Red Hat JBoss Fuse 6.3

Managing OSGi Dependencies

How to package applications for OSGi containers

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How to package applications for OSGi containers

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Abstract

The guide describes how Red Hat JBoss Fuse resolves dependencies and how to package applications to load properly.

Table of Contents

CHAPTER 1. BUNDLE CLASS LOADER

Abstract

This chapter introduces some basic OSGi class loading concepts. Ultimately, in order to understand the relationship between a bundle and its dependencies, and to understand the meaning of importing and exporting packages, it is essential to learn about the bundle class loader.

1.1. CLASS LOADER BASICS

Overview

If you are concerned about which version of a class your application uses, you inevitably have to start dealing with class loaders. In Java, the class loader is the mechanism that controls where class definitions come from and decides whether or not to allow a particular class definition to be used. So, when it comes to versioning and security, class loaders play a central role.

Because version control is also important in OSGi, it follows that class loaders play a key role in the OSGi architecture. One of the main aims of OSGi is to make class loading more flexible and more manageable.

Bundle class loader

A fundamental rule in OSGi is that *every bundle has its own class loader* and this class loader is known as the *bundle class loader*.

You might wonder whether it is really necessary to have a class loader for every bundle. The class loader per bundle architecture is chosen for the following reasons:

- A class loader encapsulates knowledge about where to find classes and a particular bundle might have knowledge about finding classes that other bundles do not possess. For example, a bundle can have private classes, not directly visible to other bundles.
- In order to support the flexible OSGi class loading architecture, each bundle needs to be in control of how and where it finds its classes.

Identity of a loaded class

In the context of OSGi, where a typical application depends on multiple class loaders (one for each bundle), it is important to understand that the fully-qualified class name—for example, **org.foo.Hello**—is *not* sufficient to identify a loaded class uniquely. In general, a loaded class is uniquely identified by combining the classloader identity with the fully-qualified class name.

For example, if the class, **org.foo.Hello**, gets loaded by the bundle classloader for version 1.3 of bundle **A**, the loaded class is uniquely identified by the combination of the class loader, **A;1.3**, and the class name, **org.foo.Hello**. In this chapter, the following notation is used for the unique identity of the loaded class:

```
A;1.3/org.foo.Hello
```

Bundle class space

The OSGi specification defines a bundle's *class space* to be the set of all classes accessible to the bundle's class loader, where each class in the set is a unique instance, qualified by the class loader that loaded it.

A bundle class space includes a bundle's private classes, as well as any public classes imported from the bundle's dependencies.

Multiple copies of a loaded class

When you have multiple class loaders at parallel locations in the class loader hierarchy (which is the case with the bundle class loaders), it is actually possible to load multiple, distinct, copies of the same class.

For example, given the appropriate conditions, it is possible that version 1.3 of bundle A and version 2.0 of bundle B could both independently load the class, **org.foo.Hello**. In this case, you would have two distinct loaded classes, as follows:

```
A;1.3/org.foo.Hello
B;2.0/org.foo.Hello
```

The OSGi framework is designed to *prevent* multiple copies of a class ever appearing in the same class space, because this almost always causes errors at run time. On the other hand, it is permissible for different copies of a class to be loaded into *different* class spaces. For example, it is perfectly alright for separate applications running in an OSGi container to use different versions of the same class.

Class loader delegation

One of the key class loader concepts is *class loader delegation*, which is where a class loader, instead of loading a class itself, asks another class loader to load the class. When class loader delegation occurs, you need to distinguish between:[1]

Initial class loader

The class loader that is initially asked to load the class.

Effective class loader

The class loader that *actually* loads the class, after delegation is taken into account.

1.2. CONFLICTING CLASSES

Overview

One of the main aims of the OSGi class loading architecture is to avoid loading conflicting class definitions into the same bundle class space. This section explains how such conflicts can arise in practice.

Symbolic references

To explain the difficulties that can be caused by having multiple copies of a loaded class, we need the concept of a *symbolic reference* to a class or interface. A symbolic reference is a point in your code where a class name is used, except the actual definition of the class. For example, when a class name is used to specify a return type, a parameter type, or a variable type, the class name is a symbolic reference.

At run time, the JVM must resolve each symbolic reference by linking it to a specific instance of a loaded class. Symbolic references are resolved using the same class loader as the class in which they appear. For example, Example 1.1, "Symbolic Reference Used in a Class Cast" shows the definition of the **TestHello** class, which is loaded by the class loader, **A**.

Example 1.1. Symbolic Reference Used in a Class Cast

```
// Java
package org.bar;

// TestHello loaded by ClassLoader 'A'
public class TestHello {
    public void useHelloObj(Object hello) {
        org.foo.Hello h = (org.foo.Hello) hello;
        System.out.println(h.getGreeting());
    }
}
```

IMPORTANT

Although the symbolic reference, **org.foo.Hello**, is initially loaded by class loader **A**, this does *not* imply that the symbolic references must be resolved to **A**/**org.foo.Hello**. If the initial class loader **A** decides to delegate to another class loader, **B**, the symbolic reference could be resolved to **B**/**org.foo.Hello** instead (so that **B** is the effective class loader). The delegation mechanism is crucial, because it enables an OSGi bundle to re-use existing loaded classes and avoid class space inconsistencies.

Class cast exceptions

When multiple class loaders are used in parallel (as happens in OSGi), there is a danger that a class could be loaded more than once. This is undesirable, because it almost inevitably causes class cast exceptions at run time.

For example, consider the **TestHello** class shown in Example 1.1, "Symbolic Reference Used in a Class Cast", where the **org.foo.Hello** symbolic reference has been resolved to **A**/**org.foo.Hello**. If you also have a **Hello** object that is an instance of **B**/**org.foo.Hello** type, you will get a class cast exception when you pass this object to the **TestHello.useHelloObj(Object)** method. Specifically, in the line of code that performs the following cast:

```
org.foo.Hello h = (org.foo.Hello) hello;
```

The **org.foo.Hello** symbolic reference has been resolved to the **A**/**org.foo.Hello** type, but the **hello** object is of **B**/**org.foo.Hello** type. Because the types do not match, you get the class cast exception.

1.3. CLASS LOADING ALGORITHM

Overview

The OSGi bundle class loading algorithm plays a key role in the OSGi framework. Ultimately, it is this algorithm that defines the relationship between a bundle and its dependencies.

Requirements on a bundle class loader

Here are some of the requirements that a bundle class loader must satisfy in order to support a flexible and consistent class loading architecture:

- In order to avoid loading multiple copies of a class, the bundle class loader must first of all try to find the class in one of its dependent bundles.
- The bundle class loader must *never* load a duplicate copy of a class into its class space.

Bundle class loading algorithm

The following is a simplified description of the bundle class loading algorithm (for example, it does not enumerate all of the ways in which class loading can fail). For a full description of the algorithm, see the *Runtime Class Loading* section of the OSGi Core Specification.

1. If the class belongs to one of the **java.*** packages or any packages listed in the **org.osgi.framework.bootdelegation** property, the bundle class loader delegates to the parent class loader.
2. If the class belongs to one of the packages listed in **Import-Package**, the bundle class loader delegates loading to the corresponding exporter bundle.
3. If the class belongs to one of the packages imported by **Require-Bundle**, the bundle class loader delegates loading to the corresponding exporter bundle.

NOTE

It is strongly recommended that you avoid using the **Require-Bundle** header. OSGi dependencies are meant to be defined at package granularity, *not* bundle granularity.

4. Next, the bundle class loader looks for the class amongst its internal classes (inside its own JAR file).
5. Next, the bundle class loader searches the internal classes of any *fragments* attached to the bundle.
6. Finally, if the class belongs to one of the packages imported using **DynamicImport-Package**, the bundle class loader delegates loading to the corresponding exporter bundle (if there is one).

[1] Terminology coined by Andreas Schaefer, an O'Reilly Java author.

CHAPTER 2. IMPORTING AND EXPORTING PACKAGES

Abstract

The key to understanding the rules for importing and exporting packages is to know what type of bundle you are dealing with. This chapter aims to show that, once you have figured out the role played by a particular bundle, you will quickly be able to figure out the requisite Maven bundle configuration.

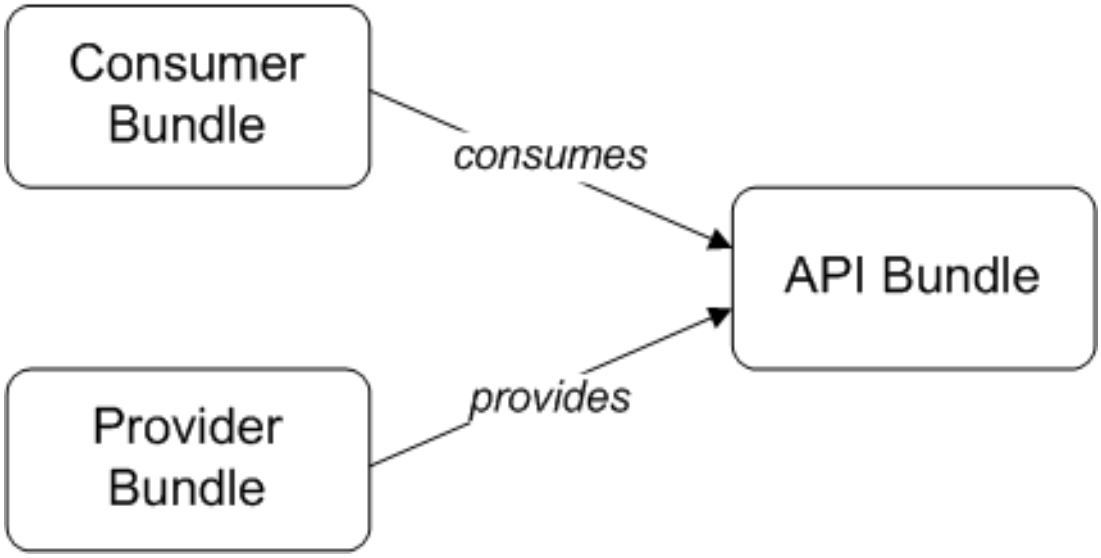
2.1. OVERVIEW OF BUNDLE TYPES

Overview

The Maven bundle plug-in is a powerful tool for generating OSGi bundle header information. When set up correctly, it can generate most of the bundle header information for you automatically. The bundle plug-in has, however, a bewildering array of options available. In order to make sense of the bundle plug-in configuration, the first question question you need to answer is: what type of bundle do I have?

Figure 2.1, "Relationship between API, Provider, and Consumer Bundles" shows the most important bundle types and bundle relationships that you will come across in a typical OSGi application.

Figure 2.1. Relationship between API, Provider, and Consumer Bundles



A well-designed application normally exposes a block of functionality through a collection of abstract Java interfaces, which constitute a pure API package. To provide a clean separation of implementation and interface description, the API package is normally deployed in one bundle, the *API bundle*, and the API implementation is deployed in a separate bundle, the *provider bundle*. The code that actually uses the API is referred to as a consumer and is packaged in a *consumer bundle*. Each of these bundle types have differing requirements when it comes to configuring their Maven bundle plug-in instructions.

Bundle Types

We can identify the following typical bundle types:

Library bundle

A library bundle contains Java classes and interfaces, which are public and intended to be used by other bundles. Often, in a library, there is no formal separation between API interfaces and implementation classes. Instead, developers simply instantiate and use the classes provided by the

library.

A library bundle does not publish or access any OSGi services.

API bundle

A pure API bundle contains only Java interfaces (or abstract classes), which are public. The implementation of the API is meant to be provided in a separate bundle or JAR.

An API bundle does not publish or access any OSGi services.

Provider bundle

A provider bundle contains the classes that implement an API. Usually, the classes in a provider bundle are all private and are *not* exported from the bundle.

The natural mechanism for a provider bundle to expose its functionality is to create and publish one or more OSGi services (where the OSGi services are then accessed through the public API).

Consumer bundle

A consumer bundle contains code that uses an API.

A consumer bundle typically accesses one or more OSGi services; it does not usually publish an OSGi service itself (unless it is acting as a hybrid of a consumer and a provider).

API/provider combination bundle

In some cases, it can make sense to package API packages and implementation packages together, resulting in an API/provider combination bundle. For example, if you intend to provide only *one* implementation of an API, it can be simpler to package the API and its implementation in a single bundle.

For the API/provider combination bundle, it is assumed that the API code and the implementation code belong to the same Maven project.

API/provider build-time combination bundle

Even if you opt for a formal separation of API code and implementation code—that is, where the API code and the implementation code are developed in separate Maven projects—you might nevertheless want to add the API interfaces to the provider bundle. Peter Kriens (creator of the Bnd tool, on which the Maven bundle plug-in is based) recommends that a provider bundle should always include its API interfaces. One reason for this is that, when you deploy a provider bundle without embedding the API, there always a risk that the required version of the API will not be available in the OSGi container at deploy time. By embedding the API interfaces in the provider, you eliminate that risk and improve the reliability of your deployment.

When you develop your API interfaces and your implementation classes in separate Maven projects, the bundle plug-in supports a special configuration that enables you to embed the API in the provider bundle at *build-time*. Hence, this bundle is called an API/provider build-time combination.

Summary of import/export rules

Table 2.1, “Import/Export Rules for Bundles” summarizes the import/export rules for the various bundle types.

Table 2.1. Import/Export Rules for Bundles

Bundle Type	Export Own Packages	Import Own Packages	Publish OSGi Service	Access OSGi Service
Library	*Yes*			
API	*Yes*			
Provider			*Yes*	
Consumer	*Maybe*	*Maybe*		*Yes*
API/provider combination	*Yes (API only)*	*Yes (API only)*	*Yes*	

Importing and exporting own packages

The basic rule for *exporting* a bundle's own packages is as follows: a bundle should export any of its own packages that are public and intended to be used by other bundles; private packages should not be exported.

The basic rule for *importing* a bundle's own packages is as follows: a bundle does *not* import any of its own packages, because those packages are already available from the bundle's own classpath (external dependencies, on the other hand, must of course be imported).

But there is a special case where it makes sense for a bundle both to export *and* to import its own packages. The OSGi container interprets this in a special way: the bundle *either* imports the package (thus using the classes from another bundle, and ignoring its own copy of those classes) *or* exports the package (thus using its own copy of the classes and making these classes available to other bundles).

For example, an API/provider combination bundle exports and imports its own API packages. This ensures the bundle is able to use the API interfaces from another bundle, if a suitable version is available. Re-using existing packages and classes is an important strategy to avoid duplicate class instances in the same class space (see Section 1.2, “Conflicting Classes”).

When to publish an OSGi service

An OSGi service is essentially a plain Java object, made accessible to other bundles by being published in the OSGi service registry (see section "Exporting a Service" in "Deploying into Apache Karaf").

Provider bundles demonstrate a typical use case of an OSGi service. The classes in a provider bundle are only meant to be accessed *indirectly*—that is, through the relevant API interfaces. But there must be some mechanism that enables you to instantiate one or more of the implementation classes, in order to bootstrap the implementation. Typically, the mechanism for bootstrapping an implementation depends on the framework or container you are currently using. For example, in Spring you would typically use a **bean** element to create an instance of an implementation class.

In the context of OSGi, however, the natural mechanism for bootstrapping an implementation is to create and publish one or more OSGi services.

Default bundle plug-in settings

Example 2.1, "Maven Bundle Plug-In Settings" shows a minimal configuration of the Maven bundle plug-in, which you can use for basic Maven projects.

Example 2.1. Maven Bundle Plug-In Settings

```
<project ... >
  ...
  <build>
    ...
    <plugins>
      <plugin>
        <groupId>org.apache.felix</groupId>
        <artifactId>maven-bundle-plugin</artifactId>
        <extensions>true</extensions>
        <configuration>
          <instructions>
        <Bundle-SymbolicName>${project.groupId}.${project.artifactId}</Bundle-SymbolicName>
            <Import-Package>*</Import-Package>
          </instructions>
        </configuration>
      </plugin>
      ...
    </plugins>
  </build>
</project>
```

Although the preceding minimal configuration is not ideal for all bundle projects, it does have a useful default behavior that is often good enough to get your project started:

- *Import rules*—when you build your Maven project, the bundle plug-in tries to discover all of the bundle's package dependencies automatically. By default, the bundle plug-in then adds *all* of the discovered package dependencies to the **Import-Package** header in the Manifest file (equivalent to the wildcard instruction, *****).

  However, the effectiveness of the initial scan depends on where the dependencies actually arise, as follows:

  - *Java source code*—Bnd scans the Java source code in your project to discover package dependencies. There is one blind spot in this process, however: the scan cannot detect dependencies that arise from using Java reflection and explicit calls on a class loader.
  - *Spring configuration file*—Bnd is *not* capable of scanning Spring configuration files to discover package dependencies. Any dependencies arising from Spring configuration must be added manually to the **Import-Package** instruction.
  - *Blueprint configuration file*—the Apache Karaf implementation of blueprint is capable of mapping XML namespaces to Java packages and dynamically resolving the resulting dependencies at run time. Hence, there is no need for blueprint's dependencies to be added to the **Import-Package** instruction.

    This is one of the major benefits of using blueprint configuration.

  Provided that the dependent bundles define a version for their exported packages, the bundle plug-in also automatically assigns a version range to the imported packages (see Section 3.3, "Automatic Import Versioning").

- *Export rules*—by default, the Maven bundle plug-in exports all of the packages in your project, except for packages that match the patterns ***.impl** or ***.internal**. It is therefore recommended that you follow the convention of naming all of your private packages with the suffix ***.impl** or ***.internal**.

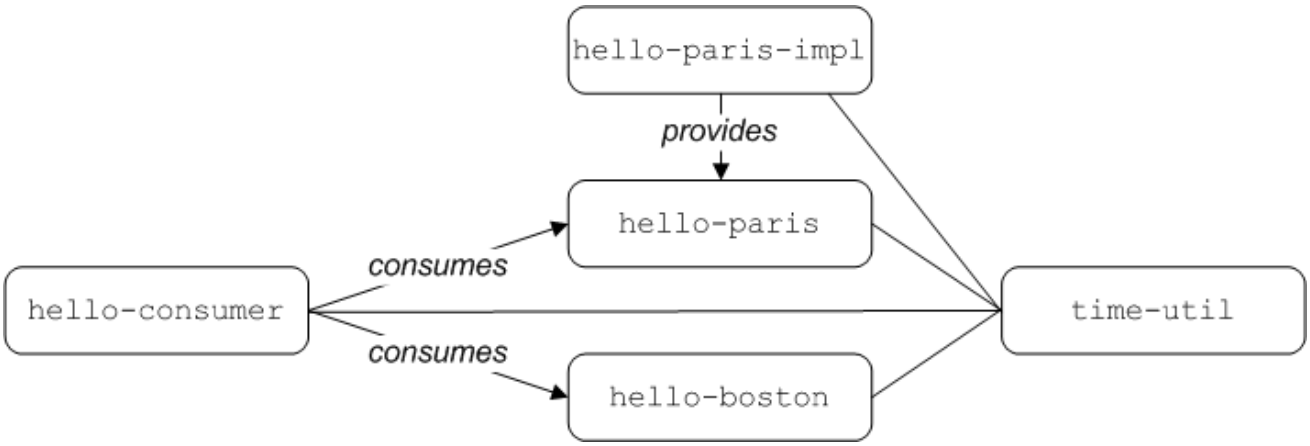
  By default, the bundle plug-in does *not* assign a version to the exported packages. This is a major disadvantage of the default export instruction (see Section 3.2, "Export Versioning").

2.2. SAMPLE OSGI APPLICATION

Example of bundle dependencies

Figure 2.2, "Sample OSGi Application" shows an overview of a sample OSGi application consisting of five bundles, which illustrates the basic bundle types discussed in the previous section. The application is driven by the **hello-consumer** bundle, which imports a **HelloParis** service from the **hello-paris** bundle and imports a **HelloBoston** service from the **hello-boston** bundle.

Figure 2.2. Sample OSGi Application



The sample bundles

The sample OSGi application consists of the following bundles:

time-util

Fits the pattern of a *library bundle*. The **time-util** bundle is a utility library that can create **Clock** instances that tell the time in a particular time zone.

The **time-util** bundle is implemented using classes from the JDK and thus has no external package dependencies.

hello-paris

Fits the pattern of an *API bundle*. The **hello-paris** bundle consists of a single Java interface, which returns a greeting, **getGreeting()**, and gives the local time in Paris, **getLocalTime()**.

The **hello-paris** bundle has the following external package dependency:

```
org.fusesource.example.time
```

hello-paris-impl

Fits the pattern of a *provider bundle*. The **hello-paris-impl** bundle implements the **hello-paris** API bundle.

The **hello-paris-impl** bundle has the following external package dependencies:

```
org.fusesource.example.hello.paris
org.fusesource.example.time
```

hello-boston

Fits the pattern of an *API/provider combination bundle*. The **hello-boston** bundle combines a Java interface and its implementation, where the Java interface returns a greeting, **getGreeting()**, and gives the local time in Boston, **getLocalTime()**.

The **hello-boston** bundle has the following external package dependency:

```
org.fusesource.example.time
```

hello-consumer

Fits the pattern of a *consumer bundle*. The **hello-consumer** bundle imports the **HelloParis** OSGi service and the **HelloBoston** OSGi service and then invokes on these services to report the local times in Paris and in Boston.

The **hello-consumer** bundle has the following external package dependencies:

```
org.fusesource.example.hello.paris
org.fusesource.example.hello.boston
org.fusesource.example.time
```

2.3. LIBRARY BUNDLE

Overview

This section explains how to set up a Maven project for a typical library bundle.

The **time-util** bundle exemplifies a library bundle, where the main purpose of a library is to make interfaces and classes available to other bundles. Hence, the library should export all of its own packages and associate a version number with the exported packages.

Directory structure

Assuming it is built as a Maven project, the **time-util** bundle has the following directory structure:

```
time-util/
  |
  \--src/
     |
     \--main/
     |  |
     |  \--java/
     |     |
     |     \--org/fusesource/example/time/
```

```
|       |
|       \-TimeUtil.java
|       |
|       \-Clock.java
|
\--test/
```

The Java source code is located under the **src/main/java** sub-directory. The **org.fusesource.example.time** package is public and all of its classes and interfaces can be exported from the bundle.

There are no blueprint resources associated with this bundle.

Sample implementation

The **time-util** bundle is essentially a wrapper around some of the standard time utilities in Java. It provides a **Clock** class, which returns the local time in a particular time zone when you invoke the **Clock.getLocalTime()** method. The **Clock** class is defined as follows:

```
// Java
package org.fusesource.example.time;

import java.util.Calendar;
import java.util.Locale;
import java.util.TimeZone;

public class Clock {
    ...
    public Clock(TimeUtil.TimeZone tz) {
        ...
    }

    public String getLocalTime() {
        return jcal.getTime().toString();
    }
}
```

The **TimeUtil** class is a factory that is used to create **Clock** instances for particular time zones. Two time zones are supported: **TimeZone.BOSTON** and **TimeZone.PARIS**. The **TimeUtil** class is defined as follows:

```
// Java
package org.fusesource.example.time;

public class TimeUtil {
  public enum TimeZone {
    BOSTON,
    PARIS
  }

  public static Clock createClock(TimeZone tz) {
      return new Clock(tz);
  }
}
```

Import and export rules

The following import and export rules apply to the **time-util** bundle:

- *Exporting own packages*—the **org.fusesource.example.time** package is public, and must be exported.
- *Importing own packages*—none of the bundle's own packages should be imported, which is the usual case for a library bundle.
- *Importing dependent packages*—any external package dependencies must be imported. In this particular example, however, there are none (the **time-util** bundle depends only on classes from the JVM).

Maven bundle plug-in settings

The Maven bundle plug-in is configured to export the library package, **org.fusesource.example.time** (coded as **${project.groupId}.time**). The **Export-Package** instruction also contains entries to block the export of any packages containing **.impl** or **.internal**. In this case, the bundle plug-in instructions are as follows:

```
<instructions>
  <Bundle-SymbolicName>${project.groupId}.${project.artifactId}</Bundle-SymbolicName>
  <Import-Package>*</Import-Package>
  <Export-Package>
    !${project.groupId}*.impl*,
    !${project.groupId}*.internal*,
    ${project.groupId}.time*;version=${project.version}
  </Export-Package>
</instructions>
```

Generated MANIFEST.MF file

When you build the bundle using Maven, the Maven bundle plug-in automatically generates the following **MANIFEST.MF** file:

```
Manifest-Version: 1.0
Bundle-Name: time-util
Built-By: JBLOGGS
Build-Jdk: 1.5.0_08
Created-By: Apache Maven Bundle Plugin
Bundle-ManifestVersion: 2
Bundle-SymbolicName: org.fusesource.example.time-util
Tool: Bnd-1.15.0
Bnd-LastModified: 1297357076457
Export-Package: org.fusesource.example.time;version="1.0"
Bundle-Version: 1.0.0
```

2.4. API BUNDLE

Overview

This section explains how to set up a Maven project for a typical API bundle.

The **hello-paris** bundle exemplifies an API bundle, which contains only public Java interfaces. Hence, the API bundle should export all of its own packages and associate a version number with the exported packages.

Directory structure

The **hello-paris** bundle has the following directory structure:

```
hello-paris/
  |
  \--src/
     |
     \--main/
     |  |
     |  \--java/
     |     |
     |     \--org/fusesource/example/hello/paris/
     |        |
     |        \-HelloParis.java
     |
     \--test/
```

The Java source code is located under the **src/main/java** sub-directory. The **org.fusesource.example.hello.paris** package is public and all of its classes and interfaces can be exported from the bundle.

There are no blueprint resources associated with this bundle.

Sample API

The **hello-paris** bundle is a pure API, which means it contains only Java interfaces. In this example, there is a single interface, **HelloParis**, which returns a localized greeting and a **Clock** object that tells the local time. The **HelloParis** interface is defined as follows:

```
// Java
package org.fusesource.example.hello.paris;

import org.fusesource.example.time.Clock;

public interface HelloParis {
    public String getGreeting();

    public Clock getLocalTime();
}
```

Maven dependencies

In the Maven POM file, the **hello-paris** bundle defines dependencies on the following Maven artifact:

- **time-util**

Import and export rules

The following import and export rules apply to the **hello-paris** bundle:

- *Exporting own packages*—the **org.fusesource.example.hello.paris** package is public, and must be exported.
- *Importing own packages*—none of the bundle's own packages should be imported.
- *Importing dependent packages*—any external package dependencies must be imported.

Maven bundle plug-in settings

The Maven bundle plug-in is configured to export the API package, **org.fusesource.example.hello.paris** (coded as **${project.groupId}.hello.paris***). The **Export-Package** instruction also contains entries to block the export of any packages containing **.impl** or **.internal**. In this case, the bundle plug-in instructions are as follows:

```
<instructions>
  <Bundle-SymbolicName>${project.groupId}.${project.artifactId}</Bundle-SymbolicName>
  <Import-Package>*</Import-Package>
  <Export-Package>
    !${project.groupId}*.impl*,
    !${project.groupId}*.internal*,
 ${project.groupId}.hello.paris*;version=${project.version}
  </Export-Package>
</instructions>
```

Generated MANIFEST.MF file

When you build the bundle using Maven, the Maven bundle plug-in automatically generates the following **MANIFEST.MF** file:

```
Manifest-Version: 1.0
Bundle-Name: hello-paris
Built-By: JBLOGGS
Build-Jdk: 1.5.0_08
Created-By: Apache Maven Bundle Plugin
Import-Package: org.fusesource.example.time;version="[1.0,2)"
Bundle-ManifestVersion: 2
Bundle-SymbolicName: org.fusesource.example.hello-paris
Tool: Bnd-1.15.0
Bnd-LastModified: 1296826928285
Export-Package: org.fusesource.example.hello.paris;uses:="org.fusesour
 ce.example.time";version="1.0"
Bundle-Version: 1.0.0
```

The **Import-Package** header lists one external package dependency, **org.fusesource.example.time**. None of the bundle's own packages are imported.

The **Export-Package** header is used to export the API package, **org.fusesource.example.hello.paris**, while the **uses** clause declares a transitive dependency on the **org.fusesource.example.time** package.

2.5. PROVIDER BUNDLE

Overview

This section explains how to set up a Maven project for a typical provider bundle.

The **hello-paris-impl** bundle exemplifies a provider bundle, which provides the implementation of an API. The provider does not export any of its own packages, because the implementation classes are private. But the provider does instantiate and export an OSGi service, which is accessed through the **HelloParis** interface.

Directory structure

The **hello-paris-impl** bundle has the following directory structure:

```
hello-paris-impl/
  |
  \--src/
     |
     \--main/
     |  |
     |  \--java/
     |  |  |
     |  |  \--org/fusesource/example/hello/paris/impl/
     |  |     |
     |  |     \--HelloParisImpl.java
     |  |
     |  \--resources/
     |     |
     |     \--OSGI-INF/blueprint/
     |        |
     |        \--paris-svc.xml
     |
     \--test/
```

The **org.fusesource.example.hello.paris.impl** package is private. By default, the Maven bundle plug-in treats any packages containing the segments **.impl** or **.internal**, as private packages.

The **src/main/resources/OSGI-INF/blueprint** directory contains a single blueprint file, **paris-svc.xml**. Any file matching the pattern, ***.xml**, in this directory is assumed to be a blueprint configuration file.

Sample implementation

The **hello-paris-impl** bundle is intended to implement all of the interfaces appearing in the **hello-paris** API bundle. In this example, a single **HelloParisImpl** class implements the **HelloParis** interface, as follows:

```
// Java
package org.fusesource.example.hello.paris.impl;

import org.fusesource.example.hello.paris.HelloParis;

import org.fusesource.example.time.Clock;
import org.fusesource.example.time.TimeUtil;

public class HelloParisImpl implements HelloParis {
    protected Clock localTime = null;

    public String getGreeting() {
```

```
        return new String("Bonjour!");
    }

    public Clock getLocalTime() {
        if (localTime==null) {
            localTime = TimeUtil.createClock(TimeUtil.TimeZone.PARIS);
        }
        return localTime;
    }

}
```

Publish OSGi service

The natural way to bootstrap the **HelloParis** implementation in OSGi is to publish the class, **HelloParisImpl**, as an OSGi service. Use the **bean** element to create a **HelloParisImpl** instance and use the **service** element to publish the bean, advertising it as a service of **HelloParis** type.

For example, the blueprint file, **OSGI-INF/blueprint/paris-svc.xml**, has the following contents:

```
<?xml version="1.0" encoding="UTF-8"?>
<blueprint xmlns="http://www.osgi.org/xmlns/blueprint/v1.0.0">

    <bean id="hello-paris-impl"
        class="org.fusesource.example.hello.paris.impl.HelloParisImpl"/>

    <service ref="hello-paris-impl"
        interface="org.fusesource.example.hello.paris.HelloParis"/>

</blueprint>
```

Maven dependencies

In the Maven POM file, the **hello-paris-impl** bundle defines dependencies on the following Maven artifacts:

- **time-util**
- **hello-paris**

Import and export rules

The following import and export rules apply to the **hello-paris-impl** bundle:

- *Exporting own packages*—none of the bundle's own packages should be exported; they are all private.
- *Importing own packages*—none of the bundle's own packages should be imported.
- *Importing dependent packages*—any external package dependencies must be imported.

Maven bundle plug-in settings

You can use the default export rules (that is, omitting the **Export-Package** instruction), as long as you

take care to put all of your code into packages containing **.impl** or **.internal** (which are not exported by default). You should explicitly list the implemented API, **org.fusesource.example.hello.paris**, in the **Import-Package** instruction and add the **provide:=true** clause to it. This signals that this bundle is acting as the *provider* of the **hello.paris** package (and ensures that the API is imported with the correct version range—see Section 3.3, "Automatic Import Versioning"). In this case, the bundle plug-in instructions are as follows:

```
<instructions>
  <Bundle-SymbolicName>${project.groupId}.${project.artifactId}</Bundle-SymbolicName>
  <Import-Package>
    ${project.groupId}.hello.paris*;provide:=true,
    *
  </Import-Package>
</instructions>
```

Generated MANIFEST.MF file

When you build the bundle using Maven, the Maven bundle plug-in automatically generates the following **MANIFEST.MF** file:

```
Manifest-Version: 1.0
Bundle-Name: hello-paris-impl
Built-By: JBLOGGS
Build-Jdk: 1.5.0_08
Created-By: Apache Maven Bundle Plugin
Import-Package: org.fusesource.example.hello.paris;version="[1.0,1.1)"
 ,org.fusesource.example.time;version="[1.0,2)",org.osgi.service.blu
 eprint;version="[1.0.0,2.0.0)"
Export-Service: org.fusesource.example.hello.paris.HelloParis
Bundle-ManifestVersion: 2
Bundle-SymbolicName: org.fusesource.example.hello-paris-impl
Tool: Bnd-1.15.0
Bnd-LastModified: 1297357383645
Bundle-Version: 1.0.0
```

The **Import-Package** header imports external package dependencies only—for example, **org.fusesource.example.hello.paris** and **org.fusesource.example.time**.

The **Export-Service** header advertises the OSGi service as a **HelloParis** instance. This enables clients to find the **HelloParisImpl** instance by searching for a service of **HelloParis** type.

2.6. API/PROVIDER COMBINATION

Overview

This section explains how to set up a Maven project for an API/provider bundle.

The **hello-boston** bundle exemplifies an API/provider combination bundle. The API/provider bundle exports only its API packages, while the implementation packages are kept private. The API/provider bundle also instantiates and exports an OSGi service, which is accessed through the **HelloBoston** interface.

Directory structure

The **hello-boston** bundle has the following directory structure:

```
hello-boston/
  |
  \--src/
     |
     \--main/
     |  |
     |  \--java/
     |  |  |
     |  |  \--org/fusesource/example/hello/boston/
     |  |  |  |
     |  |  |  \--HelloBoston.java
     |  |  |
     |  |  \--org/fusesource/example/hello/boston/impl/
     |  |     |
     |  |     \--HelloBostonImpl.java
     |  |
     |  \--resources/
     |     |
     |     \--OSGI-INF/blueprint/
     |        |
     |        \--boston-svc.xml
     |
     \--test/
```

The **org.fusesource.example.hello.boston** package is public and all of its classes and interfaces are exported from the bundle.

The **org.fusesource.example.hello.boston.impl** package is private. By default, the Maven bundle plug-in treats any packages containing the segments **.impl** or **.internal**, as private packages.

The **src/main/resources/OSGI-INF/blueprint** directory contains a single blueprint file, **boston-svc.xml**. Any file matching the pattern, ***.xml**, in this directory is assumed to be a blueprint configuration file.

Sample API

The **hello-boston** bundle contains an API, which consists of the interface, **HelloBoston**. The **HelloBoston** interface returns a localized greeting and a **Clock** object that tells the local time. It is defined as follows:

```
// Java
package org.fusesource.example.hello.boston;

import org.fusesource.example.time.Clock;

public interface HelloBoston {
    public String getGreeting();

    public Clock getLocalTime();
}
```

Sample implementation

The **hello-boston** bundle also implements the API. In this example, a single **HelloBostonImpl** class implements the **HelloBoston** interface, as follows:

```
// Java
package org.fusesource.example.hello.boston.impl;

import org.fusesource.example.hello.boston.HelloBoston;

import org.fusesource.example.time.Clock;
import org.fusesource.example.time.TimeUtil;

public class HelloBostonImpl implements HelloBoston {
    protected Clock localTime = null;

    public String getGreeting() {
        return new String("Hello!");
    }

    public Clock getLocalTime() {
        if (localTime==null) {
            localTime = TimeUtil.createClock(TimeUtil.TimeZone.BOSTON);
        }
        return localTime;
    }

}
```

Publish OSGi service

The natural way to bootstrap the **HelloBoston** implementation in OSGi is to publish the class, **HelloBostonImpl**, as an OSGi service. Use the **bean** element to create a **HelloBostonImpl** instance and use the **service** element to publish the bean, advertising it as a service of **HelloBoston** type.

For example, the blueprint file, **OSGI-INF/blueprint/boston-svc.xml**, has the following contents:

```
<?xml version="1.0" encoding="UTF-8"?>
<blueprint xmlns="http://www.osgi.org/xmlns/blueprint/v1.0.0">

    <bean id="hello-boston-impl"
        class="org.fusesource.example.hello.boston.impl.HelloBostonImpl"/>

    <service ref="hello-boston-impl"
        interface="org.fusesource.example.hello.boston.HelloBoston"/>

</blueprint>
```

Maven dependencies

In the Maven POM file, the **hello-boston** bundle defines dependencies on the following Maven artifact:

- **time-util**

Import and export rules

The following import and export rules apply to the **hello-boston** bundle:

- *Exporting own packages*—export the public API package, **org.fusesource.example.hello.boston**. Do *not* export the private package, **org.fusesource.example.hello.boston.impl**.
- *Importing own packages*—import the public API package, **org.fusesource.example.hello.boston**.
- *Importing dependent packages*—any external package dependencies must be imported.

Maven bundle plug-in settings

You must export the API package, **org.fusesource.example.hello.boston**, by including it in the **Export-Package** instruction, and add the **provide:=true** clause to it. This signals that this bundle is acting as the *provider* of the **hello.boston** package (and ensures that the API is imported with the correct version range—see Section 3.3, "Automatic Import Versioning"). In this case, the bundle plug-in instructions are as follows:

Example 2.2. Plug-In Settings for API/Provider Combination

```
<instructions>
  <Bundle-SymbolicName>${project.groupId}.${project.artifactId}</Bundle-SymbolicName>
  <Import-Package>*</Import-Package>
  <Export-Package>
    !${project.groupId}*.impl*,
    !${project.groupId}*.internal*,
    ${project.groupId}.hello.boston*;provide:=true;version=${project.version}
  </Export-Package>
</instructions>
```

Generated MANIFEST.MF file

When you build the bundle using Maven, the Maven bundle plug-in automatically generates the following **MANIFEST.MF** file:

```
Manifest-Version: 1.0
Built-By: JBLOGGS
Created-By: Apache Maven Bundle Plugin
Import-Package: org.fusesource.example.hello.boston;version="[1.0,1.1)
 ",org.fusesource.example.time;version="[1.0,2)",org.osgi.service.blue
 print;version="[1.0.0,2.0.0)"
Bnd-LastModified: 1297357441566
Export-Package: org.fusesource.example.hello.boston;uses:="org.fusesou
 rce.example.time";version="1.0"
Bundle-Version: 1.0.0
Bundle-Name: hello-boston
Build-Jdk: 1.5.0_08
Bundle-ManifestVersion: 2
Export-Service: org.fusesource.example.hello.boston.HelloBoston
Bundle-SymbolicName: org.fusesource.example.hello-boston
Tool: Bnd-1.15.0
```

The **Import-Package** header imports both the public API package, **org.fusesource.example.hello.boston**, and the external package dependencies—for example, **org.fusesource.example.time**.

The **Export-Package** header exports the public API package, **org.fusesource.example.hello.boston**, while the **uses** clause declares a transitive dependency on the **org.fusesource.example.time** package.

The **Export-Service** header advertises the OSGi service as a **HelloBoston** instance. This enables clients to find the **HelloBostonImpl** instance by searching for a service of **HelloBoston** type.

2.7. API/PROVIDER BUILD-TIME COMBINATION

Overview

This section explains how to set up a Maven project for an API/provider bundle, where the API packages and implementation packages are kept in *separate* Maven projects, but then combined into a single bundle at build-time.

You can demonstrate an API/provider build-time combination bundle by modifying the Maven configuration of the **hello-paris-impl** bundle. By exploiting the Bnd utility's **provide:=true** clause, you can modify the instructions for the Maven bundle plug-in, so that the **org.fusesource.example.hello.paris** API package gets included in the **hello-paris-impl** bundle at build time.

provide:=true clause

Whenever a bundle plays the role of provider with respect to a particular API package, you must indicate this explicitly by attaching the **provide:=true** clause to the API package, either in an import instruction or in an export instruction (otherwise, by default, the bundle plug-in would assume that the bundle is a *consumer* of the API package). In particular, for an API/provider build-time combination bundle, you must *export* the **org.fusesource.example.hello.paris** API package and attach the **provide:=true** clause, as follows:

```
<instructions>
  ...
  <Export-Package>
    ...
 ${project.groupId}.hello.paris*;provide:=true;version=${project.version},
  </Export-Package>
  ...
</instructions>
```

Exporting a package with the **provide:=true** clause has a very important side effect: *if the code for the exported package is not in the current Maven project, the Maven bundle plug-in adds the package code to the bundle at build time*.

Included Maven projects

Code from the following Maven projects is included in the **hello-paris-impl** bundle:

hello-paris-impl

Contains the private package, **org.fusesource.example.hello.paris.impl**. Build this bundle to create the API/provider build-time combination bundle, **hello-paris-impl**.

hello-paris

Contains the public API package, **org.fusesource.example.hello.paris**. This project is a prerequisite for **hello-paris-impl** and must be built (using **mvn install**) before the **hello-paris-impl** project. You do *not* deploy the **hello-paris** bundle directly into the OSGi container, however.

Import and export rules

The following import and export rules apply to the **hello-paris-impl** bundle, when it is configured as an API/provider build-time combination:

- *Exporting own packages*—no own packages to export, because the **hello-paris-impl** Maven project contains only private implementation packages.
- *Exporting dependent packages*—export the public API package, **org.fusesource.example.hello.paris**, with the **provide:=true** clause, which causes the API code to be included in the **hello-paris-impl** bundle at build time.
- *Importing own packages*—import the public API package, **org.fusesource.example.hello.paris**.
- *Importing dependent packages*—any external package dependencies must be imported.

Maven bundle plug-in settings

To include the API from the **hello-paris** bundle in the **hello-paris-impl** bundle, add the **org.fusesource.example.hello.paris** package to the **Export-Package** instruction with the **provide:=true** clause attached, as shown in Example 2.3, "Plug-In Settings for Build-Time Combination". Compare this with the regular API/provider case, Example 2.2, "Plug-In Settings for API/Provider Combination", which takes the same approach of exporting the API package with the **provide:=true** clause. The semantics, however, are a bit different, because the current example pulls in the API package from a separate Maven project.

Example 2.3. Plug-In Settings for Build-Time Combination

```
<instructions>
  <Bundle-SymbolicName>${project.groupId}.${project.artifactId}</Bundle-SymbolicName>
  <Import-Package>*</Import-Package>
  <Export-Package>
    !${project.groupId}*.impl*,
    !${project.groupId}*.internal*,
    ${project.groupId}.hello.paris*;provide:=true;version=${project.version},
  </Export-Package>
</instructions>
```

Assigning versions at package granularity

In the preceding example, the included **org.fusesource.example.hello.paris** API package is given the *same* version as the **hello-paris-impl** Maven project, by adding the **version=${project.version}** clause to the export instruction. In practice, however, you might not always want to assign versions in this way. You might prefer to assign *distinct* versions to the API package (from the **hello-paris** Maven project) and the implementation package (from the **hello-paris-impl** Maven project).

The alternative approach you can take is to store version information at *package granularity* in a

packageinfo file (see the section called "Export versions at package granularity" for details). The Maven bundle plug-in automatically scans your source code, looking for **packageinfo** files and extracting the version information from them. In this case, you must omit the version clause from the export instruction, as follows:

```
 <Export-Package>
   !${project.groupId}*.impl*,
   !${project.groupId}*.internal*,
   <!-- hello.paris version stored in packageinfo -->
${project.groupId}.hello.paris*;provide:=true,
 </Export-Package>
```

Generated MANIFEST.MF file

When you build the bundle using Maven, the Maven bundle plug-in automatically generates the following **MANIFEST.MF** file:

```
Manifest-Version: 1.0
Import-Package: org.fusesource.example.hello.paris;version="[1.0,1.1)"
 ,org.fusesource.example.time;version="[1.0,2)",org.osgi.service.bluep
 rint;version="[1.0.0,2.0.0)"
Export-Package: org.fusesource.example.hello.paris;uses:="org.fusesour
 ce.example.time";version="1.0"
Built-By: FBOLTON
Tool: Bnd-1.15.0
Bundle-Name: hello-paris-impl
Created-By: Apache Maven Bundle Plugin
Export-Service: org.fusesource.example.hello.paris.HelloParis
Build-Jdk: 1.6.0_24
Bundle-Version: 1.0.0
Bnd-LastModified: 1302098214984
Bundle-ManifestVersion: 2
Bundle-SymbolicName: org.fusesource.example.hello-paris-impl
```

The **Import-Package** header imports both the public API package, **org.fusesource.example.hello.paris**, and the external package dependencies—for example, **org.fusesource.example.time**.

The **Export-Package** header exports the public API package, **org.fusesource.example.hello.paris**, while the **uses** clause declares a transitive dependency on the **org.fusesource.example.time** package.

The **Export-Service** header advertises the OSGi service as a **HelloParis** instance.

Bundle deployment

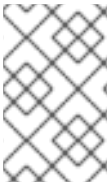
Because the **hello-paris-impl** bundle includes all of the code from the **hello-paris** Maven project, it is *unnecessary* to deploy the **hello-paris** bundle in this case.

2.8. CONSUMER BUNDLE

Overview

This section explains how to set up a Maven project for a consumer bundle.

The **hello-consumer** bundle exemplifies a consumer bundle, which imports OSGi services and accesses the services through the relevant API packages. This is the bundle that drives the sample application and, therefore, it relies on a blueprint lifecycle callback (through the blueprint **bean** element's **init-method** attribute) to initiate processing.



NOTE

Being a consumer is just a role, not an absolute category, so you will commonly come across bundles that behave both as a consumer and a provider. In the current example, however, **hello-consumer** behaves as a pure consumer.

Directory structure

The **hello-consumer** bundle has the following directory structure:

```
hello-consumer/
  |
  \--src/
     |
     \--main/
     |  |
     |  \--java/
     |  |  |
     |  |  \--org/fusesource/example/hello/consumer/
     |  |     |
     |  |     \--ConsumeHello.java
     |  |
     |  \--resources/
     |     |
     |     \--OSGI-INF/blueprint/
     |        |
     |        \--client.xml
     |
     \--test/
```

The **org.fusesource.example.hello.consumer** package is public and all of its classes and interfaces are exported from the bundle. It would not matter, however, if you made this package private instead, because it is not needed by any other bundles.

The **src/main/resources/OSGI-INF/blueprint** directory contains a single blueprint file, **client.xml**. Any file matching the pattern, ***.xml**, in this directory is assumed to be a blueprint configuration file.

Sample consumer code

The **hello-consumer** bundle effectively drives the sample application, obtaining references to the **HelloBoston** and **HelloParis** OSGi services, and then invoking methods on these services to obtain localised greetings and times.

The **hello-consumer** bundle contains the class, **ConsumeHello**, which is a client of the OSGi services, **HelloBoston** and **HelloParis**. To gain access to the OSGi services, **ConsumeHello** defines the setter methods, **getHelloBoston()** and **getHelloParis()**, and relies on the blueprint framework to inject the references. The entry point is the **init()** method, which gets invoked after the **ConsumeHello** bean is created and injected with the service references. The **ConsumeHello** class is defined as follows:

```
// Java
package org.fusesource.example.hello.consumer;

import org.fusesource.example.hello.boston.HelloBoston;
import org.fusesource.example.hello.paris.HelloParis;

public class ConsumeHello {
    protected HelloBoston helloBoston = null;
    protected HelloParis helloParis = null;

    /**
     * @param args
     */
    public static void main(String[] args) {
        // TODO Auto-generated method stub

    }

    public void init() {
        if (helloBoston==null || helloParis==null) {
            System.out.println("Initialization failed. Injected objects are null.");
            return;
        }

        String enGreeting = helloBoston.getGreeting();
        String bostonTime = helloBoston.getLocalTime().getLocalTime();
        System.out.println("Boston says:" + enGreeting + " at " + bostonTime);

        String frGreeting = helloParis.getGreeting();
        String parisTime = helloParis.getLocalTime().getLocalTime();
        System.out.println("Paris says:" + frGreeting + " at " + parisTime);
    }

    public HelloBoston getHelloBoston() {
        return helloBoston;
    }

    public void setHelloBoston(HelloBoston helloBoston) {
        this.helloBoston = helloBoston;
    }

    public HelloParis getHelloParis() {
        return helloParis;
    }

    public void setHelloParis(HelloParis helloParis) {
        this.helloParis = helloParis;
    }

}
```

Access OSGi service

The **ConsumeHello** class needs to obtain a reference to the **HelloBoston** service and a reference to the **HelloParis** service. Use the **reference** element to create proxies for the **HelloBoston** service and

for the **HelloParis** service. Use the **bean** element to create a **ConsumeHello** instance and inject the **helloBoston** and **helloParis** proxies.

The **ConsumeHello** bean also requires an entry point to initiate processing. By setting the **bean** element's **init-method** attribute to **init**, you ensure that the blueprint framework calls the **ConsumeHello.init()** method after all of the bean's properties have been injected.

For example, the blueprint file, **OSGI-INF/blueprint/client.xml**, has the following contents:

```
<?xml version="1.0" encoding="UTF-8"?>
<blueprint xmlns="http://www.osgi.org/xmlns/blueprint/v1.0.0">

   <reference id="helloBoston"
      interface="org.fusesource.example.hello.boston.HelloBoston"/>

   <reference id="helloParis"
      interface="org.fusesource.example.hello.paris.HelloParis"/>

   <bean id="client"
        class="org.fusesource.example.hello.consumer.ConsumeHello"
        init-method="init">
      <property name="helloBoston" ref="helloBoston"/>
      <property name="helloParis" ref="helloParis"/>
   </bean>

</blueprint>
```

Maven dependencies

In the Maven POM file, the **hello-consumer** bundle defines dependencies on the following Maven artifacts:

- **time-util**
- **hello-paris**
- **hello-boston**

Import and export rules

The following import and export rules apply to the **hello-consumer** bundle:

- *Exporting own packages*—a client typically does not need to export its own packages, because a client does not usually expose an API.
- *Importing own packages*—a client does not import its own packages.
- *Importing dependent packages*—any external package dependencies must be imported.

Maven bundle plug-in settings

The Maven bundle plug-in is configured to export the package, **org.fusesource.example.hello.consumer**, although the export is unnecessary in this particular example. The **Export-Package** instruction also contains entries to block the export of any packages containing **.impl** or **.internal**. In this case, the bundle plug-in instructions are as follows:

```
<instructions>
  <Bundle-SymbolicName>${project.groupId}.${project.artifactId}</Bundle-SymbolicName>
  <Import-Package>*</Import-Package>
  <Export-Package>
    !${project.groupId}*.impl*,
    !${project.groupId}*.internal*,
 ${project.groupId}.hello.consumer*;version=${project.version}
  </Export-Package>
</instructions>
```

Generated MANIFEST.MF file

When you build the bundle using Maven, the Maven bundle plug-in automatically generates the following **MANIFEST.MF** file:

```
Manifest-Version: 1.0
Built-By: JBLOGGS
Created-By: Apache Maven Bundle Plugin
Import-Package: org.fusesource.example.hello.boston;version="[1.0,2)",
 org.fusesource.example.hello.paris;version="[1.0,2)",org.fusesource.e
 xample.time;version="[1.0,2)",org.osgi.service.blueprint;version="[1.
 0.0,2.0.0)"Bnd-LastModified: 1296826333723
Export-Package: org.fusesource.example.hello.consumer;uses:="org.fuses
 ource.example.time,org.fusesource.example.hello.paris,org.fusesource.
 example.hello.boston";version="1.0"
Bundle-Version: 1.0.0
Bundle-Name: hello-consumer
Build-Jdk: 1.5.0_08
Bundle-ManifestVersion: 2
Bundle-SymbolicName: org.fusesource.example.hello-consumer
Tool: Bnd-1.15.0
Import-Service: org.fusesource.example.hello.boston.HelloBoston,org.fu
 sesource.example.hello.paris.HelloParis
```

The **Import-Package** header imports the external package dependencies—for example, **org.fusesource.example.hello.boston**.

The **Export-Package** header exports the package, **org.fusesource.example.hello.consumer**. In this case, however, the export is not really needed and the package could have been declared private instead (for example, using the **Private-Package** instruction).

The **Import-Service** header declares the OSGi services accessed by this bundle. The services are accessed respectively through the **HelloBoston** interface and through the **HelloParis** interface.

CHAPTER 3. VERSIONING

Abstract

For the stability of an OSGi application, it is essential that a bundle restricts the range of acceptable versions of its dependencies; otherwise, the bundle could be wired to an incompatible version of an imported package, with disastrous results. On the other hand, an application cannot afford to be too restrictive: a complex application might re-use a package in many different places. If a strict version restriction is placed on such a package every time it occurs, it might prove impossible to deploy the application, due to conflicting version requirements. Also, a certain amount of version flexibility is required in order to deploy patched bundles as hot fixes. This chapter describes the OSGi version policies that help you to achieve these goals and explains how to implement version polices using the Maven bundle plug-in.

3.1. SEMANTIC VERSIONING

Overview

The basic principle of semantic versioning is that an increment to a major, minor, or micro part of a version signals a particular degree of compatibility or incompatibility with previous versions of a package. The Semantic Versioning technical white paper from the OSGi Alliance makes specific recommendations about how to interpret each of the major, minor, and micro parts of a version. Based on these definitions, the paper explains how to assign a version number to an exported package and how to assign a version range to an imported package.

This section summarizes the recommendations of the OSGi technical white paper.

Version fidelity

Consider a bundle (the *importer*) that has package dependencies on another bundle (the *exporter*). At build time, the importer is compiled and tested against a *specific* version of the exporter. It follows that the build-time version of the exporter bundle is the version least likely to cause any problems or bugs, because it has already been tested against the importer.

If you deploy the importer together with the original build-time version of the exporter, you have perfect version *fidelity* between the two bundles. Unfortunately, fidelity cannot usually be achieved in real deployments, because the exporter bundle is often used by many other bundles, compiled against slightly different versions of the exporter. Particularly in a modern open-source programming environment, where an application might pull in hundreds of bundles from many third-party projects and companies, it becomes essential to allow for version flexibility when matching bundles to their dependencies.

Backward compatibility in Java

To figure out how much version flexibility we can allow, we first need to consider the rules for backward compatibility in Java. Java is one of the few languages that explicitly considers issues of binary compatibility in its specification and the detailed rules can be found in the *Binary Compatibility* chapter of The Java Language Specification. The following is an incomplete list of changes that are binary compatibility with consumers of particular classes or interfaces:

- Adding new fields, methods, or constructors to an existing class or interface.
- Deleting private fields, methods, or constructors of a class.

- Deleting package-only access fields, methods, or constructors of a class or interface.
- Re-ordering the fields, methods, or constructors in an existing type declaration.
- Moving a method upward in the class hierarchy.
- Reordering the list of direct super-interfaces of a class or interface.
- Inserting new class or interface types in the type hierarchy.

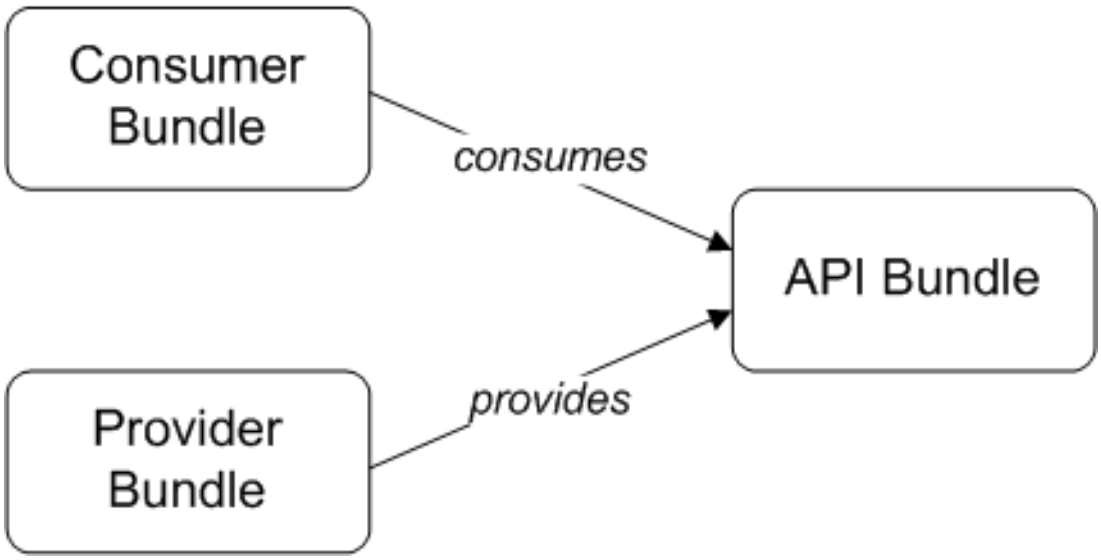
Consumers and providers

In a well-structured Java application, bundles often fall into one of the following categories: *API*, *consumer*, and *provider*. The consumer and provider roles can be defined as follows:

- *Consumer*—a bundle that uses the functionality exposed by an API, invoking methods on the API's Java interfaces.
- *Provider*—a bundle that provides the functionality of an API, containing classes that implement the API's Java interfaces.

Both the consumer and the provider import packages from an API bundle, as illustrated in Figure 3.1, "Consumers and Provider of API Interfaces". Hence, the consumer and the provider are both sensitive to changes in the API bundle.

Figure 3.1. Consumers and Provider of API Interfaces



It turns out that the rules of binary compatibility are quite different for consumers and providers. The coupling between consumer, provider and API can be described as follows:

- *Compatibility between consumer and API* —this coupling obeys the rules from the *Binary Compatibility* chapter of the *Java Language Specification*. There is quite a lot of scope for altering the API without breaking backward compatibility; in particular, it is possible to add methods to Java interfaces without breaking compatibility.
- *Compatibility between provider and API* —this coupling is not explicitly considered in the *Java Language Specification*. It turns out that this coupling is *much* more restrictive than the consumer case. For example, adding methods to Java interfaces breaks backward compatibility with the provider.

Callback interfaces

The role of a consumer is not always as clear cut as initially suggested here. Although consumers mostly interact with an API by invoking methods on the API's interfaces, there are some cases where a consumer actually *implements* one of the API interfaces (thus muddying the distinction between a consumer and a provider). A classic example of where this might happen is when an API defines a *callback interface*, which a consumer can implement in order to receive event notifications.

For example, consider the **javax.jms.MessageListener** interface from the JMS API, which is defined as follows:

```
// Java
package javax.jms;

public interface MessageListener {
    void onMessage(javax.jms.Message message);
}
```

A consumer is expected to implement the **onMessage()** method in order to receive messages from the underlying JMS service. So, in this case, the more restrictive binary compatibility rules (the same ones that apply to a provider) must be applied to the **MessageListener** interface.

NOTE

It is recommended that you try to be as conservative as possible with callback interfaces, changing them as infrequently as possible, in order to avoid breaking binary compatibility with consumers.

OSGi version syntax

The OSGi version syntax defines a version to have up to four parts, as follows:

```
<major> [ '.' <minor> [ '.' <micro> [ '.' <qualifier> ]]]
```

Where **<major>**, **<minor>**, and **<micro>** are positive integers and **<qualifier>** is an arbitrary string. For example, the following are valid OSGi versions:

```
4
2.1
3.99.12.0
2.0.0.07-Feb-2011
```

OSGi version ranges

When declaring dependencies on imported packages in OSGi, you can declare a *range* of acceptable versions. An OSGi version range is defined using a notation borrowed from mathematics: square brackets—that is, **[** and **]**— denote an inclusive range; and parentheses—that is, **(** and **)**—denote an exclusive range. You can also mix a parenthesis with a bracket to define a half-inclusive range. Here are some examples:

OSGi Version Range	Restriction on Version, v
[1.0, 2.0)	**1.0 <= v < 2.0**
[1.0, 2.0]	**1.0 <= v <= 2.0**
(1.4.1, 1.5.5)	**1.4.1 < v < 1.5.5**
(1.5, 1.9]	**1.5 < v <= 1.9**
1.0	**1.0 <= v < ∞**

Of the preceding examples, the most useful style is the half-inclusive range, **[1.0, 2.0)**. A simple version number on its own, **1.0**, is interpreted as an inclusive range up to positive infinity.

Semantic versioning rules

The fundamental idea of semantic versioning is that a bundle's version should indicate when the bundle breaks binary compatibility with its preceding version, bearing in mind that there are different kinds of binary compatibility: *compatibility of consumers* and *compatibility of providers*. The OSGi Semantic Versioning technical white paper proposes the following versioning conventions:

<major>

When a change breaks binary compabitility with both consumers *and* providers, increment the bundle's major version number. For example, a version change from **1.3** to **2.0** signals that the new bundle version is incompatible with older consumers and providers.

<minor>

When a change breaks binary compatibility with providers, but *not* consumers, increment the bundle's minor version number. For example, a version change from **1.3** to **1.4** signals that the new bundle version is incompatible with older providers, but compatible with older consumers.

<micro>

A change in micro version does not signal any backward compatibility issues. The micro version can be incremented for bug fixes that affect neither consumers nor providers of the API.

<qualifier>

The qualifier is typically used as a build identifier—for example, a time stamp.

Consumer import range

Assuming that an exporter bundle obeys the preceding OSGi semantic versioning rules, it is possible to work out the range of versions that are compatible with a consumer. For example, if a consumer is built against an exporter with version **1.3**, the next version that would break binary compatibility with the consumer is **2.0**. It follows that all exporter versions up to, but excluding, **2.0** ought to be compatible with the consumer.

In general, the consumer import range is calculated from the build-time version of the exporter according to the following rule: given the build-time version, **<major>.<minor>.<micro>.<qual>**, define the corresponding consumer import range to be **[<major>.<minor>, <major>+1)**.

Table 3.1, "Example Consumer Import Ranges" shows some examples of how to choose the correct consumer import range for a given exporter version.

Table 3.1. Example Consumer Import Ranges

Build-Time Version of Exporter	Consumer Import Range
3.0	**[3.0, 4)**
2.0.1	**[2.0, 3)**
2.1.4	**[2.1, 3)**
2.1.5.2011-02-07-LATEST	**[2.1, 3)**

Provider import range

According to the OSGi semantic versioning rules, providers are compatible with a narrower range of versions than consumers. For example, if a provider is built against an exporter with version **1.3**, the next version that would break binary compatibility with the provider is **1.4**. It follows that all exporter versions up to, but excluding, **1.4** ought to be compatible with the provider.

In general, the provider import range is calculated from the build-time version of the exporter according to the following rule: given the build-time version, **<major>.<minor>.<micro>.<qual>**, define the corresponding provider import range to be **[<major>.<minor>, <major>.<minor>+1)**.

Table 3.2, "Example Provider Import Ranges" shows some examples of how to choose the correct provider import range for a given exporter version.

Table 3.2. Example Provider Import Ranges

Build-Time Version of Exporter	Provider Import Range
3.0	**[3.0, 3.1)**
2.0.1	**[2.0, 2.1)**
2.1.4	**[2.1, 2.2)**
2.1.5.2011-02-07-LATEST	**[2.1, 2.2)**

3.2. EXPORT VERSIONING

Overview

OSGi allows you to associate a *single* version with an exported package. The version that you choose for your package (or packages) should conform to the conventions of semantic versioning, as defined in the section called "Semantic versioning rules".

Export version at bundle granularity

The simplest approach to export versioning is where you use the bundle version as the export version and you assign the same export version to all exported packages in the bundle.

Using the Maven bundle plug-in, you can implement this versioning policy using instructions like the following:

```
<instructions>
  <Bundle-SymbolicName>${project.groupId}.${project.artifactId}</Bundle-SymbolicName>
  <Import-Package>*</Import-Package>
  <Export-Package>
    !${project.groupId}*.impl.*,
    !${project.groupId}*.internal.*,
 ${project.groupId}.my.export.pkg*;version=${project.version}
  </Export-Package>
</instructions>
```

Where the **${project.version}** macro returns the the contents of the **project/version** element in the POM file (the version of the current Maven artifact).

Export versions at package granularity

Strictly speaking, importing and exporting works at the granularity level of packages, not of bundles. In principle, therefore, it is possible to assign versions at the level of individual packages, so that one bundle contains multiple packages with different versions. There are some scenarios where it can be useful to assign versions at package granularity.

For example, consider a bundle that contains both an API package and a package that implements the API (see Section 2.7, "API/Provider Build-Time Combination"). In this case, it makes more sense to use separate versions for the API package and the implementation package.

Using the Maven bundle plug-in, you can specify the version of an individual Java package by creating or modifying the standard Java **packageinfo** file in the corresponding package directory. For example, if you want to assign version **1.2.1** to the **org.fusesource.example.time** package, create a file called **packageinfo** (no suffix) in the **src/main/java/org/fusesource/example/time** directory and add the following line:

```
version 1.2.1
```

Alternatively, since Java 5 it is also possible to specify version information using annotations in a **package-info.java** file, for example:

```
@Version("1.2.1")
package org.fusesource.example.time;
```

3.3. AUTOMATIC IMPORT VERSIONING

Overview

By default, the Maven bundle plug-in automatically assigns a version range to imported packages, following the semantic versioning rules outlined in Section 3.1, "Semantic Versioning". You need to provide an additional hint to the bundle plug-in, to indicate whether the bundle imports a package in the role of a consumer or a provider (the bundle plug-in presumes the consumer role).

For automatic import versioning to work, the package dependency *must* be versioned at build time, otherwise the importing bundle cannot calculate the import range.

Automatic consumer import range

The Maven bundle plug-in automatically generates consumer import ranges that conform to the rules of semantic versioning, as defined in the section called "Consumer import range" . The only prerequisite is that the corresponding exporter actually defines a package version.

For example, given that the **hello-paris** bundle consumes version **1.2.1** of the **org.fusesource.example.time** package, the Maven bundle plug-in automatically generates a manifest with the following import:

```
Import-Package: org.fusesource.example.time;version="[1.0,2)"
```

Automatic provider import range

Because the Maven bundle plug-in assumes by default that an importer is acting in the role of consumer, it is necessary to specify *explicitly* when an importer is acting in the role of provider, using the **provide:=true** clause. There are two different approaches you can take to specifying the provider import range, depending on how you package the API and provider bundles, as follows:

- the section called "Separate API and provider bundles" .
- the section called "Combined API and provider bundle" .

Separate API and provider bundles

When the API and the provider are to be packaged in separate bundles, append the **provide:=true** clause to the relevant API packages listed in the **Import-Package** instruction.

For example, given that the **hello-paris-impl** bundle provides the implementation of the **org.fusesource.example.hello.paris** package from the **hello-paris** API bundle, you would define the **Import-Package** instructions for the **hello-paris-impl** bundle as follows:

```
<instructions>
  ...
  <Import-Package>
 ${project.groupId}.hello.paris*;provide:=true,
    *
  </Import-Package>
  ...
</instructions>
```

Given that the **org.fusesource.example.hello.paris** package has version **1.0**, the Maven bundle plug-in generates a manifest with the following imports:

```
Import-Package: org.fusesource.example.hello.paris;version="[1.0,1.1)"
 ,org.fusesource.example.time;version="[1.0,2)",org.osgi.service.bluep
 rint;version="[1.0.0,2.0.0)"
```

Combined API and provider bundle

When the API and the provider are to be combined in the same bundle, append the **provide:=true** clause to the relevant API packages listed in the **Export-Package** instruction (this is the correct setting to use both for an API/provider combination bundle and for an API/provider build-time combination bundle).

For example, given that the **hello-boston** bundle includes both the **org.fusesource.example.hello.boston** API and its implementation classes, you would define the **Export-Package** instructions for the **hello-boston** bundle as follows:

```
<instructions>
  ...
  <Export-Package>
    !${project.groupId}*.impl.*,
    !${project.groupId}*.internal.*,
 ${project.groupId}.hello.boston*;provide:=true;version=${project.version}
  </Export-Package>
  ...
</instructions>
```

Given that the **org.fusesource.example.hello.boston** package has version **1.0**, the Maven bundle plug-in generates a manifest with the following highlighted import and export:

```
Import-Package: org.fusesource.example.hello.boston;version="[1.0,1.1)
 ",org.fusesource.example.time;version="[1.0,2)",org.osgi.service.blue
 print;version="[1.0.0,2.0.0)"
Export-Package: org.fusesource.example.hello.boston;uses:="org.fusesou
 rce.example.time";version="1.0"
```

NOTE

In the case where the API and the provider code are located in separate Maven projects, setting **provide:=true** on an exported API package in the provider's POM has the important side-effect that *the API interfaces are included in the provider bundle* . For a detailed explanation, see Section 2.7, “API/Provider Build-Time Combination” .

Customize import range

Occasionally, it will be necessary to customize the import version range—for example, if the corresponding exporter does not follow the OSGi semantic versioning conventions. The simplest case is where you specify the import range explicitly, as in the following example:

```
<Import-Package>
  com.package.with.wrong.semantics*;version="[1.3,1.3.4]",
  *
</Import-Package>
```

Custom import rule

Sometimes, a third-party exporter might follow a consistent versioning convention, but this convention is different from the OSGi convention. In this case, it make sense to define a custom import rule that codifies the alternative convention. For example, if a third-party exporter increments the minor version number whenever binary compatibility with consumers is broken, you could use Bnd's **range** macro to codify this rule on consumer imports, as follows:

```
<Import-Package><![CDATA[
  com.package.with.wrong.semantics*;version="$<range;[==,=+)>",
  *
  ]]>
</Import-Package>
```

Where the Bnd macro is written in the format, **$<*Macro*>** and must be enclosed in a CDATA section to avoid clashing with the XML interpretations of **<** and **>** (actually, Bnd supports a variety of different macro delimiters, most of which cannot be used here: braces, **${...}**, clash with Maven properties; while square brackets, **$[...]**, and parentheses, **$(...)**, clash with the syntax of version ranges).

Entries like **==** and **=+** are masks that return a version based on the version of the corresponding exporter. The equals sign, **=**, returns the corresponding version part unchanged; the plus sign, **+**, returns the corresponding version part plus one; and the minus sign, **-**, returns the corresponding version part minus one. For example, if the corresponding exporter has the version, **1.3.0.4**, the range mask, **[==,=+)**, resolves to **[1.3,1.4)**. For more details, consult the Bnd documentation for the range macro.

The **range** macro is a relatively new addition to Bnd. In POMs that were written before the **range** macro became available, you might come across ranges written using the Bnd **version** macro. For example, the range, **$<range;[==,=+)>**, could also be written using the **version** macro as follows:

```
<Import-Package><![CDATA[
  com.package.with.wrong.semantics*;version="[$<version;==>,$<version;=+>)",
  *
  ]]>
</Import-Package>
```

NOTE

At the time of writing, the Bnd tool has a bug that causes two **NullPointerException** exceptions, accompanied by lengthy stack traces, to be generated whenever you build a Maven project featuring the **range** or **version** macros as shown above. Although alarming, *these exceptions are harmless non-fatal errors*. If you check the generated bundle after building, you will see that the **Manifest.mf** file is generated exactly as specified by the bundle instructions.

Customize version policies

Bnd and the Maven bundle plug-in support directives that enable you to override the default versioning policies. Occasionally, you might come across an entire subsystem that consistently follows a different versioning convention from OSGi and, in this case, it makes sense to override the default versioning policies.

Since Bnd version 1.15 (version 2.2.0 of the Maven bundle plug-in), the following directives can be used to specify versioning policies:

-consumer-policy

Specifies a macro to calculate the consumer import range.

-provider-policy

Specifies a macro to calculate the provider import range.

In the Maven bundle plug-in, these directives are set using the elements, **_consumer-policy** and **_provider-policy**—for example:

```
<instructions>
  ...
  <_consumer-policy>$&lt;range;[==,=+)></_consumer-policy>
  <_provider-policy>$&lt;range;[===,==+)></_provider-policy>
  ...
</instructions>
```

Where the macro, **$<*Macro*>**, is escaped as, **$<*Macro*>**, in XML (or you could use a CDATA section).

NOTE

Any Bnd directives that start with the hyphen character, **-**, can also be set in the Maven bundle plug-in using an element whose name is obtained by changing the initial hyphen, **-**, to an underscore, _.