method.

For example, if bundle A contributed T1 and bundle B contributed T2 to the postponed list, then both T1 and T2 must be satisfied. However, if only bundle A contributed T1 and T2, then either a satisfied T1 or T2 is sufficient to return true. This example is depicted in Figure 9.43.

Figure 9.43 *Evaluation of postponed tuples*



Evaluating the tuples must be grouped so that Condition objects of the same implementation can be evaluated together. For example, if the user needs to be prompted it is necessary that duplicate conditions are removed and all questions are asked once.

The evaluation of multiple conditions is possible with the isSatisfied(Condition[], Dictionary) method. This is an instance method but it should be implemented as if it was static. The Condition class can use the set to remove duplicates, remove overlapping conditions, and group any required user interaction. The method can use any semantics to decide if the conditions together evaluate to true or not.

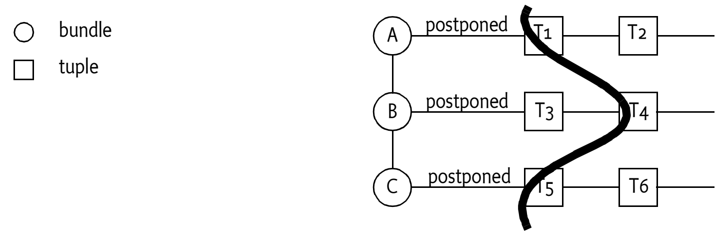
The Dictionary argument of the isSatisfied(Condition[], Dictionary) method is intended to be used by the Condition implementation class to maintain state during an invocation of the Framework Security Manager checkPermission method. It is a Dictionary object that:

- 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.
- 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 Framework Security Manager must find at least one tuple per Bundle Protection domain that can be satisfied. It is possible that there are multiple tuples per Bundle Protection Domain, but only one of these tuples needs to be satisfied. The isSatisfied(Condition[],Dictionary) method must verify that all the given conditions are satisfied, not allowing for an OR operation. Grouping can therefore only take place between tuples of different Bundle Protection Domains. That is, grouping must only use the conditions of one tuple per Bundle Protection Domain.

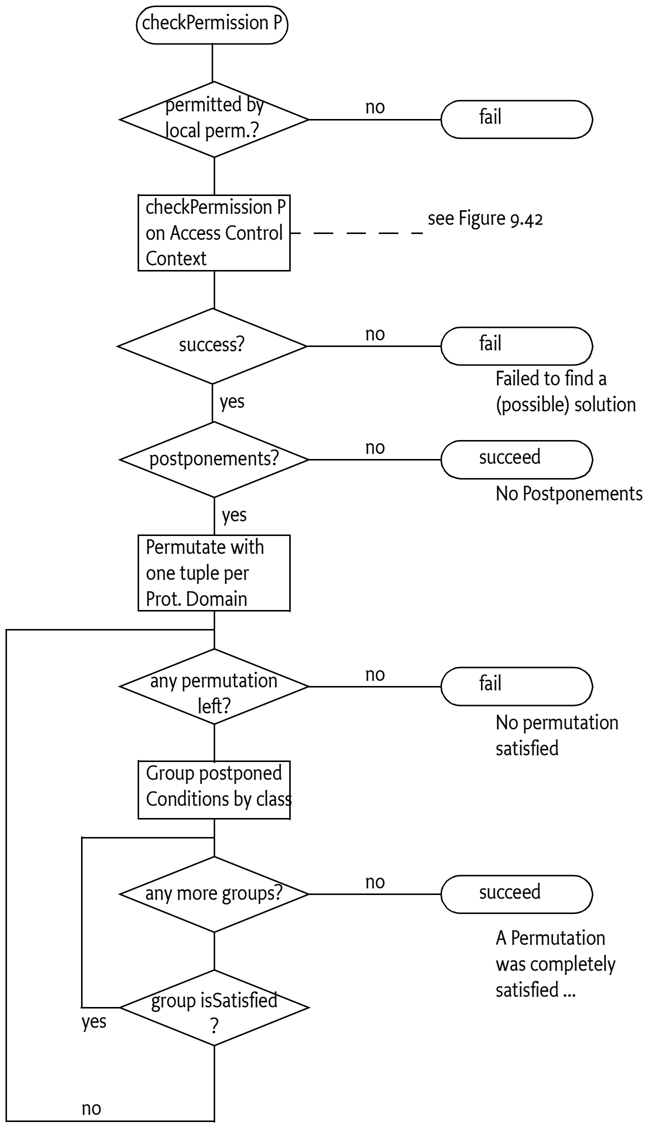
In Figure 9.44, 3 Bundle Protection Domains are show with each 2 tuples on their postponed list. The Framework security manager must permute these tuples: (T1,T3,T5), (T2,T3,T5), (T1,T4,T5), (T2,T4, T5), (T1, T3, T6), (T2, T3, T6), (T1, T4, T6), (T2, T4, T6) and evaluate each permutation. Within each permutation, it must use the isSatisfied(Condition[],Dictionary) to evaluate all Condition objects of the same type. The order of the permutations is Framework dependent and can be optimized.

Figure 9.44 *Multiple tuples per domain*



The algorithm for the overall evaluation of the Framework Security Manager's checkPermission method is shown in Figure 9.45 as a flow chart.

Figure 9.45 Flow chart for Framework Security Manager checkPermission method


checkPermission P
permitted by local perm.?
no
fail
checkPermission P on Access Control Context
see Figure 9.42
success?
no
fail
Failed to find a (possible) solution
yes
postponements?
no
succeed
No Postponements
yes
Permutate with one tuple per Prot. Domain
any permutation left?
no
fail
No permutation satisfied
Group postponed Conditions by class
any more groups?
no
succeed
A Permutation was completely satisfied ...
group isSatisfied ?
yes
no

9.5.2 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 tuples are already pre-processed to only match the given bundles. That is, all Bundle∗Condition objects have already been evaluated and removed):

```
C: {                    (Q)      }
   {  [IC0]             (P)      }
   {  [PC2]             (P)      }
```

First, the Bundle Protection Domain of bundle C is asked if it implies permission P. Bundle C has three tuples. The first tuple has no conditions, only a permission that does not imply permission P. The second tuple has an immediate condition IC0, which is not satisfied. Therefore, the tuple's permissions are not considered. The last tuple contains a postponed condition PC2. Permission P is implied by its permissions. It is not possible to make the decision at this moment in time, therefore the evaluation of tuple C3 is postponed. However, true is returned to indicate that the bundle is potentially permitted.

```
B: { [IC1] [PC1] [PC2]  (P)  (R)  }
   { [PC2]              (P)  (R)  }
   {                    (Q)       }
```

Next, bundle B is considered. Its first tuple has and immediate Condition object is IC1. This condition turns out to be satisfied. This tuple is a potential candidate because it has only two postponed conditions left. It is therefore necessary to check if the tuple is a possibility. It is, because its permissions imply permission P. The tuple is therefore placed on the postponed list to be checked later.

The second tuple is similar. It must also be placed on the postponed list because it implies permission P and it has a postponed condition PC2.

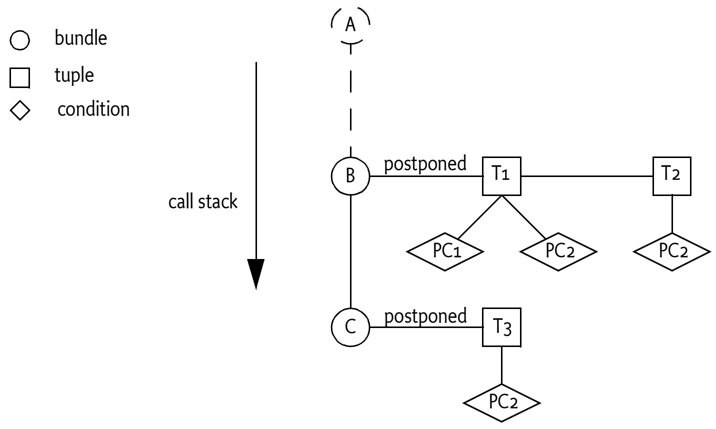
The last tuple is rejected because it does not imply permission P. However, because there are 2 tuples postponed, the bundle is potentially permitted.

```
A: {   [IC1]  [PC1]     (P)  (Q)  }
   {   [IC2]            (P)  (R)  }
   {                    (S)       }
```

Bundle A's IC1 is evaluated first then it is satisfied. Permission P is implied by the tuple A1's permissions, therefore this tuple is postponed for evaluation. However, the second tuple is also satisfied and it directly implies permission P. Therefore, the postponed evaluation of PC1 is removed, and bundle A is directly permitted. Tuple A3 does not have to be considered.

After the checkPermission method of the Access Control Context method returns, the Framework Security Manager must evaluate any postponed tuples. The list of postponed tuples looks like Figure 9.43.

Figure 9.46 *Evaluation of postponed tuples*



The Framework Security Manager must now evaluate the permutations (T1, T3) or (T3,T2). The order of the permutation is undefined, assume (T1, T3) gets chosen first. The condition class PC2 appears in both tuples, therefore T1:PC2 and T3:PC2 must therefore be evaluated in a group with the group version of the isSatisfied(Condition[],Dictionary) method. PC1, which must also be true to match, is evaluated with the non-grouped version of isSatisfied().

Further assume that (T1, T3) fails, though the user was prompted and agreed, PC1 failed. The PC2 class left a marker in the Dictionary object to prevent another prompt with the same question.

The Framework Security Manager must now try (T2,T3). This must evaluate T2:PC2 and T3:PC2 with the isSatisfied(Condition[],Dictionary) method. This method was already called for the previous permutation, which could have left information in the Dictionary argument for further evaluations. However, the Dictionary object now contains the marker from the previous invocation. The isSatisfied(Condition[],Dictionary) method sees the marker and now returns true without prompting the user. This means that the permutation (T2,T3) matches and the Framework Security Manager's checkPermission method succeeds.

9.5.3 Using the Access Control Context Directly

Bundle programmers can use the standard Java API to do security checks. However, when the Access Controller is used directly (or the Access Control Context) to do the check instead of the Security Manager, then the evaluation cannot handle postponed conditions. Therefore, the postponed conditions must be treated as immediate conditions by the Bundle Protection Domain in this case.

The implication of this is that the result of checking a permission can depend on the way the check is performed. The normal way of the Security Manager checkPermission method can behave differently than the Access Control Context checkPermission method, depending on the way the check is executed.

For example, a bundle on the stack has the needed permission P tied to a User Prompt Condition and another bundle does not have the Permission P. The check would fail if the Security Manager was called and the user would never be prompted. If the Access Control Context were called directly, the user would be prompted before the check failed.

9.5.4 Optimizations

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 permission 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 therefore free to change the algorithms described in this specification as long as the external effect remain the same.

The first optimization is therefore pruning the instantiated permission table. A Condition object can be pruned if it is immutable.

If an immutable Condition object is satisfied, it can be removed from the tuple's Condition objects because it cannot influence the evaluation anymore. If it is not satisfied, the corresponding tuple can be completely discarded because one of the Condition objects is not satisfied, making it impossible for the tuple to be used.

If a tuple has no more Condition objects after this pruning, the evaluation of the permissions can be optimized by placing all such permissions in a single Permission object (which contains PermissionCollection objects). Java 2 security has highly optimized code to do the checking of permissions when they are placed together in a Permission Collection.

For example, assume the following permission table:

```
{
   [ ...BundleLocationCondition
         "http://www.acme.com/*" ]
   ( ...SocketPermission "www.acme.com" )
} {
   [ ...BundleLocationCondition
         "http://www.et.com/*" ]
    [ ...Prompt "Call home?" ]
   ( ...SocketPermission "www.et.com" )
}
```

Assume this table is instantiated for a bundle with a location of http://www.acme.com/bundle.jar. The first tuple'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 tuple can be discarded because it is immutable and not satisfied for the bundle's location. Any condition that is not satisfied and immutable makes the tuple void.

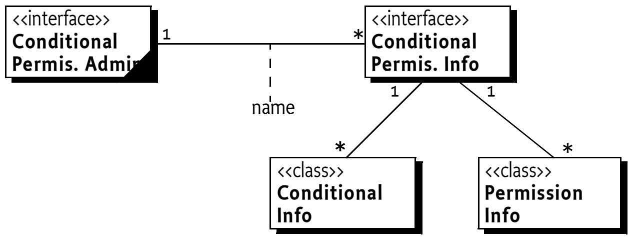
9.6 Permission Management

The system permissions are managed with the Conditional Permission Admin service. The Conditional Permission Admin can also register the Permission Admin service, in that case the two must interact as described in *Relation to Permission Admin* on page 244.

Permissions are added in their encoded form as a tuple with the addConditionalPermissionInfo(ConditionInfo[],PermissionInfo[]) or setConditionalPermissionInfo(String,ConditionInfo[],PermissionInfo[]) method. The difference between the methods is the name parameter. The name parameter can be null, or a non-empty String object. ConditionalPermissionInfo objects can be added anonymously or by name. Each ConditionalPermissionInfo object has a name to distinguish it from others, as well as identifying it to a management server. If no name is given, or the name is null, the Conditional Permission Admin service will automatically create a name.

The methods return a ConditionalPermissionInfo object that provides access to the tuple. These objects can also be enumerated with the getConditionalPermissionInfos() method or a specific named one with the getConditionalPermissionInfo(String) method. The name of the object is returned with the getName() method. The ConditionalPermissionInfo delete() method allows a ConditionalPermissionInfo to be deleted. The tuple consists of an array of ConditionInfoobjects and an array of PermissionInfo objects. This is depicted in Figure 9.47.

Figure 9.47 *Structure of the Info objects.*



Both the ConditionalInfo and PermissionInfo objects can be constructed from encoded strings. The format of the encoded strings are:

```
ConditionalInfo ::= '[' qname ( quoted ) * ']' // See 1.3.2
PermissionInfo  ::= '(' qname quoted quoted ')'
```

Extra white space must be ignored.

As a convention, ConditionalPermissionInfo objects are enclosed in curly braces ('{}', \u007B, \u007D). There are no encoding and decoding methods. The following example is a code snippet the reads a stream with conditional permissions using the curly brace convention. The method parses the file line by line. Each line is trimmed for white space, and then compared to one of the controlling characters. If a matching'}' is found, the current conditions and permissions are set.

```
ConditionInfo   EMPTY_CS[] = new ConditionInfo[0];
PermissionInfo  EMPTY_PS[] = new PermissionInfo[0];
```

```
public void setConditionalPermissionInfo(
   ConditionalPermissionAdmin admin,
   InputStream in) throws Exception {

   Vector conditions = null;
   Vector permissions = null;

   InputStreamReader ir = new InputStreamReader(
      in, "UTF-8");
   BufferedReader br = new BufferedReader(ir);

   String line = br.readLine();

   while (line != null) {
      line = line.trim();
      if ( line.length() == 0 )
         continue;

      switch (line.charAt(0)) {
         case '[' :
            conditions.add(new ConditionInfo(line));
            break;

         case '(' :
            permissions.add(new PermissionInfo(line));
            break;

         case '#':
            break;

         case '{':
            conditions = new Vector();
            permissions = new Vector();
            break;

         case '}' :
            admin.addConditionalPermissionInfo(
                  (ConditionInfo[])
                     conditions.toArray(EMPTY_CS),
                  (PermissionInfo[])
                     permissions.toArray(EMPTY_PS));
            conditions = permissions = null;
            break;

         default:
            throw new RuntimeException("Invalid format");

      }
      line = br.readLine();
   }
}
```

9.6.1 Default Permissions

Conditional Permission Admin does not have a specific concept of default permissions. Default permissions are derived from the ConditionalPermissionInfo objects that do not have any Condition objects. These ConditionalPermissionInfo objects are applied to all bundles, effectively making them default permissions. This is a different from Permission Admin; in Permission Admin default permissions only apply when there are no specific permissions set.

9.7 Conditions

The purpose of a condition is to decide if a permission set is applicable or not. That is, it acts as a guard. The condition 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 *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 asked 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. If it returns false, the isSatisfied method is quick and can be called during the permission check, otherwise the calling of isSatisfied must be postponed until the end of the check.

For example, a condition could verify that a mobile phone is roaming. That is, it is not in the home PLMN. 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. 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 Condtional Permission Admin can make significant optimizations by pruning tuples from its instantiated permission table. For example, the Bundle Protection Domain can prune any tuple from its view of the permission table that contains a Condition object that is immutable and not satisfied. Such conditions can never be satisfied in the future and therefore the permission tuple can be completely discarded for that Bundle Protection Domain.

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. The following sections first describe how to create a condition class and then define the standard Condition classes.

9.7.1 Custom Conditions

Condition objects are constructed from ConditionInfo objects when the permission table is instantiated for a Bundle Protection Domain. The ConditionInfo object supports a variable number of arguments.

The Framework Security Manager 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 maintain only 2 instances: One for bundles that match the given location and one for the others. In the getCondition method it can compare the bundle's location with argument and return either instance.

This is such a common pattern that the Condition interface provides two such 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. 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 226. Thus, any queries made on a Condition object will be with the given Bundle object as context.

If the Framework Security Manager cannot find a proper way to construct the Condition object, it should log this and assume that the condition is false.

The next aspect that needs to be addressed is the time of evaluation and the mutability.

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 tuple can be immediately discarded, it is not even necessary to instantiate any further Condition or Permission objects.

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. Additional permission checks should be avoided. 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 *Check Permission Algorithm* on page 228, the evaluation of the isSatisfied() method can be postponed towards the end of the check. The Condition object must return true for the isPostponed() method to be postponed.

Postponed Condition objects must optimize their evaluation by implementing an instance method isSatisfied(Condition[],Dictionary). This method must evaluate a number of conditions together; it is unrelated to the given instance. This grouped evaluation can be used to minimize the number of user prompting, minimize network access, etc.

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 isImmutable() { 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();
            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 isSatisfiedmethod 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.

9.7.2 Implementation Issues

9.7.2.1 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.

9.7.2.2 Threading

A Condition implementation is guaranteed that a 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.

9.7.2.3 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 72.

9.7.2.4 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.

9.8 Standard Conditions

This specification provides a number of standard conditions. The OSGi specifications JAR file, which contains all the specification classes, does contain a non-functional implementation of these conditions. Actual Framework implementers must replace these classes with an implementation that is tied to their Framework implementation for efficiency reasons.

9.8.1 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 string argument is a matching Distinguished Name as defined in *Certificate Matching* on page 21. For example:

```
[ ...BundleSignerCondition "* ;cn=S&V, o=Tweety Inc., c=US"]
```

The Bundle Signer Condition is immutable and can be completely evaluated during the getCondition method.

9.8.2 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/*      Apps from ACME
https://www.operator.com/download/*  Operator apps
```

The Bundle Location Condition must be created through its static getCondition(Bundle,ConditionInfo) method. The string argument is a location string with possible wildcards ('*'). Wildcards are matched using Filter string matching. For example:

```
http://www.acme.com/*
*://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.

9.9 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:

```
 permission.perm ::= line *
 line            ::= ( comment | pinfo ) '\r\n'
 comment         ::= ( '#' | '//' |  /* blank */ )
 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   "..cm" "SET" )
( ..PackagePermission   "com.acme.chess" "IMPORT,EXPORT" )
( ..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.

9.9.1 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.

9.10 Relation to Permission Admin

If the framework provides a Conditional Permission Admin service and a Permission Admin service then the location bound permission of the Permission Admin service must override any information of the Conditional Permission Admin service. Otherwise, the concepts of Conditional Permission Admin service apply.

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.

New applications should use the Conditional Permission Admin service. The Permission Admin service will be deprecated in a future release.

9.11 Security

9.11.1 Service Registry Security

9.11.1.1 Conditional Permission Admin Service

The Conditional Permission Admin service should be part of the Framework and therefore has All Permission.

9.11.1.2 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.

9.12 org.osgi.service.condpermadmin

Conditional Permission Admin 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.service.condpermadmin; version=1.0
```

9.12.1 Summary

- BundleLocationCondition - Condition to test if the location of a bundle matches a pattern.
- BundleSignerCondition - Condition to test if the signer of a bundle matches a pattern.
- Condition - The interface implemented by a Condition.
- ConditionalPermissionAdmin - Framework service to administer Conditional Permissions.
- ConditionalPermissionInfo - A binding of a set of Conditions to a set of Permissions.
- ConditionInfo - Condition representation used by the Conditional Permission Admin service.

9.12.2 public class BundleLocationCondition

Condition to test if the location of a bundle matches a pattern. Pattern matching is done according to the filter string matching rules.

9.12.2.1 public static Condition getCondition(Bundle bundle, ConditionInfo info)

bundle The Bundle being evaluated.

info The ConditionInfo to construct the condition for. The args of the ConditionInfo must be a single String which specifies the location pattern to match against the Bundle location. Matching is done according to the filter string matching rules. Any '*' characters in the location argument are used as wildcards when matching bundle locations unless they are escaped with a '\'character.

□ Constructs a condition that tries to match the passed Bundle's location to the location pattern.

Returns Condition object for the requested condition.

9.12.3 public class BundleSignerCondition

Condition to test if the signer of a bundle matches 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).

9.12.3.1 public static Condition getCondition(Bundle bundle, ConditionInfo info)

bundle The Bundle being evaluated.

info The ConditionInfo to construct the condition for. The args of the ConditionInfo specify a single String specifying the chain of distinguished names pattern to match against the signer of the Bundle.

□ 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.

9.12.4 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.

9.12.4.1 public static final Condition FALSE

A Condition object that will always evaluate to false and that is never postponed.

9.12.4.2 public static final Condition TRUE

A Condition object that will always evaluate to true and that is never postponed.

9.12.4.3 public boolean isMutable( )

□ Returns whether the Condition is mutable.

Returns true to indicate the value returned by isSatisfied() can change. Otherwise, false if the value returned by isSatisfied() will not change.

9.12.4.4 public boolean isPostponed( )

- Returns whether the evaluation must be postponed until the end of the permission check. This method returns true if the evaluation of the Condition must be postponed until the end of the permission check. If this method returns false, 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, need to be consulted.

Returns true to indicate the evaluation must be postponed. Otherwise, false if the evaluation can be immediately performed.

9.12.4.5 public boolean isSatisfied( )

- Returns whether the Condition is satisfied.

Returns true to indicate the Conditions is satisfied. Otherwise, false if the Condition is not satisfied.

9.12.4.6 public boolean isSatisfied(Condition[] conditions, Dictionary context)

conditions The array of Conditions.

context A Dictionary object that implementors can use to track state. If this method is invoked multiple times in the same permission evaluation, 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 invocatios are needed.

- Returns whether a the set of Conditions are satisfied. Although this method is not static, it must be implemented as if it were static. All of the passed Conditions will be of the same type and will correspond to the class type of the object on which this method is invoked.

Returns true if all the Conditions are satisfied. Otherwise, false if one of the Conditions is not satisfied.

9.12.5 public interface ConditionalPermissionAdmin

Framework service to administer Conditional Permissions. Conditional Permissions can be added to, retrieved from, and removed from the framework.

9.12.5.1 public ConditionalPermissionInfo addConditionalPermissionInfo(ConditionInfo[] conds, PermissionInfo[] perms)

conds The Conditions that need to be satisfied to enable the corresponding Permissions.

perms The Permissions that are enable when the corresponding Conditions are satisfied.

- Create a new Conditional Permission Info. The Conditional Permission Info will be given a unique, never reused name.

Returns The ConditionalPermissionInfo for the specified Conditions and Permissions.

Throws `SecurityException` – If the caller does not have AllPermission.

9.12.5.2 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.

Returns An AccessControlContext that has the Permissions associated with the signer.

9.12.5.3 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.

9.12.5.4 public Enumeration getConditionalPermissionInfos( )

□ Returns the Conditional Permission Infos that are currently managed by Conditional Permission Admin. Calling `ConditionalPermissionInfo.delete()` will remove the Conditional Permission Info from Conditional Permission Admin.

Returns An enumeration of the Conditional Permission Infos that are currently managed by Conditional Permission Admin.

9.12.5.5 public ConditionalPermissionInfo setConditionalPermissionInfo(String name, ConditionInfo[] conds, PermissionInfo[] perms)

name The name of the Conditional Permission Info, or null.

conds The Conditions that need to be satisfied to enable the corresponding Permissions.

perms The Permissions that are enable when the corresponding Conditions are satisfied.

□ Set or create a Conditional Permission Info with a specified name. 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.

Returns The ConditionalPermissionInfo that for the specified name, Conditions and Permissions.

Throws `SecurityException` – If the caller does not have AllPermission.

9.12.6 public interface ConditionalPermissionInfo

A binding of a set of Conditions to a set of Permissions. Instances of this interface are obtained from the Conditional Permission Admin service.

9.12.6.1 public void delete( )

□ Removes this Conditional Permission Info from the Conditional Permission Admin.

Throws `SecurityException` – If the caller does not have AllPermission.

9.12.6.2 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.

9.12.6.3 public String getName( )

□ Returns the name of this Conditional Permission Info.

Returns The name of this Conditional Permission Info.

9.12.6.4 public PermissionInfo[] getPermissionInfos( )

□ Returns the Permission Infos for the Permission in this Conditional Permission Info.

Returns The Permission Infos for the Permission in this Conditional Permission Info.

9.12.7 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.

9.12.7.1 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.

9.12.7.2 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 encodedCondition is not properly formatted.

See Also getEncoded

9.12.7.3 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.

9.12.7.4 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.

9.12.7.5 public final String getEncoded( )

□ Returns the string encoding of this ConditionInfo in a form suitable for restoring this ConditionInfo.

The encoding format is:

```
    [type “arg0” “arg1” ...]
```

where *argN* are strings that are encoded for proper parsing. Specifically, the “, \, carriage return, and linefeed characters are 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.

9.12.7.6 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.

9.12.7.7 public int hashCode( )

□ Returns the hash code value for this object.

Returns A hash code value for this object.

9.12.7.8 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.

9.13 References

[46] *Java 1.3*
http://java.sun.com/j2se/1.3

10 Permission Admin Service Specification

Version 1.2

10.1 Introduction

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 11.

10.1.1 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.

10.1.2 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 81.

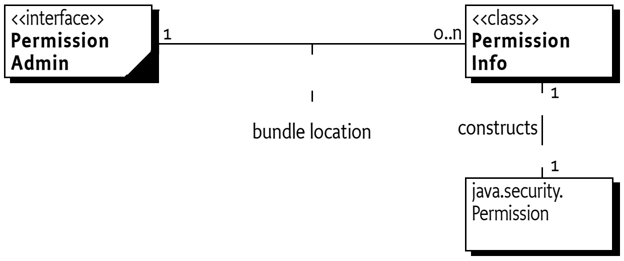


Figure 10.48 Class Diagram org.osgi.service.permissionadmin.

10.1.3 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.

10.2 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 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.

10.2.1 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.

10.3 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 Service Platform. 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.

10.4 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. For example:

```
Import-Package: org.osgi.service.permissionadmin; version=1.2
```

10.4.1 Summary

- PermissionAdmin - The Permission Admin service allows management agents to manage the permissions of bundles.
- PermissionInfo - Permission representation used by the Permission Admin service.

10.4.2 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.

10.4.2.1 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.

10.4.2.2 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.

10.4.2.3 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.

10.4.2.4 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.

10.4.2.5 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.

10.4.3 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.

10.4.3.1 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.

10.4.3.2 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 encodedPermission is not properly formatted.

See Also `getEncoded`

10.4.3.3 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.

10.4.3.4 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.

10.4.3.5 **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 are encoded for proper parsing. Specifically, the “,\, carriage return, and linefeed characters are 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.

10.4.3.6 **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.

10.4.3.7 **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.

10.4.3.8 **public int hashCode( )**

☐ Returns the hash code value for this object.

Returns A hash code value for this object.

10.4.3.9 **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.

11 URL Handlers Service Specification

Version 1.0

11.1 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 Service Platform 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 Service Platform. 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.

The Release 4 specifications has also standardized a Connector service that has similar capabilities. See the *IO Connector Service Specification* on page 223.

11.1.1 Essentials

- *Multiple Access* – Multiple bundles should be allowed to register ContentHandler objects and URLStreamHandler objects.
- *Existing Schemes Availability* – Existing schemes in an OSGi Service Platform 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.

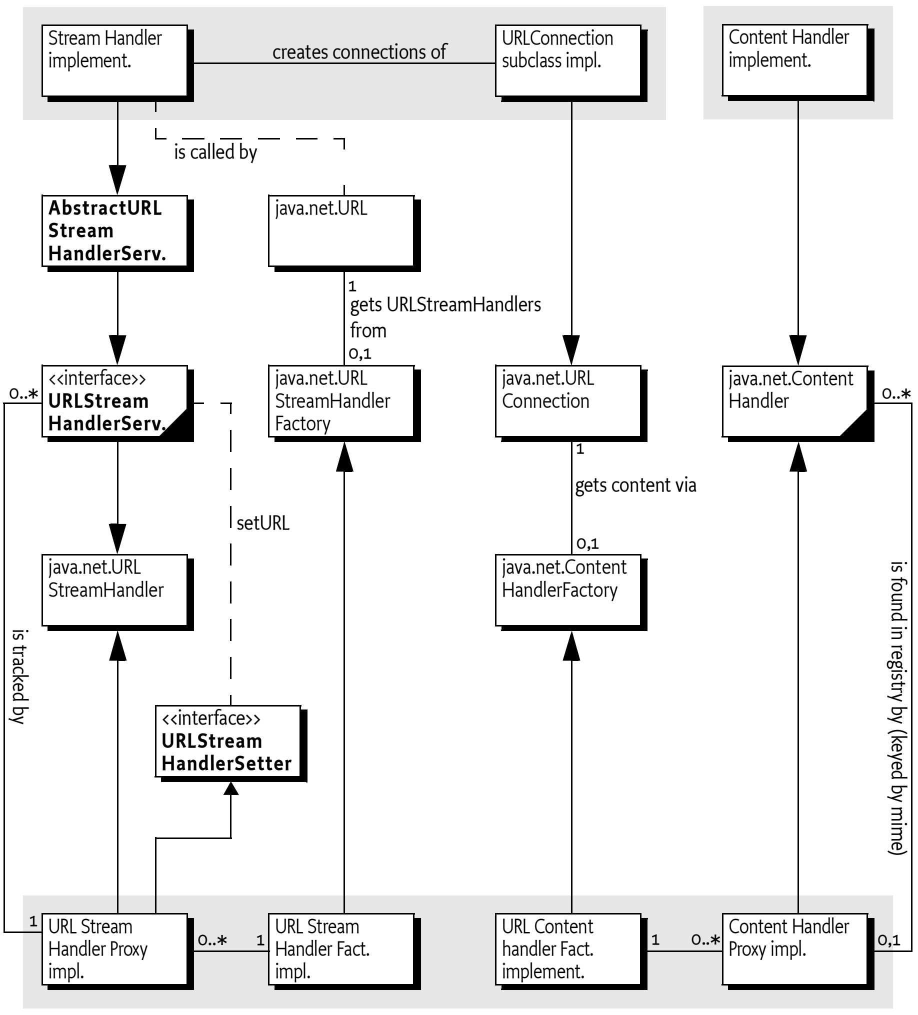
11.1.2 Entities

- *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 name space for byte stream formats. See [49] *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 11.49 Class Diagram, java.net (URL and associated classes)


Stream Handler implement.
creates connections of
URLConnection subclass impl.
Content Handler implement.
is called by
AbstractURL Stream HandlerServ.
java.net.URL
1
gets URLStreamHandlers from
0,1
0..*
<<interface>> URLStream HandlerServ.
java.net.URL StreamHandler Factory
java.net.URL Connection
java.net.Content Handler
0..*
1
gets content via
0,1
setURL
java.net.URL StreamHandler
java.net.Content HandlerFactory
is tracked by
is found in registry by (keyed by mime)
<<interface>> URLStream HandlerSetter
1
URL Stream Handler Proxy impl.
0..*
1
URL Stream Handler Fact. impl.
URL Content handler Fact. implement.
1
0..*
Content Handler Proxy impl.
0,1

11.1.3 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 runtime).

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.

11.2 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 Service Platform. 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, see [47] *Java*.

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.

11.3 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 [49] *MIME Multipurpose Internet Mail Extension*.

11.3.1 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 111) 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.

11.3.2 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.

It is thus not guaranteed that a registered URLStreamHandlerService object is used. Therefore, built-in handlers should take priority over handlers from the service registry to guarantee consistency. The built-in handlers, as defined in the OSGi execution environments must never be overridden.

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.

11.3.3 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 bar ('|', \u007C) and that are searched in the left-to-right order (the names must *not* end in a period). 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 '/' 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 slashes in the MIME name must be converted to a period ('.' \u002E). All other characters that are not allowed in a Java class name must be converted to an underscore ('_' or \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
```

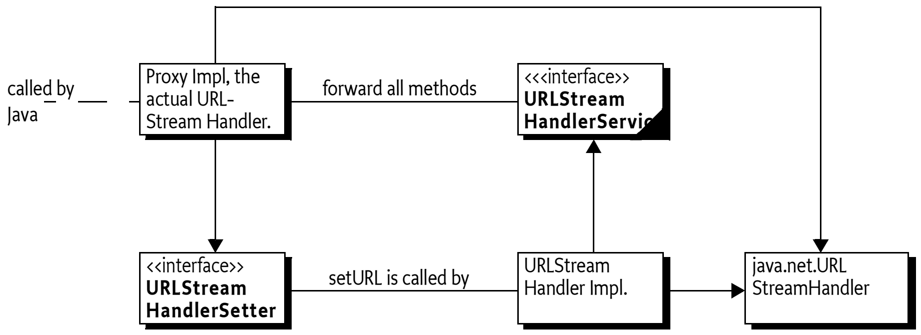
The Java run-time specific packages should be listed in the appropriate properties so that implementations of the URL Stream Handler Factory and Content Handler Factory can be made aware of these packages.

11.3.4 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 then the setURL method of URLStreamHandler class.

Figure 11.50 *Proxy Issues*


called by Java
Proxy Impl, the actual URL-Stream Handler.
forward all methods
<<<interface>> URLStream HandlerServic
<<interface>> URLStream HandlerSetter
setURL is called by
URLStream Handler Impl.
java.net.URL StreamHandler

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 then 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 URLStreamHandler.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 URLStreamHandlerSetter object in realHandler as opposed to super.

11.3.5 Stream Handlers that use java.net.Proxy

Java 1.5 introduced a new method on the URLStreamHandler class: URLConnection 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 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 Unsupported Operation Exception 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 URLStreamHandler class that is used to proxy the URL Stream Handler services.

11.4 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 URLStreamHandlerService. When it is started, it registers itself with the OSGi Framework. The OSGi Framework calls the openConnection method when a new java.net.URLConnection must be created. In this example, a DataConnection object is returned.

```
public class DataProtocol
   extends AbstractURLStreamHandlerService
   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";
    }
  }
```

11.5 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 ) {
      Hashtableproperties = 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();
    }
}
```

11.6 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.

11.7 Changes 4.1

- Added support for the new Java 1.5 openConnection method. See *Stream Handlers that use java.net.Proxy* on page 269.
- Allow both String and String[] properties for the scheme and MIME properties.

11.8 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. For example:

```
Import-Package: org.osgi.service.url; version=1.0
```

11.8.1 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.

11.8.2 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.URL-StreamHandler except for parseURL and setURL, which use the URLStream-HandlerSetter parameter. Subclasses of this abstract class should not need to override the setURL and parseURL(URLStreamHandlerSetter,...) methods.

11.8.2.1 protected URLStreamHandlerSetter realHandler

The URLStreamHandlerSetter object passed to the parseURL method.

11.8.2.2 public AbstractURLStreamHandlerService( )

11.8.2.3 public boolean equals(URL u1, URL u2)

□ This method calls super.equals(URL,URL).

See Also `java.net.URLStreamHandler.equals(URL,URL)`

11.8.2.4 public int getDefaultPort( )

□ This method calls super.getDefaultPort.

See Also `java.net.URLStreamHandler.getDefaultPort`

11.8.2.5 public InetAddress getHostAddress(URL u)

□ This method calls super.getHostAddress.

See Also `java.net.URLStreamHandler.getHostAddress`

11.8.2.6 public int hashCode(URL u)

□ This method calls super.hashCode(URL).

See Also `java.net.URLStreamHandler.hashCode(URL)`

11.8.2.7 public boolean hostsEqual(URL u1, URL u2)

□ This method calls super.hostsEqual.

See Also `java.net.URLStreamHandler.hostsEqual`

11.8.2.8 public abstract URLConnection openConnection(URL u) throws IOException

See Also `java.net.URLStreamHandler.openConnection`

11.8.2.9 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`

11.8.2.10 public boolean sameFile(URL u1, URL u2)

☐ This method calls super.sameFile.

See Also `java.net.URLStreamHandler.sameFile`

11.8.2.11 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.

11.8.2.12 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)`

11.8.2.13 public String toExternalForm(URL u)

☐ This method calls super.toExternalForm.

See Also `java.net.URLStreamHandler.toExternalForm`

11.8.3 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.

11.8.3.1 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.

11.8.3.2 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.

11.8.4 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 URL-

StreamHandlerSetter object received in the parseURL method instead of URLStreamHandler.setURL to avoid a SecurityException.

See Also `AbstractURLStreamHandlerService`

11.8.4.1 public boolean equals(URL u1, URL u2)

See Also `java.net.URLStreamHandler.equals(URL, URL)`

11.8.4.2 public int getDefaultPort( )

See Also `java.net.URLStreamHandler.getDefaultPort`

11.8.4.3 public InetAddress getHostAddress(URL u)

See Also `java.net.URLStreamHandler.getHostAddress`

11.8.4.4 public int hashCode(URL u)

See Also `java.net.URLStreamHandler.hashCode(URL)`

11.8.4.5 public boolean hostsEqual(URL u1, URL u2)

See Also `java.net.URLStreamHandler.hostsEqual`

11.8.4.6 public URLConnection openConnection(URL u) throws IOException

See Also `java.net.URLStreamHandler.openConnection`

11.8.4.7 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`

11.8.4.8 public boolean sameFile(URL u1, URL u2)

See Also `java.net.URLStreamHandler.sameFile`

11.8.4.9 public String toExternalForm(URL u)

See Also `java.net.URLStreamHandler.toExternalForm`

11.8.5 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` 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.

11.8.5.1 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.

11.8.5.2 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)`

11.9 References

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http://www.ietf.org/rfc/rfc1738.txt

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http://www.nacs.uci.edu/indiv/ehood/MIME/MIME.html

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