Spring Dynamic Modules Reference Guide

2.0.0.M1

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Preface

Application development has seen significant changes in the last years, moving towards a simpler, more agile, POJO-based programming model in order to keep a fast pace. Dependency injection and Aspect Oriented Programming, which were once *bleeding edge* ideas, are used on a daily basis by most developers to manage and simplify the complexity of their applications.

However, in terms of deployment, things have remained mainly unchanged. Even though code bases are divided into modules, whether logical, conceptual or physical, at runtime they are seen as one monolithic application in which, making a change (be it large or small), requires a restart. OSGi aims to change this by allowing applications to be divided into *modules* that can have different life cycles, dependencies and still exist as a whole.

Spring Dynamic Modules focuses on integrating Spring Framework powerful, non-invasive programming model and concepts with the dynamics and modularity of OSGi platform. It allows transparent exporting and importing of OSGi services, life cycle management and control. Moreover, the Spring DM model was standardized in OSGi r4.2, in the form of the Blueprint Container for which Spring DM 2.0+ serves as the reference implementation (RI).

While every effort has been made to ensure that this documentation is comprehensive and there are no errors, nevertheless some topics might require more explanation and some typos might have crept in. If you do spot any mistakes or even more serious errors and you can spare a few cycles during lunch, please do bring the error to the attention of the Spring Dynamic Modules team by raising an issue. Thank you.

Part I. Introduction

This document is the reference guide for Spring Dynamic Modules. It explains the relationship between Spring Dynamic Modules and the OSGi 4.2 Blueprint specification, defines Spring Dynamic Modules concepts and semantics, the syntax for the OSGi Service Platform based namespaces, the Dynamic Modules extender bundle and the OSGi manifest header entries defined by Dynamic Modules.

For an introduction to OSGi or Spring, or Spring DM examples, please refer to Chapter 3, *Getting Started* - this documentation refers only to Spring DM and assumes the user is familiar with OSGi and Spring concepts.

Note: OSGi is a trademark of the OSGi Alliance. Project name is pending final approval from the Alliance.

Note: Please see the known issues page for Spring Dynamic Modules release.

Chapter 1. Why Spring Dynamic Modules?

The Spring Framework is the leading full-stack Java/JEE application framework. It provides a lightweight container and a non-invasive programming model enabled by the use of dependency injection, AOP, and portable service abstractions. The OSGi Service Platform offers a dynamic application execution environment in which modules (bundles) can be installed, updated, or removed on the fly. It also has excellent support for modularity and versioning.

Spring Dynamic Modules makes it easy to write Spring applications that can be deployed in an OSGi execution environment, and that can take advantage of the services offered by the OSGi framework. Spring's OSGi support also makes development of OSGi applications simpler and more productive by building on the ease-of-use and power of the Spring Framework. For enterprise applications, the combination of Spring Dynamic Modules and the OSGi platform provides:

- Better separation of application logic into modules, with runtime enforcement of module boundaries
- The ability to deploy multiple versions of a module (or library) concurrently
- The ability to dynamically discover and use services provided by other modules in the system
- The ability to dynamically install, update and uninstall modules in a running system
- Use of the Spring Framework to instantiate, configure, assemble, and decorate components within and across modules.
- A simple and familiar programming model for enterprise developers to exploit the features of the OSGi platform.

We believe that the combination of OSGi and Spring offers a comprehensive model for building enterprise applications.

The OSGi Alliance found valuable the programming model proposed by Spring DM and, in OSGi 4.2, standardized it by introducing the Blueprint Container, as part of the Compendium services.

Chapter 2. Requirements

Spring Dynamic Modules 2.x binaries requires JDK level 5.0 and above, and OSGi R4 (R4.2 recommended) and above. For JDK 1.4, consider using Spring Dynamic Modules 1.x.

Bundles deployed for use with Spring Dynamic Modules should specify `"Bundle-ManifestVersion: 2"` in their manifest (require OSGi R4 behaviour). Note that for OSGi 4.2 specific functionality (such as the Blueprint Container), an appropriate container needs to be used.

We test against Equinox 3.5.x, Felix 2.0.0+, and Knopflerfish 3.0.x as part of our continuous integration process.

Chapter 3. Getting Started

Learning a new framework is not always straight forward. In this section, we (the Spring DM team) tried to provide, what we think is, an easy to follow guide for starting with Spring Dynamic Modules. Of course, feel free to create your own learning 'path' as you see fit and, if possible, please report back any improvements to the documentation that can help others.

3.1. First Steps

As explained in Chapter 1, *Why Spring Dynamic Modules?*, Spring DM provides integration between Spring framework and OSGi. Thus, it is important to become acquainted with both of these frameworks (libraries or environments depending on how you want to name them). Throughout the Spring DM documentation, each section provides links to resources relevant however, it is best to become familiar with these topics beforehand.

3.1.1. Knowing Spring

Spring DM uses heavily Spring framework's core functionalty, such as the IoC container, resource abstract or AOP infrastructure. While it is not important to know the Spring APIs, understanding the concepts behind them is. At a minimum, the idea behind IoC should be familiar. These being said, the more knowledge one has about the Spring, the faster she will pick Spring Dynamic Modules. Besides the very comprehensive (and sometimes disarming) documentation that explains in detail the Spring Framework, there are a lot of articles, blog entries and books on the matter - take a look at the Spring framework home page for more information. In general, this should be the starting point for OSGi (or Eclipse plugin) developers wanting to try Spring DM.

3.1.2. Knowing OSGi

Java developers, new to OSGi, can start by reading the OSGi Alliance introduction, the OSGi specifications or one of the articles/blogs available on the internet (such as the SpringSource blogs). Additionally, the Spring DM home page hosts various links to useful materials.

3.1.3. Quick start - OSGi 4.2 Blueprint Container

As an alternative to the recommended Spring documentation, if OSGi 4.2 is an option, one can read the Blueprint Container specification for a quick introdution to dependency injection and Spring DM functionality. Note that Blueprint is a subset of Spring and Spring DM and we recommend the official documentation to get access to the whole set of features.

3.1.4. Trying Out The Samples

Once one is familiar with the concepts behind Spring and OSGi, she can start reading the Spring DM reference documentation (this document) and take the Spring DM samples for a spin. The samples are available either in the .zip distribution or from the Spring DM repository. The samples are a convenient way to get started quickly with Spring DM as they show various features of Spring DM and help one get pass the initial struggles with OSGi. However, they are not meant as the definitive guide in using OSGi rather, they aim to be a launching pad for "newbies" trying out OSGi in Spring.

The current distribution contains:

- Simple Service Sample

  A simple example that illustrates OSGi service publication and consumption through Spring DM. This is a good starting point for users learning the basics.

- Weather Sample

  A demo that shows more advanced features of Spring DM and OSGi. The application creates a very simple weather information services presenting some best practices in designing an application to take advantage of the modularity offered by OSGi.

- Simple Web App Sample

  As the name implies, this is a simple web application, containing Servlets, JSPs and JSP tags, that runs inside OSGi through Spring DM.

- Web Console Sample

  A more complicated sample that demos a Spring MVC annotation based, web application that runs inside OSGi through Spring DM, featuring class path scanning and various Spring taglib. Additionally, the web application interacts with the OSGi environment through the web UI.

Each project contains instructions regarding its content and startup procedure. Users are encouraged to experiment with the samples to get a better understanding of the technologies used.

3.2. Need Help?

If you encounter issues or you are just looking for an advice, feel free to use one of the links below:

3.2.1. Community Support

The Spring DM forum is a message board for all Spring DM users to share information and help each other. Note that registration is needed *only* for posting.

3.2.2. Professional Support

Professional, from-the-source support, with guaranteed response time, is available from SpringSource, the company behind Spring Dynamic Modules and Spring.

3.3. Following Development

For information on the Spring DM source code repository, nightly builds and snapshot artifacts please see the Spring DM home page.

You can help make Spring DM best serve the needs of the Spring community by interacting with developers through the Spring Community forums.

If you encounter a bug or want to suggest an improvement, please create a ticket on the Spring DM issue tracker.

To stay up to date with the latest news and announcements in the Spring eco system, subscribe to the Spring

Community Portal.

Lastly, you can follow the SpringSource OSGi blog or the project team on Twitter (Adrian, Costin)

Chapter 4. What is new?

While a relatively young project, each version of Spring Dynamic Modules (even minor ones) offers new functionality. This chapter is a guide to the new and improved feature and intended as a high-level, short summary. Please follow the appropriate links for more in-depth information.

4.1. 2.0.x

4.1.1. OSGi 4.2 Blueprint Reference Implementation (RI)

Spring DM served as the basis for the Blueprint Container specification, introduced by OSGi 4.2. Spring DM 2.0 stands as the RI for the aforementioned specification, providing the Blueprint API and implementation out of the box. Various aspect of Spring DM have been adjusted for consistency to the Blueprint specification. For more information on the two models, see Chapter 5, *OSGi 4.2 Blueprint Container* for more information.

4.1.2. Java 5

As of 2.x, Spring DM requires JDK 5 to run (or compile). The framework code has been revised to take advantage of the JDK 5 features such as language improvements, concurrency and generics: for example, various enum-like classes used by the exporter and importer API have been deprecated and replaced with proper Java 5`enums`. Considerable effort has been spent to keep the code backwards compatible however, it is recommended to compile the code against the Spring DM 2.x code and perform sanity checks before upgrading.

4.1.3. Spring 3.x

Besides the Java 5 upgrade, DM 2.0 requires Spring 3.x to get access to the latest framework features and JDK optimizations.

4.1.4. Service Importer Improvements

2.0.x provides several improvements for service imports (whether single or collection based) in terms of speed, configuration and service lifecycle. Section 8.2, “Defining References To OSGi Services” provides more details.

4.1.5. Java 2 Security Integration

Continuing the work in 1.2.x, Spring DM 2.0 executes all user code using its credentials (the managed bundle permissions). See Appendix B, *Security Integration* for more information.

4.2. 1.2.x

4.2.1. Java 2 Security Integration

Since 1.2.x, Spring Dynamic Modules is aware of secured environments by making use of dedicated privileged

blocks for executing security sensitive code. Thus, Spring DM can run as a *trusted* library without requiring escalated permissions for its managed bundles. See Appendix B, *Security Integration* for more information.

4.2.2. Compendium Services Support

1.2.x provides integration with the Configuration Admin, part of the OSGi compendium services. Chapter 11, *Compendium Services* provides more details on the topic.

4.2.3. Changed Spring DM Symbolic Names

Since 1.2.0 M2, the Spring DM bundles symbolic names have been aligned with Spring's 2.5.6+. Thus the prefix `org.springframework.bundle.osgi` has been changed to `org.springframework.osgi`; for example Spring DM extender symbolic name was changed from `org.springframework.bundle.osgi.extender` to `org.springframework.osgi.extender` (notice the missing `bundle` word). Additionally, the documentation has been updated to reflect Spring 2.5.6+ symbolic names.

4.2.4. Usage of SpringSource Enterprise Bundle Repository (EBR)

To minimize the number of repositories used and the confusion caused by OSGified vs non-OSGified artifacts especially to users using Spring dm Server, after 1.2.0 RC1, Spring Dynamic Modules aligned as many of its dependencies as possible with SpringSource EBR. In practice this means that Spring framework artifacts, such as `spring-aop.jar` can be now found as `org.springframework.aop.jar`; We apologize for any inconvenience created to users relying on these naming conventions.

4.3. 1.1.x

4.3.1. Web Support

The biggest feature in Spring Dynamic Modules 1.1.x is the transparent support for web applications on OSGi platforms. By integrating directly with web containers (such as Apache Tomcat and Jetty), Spring DM allows WARs using Servlet, JSP and taglib technologies to be used with little or no effort at all. Please see Chapter 10, *Web Support* for details.

4.3.1.1. Spring-MVC Integration

Additionally, with 1.1.x it is possible to run Spring-MVC applications inside OSGi environments. See Section 10.7, “Spring-MVC Integration” for more information.

4.3.2. Classpath Resource Abstraction

1.1.x adds support for `classpath:` and `classpath*:` prefixes to the OSGi `Resource` abstraction. This allows the discovery of classpath resources (such as Spring's component scanning) to work out-of-the-box across multiple bundles on the supported OSGi platforms. See Section 6.4, “The Resource Abstraction” for more information.

4.3.3. Pluggable Extender Configuration

1.1.x makes it easy to change the default configuration for the various extenders used by Spring DM. By using

fragments, users can customize the way application contexts are started, the web container used for web deployment or the thread-pool for running Spring applications. Additionally, it is possible to receive events regarding the OSGi Spring application contexts lifecycle. Section 6.1, “The Spring Dynamic Modules Extender Bundle” lists the available options and explains them in detail.

4.3.4. Improved Class Loading

In 1.1.x, the proxy creation has been improved, leading to better package wiring for the managed bundles. See the FAQ for more information.

Part II. Reference Documentation

Document structure

This part of the reference documentation explains the core functionality offered by Spring Dynamic Modules.

Chapter 5, *OSGi 4.2 Blueprint Container* describes the relationship between Spring DM and OSGi 4.2 Blueprint Container specification (part of the Compendium Services) and the similiarities and differences between them.

Chapter 6, *Bundles and Application Contexts* describes the relationship between an OSGi Bundle and a Spring Application Context, and introduces the Spring Extender Bundle support for instantiating application contexts automatically.

Chapter 7, *Packaging and Deploying Spring-based OSGi applications* describes how to deploy the Spring Framework jar files in an OSGi environment, and how to reference external APIs from your application bundles should you need to do so. This chapter also explains some of the issues to be aware of when using existing enterprise libraries not designed for OSGi in an OSGi environment.

Chapter 8, *The Service Registry* describes how to export Spring beans as services in the OSGi service registry, and how to inject references to OSGi services into beans. This chapter also defines how the dynamic life-cycle of OSGi services and bundles is supported.

Chapter 9, *Working With Bundles* describes how to declare a bean that represents an OSGi bundle, including support for installing new bundles into the OSGi platform.

Chapter 10, *Web Support* explains how to run web applications inside an OSGi environment using Spring DM.

Chapter 11, *Compendium Services* describes the support provided for the OSGi Compendium Services, specifically the Configuration Admin service.

Chapter 12, *Testing OSGi based Applications* explains the integration testing support provided by Spring Dynamic Modules. This support enables you to write simple JUnit integration tests that can start up an OSGi environment, install the bundles needed for the integration test, execute the test case(s) inside of OSGi, and return the results to the runner. This makes it easy to integrate OSGi integration testing into any environment that can work with JUnit.

Chapter 5. OSGi 4.2 Blueprint Container

Based on the Spring DM programming model, the OSGi Alliance introduced in OSGi 4.2 Release the Blueprint Container specification (part of the Compendium Service). Spring DM 2.0 serves as the Blueprint Reference Implementation - the official, complete implementation of the spec.

For this reason, users familiar with Spring DM, will find Blueprint very familiar and vice versa. In fact, we recommend that the Blueprint specification is used as a complement to this documentation. It should be mentioned that various aspects of Spring DM 1.x have been adjusted or slightly changed in 2.0, for consistency reason, to closely follow the Blueprint specification. As a general rule, unless mentioned otherwise, the Spring DM 2.x and Blueprint behaviour should be the same.

Existing and new users have the freedom to mix and match the programming model they want, since Spring DM 2.0 supports both the Spring/Spring DM 1.x declarations and the Blueprint one, inside the same application. That is, one can declare inside the same configuration, beans using both namespaces, at any point, without having to make an up-front choice.

Please note that this documentation will focus on Spring DM specific configurations and option; for Blueprint specific behaviour please refer to the OSGi 4.2 Compendium spec, section 121.

5.1. Blueprint Requirements

The Blueprint Container spec is part of the OSGi 4.2 release and relies on it, in its API. Thus, in order to use Blueprint, one must use an OSGi 4.2 compatible platform as a runtime environment. Spring DM itself requires only an OSGi 4.0 framework so if 4.2 is not an option, one can safely downgrade at the loss of the Blueprint model which can be built on top of Spring/Spring DM.

Note

On environments prior to OSGi 4.2, Spring DM will disable the Blueprint functionality automatically - users will be notified through a log message similar to the following:

```
Pre-4.2 OSGi platform detected; disabling Blueprint Container functionality
```

5.2. Blueprint/Spring DM Differences

There are a lot of similarities in terms of functionality and configuration between Spring DM 1.x and Blueprint which should be no surprise considering that DM was the basis of the Blueprint spec. In addition to fully supporting the Blueprint configuration schema, DM 2.x enhanced its declarations by providing option that allow for Blueprint specific behaviour. The table below aggregates the most important user facing differences between Spring/Spring DM configurations and Blueprint. Additional comparison information is available throughout the documentation (such as Section 7.2, “Blueprint Manifest Configuration Comparison” or Section 8.1.10.2, “Blueprint `service` Comparison”). Again, one can simply switch between the two definition styles, if need be.

5.2.1. XML Declarations

Most of the XML declarations are similar between Spring and Blueprint. Using the Spring namespace mechanism, the same configuration can contain both Spring, Spring DM, Blueprint and other namespaces.

Moreover, custom elements can be used for virtually all elements of a Spring configuration (namespace, bean declaration, decoration, etc...). The table below focuses *only* on the usual, standard Spring namespaces and their Blueprint equivalent.

Table 5.1. XML Configuration Differences

Element/Attribute	Spring DM	Blueprint

Namespace Declaration	`http://www.osgi.org/xmlns/blueprint/v1.0.0`	`http://www.springframework.org/schema/be`
		
		or
		`http://www.springframework.org/schema/os`

Root Element	`<beans>`	`<blueprint>`
Default Lazy	`default-lazy`	`default-activation`
Default Init Method	`default-init-method`	-
Default Destroy Method	`default-destroy-method`	-
Default Autowire Strategy	`default-autowire`, `default-autowire-candidates`	-
Root Element	`<beans>`	`<blueprint>`
Bean ID	`id`	`id`
Bean Name/Alias	`name`/`<alias>`	-
Bean Class	`class`	`class`
Bean Scope Name	`scope`	`scope`
Built-in Scopes	`singleton`, `prototype`, `request`, `session`, `bundle`	`singleton`, `prototype`
Lazy Initialization Name/Values	`lazy-init=true/false`	`activation=lazy/eager`
Depends	`depends-on`	`depends-on`
Init Method	`init-method`	`init-method`
Destroy Method	`destroy-method`	`destroy-method`
Factory Method	`factory-method`	`factory-bean`
Factory Bean	`factory-bean`	`factory-ref`
Bean Inheritance	`parent`	-
Autowire Strategy	`autowire`, `autowire-candidate`	-
Constructor	`<constructor-arg>`	`<argument>`
Property	`<property>`	`<property>`
Value	`<value>`	`<value>`
Service Exporter	`<service>`	`<service>`
Service Importer	`<reference>`/`<list>`/`<set>`	`<reference>`/`<list>`

The configurations below are equivalent in terms of functionality:

```
<?xml version="1.0" encoding="UTF-8"?>
<blueprint xmlns="http://www.osgi.org/xmlns/blueprint/v1.0.0" default-activation="lazy">
    <bean id="object" class="java.lang.Object"/>

    <bean id="length" class="java.lang.Integer">
        <argument value="4"/>
    </bean>

    <bean id="buffer" class="java.lang.StringBuffer" depends-on="simple">
            <property name="length" ref="length"/>
    </bean>

    <bean id="current-time" class="java.lang.System" factory-method="currentTimeMillis" scope="prototype"/>

    <bean id="list" class="java.util.ArrayList" destroy-method="clear" activation="eager">
            <argument ref="length"/>
    </bean>
</blueprint>
```

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/
    default-lazy-init="true">

    <bean id="object" class="java.lang.Object"/>

    <bean id="length" class="java.lang.Integer">
        <constructor-arg value="4"/>
    </bean>

    <bean id="buffer" class="java.lang.StringBuffer" depends-on="simple">
            <property name="length" ref="length"/>
    </bean>

    <bean id="current-time" class="java.lang.System" factory-method="currentTimeMillis" scope="prototype"/>

    <bean id="list" class="java.util.ArrayList" destroy-method="clear" lazy-init="false">
            <constructor-arg ref="length"/>
    </bean>
</beans>
```

As mentioned before, in Spring DM one can mix and match the namespaces:

```
<beans xmlns="http://www.springframework.org/schema/beans"
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xmlns:bp="http://www.osgi.org/xmlns/blueprint/v1.0.0"
        xmlns:p="http://www.springframework.org/schema/p"
        xmlns:osgi="http://www.springframework.org/schema/osgi"
        xmlns:task="http://www.springframework.org/schema/task"
        xmlns:util="http://www.springframework.org/schema/util"
        xsi:schemaLocation="
                http://www.osgi.org/xmlns/blueprint/v1.0.0 http://www.osgi.org/xmlns/blueprint/v1.0.0/blueprint.
                http://www.springframework.org/schema/beans http://www.springframework.org/schema/beans/spring-b
                http://www.springframework.org/schema/osgi http://www.springframework.org/schema/osgi/spring-osg
                http://www.springframework.org/schema/task http://www.springframework.org/schema/task/spring-tas
                http://www.springframework.org/schema/util http://www.springframework.org/schema/util/spring-uti

    <util:constant id="thread-priority" static-field="java.lang.Thread.MIN_PRIORITY"/>

    <bean id="exampleThread" class="java.lang.Thread" p:priority-ref="thread-priority">
            <constructor-arg>
               <bp:bean class="org.example.SomeRunnable"/>
            </constructor-arg>
    </bean>

    <task:executor id="rangeWithBoundedQueue" size="7-42" queue-capacity="#{ T(java.lang.Math).random() * 30.0 }

    <bp:reference-list id="cloneableServices" interface="java.lang.Cloneable" />
<beans>
```

The example above, uses the Spring `beans`, `util`, `p`, Spring Expression Language (SpEL) and the `task` namespace introduced in Spring 3.x, and Spring DM namespace.

5.2.2. Container Capabilities

From a container perspective, the Blueprint spec standardizes the a subset of the Spring container. A high-level view comparison, by no means comprehensive, is summarized in the table below:

Table 5.2. Container Capabilities Differences

Feature	**Spring DM**	**Blueprint**
Object Instantiation		
Constructor Instantiation	Y	Y
Static Factory Instantiation	Y	Y
Instance Factory Instantiation	Y	Y
Dependency Injection		
Constructor Injection	Y	Y
Setter Injection	Y	Y
Field Injection	Y	N
Method Injection	Y	N
Arbitrary Method Injection	Y	N
Autowiring	Y	N
Component Lifecycle		
Lazy Initialization	Y	Y
Bean Scopes	Y	Y
Custom Bean Scopes	Y	N
Built-in Callbacks	Y	N
Custom Callbacks	Y	Y
Initialization Processing	Y	N

As with the XML configuration, since Spring DM translates the Blueprint configuration into Spring metadata, one can rely on Spring for features beyond the Blueprint container. For example, one can configure a bean using Blueprint and use annotation on the same instance, for field injection. The same object can implement Spring's `Aware` interfaces or rely on other post processors for certain behaviour.

Note that additional information on Blueprint is available through out the documentation. These being said, it is highly recommended to read and use the Blueprint specification as guidance, if the Blueprint Container becomes the programming model of choice.

5.3. Using Blueprint

There are no extra jars or steps that need to be executed to *enable* the Blueprint functionality in Spring DM. This is built directly into the core, in fact the Blueprint APIs are exported by the Spring DM core. Please see the next section for information on how to install Spring DM and the OSGi compendium spec (section 121) for Blueprint related information such as bootstrapping and configuration locations. For those in a hurry, simply install and start the Spring DM jars (io, core, extender) and their dependencies (namely Spring and slf4j) and you should be all set: Spring DM will automatically detect the running environment and the types of bundles started.

Chapter 6. Bundles and Application Contexts

The unit of deployment (and modularity) in OSGi is the *bundle* (see section 3.2 of the OSGi Service Platform Core Specification). A bundle known to the OSGi runtime is in one of three steady states: installed, resolved, or active. Bundles may export services (objects) to the OSGi service registry, and by so doing make these services available for other bundles to discover and to use. Bundles may also export Java packages, enabling other bundles to import the exported types.

In Spring the primary unit of modularity is an *application context*, which contains some number of beans (objects managed by the Spring application context). Application contexts can be configured in a hierarchy such that a child application context can see beans defined in a parent, but not vice-versa. The Spring concepts of exporters and factory beans are used to export references to beans to clients outside of the application context, and to inject references to services that are defined outside of the application context.

There is a natural affinity between an OSGi bundle and a Spring application context. Using Spring Dynamic Modules, an active bundle may contain a Spring application context, responsible for the instantiation, configuration, assembly, and decoration of the objects (beans) within the bundle. Some of these beans may optionally be exported as OSGi services and thus made available to other bundles; beans within the bundle may also be transparently injected with references to OSGi services.

This chapter describes the lifecycle relationship between bundles and their application contexts, as imposed by Spring DM based on the events occurring at runtime, inside an OSGi environment.

6.1. The Spring Dynamic Modules Extender Bundle

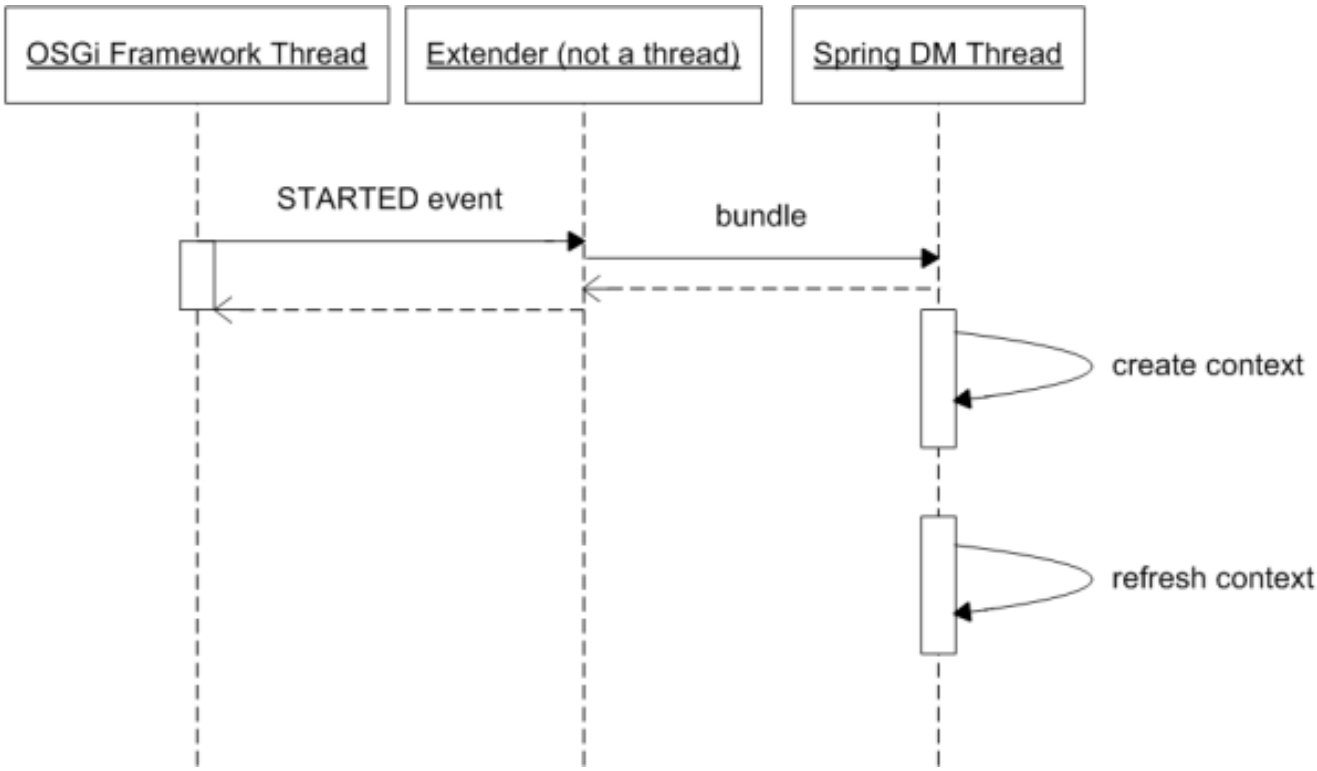
> **Extender Pattern**
>
> A common pattern in OSGi applications is the *extender*, that (quoting Peter Kriens, OSGi Technical Director), “allows other bundles to extend the functionality in a specific domain”. See this OSGi Alliance blog entry for an in-depth explanation.

The component responsible for detecting the *Spring-powered bundles* and instantiating their application context is the Spring DM *extender*. It serves the same purpose as the ContextLoaderListener does for Spring web applications. Once the extender bundle is installed and started it looks for any existing Spring-powered bundles that are already in the *ACTIVE* state and creates application contexts on their behalf. In addition, it listens for bundle starting events and automatically creates an application context for any Spring-powered bundle that is subsequently started. Section 7.1, “Bundle Format And Manifest Headers” describes what the extender recognizes as a "Spring-powered bundle" while Section 7.3, “Extender Configuration Options” how the extender can be configured. The extender monitors the lifecycle of the bundle it manages and will destroy automatically the contexts for bundles that are stopped. When the extender bundle itself is stopped, it will automatically close all the contexts that it manages, based on the service dependency between them. The extender bundle symbolic name is `org.springframework.osgi.extender`.

6.2. Application Context Creation

Once started, the extender analyses the existing started bundles and monitors any new bundle that will start. Once a Blueprint or Spring-DM configuration is detected, the extender will create an application context for it in an asynchronous manner, on a different thread then the one starting the bundle (or delivering the STARTED

event). This behaviour follows the OSGi specification recommendation and ensures that starting an OSGi Service Platform is fast and that bundles with service inter-dependencies do not cause deadlock (waiting for each other) on startup, as pictured below:



The extender considers only bundles successfully started, that is, bundles in *ACTIVE* state; bundles in other states are ignored. Therefore a Spring-powered/Blueprint bundle will have its application context created *after* it has been fully started. It is possible to force synchronous/serialized creation of application contexts for started bundles, on a bundle-by-bundle basis. See Section 7.1, “Bundle Format And Manifest Headers” for information on how to specify this behaviour.

If application context creation fails for any reason then the failure cause is logged. The bundle remains in the ACTIVE state; the application context lifecycle will not influence the bundle lifecycle in anyway. Naturally, since the context has failed, so will the functionality associated with it; for example there will be no services exported to the registry from the application context in this scenario.

6.2.1. Mandatory Service Dependencies

If an application context declares mandatory availability for certain imported OSGi services, the creation of the application context is blocked until all the mandatory dependencies can be satisfied through matching services available in the OSGi service registry. In practice, for most enterprise applications built using Spring Dynamic Modules services, the set of available services and bundles will reach a steady state once the platform and its installed bundles are all started. In such a world, the behaviour of waiting for mandatory dependencies simply ensures that bundles A and B, where bundle A depends on services exported by bundle B, may be started in any order.

A timeout applies to the wait for mandatory dependencies to be satisfied. By default the timeout is set to 5 minutes, but this value can be configured using the `timeout` directive. See Section 7.1, “Bundle Format And Manifest Headers” for details.

Blueprint users could achieve the same result through the `blueprint.timeout` attribute declared on the `Bundle-SymbolicName`

It is possible to change the application context creation semantics so that application context creation fails if all mandatory services are not immediately available upon startup (see the aforementioned section for more information). Again, note that regardless of the configuration chosen, the failure of the application context will not change the bundle state.

For more information on the *availability* of imported services, see Section 8.2.1, “Imported Service Availability”

6.2.2. Application Context Service Publication

Once the application context creation for a bundle has completed, the application context object is automatically exported as a service available through the OSGi Service Registry. The context is published under the interface `org.springframework.context.ApplicationContext` (and also all of the visible super-interfaces and types implemented by the context). The published service has a service property named `org.springframework.context.service.name` whose value is set to the bundle symbolic name of the bundle hosting the application context. In case of a Blueprint bundle, the container will be published under `org.osgi.service.blueprint.container.BlueprintContainer` while the bundle symbolic name will be published under `osgi.blueprint.container.symbolicname` property.

It is possible to prevent publication of the application context as a service using a directive in the bundle's manifest. See Section 7.1, “Bundle Format And Manifest Headers” for details.

Note: the application context is published as a service primarily to facilitate testing, administration, and management. Accessing this context object at runtime and invoking `getBean()` or similar operations is discouraged. The preferred way to access a bean defined in another application context is to export that bean as an OSGi service from the defining context, and then to import a reference to that service in the context that needs access to the service. Going via the service registry in this way ensures that a bean only sees services with compatible versions of service types, and that OSGi platform dynamics are respected.

6.3. Bundle Lifecycle

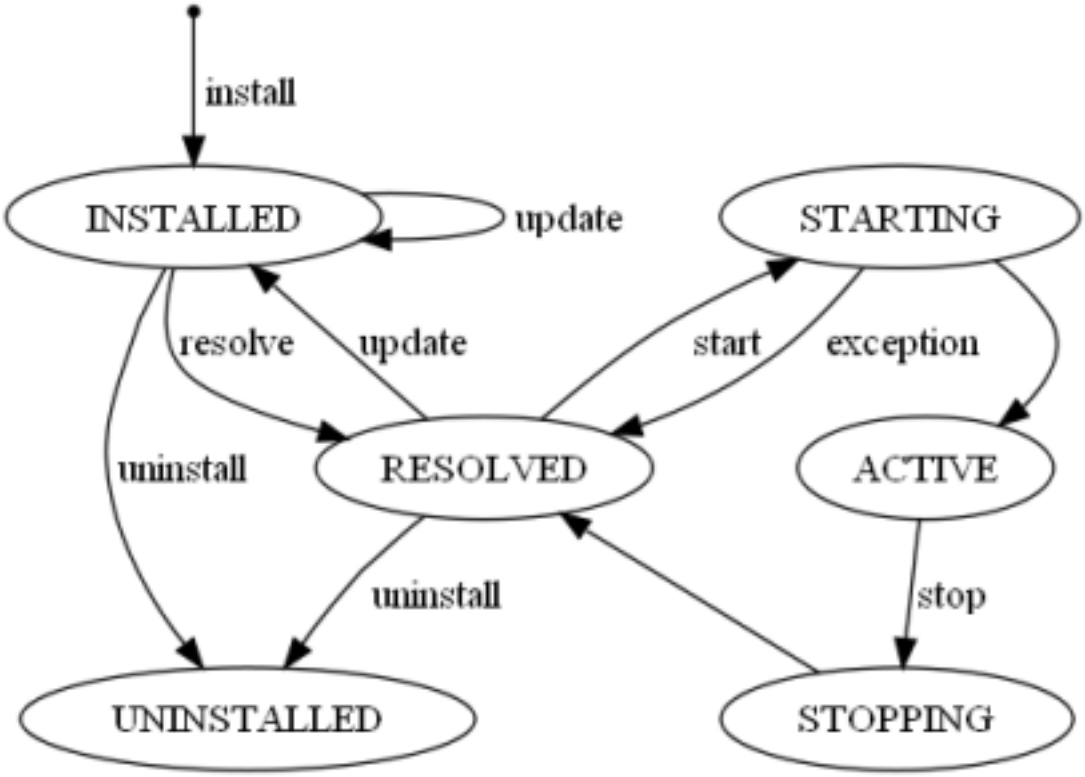
OSGi is a dynamic platform: bundles may be installed, started, updated, stopped, and uninstalled at any time during the running of the framework.

When an active bundle is stopped, any services it exported during its lifetime are automatically unregistered and the bundle returns to the resolved state. A stopped bundle should release any resources it has acquired and terminate any threads. Packages exported by a stopped bundle continue to be available to other bundles.

A bundle in the resolved state may be uninstalled: packages that were exported by an uninstalled bundle continue to be available to bundles that imported them (but not to newly installed bundles).A bundle in the resolved state may also be updated. The update process migrates from one version of a bundle to another version of the same bundle.

Finally of course, a resolved bundle can be started, which transitions it to the active state.

The diagram below represents the bundle states and its transitions:



The OSGi `PackageAdmin` `refreshPackages` operation refreshes packages across the whole OSGi framework or a given subset of installed bundles. During the refresh, an application context in an affected bundle will be stopped and restarted. After a `refreshPackages` operation, packages exported by older versions of updated bundles, or packages exported by uninstalled bundles, are no longer available. Consult the OSGi specifications for full details.

When a Spring-powered or Blueprint bundle is stopped, the application context created for it is automatically destroyed. All services exported by the bundle will be unregistered (removed from the service registry) and the normal application context tear-down life-cycle is observed (`org.springframework.beans.factory.DisposableBean` implementors and `destroy-method` callbacks are invoked on beans in the context).

If a Spring-powered bundle that has been stopped is subsequently re-started, a new application context will be created for it.

6.4. The Resource Abstraction

The Spring Framework defines a resource abstraction for loading resources within an application context (see Spring's resource abstraction). All resource loading is done through the `org.springframework.core.io.ResourceLoader` associated with the application context. The `org.springframework.core.io.ResourceLoader` is also available to beans wishing to load resources programmatically. Resource paths with explicit prefixes - such as `classpath:` - are treated uniformly across all application context types (for example, web application contexts and classpath-based application contexts). Relative resource paths are interpreted differently based on the type of application context being created. This enables easy integration testing outside the ultimate deployment environment.

OSGi 4.0.x specification defines three different spaces from which a resource can be loaded. Spring DM supports all of them through its dedicated OSGi-specific application context and dedicated prefixes:

Table 6.1. OSGi resource search strategies

OSGi Search Strategy	Prefix	Explanation
Class Space	`classpath:`	Searches the bundle classloader (the bundle, all imported packages and required bundles). Forces the bundle to be resolved. This method has similar semantics to `Bundle#getResource(String)`
Class Space	`classpath*:`	Searches the bundle classloader (the bundle and all imported packages and required bundles). Forces the bundle to be resolved. This method has similar semantics to `Bundle#getResources(String)`
JAR File (or JarSpace)	`osgibundlejar:`	Searches only the bundle jar. Provides low-level access without requiring the bundle to be resolved.
Bundle Space	`osgibundle:`	Searches the bundle jar and its attached fragments (if there are any). Does not create a class loader or force the bundle to be resolved.

Please consult section 4.3.12 of the OSGi specification for an in depth explanation of the differences between them.

Note

If no prefix is specified, the bundle space (`osgibundle:`) will be used.

Note

Due to the OSGi dynamic nature, a bundle classpath can change during its life time (for example when dynamic imports are used). This might cause different classpath `Resources` to be returned when doing pattern matching based on the running environment or target platform.

All of the regular Spring resource prefixes such as `file:` and `http:` are also supported, as are the pattern matching wildcards. Resources loaded using such prefixes may come from any location, they are not restricted to being defined within the resource-loading bundle or its attached fragments.

OSGi platforms may define their own unique prefixes for accessing bundle contents. For example, Equinox defines the `bundleresource:` and `bundlentry:` prefixes. These platform specific prefixes may also be used with Spring OSGi, at the cost, of course, of tying yourself to a particular OSGi implementation.

6.5. Bundle Scope

Spring Dynamic Modules introduces a new bean scope named `bundle`. This scope is relevant for beans

exported as an OSGi service and can be described as *one instance per bundle*. Beans exported as OSGi service, that have `bundle` scope, will result in a different instance created for each unique bundle that imports the service through the OSGi service registry. Consumers of the same bundle (whether defined through Spring DM or not) will see the same bean instance. When a bundle has stopped importing the bundle (for whatever reason), the bean instance is disposed. To the declaring bundle, a `bundle`-scoped bean behaves just like a singleton (i.e. there is only one instance per bundle, including the declaring one).This contract lifecycle is similar to that of the `org.osgi.framework.ServiceFactory` interface.

For more information regarding service publication and consumption, see Chapter 8, *The Service Registry*.

Important

The bundle scope is relevant, only if the declaring bean is consumed through the OSGi service registry. That is, instances are created and destroyed (tracked) only when the bean exported as a service, is requested or released as an OSGi service by other bundles.

6.6. Accessing the BundleContext

In general there is no need to depend on any OSGi APIs when using the Spring Dynamic Modules support. If you *do* need access to the OSGi `BundleContext` object for your bundle, then Spring makes this easy to do.

The OSGi application context created by the Spring extender will automatically contain a bean of type `BundleContext` and with name `bundleContext`. You can inject a reference to this bean into any bean in the application context either by-name or by-type. In addition, Spring Dynamic Modules defines the interface `org.springframework.osgi.context.BundleContextAware`:

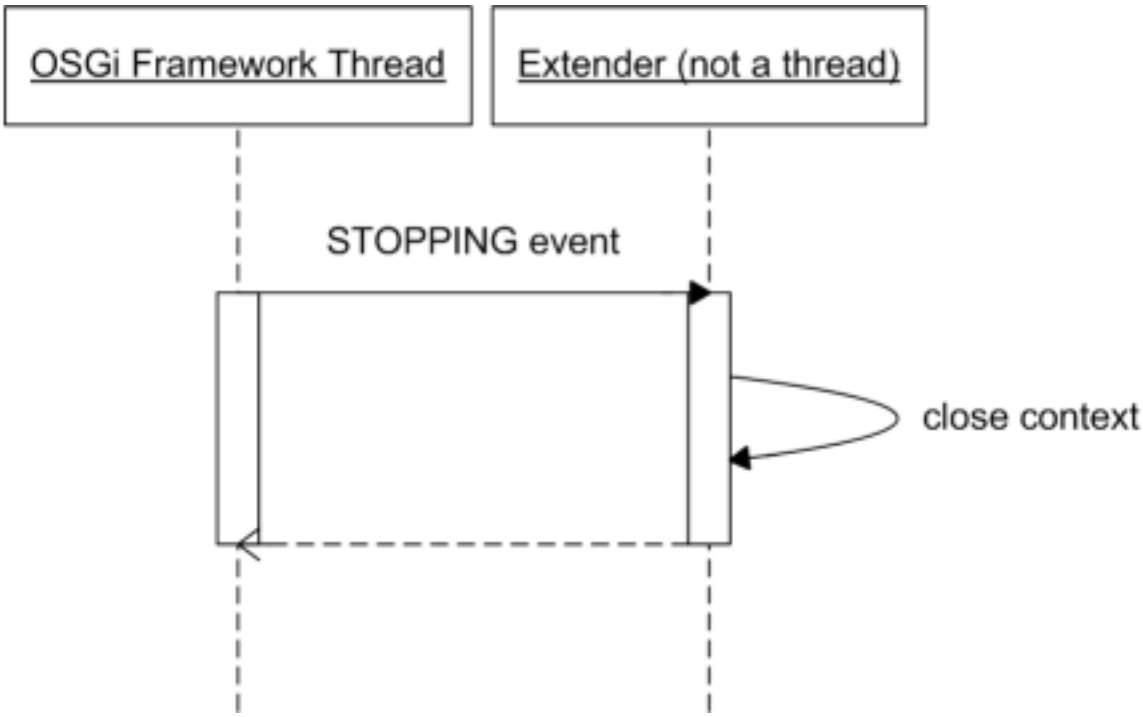
```
public interface BundleContextAware {
  public void setBundleContext(BundleContext context);
}
```

Any bean implementing this interface will be injected with a reference to the bundle context when it is configured by Spring. If you wish to use this facility within a bundle, remember to import the package `org.springframework.osgi.context` in your bundle manifest since otherwise the interface will not be visible to your bundle.

6.7. Application Context Destruction

The application context is bound to the bundle in which it lives. Thus, if the declaring bundle is being shutdown (for whatever reasons), the application context will be destroyed as well, all exported services being unregistered and all service imported dispose of.

As opposed to the application creation, the application context is destroyed in a synchronized manner, on the same thread that stops the bundle. This is required since once stopped, a bundle can not longer be used (even for class loading) preventing the application context shutdown from executing correctly.



Note that a bundle can be closed individually or as part of a bigger event such as shutting down the entire OSGi platform. In this case or when the extender bundle is being closed down, the application contexts will be closed in a managed manner, based on the service dependencies between them. Please see the next section for more details.

6.8. Stopping the Extender Bundle

> **Shutdown algorithm change in 2.x**
>
> The shutdown algorithm implementation in Spring DM 2.0 has been revised to be better aligned with the Blueprint Container spec. Namely, the previous implementation performed ordering in only one pass while the latter performs multiple steps to accommodate the service changes in the OSGi space. Users should not discover any differences at runtime however, if that's not the case, please let us know.

If the extender bundle is stopped, then all the application contexts created by the extender will be destroyed. The algorithm described here is identical to that used by the Blueprint specification (section 121.3.11). Application contexts are shutdown in the following order:

1. Application contexts that do not export any services, or that export services that are not currently referenced, are shutdown in reverse order of bundle id. (Most recently installed bundles have their application contexts shutdown first).

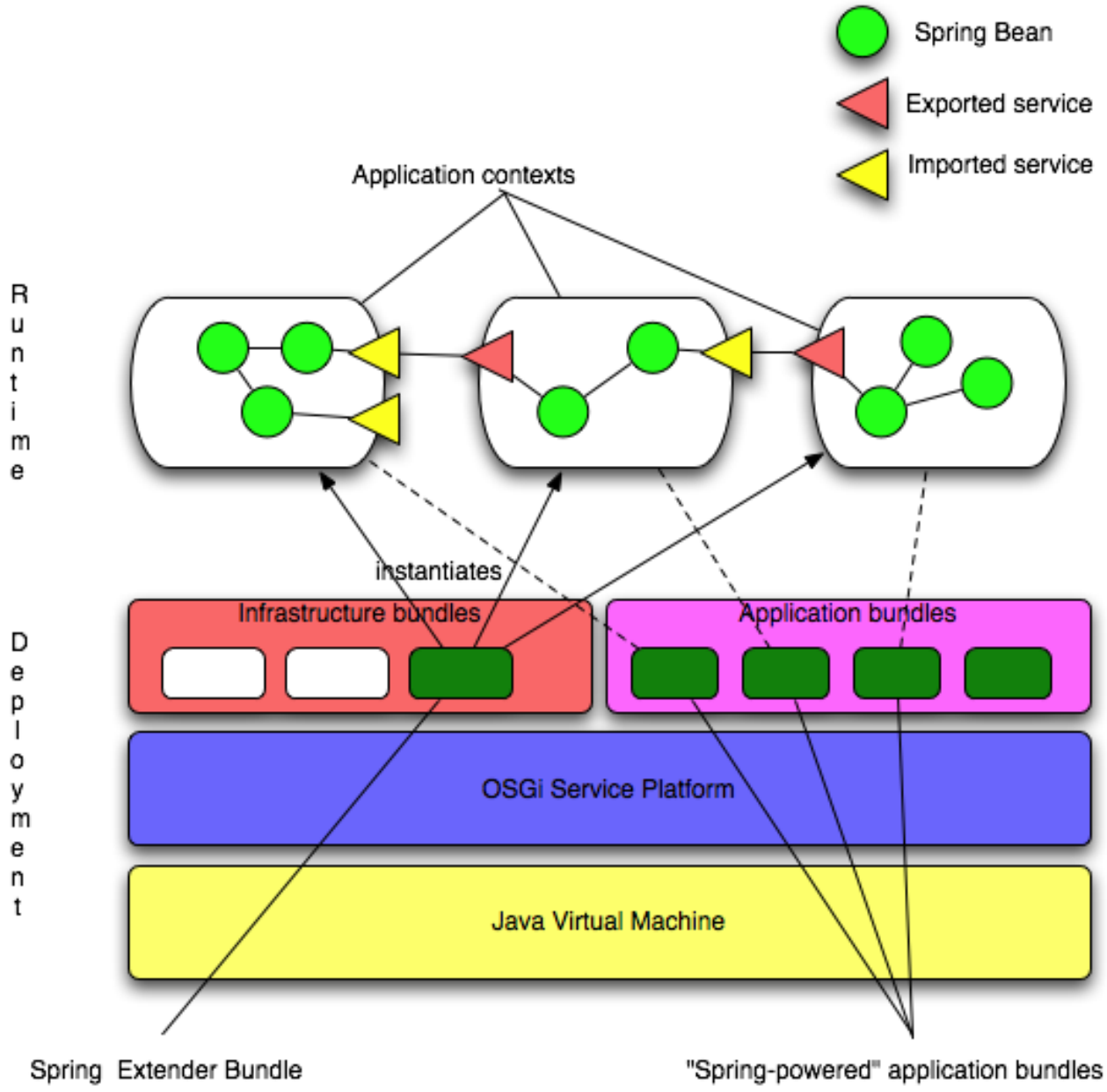
2. Shutting down the application contexts in step 1 may have released references these contexts were holding such that there are now additional application contexts that can be shutdown. If so, repeat step 1 again.

3. If there are no more active application contexts, we have finished. If there *are* active application contexts then there must be a cyclic dependency of references. The circle is broken by determining the highest ranking service exported by each context: the bundle with the lowest ranking service in this set (or in the event of a tie, the highest service id), is shut down. Repeat from step 1.

Chapter 7. Packaging and Deploying Spring-based OSGi applications

A traditional Spring application uses either a single application context, or a parent context containing service layer, data layer, and domain objects with a child context containing web layer components. The application context may well be formed by aggregating the contents of multiple configuration files.

When deploying an application to OSGi the more natural structure is to package the application as a set of peer bundles (application contexts) interacting via the OSGi service registry. Independent subsystems should be packaged as independent bundles or sets of bundles (vertical partitioning). A subsystem may be package in a single bundle, or divided into several bundles partitioned by layer (horizontal partitioning). A straightforward web application may for example be divided into four modules (bundles): a web bundle, service layer bundle, data layer bundle, and domain model bundle. Such an application would look like this:



In this example the data layer bundle yields a data layer application context that contains a number of internal components (beans). Two of those beans are made publicly available outside of the application context by

publishing them as services in the OSGi service registry.

The service layer bundle yields a service layer application context that contains a number of internal components (beans). Some of those components depend on data layer services, and import those services from the OSGi service registry. Two of the service layer components are made externally available as services in the OSGi service registry.

The web component bundle yields a web application context that contains a number of internal components (beans). Some of those components depend on application services, and import those services from the OSGi service registry. Since the domain model bundle contributes only domain model types, but does not need to create any components of its own, it has no associated application context.

7.1. Bundle Format And Manifest Headers

Each application module should be packaged as an OSGi bundle. A bundle is essentially a jar file with a `META-INF/MANIFEST.MF` file containing a series of headers recognized by the OSGi Service Platform. See the OSGi Service Platform Core Specification section 3.2 for details. Some OSGi implementations may support exploded jar files, but the format remains the same.

The Spring extender recognizes a bundle as "Spring-powered" and will create an associated application context when the bundle is started and one or both of the following conditions is true:

- The bundle path contains a folder `META-INF/spring` with one or more files in that folder with a '.xml' extension.
- `META-INF/MANIFEST.MF` contains a manifest header `Spring-Context`.

In addition, if the optional `SpringExtender-Version` header is declared in the bundle manifest, then the extender will only recognize bundles where the specified version constraints are satisfied by the version of the extender bundle (`Bundle-Version`). The value of the `SpringExtender-Version` header must follow the syntax for a version range as specified in section 3.2.5 of the OSGi Service Platform Core Specification.

In the absence of the `Spring-Context` header the extender expects every ".xml" file in the `META-INF/spring` folder to be a valid Spring configuration file, and all directives (see below) take on their default values.

Tip

An application context is constructed from this set of files. A suggested practice is to split the application context configuration into at least two files, named by convention *modulename*-context.xml and *modulename*-osgi-context.xml. The *modulename*-context.xml file contains regular bean definitions independent of any knowledge of OSGi. The *modulename*-osgi-context.xml file contains the bean definitions for importing and exporting OSGi services. It may (but is not required to) use the Spring Dynamic Modules OSGi schema as the top-level namespace instead of the Spring 'beans' namespace.

The `Spring-Context` manifest header may be used to specify an alternate set of configuration files. The resource paths are treated as relative resource paths and resolve to entries defined in the bundle and the set of attached fragments. When the `Spring-Context` header defines at least one configuration file location, any files in `META-INF/spring` are ignored unless directly referenced from the `Spring-Context` header.

The syntax for the `Spring-Context` header value is:

```
Spring-Context-Value ::= context ( ',' context ) *
context ::= path ( ';' path ) * (';' directive) *
```

This syntax is consistent with the OSGi Service Platform common header syntax defined in section 3.2.3 of the OSGi Service Platform Core Specification.

For example, the manifest entry:

```
Spring-Context: config/account-data-context.xml, config/account-security-context.xml
```

will cause an application context to be instantiated using the configuration found in the files `account-data-context.xml` and `account-security-context.xml` in the bundle jar file.

A number of directives are available for use with the `Spring-Context` header. These directives are:

- *create-asynchronously* (false|true): controls whether the application context is created asynchronously (the default), or synchronously.

  For example:

  ```
  Spring-Context: *;create-asynchronously:=false
  ```

  Creates an application context synchronously, using all of the "*.xml" files contained in the `META-INF/spring` folder.

  ```
  Spring-Context: config/account-data-context.xml;create-asynchrously:=false
  ```

  Creates an application context synchronously using the `config/account-data-context.xml` configuration file. Care must be taken when specifying synchronous context creation as the application context will be created on the OSGi event thread, blocking further event delivery until the context is fully initialized. If an error occurs during the synchronous creation of the application context then a `FrameworkEvent.ERROR` event is raised. The bundle will still proceed to the `ACTIVE` state.

- *wait-for-dependencies* (true|false): controls whether or not application context creation should wait for any mandatory service dependencies to be satisfied before proceeding (the default), or proceed immediately without waiting if dependencies are not satisfied upon startup.

  For example:

  ```
  Spring-Context: config/osgi-*.xml;wait-for-dependencies:=false
  ```

  Creates an application context using all the files matching "osgi-*.xml" in the config directory. Context creation will begin immediately even if dependencies are not satisfied. This essentially means that mandatory service references are treated as though they were optional - clients will be injected with a service object that may not be backed by an actual service in the registry initially. See Section 8.2.2.9, “`reference` And OSGi Service Dynamics” for more details.

- *timeout* (300): the time to wait (in seconds) for mandatory dependencies to be satisfied before giving up and failing application context creation. This setting is ignored if `wait-for-dependencies:=false` is specified. The default is 5 minutes (300 seconds).

  For example:

```
Spring-Context: *;timeout:=60
```

Creates an application context that waits up to 1 minute (60 seconds) for its mandatory dependencies to appear.

- *publish-context* (true|false): controls whether or not the application context object itself should be published in the OSGi service registry. The default is to publish the context.

  For example:

```
Spring-Context: *;publish-context:=false
```

If there is no `Spring-Context` manifest entry, or no value is specified for a given directive in that entry, then the directive takes on its default value.

7.2. Blueprint Manifest Configuration Comparison

The table below summarizes the differences between the manifest configuration options in Spring DM and Blueprint Container:

Table 7.1. Configuration Setting Differences

Option	Spring DM	Blueprint
Default Configuration Location	`META-INF/spring`	`OSGI-INF/blueprint`
Custom Locations Header	`Spring-Context`	`Bundle-Blueprint`
Attribute Header	`Spring-Context`	`Bundle-SymbolicName`
Asynchronous Creation Attribute	`create-asynchronously`	-
Startup Mandatory Dependencies Attribute	`wait-for-dependencies`	`blueprint.graceperiod`
Startup Mandatory Timeout Attribute	`timeout` (in s)	`blueprint.timeout` (in ms)
Container API Service Publication Attribute	`publish-context`	-

The manifests below are equivalent in terms of settings:

```
Bundle-SymbolicName: org.example.account.bundle
Spring-Context: config/account-data-context.xml, config/osgi-*.xml;    ❶
 wait-for-dependencies:=true;
 timeout:=10                                                           ❷
```

❶ All Spring DM specific attributes are grouped under `Spring-Context` header.
❷ Timeout specified in *seconds*.

```
Bundle-SymbolicName: org.example.account.bundle;                       ❶
 blueprint.graceperiod:=true;
 blueprint.timeout:=10000                                              ❷
```

```
Blueprint-Bundle: config/account-data-context.xml, config/osgi-*.xml   ❶
```

❶ Blueprint settings are spread between `Bundle-SymbolicName` and `Blueprint-Bundle`.
❷ Timeout specified in *milliseconds*.

7.3. Extender Configuration Options

Aside from bundle-specific configurations, Spring DM allows the core extender generic behaviour be configured. This is useful when embedding Spring DM inside a managed environment or when a bundles-wide functionality is desired. To allow for extensible configuration, the extender relies on OSGi fragments to override its defaults. The extender looks for all XML files under `META-INF/spring/extender` folder in its bundle space and assembled them into an application context (of type `OsgiBundleXmlApplicationContext`) that is used internally as its configuration. To override a default setting of the extender, look up the appropriate bean name from the table below, define it in a suitable manner and then attach it as a fragment to the `spring-osgi-extender.jar`, using:

```
Fragment-Host: org.springframework.osgi.extender
```

The following beans are currently recognized by the extender:

Table 7.2. Extender Configuration Options

Bean Name	Type	Role	Default Behaviour/Value
`taskExecutor`	`TaskExecutor` [a]	Creates and runs the Spring application contexts associated with each bundle. The task executor is responsible for managing its own pool of threads used by the application contexts	`SimpleAsyncTaskExecutor` is used by default which means a new thread will be created for each application contexts. While this is suitable for testing and development, we strongly recommend to use a thread pool in a production environment
`shutdownTaskExecutor`	`TaskExecutor` [b]	Destroys managed Spring application contexts associated with each bundle. The task executor is responsible for managing its own pool of threads used by the application contexts	`TimerTaskExecutor` is used by default which means all application context will be destroyed in a serialized manner (which is desired). Since the shutdown order normally matters, it is recommended to keep the default implementation or, for managed environments, to use a thread-pool that executes only one task at a time (so that contexts are

Bean Name	Type	Role	Default Behaviour/Value
			stopped in the given order).
`extenderProperties`	`java.util.Properties`	Defines simple properties such as the maximum time for contexts to gracefully close	See the defaults below
`osgiApplicationEventMulticaster`	`ApplicationEventMulticaster`[c]	`ApplicationEventMultiCaster` used for propagating Spring DM events to third parties.	An instance of `SimpleApplicationEventMulticaste` is used. See `AbstractApplicationContext` javadoc for more information regarding available beans in an application context.
`applicationContextCreator`	`OsgiApplicationContextCreator`[d]	Allows customization of the application context created by the extender. This includes changing the application context class type or additional processing (see below).	The Extender default behaviour applies.
(irrelevant)	`OsgiBeanFactoryPostProcessor`[d]	Similar to Spring's `BeanFactoryPostProcessor` interface, beans of type `OsgiBeanFactoryPostProcessor` are automatically detected and applied to all contexts created by the extender (whether user-defined or not). This type of post processor is useful as it allows customization of the bean factory such as adding/removing/changing existing bean definitions or adding new bean instances.	The Extender default behaviour applies.
`osgiApplicationContextListener`	`OsgiBundleApplicationContextListener`[e]	Application context event listener registered automatically by the extender.	Default implementation provides logging of the managed application contexts lifecycle.

[a] `org.springframework.core.task`

[b] `org.springframework.core.task`

[c] `org.springframework.context.event`

[d] `org.springframework.osgi.extender package`

[e] `org.springframework.osgi.context.event package`

From the `extenderProperties` bean, the following properties are recognized:

Table 7.3. Available `extenderProperties`

Name	Type	Description	Default Value
`shutdown.wait.time`	`java.lang.Long`	The amount of time the extender will wait for each application context to shutdown gracefully. Expressed in milliseconds.	10000 ms (10 s)
`process.annotations`	`java.lang.Boolean`	Flag indicating whether or not, the extender will process Spring DM annotations. Note that this can be enabled in each process bundle by adding the appropriate bean post processor. See Section A.1, “Annotation-Based Injection” for more information.	false
`dependencies.wait.time`	`java.lang.Long`	The amount of time the newly created application contexts will wait for their mandatory service dependencies during startup. Expressed in milliseconds. This settings is used only if the context owning bundle manifest does *not* define a value.	300000 ms (300 s or 5 min)

Note

Since an application context is used, the full power of the Spring IoC container can be used for creating the extender configuration beans

7.3.1. Listening To Extender Events

There are cases when the failure or succesful startup of an application context needs to be acknowledged for logging purposes (for example). For these cases, Spring DM offers a dedicated package `org.springframework.osgi.context.event` which defines the events that OSGi application contexts can send during their lifecycle. At the moment, the following events are available:

Table 7.4. Spring DM build-in events

Event	Explanation
`OsgiBundleContextRefreshedEvent`	Published when an OSGi application context has been succesfully initialized or refreshed (e.g. using the `refresh()` method on the `ConfigurableApplicationContext` interface). There are no guarantees on how many times this event might be received during the lifecycle of an application context - this is left up to the used implementation.
`OsgiBundleContextFailedEvent`	Published when an OSGi application context is closed due to a failure. This event can appear any time during the lifecycle of an application context - before, during or after refresh. Usually the cause indicates an error in the configuration - syntax typo, incorrect wiring, missing bean and so forth.
`OsgiBundleContextClosedEvent`	Published when an OSGi application context is closed after a successful refresh (normally issued a Spring bundle is being stopped).

Parties interested in receiving these events should implement `OsgiBundleApplicationContextListener` and then publish it as an OSGi service. The Spring DM extender will automatically detect the listener and will send the events to it. By taking advantage of the OSGi service registry, the extender decouples the received from the event publisher and moreover, makes the registration/unregistration process easier. For example, there is nothing special a client should do to unregister the listener - simply stopping the bundle will automatically unregister all its published services (including the listener), an event which will detected by the extender which will remove the listener. Of course, it is also possible for the client to unregister the listener manually during a bundle lifecycle.

Note

The Spring DM events semantics are slightly different then Spring's. The OSGi events are not sent to beans inside the *causing* application context but to other parties (possible beans in other application contexts) interested in monitoring its behaviour.

7.4. Required Spring Framework And Spring Dynamic Modules Bundles

The Spring Dynamic Modules project provides a number of bundle artifacts that must be installed in your OSGi platform in order for the Spring extender to function correctly:

- The extender bundle itself, `org.springframework.osgi.extender`
- The core implementation bundle for the Spring Dynamic Modules support, `org.springframework.osgi.core`
- The Spring Dynamic Modules I/O support library bundle, `org.springframework.osgi.io`

In addition, the Spring Framework provides a number of bundles that are required to be installed as

dependencies. As of release 2.5 of the Spring Framework, the Spring jars included in the Spring distribution are valid OSGi bundles and can be installed directly into an OSGi platform. The minimum required set of bundles is:

- org.springframework.aop.jar (bundle symbolic name `org.springframework.aop`)
- org.springframework.asm.jar (bundle symbolic name `org.springframework.asm`)
- org.springframework.beans.jar (bundle symbolic name `org.springframework.beans`)
- org.springframework.core.jar (bundle symbolic name `org.springframework.core`)
- org.springframework.context.jar (bundle symbolic name `org.springframework.context`)
- org.springframework.expression.jar (bundle symbolic name `org.springframework.expression`)

In additional the following supporting library bundles are required. OSGi-ready versions of these libraries are shipped with the Spring Dynamic Modules distribution.

- aopalliance
- cglib-nodep (when proxying classes rather then interfaces, needed in most cases)
- commons-logging API (SLF4J version *highly* recommended:
  - SLF4J API (com.springsource.sfl4j.api.jar)
  - SLF4J Implementation Bridge (such as Log4j - com.springsource.sfl4j.log4j.jar)
  - SLF4J commons logging adapter (com.springsource.sfl4j.org.apache.commons.logging.jar)
- logging implementation suitable for commons-logging (such as log4j)

7.5. Spring XML Authoring Support

Spring 2.0 introduced (among other things) easier XML configuration and extensible XML authoring. The latter gives the ability of creating custom schemas that are discovered automatically (in non-OSGi environment) by the Spring XML infrastructure by including them in the classpath. Spring DM is aware of this process and supports it in OSGi environments so that custom schemas are available to bundles that use them without any extra code or manifest declaration.

All bundles deployed in the OSGi space (whether they are `Spring-powered` or not) are scanned by Spring DM for custom Spring namespace declaration (by checking the bundle space for`META-INF/spring.handlers` and `META-INF/spring.schemas`). If these are found, Spring DM will make the schemas and the namespaces available through an OSGi service that will be automatically used by Spring-powered bundles. This mean that if you deploy a bundle that uses a custom schema, all you have to do is deploy the library that provides the namespace parser and the schema. Bundles that embedded inside their classpath libraries that provide custom schemas will use these over those available in the OSGi space. However, the namespaces of the embedded libraries will not shared with other bundles, that is, they will not be seen by any other bundle.

In short, when using Spring DM, custom Spring namespaces are supported transparently without any additional work. Embedded namespace providers will have priority but will not be shared, as opposed to providers deployed as bundles which will be seen (and used) by others.

7.6. Importing and Exporting Packages

Refer to the OSGi Service Platform for details of the `Import-Package` and `Export-Package` manifest headers. Your bundle will need an `Import-Package` entry for every external package that the bundle depends on. If your bundle provides types that other bundles need access to, you will need `Export-Package` entries for every package that should be available from outside of the bundle.

Important

Both `Export` and `Import-Package` have a crucial role in defining a bundle class space. If used incorrectly, the bundle might not be able to load certain classes or resources, load incorrect versions or even load multiple versions at the same time which usually result in `ClassCastException`, `NoClassDefFoundError` or `LinkageError`. We strongly recommend that you get familiar with the basics and, at least for starters, use tools (such as Bundlor or BND) for creating proper OSGi manifests.

7.7. Considerations When Using External Libraries

What is the context class loader?

The thread context class loader was introduced in J2SE without much fanfare. Below is a short definition for it, quoted from one of the tutorials available on Java site:

The Java 2 platform also introduced the notion of *context class loader*. A thread's context class loader is, by default, set to the context class loader of the thread's parent. The hierarchy of threads is rooted at the primordial thread (the one that runs the program). The context class loader of the primordial thread is set to the class loader that loaded the application. So unless you explicitly change the thread's context class loader, its context class loader will be the application's class loader. That is, the context class loader can load the classes that the application can load. This loader is used by the Java runtime such as the RMI (Java Remote Method Invocation) to load classes and resources on behalf of the user application. The context class loader, like any Java 2 platform class loader, has a parent class loader and supports the same delegation model for class loading described previously.

Many enterprise application libraries assume that all of the types and resources that comprise the application are accessible through the context class loader. While most developers do not use the context class loader, the loader is used heavily by application servers, containers or applications that are multi-threaded.

In OSGi R4, the set of types and resources available through the context class loader is undefined. This means that the OSGi platform does not make a guarantee of the thread context class loader value or in other words, it does not manage it.

Thus code (for example libraries) that performs manual class loading or that generates new classes dynamically can cause problems when executed inside an OSGi environment.

Spring Dynamic Modules guarantees that during the creation of an application context on behalf of a given bundle, all of the types and resources on the bundle's classpath are accessible via the context class loader. Spring Dynamic Modules also allows you to control what is accessible through the context class loader when invoking external services and when servicing requests on exported services. See Chapter 8, *The Service Registry* for details on this.

Work is underway in the OSGi R5 timeframe to provide standardized support for dealing with generated classes and implicit class path dependencies introduced by third-party libraries. In the interim you may need to rely on workarounds such as the `DynamicImport-Package` manifest header, or the facilities provided by specific OSGi implementations such as Equinox's buddy mechanism. The Spring Dynamic Modules documentation contains more details on known issues with common enterprise libraries and the workarounds.

7.8. Diagnosing Problems

Your chosen OSGi platform implementation should be able to provide you with a good deal of information about the current status of the OSGi environment. For example, starting Equinox with the `-console` argument provides a command-line console through which you can determine which bundles are installed and their states, the packages and services exported by bundles, find out why a bundle has failed to resolve, and drive bundles through the lifecycle. All the OSGi platform tested, provide their own logging, which can be enabled and customized through dedicated settings. For more information, please refer to OSGi platforms documentation.

In addition, Spring itself and the Spring Dynamic Modules bundles contain extensive logging instrumentation that can help you diagnose problems. The recommended approach is to deploy the Simple Logging Facade for Java (slf4j) slf4j-api.jar and slf4j-log4j13.jar bundles (the jar files distributed by the project are valid OSGi bundles). Then you simply need to create a `log4j.properties` file in the root of your bundle classpath.

Managed, OSGi-aware runtime environments such as dmServer provide additional logging and insight not just for the bundle at hand, but also regarding the application context and the VM among other things.

Note that Spring Dynamic Modules uses commons-logging API internally which means that its logging implementation is fully pluggable. Please see the FAQ and Resources pages for more information on other logging libraries besides log4j.

Chapter 8. The Service Registry

The OSGi service registry enables a bundle to publish objects to a shared registry, advertised via a given set of Java interfaces. Published services also have service properties associated with them in the registry. The registry is a crucial feature of OSGi, facilitating decoupling between bundles by promoting a dynamic collaborative model based on a service-oriented paradigm (publish/find/bind).

Spring Dynamic Modules integrates tightly with the service registry, allowing clients to publish, find and bind services in a POJO-friendly manner, without coupling themselves to the OSGi API.

By using the `osgi` namespace for Spring (see Appendix H, *Spring Dynamic Modules Schema*) one can be indicate what Spring beans to export as OSGi services (and how) and to define the criteria and the manner in which services available in the OSGi registry are imported as beans.

Just like the rest of the namespaces, the `osgi` namespace can be embedded or nested inside another top-level namespace (typically the Spring `beans` namespace) or be made the default namespace.

The following example shows the use of the `osgi` namespace within the familiar Spring beans element:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"                    ❶
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:osgi="http://www.springframework.org/schema/osgi"                    ❷
   xsi:schemaLocation="http://www.springframework.org/schema/beans
       http://www.springframework.org/schema/beans/spring-beans.xsd          ❸
       http://www.springframework.org/schema/osgi
       http://www.springframework.org/schema/osgi/spring-osgi.xsd">

    <osgi:service id="simpleServiceOsgi" ref="simpleService"                  ❹
      interface="org.xyz.MyService" />
</beans>
```

❶ Use Spring Framework `beans` schema as the default namespace.
❷ Import Spring Dynamic Modules schema and associate a prefix with its namespace (`osgi` in this example).
❸ Make sure to import Spring beans schema version *2.5*.
❹ Use Spring Dynamic Modules elements using the declared namespace prefix (in this example `osgi`).

Using the OSGi namespace as a top-level namespace, the same service would be declared as follows:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans:beans                                                                  ❶
   xmlns="http://www.springframework.org/schema/osgi"                         ❷
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:beans="http://www.springframework.org/schema/beans"                  ❸
   xsi:schemaLocation="http://www.springframework.org/schema/osgi
       http://www.springframework.org/schema/osgi/spring-osgi.xsd
       http://www.springframework.org/schema/beans
       http://www.springframework.org/schema/beans/spring-beans.xsd">         ❹

    <service id="simpleServiceOsgi" ref="simpleService"                       ❺
       interface="org.xyz.MyService" />

</beans:beans>                                                                ❶
```

❶ `beans` root element has to be prefixed with Spring Framework beans schema prefix (`beans` in this example).
❷ Use Spring Dynamic Modules schema as the default namespace.
❸ Import Spring Framework `beans` schema and associate a prefix with its namespace (`beans` in this example).

❹ Make sure to import Spring beans schema version *2.5*.
❺ Use Spring Dynamic Modules elements without any prefix.

Using the OSGi namespace as a top-level namespace is particularly convenient when following the configuration recommendation from the previous section, to use a dedicated configuration file for all OSGi-related declarations.

8.1. Exporting A Spring Bean As An OSGi Service

The `service` element is used to define a bean representing an exported OSGi service. There are no requirements for the class or object being exported - practically any bean can be exported. At a minimum you must specify the bean to be exported, and the *service interface* that the service advertises.

Note

The publication *interface* is used by service consumers, to identify the service. A service instance must implement the interface - specifying a non-implemented interface results in an error. The term *interface* is used in an abstract form; in practice any Java interface or class, implemented or extended by the service instance can be specified.

For example, the declaration

```
<service ref="beanToPublish" interface="com.xyz.MessageService"/>
```

exports the bean with name `beanToPublish` with interface `com.xyz.MessageService`. The published service will have a service property with the name `org.springframework.osgi.bean.name` set to the name of the target bean being registered (`beanToPublish` in this case).

As an alternative to exporting a named bean, the bean to be exported to the service registry may be defined as an anonymous inner bean of the service element. Typically the top-level namespace would be the `beans` namespace when using this style:

```
<osgi:service interface="com.xyz.MessageService">
  <bean class="SomeClass">
     ...
  </bean>
</osgi:service>
```

8.1.1. Using The Service Registration

Each `service` declaration, provides control access to the exported service. The declaration returns an element of type `org.osgi.framework.ServiceRegistration` which can be used to read or even modify the properties published for the OSGi service. Since DM 2.X, the definition has been aligned with the Blueprint spec and unregistration of the service is not possible any more (an exception is thrown if the `unregister` is called). Additionally, the returned service registration will track the service being registered (if multiple registration occur, these will be reflected in the returned registration object). See Section 8.2.1.2, “Relationship Between The Service Exporter And Service Importer” for more information on when registration/unregistration of exported services can occur.

To use the service registration, simply inject the service bean definition into the relevant class; the example below shows one way of updating the service properties from Java:

```
<service id="myServiceRegistration" ref="beanToPublish"
     interface="com.xyz.MessageService"/>
```

```
<bean id="propUpdater" class="com.xyz.ServicePropertiesUpdater">
   <property name="serviceRegistration ref="myServiceRegistration"/>
</bean>
```

Where `ServicePropertiesUpdater` can have the following definition:

```
public class ServicePropertiesUpdater implements BeanNameAware {

        private ServiceRegistration serviceRegistration;
        private String beanName;

        public void setServiceRegistration(ServiceRegistration serviceRegistration) {
                this.serviceRegistration = serviceRegistration;
        }

        public void setBeanName(String beanName) {
                this.beanName = beanName;
        }

        public void update() {
                ServiceReference reference = serviceRegistration.getReference();
                // get current properties
                Dictionary dictionary = OsgiServiceReferenceUtils.getServiceProperties(reference);
                dictionary.put("last-update", new Date());
                dictionary.put("updated-by", beanName);
                dictionary.put("user.name", System.getProperties().getProperty("java.version"));
                // update properties
                serviceRegistration.setProperties(dictionary);
        }
}
```

Each time the update() method is called, the service properties are retrived, new ones are added and finally the service registration updated.

8.1.2. `org.osgi.framework.ServiceFactory` Support

OSGi Service Platform Core Specification allows services not just to be registered directly, but also to be created on demand, through the `org.osgi.framework.ServiceFactory` interface (see section 5.6). Spring DM recognizes this OSGi interface and honours its contract, by forwarding each new bundle request, to the backing bean implementing the aforementioned interface.

As an alternative to implementing the OSGi API, one can use the `bundle` scope, introduced by Spring DM which offers a *instance-per-bundle* contract (see Section 6.5, “Bundle Scope” for more information). To declare a bean with `bundle` scope simply use the `scope` attribute of the `bean` element:

```
<osgi:service ref="beanToBeExported" interface="com.xyz.MessageService"/>

<bean id="beanToBeExported" scope="bundle" class="com.xyz.MessageServiceImpl"/>
```

8.1.3. Controlling The Set Of Advertised Service Interfaces For An Exported Service

The OSGi Service Platform Core Specification defines the term *service interface* to represent the specification of a service's public methods. Typically this will be a Java interface, but the specification also supports registering service objects under a class name, so the phrase *service interface* can be interpreted as referring to either an interface or a class.

There are several options for specifying the service interface(s) under which the exported service is registered. The simplest mechanism, shown above, is to use the `interface` attribute to specify a fully-qualified interface

name. To register a service under multiple interfaces the nested `interfaces` element can be used in place of the `interface` attribute.

```
<osgi:service ref="beanToBeExported">
  <osgi:interfaces>
     <value>com.xyz.MessageService</value>
     <value>com.xyz.MarkerInterface</value>
  </osgi:interfaces>
</osgi:service>
```

It is illegal to use both `interface` attribute and `interfaces` element at the same time - use only one of them.

8.1.3.1. Detecting The Advertised Interfaces At Runtime

Hierarchy visibility

Note that when using `auto-export`, only types visible to the bundle exporting the service are registered. For example, a super-interface `SI` would not be exported as a supported service interface even when using `auto-export="interfaces"` if `SI` was not on the exporting bundle's classpath.

Even if exported service class does implement `SI` transitively based on its parent, if the declaring bundle doesn't import the interface, the class is unknown to the exported service. While this might seem counter intuitive, it is actually one of the most powerful features of OSGi which give the bundle authors control over the class visibility and path.

Please see the FAQ for a more detailed explanation.

Using the `auto-export` attribute you can avoid the need to explicitly declare the service interfaces at all by analyzing the object class hierarchy and its interfaces.

The `auto-export` attribute can have one of four values:

- `disabled` : the default value; no auto-detected of service interfaces is undertaken and the `interface` attribute or `interfaces` element must be used instead.
- `interfaces` : the service will be registered using all of the Java interface types implemented by the bean to be exported
- `class-hierarchy` : the service will be registered using the exported bean's implementation type and super-types
- `all-classes` : the service will be registered using the exported bean's implementation type and super-types plus all interfaces implemented by the bean.

`auto-export` and `interface(s)` option are not exclusive; both can be used at the same time for fine grained control over the advertised interfaces if there is such a need. However, the former option should be enough for most cases.

For example, to automatically register a bean under all of the interfaces that it supports you would declare:

```
<service ref="beanToBeExported" auto-export="interfaces"/>
```

Given the interface hierarchy:

```
public interface SuperInterface {}
```

```
public interface SubInterface extends SuperInterface {}
```

then a service registered as supporting the `SubInterface` interface is *not* considered a match in OSGi when a lookup is done for services supporting the `SuperInterface` interface. For this reason it is a best practice to export all interfaces supported by the service being registered explicitly, using either the `interfaces` element or `auto-export="interfaces"`.

8.1.4. Controlling The Set Of Advertised Properties For An Exported Service

As previously described, an exported service is always registered with the service property `org.springframework.osgi.bean.name` set to the name of the bean being exported. Since DM 2.x, the bean name is also published under `osgi.service.blueprint.compname` (introduced by the OSGi 4.2 Blueprint spec). Additional service properties can be specified using the nested `service-properties` element. The `service-properties` element contains key-value pairs to be included in the advertised properties of the service. The key must be a string value, and the value must be a type recognized by OSGi Filters. See section 5.5 of the OSGi Service Platform Core Specification for details of how property values are matched against filter expressions.

The `service-properties` element must contain at least one nested `entry` element from the Spring beans namespace. For example:

```
<service ref="beanToBeExported" interface="com.xyz.MyServiceInterface">
  <service-properties>
    <beans:entry key="myOtherKey" value="aStringValue"/>
    <beans:entry key="aThirdKey" value-ref="beanToExposeAsProperty"/>
  </service-properties>
</service>
```

Non-String values can be specified by enforcing the value type. Consider the publication of an OSGi event consumer (`org.osgi.service.event.EventHandler`) that needs to specify the topics it follows as an array under `event.topics` property. Below are a list of configuration on how this can be achieved:

```
<osgi:service
     id="eventMonitorService"
     ref="someBean"
     interface="org.osgi.service.event.EventHandler">
        <osgi:service-properties value-type="java.lang.String[]">      ❶
            <entry key="event.topics" value="eventQueue"/>
        </osgi:service-properties>
</osgi:service>
```

❶ Specify an array type for *all* the values declared inside the `service-properties` element.

```
<osgi:service
     id="eventMonitorService"
     ref="someBean"
     interface="org.osgi.service.event.EventHandler">
        <osgi:service-properties>
            <entry key="event.topics">
                <value type="java.lang.String[]">eventQueue</value>    ❶
            </entry>
            </osgi:service-properties>
</osgi:service>
```

❶ Indicate the value type just for this particular value.

```
<osgi:service
```

```
    id="eventMonitorService"
    ref="someBean"
    interface="org.osgi.service.event.EventHandler">
       <osgi:service-properties>
           <entry key="event.topics">
               <array value-type="java.lang.String">                ❶
                   <value>eventQueue</value>
               </array>
           </entry>
       </osgi:service-properties>
</osgi:service>
```

❶ Use Spring 3.x `<array>` element to create an nested array on the fly.

The Spring Dynamic Modules roadmap includes support for exporting properties registered in the OSGi Configuration Administration service as properties of the registered service. See Appendix F, *Roadmap* for more details.

8.1.5. The depends-on Attribute

Spring will manage explicit dependencies of a service element, ensuring for example that the bean to be exported as a service is fully constructed and configured before exporting it. If a service has implicit dependencies on other components (including other service elements) that must be fully initialized before the service can be exported, then the optional `depends-on` attribute can be used to express these dependencies.

```
<service ref="beanToBeExported" interface="com.xyz.MyServiceInterface"
    depends-on="myOtherComponent"/>
```

8.1.6. The context-class-loader Attribute

The OSGi Service Platform Core Specification (most current version is 4.x at time of writing) does not specify what types and resources are visible through the context class loader when an operation is invoked on a service obtained via the service registry. Since some services may use libraries that make certain assumptions about the context class loader, Spring Dynamic Modules enables you to explicitly control the context class loader during service execution. This is achieved using the option `context-class-loader` attribute of the service element.

The permissible values for the `context-class-loader` attribute are `unmanaged` (the default) and `service-provider`. When the `service-provider` value is specified, Spring Dynamic Modules ensures that the context class loader can see all of the resources on the class path of the bundle exporting the service.
When setting `context-class-loader` to `service-provider`, the service object will be proxied to handle the class loader. If the service advertises any concrete class then CGLIB library is required .

8.1.7. The `ranking` Attribute

When registering a service with the service registry, you may optionally specify a service ranking (see section 5.2.5 of the OSGi Service Platform Core Specification). When a bundle looks up a service in the service registry, given two or more matching services the one with the highest ranking will be returned. The default ranking value is zero. To explicitly specify a ranking value for the registered service, use the optional `ranking` attribute.

```
<service ref="beanToBeExported" interface="com.xyz.MyServiceInterface"
  ranking="9"/>
```

8.1.8. The `cache-target` Attribute

By default, services exported are being retrieved from the container each time they are requested. This allows *scoped* beans to behave correctly depending on the context available when the request is being performed. However, there are cases when the target bean (the entity being exported) needs to be cached no matter its scope. The Blueprint spec for example requires this behaviour for all exported services.

To accommodate both cases one, Spring DM 2.0 introduces a new attribute, `cache-target` which, as the name suggests, enables the caching of the exported bean. The instance of the bean retrieved, for the first service registration is cached internally by the exporter which will later reuse it.

```
<service ref="beanToBeExported" interface="com.xyz.MyServiceInterface"
  cache-target="true"/>
```

8.1.9. `service` Element Attributes

As a summary, the following table lists the attributes names, possible values and a short description for each of them.

Table 8.1. OSGi <service> attributes

Name	Values		Description
interface	fully qualified class name (such as `java.lang.Thread`)		the fully qualified name of the class under which the object will be exported
ref	any bean name		Reference to the named bean to be exported as a service in the service registry.
context-class-loader	unmanaged	service-provider	Defines how the context class loader will be managed when an operation is invoked on the exported service. The default value is `unmanaged` which means that no management of the context class loader is attempted. A value of `service-provider` guarantees that

Name	Values				Description
					the context class loader will have visibility of all the resources on the class path of bundle exporting the service.
auto-export	disabled	interfaces	class-hierarchy	all-classes	Enables Spring to automatically manage the set of service interfaces advertised for the service. By default this facility is `disabled`. A value of `interfaces` advertises all of the Java interfaces supported by the exported service. A value of `class-hierarchy` advertises all the Java classes in the hierarchy of the exported service. A value of `all-classes` advertises all Java interfaces and classes.
ranking	any integer value				Specify the service ranking to be used when advertising the service. Default value is 0.
cache-target	true		false		Specify whether the bean exported as an OSGi service is cached (on first registration) or

Name	Values		Description
			not. Default value is `false`

8.1.10. Service Registration And Unregistration Lifecycle

The service defined by a `service` element is registered with the OSGi service registry when the application context is first created. It will be unregistered automatically when the bundle is stopped and the application context is disposed. Additionally, based on the mandatory service import availability, the service can be unregistered and registered at runtime (see ???).

If you need to take some action when a service is unregistered because its dependencies are not satisfied (or when it is registered), then you can define a listener bean using the nested `registration-listener` element.

The declaration of a registration listener must use either the `ref` attribute to refer to a top-level bean definition, or declare an anonymous listener bean inline. For example:

```
<service ref="beanToBeExported" interface="SomeInterface">
  <registration-listener ref="myListener"                          ❶
    registration-method="serviceRegistered"                        ❷
    unregistration-method="serviceUnregistered"/>                  ❷
  <registration-listener
     registration-method="register">                               ❸
     <bean class="SomeListenerClass"/>                             ❹
  </registration-listener>
</service>
```

❶ Listener declaration referring to a top-level bean declaration.
❷ Indicate the `registration` and `unregistration` methods.
❸ Declare only a `registration` custom method for this listener.
❹ Nested listener bean declaration.

The optional `registration-method` and `unregistration-method` attributes specify the names of the methods defined on the listener bean that are to be invoked during registration and unregistration. A registration and unregistration callback methods must have a signature matching one of the following formats:

```
public void anyMethodName(ServiceType serviceInstance, Map serviceProperties);
```

```
public void anyMethodName(ServiceType serviceInstance, Dictionary serviceProperties);
```

where `ServiceType` can be any type compatible with the exported service interface of the service.

The register callback is invoked when the service is initially registered at startup, and whenever it is subsequently re-registered. The unregister callback is invoked during the service unregistration process, no matter the cause (such as the owning bundle stopping).

Spring DM will use the declared `ServiceType` argument type and invoke the registration/unregistration method only when a service of a compatible type will be registered/unregistered.

`serviceProperties` represents a map holding all the properties of the registered/unregistered service. To preserve compatibility with the OSGi specification this argument can be cast, if needed, to a `java.util.Dictionary`.

8.1.10.1. Using `OsgiServiceRegistrationListener` Interface

While we discourage, it is possible to implement a Spring DM specific interface, namely `org.springframework.osgi.service.exporter.OsgiServiceRegistrationListener` which avoids the need to declare the `registration-method` and `unregistration-method`. However, by implementing `OsgiServiceRegistrationListener`, your code becomes Spring DM aware (which goes against the POJO philosophy).

It is possible for a listener to implement `OsgiServiceRegistrationListener` interface and declare custom methods. In this case, the Spring DM interface methods will be called first, followed by the custom methods.

8.1.10.2. Blueprint `service` Comparison

The Blueprint Container offers a `service` element, identical in functionality with the one in Spring DM. In most cases, the configuration should be identical. Below is a summary of the configuration options available in Spring DM and Blueprint:

Table 8.2. Spring DM / Blueprint `<service>` Configuration Comparison

Spring DM	Blueprint
interface	interface
ref	ref
auto-export	auto-export
ranking	ranking
context-class-loader	-
cache-target	- (caching is always enabled)

Since the `registration-listener` declaration is identical in declaration and functionality between Blueprint and Spring DM, this section does not mention it.

8.2. Defining References To OSGi Services

To use services, clients need to look for them inside the OSGi service registry. If found, the platform returns a reference which can be used to get the actual service instance. Consumers should return the service instance as soon as possible and not hold on to it since the service provider can unpublish the service at any point. Since there is no mechanism in Java to force such cleanup, the OSGi specification uses the service references and the aforementioned *protocol* to decouple service providers from service consumers. Please see chapter 5, the Service Layer inside the OSGi Core spec for an in-depth discussion.

Spring Dynamic Modules facilitates the consumption of OSGi services by taking care of not just of the retrieval of service references and instances but also considering the service dynamics. With Spring DM, imported OSGi services become Spring beans which can be injected, as usual, into other application components. The service lookup is made using the service interface type that the service is required to support, plus an optional filter expression that matches against the service properties published in the registry. The service instance retrieval is done on demand, on the first request. Once the service becomes unavailable, Spring DM automatically unregisters the service to avoid using *stale* references.

As a consumer, one can find zero, one or multiple services matching the desired description. In most scenarios, a single matching service is all that is needed; for those the `reference` element defines a reference to a single service that meets the required specification. In other cases, especially when using the OSGi whiteboard pattern, references to *all available* matching services are required. Spring Dynamic Modules supports the management of this group of references as either a `List` or a `Set` collection.

8.2.1. Imported Service Availability

> **What happened to `cardinality`?**
>
> Since Spring DM 2.x, the `cardinality` notion has been deprecated in favour of `availability`. The main reasons behind it were aligning the terminology with the Blueprint spec and eliminating the repetition of specifying the number of imported services: as `osgi` elements already specify whether one or multiple services are imported, the `cardinality` right side (`..N/..1`) was redundant.

Due to the dynamic nature of OSGi, services can come and go, be available or unavailable at certain points in time. Depending on the type of service, this can have a negative impact on the consumers. Spring DM alleviates this problem by introducing the notion of `availability` (formerly known as `cardinality`) which indicates whether an imported service is `mandatory` or `optional`.

As the name implies, a `mandatory` service implies a crucial application dependency: the service is *required* and its presence can heavily impact the application, in a negative way.

An `optional` service means just the opposite. The service is tracked and bound (if present), just like a `mandatory` reference, but its presence is not required. It is fine, from an application perspective if the service is not available - its existence (or lack of) does not impact the application functionality.

As an example, an application could have a `mandatory` dependency on a `DataSource` and an `optional` one for a logging service: the application can run fine if it cannot log (it does not impact the runtime) but it fails if the backing database is not available.

In Spring DM, a `mandatory` service import that is unsatisfied (there are no services matching the description) can either prevent an application context from starting up or, if already started, cause the unregistration of the exported services dependent on it.

8.2.1.1. Mandatory Services and Application Startup

The availability of a service impacts the startup of an Spring-powered application and the publication of any exported services that depend on it. As mentioned in Section 6.2.1, “Mandatory Service Dependencies”, a SpringDM application will not start unless *all* `mandatory` services are available, at the same time. Before initializing the context, Spring DM discovers all the `mandatory` service declarations and waits for a period of time (5 minutes by default unless otherwise specified by each bundle - see the `timeout` directive in Section 7.1, “Bundle Format And Manifest Headers”) for all imports to be satisfied, at the same time. If the timeout occurs, the application initialization fails (since the required or mandatory services are not available) or succeeds, meaning the application context is being initialized.

This way, the framework prevents the application from starting up only to fail since its required services are unavailable. This feature avoids the need for ordering the bundle startup sequence as the configuration already acts as a service *barrier* blueprint: no matter the order of the services started, on whether they come and go, only when all of them are present, will the context initialization commence.

Note

The fact that an application has mandatory service references, gives no guarantee that a valid service object is available when the service reference is used, since services can get unregistered at any time. Spring DM guarantees that all the mandatory services were present, at the same time, before the application was started but it cannot prevent or guarantee that this services will not be disappear during the application life span.

Warning

It is an error to declare a mandatory reference to a service that is also exported by the same bundle, this behaviour can cause application context creation to fail through either deadlock or timeout.

8.2.1.2. Relationship Between The Service Exporter And Service Importer

An exported service may depend, either directly or indirectly, on other (imported) services in order to perform its function. If one of these services is marked as a *mandatory* dependency and the dependency can no longer be satisfied (because the backing service has gone away and there is no suitable replacement available), then the exported service that depends on it will be automatically unregistered from the service registry - meaning that it is no longer available to clients. If the mandatory dependency becomes satisfied once more (by registration of a suitable service), then the exported service will be re-registered in the service registry.

This automatic publication management ensures that only when the exported service can work reliable, it is made available for potential OSGi clients. This behaviour takes advantage of the OSGi dynamic nature allowing an application to cope with the ongoing changing without being restarted.

This automatic unregistering and re-registering of exported services based on the availability of mandatory dependencies only takes into account declarative dependencies. If exported service `S` depends on bean `A`, which in turn depends on mandatory imported service `M`, and these dependencies are explicit in the Spring configuration file as per the example below, then when `M` becomes unsatisfied `S` will be unregistered. When `M` becomes satisfied again, `S` will be re-registered.

```
<osgi:service id="S" ref="A" interface="SomeInterface"/>

<bean id="A" class="SomeImplementation">
   <property name="helperService" ref="M"/>
</bean>

<!-- the reference element is used to refer to a service
     in the service registry -->
<osgi:reference id="M" interface="HelperService" availability="mandatory"/>
```

If however the dependency from `A` on `M` is not established through configuration as shown above, but instead at runtime through for example passing a reference to `M` to `A` without any involvement from the Spring container, then Spring Dynamic Modules will *not* track this dependency.

8.2.2. Referencing An Individual Service

The `reference` element is used to define a reference to a service in the service registry.

Since there can be multiple service matching a given description, the service returned is the service that would be returned by a call to `BundleContext.getServiceReference`. This means that the service with the highest ranking will be returned, or if there is a tie in ranking, the service with the lowest service id (the service registered first with the framework) is returned (please see Section 5 from the OSGi spec for more information on the service selection algorithm).

8.2.2.1. Controlling The Set Of Advertised Interfaces For The Imported Service

The `interface` attribute identifies the service interface that a matching service must implement. For example, the following declaration creates a bean `messageService`, which is backed by the service returned from the service registry when querying it for a service offering the `MessageService` interface.

```
<reference id="messageService" interface="com.xyz.MessageService"/>
```

Just like the `service` declaration, when specifying multiple interfaces, use the nested `interfaces` element instead of `interface` attribute:

```
<osgi:reference id="importedOsgiService">
  <osgi:interfaces>
     <value>com.xyz.MessageService</value>
     <value>com.xyz.MarkerInterface</value>
  </osgi:interfaces>
</osgi:reference>
```

It is illegal to use both `interface` attribute and `interfaces` element at the same time - use only one of them.

The bean defined by reference element implements all of the advertised interfaces of the service that are visible to the bundle (called *greedy proxying*). If the registered service interfaces include Java class types (as opposed to interface types) then support for these types is subject to the restrictions of Spring's AOP implementation (see the Spring Reference Guide). In short, if the specified interfaces are classes (rather then interfaces), then `cglib` library must be available, and `final` methods are not supported.

8.2.2.2. The `filter` Attribute

The optional `filter` attribute can be used to specify an OSGi filter expression and constrains the service registry lookup to only those services that match the given filter.

For example:

```
<reference id="asyncMessageService" interface="com.xyz.MessageService"
  filter="(asynchronous-delivery=true)"/>
```

will match only OSGi services that advertise `MessageService` interface and have the property named `asynchronous-delivery` set to value `true`.

8.2.2.3. The `bean-name` Attribute

The `bean-name` attribute is a convenient short-cut for specifying a filter expression that matches on the `bean-name` property automatically set when exporting a bean using the `service` element (see Section 8.1, “Exporting A Spring Bean As An OSGi Service”).

Consider the following exporter/importer declarations:

```
<bean id="❶messageServiceBean" scope="bundle" class="com.xyz.MessageServiceImpl"/>
<!-- service exporter -->
<osgi:service id="messageServiceExporter" ref="❶messageServiceBean" interface="com.xyz.MessageService"/>
```

```
<osgi:reference id="messageService" interface="com.xyz.MessageService"
   bean-name="❶messageServiceBean"/>
```

❶ the name used with `bean-name` attribute

will match only OSGi services that advertise `MessageService` interface and have the property named `org.springframework.osgi.bean.name` set to value `messageServiceBean`. In short, this means finding all Spring DM exported beans that implement interface `MessageService` and are named `messageServiceBean`.

8.2.2.4. The `availability` Attribute

> **Nested <reference> declarations**
>
> In order for Spring DM to detect mandatory dependencies, any nested/inner reference declaration will be transformed into top-level one with a generated name.

The `availability` attribute is used to specify whether or not a matching service is required at all times. An `mandatory` availability (the default) indicates that a matching service must always be present. A value of `optional` indicates that a matching service is not required at all times (see Section 8.2.2.9, "`reference` And OSGi Service Dynamics" for more details). The differences in behaviour between `mandatory` and `optional` services are explained at length in Section 8.2.1, "Imported Service Availability".

8.2.2.5. The `depends-on` Attribute

The `depends-on` attribute is used to specify that the service reference should not be looked up in the service registry until the named dependent bean has been instantiated.

8.2.2.6. The `context-class-loader` Attribute

The OSGi Service Platform Core Specification (latest version is 4.1 at time of writing) does not specify what types and resources are visible through the context class loader when an operation is invoked on a service obtained via the service registry. Since some services may use libraries that make certain assumptions about the context class loader, Spring Dynamic Modules enables you to explicitly control the context class loader during service invocation. This is achieved using the option `context-class-loader` attribute of the `reference` element.

> **context class loader management on the importer and exporter**
>
> Spring DM has the ability to do context class loader management on both the importer and exporter side. Normally, if Spring DM works on both sides, only one side should have this feature enabled. However, if both sides (importer and exporter) take advantage of this capability, the last entity in the call chain will win. This means that the exporter setting, if enabled, will always override the importer setting (whatever that is).

The permissible values for the `context-class-loader` attribute are:

- `client` - during the service invocation, the context class loader is guaranteed to be able to see types on the classpath of the invoking bundle. This is the default option.
- `service-provider` - during the service invocation, the context class loader is guaranteed to be able to see types on the classpath of the bundle exporting the service.
- `unmanaged` - no context class loader management will occur during the service invocation

8.2.2.7. The `sticky` Attribute

Newly introduced in DM 2.x, the `sticky` attribute specifies whether an importer will use a backing service until it becomes unavailable or whether it will consider other *better* candidates (defined as services matching the importer criteria but with a higher ranking or a lower service id) that might appear. In Spring DM 1.x, the importer would always select the best service available at any point in time. Thus, if a service with a higher ranking id becomes available, the proxy would automatically bind to it. In highly dynamic environments, this lack of service affinity becomes problematic so in DM 2.x, the behaviour has changed (aligning itself with the Blueprint spec). Thus, service importers become `sticky` by default meaning that a proxy will use the bound backing service until it becomes unavailable, ignoring any other service updates. Only when the backing service goes down, the proxy will look for a replacement selecting the best candidate at that point in time. To revert to the Spring DM 1.x behaviour, mark the importers as being non-sticky.

8.2.2.8. `reference` Element Attributes

As a summary, the following table lists the `reference` element attributes names, possible values and a short description for each of them.

Table 8.3. OSGi <reference> attributes

Name	Values		
interface	fully qualified class name (such as `java.lang.Thread`)		
filter	OSGi filter expression (such as `((asynchronous-delivery=true)`)		
bean-name	any string value		
context-class-loader	client	service-provider	unmanaged
availability	optional	mandatory	
timeout	any positive long		
sticky	true	false	

8.2.2.9. `reference` And OSGi Service Dynamics

The bean defined by the `reference` element is unchanged throughout the lifetime of the application context (the object reference remains constant). However, the OSGi service that backs the reference may come and go at any time. For a mandatory service reference, the creation of the application context will block until a matching service is available. Section 8.2.1, “Imported Service Availability” provides more details.

When the service backing a `reference` bean goes away, Spring Dynamic Modules tries to replace the backing service with another service matching the reference criteria. An application may be notified of a change in backing service by registering a `reference-listener`. If no matching service is available, then the `reference` is said to be *unsatisfied*. An unsatisfied mandatory service causes any exported service (`service` bean) that depends on it to be unregistered from the service registry until such time as the reference is satisfied again. See Section 8.2.1.2, “Relationship Between The Service Exporter And Service Importer” for more information.

When an operation is invoked on an unsatisfied `reference` bean (either optional or mandatory), the invocation blocks until the reference becomes satisfied. The optional `timeout` attribute of the `reference` element enables a timeout value (in milliseconds) to be specified. If no matching service becomes available within the timeout period, an unchecked `ServiceUnavailableException` is thrown.

8.2.2.10. Getting A Hold Of The Managed Service Reference

Spring DM can automatically convert a managed OSGi service to service reference. That is, if the property into which a reference bean is to be injected, has type `ServiceReference` (instead of the service interface supported by the reference), then the managed OSGi `ServiceReference` for the service will be injected in place of the service itself:

```
public class BeanWithServiceReference {
        private ServiceReference serviceReference;
        private SomeService service;

        // getters/setters ommitted
}
```

```
<reference id="service" interface="com.xyz.SomeService"/>

<bean id="someBean" class="BeanWithServiceReference">
  <property name="serviceReference" ref="service"/>                    ❶
  <property name="service" ref="service"/>                             ❷
</bean>
```

❶ Automatic managed service to `ServiceReference` conversion.
❷ Managed service is injected without any conversion

Note

The injected `ServiceReference` is managed by Spring DM and will change at the same time as the referenced backing OSGi service instance.

There are cases when the managed `ServiceReference` is needed to get a hold of the OSGi service. Unfortunately, most of the OSGi frameworks expect their own `ServiceReference` classes and will fail when the Spring DM managed reference is used. For such cases, one can get a hold of the native `ServiceReference` bound at that moment, by casting the reference object to `ServiceReferenceProxy` and then calling `getTargetServiceReference`. Using the example context above, one might use the following code:

```
ServiceReference nativeReference = ((ServiceReferenceProxy)serviceReference).getTargetServiceReference()
```

The returned `nativeReference` can be safely passed to the OSGi framework however, since it is not managed by Spring DM, in time, it might refer to a service different then the one backing the imported OSGi service.

To avoid this desynchronization, consider using managed `ServiceReference` objects mainly for reading the bound OSGi service properties rather then getting a hold of OSGi services (which can be simply injected by Spring DM).

8.2.3. Referencing A Collection Of Services

Natural vs custom ordering

Java collection API defines two interfaces for ordering objects - `Comparable` and Comparator. The first is meant to be implemented by objects for providing *natural ordering*. `String`, `Long` or `Date` are good examples of objects that implement the `Comparable` interface.

However, there are cases where sorting is different then the natural ordering or, the objects meant to be sort do not implement Comparable. To address this cases, `Comparator` interface was designed.

For more information on this subject, please consult the Object ordering chapter from Java collection tutorial,

Sometimes an application needs access not simply to any service meeting some criteria, but to *all* services meeting some criteria. Spring DM allows the matching services may be held in a `List` or `Set` (optionally sorted).

The difference between using a `List` and a `Set` to manage the collection is one of equality. Two or more services published in the registry (and with distinct service ids) may be "equal" to each other, depending on the implementation of equals used by the service implementations. Only one such service will be present in a set, whereas all services returned from the registry will be present in a list. For more details on collections, see this tutorial.

The `set` and `list` schema elements are used to define collections of services with set or list semantics respectively.

These elements support the attributes `interface`, `filter`, `bean-name`, `availability`, and `context-class-loader`, with the same semantics as for the `reference` element. The allowable values for the `availability` attribute are `mandatory` and `optional`.

An availability value of `optional` indicates that it is permissible to be no matching services. An availability value of `mandatory` indicates that at least one matching service is required at all times. Such a reference is considered a *required* reference and any exported services from the same bundle (`service` defined beans) that depend on a mandatory reference will automatically be unregistered when the reference becomes unsatisfied, and reregistered when the reference becomes satisfied again. See Section 8.2.1, “Imported Service Availability” for more details.

The bean defined by a `list` element is of type `java.util.List`. The bean defined by a `set` element is of type `java.util.Set`.

Note

Make sure the Spring DM collections are injected into properties of compatible types (for example `set` into `Set` or `Collection`) since otherwise the container will automatically perform type conversion, transforming the Spring DM managed collection into a 'normal' one, unaware of the OSGi dynamics.

The following example defines a bean of type `List` that will contain all registered services supporting the `EventListener` interface:

```
<list id="myEventListeners" interface="com.xyz.EventListener"/>
```

The members of the collection defined by the bean are managed dynamically by Spring. As matching services are registered and unregistered in the service registry, the collection membership will be kept up to date. Each member of the collection supports the service interfaces that the corresponding service was registered with and that are visible to the bundle.

Spring DM supports sorted collections as well, both for set and list.

It is possible to specify a sorting order using either the `comparator-ref` attribute, or the nested `comparator` element. The `comparator-ref` attribute is used to refer to a named bean implementing `java.util.Comparator`. The `comparator` element can be used to define an inline bean. For example:

```
<set id="myServices" interface="com.xyz.MyService"
  comparator-ref="someComparator"/>

<list id="myOtherServices"
  interface="com.xyz.OtherService">
  <comparator>
     <beans:bean class="MyOtherServiceComparator"/>
  </comparator>
</list>
```

To sort using a natural ordering instead of an explicit comparator, you can use the `natural` element inside of `comparator`. You need to specify the basis for the natural ordering: based on the service references, following the `ServiceReference` natural ordering defined in the OSGi Core Specification release 4, version 4.1, section 6.1.23; or based on the services themselves (in which case the services must be `Comparable`).

```
<list id="myServices" interface="com.xyz.MyService">
  <comparator><natural basis="services"/></comparator>
</list>

<set id="myOtherServices"interface="com.xyz.OtherService">
  <comparator><natural basis="service-references"/></comparator>
</set>
```

Note

For a sorted set, a `SortedSet` implementation will be created. However, since the JDK API does not provide a dedicated `SortedList`interface, the sorted list will implement only the `List` interface.

8.2.3.1. Greedy Proxying

All OSGi services imported by a Spring DM service collection publish and are type-compatible with the classes declared by the `interfaces` property. However, some services might expose additional (optional) classes that could be relevant to your application.

For these cases, Spring DM collections offer a dedicated attribute called `greedy-proxying` which will cause the creates proxies to use *all* the classes advertised by the imported services, visible to the consuming importing bundle. Thus, it is possible to cast the imported proxies to classes different then those specified in the `interfaces`. For example, with the following list definition:

```
<list id="services" interface="com.xyz.SomeService" greedy-proxying="true"/>
```

one can do the following iteration (assuming `MessageDispatcher` type is imported by the bundle):

```
for (Iterator iterator = services.iterator(); iterator.hasNext();) {
        SomeService service = (SomeService) iterator.next();
        service.executeOperation();
        // if the service implements an additional type
        // do something extra
        if (service instanceof MessageDispatcher) {
                ((MessageDispatcher)service).sendAckMessage();
        }
}
```

Note

Before using greedy proxies and `instanceof` statements, consider using a different interface/class for your services which provides better polymorphism and is more object-oriented.

8.2.3.2. Member Type

Since Spring DM 2.x, service collections can contain either service instances (default) or service references. The latter is useful if the services themselves are not relevant but rather their properties and availability. For example, to track the service references, the following configuration can be used:

```
<list id="services" interface="com.xyz.SomeService" member-type="service-reference"/>
```

Note that the collection contains *native* service references which can be used by client to retrieve the backing service (if needed). However, when using Spring DM this use case is discouraged since one can let the framework track the services instead and get the (native) associated service reference from the proxy directly (see Section 8.2.2.10, “Getting A Hold Of The Managed Service Reference” for more details).

8.2.3.3. Collection (`list` And `set`) Element Attributes

`list` and `set` elements support all the attributes available to `reference` element except the `timeout` attribute. See the following table as a summary of the `list` and `set` element attribute names, possible values and a short description for each of them.

Table 8.4. <list>/<set> attributes

Name	Values	Description
interface	fully qualified class name (such as `java.lang.Thread`)	The fully qualified name of the class under which the object will be exported.
filter	OSGi filter expression (such as `((asynchronous-delivery=true))`)	OSGi filter expression that is used to constrain the set of matching services in the service registry.
bean-name	any string value	Convenient shortcut for specifying a filter expression that matches on the bean-name property that is automatically advertised for beans published using the <service> element.
context-class-loader	client | service-provider | unmanaged	Defines how the

Name	Values			Description
				context class loader is managed when invoking operations on a service backing this service reference. The default value is `client` which means that the context class loader has visibility of the resources on this bundle's classpath. Alternate options are `service-provider` which means that the context class loader has visibility of resources on the bundle classpath of the bundle that exported the service, and `unmanaged` which does not do any management of the context class loader.
availability	optional		mandatory	Defines the desired availability of the relationship to the backing service. If not specified, the `default-availability` attribute will apply. 'mandatory' value (the default) means that a backing service must

Name	Values		Description
			exist at all times. The 'optional' value indicates that it is acceptable to be for an importer to have no backing service.
comparator-ref	any string value		Named reference to a bean acting as comparator for the declaring collection. Declaring a comparator automatically makes the declaring collection sorted.
greedy-proxying	true	false	Indicates whether the proxies created for the imported OSGi services will be generated using just the classes specified (`false`) or all the classes exported by the service and visible to the importing bundle (`true`). The default value is `false`.
member-type	service-object	service-reference	Indicates the type of object that will be placed within the reference collection. `service-object` (the default) indicates the

Name	Values		Description
			collection contains service proxies for imported services. `service-reference` indicates the collection contains `ServiceReference` objects matching the target service type.

The table below lists the attributes available for the `comparator/natural` sub element.

Table 8.5. collection <comparator> attributes

Name	Values	
basis	service	service-reference

8.2.3.4. `list` / `set` And OSGi Service Dynamics

A collection of OSGi services will change its content during the lifetime of the application context since it needs to reflect the state of the OSGi space. As service are registered and unregistered, they will be added or removed from the collection.

While a `reference` declaration will try to find a replacement if the backing service is unregistered, the collection will simply remove the service from the collection. Like `reference`, a collection of services can have a specified `availability`. As opposed to `reference`s though, since Spring DM 2.x, a collection content can be queried, no matter its availability and the number of services held.

Just like `reference`, mandatory collections will trigger the unregistration of any exported service that depends upon it. See Section 8.2.1.2, “Relationship Between The Service Exporter And Service Importer” for more information.

8.2.3.5. `Iterator` Contract And Service Collections

The recommend way of traversing a collection is by using an `Iterator`. However, since OSGi services can come and go, the content of the managed service collection will be adjusted accordingly. Spring DM will transparently update all `Iterators` held by the user so it is possible to safely traverse the collection while it is being modified. Moreover, the `Iterators` will reflect all the changes made to the collection, even if they occurred after the `Iterators` were created (that is during the iteration). Consider a case where a collection shrinks significantly (for example a big number of OSGi services are shutdown) right after an iteration started. To avoid dealing with the resulting 'dead' service references, Spring DM iterators do not take collection snapshots (that can be inaccurate) but rather are updated on each service event so they reflect the latest collection state, no matter how fast or slow the iteration is.

It is important to note that a service update will only influence `Iterator` operations that are executed after the event occurred. Services already returned by the iterator will not be updated even if the backing service has been unregistered. As a side note, if an operation is invoked on such a service that has been unregistered, a `ServiceUnavailableException` will be thrown.

To conclude, while a `reference` declaration will search for candidates in case the backing service has been unregistered, a service collections will not replace unregistered services returned to the user. However, it will remove the unregistered services from the collection so future iterations will not encounter them.

Please note that the `Iterator` contract is guaranteed meaning that `next()` method *always* obey the result of the previous `hasNext()` invocation.

Table 8.6. Dynamic service collection `Iterator` contract

hasNext() returned value	**next() behaviour**
true	*Always* return a non-null value, even when the collection has shrunk as services when away.
false	per `Iterator` contract, `NoSuchElementException` is thrown. This applies even if other services are added to the collection

The behaviour described above, offers a consistent view over the collection even if its structure changes during iteration. To simply *refresh* the iterator, call `hasNext()` again. This will force the `Iterator` to check again the collection status for its particular entry in the iteration.

In addition, any elements added to the collection during iteration over a *sorted* collection will only be visible if the iterator has not already passed their sort point.

8.2.4. Dealing With The Dynamics Of OSGi Imported Services

Where is the `listener` element ?

Since Spring DM 2.x, the `reference-listener` replaced the `listener` element which has been deprecated. The main reasons behind the decisions were to align the configuration format closer with the Blueprint spec and to avoid some of the confusion regarding the type of listener declared (service or reference based). Note that `listener` element is still supported.

Whether you are using `reference` or `set` or `list`, Spring Dynamic Modules will manage the backing service. However there are cases where the application needs to be aware when the backing service is updated.

Such applications, that need to be aware of when the service backing a `reference` bean is bound and unbound, can register one or more listeners using the nested `reference-listener` (or `listener`) element. This element is available on both `reference` and `set`, `list` declarations. In many respects, the service importer listener declaration is similar to the service exporter listener declaration (Section 8.1.10, “Service Registration And Unregistration Lifecycle”). The `reference-listener` element refers to a bean (either by name, or by defining one inline) that will receive bind and unbind notifications. If this bean implements Spring DM's `org.springframework.osgi.service.importer.OsgiServiceLifecycleListener` interface, then the `bind` and `unbind` operations in this interface will be invoked. Instead of implementing this interface (or in addition), custom bind and unbind callback methods may be named.

An example of declaring a listener that implements `OsgiServiceLifecycleListener`:

```
<reference id="someService" interface="com.xyz.MessageService">
  <reference-listener ref="aListenerBean"/>
</reference>
```

An example of declaring an inline listener bean with custom bind and unbind methods:

```
<reference id="someService" interface="com.xyz.MessageService">
  <reference-listener bind-method="onBind" unbind-method="onUnbind">
     <beans:bean class="MyCustomListener"/>
  </reference-listener>
</reference>
```

If the listener bean implements the `OsgiServiceLifecycleListener` interface *and* the listener definition specifies custom bind and unbind operations then both the `OsgiServiceLifecycleListener` operation and the custom operation will be invoked, in that order.

The signature of a custom bind or unbind method must be one of:

```
public void anyMethodName(ServiceType service, Dictionary properties);

public void anyMethodName(ServiceType service, Map properties);

public void anyMethodName(ServiceReference ref);
```

where `ServiceType` can be any type. Please note that bind and unbind callbacks are invoked *only* if the backing service matches the type declared in the method signature(`ServiceType`). If you want the callbacks to be called no matter the type, use `java.lang.Object` as a `ServiceType`.

The `properties` parameter contains the set of properties that the service was registered with.

If the method signature has a single argument of type `ServiceReference` then the `ServiceReference` of the service will be passed to the callback in place of the service object itself.

When the listener is used with a `reference` declaration:

- A *bind* callback is invoked when the reference is initially bound to a backing service, and whenever the backing service is replaced by a new backing service.
- An *unbind* callback is only invoked when the current backing service is unregistered, and no replacement service is immediately available (i.e., the `reference` becomes unsatisfied).

When the listener is used with a collection declaration (`set` or `list`):

- A *bind* callback is invoked when a new service is added to the collection.
- An *unbind* callback is invoked when a service is unregistered and is removed from the collection.

Again note that service collections there is *no* notion of *service rebind*: services are added or removed from the collection.

Bind and unbind callbacks are made synchronously as part of processing an OSGi `serviceChanged` event for the backing OSGi service, and are invoked on the OSGi thread that delivers the corresponding OSGi `ServiceEvent`.

The table below lists the attributes available for the `reference listener` sub element.

Table 8.7. OSGi <reference-listener> attributes

Name	Values	Description
ref	bean name reference	Name based reference to another bean acting as listener.
bind-method	string representing a valid method name	The name of the method to be invoked when a backing service is bound.
unbind-method	string representing a valid method name	The name of the method to be invoked when a backing service is bound.

8.2.5. Blueprint `reference` Comparison

Similar to Spring DM, the Blueprint Container offers a `reference` and `list` elements, identical in functionality with the those in Spring DM. Below is a summary of the configuration options available in Spring DM and Blueprint:

Table 8.8. Spring DM / Blueprint Service Importer Configuration Comparison

Spring DM	Blueprint
Common Elements/Attributes	
interface	interface
interfaces	- (multiple interfaces not supported)
ref	ref
filter	filter
bean-name	component-name
availability	availability
context-class-loader	-
`<reference>`	
timeout	timeout
sticky	- (the importer is always sticky)
`<list>`	
member-type	member-type
comparator-ref	-
greedy-proxying	-

Since the `registration-listener` declaration is identical in declaration and functionality between Blueprint and Spring DM, this section does not mention it.

8.3. Listener And Service Proxies

While the importer listener provides access to the OSGi service bound at a certain point, it is important to note that the given argument is *not* the actual service but a *proxy*. This can have subtle side effects especially with regards to service class name and identity. The reason behind using a proxy is to prevent the listener from holding strong reference to the service (which can disappear at any point). Listeners interested in tracking certain services should not rely on instance equality (`==`). Object equality (`equals/hashcode`) can be used but only if the backing service has exposed the aforementioned methods as part of its contract (normally by declaring them on a certain published interface/class). If these methods are not published, the proxy will invoke its own method, not the targets. This is on purpose since, while the proxy tries to be as transparent as possible, it is up to the developer to define the desired semantics.

Thus, it is recommended (especially for `reference` importers) to do tracking based on just the service interface/contract (not identity), service properties (see `org.osgi.framework.Constants#SERVICE_ID`) or service notification (bind/unbind).

8.4. Accessing The Caller `BundleContext`

It is sometime useful for an imported service to know which bundle is using it at a certain time. To help with this scenarion, in Spring DM imported services publish the importing bundle `BundleContext` through `LocalBundleContext` class. Each time a method on the importer is invoked, the caller `BundleContext` will be made available, using a `ThreadLocal`, through `getInvokerBundleContext()`.

Please be careful when using this class since it ties your code to Spring DM API.

8.5. Exporter/Importer Listener Best Practices

As mentioned above, Spring DM exporter and importer allow listeners to be used for receiving notifications on when services are bound, unbound, registered or unregistered. Below you can find some guidance advices when working with listeners:

- Do *not* execute long activity tasks inside the listener. If you really have to, use a separate thread for executing the work. The listener are called synchronously and so try to be as fast as possible. Doing work inside the listener prevents other the event to be sent to other listeners and the OSGi service to resume activity.
- Use listener custom declaration as much as possible - it doesn't tie your code to Spring DM API and it doesn't enforce certain signature names.
- If find yourself repeating bind/unbind method declarations for your listener definitions, consider using Spring bean definition inheritance to define a common definition that can be reused and customized accordingly.
- Prefer `java.util.Map` instead of `java.util.Dictionary` class. The first is an interface while the latter is a deprecated, abstract class. To preserve compatibility, Spring DM will pass to the listeners a `Map` implementation that can be casted, if needed, to a `Dictionary`.

- Be careful when using overloaded methods: all methods matching a certain service type will be called which is not always expected. Consider the following listener:

```
public class MyListener {
    void register(❶Object service, Map properties);
    void register(❷Collection dataService, Map properties);
    void register(❸SortedSet orderedDataService , Map properties);
}
```

❶ `Object` type - will match all services for which the listener is triggered. This method will be always called.

❷ `Collection` type - if this method is called, the `Object` method is also called.

❸ `SortedSet` type - if this method is called, then both the `Object` and `Collection` methods are called.

8.5.1. Listener And Cyclic Dependencies

There are cases where an exporter/importer listener needs a reference back to the bean it is defined on:

```
<bean id="listener" class="cycle.Listener">                          ❶
    <property name="target" ref="importer" />                        ❷
</bean>

<osgi:reference id="importer" interface="SomeService">               ❸
    <osgi:listener bind-method="bind" ref="listener" />              ❹
</osgi:reference>
```

❶ Listener bean
❷ Dependency listener -> importer
❸ Importer declaration
❹ Dependency importer -> listener

The declaration above while valid, creates a dependecy between the `listener` and the importer it is defined upon. In order to create the importer, the `listener` has to be resolved and created but in order to do that, the importer called `service` needs to be retrieved (instantiated and configured). This cycle needs to be broken down so that at least one bean can be fully created and configured. This scenario is supported by Spring DM for both exporter and importers however, if the listener is defined as a nested bean, the cycle cannot be resolved:

```
<osgi:reference id="importer" interface="SomeService">               ❶
    <osgi:listener bind-method="bind">                               ❷
        <bean class="cycle.Listener">                                ❸
            <property name="target" ref="importer" />                ❹
        </bean>
    </osgi:listener>
</osgi:reference>
```

❶ OSGi service importer
❷ Dependency between importer -> listener
❸ Nested listener declaration
❹ Dependency nested listener -> importer

Beans and Cycles

Cyclic dependencies (A depends on B which depends back on A) increase the complexity of your

configuration and in most cases indicate a design issue. What beans should be created and destroyed first for example? While they are a bad practice, the Spring container makes a best attempt to solve the cyclic configurations when singletons are involved (since the instances can be cached). However this does not work all the time and depends heavily on your specific configuration (Can the bean class be partially initialized ? Does it rely on special `Aware` interfaces? Are `BeanPostProcessors` involved?)

The example above will fail since `service` bean cannot be initialized as it depends on the listener. The same cycle was seen before but in this case there is subtle yet big different from the container perspective - the listener is declared as a nested/inner-bean (hence the missing bean `id`). Inner beans have the same life cycle as their declaring parents and do not have any name. By definition, they are not tracked by the container and are simply created on demand. Since the importer cannot be partially created and the nested listener cannot be cached, the container cannot break the cycle and create the beans. While the two configurations shown above seem similar, one works while the other does not. Another reason to not use cycles unless you really, really have to.

To conclude, if you need inside the listener to hold a reference to the exporter/importer on which the listener is declared, either declare the listener as a *top-level* bean (as shown before) or consider doing *dependency lookup*. However, the latter approach requires extra contextual information such as the `BeanFactory` to use and the bean name and is more fragile then *dependency injection*.

Note

For those interested in the technical details, neither the exporter and importer cannot be partially initialized since they require the application context `ClassLoader` which is requested through the `BeanClassLoaderAware` which relies on a buit-in `BeanPostProcessor` which is applied only after the bean has been configured and is ready for initialization. If the `ClassLoader` was not required then the exporter/importer could have been partially initialized and the case above supported.

8.6. Service Importer Global Defaults

The `osgi` namespace offers two global attributes for specifying default behaviours for all importers declared in that file.

Thus, when using the `osgi` namespace to enclose `set`, `list` or `reference` elements, one can use:

- `default-timeout` - can be used to specify the default timeout (in milliseconds) for all importer elements that do not explicitly specify one. For example:

```
<beans xmlns="http://www.springframework.org/schema/beans"
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xmlns:osgi="http://www.springframework.org/schema/osgi"                    ❶
          osgi:default-timeout="5000">                                           ❷

  <reference id="someService" interface="com.xyz.AService"/>                    ❸

  <reference id="someOtherService" interface="com.xyz.BService"
       timeout="1000"/>                                                         ❹

</beans:beans>
```

❶ Declare `osgi` namespace prefix.

❷ Declare `default-timeout`(in miliseconds) on the root element. If the default is not set, it will have a

value of 5 minutes. In this example, the default value is 5 seconds.

❸ This `reference` will inherit the default timeout value since it does not specify one. This service reference will have a timeout of 5 seconds.

❹ This `reference` declares a timeout, overriding the default value. This service reference will have a timeout of 1 second.

- `default-availability` - can be used to specify the default availability for all importer elements that do not explicitly specify one. Possible values are `optional` and `mandatory`. The `default-cardinality` attribute, used by Spring DM 1.x, is still available but it has been deprecated.

  Consider the following example:

```
<beans:beans
      xmlns="http://www.springframework.org/schema/osgi"                    ❶
      xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
      xmlns:beans="http://www.springframework.org/schema/beans"             ❷
      xmlns:osgi="http://www.springframework.org/schema/osgi"               ❸
         osgi:default-availability="optional"                               ❹
         default-lazy-init="false">                                         ❺

  <reference id="someService" interface="com.xyz.AService"/>                ❻

  <set id="someSetOfService" interface="com.xyz.BService"/>                 ❼

  <list id="anotherListOfServices" interface="com.xyz.CService"
              availability="mandatory"/>                                    ❽

</beans:beans>
```

❶ Declare Spring Dynamic Modules schema as the default namespace.

❷ Import Spring Framework beans schema and associate a prefix with its namespace (`beans` in this example).

❸ Import Spring Dynamic Modules schema and associate a prefix with its namespace (`osgi` in this example). This is required since the global attributes have to be declared to an element (`beans`) belonging to another schema. To avoid ambiguity, the Spring DM schema is imported under a specified prefix as well.

❹ Declare `default-availability` on the root element. If the default is not set, it will have a value of `mandatory`. In this example, the default value is `optional`. Note the `osgi` prefix added to the global attribute.

❺ `beans` element attributes (such as `default-lazy-init`) do not need a prefix since they are declared as being local and unqualified (see the beans schema for more information).

❻ The `reference` declaration will inherit the default availability value since it does not specify one.

❼ The `set` declaration will inherit the default availability value since it does not specify one.

❽ The `list` declaration specifies its availability (`mandatory`), overriding the default value.

The `default-*` attributes allow for concise and shorter declarations as well as easy propagation of changes (such as increasing or decreasing the timeout).

Chapter 9. Working With Bundles

Spring DM offers a dedicated schema element for interacting with existing bundles or for installing new ones. While it is not intended to be used as a replacement for proper OSGi services, the `bundle` element offers a very easy way of executing actions on bundles based on the lifecycle of the application context.

The `bundle` element defines a bean of type `org.osgi.framework.Bundle`. It provides a simple way to work directly with bundles, including driving their lifecycle. In the simplest case all you need to do is specify the `symbolic-name` of the bundle you are interested in:

```
<bundle id="aBundle" symbolic-name="org.xyz.abundle"/>
```

The bean `aBundle` can now be injected into any property of type `Bundle`.

If the needed bundle is not installed, one can use `location` attribute to indicate install or/and the `action/destroy-action` attributes provide declarative control over the bundle's lifecycle. The `location` attribute is used to specify a URL where the bundle jar file artifact can be found. The `action` attribute specifies the lifecycle operation to be invoked on the bundle object. The supported action values are `install`, `start`, `update`, `stop`, and `uninstall`. These actions have the same semantics as the operations of the corresponding names defined on the `Bundle` interface (see the OSGi Service Platform Core Specification), with the exception that pre-conditions are weakened to allow for example a *start* action to be specified against a bundle that is not currently installed (it will be installed first).

The following table shows how actions are interpreted for the given Bundle states:

Table 9.1. <bundle> `action` values

Action	`UNINSTALLED`	`INSTALLED/RESOLVED`	`ACTIVE`
`START`	installs and starts the bundle	starts the bundle	no action taken, bundle already started
`UPDATE`	installs the bundle and then updates it (`Bundle.update()`)	updates the bundle	updates the bundle
`STOP`	no action taken	no action taken	bundle is stopped
`UNINSTALL`	no action taken	bundle is uninstalled	bundle is stopped and then uninstalled

For example:

```
<!-- ensure this bundle is installed and started -->
<bundle id="aBundle" symbolic-name="org.xyz.abundle"
   location="http://www.xyz.com/bundles/org.xyz.abundle.jar"
   action="start"/>
```

The following table lists the `bundle` element attributes names, possible values and a short description for each of them:

Table 9.2. <bundle> attributes

Name	Values					Description
symbolic-name	any valid symbolic-name String					The symbolic name of the bundle object. Normally used when interacting with an already installed bundle.
location	String that can be converted into an `URL`					Location used to install, update or/and identify a bundle.
action	start	stop	install	uninstall	update	Lifecyle action to drive on the bundle. The action is executed at startup.
destroy-action	(same as action)					Lifecyle action to drive on the bundle. The action is executed at shutdown.

The samples that ship with the Spring Dynamic Modules project include further support for a `virtual-bundle` element that can be used to create and install OSGi bundles on the fly from existing artifacts.

Chapter 10. Web Support

OSGi bundles and WARs

Web ARchives, or in short WARs, are specialized JAR for packaging web applications. Since the same archive format is used (Java ARchive), each war can be considered an OSGi bundle if the proper OSGi manifest entries are present. Note that it is not required for a bundle to have a `.jar` file extension, which means `.war` files can be installed just as well.

A major feature introduced in the 1.1.0 release is *support for web applications* which enables easy deployment of web artifacts to OSGi.

The biggest problems in running web applications in OSGi involve resource and class loading; there is no notion of *bundle space* or *imported packages* in a web application. Each web container has its own class loading hierarchy and classpath assumption which can conflict with the OSGi space. Spring DM addresses these problems by bridging the web container and the OSGi space so loading is no longer a concern. Unique in its functionality, the web support in Spring DM integrates directly with the web container so the WAR processing is literally handled by the server, giving full access to its configuration and capabilities(non-blocking vs blocking IO, thread pool, specification support (Servlet 2.3, 2.4, 2.5) and so on). The entire `web.xml` syntax is supported (without any parsing on Spring DM behalf), as well as any custom configuration file particular to the target container. In short, everything that the target container supports is available to the OSGi WAR through Spring DM.

Deployment scenarios

Users new to OSGi can benefit greatly from the SpringSource dm Server documentation which explains how OSGi can work in various development and production scenarios. The programmer guide describes the sophisticated eclipse tooling in detail.

Tip

As a complement to this chapter, the Spring DM distribution contains a number of web samples involving static resources, Servlets and JSPs running inside OSGi.

Note

For more information on web applications on Java platform, please see the Servlet home page.

10.1. Supported Web Containers

Currently, Spring DM supports Apache Tomcat 5.5.x/6.0.x and Jetty 6.1.8+/6.2.x out of the box (other containers can be easily plugged in). The web support is JDK 1.4 compatible. Please check the chosen container requirements for more information on the required JVM. In general, Servlet 2.4/JSP 2.0 require JDK 1.4 while Servlet 2.5/JSP 2.1 require JDK 1.5.

10.2. Web Support Usage

WAR vs Web Application

This document understand by web application an instance of a WAR: a WAR is a definition while a web application a runtime instance of a definition. This is similar to the difference between a class and an object: the class represents a (bytecode) definition while the object, the instance of a class.

Just like with non-WAR bundles, Spring DM Web uses the extender pattern to detect and install WARs. However, one crucial difference from the standard Spring DM Extender is that Spring DM will only trigger the install and uninstall of the WAR - the actual web application creation and thread management is delegated to the web container in which the WAR is installed. That is, Spring DM Web *only* dictates when a WAR is deployed to and undeployed from a web container; it is up to the web container to create and manage the equivalent web application.

To use Spring DM Web, install:

- `spring-osgi-web.jar` - Spring DM web support
- `spring-osgi-web-extender.jar` - Spring DM web extender

bundles to detect started OSGi WAR bundles and to deploy them to one of the supported web containers. Note that the web extender consider a war a bundle that has trailing `.war` in its location or contains a `WEB-INF` entry. By default, Tomcat will be used but this can be changed to Jetty or to another custom server. When the war bundle is stopped, Spring DM will also stop and uninstall the web application associated with it. Different from *traditional* web development, the Servlet classes need to be explicitly imported as the OSGi class path always takes priority (see below).

Since, when running a web application, it's the web container that does the bootstrapping and instantiation, there is no need to place the Spring .xml files under `META-INF/spring` or use the Spring DM manifest entries. Simply bundle your files in the WAR and use your web framework (or `Servlets`/`Listeners`) to bootstrap the Spring container. See Section 10.7, “Spring-MVC Integration” for Spring-MVC integration and/or Spring reference documentation for more information. These being said, the Spring Extender is still required as it performs namespace handlers discovery - without it, it would not be possible to use Spring namespaces (like `osgi:`, `aop:` or even `beans:` for that matter).

10.3. WAR Classpath In OSGi

The servlet specification defines a number of rules and locations which special meaning inside a WAR. This section will explain how these are handled in an OSGi environment.

10.3.1. Static Resources

When installing a WAR bundle, for static resources, Spring DM will only consider what is available in the bundle space - this means what is available in the bundle jar and its attached fragments. Conforming to the Servlet spec, resources under `WEB-INF` folder will be available through the `ServletContext` API but not to remote clients connecting to the web application. In addition, any resource available in the classpath (imported packages, required bundles or dynamic imports) can be loaded and used by the application code but cannot be seen *outside* of it.

10.3.2. Servlets

The main difference from the *traditional* WAR deployment is that the Servlet packages need to be imported so they are available to the WAR bundle. To do that, add the following packages to the `Import-Package` entry:

```
Import-Package: javax.servlet,javax.servlet.http,javax.servlet.resources
```

Additionally, the servlet specification defines the classpath of a WAR, based on some predefined locations. To quickly recap, these are:

- `WEB-INF/classes` - all resources under `WEB-INF/classes`
- `WEB-INF/lib/*.jar` - all jars under `WEB-INF/lib`

In addition, each container implementation can provide *common* libraries that are appended to the war classpath. Since OSGi, with its class wiring, versioning, reloading, superseeds the WAR classpath, Spring DM will ignore the WAR predefined locations and will *always* use the OSGi classpath instead. This means that classes imported by a WAR bundle can be used even if they are not present under `WEB-INF/classes` folder or inside a jar under `WEB-INF/lib`. This also means that any class under `WEB-INF/classes` will not be considered if it's not available in the WAR OSGi classpath.

One of the easiest ways to support the pre-defined WAR locations, is to add them to the bundle classpath, by adding them to the bundle manifest:

```
Bundle-Classpath: .,WEB-INF/classes,WEB-INF/lib/some.jar,WEB-INF/lib/lib.jar
```

Make sure the default `Bundle-Classpath` location (`.`) is present and there are no whitespaces between the commas.

Note

Since the OSGi API doesn't provide a hook for bundles to be pre-processed, Spring DM cannot automate this process in a reliable way. However, we are working on finding a suitable solution. Note that there are tools (bnd) that can add these entries during packaging.

Before creating entries for embedded libraries, consider whether they can be installed as OSGi bundles - doing so allows them to be shared with other WARs if needed and since OSGi allows versioning, it is perfectly okay to have multiple versions of the same library inside the same VM.

10.3.3. Java Server Pages

For JSPs, Spring DM integrates with Tomcat Jasper 2 Engine which means JSP 1.2, 2.0 and 2.1 are supported. OSGified versions for Jasper (from Tomcat 5.5.x and 6.0.x distribution respectively) are available in the Spring DM OSGi repository. No imports on Jasper classes are required for the OSGi bundle.

10.3.3.1. Tag Libraries

The JSP spec allows the creation of tag libraries to “define declarative, modular functionality that can be reused by any JSP page”. Also known as taglibs, these reusable components consist of Java classes (the tag implementation) and description files that indicate how the tags can be used. Spring DM extends the JSP convention, of placing the taglibs either packed as a jar under `WEB-INF/lib` or unpacked under `WEB-INF/classes`, by detecting any taglib defined in the bundle classpath (imported packages or required bundles).

Spring DM will automatically look for any taglib file (`*.tld`) available in the bundle classpath and will make them available to the Jasper engine. However, while the tag definitions are automatically discovered, the tag classes are not - again, the OSGi classpath takes priority. This means that in order to use a tag, the war bundle would have to import the tag corresponding classes since otherwise, they are not seen by the bundle and the tag cannot be used.

When dealing with libraries that export a lot of tags, one can use the `Require-Bundle` header instead of `Import-Package` for importing the tags:

```
Require-Bundle: org.springframework.osgi.jstl.osgi
```

Using the manifest entry above, all the classes (and thus tag implementations) exported by the JSP Standard Tag Library (or JSTL in short), are seen by the war bundle and thus can be used inside the JSPs.

Warning

Before using `Require-Bundle` on a large scale, please read the OSGi specification (section 3.13) for an in-depth review of its implications.

No matter what mechanism you decide to use for the war classpath, due to the OSGi capabilities, it is possible to create libraries that are *shared* between multiple WARs while having full control over the used packages. Each bundle can import only the packages (and the versions) needed not an entire library jar - in fact, packages from different bundles/jars can be selectively used to obtain the desired behaviour - a very powerful capability which should make web application deployment easier.

10.4. Configuring The Web Extender

Just like the core extender, the web extender can be configured by using OSGi fragments. Following a similar pattern, the web extender looks for all XMLs under `META-INF/spring/extender` folder in *its* bundle space and assembles them into an application context that is used internally as its configuration. To override a default setting of the web extender, look up the appropriate bean name from the table below, define it in a suitable manner and then attach it as a fragment to the `spring-osgi-web.jar`, using:

```
Fragment-Host: org.springframework.osgi.web.extender
```

The following beans are currently recognized by the web extender:

Table 10.1. Web Extender Configuration Options

Bean Name	Type	Role	Default Class	Default Behaviour
`warDeployer`	`WarDeployer`[a]	Installs OSGi bundles as web applications. The deployers takes care of locating the required web container and installing and uninstalling web applications.	`TomcatWarDeployer`[b]	Installs OSGi WARs to Tomcat 5.5.x/6.0.x. The servers needs to be installed, started and published as OSGi services as explained here.
`contextPathStrategy`	`ContextPathStrategy`[a]	Determines the context path associated with an OSGi bundle/WAR. The returned path is used by the war deployer to install	`DefaultContextPathStrategy`[c]	Returns the context path of the war based on the `Web-ContextPath` manifest header or (if missing), the file name from the bundle location,

Bean Name	Type	Role	Default Class	Default Behaviour
		the war application.		falling back to the bundle name and bundle symbolic name respectively. If neither of these is present, the bundle object identity will be used.

[a]Part of `org.springframework.osgi.web.deployer` package

[b]Part of `org.springframework.osgi.web.deployer.tomcat` package

[c]Part of `org.springframework.osgi.web.deployer.support` package

Note that to properly support wars, whether they are using Servlet 2.5 or not, the Spring DM web extender considers as WARs bundles that contains a `.war` extension.

10.4.1. Changing The War Deployer

To change the Tomcat deployer to Jetty for example, one can create a configuration file `META-INF/spring/extender/jetty-deployer.xml` with the following content:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation="http://www.springframework.org/schema/beans
       http://www.springframework.org/schema/beans/spring-beans.xsd">

    <bean id="warDeployer"                                                    ❶
        class="org.springframework.osgi.web.deployer.jetty.JettyWarDeployer" />  ❷
</beans>
```

❶ Pre-defined bean name used by the web extender

❷ Bean implementing `org.springframework.osgi.web.deployer.WarDeployer` interface

Once the file is created, it should be bundled in an OSGi fragment attached to the Spring DM Web Extender bundle by adding the `Fragment-Host` header:

```
Fragment-Host: org.springframework.osgi.web.extender
```

Now the fragment can be deployed alongside `spring-osgi-web.jar` bundle to plug in Jetty.

A pre-packed Jetty fragment is available in the Spring DM maven repository under `jetty.web.extender.fragment.osgi` artifactId (make sure to use version 1.0.1+).

10.5. Customizing The Standard Deployers

By default, the out of the box deployers look up the needed services, at startup. As the services are considered mandatory, the deployers will wait for them and, in case they are not found, will throw an exception. In cases where the default timeout or service lookup filter is not be appropriate, one can customize the service used through a Spring DM reference:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:osgi="http://www.springframework.org/schema/osgi"
   xmlns:p="http://www.springframework.org/schema/p"                          ❹
   xsi:schemaLocation="http://www.springframework.org/schema/beans
```

```
     http://www.springframework.org/schema/beans/spring-beans.xsd
     http://www.springframework.org/schema/osgi
     http://www.springframework.org/schema/osgi/spring-osgi.xsd">

    <osgi:reference id="myTomcatServer"                                    ❶
                interface="org.apache.catalina.Service"
                filter="(environment=testing)"
                cardinality="0..1"/>

    <bean id="warDeployer"                                                 ❷
        class="org.springframework.osgi.web.deployer.tomcat.TomcatWarDeployer"
        p:service-ref="myTomcatServer"/>                                   ❸

</beans>
```

❶ User defined OSGi service lookup
❷ Deployer definition (name is important)
❸ *Service* property assignment (through `p` namespace)
❹ Spring's `p` namespace declaration - see this blog entry for more information

Make sure to add the packages on which your configuration depends to the fragment manifest (since the web extender bundle imports only the packages it needs: Spring DM web support's). For the example above, one must import Catalina `Service`'s package. Since the `Service` interface signature depends on the `Connector` class from another package, its package needs to be imported as well - not doing so results in `ClassNotFoundException/NoClassDefFoundErrors`:

```
# Catalina packages
Import-Package: org.apache.catalina,org.apache.catalina.connector
# Spring DM Web Extender
Fragment-Host: org.springframework.osgi.web.extender
```

10.6. OSGi-ready Libraries And Web Development

Unfortunately, at the moment most libraries used for web development are not OSGi bundles, which means they cannot be used inside the OSGi space unless they are embedded in other bundles. To address this problem, the Spring DM project has osgified most of the common libraries and made them available through a dedicated Maven repository (which can be found in the appendix). Please note that the current repository, for now, is *provided as-is* without any support. These being said, we hope you find it useful.

10.6.1. Deploying Web Containers As OSGi Bundles

Spring DM web support expects the web containers to be installed as OSGi services. Since neither the Tomcat nor the Jetty distribution do this, Spring DM offers two simple yet useful OSGi Activators for both containers at the Spring DM OSGi repository. Once installed, these will programmatically start the appropriate web container based on a default configuration (which can be customized and publish it as an OSGi service. While the activators are generic, they can be easily customized for advance usages or even replaced - it's up to each deployer to decide how the server instances are looked up.

Note

The activator binaries and sources can be found either in the Spring DM repository (see below) or under the `lib/` folder inside the Spring DM (`with-dependencies`) distribution

All entries in the repository belong to the `org.springframework.osgi` group and have an `.osgi` termination to differentiate them from the original jars.

10.6.1.1. Tomcat 5.5.x/6.0.x

Apache Tomcat version 5.5.x and 6.0.x are available as OSGi artifacts in the repository under `catalina.osgi` artifactId. The jars require only commons-logging, JMX and Servlet/JSP libraries to be present.

In addition to the Catalina artifacts, the repository contains also a Tomcat activator (that works with both 5.5.x and 6.0.x versions) named `catalina.osgi.start`. The activator understands Tomcat XML configuration and contains a default, minimal setup that starts the server on `localhost`, port `8080`. This behaviour can be customized by placing the desired configuration (which will override the default one) under `conf/server.xml` location (following the Tomcat folder layout) in a fragment attached to the Tomcat activator.

To attach fragments to the Tomcat activator, specify the following host name in the fragment manifest:

```
Fragment-Host: org.springframework.osgi.catalina.start.osgi
```

10.6.1.2. Jetty 6.1.8+/6.2.0

Since Jetty is OSGi-ready by default, the official distribution can be installed without any transformation/processing on the OSGi platform. However, since there is no activator, Spring DM provides one, similar in functionality to the one available for Tomcat. The activator has `jetty.start.osgi` as artifact id. Just like the Tomcat case, a default configuration is included which starts a Jetty instance on `localhost`, port `8080`. To change the defaults, place your Jetty configuration under `etc/jetty.xml` location.

To attach fragments to the Jetty activator, specify the following host name in the fragment manifest:

```
Fragment-Host: org.springframework.osgi.jetty.start.osgi
```

Just like the extender, each activator uses a default configuration if the user doesn't provide one. For the latter case, one should use fragments (as mentioned above) to provide a customized configuration and to avoid modifying the distribution jar.

10.6.2. Common Libraries

The Servlet, Java Server Pages, Standard Taglib, Commons-EL and other web libraries are available as well in the Spring DM repository. When browsing use an S3 compatible application .

10.7. Spring-MVC Integration

Since 1.1, Spring DM integrates closely with Spring-MVC framework. This section details how Spring-MVC applications can be run into OSGi environments (it is assumed the reader is familiar with Spring-MVC concepts and APIs).

In order to be properly used inside an OSGi platform, a Spring-MVC application needs to adapt to its new environment. Spring DM provides a dedicated, OSGi-aware, web application context (called `OsgiBundleXmlWebApplicationContext`) that offers the same functionality and behaviour to its Spring-MVC brethren, `XmlWebApplicationContext`. The application context is aware of the web application `BundleContext` and thus is able to load resources from the OSGi space, import and export OSGi services and support the `BundleContextAware` and component scanning across the bundles included in the classpath.

To use this application context instead of the default one, use the `contextClass` parameters supported by Spring's `ContextLoaderListener` and `DispatcherServlet` inside your web application `WEB-INF/web.xml`:

```
<context-param>
  <param-name>contextClass</param-name>
  <param-value>org.springframework.osgi.web.context.support.OsgiBundleXmlWebApplicationContext</param-value>
</context-param>

<listener>
  <listener-class>org.springframework.web.context.ContextLoaderListener</listener-class>
</listener>

<servlet>
  <servlet-name>petclinic</servlet-name>
  <servlet-class>org.springframework.web.servlet.DispatcherServlet</servlet-class>
  <load-on-startup>2</load-on-startup>
  <init-param>
    <param-name>contextClass</param-name>
    <param-value>org.springframework.osgi.web.context.support.OsgiBundleXmlWebApplicationContext</param-value>
  </init-param>
</servlet>
```

❶ Name of the `context-param` used by Spring's `ContextLoaderListener` to determine the root web application context type
❷ Fully qualified name of the OSGi-aware web application context class
❸ Spring configuration bootstrap listener
❹ Spring MVC front controller
❺ Name of the `init-param` used by Spring's `DispatcherServlet` to determine the web application context type

With this configuration, deployed Spring-MVC bundles will be able to look up the existing `BundleContext` and be aware of the OSGi environment.

Note

You still need to add the proper package imports to your Spring-MVC application - the WAR is still a bundle after all which means without the proper manifest entries, it will have an invalid class path and will not be able to work properly.

Chapter 11. Compendium Services

The OSGi Service Platform Service Compendium specification defines a number of additional services that may be supported by OSGi implementations. Spring Dynamic Modules supports an additional "compendium" namespace that provides integration with some of these services. By convention, the prefix `osgix` is used for this namespace:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans:beans xmlns="http://www.springframework.org/schema/osgi"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:❶osgix="http://www.springframework.org/schema/osgi-compendium"                    ❶
   xmlns:beans="http://www.springframework.org/schema/beans"
   xsi:schemaLocation="http://www.springframework.org/schema/osgi
             http://www.springframework.org/schema/osgi/spring-osgi.xsd
     http://www.springframework.org/schema/osgi-compendium                                 ❷
             http://www.springframework.org/schema/osgi-compendium/spring-osgi-compendium.xsd   ❸
     http://www.springframework.org/schema/beans
             http://www.springframework.org/schema/beans/spring-beans.xsd">

   <!-- use the OSGi namespace elements directly -->
   <service id="simpleServiceOsgi" ref="simpleService"
       interface="org.xyz.MyService" />

   <!-- qualify compendium namespace elements -->
   <osgix:cm-properties id="cm" persistent-id="com.xyz.myapp"/>

</beans:beans>
```

❶ Compendium namespace declaration (bound to `osgix` prefix)
❷ Schema location (namespace URI)
❸ XML schema to use for the compendium namespace

At present this namespace provides support for the Configuration Admin service. Support for other compendium services may be added in future releases.

11.1. Configuration Admin

One of the most important compendium services, is the Configuration Admin which, as a name implies, provides configuration to interested bundles through the OSGi service registry. Spring DM provides dedicated support for Configuration Admin (CM), allowing consumption and injection of the configuration data in a declarative way.

11.1.1. Exposing Configuration Admin Entries As `Properties`

In its simplest form, the CM can be seen as a configuration source, namely a `Dictionary` whose keys are always `Strings`. Spring DM can expose entries in the CM as a `Properties` object, through the `cm-properties` element. A minimal declaration looks as follows:

```
<osgix:cm-properties id="ds.cfg" persistent-id="data.source.office.1"/>
```

The configuration above, exposes the properties available in the CM under *data.source.office.1* entry as a bean named *ds.cfg*.

Note

The `persistent-id` attribute must refer to the persistent-id of an OSGi `ManagedService`, it is a

configuration error to specify a factory persistent id referring to a `ManagedServiceFactory`.

Those familiar with Spring's util namespace will find `<osgi:cm-properties/>` element similar to `<util:properties/>`.

It is possible to specify a default set of property values to be used in the event that the configuration dictionary does not contain an entry for a given key. The declaration is similar to the `props` element inside the Spring beans namespace:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans:beans xmlns="http://www.springframework.org/schema/osgi-compendium"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:beans="http://www.springframework.org/schema/beans"
   xmlns:osgix="http://www.springframework.org/schema/osgi-compendium"
   xsi:schemaLocation="
      http://www.springframework.org/schema/beans
        http://www.springframework.org/schema/beans/spring-beans.xsd
      http://www.springframework.org/schema/osgi-compendium
        http://www.springframework.org/schema/osgi-compendium/spring-osgi-compendium.xsd">

   <osgix:cm-properties id="cfg.with.defaults" persistent-id="data.source.office.2">
      <beans:prop key="host">localhost</beans:prop>
      <beans:prop key="port">3306</beans:prop>
   </osgix:cm-properties>

</beans:beans>
```

By default, the properties found in the Configuration Admin entry will override the local properties. Thus, for the previous example, if the `data.source.office.2` configuration contains a *host* entry, its value will override the locally defined `localhost`. For cases where this behaviour is undesired, the attribute `local-override` (default `false`) allows one to revert the merging algorithm, forcing the local properties to override the entries in the CM.

Since `cm-properties` exposes the CM entries as `Properties`, it can be used with Spring's `PropertyPlaceholderConfigurer` and `PropertyOverrideConfigurer` to externalize and customize environment-specific properties:

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://www.springframework.org/schema/beans"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xmlns:osgix="http://www.springframework.org/schema/osgi-compendium"
   xmlns:ctx="http://www.springframework.org/schema/context"
   xsi:schemaLocation="
        http://www.springframework.org/schema/beans
          http://www.springframework.org/schema/beans/spring-beans.xsd
        http://www.springframework.org/schema/context
          http://www.springframework.org/schema/context/spring-context.xsd
        http://www.springframework.org/schema/osgi-compendium
          http://www.springframework.org/schema/osgi-compendium/spring-osgi-compendium.xsd">

   <!-- Configuration Admin entry -->
   <osgix:cm-properties id="cmProps" persistent-id="com.xyz.myapp">
      <prop key="host">localhost</prop>
   </osgix:cm-properties>

   <!-- placeholder configurer -->
   <ctx:property-placeholder properties-ref="cmProps" />

   <bean id="dataSource" ...>
      <property name="host" value="${host}"/>
      <property name="timeout" value="${timeout}"/>
   </bean>

</beans>
```

An important aspect of `cm-properties` is does *not* reflect any that any subsequent changes made to the entry it represents, made through the Configuration Admin API. That is, once resolved, the `cm-properties` content remains the same, regardless of any updates made the to CM entry it represents.

11.1.2. Managed Properties

Based on a configuration admin entry, Spring DM can autowire by name, the properties of a given bean. To use this feature, define a nested `managed-properties` inside the bean definition:

```
<bean id="managedComponent" class="MessageTank">
   <osgix:managed-properties persistent-id="com.xyz.messageservice"/>
</bean>
```

For each key in the dictionary stored by Configuration Admin under the given persistent id, if the bean type has a property with a matching name (following JavaBeans conventions), then that component property will be dependency injected with the value stored in Configuration Admin under the key. If the definition of `SomeClass` from the example above is as follows:

```
public class MessageTank {
  private int amount;
  public int getAmount() { return this.amount; }
  public void setAmount(int amount) { this.amount = amount; }
}
```

and the configuration dictionary stored under the pid `com.xyz.messageservice` contains an entry `amount=200`, then the `setAmount` method will be invoked on the bean instance during configuration, passing in the value `200`.

If a property value is defined both in the configuration dictionary stored in the Configuration Admin service and in a property element declaration nested in the component element, then the value from Configuration Admin takes precedence:

```
<bean id="managedComponent" class="MessageTank">
   <osgix:managed-properties persistent-id="com.xyz.messageservice"/>
   <property name="amount" value="100"/>
   <property name="threshold" value="500"/>
</bean>
```

Property values specified via property elements can therefore be treated as default values to be used if none is available through Configuration Admin.

Warning

Do not share the same *persistent-id* (PID) between multiple bundles or definitions, as *only one* of them will receive notifications. `managed-properties` relies on `org.osgi.service.cm.ManagedService` contract which mandates that each `ManagedService` instance must be identified with its own unique PID. Please see the Configuration Admin spec, specifically section 104.3 and 104.5

11.1.2.1. Configuration Admin Runtime Updates

A powerful feature of Configuration Admin is the ability to update (or delete) entries at runtime. That is, the configuration data stored in Configuration Admin may be updated after the bean has been created. By default, any post-creation updates will be ignored. However, one can configure `managed-properties` element to receive configuration updates through the `update-strategy` attribute, which can have a value of either `bean-managed` or `container-managed`.

`bean-managed` strategy will pass all the updates made to the configuration to a callback present on the bean, specified through the `update-method` attribute (which becomes required). The update method must have one of the following signatures:

```
public void anyMethodName(Map properties)
public void anyMethodName(Map<String,?> properties); // for Java 5
```

In contrast, the `container-managed` update strategy will re-inject bean properties by name based on the new properties received in the update. For `container-managed` updates, the component class must provide setter methods for the component properties that it wishes to have updated. Consider the following class definitions:

```
public class ContainerManagedBean {
  // will be reinjected (since it has a setter)
  private Integer integer;
  // will not be reinjected (no setter present)
  private Long waitTime;

  public void setInteger(Integer integer) { this.integer = integer; }
}


public class SelfManagedBean {

  // update callback
  public void updateCallback(Map properties) {
        System.out.println("Received properties " + properties);
        System.out.println("Props can be used as a Dictionary " + (Dictionary) properties);
        // do more work ...
  }
}
```

and configuraton:

```
<bean id="containerManaged" class="ContainerManagedBean">
   <osgix:managed-properties persistent-id="labX" update-strategy="container-managed"/>
   <property name="integer" value="23"/>
</bean>

<bean id="beanManaged" class="SelfManagedBean">
   <osgix:managed-properties persistent-id="labY" update-strategy="bean-managed" update-method="updateCallback"/
</bean>
```

Any updates made to the CM entry `labX` will be automatically reinjected on existing instances of `containerManaged` bean while the `labY` updates will be passed to `updateCallback` method.

The update options are summarized in the table below:

Table 11.1. Managed Properties Update Options

`update-strategy`	`update-method`	Behaviour
`container-managed`	*ignored*	Reinjects the bean properties, using the properties present in the update. The re-injection will be applied while locking (through a `synchronized` instruction) the bean instance. If the locking or re-injection strategy is not suitable, consider using the `bean-managed` approach.
`bean-managed`	*required*	Invokes the `update-method` callback on the bean instance, passing the updated configuration (as a `Map` object that can be safely cast to a `Dictionary` if needed). No locking is performed.

11.1.3. Managed Service Factories

The Configuration Admin service supports a notion of a *managed service factory*(see section 104.6 in the Compendium Specification). A managed service factory is identified by a factory pid which allows *multiple* `Configuration` objects to be associated with the factory. `Configuration` objects associated with the factory can be added or removed at any point. The main intent of a factory is to create an OSGi service for each configuration: adding a new `Configuration` entry results in a new OSGi service being registered, removing a `Configuration`, unregisters the service. Spring DM provides support for the *managed service factory* concept through the `managed-service-factory` element. Once defined, the configuration associated with the factory pid will automatically create (or remove) bean instances which will be registered (or unregistered) in the OSGi space based on a *template* bean definition and the CM configuration.

This might sound more complicated then it actually is, so let's look at a simplistic example:

```
<osgix:managed-service-factory id="simple-msf"
   factory-pid="com.xyz.messageservice"                                    ❶
   auto-export="all-classes">                                              ❷

   <bean class="com.xyz.MessageTank"/>                                     ❸
</osgix:managed-service-factory>
```

❶ factory persistent id (pid)
❷ Shortcut flag used to determine under what interfaces the OSGi service is published (more info below)
❸ bean definition *template*. For each detected configuration, a new service will be created using the bean definition template.

In its simplest form, the `managed-service-factory` requires the *factory pid*, a *bean definition* used as a template and some information on how possible bean instances are published as services. Basically, the definition above instructs Spring DM to to monitor the given factory pid (through a dedicated `ManagedServiceFactory` implementation (see the Compendium Spec for more info)) and for every `Configuration` object associated with the factory pid, to create a new, anonymous instance of the nested bean declared and export that instance as an OSGi service. The lifecycle of these beans instances is tied to the lifecycle of the associated `Configuration` objects. If a new configuration is added, a new bean is created and exported. If a configuration object is deleted or disassociated from the factory pid then the corresponding bean instance is destroyed.

In many regards, `managed-service-factory` acts as a specialized service exporter, similar to the `service` element but supporting the concept of managed properties. In fact, many of `service`'s attributes that indicate how a bean is exported, are found in `managed-service-factory` (as you saw in the previous example with `auto-export`) as are the `managed-properties` attributes.

The list of attributes can be found below:

Table 11.2. Managed Service Factory Options

Name	Values		Description
interface	fully qualified class name (such as `java.lang.Thread`)		the fully qualified name of the class under which the object will be exported
context-class-loader	unmanaged	service-provider	Defines how the

Name	Values				Description
					context class loader will be managed when an operation is invoked on the exported service. The default value is `unmanaged` which means that no management of the context class loader is attempted. A value of `service-provider` guarantees that the context class loader will have visibility of all the resources on the class path of bundle exporting the service.
auto-export	disabled `(default)`	interfaces	class-hierarchy	all-classes	Enables Spring to automatically manage the set of service interfaces advertised for the service. By default this facility is `disabled`. A value of `interfaces` advertises all of the Java interfaces supported by the exported service. A value of `class-hierarchy` advertises all the Java classes in the hierarchy of the exported

Name	Values				Description
					service. A value of `all-classes` advertises all Java interfaces and classes.
update-strategy	none (`default`)	bean-managed	container-managed		Defines the update strategy for configuration modifications made after the associated beans have been created.

Similar to the `service` element, a list of interfaces or/and registration listeners can be declared to be notified when a service is being registered/unregistered. For more information on the semantics, please see Section 8.1.3, “Controlling The Set Of Advertised Service Interfaces For An Exported Service” and Section 8.1.10, “Service Registration And Unregistration Lifecycle” chapters.

Now that the `managed-service-factory` options have been explained, let's look at a more complex configuration:

```
<bean id="queueTracker" class="org.xyz.queue.QueueTracker"/>

<osgix:managed-service-factory id="data-msf"
   factory-pid="org.xyz.labX"                                          ❶
   update-strategy="bean-managed"                                      ❷
   update-method="refresh">                                            ❸
   <osgix:interfaces>
       <value>java.util.Collection</value>                             ❹
       <value>java.util.Queue</value>                                  ❹
   </osgix:interfaces>
   <osgix:registration-listener ref="queueTracker"                     ❺
       registration-method="track"                                     ❻
       unregistration-method="untrack"/>                               ❼

   <bean class="com.xyz.ResizableQueue">                               ❽
       <property name="size" value="100"/>
       <property name="concurrency" value="10"/>
       <property name="fair" value="false"/>
   </bean>
</osgix:managed-service-factory>
```

❶ `ManagedServiceFactory` factory persistent id
❷ how should Spring DM behave when a `Configuration` is updated
❸ the method to invoke when for `bean-managed` updates
❹ the interfaces under which the nested beans are published as OSGi services
❺ listener notified when a service (based on the CM `Configuration`) is registered/unregistered
❻ custom (optional) service registration method
❼ custom (optional) service unregistration method
❽ bean definition template

The example above, creates a imaginary `ResizeableQueue` instance for each `Configuration` entry present under the `org.xyz.labX` factory pid. Each instance has default values assigned to `size`, `concurrency` and `fair` parameters. However, just like `managed-properties`, during the bean creation, the values received from the

Configuration Admin will be injected by name, possibly overriding existing settings. Once created and configured, each nested, anonymous bean instance is registered as an OSGi service under the `java.util.Collection` and `java.util.Queue` interfaces. The OSGi service lifecycle is monitored by a registration listener, namely the bean `queueTracker`. Finally, due to the specified `update-strategy`, any updates executed to each CM configuration will cause the `refresh` callback to be invoked on the associated bean instance.

11.1.4. Direct Access To Configuration Data

The simplest way to work directly with the configuration data stored under a given persistent id or factory persistent id, is to register a service that implements either the `ManagedService` or `ManagedServiceFactory` interface and specify the pid that you are interested in as a service property (for more information, see the Configuration Admin chapter in the OSGi compendium spec). For example:

```
<osgi:service interface="org.osgi.service.cm.ManagedService" ref="myManagedService">
   <osgi:service-properties>
     <entry key="service.pid" value="my.managed.service.pid"/>
   </osgi:service-properties>
</osgi:service>

<bean id="myManagedService" class="com.xyz.MyManagedService"/>
```

Chapter 12. Testing OSGi based Applications

By following best practices and using the Spring Dynamic Modules support, your bean classes should be easy to unit test as they will have no hard dependencies on OSGi, and the few OSGi APIs that you may interact with (such as `BundleContext`) are interface-based and easy to mock. Whether you want to do unit testing or integration testing, Spring DM can ease your task.

12.1. OSGi Mocks

> **Mocks vs Stubs**
>
> There are various strategies to unit test code that requires collaborators. The two most popular strategies are *stubs* and *mocks*.
>
> See this article by Martin Fowler which describes in detail the difference between them.

Even though most OSGi API are interfaces and creating mocks using a specialized library like EasyMock is fairly simple, in practice the amount of code of setting the code (especially on JDK 1.4) becomes cumbersome. To keep the tests short and concise, Spring DM provides OSGi mocks under `org.springframework.osgi.mock` package.

It's up to you to decide whether they are useful or not however, we make extensive use of them inside Spring DM test suite. Below you can find a code snippet that you are likely to encounter in our code base:

```
private ServiceReference reference;
private BundleContext bundleContext;
private Object service;

protected void setUp() throws Exception {
        reference = new MockServiceReference();
        bundleContext = new MockBundleContext() {

                public ServiceReference getServiceReference(String clazz) {
                        return reference;
                }

                public ServiceReference[] getServiceReferences(String clazz, String filter)
                                throws InvalidSyntaxException {
                        return new ServiceReference[] { reference };
                }

                public Object getService(ServiceReference ref) {
                    if (reference == ref)
                       return service;
                    super.getService(ref);
                }
        };

        ...
}

public void testComponent() throws Exception {
    OsgiComponent comp = new OsgiComponent(bundleContext);

    assertSame(reference, comp.getReference());
    assertSame(object, comp.getTarget());
}
```

As ending words, experiment with them and choose whatever style or library you feel most confortable with. In our test suite we use the aforementioned mocks, EasyMock library and plenty of integration testing (see below).

12.2. Integration Testing

What about JUnit4/TestNG?

While JUnit4/TestNG overcome the class inheritance problem that appears when building base JUnit classes, by decoupling the runner from the test through annotations, Spring DM cannot use them since it has to support Java 1.4.

However, it is planned for the future to provide an optional, JVM 5-based testing extension to integrate the existing testing framework with the aforementioned libraries.

In a restricted environment such as OSGi, it's important to test the visibility and versioning of your classes, the manifests or how your bundles interact with each other (just to name a few).

To ease integration testing, the Spring Dynamic Modules project provides a test class hierarchy (based on `org.springframework.osgi.test.AbstractOsgiTests`) that provides support for writing regular `JUnit` test cases that are then automatically executed in an OSGi environment.

In general, the scenario supported by Spring DM testing framework is:

- start the OSGi framework (Equinox, Knopflerfish, Felix)
- install and start any specified bundles required for the test
- package the test case itself into a `on the fly` bundle, generate the manifest (if none is provided) and install it in the OSGi framework
- execute the test case inside the OSGi framework
- shut down the framework
- passes the test results back to the originating test case instance that is running outside of OSGi

Warning

The testing framework is aimed at running OSGi integration tests from a non-OSGi environment (like Ant/Maven/IDE). The testing framework is NOT meant to be used as an OSGi bundle (nor will it work for that matter). In practice this means that the testing bundle should be separate from the bundle(s) it tests (similar to unit testing, where tests are separate from the classes they test).

By following this sequence it is trivial to write JUnit-based integration tests for OSGi and have them integration into any environment (IDE, build (ant, maven), etc.) that can work with JUnit.

The rest of this chapter details (with examples) the features offered by Spring DM testing suite.

12.2.1. Creating A Simple OSGi Integration Test

While the testing framework contains several classes that offer specific features, it is most likely that your test cases will extend `org.springframework.osgi.test.AbstractConfigurableBundleCreatorTests` (at least this is what we use in practice).

Let's extend this class and interact with the OSGi platform through the `bundleContext` field:

```
public class SimpleOsgiTest extends AbstractConfigurableBundleCreatorTests {

public void testOsgiPlatformStarts() throws Exception {
        System.out.println(bundleContext.getProperty(Constants.FRAMEWORK_VENDOR));
        System.out.println(bundleContext.getProperty(Constants.FRAMEWORK_VERSION));
        System.out.println(bundleContext.getProperty(Constants.FRAMEWORK_EXECUTIONENVIRONMENT));
        }
}
```

Simply execute the test as you normally do with any JUnit test. On Equinox 3.2.x, the output is similar to:

```
Eclipse
1.3.0
OSGi/Minimum-1.0,OSGi/Minimum-1.1,JRE-1.1,J2SE-1.2,J2SE-1.3,J2SE-1.4}
```

It is likely that you will see different log statements made by the testing framework during your own test execution, but these can be disabled as they only have an informative value and do not affect the actual execution.

Note that you did not have to create any bundle, write any MANIFEST or bother with imports or exports, let alone starting and shutting down the OSGi platform. The testing framework takes care of these automatically when the test is executed.

Let's do some quering and figure out what the environment in which the tests run is. A simple way to do that is to query the `BundleContext` for the installed bundles:

```
public void testOsgiEnvironment() throws Exception {
        Bundle[] bundles = bundleContext.getBundles();
        for (int i = 0; i < bundles.length; i++) {
                System.out.print(OsgiStringUtils.nullSafeName(bundles[i]));
                System.out.print(", ");
        }
        System.out.println();
}
```

The output should be similar to:

```
OSGi System Bundle, ObjectWeb ASM, log4j.osgi, spring-test, spring-osgi-test, spring-osgi-core,
    spring-aop, spring-osgi-io, slf4j-api,
spring-osgi-extender, etc... TestBundle-testOsgiPlatformStarts-com.your.package.SimpleOsgiTest,
```

As you can see, the testing framework installs the mandatory requirements required for running the test such as the Spring, Spring DM, slf4j jars among others.

12.2.2. Installing Test Prerequisites

OSGi-friendly libraries

To work in OSGi environments, jars need to declare in their `MANIFEST.MF`, Export or Import packages; that is declare what classes they need or offer to other bundles. Most libraries are OSGi unaware and do not provide the proper manifest entries which means they are unusable in an OSGi environment.

At the moment, there are several initiatives in the open source space to provide the proper manifest - please see the FAQ for more information.

Besides the Spring DM jars and the test itself is highly likely that you depend on several libraries or your own code for the integration test.

Consider the following test that relies on Apache Commons Lang:

```
import org.apache.commons.lang.time.DateFormatUtils;
    ...
          public void testCommonsLangDateFormat() throws Exception {
                System.out.println(DateFormatUtils.format(new Date(), "HH:mm:ssZZ"));
        }
}
```

Running the test however yields an exception:

```
java.lang.IllegalStateException: Unable to dynamically start generated unit test bundle
     ...
Caused by: org.osgi.framework.BundleException: The bundle could not be resolved.
Reason: Missing Constraint: Import-Package: org.apache.commons.lang.time; version="0.0.0"
    ...
        ... 15 more
```

The test requires `org.apache.commons.lang.time` package but there is no bundle that exports it. Let's fix this by installing a commons-lang bundle (make sure you use at least version 2.4 which adds the proper OSGi entries to the jar manifest).

One can specify the bundles that she wants to be installed using `getTestBundlesNames` or `getTestBundles` method. The first one returns an array of String that indicate the bundle name, package and versioning through as a String while the latter returns an array of `Resources` that can be used directly for installing the bundles. That is, use `getTestBundlesNames` when you rely on somebody else to locate (the most common case) the bundles and `getTestBundles` when you want to locate the bundles yourself.

By default, the test suite performs a lookup for artifacts, similar to the one used by Maven2, searching first the items as being relative to the current project and then falling back to the local repository. The locator expects the bundle String to be a comma separated values containing the artifact group, name, version and (optionally) type. It's likely that in the future, various other locators will be available. One can plug in their own locator through the `org.springframework.osgi.test.provisioning.ArtifactLocator` interface.

Let's fix our integration test by installing the required bundle (and some extra osgi libraries):

```
protected String[] getTestBundlesNames() {
        return new String[] { "net.sourceforge.cglib, com.springsource.net.sf.cglib, 2.1.3",
                "javax.transaction, com.springsource.javax.transaction, 1.1.0",
                "commons-lang, commons-lang, 2.4" };
        };
}
```

Rerunning the test should show that these bundles are now installed in the OSGi platform.

Note

The artifacts mentioned above have to exist in your local maven repository.

12.2.3. Advanced Testing Framework Topics

The testing framework allows a lot of customization to be made. This chapter details some of the existing hooks that you might want to know about. However, these are advanced topics as they increase the complexity of your test infrastructure.

12.2.3.1. Customizing The Test Manifest

There are cases where the auto-generated test manifest does not suit the needs of the test. For example the manifest requires some different headers or a certain package needs to be an optional import.

For simple cases, one can work directly with the generated manifest - in the example below, the bundle class path is being specified:

```
protected Manifest getManifest() {
      // let the testing framework create/load the manifest
      Manifest mf = super.getManifest();
      // add Bundle-Classpath:
      mf.getMainAttributes().putValue(Constants.BUNDLE_CLASSPATH, ".,bundleclasspath/simple.jar");
      return mf;
}
```

Another alternative is to provide your own manifest by overriding `getManifestLocations()`:

```
protected String getManifestLocation() {
      return "classpath:com/xyz/abc/test/MyTestTest.MF";
}
```

However each manifest needs the following entry:
“Bundle-Activator: org.springframework.osgi.test.JUnitTestActivator”

since without it, the testing infrastructure cannot function properly. Also, one needs to import JUnit, Spring and Spring DM specific packages used by the base test suite:

```
Import-Package: junit.framework,
  org.osgi.framework,
  org.apache.commons.logging,
  org.springframework.util,
  org.springframework.osgi.service,
  org.springframework.osgi.util,
  org.springframework.osgi.test,
  org.springframework.context
```

Failing to import a package used by the test class will cause the test to fail with a `NoDefClassFoundError` error.

12.2.3.2. Customizing Test Bundle Content

By default, for the on-the-fly bundle, the testing infrastructure uses all the classes, xml and properties files found under `./target/test-classes` folder. This matches the project layout for maven which is used (at the moment by Spring DM). These settings can be configured in two ways:

1. programmatically by overriding `AbstractConfigurableBundleCreatorTests` `getXXX` methods.
2. declaratively by creating a properties file having a similar name with the test case. For example, test `com.xyz.MyTest` will have the properties file named `com/xyz/MyTest-bundle.properties`. If found, the following properties will be read from the file:

Table 12.1. Default test jar content settings

Property Name	Default Value	Description
root.dir	`file:./target/test-classes`	the root folder considered as the jar root
include.patterns	`/**/*.class,/**/*.xml,/**/*.properties`	Comma-separated string of Ant-style patterns

Property Name	Default Value	Description
manifest	(empty)	manifest location given as a String. By default it's empty meaning the manifest will be created by the test framework rather then being supplied by the user.

This option is handy when creating specific tests that need to include certain resources (such as localization files or images).

Please consult `AbstractConfigurableBundleCreatorTests` and `AbstractOnTheFlyBundleCreatorTests` tests for more customization hooks.

12.2.3.3. Understanding The `MANIFEST.MF` Generation

A useful feature of the testing framework represents the automatic creation of the test manifest based on the test bundle content. The manifest creator component uses byte-code analysis to determine the packages imported by the test classes so that it can generate the proper OSGi directives for them. Since the generated bundle is used for running a test, the creator will use the following assumptions:

- No packages will be exported.

  The *on-the-fly* bundle is used for running a test which (usually) consumes OSGi packages for its execution. This behaviour can be changed by customizing the manifest.

- Split packages (i.e. classes from the same package can come from different bundles) are not supported.

  This means that packages present in the test framework are considered complete and no `Import-Package` entry will be generated for them. To avoid this problem, consider using sub-packages or moving the classes inside one bundle. Note that split packages are discouraged due to the issues associated with them (see the OSGi Core spec, Chapter 3.13 - Required Bundles).

- The test bundle contains only test classes.

  The byte-code parser will look only at the test classes hierarchy. Any other class included in the bundle, will not be considered so no imports will be generated for it. To change the default behaviour, override `createManifestOnlyFromTestClass` to return `false`:

```
protected boolean createManifestOnlyFromTestClass() {
        return false;
}
```

Note

The time required to generate the manifest might increase depending on the number and size of classes in the bundle.

Additionally consider customizing the manifest yourself or attaching the extra code as inner classes to the test class (so it gets parsed automatically).

The reason behind *the lack of such features* is the byte-code parser is aimed to be simple and fast at creating test manifests - it is not meant as a general-purpose tool for creating OSGi artifacts.

12.2.4. Creating An OSGi Application Context

Spring DM testing suite builds on top of Spring testing classes. To create an application context (OSGi specific), one should just override `getConfigLocations[]` method and indicate the location of the application context configuration. At runtime, an OSGi application context will be created and cached for the lifetime of the test case.

```
protected String[] getConfigLocations() {
   return new String[] { "/com/xyz/abc/test/MyTestContext.xml" };
}
```

12.2.5. Specifying The OSGi Platform To Use

The testing framework supports out of the box, three OSGi 4.0 implementations namely: Equinox, Knopflerfish and Felix. To be used, these should be in the test classpath. By default, the testing framework will try to use Equinox platform. This can be configured in several ways:

1. programmatically through `getPlatformName()` method
   .

   Override the aforementioned method and indicate the fully qualified name of the `Platform` interface implementation. Users can use the `Platforms` class to specify one of the supported platforms:

```
protected String getPlatformName() {
   return Platforms.FELIX;
}
```

2. declaratively through `org.springframework.osgi.test.framework` system property.

   If this property is set, the testing framework will use its value as a fully qualified name of a Platform implementation. It that fails, it will fall back to Equinox after logging a warning message. This option is useful for building tools (such as ant or maven) since it indicates a certain target environment without changing and test code.

12.2.6. Waiting For The Test Dependencies

A built-in feature of the testing framework is the ability to wait until all dependencies are deployed before starting the test execution. Since the OSGi platforms are concurrent by nature, installing a bundle doesn't mean that all its services are running. By running a test before its dependency services are fully initialized can cause sporadic errors that pollute the test results. By default, the testing framework inspects all bundles installed by the user and, if they are Spring-powered bundles, waits until they are fully started (that is their application context is published as an OSGi service). This behaviour can be disabled by overriding `shouldWaitForSpringBundlesContextCreation` method. Consult `AbstractSynchronizedOsgiTests` for more details.

12.2.7. Testing Framework Performance

Considering all the functionality offered by the testing framework, one might wonder if this doesn't become a performance bottleneck. First, it's worth noting that all the work done automatically by the testing infrastructure has to be done anyway (such as creating the manifest or creating a bundle for the test or installing the bundles). Doing it manually simply does not work as it's too error prone and time consuming. In fact, the current

infrastructure started as way to do efficient, automatic testing without worrying about deployment problems and redundancy.

As for the numbers, the current infrastructure has been used internally for the last half a year - our integration tests (around 120) run in about 3:30 minutes on a laptop. Most of this time is spent on starting and stopping the OSGi platform: the "testing framework" takes around 10% (as shown in our profiling so far). For example, the manifest generation has proved to take less then 0.5 seconds in general, while the jar creation around 1 second.

However, we are working on making it even faster and smarter so that less configuration options are needed and the contextual information available in your tests is used as much as possible. If you have any ideas or suggestion, feel free to use our issue tracker or/and forum.

Hopefully this chapter showed how Spring DM testing infrastructure can simplify OSGi integration testing and how it can be customized. Consider consulting the javadocs for more information.

Part III. Other Resources

In addition to this reference documentation, there are a number of other resources that may help you learn how to use OSGi and Spring Dynamic Modules. These additional, third-party resources are enumerated in this section.

Chapter 13. Useful Links

- *Spring DM Home Page* - here
- *SpringSource OSGi blog* - here
- *Spring DM Demos* - here
- *Getting Started with OSGi* - by Neil Bartlett here and here.
- *Equinox Documents* - here
- *Felix-related presentations* - various presentations hosted by Apache Felix project.
- *Launching Spring Dynamic Modules using pax-runner* - screencast
- *OSGi Alliance Blog* - here

Part IV. Appendixes

Document structure

Various appendixes outside the reference documentation.

Appendix A, *Extensions* describes extensions that are included in the 1.0 distribution, but are not guaranteed to be maintained in a backward-compatible form in future point releases. We anticipate these features moving into the core specification over time.

Appendix B, *Security Integration* provides information on how to run Spring DM in an OSGi environment with a `SecurityManager` enabled (Java 2 Security activated).

Appendix C, *Eclipse Plug-in Development integration* describes how to integrate Spring DM with Eclipse Plug-in Development Environment.

Appendix D, *Spring Dynamic Modules Maven Archetype* describes the Spring DM Maven 2 archetype usage.

Appendix E, *Useful OSGi tips* provides some useful OSGi tips, especially meaningful when used along with Spring DM.

Appendix F, *Roadmap* describes some features that are included in the 1.0 distribution but are still considered early-access. The externals of these features may change in future releases. This appendix also discusses other planned features for which no implementation yet exists.

Appendix G, *Spring DM OSGi Repository* describes the repository used by Spring DM for its osgi artifacts.

Appendix H, *Spring Dynamic Modules Schema* defines the schemas provided by Spring Dynamic Modules.

Appendix A. Extensions

Spring DM and Spring annotations

This chapter describes the annotations present in Spring DM and how to enable/disable them. Spring DM annotatations are separate from the annotation support in Spring framework; enabling or disabling one does not interfere with the other.

This appendix describes extensions to the core functionality that are shipped with the 1.0 distribution, but are not guaranteed to have backwards compatibility across point releases. We anticipate these features migrating into the core specification in future releases.

A.1. Annotation-Based Injection

The `org.springframework.osgi.extensions.annotation` bundle that ships with Spring Dynamic Modules provides early access to annotation-based support for injecting references to OSGi services. JDK 1.5 or above is required to use this feature.

Bean class (setter) methods may be annotated with `org.springframework.osgi.extensions.annotation.ServiceReference`. By default the property type of the annotated property is used to look up a service with a matching service interface in the OSGi service registry and inject the result. For example, given the configuration:

```
<bean id="annotationDriven" class="MyAnnotationDrivenBeanClass"/>
```

and the class declaration:

```
public class MyAnnotationDrivenBeanClass {

  @ServiceReference
  public void setMessageService(MessageService aService) { ... }

}
```

then a service lookup for services implementing the `MessageService` interface will be performed, and the best match (using the same algorithm as documented for the `reference` element) will be injected.

The `ServiceReference` annotation class has a number of attributes that can be used to control the service lookup (for example, to specify a filter string) that mirror the options provided by the `reference` element. See the javadoc for more information.

A.1.1. Enabling/Disabling Annotation Processing

By default, as Spring-OSGi is JDK 1.4 compatible, annotation injection is disabled. There are currently two ways for enabling it:

- through Spring DM extender (see Section 7.3, “Extender Configuration Options”).

  This is an extender wide configuration which means all bundles started by the extender will have annotation

injection applied to them.

- by specifying a dedicated bean post processor

  By specifying the Spring DM annotation extension processor, one can enable *per-bundle* annotation injection. To do that, add the following to your bundle configuration:

```
<!-- annotation processor -->
<bean class="org.springframework.osgi.extensions.annotation.ServiceReferenceInjectionBeanPostProcessor"/>
```

As a reminder, for the annotations to work, the containing bundle needs to import `org.springframework.osgi.extensions.annotation` package, which is available in the `spring-osgi-annotation` bundle.

Appendix B. Security Integration

Since 1.2.0, Spring DM integrates with Java 2 security. Namely Spring DM uses privileged blocks for executing security sensitive operations using its own permissions.

Being a framework, Spring DM needs to introspect bundles to determine their content and configuration. In general, it is recommended to grant `java.security.AllPermission` to Spring DM bundles. For those that would like to restrict the properties, below you can find a list of permissions that are needed for Spring DM to work properly. However, we *strongly* recommend to test whether the permissions are needed or not for your environment since the minimum number depends heavily on what parts of the framework are used.

Table B.1. Spring DM Permission Table

Permission	Target	Action	Usage
`java.io.FilePermission`	*depends*, <<ALL FILES>> recommended	read/write	Required by the logging system and web extender for installing the wars and JSP taglibs
`java.lang.RuntimePermission`	*	accessDeclaredMembers	Used in some cases for reflection (such as accessing the `BundleContext` from a given `Bundle` (on R4.0 platforms).
`java.lang.reflect.ReflectPermission`	*	suppressAccessChecks	Used for accessing (through reflection) non-public methods or fields internally.
`java.util.PropertyPermission`	*	read,write	In use by the testing framework mainy. Useful for reading the environment, including OSGi properties.
`org.osgi.framework.AdminPermission`	*	class, execute, listener, metadata, resolve, resource	Used by the extender to listen read the content of started bundles.
`org.osgi.framework.BundlePermission`	*	HOST	Useful when attaching a custom configuration (as fragment) to the extender/web extender.
`org.osgi.framework.PackagePermission`	*	EXPORT, IMPORT	Basic permission used for importing and exporting the Spring DM bundles content.
`org.osgi.framework.ServicePermission`	*	get,register	Used for publishing and lookup of Spring DM internal services (such as the Spring namespace handlers/resolvers).

Note that as of Spring DM 2.0, the extender will use the target bundle permissions for all actions executed on its behalf. That is, loading of classes, publishing the services, importing packages or the method invocations are executed using the bundle credentials just as if the user bundle would

As a general recommendation, for security sensible environments, to determine the minimum number of permissions start with a basic set of bundles and no permissions. This way, on each run, one can find out what permissions are needed and by whom and tweak the system accordingly.

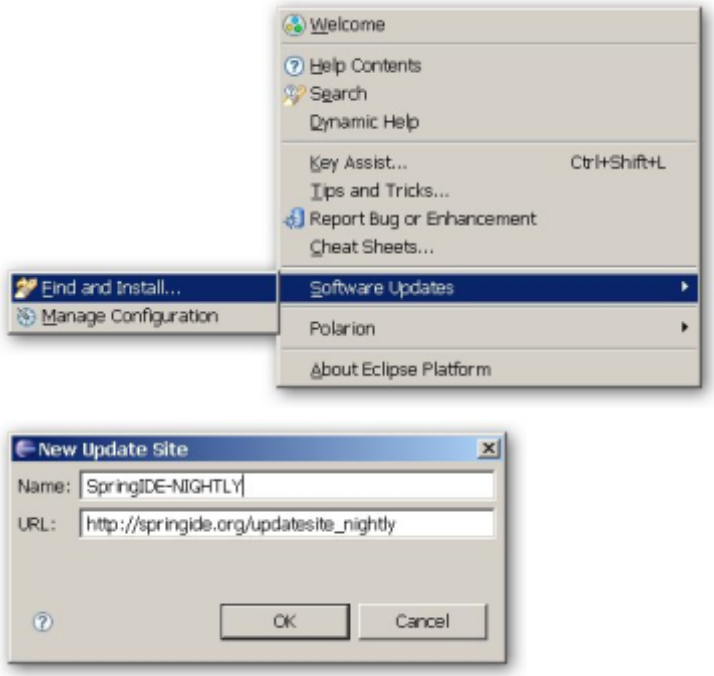
Appendix C. Eclipse Plug-in Development integration

Eclipse PDE "provides comprehensive OSGi tooling, which makes it an ideal environment for component programming, not just Eclipse plug-in development". In fact, Eclipse IDE is built on top of OSGi and uses at its core the Equinox OSGi implementation. Moreover, all the Eclipse plug-ins are OSGi bundles. This makes Eclipse with PDE a very attractive tool for creating OSGi bundles. While Spring Dynamic Modules artifacts can be integrated as *normal* libraries, through Spring IDE, Spring DM can be installed as a target platform ready to be used with PDE.

The following steps illustrate how to install Spring IDE extension for OSGi and how to use it in your project. Please see Spring IDE installation page for information on its requirement and install process.

1. **Set Up Nightly Update Site**

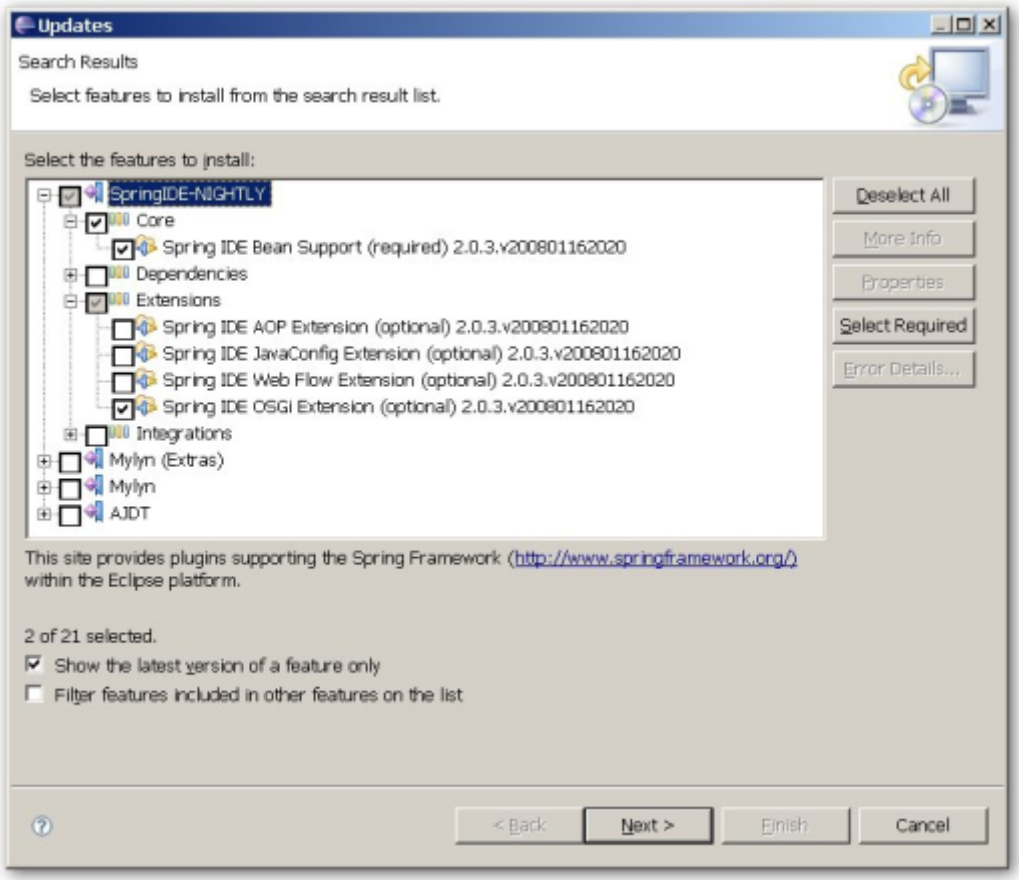
   At the moment, the OSGi extension is available only on Spring-IDE nightly builds update site. Add it to the Eclipse configuration by opening the software update menu:



   and create a new update site pointing to `http://www.springide.org/updatesite_nightly`

2. **Select Spring IDE OSGi extension**

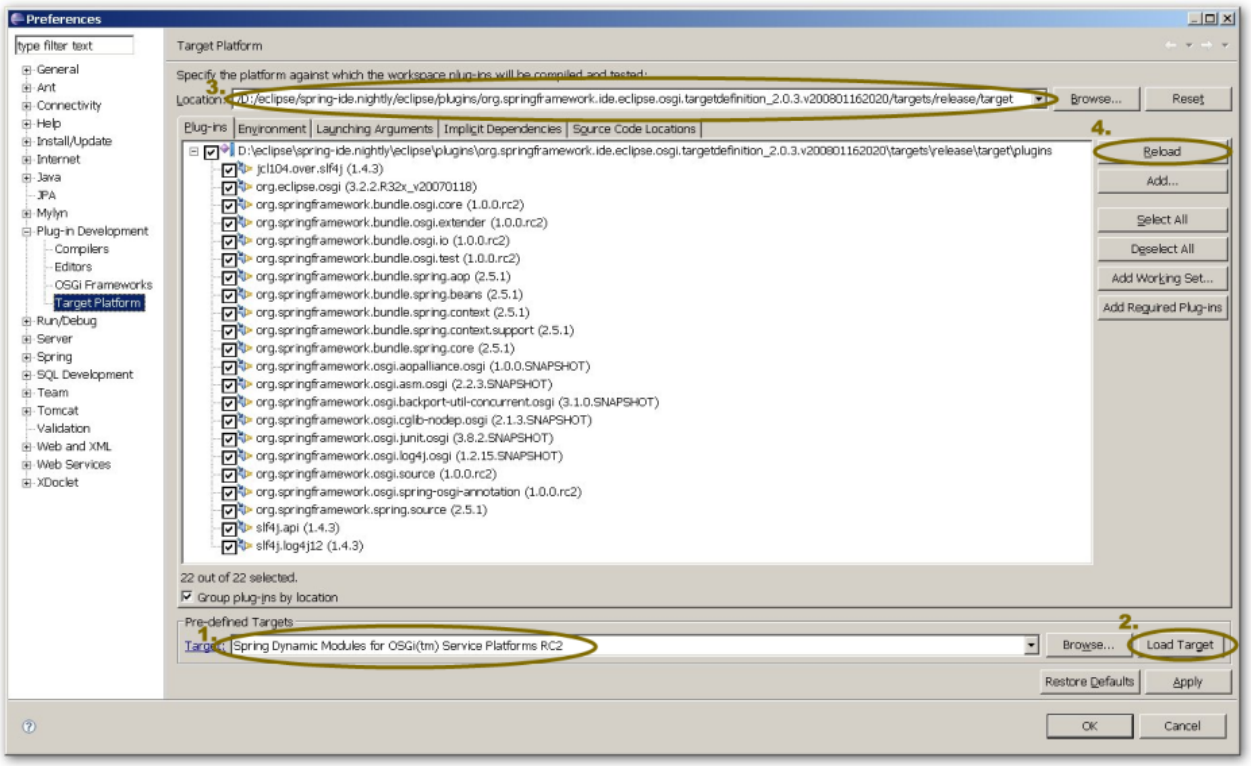
   After using the nightly update site and performing the update, Eclipse will show the search results. Unfold the *Extension* menu and select `Spring IDE OSGi Extension`:



and proceed with the instalation.

3. **Select Spring Dynamic Modules Target Platform**

Once the plug-in has been installed, Spring Dynamic Modules can be selected as a PDE target platform. Select Window/Preferences/Plug-in Development and then Target Platform.



Select the Spring DM version that you desire from the Pre-defined Target (1) drop box and press Load Target (2). Eclipse will load the target and all bundles defined by it - this includes Spring DM bundles and all of its dependencies (SLF4J is used for logging). The configuration can be customised appropriately by removing and adding bundles.

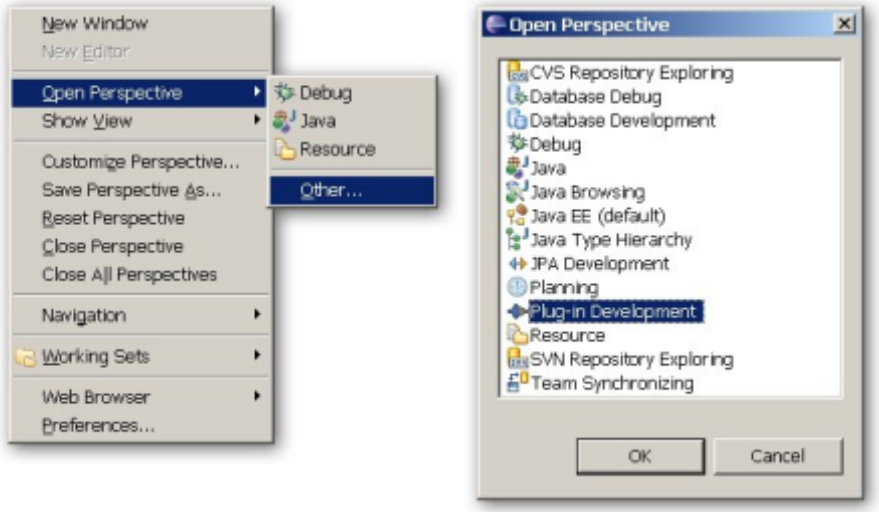
In its current form, the plug-in offers two predefined targets - one for the stable released versions and one for the SNAPSHOT/nightly Spring DM jars. The latter does not contain any jars as it is expected for the user to download them manually. Simply locate the path where the plug-ins should be located (3), enter that folder and do a

```
mvn install
```

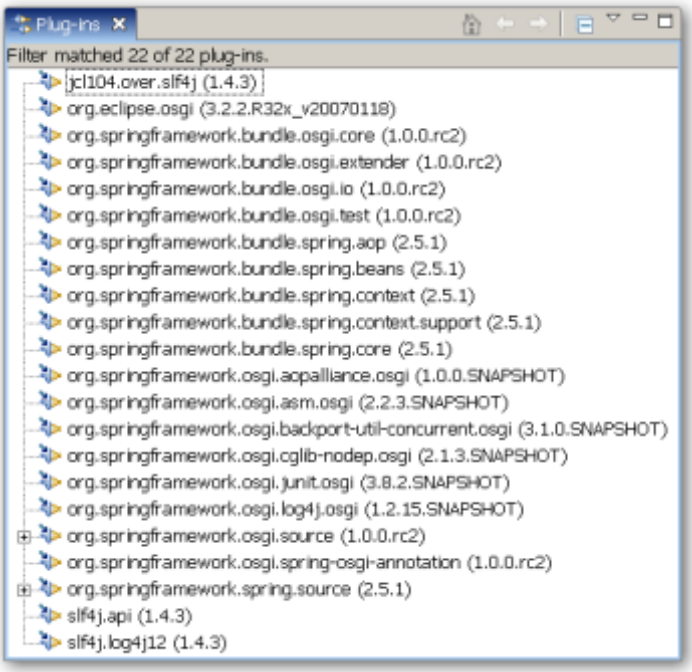
The latest Spring DM SNAPSHOT will be downloaded along with all of its dependencies. Simply click on the reload button (4) and Eclipse will pick up the bundles.

4. **Select PDE Perspective**

Once the installation is completed just select the PDE perspective:



and the Spring DM and its dependencies should be available in the plug-ins view:


Plug-ins
Filter matched 22 of 22 plug-ins.
jcl104.over.slf4j (1.4.3)
org.eclipse.osgi (3.2.2.R32x_v20070118)
org.springframework.bundle.osgi.core (1.0.0.rc2)
org.springframework.bundle.osgi.extender (1.0.0.rc2)
org.springframework.bundle.osgi.io (1.0.0.rc2)
org.springframework.bundle.osgi.test (1.0.0.rc2)
org.springframework.bundle.spring.aop (2.5.1)
org.springframework.bundle.spring.beans (2.5.1)
org.springframework.bundle.spring.context (2.5.1)
org.springframework.bundle.spring.context.support (2.5.1)
org.springframework.bundle.spring.core (2.5.1)
org.springframework.osgi.aopalliance.osgi (1.0.0.SNAPSHOT)
org.springframework.osgi.asm.osgi (2.2.3.SNAPSHOT)
org.springframework.osgi.backport-util-concurrent.osgi (3.1.0.SNAPSHOT)
org.springframework.osgi.cglib-nodep.osgi (2.1.3.SNAPSHOT)
org.springframework.osgi.junit.osgi (3.8.2.SNAPSHOT)
org.springframework.osgi.log4j.osgi (1.2.15.SNAPSHOT)
org.springframework.osgi.source (1.0.0.rc2)
org.springframework.osgi.spring-osgi-annotation (1.0.0.rc2)
org.springframework.spring.source (2.5.1)
slf4j.api (1.4.3)
slf4j.log4j12 (1.4.3)

Appendix D. Spring Dynamic Modules Maven Archetype

As part of the distribution, Spring DM provides a Maven archetype which creates the basic structure of a Java project that uses Spring DM, especially useful to new users. To run the archetype (and create the new project), simply run the following command line:

```
mvn archetype:generate
```

The maven plugin will display a selection of possible archetype, from which you should pick `spring-osgi-bundle-archetype (Spring-OSGi archetype)` (currently number 32), and will request input regarding the project about to be created. A list of all available archetypes included with the plugin and their versions is available here.

Note that it is still possible to select the osgi archetype directly from the command line (i.e. the old way of using the archetype):

```
mvn archetype:create \
-DarchetypeGroupId=org.springframework.osgi \
-DarchetypeArtifactId=spring-osgi-bundle-archetype \
-DarchetypeVersion=   \
-DgroupId=<your-project-groupId>  \
-DartifactId=<your-project-artifactId> \
-Dversion=<your-project-version>
```

Note

The command above should be invoked as one line - the `\` is used as a convenience to break the long line into smaller pieces

In both cases, the result of the commands is a Maven 2 project that defines two packages (one public and one private) and two Spring configurations: `src/main/resources/META-INF/spring/bundle-context.xml` and `src/main/resources/META-INF/spring/bundle-context-osgi.xml` The project is packaged as an OSGi bundle.

Notice that by default, the project does not contain a MANIFEST.MF for your project. The Maven infrastructure will generate it, either through SpringSource Bundlor (the default) or Apache Felix bundle plug-in. To generate the manifest, run the following (from the project root):

```
mvn package
```

Note

To avoid the confusion between the generated artifacts and maintained files, the manifest file resides under `META-INF` folder while Spring configuration files under `src/main/resources/META-INF` directory.

This will compile your project, pack it as a jar and create the OSGi manifest based on your classes under `/META-INF` folder (so that users running Eclipse PDE can use it right away.

D.1. Generated Project Features At-A-Glance

- Packaged as an OSGi bundle
- `META-INF/MANIFEST.MF` automatically generated
- `src/main/java/<package>` public package exported by the bundle
- `src/main/java/<package>/internal` private package, not exported by the bundle
- `src/main/resources/META-INF/spring/bundle-context.xml` is a Spring configuration file that defines the simple bean.
- `src/main/resources/META-INF/spring/bundle-context-osgi.xml` is a Spring configuration file ready for you to add bean definitions from the osgi namespace (services, references etc.)
- `.project`, `.classpath`, and `build.properties` files created to enable use of this project directly inside eclipse as a PDE plugin project

Appendix E. Useful OSGi tips

E.1. OSGi Fragments

Check the target OSGi platform fragment support

Before using fragments, make sure the target OSGi environment supports them (and to what degree). Out of the OSGi platforms on which Spring DM is tested upon, at the time of this writing, Apache Felix does not support fragments (it simply ignores them).

Part of the OSGi R4 release, *fragments* are a very useful and powerful feature. A fragment is "a bundle that is *attached* to a *host bundle*", adding content to the target bundle. A fragment cannot have its own class loader nor a bundle activator and cannot override the information already present in the host. In short, through fragments, bundles can be extender with resources, classes and even manifest entries. To quote the spec again, 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."

Note

For a full description on fragments, please see the OSGi specification, section 3.14.

In Spring DM, fragments are useful for configuring various components such as the extenders. To do that, simply bundle the resources as you normally would and add an extra entry to the bundle manifest:

```
Fragment-Host: <host bundle symbolic name>
```

This line indicates that the containing bundle is a fragment and that it should be attached to the host specified by a symbolic name. The fragment and host bundle symbolic name should be different. For example, to attach a fragment (with extra configuration) the Spring DM extender, one could use the following manifest:

```
Manifest-Version: 1.0                                                    ❶
Bundle-ManifestVersion: 2                                                ❷
Fragment-Host: org.springframework.osgi.extender                         ❸
Bundle-SymbolicName: org.mydomain.project.fragment                       ❹
Bundle-Name: my-fragment                                                 ❺
Bundle-Description: Fragment attached to Spring DM extender              ❻
```

❶ Manifest version.

❷ OSGi bundle version. A value of `1` (which is also the default) indicates an OSGi Release 3 bundle so it's best to specify `2` to indicate an OSGi Release 4 bundle.

❸ The symbolic name of the bundle to which this fragment should be attached to. In this case, the value `org.springframework.osgi.extender` points to the `spring-osgi-extender.jar`. `Fragment-Host` is the *key* entry which tells the OSGi platform that the containing bundle is a of a special kind - it's a fragment.

❹ The fragment symbolic name.

❺ The bundle name - an optional yet useful header.

❻ The bundle description - just like the name, this header is useful for humans not for the OSGi platform itself. However, it is recommended that you define it to help identify the bundle purpose.

Note

The Manifest entries order does not matter, but they case sensitive.

When multiple bundles with the same symbolic names are present, one can add the bundle version to make sure the proper wiring is done:

```
Fragment-Host: org.springframework.osgi.extender;bundle-version=1.1.0
```

The default value for `bundle-version` (when it's not specified) is `[0.0.0,#)`

Appendix F. Roadmap

This appendix documents features on the Spring Dynamic Modules roadmap. The design of these features specified here is subject to change. As a most up to date source, please see our issue tracker.

F.1. Start Level Integration

A future release of Spring Dynamic Modules may offer the following additional guarantee with respect to application context creation and start levels:

Application context creation happens asynchronously. However, the extender bundle does guarantee that the creation of all application contexts for bundles at start level `n` will be complete before the creation of any application context at start level `m`, where `m > n`. Care must therefore be taken not to introduce any mandatory dependencies on services exported by bundles with higher start levels or a deadlock will be introduced.

In a similar vein, when shutting down the extender bundle, application contexts at start level `m` will be shut down before application contexts at start level `n`, where `m > n`.

F.2. Web Library Integration

While support for generic and Spring-MVC web applications is available in 1.1.0, in the future we'd like to provide integration (if needed) with other popular web libraries (such as JSF and Spring Web Flow) in the upcoming releases.

F.3. ORM/Persistence Support

Care needs to be taken when using JPA or Hibernate under OSGi as the persistence engines must have visibility of the persistent types and mapping files. The Spring Dynamic Modules project will be investigating an extension model to make managing this easier when persistent configuration is split across several bundles. See Peter Krien's blog entry on the topic for an insight into the issues.

Also, the project aims to simplify deployment of JDBC drivers and pooling libraries that at the moment require special `DynamicImport-Package`.

Appendix G. Spring DM OSGi Repository

At the moment, most libraries are not released as OSGi bundles which means they cannot be used inside the OSGi space unless they are embedded in other bundles. Though there are tools that make the bundling process easy, it is desirable to have the artifacts prepacked so they can be used immediately for development.

SpringSource Enterprise Bundle Repository (or SpringSource Repository) addresses this problem by providing "a collection of open source libraries commonly used for developing enterprise Java applications with the Spring Framework" (taken from the Repository FAQ). With the availability of the Bundle Repository, the Spring DM old repository (see below) has been deprecated and it is being used until migrating completely to SpringSource Repository. It is highly recommended that users migrate as well to SpringSource Repository as it provides significantly more libraries and it is intended to be a user-facing infrastructure component.

G.1. Spring DM Temporary OSGi Repository

Unfortunately, not all Spring DM dependencies are available in SpringSource Repository and thus Spring DM still needs to maintain some of its own dedicated Maven repository available at `http://maven.springframework.org/osgi`.

Warning

The repository is *provided as-is* without any kind of support. The repository structure/content can (and will) change until it becomes stable. Before using Spring DM repository make sure the needed artifact are not available in SpringSource Repository. These being said, we hope you find it useful and we'd like to know if there are improvement that can be made to it.

G.1.1. Repository Conventions

Currently, all the artifacts published in the repository are marked as `SNAPSHOT`s meaning that, in time, their content can change. This allows clients to download possible manifest updates made to the libraries. We foresee that, as the library usage increases, several popular items will have the `SNAPSHOT` marker remove. Additionally, to differentiate the *OSGi*-enabled artifacts from the original ones, all libraries are placed under `org.springframework.osgi` group and their names contains a `.osgi` suffix.

So for example, an OSGi version of `mx4j-3.0.2` jar is available in the Spring DM OSGi repository under at: `org/springframework/osgi/mx4j.osgi/3.0.2-SNAPSHOT/mx4j.osgi-3.0.2-SNAPSHOT.jar`

G.1.2. Browsing The Repository Content

The repository is currently hosted at Amazon S3. To browse the repository structure, use a S3 compatible browser (such as this one) since a vanilla web browse will not be suitable.

G.1.3. Using The Repository With Maven

The use the repository, simply add it ot the `repositories` group; since the repository contains `SNAPSHOT` artifacts, make sure to mark it accordingly:

```
<repositories>
  <repository>
    <id>spring-osgified-artifacts</id>
```

```
    <snapshots>
      <enabled>true</enabled>
    </snapshots>
    <name>Springframework Maven OSGified Artifacts Repository</name>
    <url>http://maven.springframework.org/osgi</url>
  </repository>
</repositories>
```

G.1.4. Using The Repository With Ant/Ivy

When using Ant consider using the excellent Ivy subproject for retrieving the OSGi dependencies from the Spring DM repository as Ivy can work with a Maven-style repository. Please see the Ivy tutorial for more information.

Appendix H. Spring Dynamic Modules Schema

Spring Core Schema

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>

<xsd:schema xmlns="http://www.springframework.org/schema/osgi"
        xmlns:xsd="http://www.w3.org/2001/XMLSchema"
        xmlns:beans="http://www.springframework.org/schema/beans"
        xmlns:tool="http://www.springframework.org/schema/tool"
        targetNamespace="http://www.springframework.org/schema/osgi"
        elementFormDefault="qualified"
        attributeFormDefault="unqualified"
        version="2.0.0.M1">

        <xsd:import namespace="http://www.w3.org/XML/1998/namespace"/>
    <xsd:import namespace="http://www.springframework.org/schema/beans"/>
    <xsd:import namespace="http://www.springframework.org/schema/tool"/>

    <xsd:annotation>
        <xsd:documentation><![CDATA[
    Namespace support for the core services provided by Spring Dynamic Modules.
        ]]></xsd:documentation>
    </xsd:annotation>

    <xsd:attributeGroup name="defaults">
            <xsd:annotation>
                    <xsd:documentation><![CDATA[Defaults for Spring-DM OSGi declarations.]]>
                    </xsd:documentation>
            </xsd:annotation>
            <!-- attributes -->
            <xsd:attribute name="default-timeout" type="xsd:long" default="30000">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
    Default timeout (in milliseconds) for all reference (service importers) elements that do not explicitly spec
    Default value is 300000 ms (5 minutes).
                            ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="default-availablility" type="TavailabilityOptions" default="mandatory">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
    Default availability for all OSGi references (singular or collections) elements that do not explicitly speci
    Default value is 'mandatory' which means that a backing service must exist while 'optional' indicates that i
    acceptable to be no backing service.
                        ]]></xsd:documentation>
                </xsd:annotation>
        </xsd:attribute>
            <xsd:attribute name="default-cardinality" type="TdefaultCardinalityOptions" default="1..X">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
    As of Spring DM 2.0, 'default-cardinality' has been replaced by 'default-availability' attribute.

    Default cardinality (of the relationship to the backing service(s)) for all OSGi references (singular or col
    elements that do not explicitly specify one.
    Default value is '1..X' (resolved to '1..1' for osgi:reference and '1..N' for osgi:list/set) which means tha
    service must exist (this is a mandatory service reference). A value of '0..X' (resolved to '0..1' for osgi:r
    and '0..N' for osgi:list/set) indicates that it is acceptable to be no backing service (an optional service
                        ]]></xsd:documentation>
                </xsd:annotation>
        </xsd:attribute>
    </xsd:attributeGroup>

    <xsd:simpleType name="TavailabilityOptions">
        <xsd:restriction base="xsd:NMTOKEN">
            <xsd:enumeration value="mandatory">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
    Mandatory service reference - a backing service must exist.
                            ]]></xsd:documentation>
                    </xsd:annotation>
```

```
        </xsd:enumeration>
        <xsd:enumeration value="optional">
                <xsd:annotation>
                        <xsd:documentation><![CDATA[
Optional service reference - A backing service can be missing.
                        ]]></xsd:documentation>
                </xsd:annotation>
        </xsd:enumeration>
    </xsd:restriction>
</xsd:simpleType>

<xsd:simpleType name="TdefaultCardinalityOptions">
    <xsd:restriction base="xsd:NMTOKEN">
        <xsd:enumeration value="1..X">
                <xsd:annotation>
                        <xsd:documentation><![CDATA[
A backing service must exist (this is a mandatory service reference).
                        ]]></xsd:documentation>
                </xsd:annotation>
        </xsd:enumeration>
        <xsd:enumeration value="0..X">
                <xsd:annotation>
                        <xsd:documentation><![CDATA[
A backing service can be missing (this is an optional service reference).
                        ]]></xsd:documentation>
                </xsd:annotation>
        </xsd:enumeration>
    </xsd:restriction>
</xsd:simpleType>

<!-- reference -->
<xsd:element name="reference" type="TsingleReference">
    <xsd:annotation>
        <xsd:documentation><![CDATA[
Defines a reference to a service obtained via the OSGi service registry.
        ]]></xsd:documentation>
    </xsd:annotation>
</xsd:element>

<xsd:complexType name="Treference">
    <xsd:complexContent>
        <xsd:extension base="beans:identifiedType">
            <xsd:sequence minOccurs="0" maxOccurs="1">
                    <xsd:element name="interfaces" type="beans:listOrSetType" minOccurs="0" maxOccurs="1">
                        <xsd:annotation>
                                <xsd:documentation><![CDATA[
    The set of service interfaces that the services obtained via the registry are required to support.
By convention, the interface attribute is a Java interface type, but may also be a (non-final)
class type.
                                ]]></xsd:documentation>
                        </xsd:annotation>
                </xsd:element>
                <xsd:element name="reference-listener" type="Tlistener" minOccurs="0" maxOccurs="unbounded">
                  <xsd:annotation>
                          <xsd:documentation><![CDATA[
Defines a listener that will receive notification when a service backing this reference is
bound or unbound.
                          ]]></xsd:documentation>
                  </xsd:annotation>
                </xsd:element>
                <xsd:element name="listener" type="Tlistener" minOccurs="0" maxOccurs="unbounded">
                  <xsd:annotation>
                          <xsd:documentation><![CDATA[
Defines a listener that will receive notification when a service backing this reference is
bound or unbound. Deprecated since Spring DM 2.x, in favour of 'reference-listener'.
                          ]]></xsd:documentation>
                  </xsd:annotation>
                </xsd:element>
            </xsd:sequence>
            <xsd:attribute name="interface" use="optional" type="xsd:token">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
The service interface that the services obtained via the registry are required to support.
By convention this is a Java interface type, but may also be a (non-final) class type.
                            ]]></xsd:documentation>
                            <xsd:appinfo>
                                    <tool:annotation>
                                            <tool:expected-type type="java.lang.Class" />
```

```
                                    </tool:annotation>
                                </xsd:appinfo>
                        </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="filter" use="optional" type="xsd:string">
                      <xsd:annotation>
                              <xsd:documentation><![CDATA[
    Defines an OSGi filter expression that is used to constrain the set of matching services
    in the service registry.
                              ]]></xsd:documentation>
                      </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="depends-on" type="xsd:string" use="optional">
                                    <xsd:annotation>
                                            <xsd:documentation><![CDATA[
        Used to refer to the name of another bean that this bean depends on. Ensures that the
        service registry look-up does not happen until after the dependent bean has been created
        (most commonly used to refer to a bundle bean).
                                            ]]></xsd:documentation>
                                    </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="bean-name" type="xsd:string" use="optional">
                        <xsd:annotation>
                                <xsd:documentation><![CDATA[
    Convenient shortcut for specifying a filter expression that matches on the bean-name property
    that is automatically advertised for beans published using the service element.
                                ]]></xsd:documentation>
                        </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="context-class-loader" type="TreferenceClassLoaderOptions" default="client">
                        <xsd:annotation>
                                <xsd:documentation><![CDATA[
    Defines how the context class loader is managed when invoking operations on a service
    backing this service reference. The default value is 'client' which means that the context
    class loader has visibility of the resources on this bundle's classpath. Alternate
    options are 'service-provider' which means that the context class loader has visibility of
    resources on the bundle classpath of the bundle that exported the service, and 'unmanaged'
    which does not do any management of the context class loader.
                                ]]></xsd:documentation>
                        </xsd:annotation>
                </xsd:attribute>
            </xsd:extension>
        </xsd:complexContent>
    </xsd:complexType>

    <xsd:simpleType name="TreferenceClassLoaderOptions">
        <xsd:restriction base="xsd:NMTOKEN">
            <xsd:enumeration value="client"/>
            <xsd:enumeration value="service-provider"/>
            <xsd:enumeration value="unmanaged"/>
        </xsd:restriction>
    </xsd:simpleType>

    <xsd:complexType name="Tlistener">
            <xsd:annotation>
                    <xsd:documentation><![CDATA[
    Defines a listener that will be notified when the service backing the enclosing service reference element is
    unbound. Use either the 'ref' attribute or a nested bean declaration for the listener bean.
                    ]]></xsd:documentation>
            </xsd:annotation>
        <xsd:sequence minOccurs="0" maxOccurs="1">
            <!-- nested bean declaration -->
            <xsd:any namespace="##other" minOccurs="1" maxOccurs="1" processContents="skip"/>
        </xsd:sequence>

        <!-- shortcut for bean references -->
        <xsd:attribute name="ref" type="xsd:string" use="optional">
                <xsd:annotation>
                        <xsd:documentation><![CDATA[
    Refers by name to the bean that will receive bind and unbind events
                        ]]></xsd:documentation>
                </xsd:annotation>
        </xsd:attribute>
        <xsd:attribute name="bind-method" type="xsd:token" use="optional">
                <xsd:annotation>
                        <xsd:documentation><![CDATA[
    The name of the method to be invoked when a backing service is bound.
                        ]]></xsd:documentation>
```

```
            </xsd:annotation>
        </xsd:attribute>
        <xsd:attribute name="unbind-method" type="xsd:token" use="optional">
                <xsd:annotation>
                        <xsd:documentation><![CDATA[
    The name of the method to be invoked when a backing service is unbound.
                        ]]></xsd:documentation>
                </xsd:annotation>
        </xsd:attribute>
    </xsd:complexType>

    <!-- single reference -->
    <xsd:complexType name="TsingleReference">
        <xsd:complexContent>
            <xsd:extension base="Treference">
                 <xsd:attribute name="availability" use="optional" type="TavailabilityOptions">
                        <xsd:annotation>
                              <xsd:documentation><![CDATA[
    Defines the required availability of the backing service. If not specified,
    the default-availability attribute will apply. 'mandatory' means that a backing service
    must exist, 'optional' indicates that it is acceptable to have no backing service.
                              ]]></xsd:documentation>
                         </xsd:annotation>
                 </xsd:attribute>
                 <xsd:attribute name="cardinality" use="optional" type="TsingleReferenceCardinality">
                        <xsd:annotation>
                              <xsd:documentation><![CDATA[
        As of Spring DM 2.0, 'cardinality' has been replaced by the 'availability' attribute.

    Defines the required cardinality of the relationship to the backing service. If not specified,
    the default-cardinality attribute will apply. A value of '1..1' means that a backing service
    must exist (this is a mandatory service reference). A value of '0..1' indicates that it is
    acceptable to be no backing service (an optional service reference).
                              ]]></xsd:documentation>
                         </xsd:annotation>
                </xsd:attribute>
                            <xsd:attribute name="timeout" use="optional" type="xsd:long">
                    <xsd:annotation>
                              <xsd:documentation><![CDATA[
    For a 'reference' element, the amount of time (in milliseconds) to wait for a backing service to be
    available when an operation is invoked. If not specified, the default-timeout attribute will apply.
    See also the default-timeout attribute of the osgi element.
                              ]]></xsd:documentation>
                         </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="sticky" type="xsd:boolean" default="true">
                        <xsd:annotation>
                                <xsd:documentation><![CDATA[
    Defines whether the backing service should be changed if a 'better' OSGi service becomes
    available. If 'true', the proxy will rebind only if the backing service is no longer available.
    If 'false', the rebind will occur every time a 'better' candidate appears. A better service is
    defined by having either a higher ranking or the same ranking and a lower service id.
                                ]]></xsd:documentation>
                        </xsd:annotation>
                </xsd:attribute>
            </xsd:extension>
        </xsd:complexContent>
    </xsd:complexType>

    <xsd:simpleType name="TsingleReferenceCardinality">
        <xsd:restriction base="xsd:NMTOKEN">
            <xsd:enumeration value="1..1"/>
            <xsd:enumeration value="0..1"/>
        </xsd:restriction>
    </xsd:simpleType>

        <!-- reference collections (set, list) -->
        <xsd:element name="list" type="TreferenceCollection">
                <xsd:annotation>
                        <xsd:documentation source="java:org.springframework.osgi.service.importer.support.OsgiSe
        Defines a bean of type 'List' that contains all of the services matching the given criteria.
        The list members are managed dynamically as matching backing services come and go.
                        ]]></xsd:documentation>
                        <xsd:appinfo>
                                <tool:annotation>
                                        <tool:exports type="java.util.List"/>
                                </tool:annotation>
                        </xsd:appinfo>
```

```
            </xsd:annotation>
        </xsd:element>

        <xsd:element name="set" type="TreferenceCollection">
                <xsd:annotation>
                        <xsd:documentation source="java:org.springframework.osgi.service.importer.support.OsgiSe
        Defines a bean of type 'Set' that contains all of the services matching the given criteria.
        The set members are managed dynamically as matching backing services come and go.
                        ]]></xsd:documentation>
                        <xsd:appinfo>
                                <tool:annotation>
                                        <tool:exports type="java.util.Set"/>
                                </tool:annotation>
                        </xsd:appinfo>
                </xsd:annotation>
        </xsd:element>

        <xsd:complexType name="TreferenceCollection">
                <xsd:complexContent>
                        <xsd:extension base="Treference">
                                <xsd:sequence minOccurs="0" maxOccurs="1">
                                        <xsd:element name="comparator" type="Tcomparator">
                                                <xsd:annotation>
                                                        <xsd:documentation source="java:java.util.Comparator"><!
        Used to define an inline bean of type Comparator that will be used to sort the matching services.
                                                        ]]></xsd:documentation>
                                                        <xsd:appinfo>
                                                                <tool:annotation>
                                                                        <tool:expected-type type="java.util.Comp
                                                                  </tool:annotation>
                                                        </xsd:appinfo>
                                                </xsd:annotation>
                                        </xsd:element>
                                </xsd:sequence>
                                <xsd:attribute name="comparator-ref" type="xsd:string" use="optional">
                                        <xsd:annotation>
                                                <xsd:documentation><![CDATA[
        Used to refer to a named bean implementing the Comparator interface that will be used to
        sort the matching services.
                                                ]]></xsd:documentation>
                                        </xsd:annotation>
                                </xsd:attribute>
                            <xsd:attribute name="availability" use="optional" type="TavailabilityOptions">
                        <xsd:annotation>
                              <xsd:documentation><![CDATA[
    Defines the required availability of the backing service. If not specified,
    the default-availability attribute will apply. 'mandatory' means that a backing service
    must exist, 'optional' indicates that it is acceptable to have no backing service.
                              ]]></xsd:documentation>
                    </xsd:annotation>
                </xsd:attribute>
                             <xsd:attribute name="cardinality" use="optional" type="TcollectionCardinality">
                        <xsd:annotation>
                              <xsd:documentation><![CDATA[
        As of Spring DM 2.0, 'cardinality' has been replaced by the 'availability' attribute.

    Defines the required cardinality of the relationship to the backing services. If not specified,
    the default-cardinality attribute will apply. A value of '1..N' means that at least one backing
    service must exist (this is a mandatory service reference. A value of '0..N' indicates that it
    is acceptable for there to be no backing service (an optional service reference).
                              ]]></xsd:documentation>
                    </xsd:annotation>
                </xsd:attribute>
                             <xsd:attribute name="greedy-proxying" use="optional" type="xsd:boolean" default="fal
                        <xsd:annotation>
                              <xsd:documentation><![CDATA[
    Indicates whether the proxies created for the imported OSGi services will be generated using
    just the classes specified (false) or all the classes exported by the service and visible to
    the importing bundle (true). The default value is false.
                              ]]></xsd:documentation>
                    </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="member-type" type="TmemberType" use="optional" default="service-object">
                    <xsd:annotation>
                        <xsd:documentation>
                          <![CDATA[
    Indicates the type of object that will be placed within the reference collection.
    'service-object' indicates the collection contains service proxies for imported services.
```

```
    'service-reference' indicates the collection contains ServiceReference objects matching the
    target service type.
                          ]]>
                        </xsd:documentation>
                    </xsd:annotation>
                </xsd:attribute>
                        </xsd:extension>
                </xsd:complexContent>
        </xsd:complexType>

        <xsd:complexType name="Tcomparator">
                <xsd:annotation>
                        <xsd:documentation source="java:java.util.Comparator"><![CDATA[
        Used to define an inline bean of type Comparator that will be used to sort the matching services.
                        ]]></xsd:documentation>
                        <xsd:appinfo>
                                <tool:annotation>
                                        <tool:exports type="java.util.Comparator" />
                                  </tool:annotation>
                        </xsd:appinfo>
                </xsd:annotation>
                <xsd:choice>
                   <xsd:element name="natural" type="TnaturalOrdering"/>
                <xsd:sequence minOccurs="1" maxOccurs="1">
                    <!-- nested bean declaration -->
                          <xsd:any namespace="##other" minOccurs="1" maxOccurs="1" processContents="skip"/>
                </xsd:sequence>
        </xsd:choice>
        </xsd:complexType>

        <xsd:complexType name="TnaturalOrdering">
                <xsd:attribute name="basis" type="TorderingBasis" use="required"/>
        </xsd:complexType>

        <xsd:simpleType name="TorderingBasis">
                <xsd:restriction base="xsd:NMTOKEN">
            <xsd:enumeration value="service"/>
            <xsd:enumeration value="service-reference"/>
        </xsd:restriction>
        </xsd:simpleType>

    <xsd:simpleType name="TmemberType">
        <xsd:restriction base="xsd:NMTOKEN">
            <xsd:enumeration value="service-object" />
            <xsd:enumeration value="service-reference" />
        </xsd:restriction>
    </xsd:simpleType>

        <xsd:simpleType name="TcollectionCardinality">
        <xsd:restriction base="xsd:NMTOKEN">
            <xsd:enumeration value="1..N"/>
            <xsd:enumeration value="0..N"/>
        </xsd:restriction>
    </xsd:simpleType>

    <!-- service -->

    <xsd:element name="service" type="Tservice"/>

    <xsd:complexType name="TbaseService">
        <xsd:complexContent>
           <xsd:extension base="beans:identifiedType">
                <xsd:attribute name="interface" type="xsd:token" use="optional">
                        <xsd:annotation>
                                <xsd:documentation><![CDATA[
    Defines the interface to advertise for this service in the service registry.
                                ]]></xsd:documentation>
                                                <xsd:appinfo>
                                                        <tool:annotation>
                                                                <tool:expected-type type="java.lang.Class" />
                                                          </tool:annotation>
                                                </xsd:appinfo>
                        </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="depends-on" type="xsd:string" use="optional">
                        <xsd:annotation>
                                <xsd:documentation><![CDATA[
    Used to ensure that the service is not exported to the registry before the named bean
```

```
has been created.
                        ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="context-class-loader" type="TserviceClassLoaderOptions" default="unmanaged"
                    <xsd:annotation>
                        <xsd:documentation><![CDATA[
Defines how the context class loader will be managed when an operation is invoked on the
exported service. The default value is 'unmanaged' which means that no management of
the context class loader is attempted. A value of 'service-provider' guarantees that
the context class loader will have visibility of all the resources on the class path of
bundle exporting the service.
                        ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="auto-export" type="TautoExportModes" default="disabled">
                    <xsd:annotation>
                        <xsd:documentation><![CDATA[
Enables Spring to automatically manage the set of service interfaces advertised for the
service. By default this facility is disabled. A value of 'interfaces' advertises all
of the Java interfaces supported by the exported service. A value of 'class-hierarchy'
advertises all the Java classes in the hierarchy of the exported service. A value of
'all-classes' advertises all Java interfaces and classes.
                        ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
            </xsd:extension>
    </xsd:complexContent>
</xsd:complexType>

<xsd:complexType name="Tservice">
        <xsd:annotation>
                <xsd:documentation source="java:org.springframework.osgi.service.exporter.support.OsgiServic
Exports the reference bean as a service in the OSGi service registry. The bean defined by this element is of
type org.osgi.framework.ServiceRegistration.
                ]]></xsd:documentation>
                    <xsd:appinfo>
                        <tool:annotation>
                                <tool:exports type="org.osgi.framework.ServiceRegistration"/>
                        </tool:annotation>
                    </xsd:appinfo>
        </xsd:annotation>
    <xsd:complexContent>
        <xsd:extension base="TbaseService">
                <xsd:sequence minOccurs="0" maxOccurs="1">
                <xsd:element name="interfaces" type="beans:listOrSetType" minOccurs="0" maxOccurs="1">
                        <xsd:annotation>
                            <xsd:documentation><![CDATA[
The set of service interfaces to advertise in the service registry.
                            ]]></xsd:documentation>
                        </xsd:annotation>
                </xsd:element>
                <xsd:element name="registration-listener" type="TserviceRegistrationListener" minOccurs="0"
                        <xsd:annotation>
                            <xsd:documentation><![CDATA[
Defines a listener that will be notified when this service is registered or unregistered in the
OSGi service registry.
                            ]]></xsd:documentation>
                        </xsd:annotation>
                    </xsd:element>
                <xsd:element name="service-properties" type="TserviceProperties" minOccurs="0" maxOccurs="1"
                           <xsd:annotation>
                            <xsd:documentation><![CDATA[
Defines the service properties.
                            ]]></xsd:documentation>
                        </xsd:annotation>
                </xsd:element>
                <!-- nested bean declaration -->
                    <xsd:any namespace="##other" minOccurs="0" maxOccurs="1" processContents="skip"/>
            </xsd:sequence>
            <xsd:attribute name="ref" type="xsd:string" use="optional">
                    <xsd:annotation>
                        <xsd:documentation><![CDATA[
Refers to the named bean to be exported as a service in the service registry.
                        ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="ranking" type="xsd:int" default="0">
```

```
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
Specifies the service ranking to be used when advertising the service.
                            ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="cache-target" type="xsd:boolean" default="false">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
Specifies the caching of the exported target object. When enabled, the exporter will ignore the scope of the
target bean and use only the first resolved instance for registration. When disabled (default), the scope of
the target bean is considered and each service request, will be directed to the container.
                            ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
        </xsd:extension>
    </xsd:complexContent>
</xsd:complexType>

<xsd:complexType name="TserviceProperties">
        <xsd:annotation>
                <xsd:documentation><![CDATA[
Services properties used by the service exporter.
                ]]></xsd:documentation>
                    <xsd:appinfo>
                            <tool:annotation>
                                    <tool:exports type="java.util.Map"/>
                            </tool:annotation>
                    </xsd:appinfo>
        </xsd:annotation>

        <xsd:complexContent>
        <xsd:extension base="beans:mapType">
                <!-- shortcut for bean references -->
                    <xsd:attribute name="ref" type="xsd:string" use="optional">
                            <xsd:annotation>
                                    <xsd:documentation><![CDATA[
Refers by name to the bean that will receive register and unregister events.
                                    ]]></xsd:documentation>
                            </xsd:annotation>
                    </xsd:attribute>
                </xsd:extension>
        </xsd:complexContent>
</xsd:complexType>

<xsd:complexType name="TserviceRegistrationListener">
        <xsd:annotation>
                <xsd:documentation><![CDATA[
Defines a listener that will be notified when the bean is registered or unregistered in the OSGi Service Reg
Use either the 'ref' attribute or a nested bean declaration for the listener bean.
                ]]></xsd:documentation>
        </xsd:annotation>
    <xsd:sequence minOccurs="0" maxOccurs="1">
        <!-- nested bean declaration -->
        <xsd:any namespace="##other" minOccurs="1" maxOccurs="1" processContents="skip"/>
    </xsd:sequence>

    <!-- shortcut for bean references -->
    <xsd:attribute name="ref" type="xsd:string" use="optional">
            <xsd:annotation>
                    <xsd:documentation><![CDATA[
Refers by name to the bean that will receive register and unregister events.
                    ]]></xsd:documentation>
            </xsd:annotation>
    </xsd:attribute>
    <xsd:attribute name="registration-method" type="xsd:token" use="optional">
            <xsd:annotation>
                    <xsd:documentation><![CDATA[
The name of the method to be invoked when the service is registered.
                    ]]></xsd:documentation>
            </xsd:annotation>
    </xsd:attribute>
    <xsd:attribute name="unregistration-method" type="xsd:token" use="optional">
            <xsd:annotation>
                    <xsd:documentation><![CDATA[
The name of the method to be invoked when the service is unregistered.
                    ]]></xsd:documentation>
            </xsd:annotation>
```

```
    </xsd:attribute>
</xsd:complexType>

<xsd:simpleType name="TserviceClassLoaderOptions">
    <xsd:restriction base="xsd:NMTOKEN">
        <xsd:enumeration value="service-provider"/>
        <xsd:enumeration value="unmanaged"/>
    </xsd:restriction>
</xsd:simpleType>

<xsd:simpleType name="TautoExportModes">
    <xsd:restriction base="xsd:NMTOKEN">
        <xsd:enumeration value="disabled"/>
        <xsd:enumeration value="interfaces"/>
        <xsd:enumeration value="class-hierarchy"/>
        <xsd:enumeration value="all-classes"/>
    </xsd:restriction>
</xsd:simpleType>

<!-- bundle -->

<xsd:element name="bundle" type="Tbundle">
        <xsd:annotation>
                <xsd:documentation source="java:org.springframework.osgi.bundle.BundleFactoryBean"><![CDATA[
Defines a bean representing a Bundle object. May be used to drive bean lifecycle transitions.
                ]]></xsd:documentation>
                    <xsd:appinfo>
                            <tool:annotation>
                                    <tool:exports type="org.osgi.framework.Bundle"/>
                            </tool:annotation>
                    </xsd:appinfo>
        </xsd:annotation>
</xsd:element>

<xsd:complexType name="Tbundle">
    <xsd:complexContent>
        <xsd:extension base="beans:identifiedType">
                  <!-- optional nested bean declaration -->
            <xsd:sequence minOccurs="0" maxOccurs="1">
                                <xsd:any namespace="##other" minOccurs="1" maxOccurs="1" processContents="la
                                   <xsd:annotation>
                                <xsd:documentation><![CDATA[
OSGi bundle to work with.
                                ]]></xsd:documentation>
                                                        <xsd:appinfo>
                                                                <tool:annotation>
                                                                        <tool:expected-type type="org.osgi.fra
                                                                  </tool:annotation>
                                                        </xsd:appinfo>
                        </xsd:annotation>
                        </xsd:any>
                    </xsd:sequence>

            <xsd:attribute name="symbolic-name" type="xsd:string" use="optional">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
The bundle symbolic name of the bundle object. Normally used when interacting with an already
installed bundle.
                            ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="depends-on" type="xsd:string" use="optional">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
Indicates that this bundle object should not be created until the named bean has been created.
                            ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>

            <xsd:attribute name="location" type="xsd:string" use="optional">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
Location used to install, update or/and identify a bundle.
                            ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
            <xsd:attribute name="action" type="TbundleAction" use="optional">
                    <xsd:annotation>
```

```
                                <xsd:documentation><![CDATA[
    Lifecyle action to drive on the bundle. 'start' starts the bundle, installing if necessary.
    'stop' stops the bundle if it is currently ACTIVE. 'install' installs the bundle if it is
    currently uninstalled. 'uninstall' stops the bundle if needed, and then uninstalls it.
    'update' installs the bundle if needed, and then invokes the Bundle.update() operation.
                                ]]></xsd:documentation>
                        </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="destroy-action" type="TbundleAction" use="optional">
                        <xsd:annotation>
                                <xsd:documentation><![CDATA[
    Lifecyle action to drive on the bundle. 'start' starts the bundle, installing if necessary.
    'stop' stops the bundle if it is currently ACTIVE. 'install' installs the bundle if it is
    currently uninstalled. 'uninstall' stops the bundle if needed, and then uninstalls it.
    'update' installs the bundle if needed, and then invokes the Bundle.update() operation.
                                ]]></xsd:documentation>
                        </xsd:annotation>
                </xsd:attribute>
                <xsd:attribute name="start-level" type="xsd:int" use="optional" default="0">
                        <xsd:annotation>
                                <xsd:documentation><![CDATA[
    Start level to set for the bundle.
                                ]]></xsd:documentation>
                        </xsd:annotation>
                </xsd:attribute>
            </xsd:extension>
        </xsd:complexContent>
    </xsd:complexType>

    <xsd:simpleType name="TbundleAction">
        <xsd:restriction base="xsd:NMTOKEN">
            <xsd:enumeration value="start"/>
            <xsd:enumeration value="stop"/>
            <xsd:enumeration value="install"/>
            <xsd:enumeration value="uninstall"/>
            <xsd:enumeration value="update"/>
        </xsd:restriction>
    </xsd:simpleType>

</xsd:schema>
```

Spring Compendium Schema

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>

<xsd:schema xmlns="http://www.springframework.org/schema/osgi-compendium"
            xmlns:xsd="http://www.w3.org/2001/XMLSchema"
            xmlns:beans="http://www.springframework.org/schema/beans"
            xmlns:osgi="http://www.springframework.org/schema/osgi"
            xmlns:tool="http://www.springframework.org/schema/tool"
            targetNamespace="http://www.springframework.org/schema/osgi-compendium"
            elementFormDefault="qualified"
            attributeFormDefault="unqualified"
            version="2.0.0.M1">

        <xsd:import namespace="http://www.w3.org/XML/1998/namespace"/>
    <xsd:import namespace="http://www.springframework.org/schema/beans"/>
    <xsd:import namespace="http://www.springframework.org/schema/tool"/>
    <xsd:import namespace="http://www.springframework.org/schema/osgi"
            schemaLocation="http://www.springframework.org/schema/osgi/spring-osgi.xsd"/>


    <xsd:annotation>
        <xsd:documentation><![CDATA[
    Namespace support for the compendium services provided by Spring Dynamic Modules.
        ]]></xsd:documentation>
    </xsd:annotation>

        <!-- internal reusable type -->
        <xsd:attributeGroup name="updateAttributes">
                <xsd:attribute name="update-strategy" use="optional">
                        <xsd:annotation>
                                <xsd:documentation><![CDATA[
        The strategy to use when the configuration data backing the beans defined by this element is
        updated. The default value is 'none', meaning that any update after the initial configuration
```

```
    of the beans is ignored. A value of 'bean-managed' means that the method specified in the
    'update-method' attribute will be invoked. A value of 'container-managed' means that the container
    will autowire the bean instance by name with the new property set.
                        ]]></xsd:documentation>
                </xsd:annotation>
                <xsd:simpleType>
                        <xsd:restriction base="xsd:NMTOKEN">
                    <xsd:enumeration value="none"/>
                    <xsd:enumeration value="bean-managed"/>
                    <xsd:enumeration value="container-managed"/>
                </xsd:restriction>
                </xsd:simpleType>
            </xsd:attribute>
            <xsd:attribute name="update-method" type="xsd:string" use="optional">
                    <xsd:annotation>
                            <xsd:documentation><![CDATA[
    The update-method to invoke when using a 'bean-managed' update strategy.
                            ]]></xsd:documentation>
                    </xsd:annotation>
            </xsd:attribute>
    </xsd:attributeGroup>


<xsd:element name="managed-properties">
        <xsd:annotation>
                <xsd:documentation><![CDATA[
Defines a bean based on the given class name and configuration, with properties autowired-by-name
based on the configuration stored under the given persistent id.
                ]]></xsd:documentation>
        </xsd:annotation>
        <xsd:complexType>
                   <xsd:attributeGroup ref="updateAttributes"/>
                <xsd:attribute name="persistent-id" type="xsd:string" use="required">
                            <xsd:annotation>
                                    <xsd:documentation><![CDATA[
    The persistent-id under which the configuration for this bean is stored in
    the Configuration Admin service.
                                ]]></xsd:documentation>
                            </xsd:annotation>
                    </xsd:attribute>
            </xsd:complexType>
    </xsd:element>

<!--  managed-service-factory -->

<xsd:element name="managed-service-factory">
           <xsd:annotation>
                <xsd:documentation><![CDATA[
Defines a collection of beans based on the given class name, with properties autowired-by-name based
on the configuration sets stored under the given factory persistent id.
                ]]></xsd:documentation>
        </xsd:annotation>
    <xsd:complexType>
            <xsd:complexContent>
                <xsd:extension base="osgi:TbaseService">
                        <xsd:sequence>
                        <xsd:element name="interfaces" type="beans:listOrSetType" minOccurs="0" maxOccurs="1
                                    <xsd:annotation>
                                            <xsd:documentation><![CDATA[
The set of service interfaces to advertise in the service registry.
                                            ]]></xsd:documentation>
                                    </xsd:annotation>
                        </xsd:element>
                        <xsd:element name="registration-listener" type="osgi:TserviceRegistrationListener" m
                                    <xsd:annotation>
                                            <xsd:documentation><![CDATA[
Defines a listener that will be notified when this service is registered or unregistered in the
OSGi service registry.
                                            ]]></xsd:documentation>
                                    </xsd:annotation>
                                <xsd:element>
                                    <!-- the bean definition template -->
                        <xsd:any namespace="##other" minOccurs="1" maxOccurs="1" processContents="skip">
                                                    <xsd:annotation>
                                            <xsd:documentation><![CDATA[
    Defines the service definition template.
                                            ]]></xsd:documentation>
                                    </xsd:annotation>
```

```
                            </xsd:any>
                                   </xsd:sequence>
                                   <xsd:attribute name="factory-pid" type="xsd:string" use="required">
                                               <xsd:annotation>
                                                       <xsd:documentation><![CDATA[
        The persistent-id under which the configuration for this bean is stored in
        the Configuration Admin service.
                                                       ]]></xsd:documentation>
                                               </xsd:annotation>
                                       </xsd:attribute>
                                       <xsd:attributeGroup ref="updateAttributes"/>
                                </xsd:extension>
                        </xsd:complexContent>
                </xsd:complexType>
        </xsd:element>


    <!-- cm-properties -->
    <xsd:element name="cm-properties">
            <xsd:annotation>
                    <xsd:documentation source="java:org.springframework.osgi.compendium.cm.ConfigAdminProperties
    Exposes the properties found in the Configuration Admin service under the given persistent id.
                    ]]></xsd:documentation>
                        <xsd:appinfo>
                                <tool:annotation>
                                        <tool:exports type="java.util.Properties"/>
                                </tool:annotation>
                        </xsd:appinfo>
            </xsd:annotation>
            <xsd:complexType>
                    <xsd:complexContent>
                            <xsd:extension base="beans:propsType">
                                    <xsd:attribute name="id" type="xsd:ID"/>
                                <xsd:attribute name="persistent-id" type="xsd:string" use="required">
                                        <xsd:annotation>
                                                <xsd:documentation><![CDATA[
        The persistent id under which the properties reside.
                                                ]]></xsd:documentation>
                                        </xsd:annotation>
                                </xsd:attribute>
                                        <xsd:attribute name="local-override" type="xsd:boolean">
                                                <xsd:annotation>
                                                        <xsd:documentation><![CDATA[
        Specifies whether local properties override properties from the Configuration Admin service.
        Default is "false": properties from Configuration Admin service override local defaults.
        If set to "true", local properties will override properties from Configuration Admin service.
                                                        ]]></xsd:documentation>
                                                </xsd:annotation>
                                        </xsd:attribute>
                                        <xsd:attribute name="dynamic" type="xsd:boolean">
                                                <xsd:annotation>
                                                        <xsd:documentation><![CDATA[
        Specifies whether changes to the Configuration Admin service will be reflected by the properties.
        Default is "false": the properties will be lazily resolved from the Configuration Admin and will not cha
        If set to "true", the properties object content will update accordingly to the changes in the Configurat
                                                        ]]></xsd:documentation>
                                                </xsd:annotation>
                                        </xsd:attribute>
                            </xsd:extension>
                    </xsd:complexContent>
            </xsd:complexType>
    </xsd:element>

</xsd:schema>
```

Appendix I. Acknowledgments

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