Java Modularity Support in OSGi R4

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Modularity

What is it?

What is Modularity?

- “(Desirable) property of a system, such that individual components can be examined, modified and maintained 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)

- 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?

- 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
- Java needs improvement in this area
  - Java currently lags .NET in support for modularity
  - OSGi specification deals with many of these issues and can fill that gap

Java Modularity

Standard Support & Limitations

Logical Modularity in Standard 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

Physical Modularity in Standard 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

Standard 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
- 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

Standard Java Modularity Limitations (2)

- 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
- 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

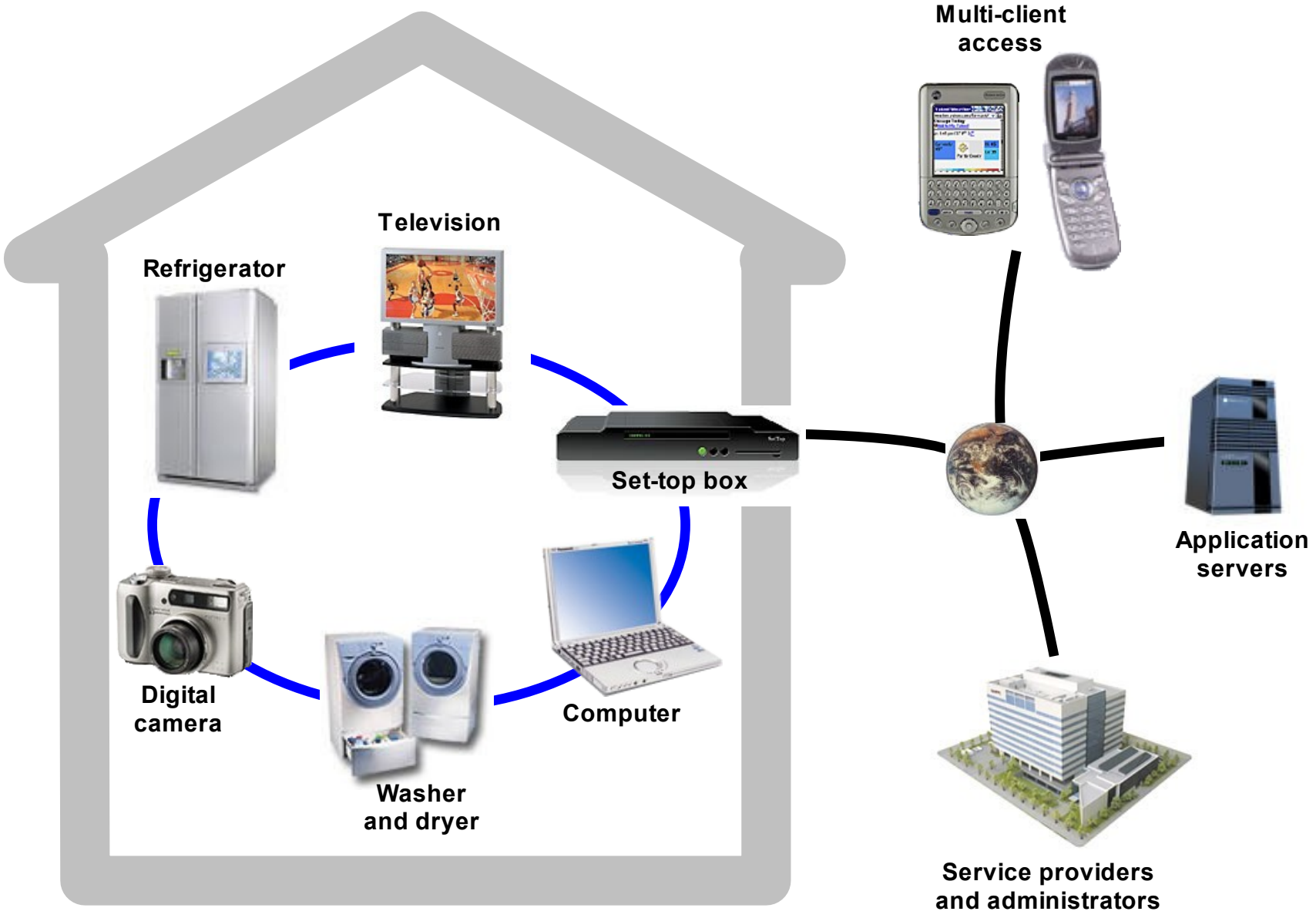
OSGi Overview

Dynamic Service Platform

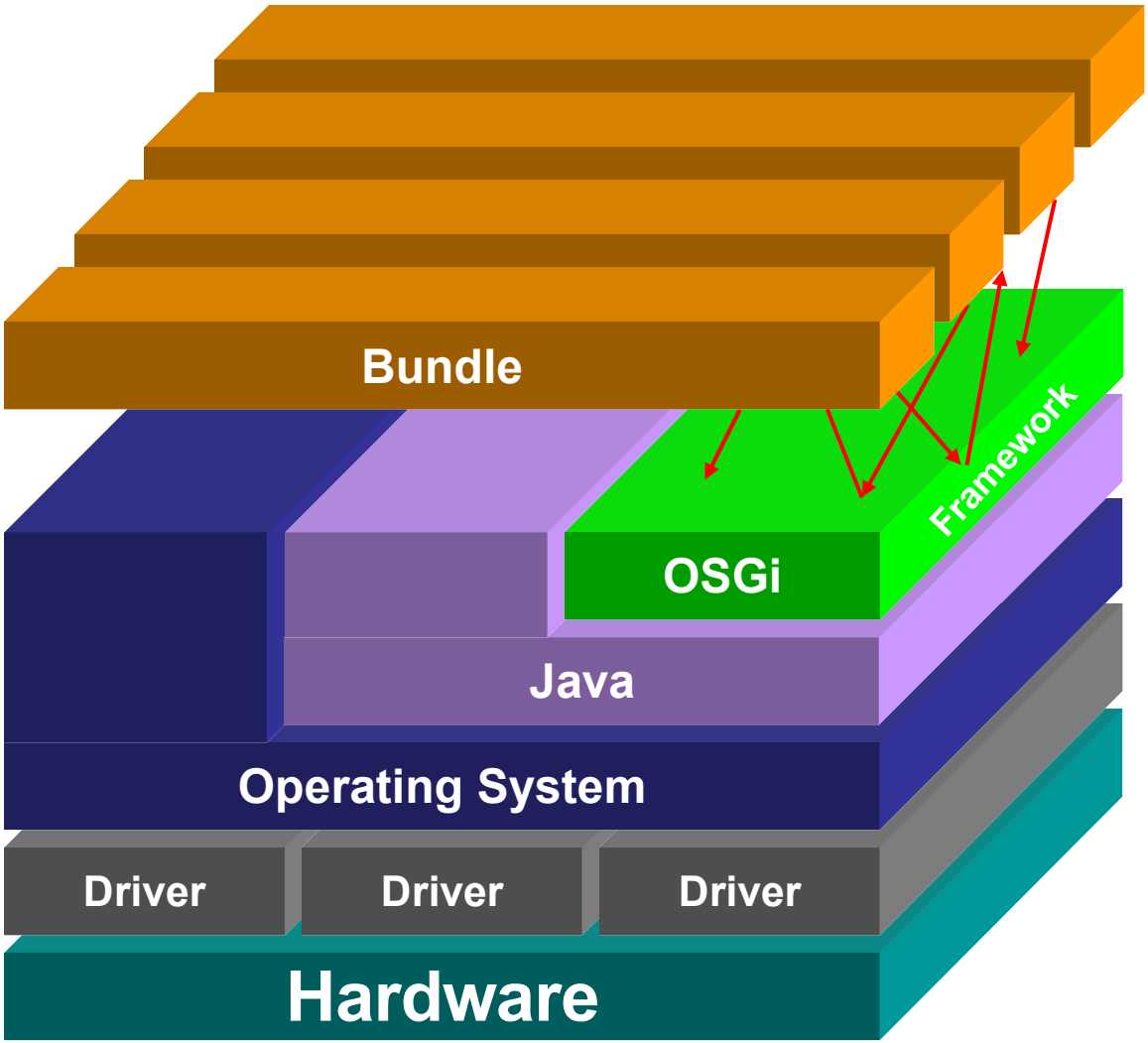
OSGi Alliance

- Formerly known as the Open Services Gateway Initiative
- Defined a framework for hosting dynamically downloadable services
- OSGi framework provides
  - Simple component model
  - Component life-cycle management
  - Service registry
  - Standard service definitions
    - Separation of specification and implementation

Home Services Gateway

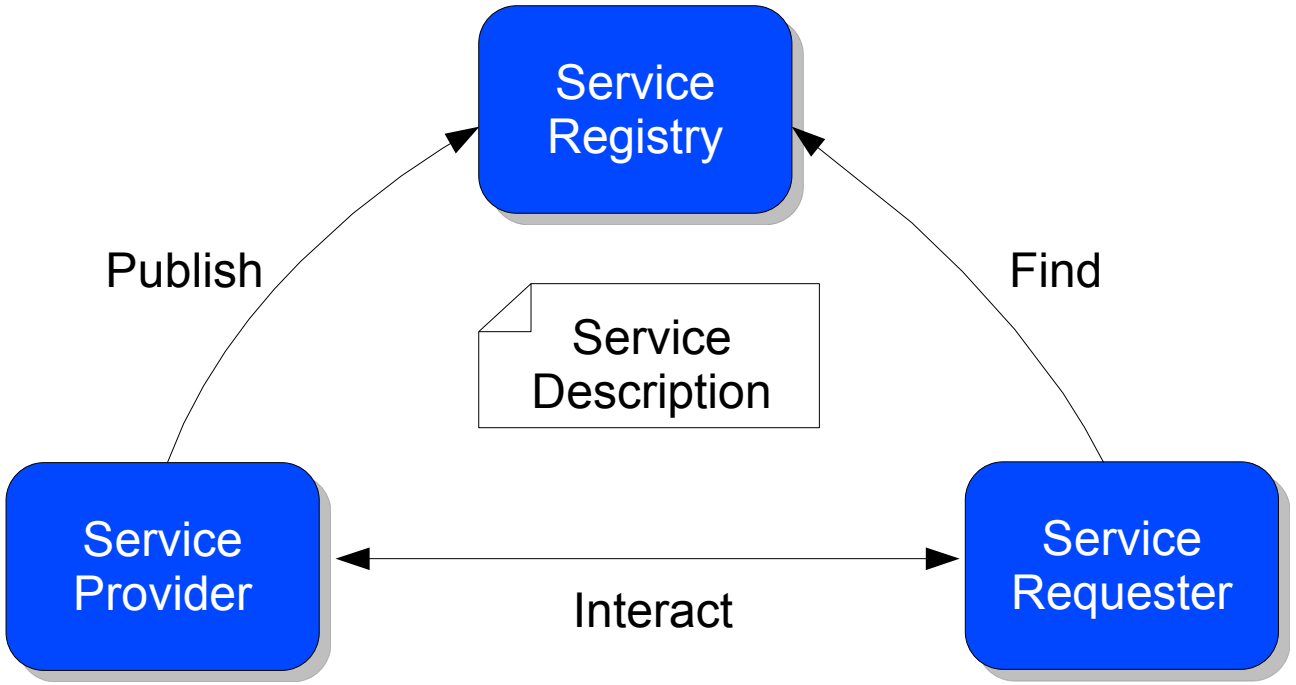


OSGi Overview



Service Orientation

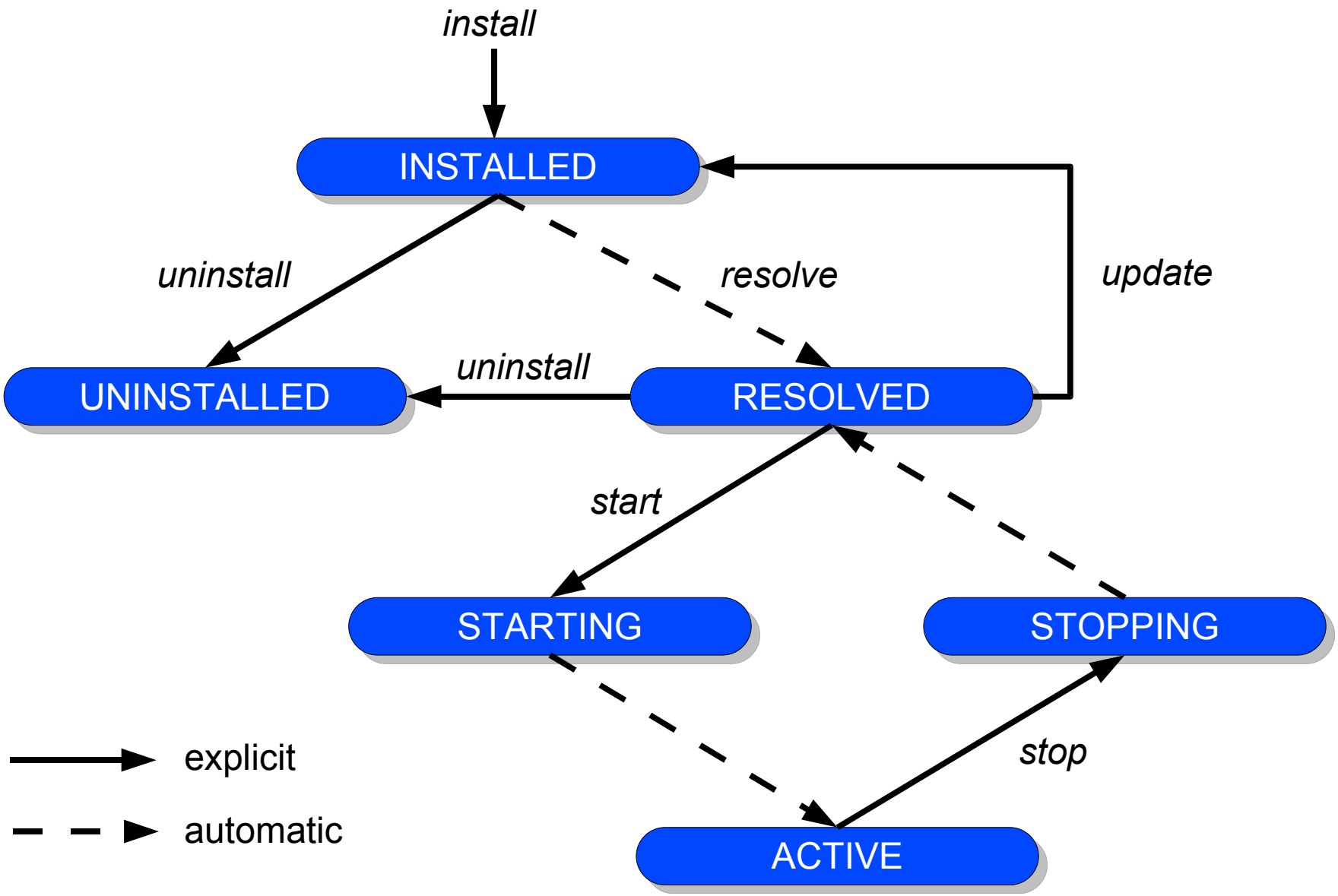
- The OSGi framework promotes a service-oriented interaction pattern



OSGi Component Model

- Simple component and packaging model
  - JAR files, called ***bundles***, contain Java classes, resources, and meta-data
  - Meta-data explicitly defines boundaries and dependencies in terms of Java package imports/exports
    - Dependencies and associated consistency are automatically managed
- Defines a component life cycle
- Explicitly considers dynamic scenarios
- Interaction through service interfaces

Component Life Cycle

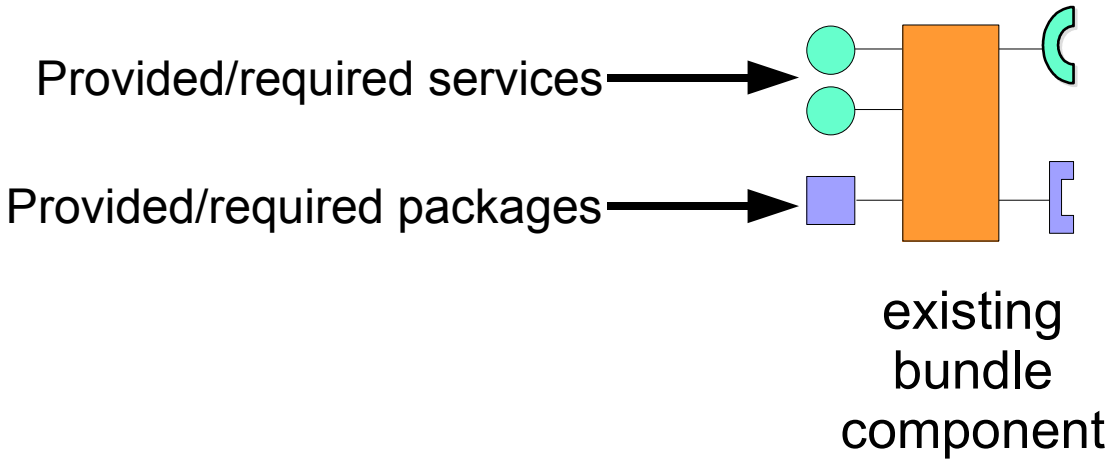


Bundle Dependency Resolution

- The framework automatically resolves package dependencies when a bundle is activated
  - Matches bundle's imports to available exports
  - Ensures package version consistency
- If a bundle cannot be successfully resolved, then it cannot be activated/used

OSGi Component Model

- A bundle represents a single component contained in a JAR file



OSGi framework

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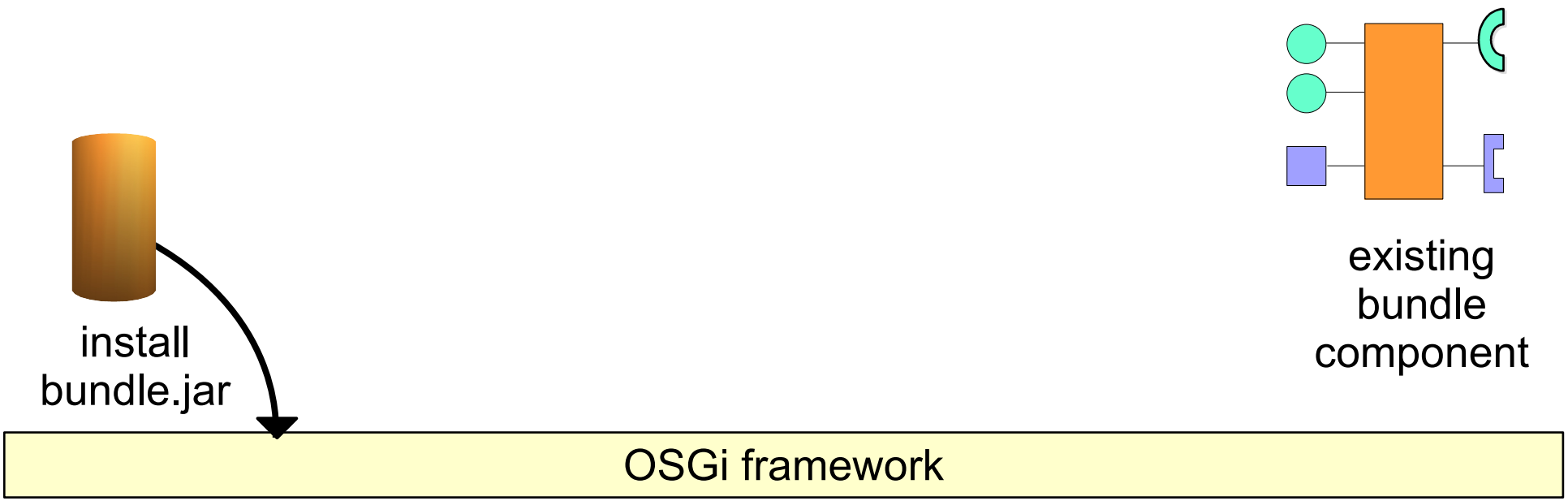

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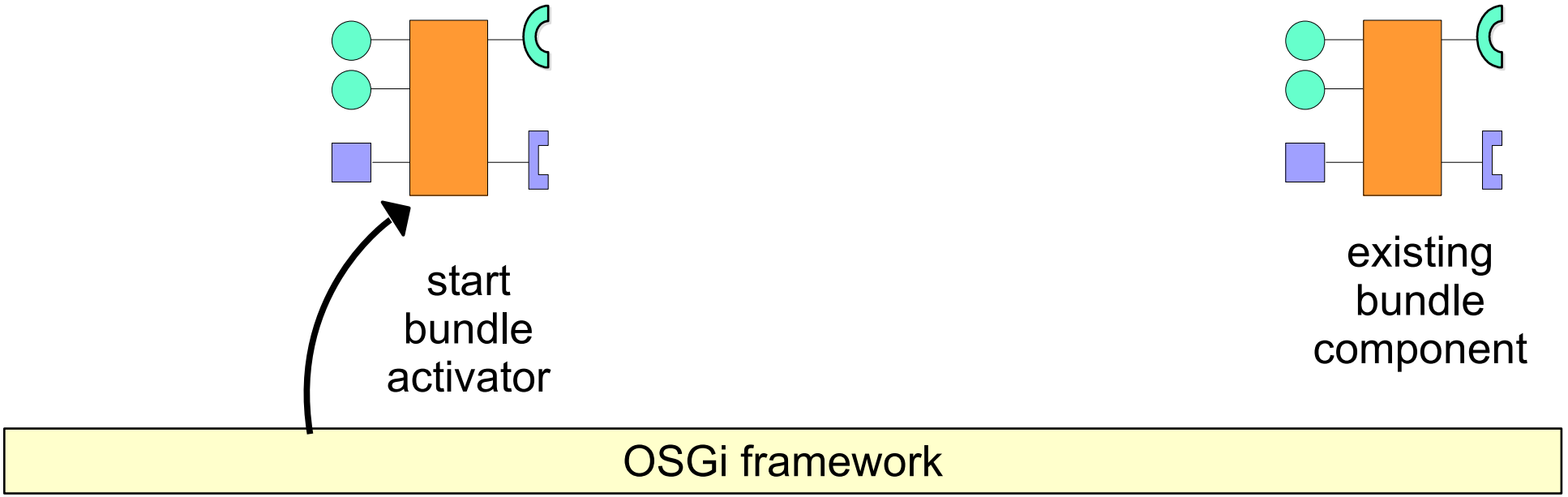

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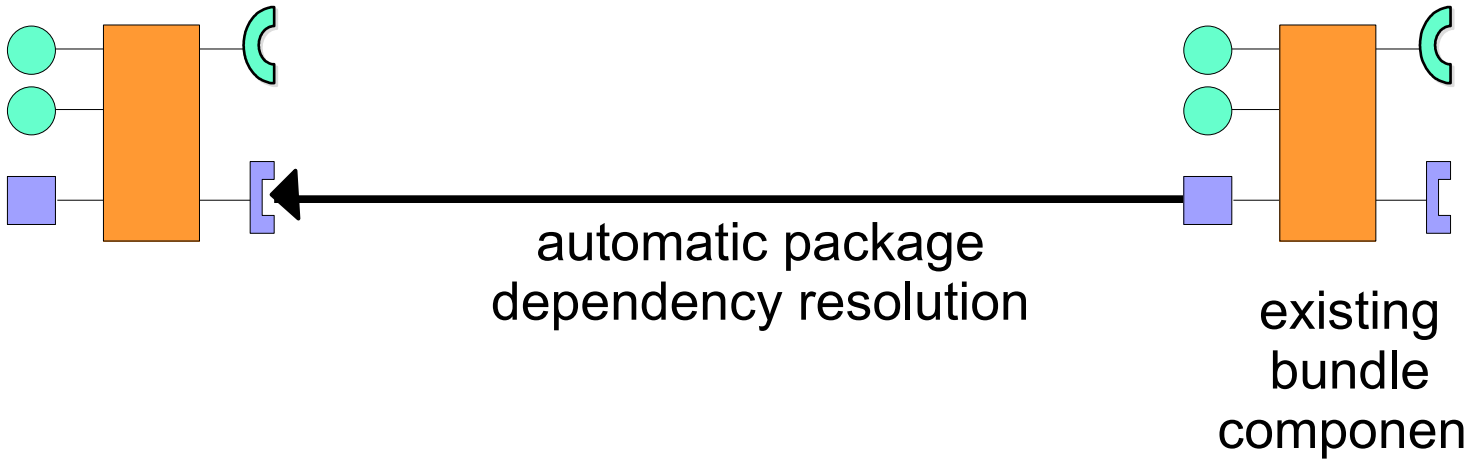

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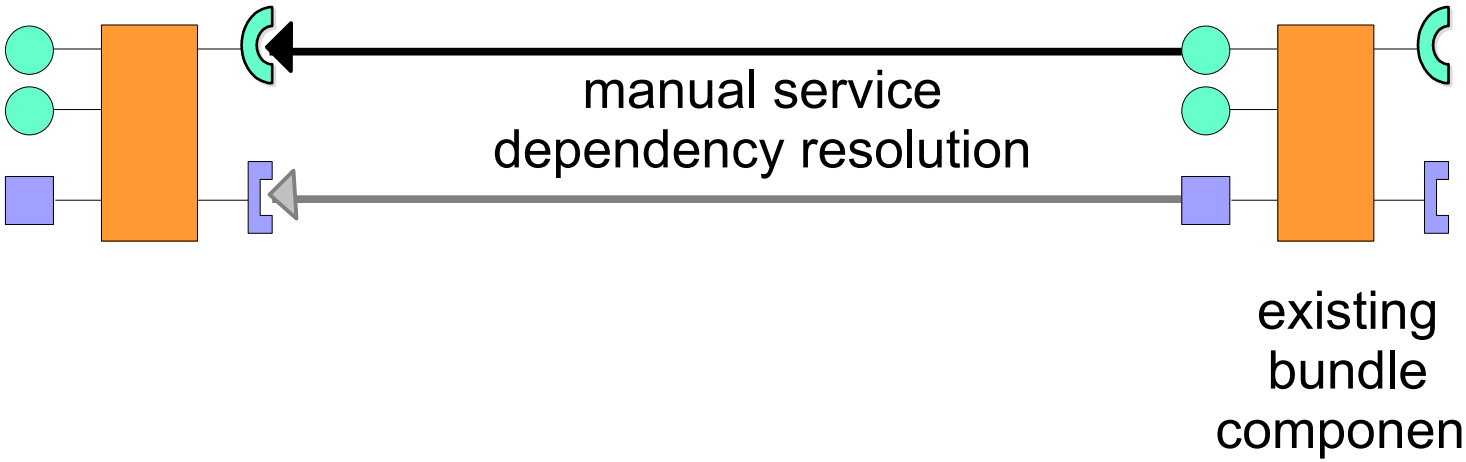

OSGi framework

OSGi R3 Bundle Manifest Example

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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:
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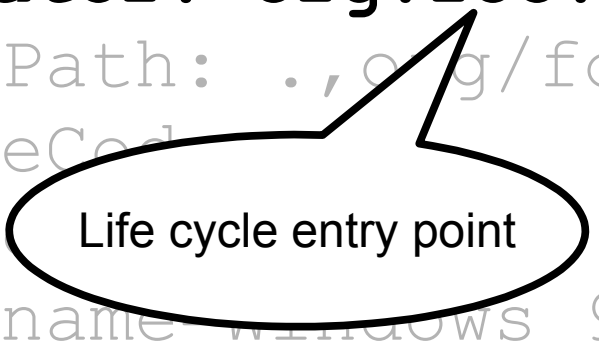

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Internal module class path

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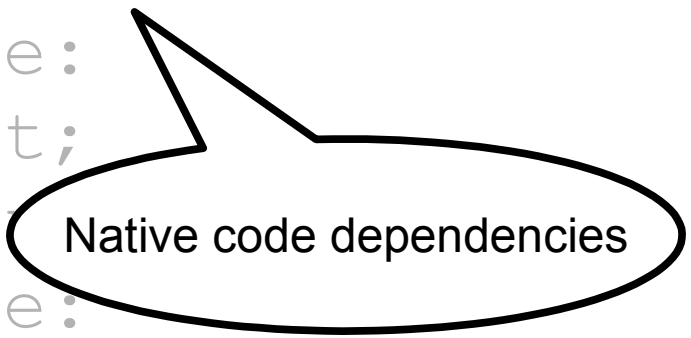

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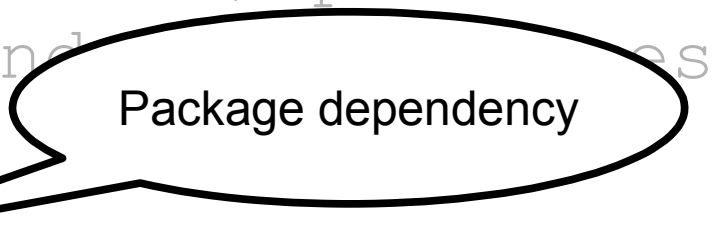

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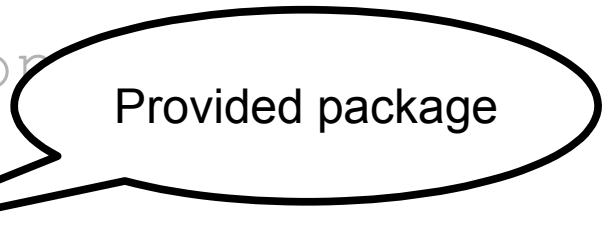

OSGi Applications

- A collection of bundles that interact via service interfaces
  - Bundles may be independently developed and deployed
  - Bundles and their associated services may appear or disappear at any time

OSGi R3 Modularity

Improving Standard Java

Success as a Modularity Framework

- OSGi framework is increasingly used as a modularity mechanism for Java
  - Provides logical and physical system structuring
    - Has benefits for development and deployment
  - Provides sophisticated dynamic module life-cycle management
    - Simplifies creation of dynamically extensible systems
      - Where system components can be added, removed, or rebound at run time while the system as a whole continues to function

OSGi R3 Modularity (1)

- Defines ***bundle***, logical and physical modularity unit
  - Explicit boundaries
    - External interface (i.e., exports)
    - Internal class path
      - Java code, resources, and native libraries
  - Explicit dependencies
    - Package dependencies (i.e., imports)
  - Explicit versioning
    - Package version, bundle version
  - Isolation via class loaders
  - Packaging format (bundle JAR file)

OSGi R3 Modularity (2)

- Defines dynamic bundle life cycle
  - Possible to install, update, and uninstall code at run time
  - Automatic package dependency resolution
  - Replaces low-level class loaders

OSGi R3 Modularity Issues (1)

- Package sharing is only global
  - Cannot have multiple shared versions
- Simplistic versioning semantics
  - Always backwards compatible
- Not intended for sharing implementation packages
  - Only for specification packages, which was why the version model is simple
- Provider selection is always anonymous
  - No way to influence selection

OSGi R3 Modularity Issues (2)

- Simplistic consistency model
  - Consistency model based on single in-use version
  - No way to declare dependencies among packages
- Coarse-grained package visibility rules
  - Classes in a package are either completely visible to everyone or hidden
- Module content is not extensible
  - All content of the logical module must be included in the physical module
- Package dependencies are not always appropriate
  - Package metadata is cumbersome in large, complex systems, tightly coupled subsystems and in less structured legacy systems

In Fairness

- It is important to point out that the preceding slides do not necessarily describe shortcomings of the OSGi framework
  - It was not designed to be a modularity layer, so it makes sense that it does not do it perfectly
  - It was used for a modularity layer by developers because it was simple and filled a specific need

OSGi R4 Framework

Modularity Support for the Future

Modularity Requirements

- Backwards compatible with OSGi R3
- Defined in terms of Java packages
  - Well-defined concept in Java
  - Maps nicely to class loaders
- Explicitly defined boundaries
- Explicitly defined dependencies
- Support for versioning and multi-versions
- Flexible, must support
  - Small to large systems
  - Static to dynamic systems

Related Work

- Module mechanisms
  - MJ: A Rational Module System for Java and its Applications (J. Corwin et al – IBM)
  - Mechanisms for Secure Modular Programming in Java (L. Bauer et al – Princeton University)
  - Units: Cool Modules for HOT Languages (M. Flatt and M. Felleisen – Rice University)
  - Evolving Software with Extensible Modules (M. Zenger – École Polytechnique Fédérale de Lausanne)
- Component and extensible frameworks
  - EJB, Eclipse, NetBeans
- Microsoft .NET
  - Assemblies and Global Assembly Cache

OSGi R4 Modularity (1)

- Limitation: Package sharing is only global

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- Limitation: ~~Package sharing is only global~~
- Multi-version support
  - Possible to have more than one version of a shared package in memory at the same time
  - General change of philosophy to the prior OSGi specifications
  - Has deep impact on service aspects as well as modularity
    - For a given bundle, the service registry is implicitly partitioned according to the package versions visible to it
    - Impact on services not explored further in this presentation

OSGi R4 Modularity (2)

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  - Exporters still export a precise version, but importers may specify an open or closed version range
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- Multi-version sharing and importing version ranges make implementation package sharing possible

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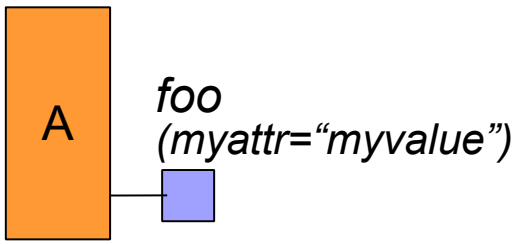


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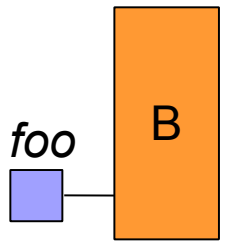

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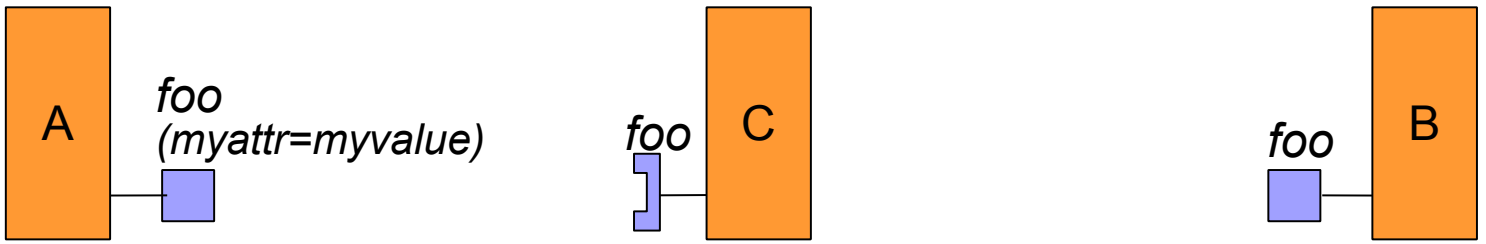

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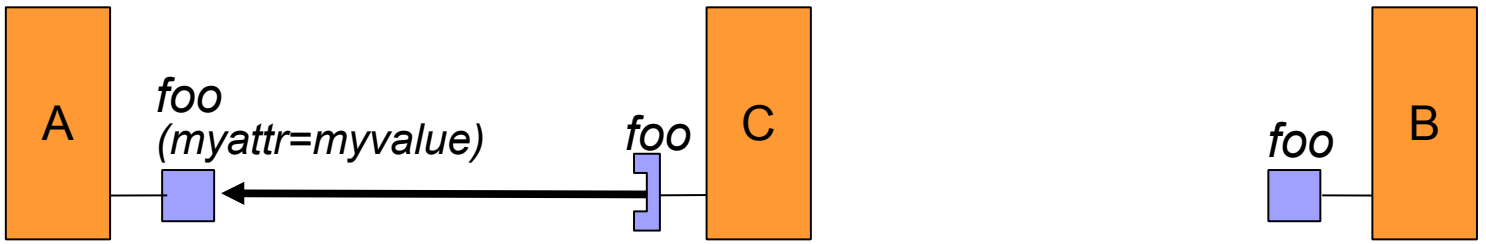

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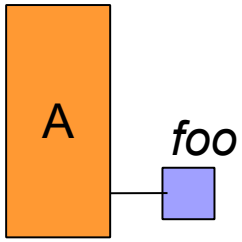

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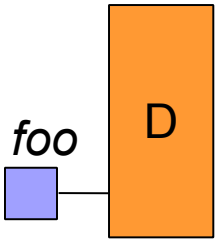

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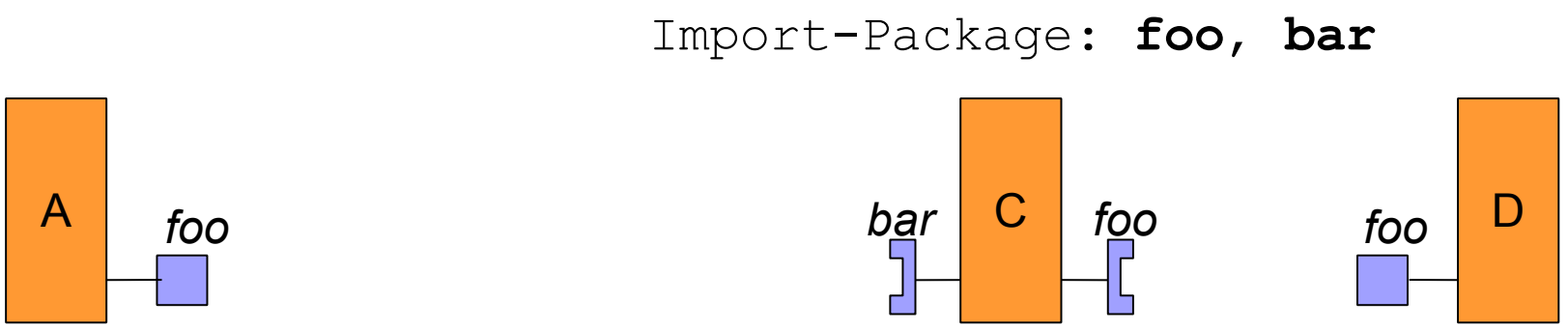

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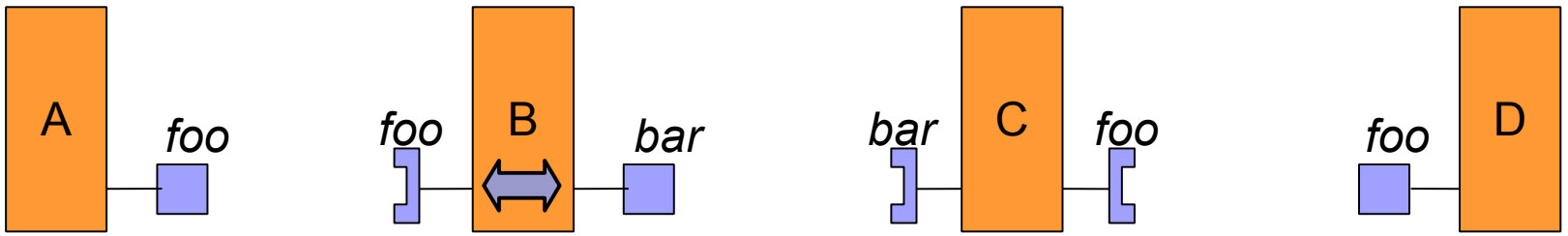

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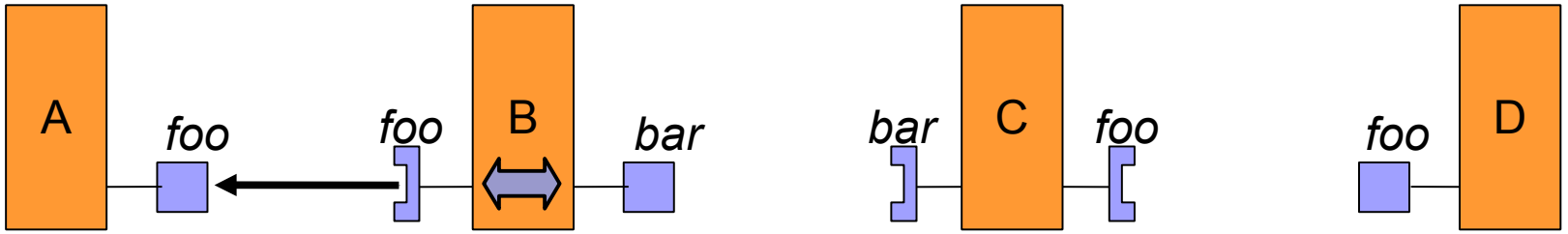

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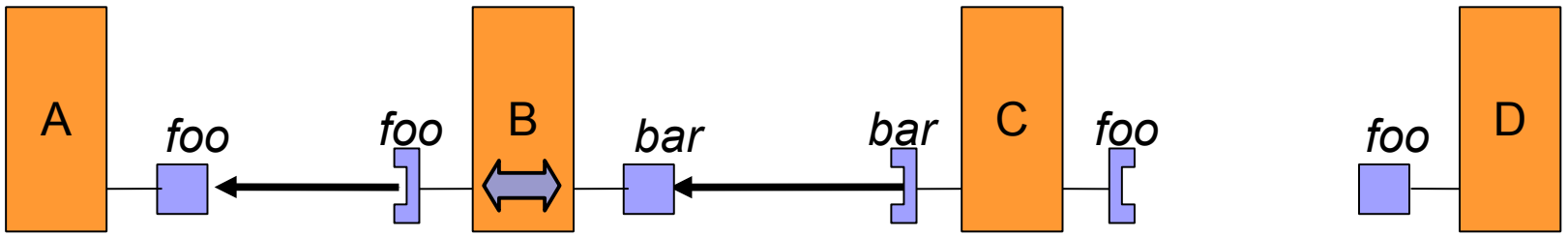

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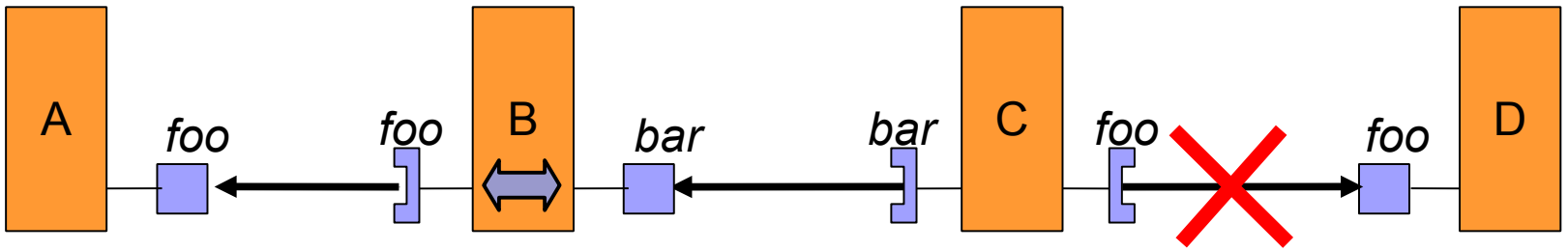

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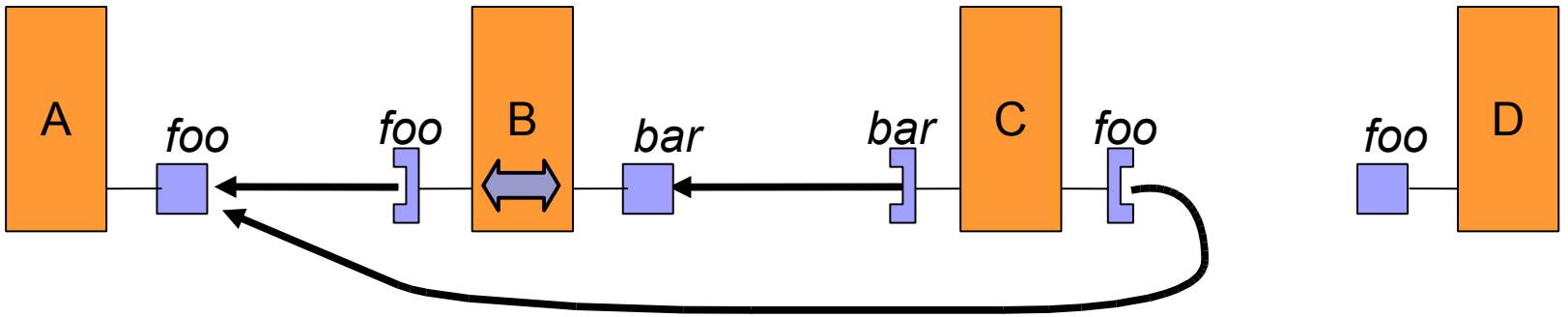

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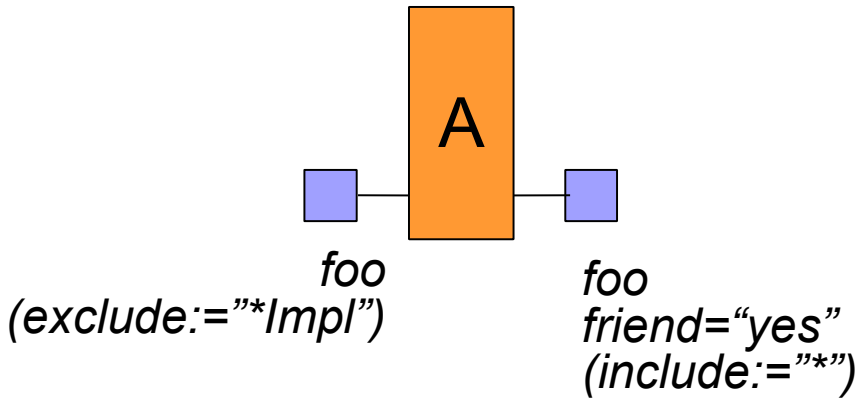
  - Exporters may declare that certain classes are included/excluded from the exported package

```
Export-Package: foo;
 exclude:="*Impl",
 foo; friend="yes";
 mandatory:="friend"
```



OSGi R4 Modularity (5)

- Limitation: ~~Coarse-grained package visibility rules~~
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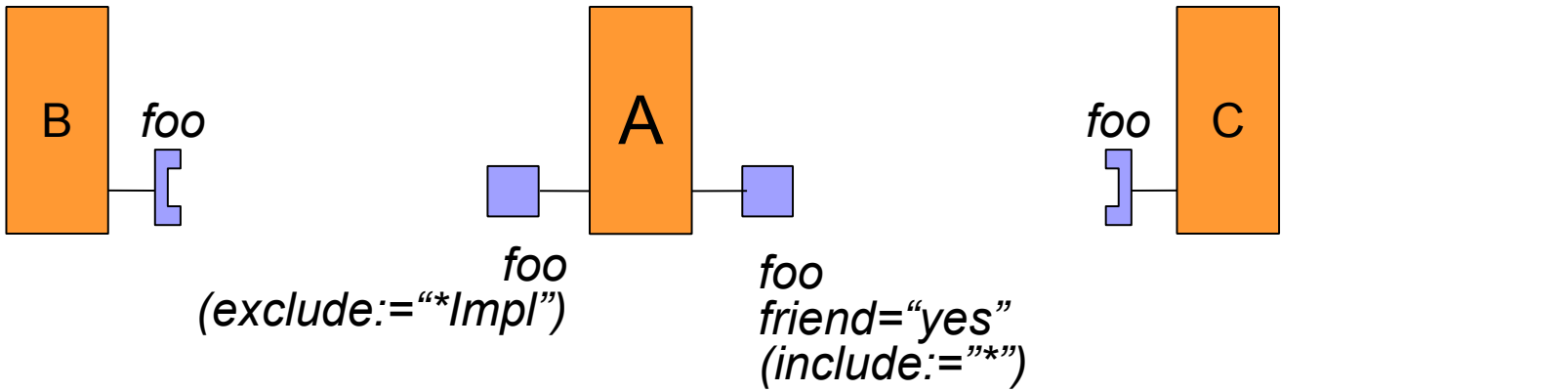

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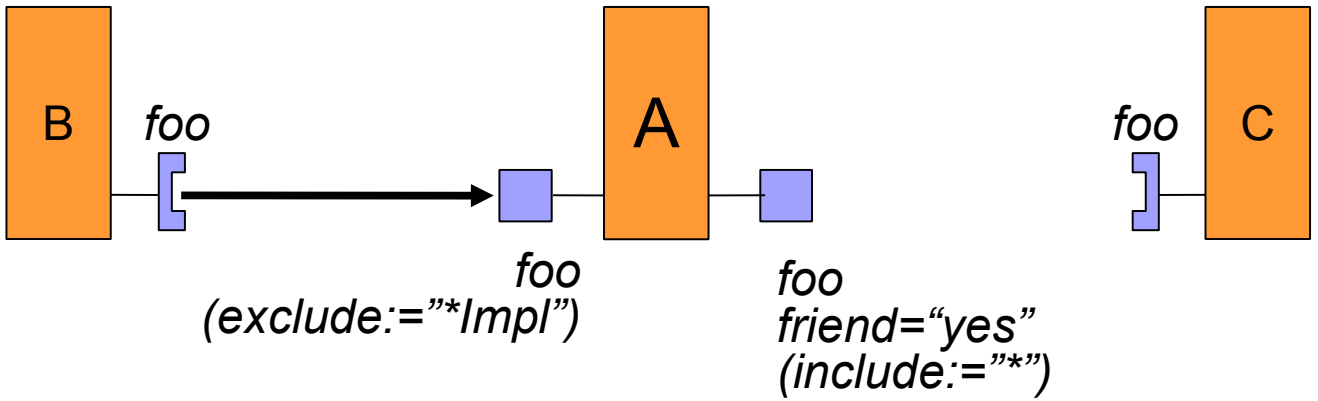

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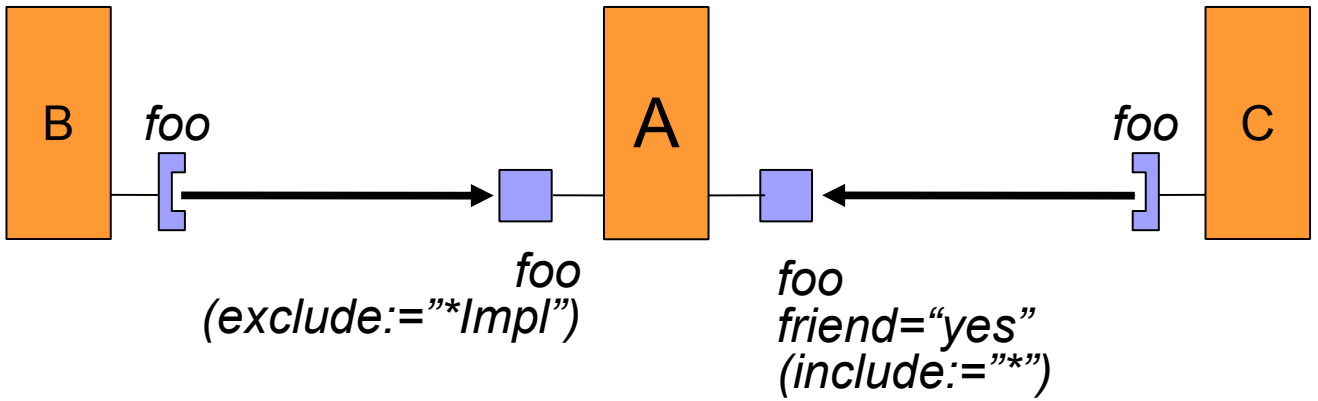

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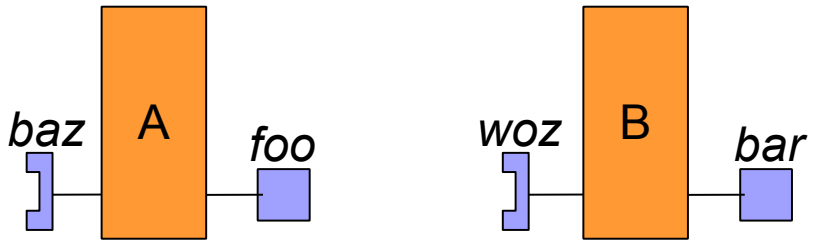
```
Fragment-Host: B
Export-Package: foo
Import-Package: baz
```

```
Bundle-SymbolicName: B
Export-Package: bar
Import-Package: woz
```



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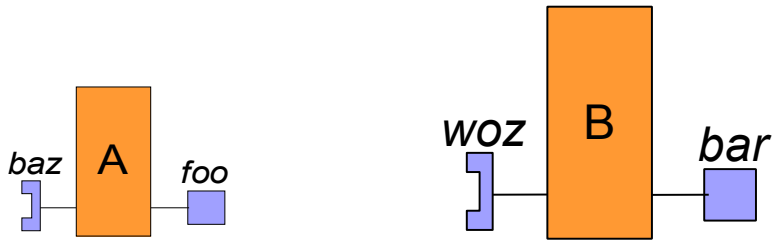

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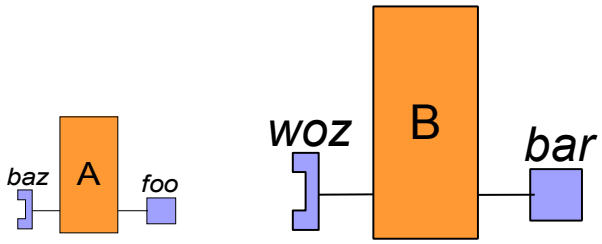

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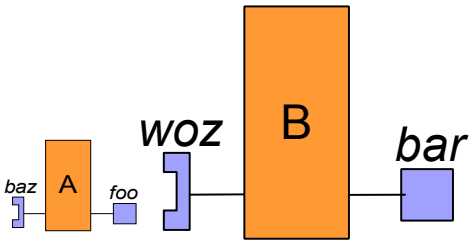

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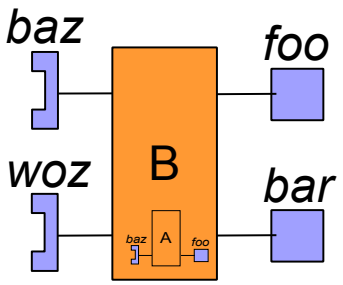

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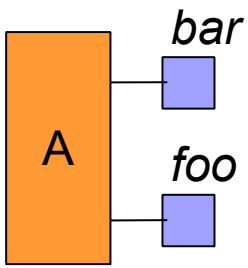
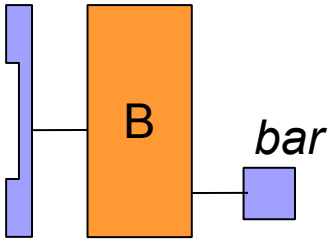
```
Bundle-SymbolicName: A
Export-Package: bar, foo
```




```
Require-Bundle: A
Export-Package: bar
```



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Require-Bundle: A
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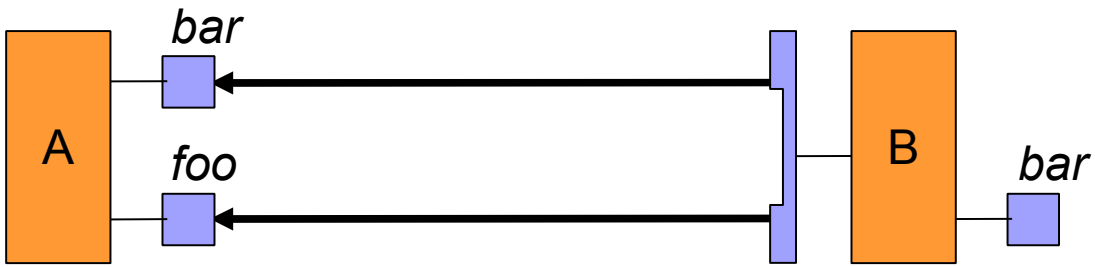
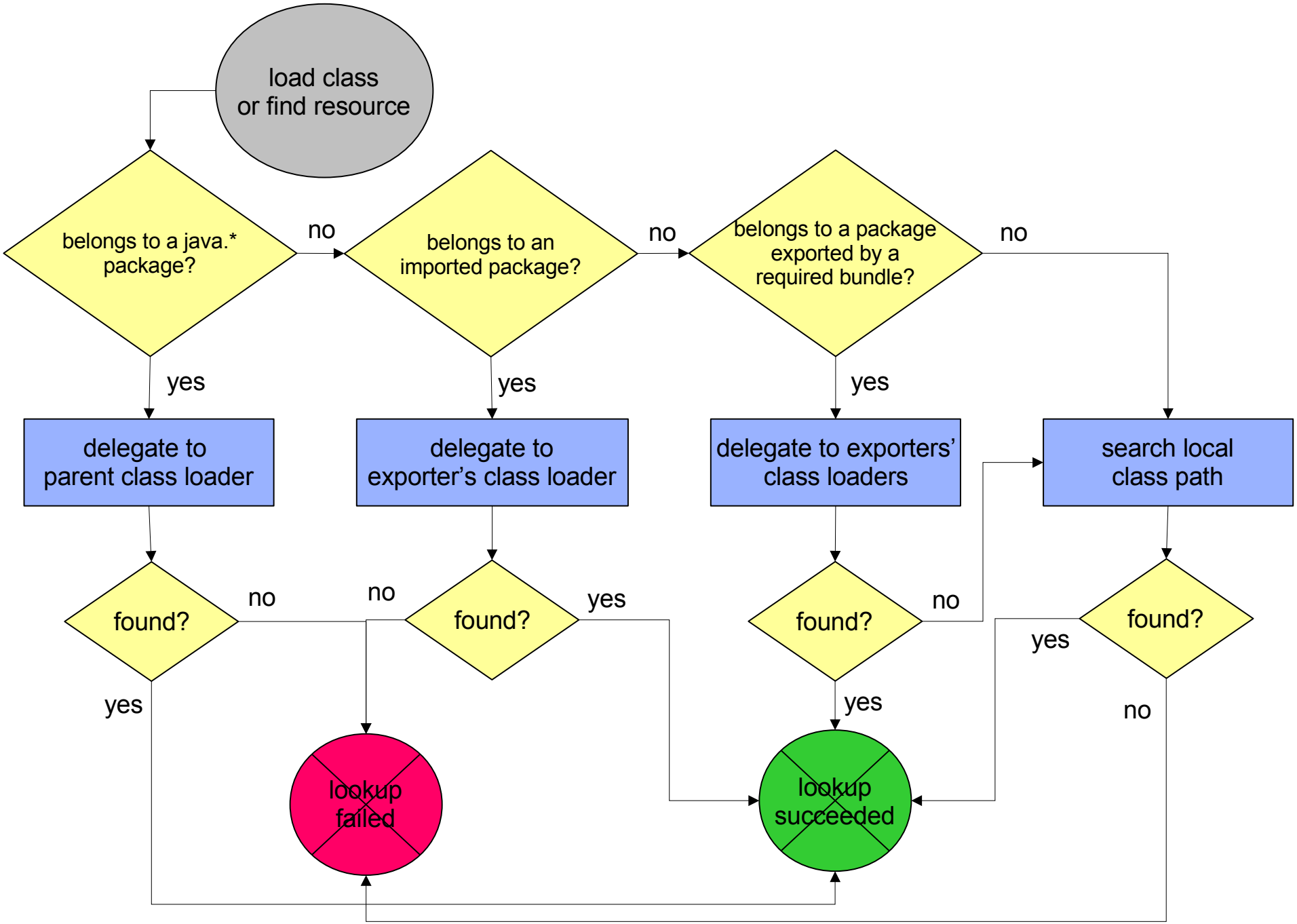


OSGi R4 Run-time Class Search Order



OSGi R4 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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Indicates R4 semantics and syntax

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Life cycle entry point

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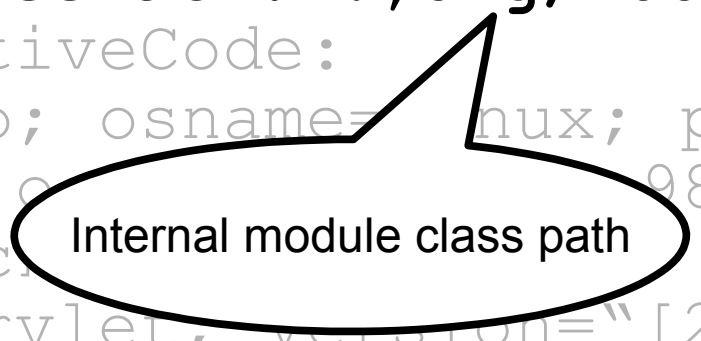

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Native code dependencies

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Optional dependency on a package version range

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```

Provided package with arbitrary attribute and excluded classes

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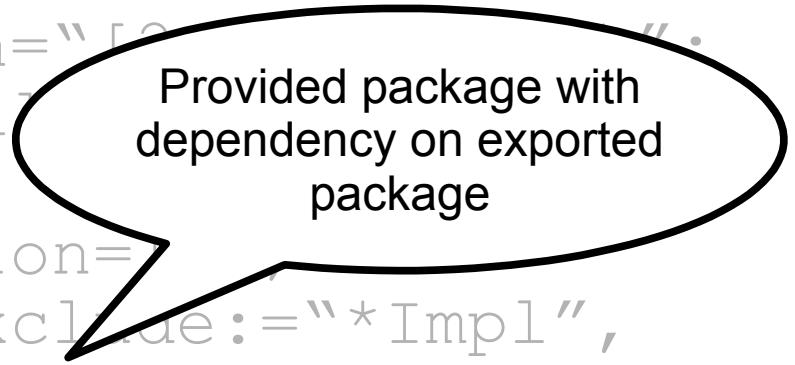

Challenges

- Manage the complexity
  - Maintain conceptual integrity
  - Keep the simple cases simple
  - Complexity should only be visible when it is required
  - Avoid bloat to support small devices

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The "good news" is that these changes generally only affect the dependency resolving algorithm

Conclusions

- Java needs improved modularity support
  - We need to stop re-inventing the wheel
  - Improve application structure
  - Simplify deployment and management especially in technological areas where deployment is inherent
    - e.g., component orientation, extensible systems, and service orientation (to some degree)
- OSGi R1/R2/R3 were all steps in the right direction
- OSGi R4 goes even further in providing sophisticated Java modularity
  - OSGi technology is cited in JSR 277, an initiative by Sun to define a module system for Java, whose expert group includes OSGi members

Questions?