JSR 277, 291 and OSGi, Oh My! - OSGi and Java Modularity

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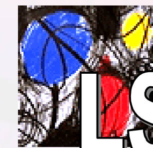
June 28th, 2006



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Agenda

- Modularity
- Modularity in Java
- Modularity in Java + OSGi technology
  - Introduction to OSGi technology
- Apache Incubator Felix Project Overview
- JSR 291 Overview
- JSR 277 Overview
- Bonus JSR 294 Overview
- Conclusion

Modularity

What is Modularity? (1)

- “(Desirable) property of a system, such that individual components can be examined, modified and maintained [and deployed] independently of the remainder of the system. Objective is that changes in one part of a system should not lead to unexpected behavior in other parts.”

  (www.maths.bath.ac.uk/~jap/MATH0015/glossary.html)

What is Modularity? (2)

- Different types of modularity
  - Logical
    - Useful during development to decompose and/or structure the system
  - Physical
    - Useful after development to simplify deployment and maintenance

Why Care About Modularity? (1)

- Simplifies the creation of large, complex systems
  - Improves robustness
  - Eases problem diagnosis
  - Enables splitting work among independent teams
- Simplifies the deployment and maintenance of systems
- Simplifies aspects of extensible and dynamic systems

Why Care About Modularity? (2)

- Java needs improvement in this area
  - Java currently lags .NET in support for modularity

Modularity in Java

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Logical Modularity in Java

- Classes
  - Provide logical static scoping via access modifiers (i.e., public, protected, private)
- Packages
  - Provide logical static scoping via “package privates”
  - Namespace mechanism, avoids name clashes
- Class loaders
  - Enable run-time code loading
  - Provide logical dynamic scoping

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Physical Modularity in Java

- Java class files
- Java Archive (JAR) files
  - Provide form of physical modularity
  - May contain applications, extensions, or services
  - May declare dependencies
  - May contain package version and sealing information

Java Modularity Limitations (1)

- Limited scoping mechanisms
  - No module access modifier
- Simplistic version handling
  - Class path is first version found
  - JAR files assume backwards compatibility at best

Java Modularity Limitations (2)

- Implicit dependencies
  - Dependencies are implicit in class path ordering
  - JAR files add improvements for extensions, but cannot control visibility
- Split packages by default
  - Class path approach searches until if finds, which can lead to shadowing or mixing of versions
  - JAR files can provide sealing

Java Modularity Limitations (3)

- Low-level support for dynamics
  - Class loaders are complicated to use
- Unsophisticated consistency model
  - Cuts across previous issues, it is difficult to ensure class space consistency

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Java Modularity Limitations (4)

- Missing module concept
  - Classes too fine grained, packages too simplistic, class loaders too low level
  - JAR files are best candidates, but still inadequate
  - Modularity is a second-class concept as opposed to the .NET platform
    - In .NET, Assembly usage is enforced with explicit versioning rules and sharing occurs via the Global Assembly Cache

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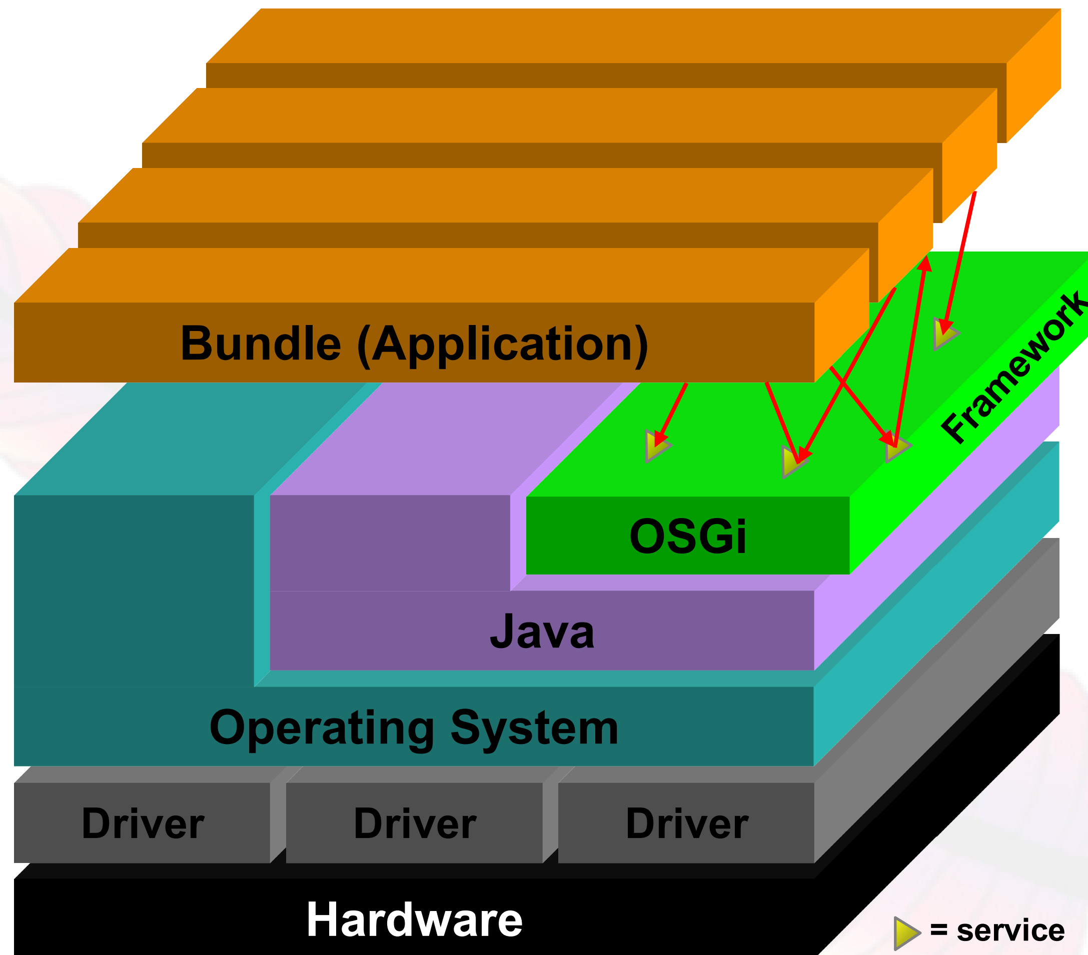
OSGi Overall Architecture



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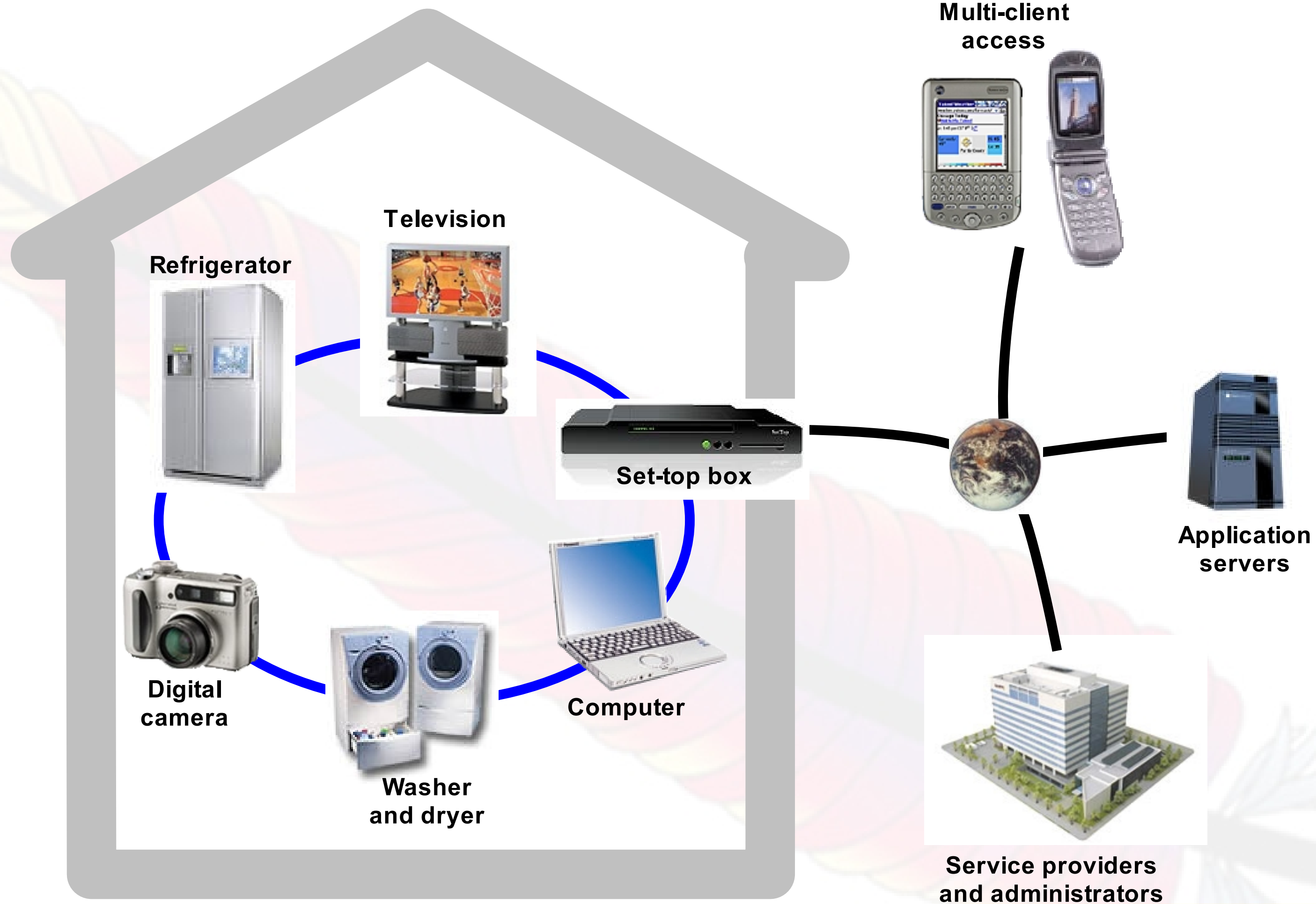
OSGi Original Target



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OSGi Framework (1)

- Horizontal software integration platform
- Component-oriented architecture
  - Module (Bundles)
  - Package sharing and version management
  - Life-cycle management and notification
- Service-oriented architecture
  - Publish/find/bind intra-VM service model
- Open remote management architecture
  - No prescribed policy or protocol

OSGi Framework (2)

- Runs multiple applications and services
- Single VM instance
- Separate class loader per bundle
  - Class loader network
  - Independent namespaces
  - Class sharing at the Java package level
- Java Permissions to secure framework

OSGi Framework Layering

SERVICE MODEL

L3 – Provides a publish/find/bind service model to decouple bundles – not discussed further here

LIFECYCLE

L2 - Manages the lifecycle of bundle in a bundle repository without requiring the VM be restarted

MODULE

L1 - Creates the concept of modules (aka. bundles) that use classes from each other in a controlled way according to system and bundle constraints

Execution Environment

L0 -
•OSGi Minimum Execution Environment
•CDC/Foundation
•JavaSE

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OSGi Module Layer

- Generic/standardized solution for Java modularity
- Bundle is the unit of modularization
  - Contains Java classes and other resources
  - Typically a JAR file
- Bundles share Java packages in a well-defined way
  - Export a package
  - Import a package
- Bundle manifest contains module metadata
  - Bundles are resolved
  - Imports are wired to exports
  - Class loader per bundle with wires form a delegation network

OSGi Bundle-ClassPath

- Manifest header

```
Bundle-Classpath::= entry ( ',' entry )*
entry ::= target ( ';' target )* ( ';' parameter ) *
target ::= path | '.'
```

- Defines the “inner” class path of a bundle
- `path` can refer to a directory in the bundle or a contained JAR
  - /WEB-INF/classes
  - util.jar

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OSGi Export-Package

- Manifest header

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

- Directive
  - uses := package list
  - mandatory := attribute list
  - include := class list
  - exclude := class list
- Attributes
  - version = version
  - arbitrary

OSGi Import-Package

- Manifest header

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

- Directive
  - resolution := mandatory | optional
- Attributes
  - version = [low,high)
  - bundle-symbolic-name = org.bundle.name
  - bundle-version = [low,high)
  - arbitrary

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OSGi DynamicImport-Package

- Manifest header

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

- Dynamic imports are matched to export definitions during class loading
  - Does not affect module resolution
  - Apply only to packages for which no wire has been established
  - Dynamic import is used as last resort
- For `Class.forName` idiom

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OSGi Require-Bundle

- Manifest header

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

- Bundles can be directly wired to the exported packages of other bundles without specifying the specific packages
- Used by Eclipse plugins as a convenience
- Not preferred approach
  - Has several drawbacks, but is seen as convenient by developers

OSGi Fragments

- Manifest header

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

- Fragments are bundles that are attached to a host bundle as part of resolving
  - Treated as part of the host bundle
  - Must not have their own class loader
- Localization is key use case

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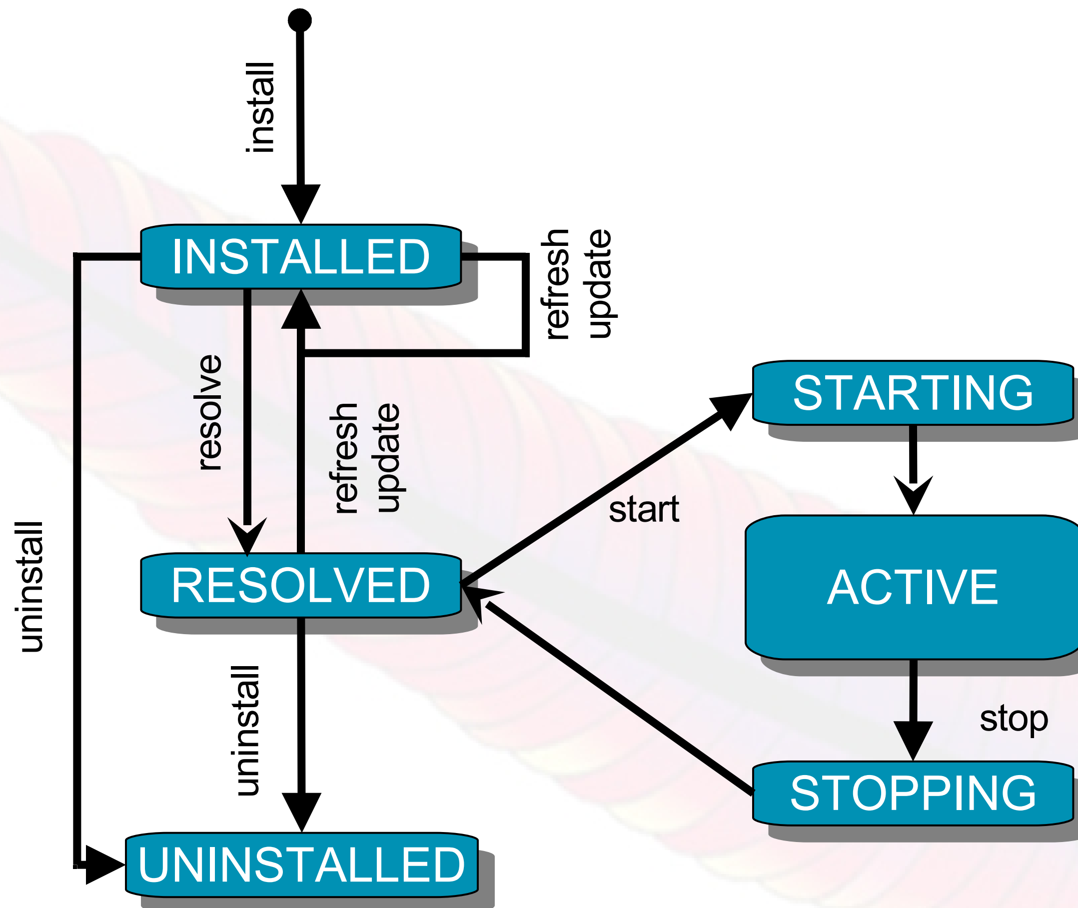
OSGi Extension Bundles

- Framework Extension
  - Loaded by framework class loader
  - Used to extend the framework implementation
- Boot Class Path Extension
  - Loaded by the boot class loader
  - Used to supply JRE extensions
- Declared as fragments of System Bundle

OSGi Lifecycle Layer (1)

- Provides APIs to control the life cycle of bundles
  - Install/update/uninstall
  - Start/stop
  - Notifications
- API provides information on state of module layer
- Builds upon the module layer
- Supports dynamic management of bundles in running VM

OSGi Lifecycle Layer (2)



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OSGi Modularity Best Practices

- Partition public and non-public classes into separate packages
  - Packages with public classes can be exported
  - Packages with non-public classes are not exported
- Import-Package rather than Require-Bundle
  - Allows substitutability of package providers
- Limit fragment use
- Do not use DynamicImport-Package

OSGi Bundle Manifest Example

```
Bundle-ManifestVersion: 2
Bundle-SymbolicName: org.foo.simplebundle
Bundle-Version: 1.0.0
Bundle-Activator: org.foo.Activator
Bundle-ClassPath: .,org/foo/embedded.jar
Bundle-NativeCode:
 libfoo.so; osname=Linux; processor=x86,
 foo.dll; osname=Windows 98; processor=x86
Import-Package:
 javax.servlet; version="[2.0.0,2.4.0)";
   resolution:="optional"
Export-Package:
 org.foo.service; version=1.1;
   vendor="org.foo"; exclude:="*Impl",
 org.foo.service.bar; version=1.1;
   uses:="org.foo.service"
```

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Bundle-Class[illegible]o/embedded.jar
Bundle-Nativ[illegible]
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```

Indicates R4
semantics and syntax

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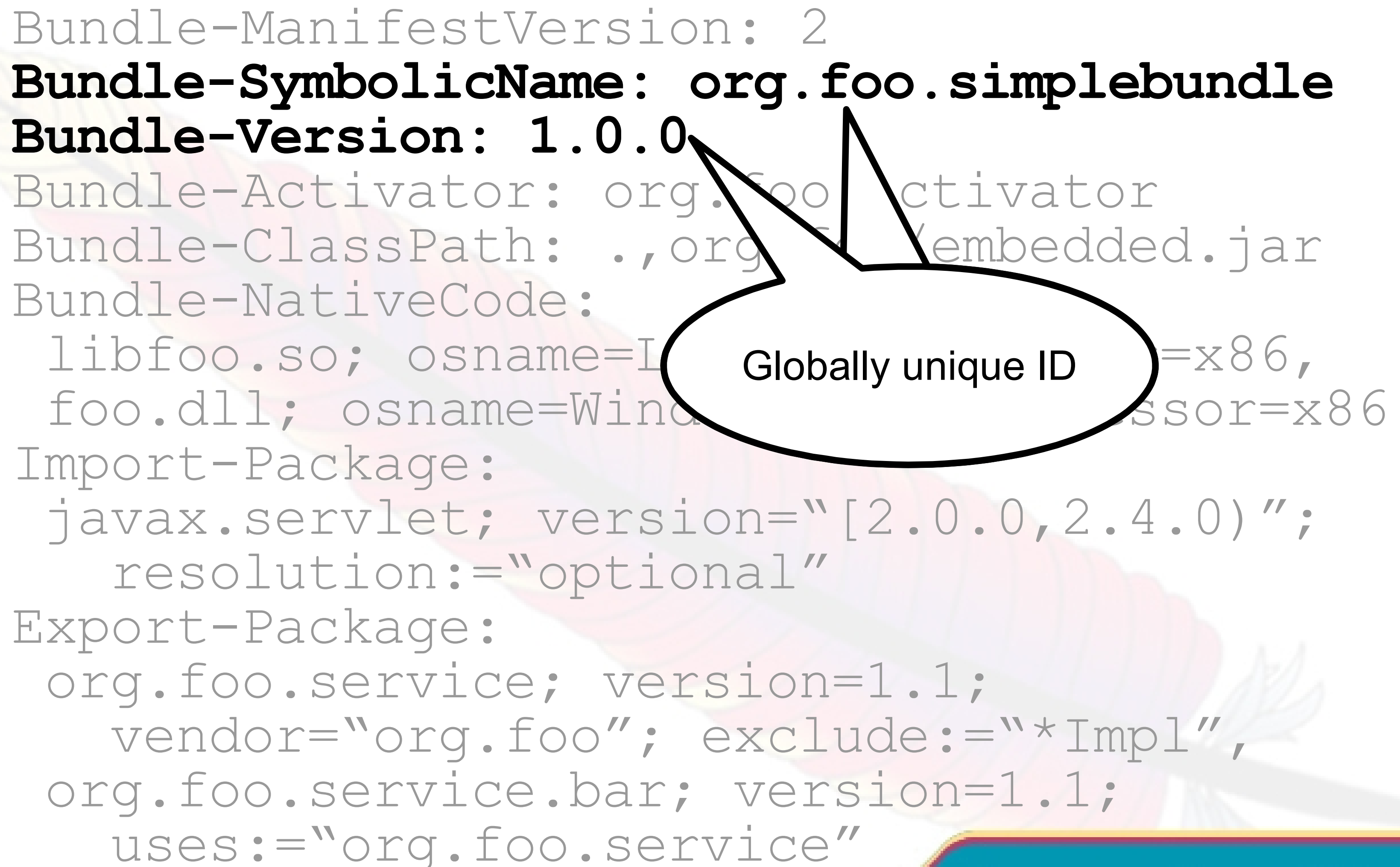
OSGi Bundle Manifest Example



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Life cycle entry point

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 foo.dll; ... 98; processor=x86
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 org.foo.service.bar; version=1.1;
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```

Internal module class path

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```

Native code dependencies

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 foo.dll; osname=Win      essor=x86
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   vendor="org.foo"; exclude:="*Impl",
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   uses:="org.foo.service"
```

Optional dependency on a
package version range

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 foo.dll; osname=Wi                    r=x86
Import-Package:
 javax.servlet; ver                     ”;
   resolution:=“option
Export-Package:
 org.foo.service; version=1.1;
   vendor=“org.foo”; exclude:=“*Impl”,
 org.foo.service.bar; version=1.1;
   uses:=“org.foo.service”
```

Provided package with
arbitrary attribute and
excluded classes

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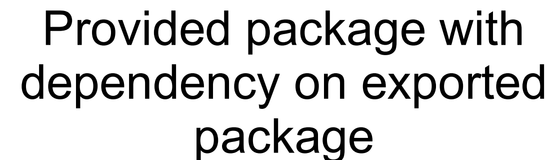

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Felix Project

- Currently in the Apache Incubator
- Apache licensed open source implementation of OSGi R4
  - Framework (in progress and functional)
  - Services (in progress and functional)
    - Package Admin, Start Level, URL Handlers, Declarative Services, UPnP Device, HTTP Service, Configuration Admin, Preferences, User Admin, Wire Admin, Event Admin, and Log
    - OSGi Bundle Repository (OBR), Dependency Manager, Service Binder, Shell (TUI and GUI), Mangen

Felix Project

- Felix community is growing strong
  - 15 committers, 7 in the last quarter
  - Code granted and contributed from several organizations and communities
    - Grenoble University, ObjectWeb, CNR-ISTI, Ascert, Luminis, Apache Directory
  - Other projects interest in Felix and/or OSGi
    - Directory, Coocon, JAMES, Jackrabbit, Harmony, Derby

Felix Project

- Felix bundle developer support
  - Apache Maven2 OSGi plugin
    - Merges OSGi bundle manifest with Maven2 POM file
    - Automatically generates Bundle-Activator, Bundle-ClassPath, and Import-Package headers as well as verifies the Export-Package header
      - Greatly simplifies bundle development by eliminating error-prone manual header creation process
    - Automatically creates final bundle JAR file
      - Automatically embeds (or unrolls and embeds) required library JAR files

Felix Project

- Felix bundle deployment support
  - OSGi Bundle Repository (OBR) service implements support for the new, OSGi supported bundle repository format
    - Supports a generic capability/requirement XML-based metadata model for deployment bundles and their transitive set of dependencies
    - Supports both install and update with mix-and-match versioning
  - In the process of setting up an official Felix bundle repository

Felix Project

- Roadmap
  - Incubator graduation hopefully soon
  - Version 0.8 public release after graduation
    - Snapshot of framework that is stable and includes major portions of R4 specification functionality
  - Version 0.9 developer release Summer 2006
    - Focusing on security aspects and R4 Require-Bundle
  - Version 1.0 release
    - Stable snapshot of version 0.9 by early Fall 2006

JSR 291 Overview: Dynamic Component Support for Java SE

JSR 291 Rationale

- Provide dynamic component support for existing Java SE platforms
- Align OSGi and JCP
- Align SE and ME
- Follow-on activity
  - Add Dolphin to the list of compatible supported platforms
  - Exploit Dolphin technology for static modules

JSR 291 Early Draft Review

- Start with OSGi R4 core specification
- List use cases and requirements
- Discuss, clarify, etc.
- Raise issues
- Produce early draft review specification
- Resolve issues and process review feedback
- Finish as soon as possible
  - After expert group has it say

JSR 291 Current Discussion (1)

- Packaging of JSR 291 output
  - Scoped to existing platforms, not future Java SE
- Use cases and requirements
  - Interoperability between JSR 291 and OSGi
    - JSR 291 bundles on OSGi R4, OSGi R4 bundles on JSR 291
      - Requires OSGi R4 service layer, sub-setting R4 problematic
    - Optional aspects of OSGi R4
      - Avoid optionality in modularity layer, do not mention services

JSR 291 Current Discussion (2)

- SPI
  - Some parts of OSGi currently depend on framework implementation
  - Alternatives
    - 291 spec. could require these ‘extras’
      - Bloat
    - A 291 implementation could include certain ‘extras’
      - Acceptable where broad support is not required
    - ‘Extras’ can be written to a SPI and support multiple 291 implementations
      - Ideal where broad support is required, e.g. Declarative Services

JSR 291 Current Discussion (3)

- JSR 277 & 291 interoperability
  - JSR 277 provides a foundation on which a 291 solution could be built
  - Two-way class sharing (?)
  - JSR 291 runtime (i.e., OSGi R4 framework) is available when using JSR 291 modules in JSR 277

JSR 291 Raised Issues

- OSGi issue 277
  - Reference content external to the bundle JAR file on the bundle class path
- OSGi issue 288
  - Standard way to gain access to arbitrary bundle contexts
    - Currently, specific to Declarative Services
- OSGi issue 323
  - Way to modify class search order

JSR 291 Further Information

- JSR home page
  - http://www.jcp.org/en/jsr/detail?id=291
- Expert Group mailing list and archives
  - http://bundles.osgi.org/mailman/listinfo/jsr-291-eg

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JSR-277 Overview:
Java Module System

JSR 277 Rationale

- JAR files are the distribution/execution format for Java applications, but...
  - Not well-suited to these tasks
    - Hard to distribute
    - Hard to version
    - Hard to reference
- Java extension mechanism is inadequate
  - Version and namespace conflicts
  - Only for a single JRE installation
- Resolve these issues

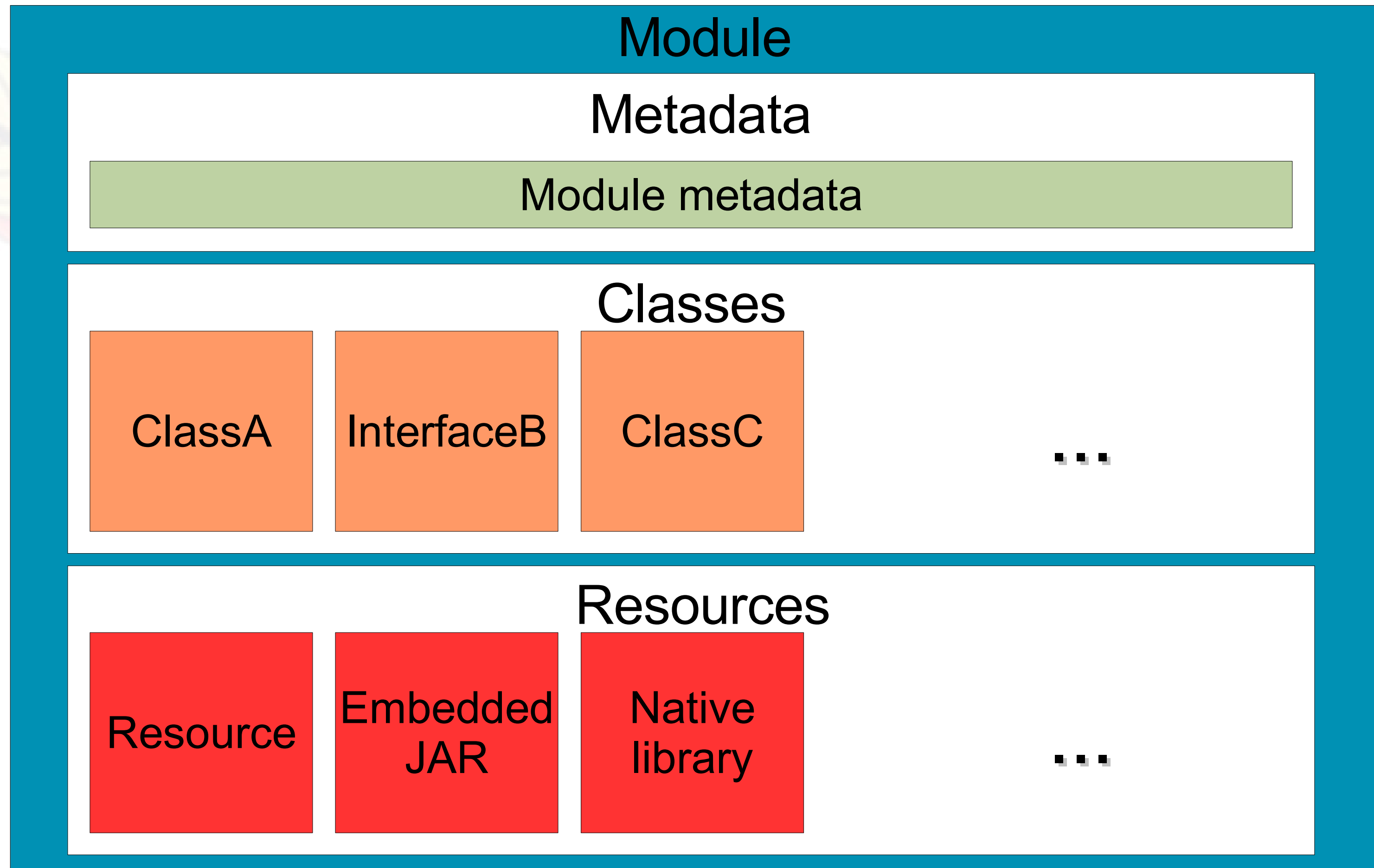
JSR 277 Focus

- Deployment modules
  - Versioning
  - Distribution and packaging
  - Repositories
  - Module interconnection/dependency resolution
  - Handled by tools on top of reflective run-time API

JSR 277 Concepts

- Module definition
  - Identify logical module
  - Specify content (i.e., code and resources)
  - Specify imports/exports
  - Inherently stateless
- Module instance
  - Instantiation of a module instance
  - Multiple instances can co-exist at run time

JSR 277 Logical Module View



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JSR 277 Versioning

- Simple version
  - major.minor[.micro[_patch]][-qualifier]
  - e.g., 1.7.0_01-b32-beta
- Version ranges
- Version policy
  - Major element change is not compatible
  - Minor element change is generally compatible
  - Remaining changes are compatible

JSR 277 Distribution Format (1)

- Physical representation of a module definition
- Unit of packaging and deployment
- Optimized for size, based on JAR file
- Contents
  - Module metadata, classes, resources, embedded JAR files, native libraries
- Code signing

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JSR 277 Distribution Format (2)

- JAM (JAva Module) format

```
org.foo.Xml-1.2.3.jam:
  /META-INF
    MANIFEST.MF
    module/org.foo.Xml.module
  /ClassA.class
  /InterfaceB.class
  /ClassC.class
  /icon/graphics.jpg
  /bin/xml-windows.dll
  /bin/xml-linux.so
  /lib/xml-parser.jarc
```

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```

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JSR 277 Module Repostiory (1)

- Discovery, storage, and retrieval of module definitions
- Enable side-by-side deployment
  - More than one version of a module definition at a time to be installed
- Multiple repositories
  - Bootstrap, shared, and user repositories
- Delegation model

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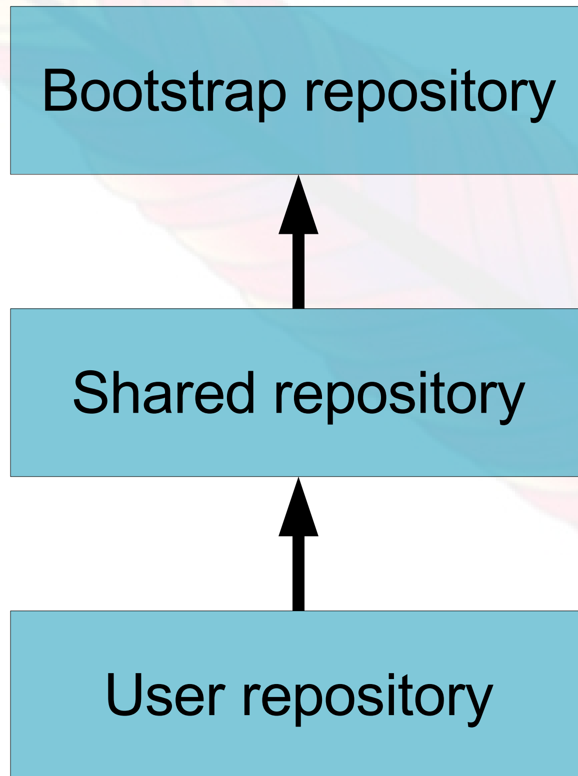
JSR 277 Module Repostiory (2)

- Repository delegation



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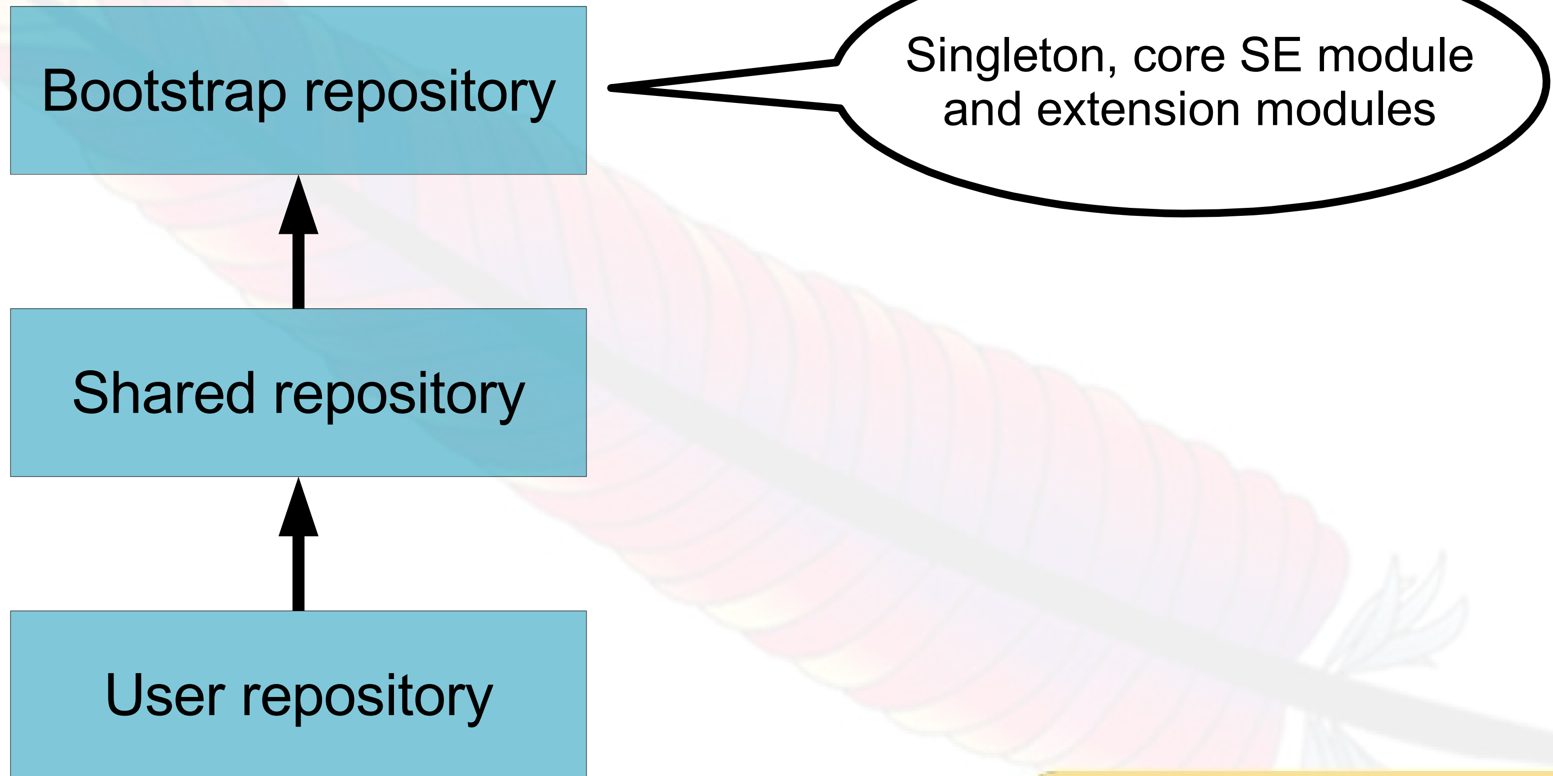

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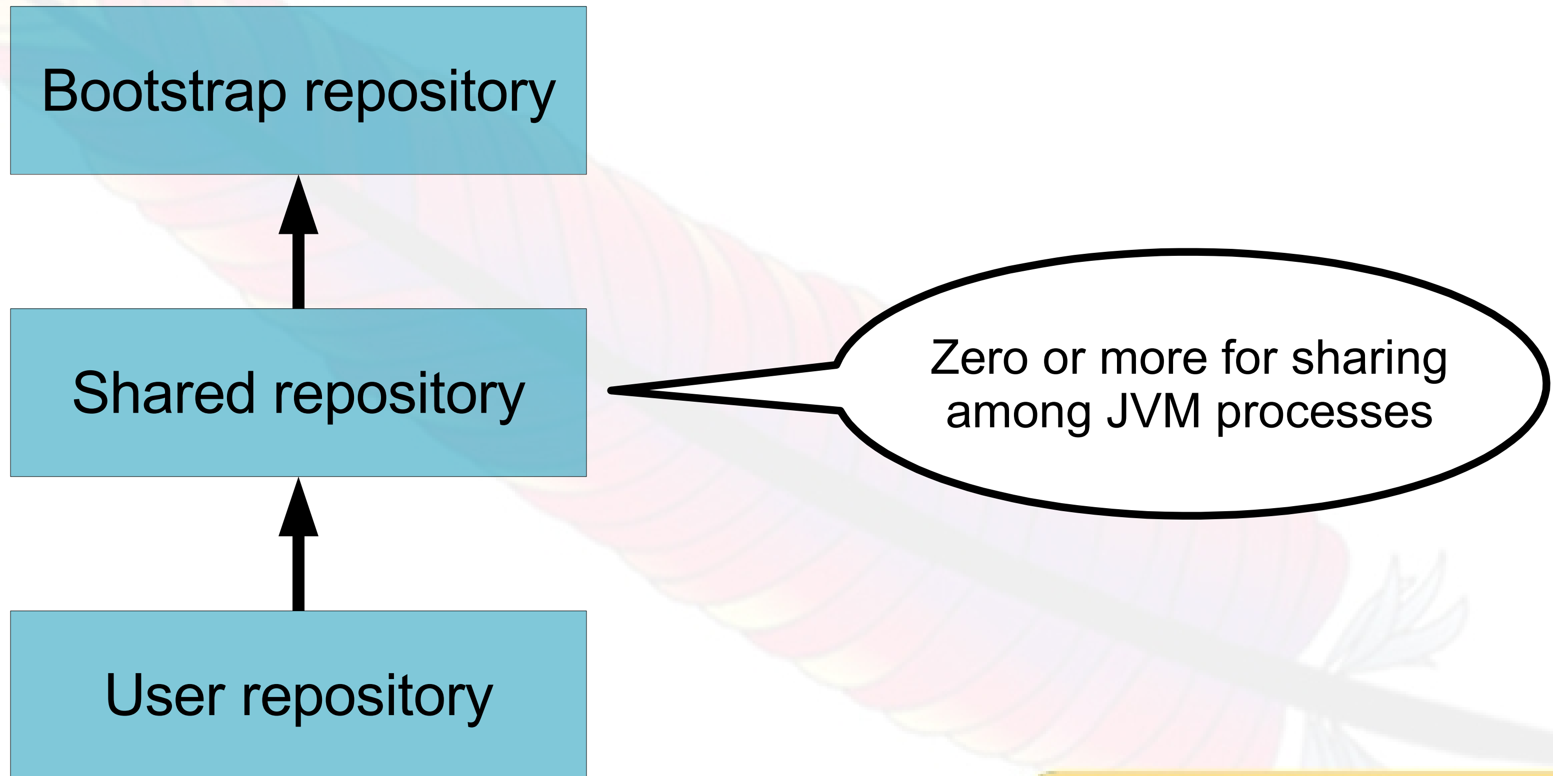

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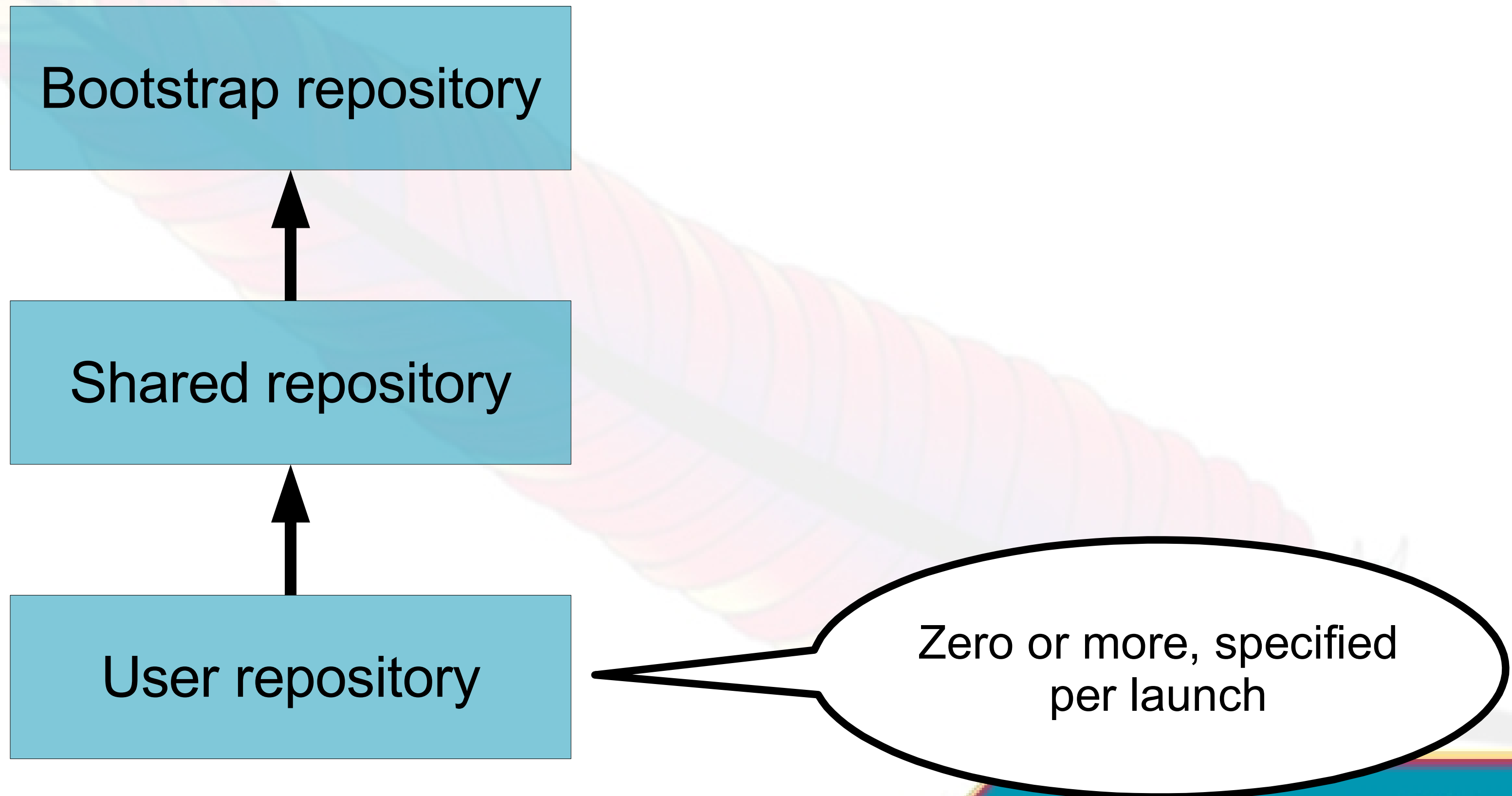

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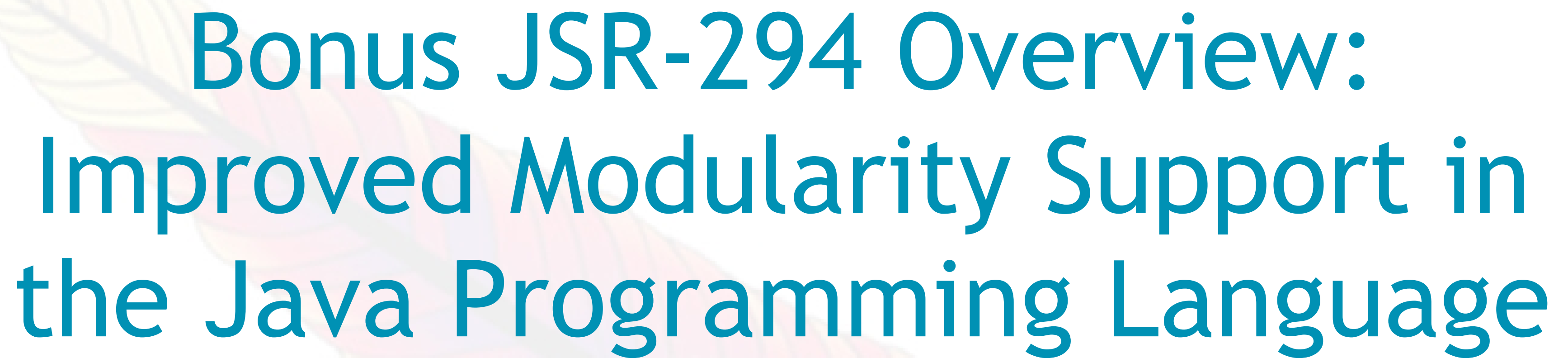
JSR Runtime Support

- Interconnection
  - Version constraints in imports
  - Construction script
- Validation
- Class loading
- Life cycle


Bonus JSR-294 Overview:
Improved Modularity Support in
the Java Programming Language

JSR 294 Rationale

- Java programming language needs better support for hierarchical, modular organization
  - Primarily to support information hiding
  - Java packages inadequate for this purpose
    - Only two levels of visibility: internal to the package or public to everyone

JSR 294 Focus

- Development modules
  - A language construct
  - Requires direct VM support to enforce access control semantics
  - Support information hiding
    - Avoid exposing system internals
  - Support separate compilation
    - Compile against a module without an implementation of it

JSR 294 Concepts (1)

- Module “files”
  - Not necessarily a file
  - Authoritative binary definition of a module
    - Name, membership, imports, exports, metadata
  - Class files can claim membership in a module
  - Claims must be cross-checked with module file
  - VM uses membership and export information to enforce access control
  - Corresponds to the metadata of the module definition in JSR 277

JSR 294 Module File Example

```
super package com.foo.moduleA {
  // Exported classes/interfaces
  export com.foo.moduleA.api.*;
  export com.foo.moduleA.ifc.InterfaceC;
  // Imported modules
  import org.bar.moduleD;
  // Module membership
  com.foo.moduleA.api;
  com.foo.moduleA.ifc;
  org.apache.stuff;
}
```

JSR 294 Separate Compilation

```
package interface com.foo.moduleA;
// Implicitly public types and members
class C implements com.foo.ifc.InterfaceC {
  String someMethod();
  C(int i);
  protected Object aFieldName;
}
```

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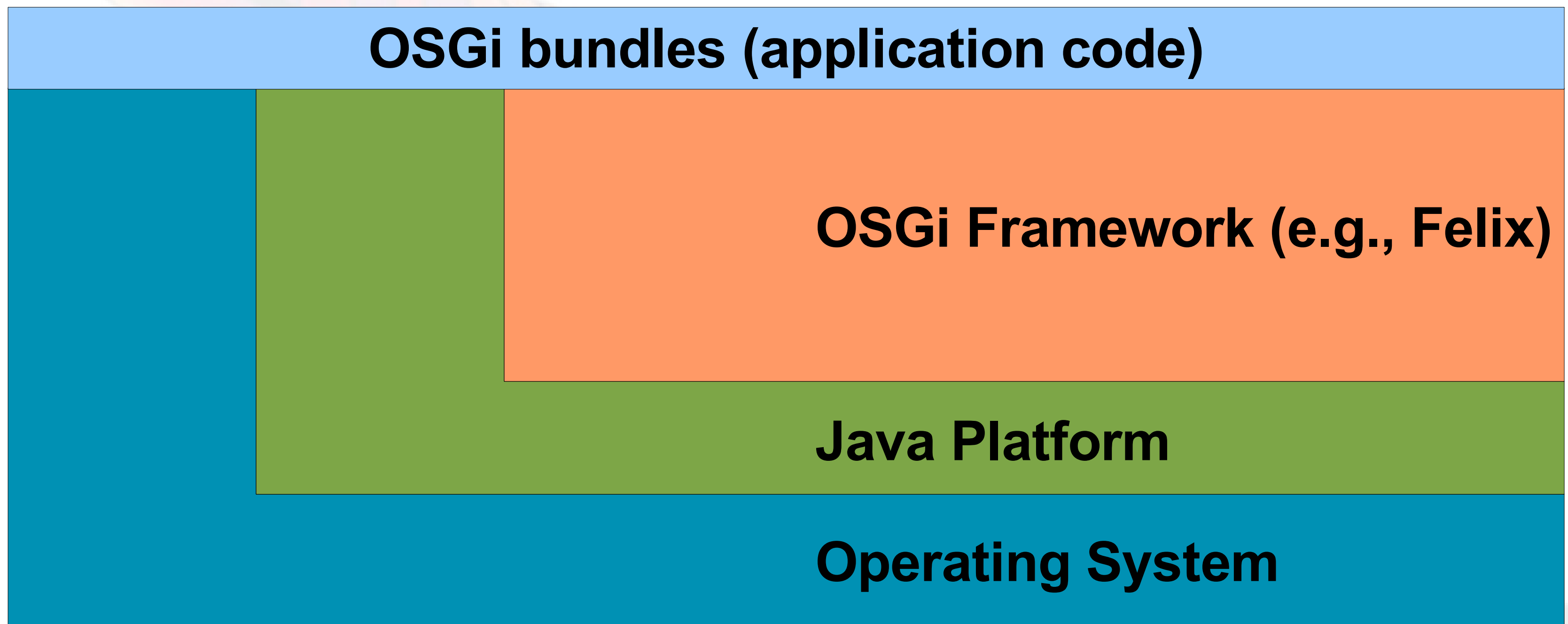
Conclusion

Issues

- OSGi specification pre-dates all existing modularity JSRs
- JSR 277, 291, and 294 have similar concepts
  - Modules with metadata for membership, imports, exports
    - Used for information hiding
- JSR 277 and 291 overlap in some areas, but differ in others
  - Overlap in packaging and deployment
  - Differ in dynamics/life cycle, support for existing JREs

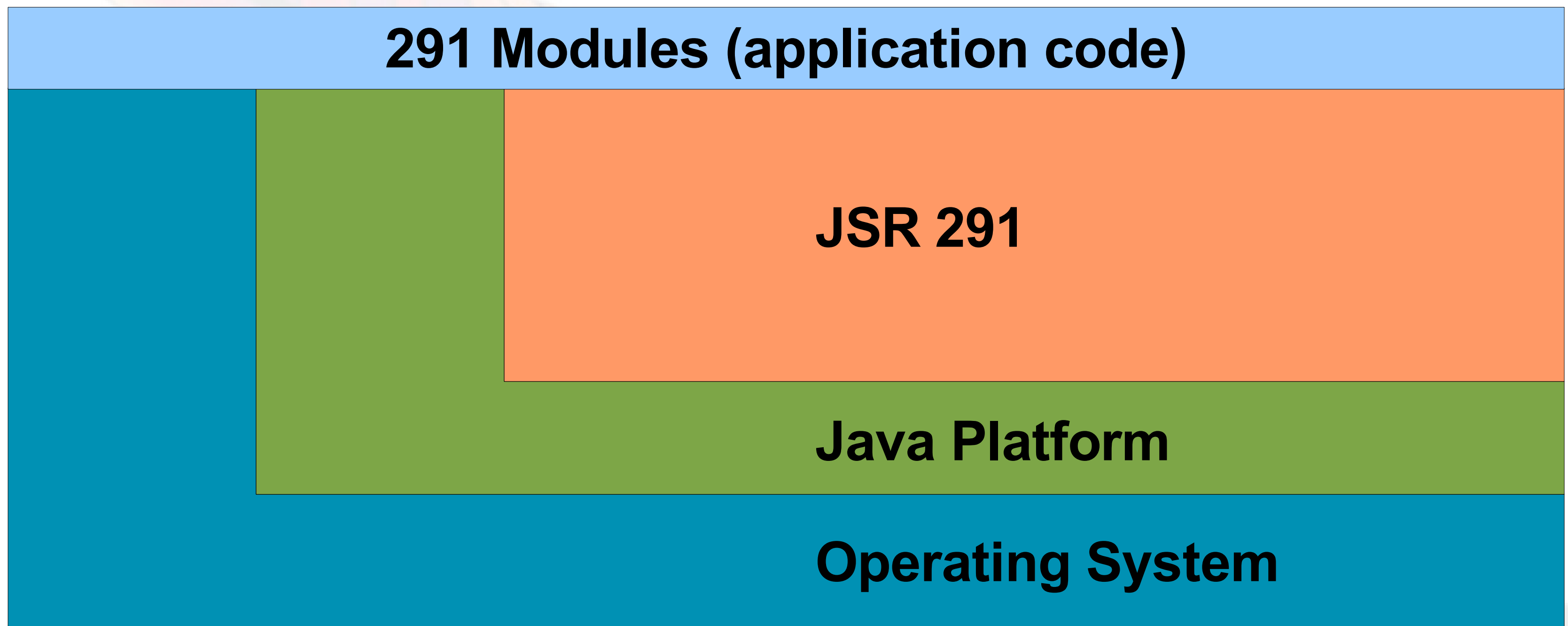
Current Solution

- OSGi framework on Java ME/SE
  - Available now and very mature



Near-term Solution

- JSR 291 framework on Java ME/SE
  - Takes EG concerns into consideration



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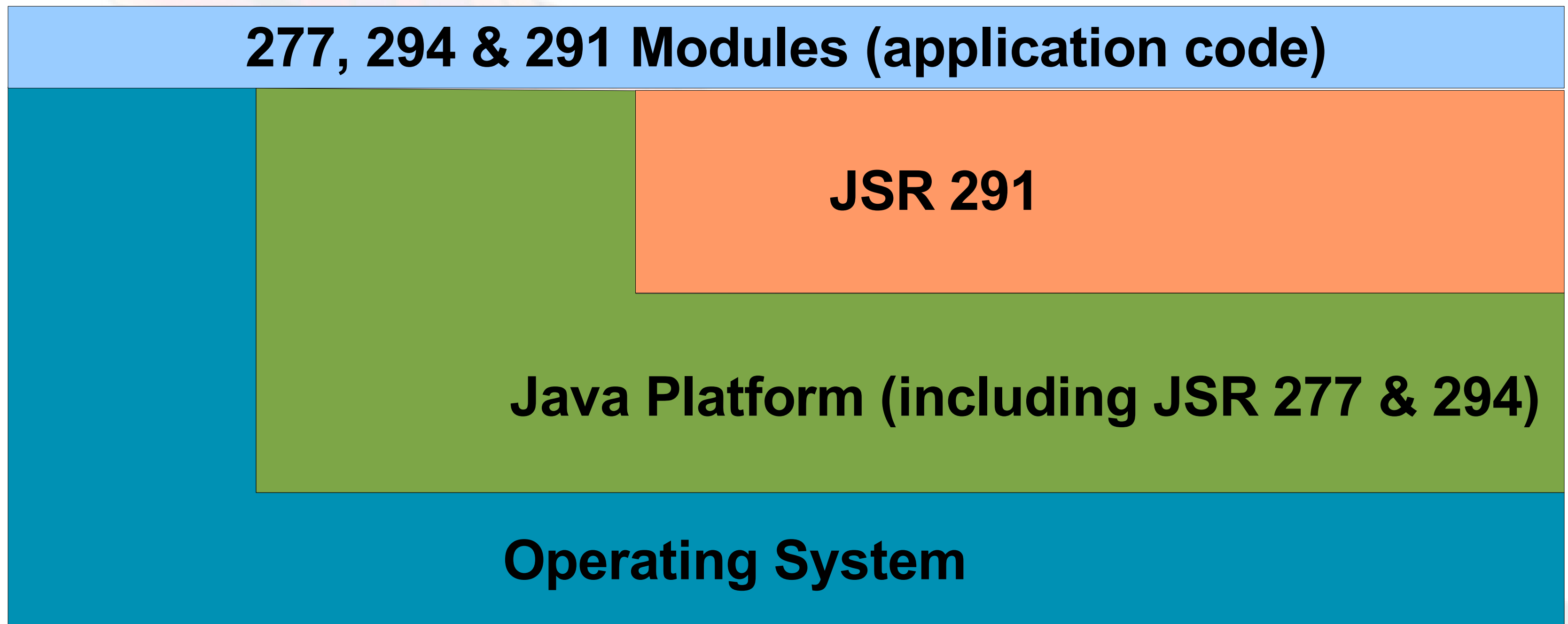
Long-term Solution

- JSR 291 re-based onto of JSR 277 & 294



Questions?