Classloading and Type Visibility in OSGi

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Overview

- Introduction to classloading
  - What is classloading?
  - How does classloading work?
  - What does classloading mean for daily development?
- Classloading in OSGi
  - What is different?
  - Dependency and visibility
  - Advanced classloading in OSGi
  - Some Equinox specifics
- Conclusions

What is Classloading?

- Classloaders are Java objects
- They are responsible for loading classes into the VM
  - Every class is loaded by a classloader into the VM
  - There is no way around
- Every class has a reference to its classloader object
  - `myObject.getClass().getClassLoader()`
- Originally motivated by Applets
  - To load classes from the server into the browser VM

Classloader API

```
public abstract class ClassLoader {

  public Class<?> loadClass(String name)

  public URL getResource(String name)
  public Enumeration<URL> getResources(String name)
  public InputStream getResourceAsStream(String name)

  public final ClassLoader getParent()

  public static URL getSystemResource(String name)
  public static Enumeration<URL> getSystemResources(String name)
  public static InputStream getSystemResourceAsStream(String name)
  public static ClassLoader getSystemClassLoader()

  ...
}
```

Implicit class loading

```
public class A {
   public void foo() {
      B b = new B();
      b.sayHello();
   }
}
```

causes the VM to load class B using the classloader of A

Dynamic class loading

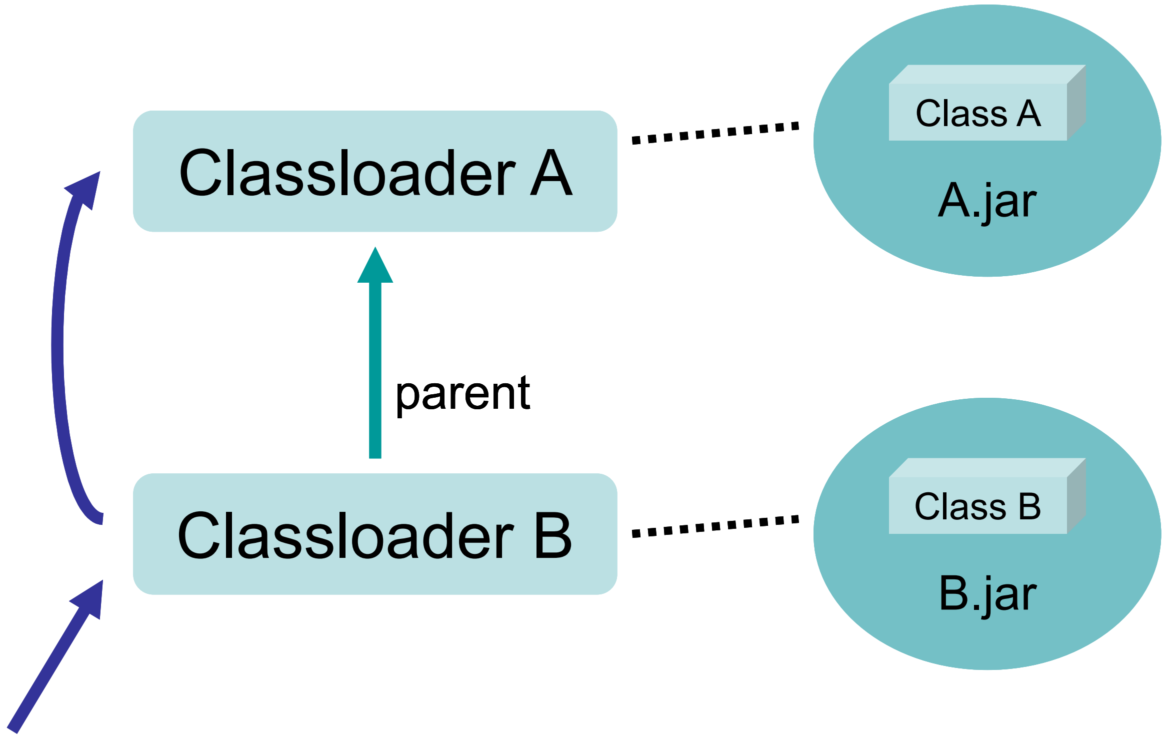
```
public void foo() {
  ClassLoader cl =
         this.getClass().getClassLoader();
  Class<?> clazz = cl.loadClass("A");
  Object obj = clazz.newInstance();

  ...
}
```

Hierarchical classloaders

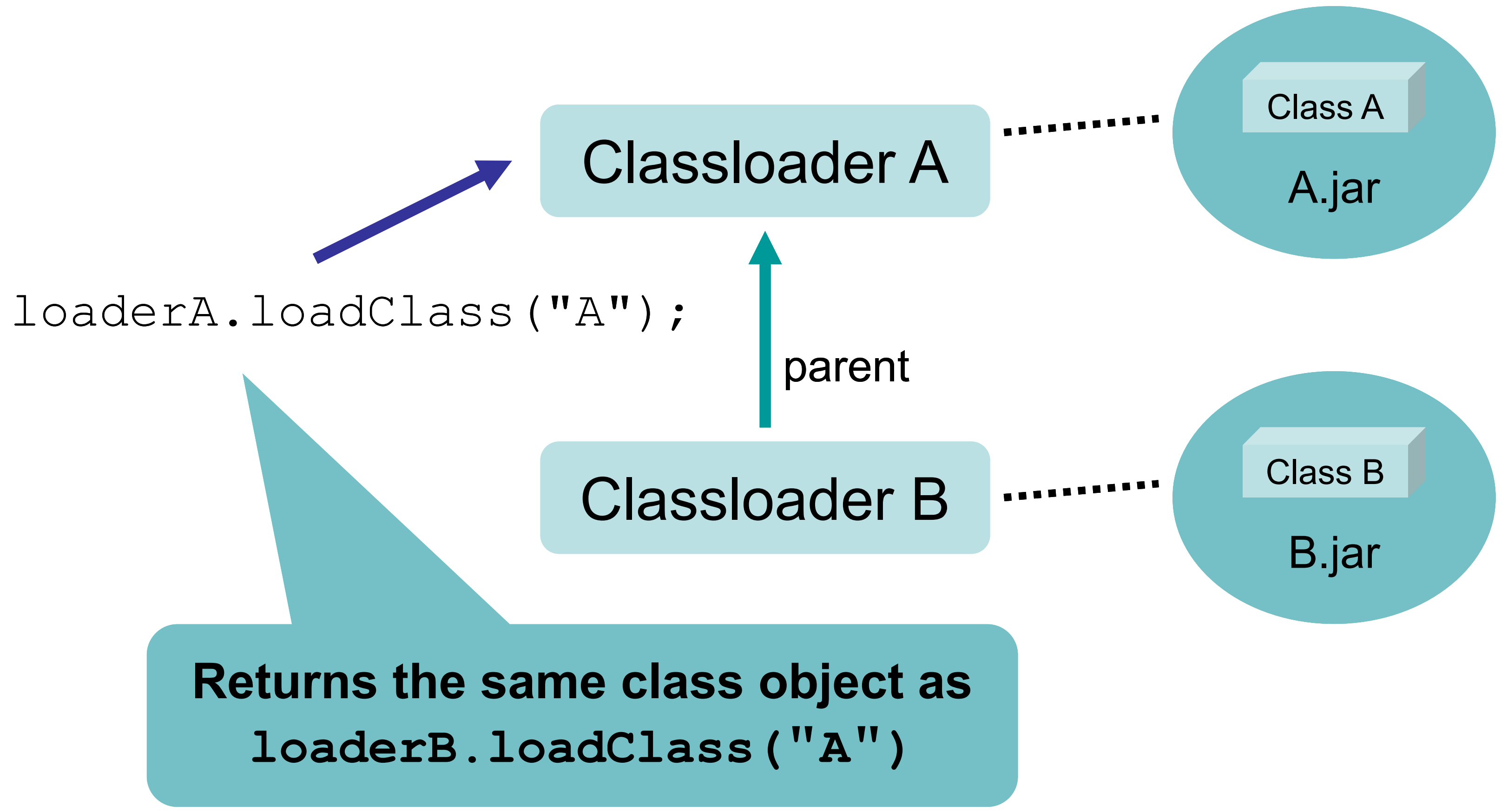
- Classloaders typically have a parent classloader
  - Chained classloading
- If a classloader is invoked to load a class, it first calls the parent classloader
  - Parent first strategy
  - This helps to prevent loading the same class multiple times

Classloader hierarchy



```
loaderB.loadClass("A");
```

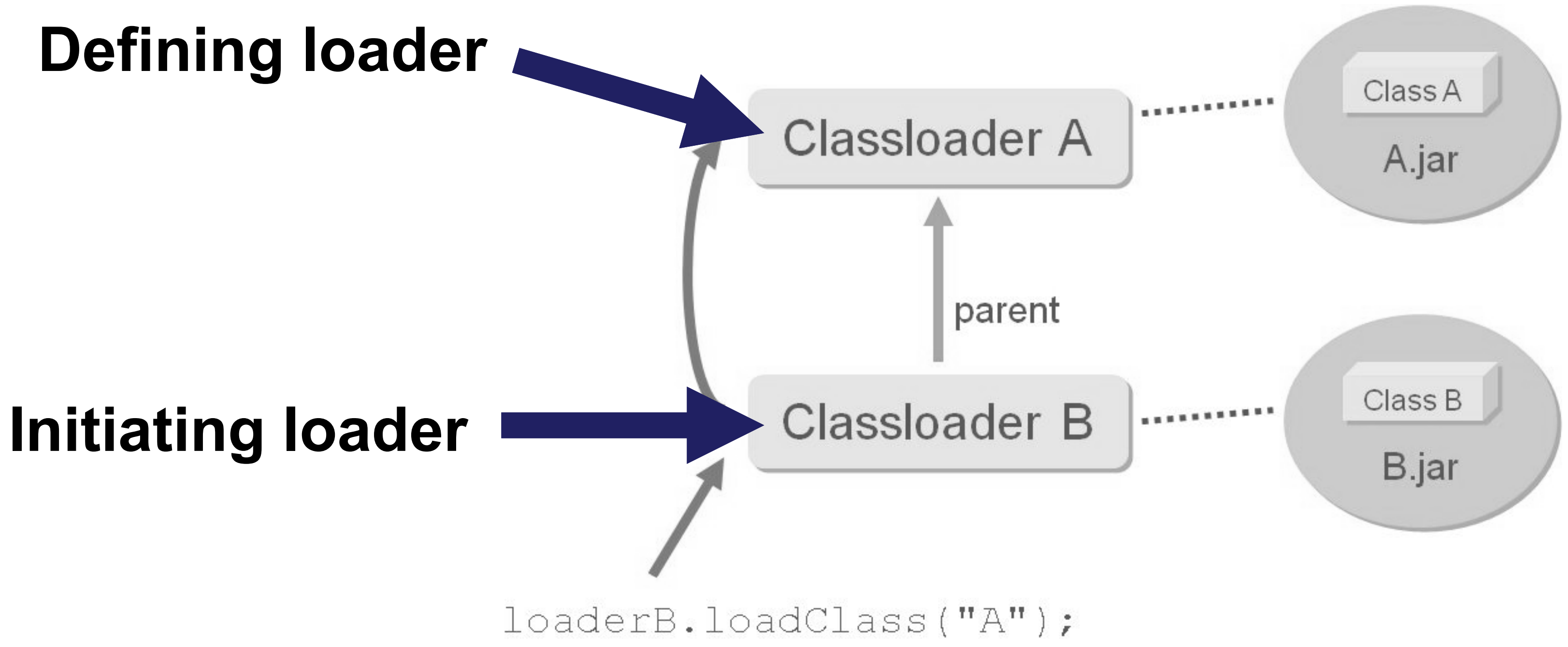
Type compatibility



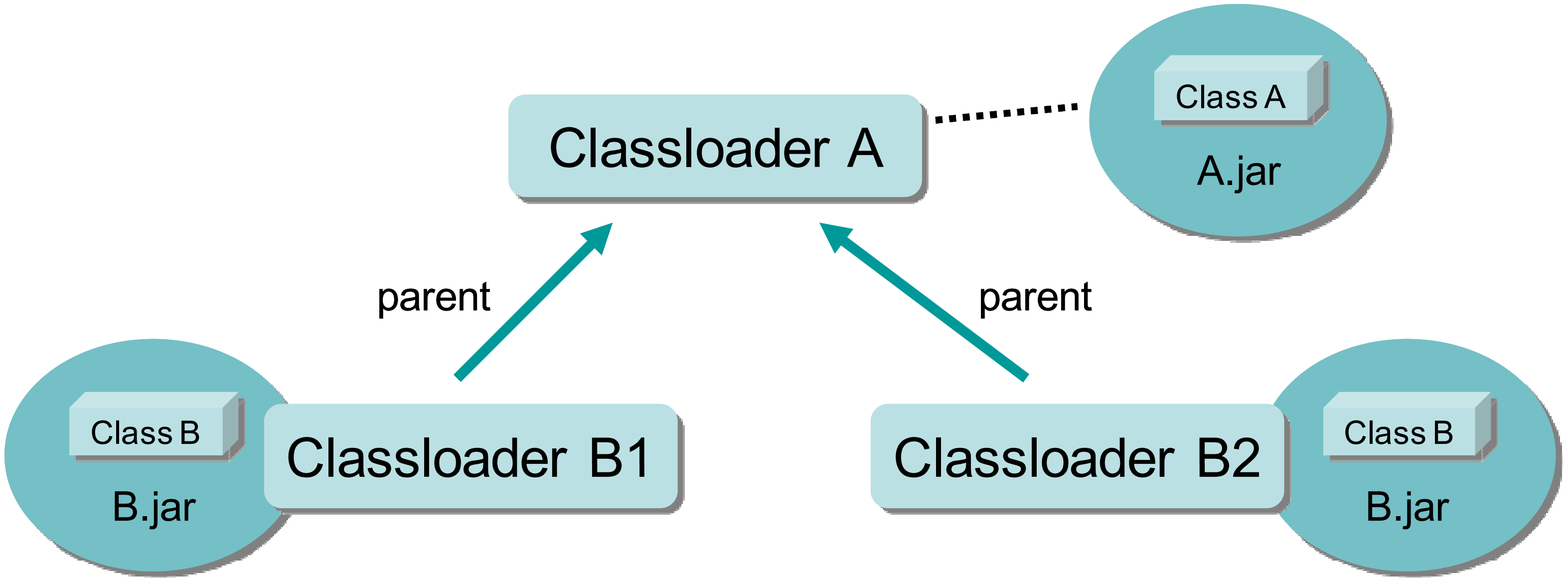
```
loaderA.loadClass("A");
```

Returns the same class object as **`loaderB.loadClass("A")`**

Defining vs. Initiating classloader

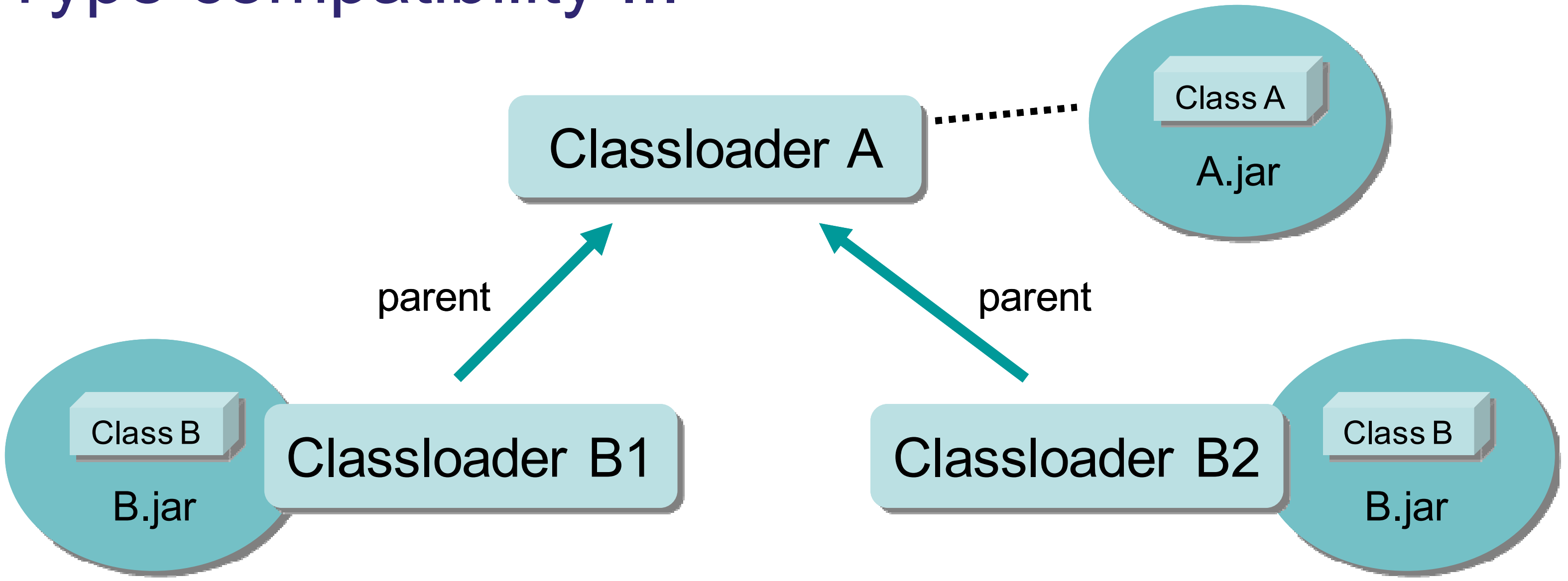


Type compatibility II



```
loaderB1.loadClass("A") == loaderB2.loadClass("A")
loaderB1.loadClass("B") != loaderB2.loadClass("B")
```

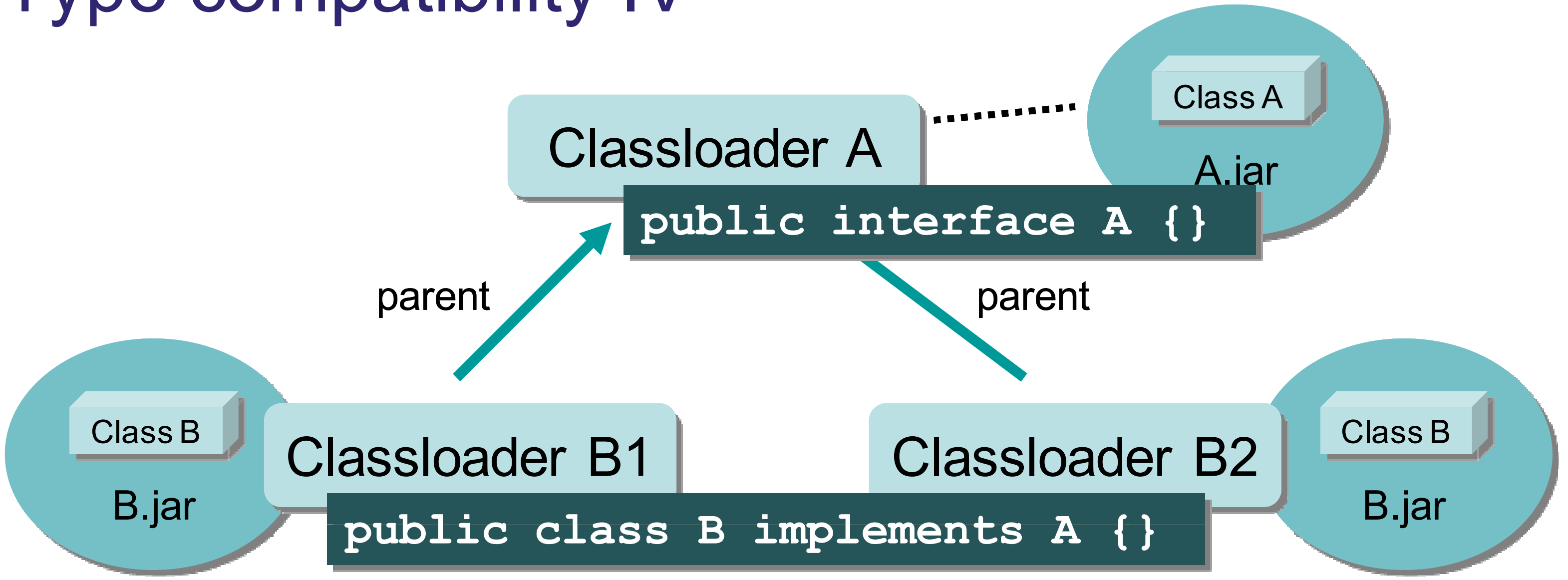
Type compatibility III



```
Object b1 = loaderB1.loadClass("B").newInstance();
b1 ! instanceof loaderB2.loadClass("B")
```

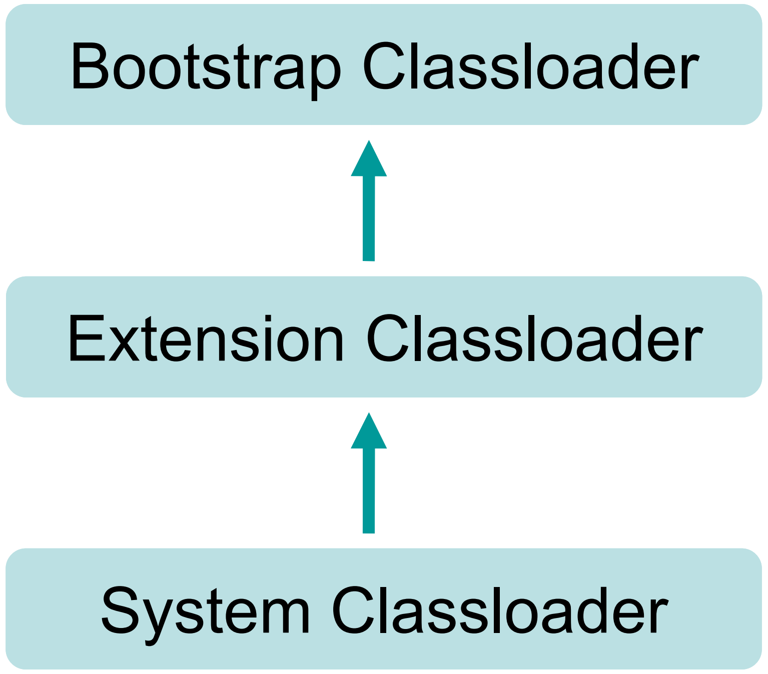
Remember: a class is identified by its name (including the package name) AND its defining classloader !!!

Type compatibility IV



```
A anA = loaderB1.loadClass("B").newInstance();
A anotherA = loaderB2.loadClass("B").newInstance();
anA = anotherA; (Assignment)
```

The default setting

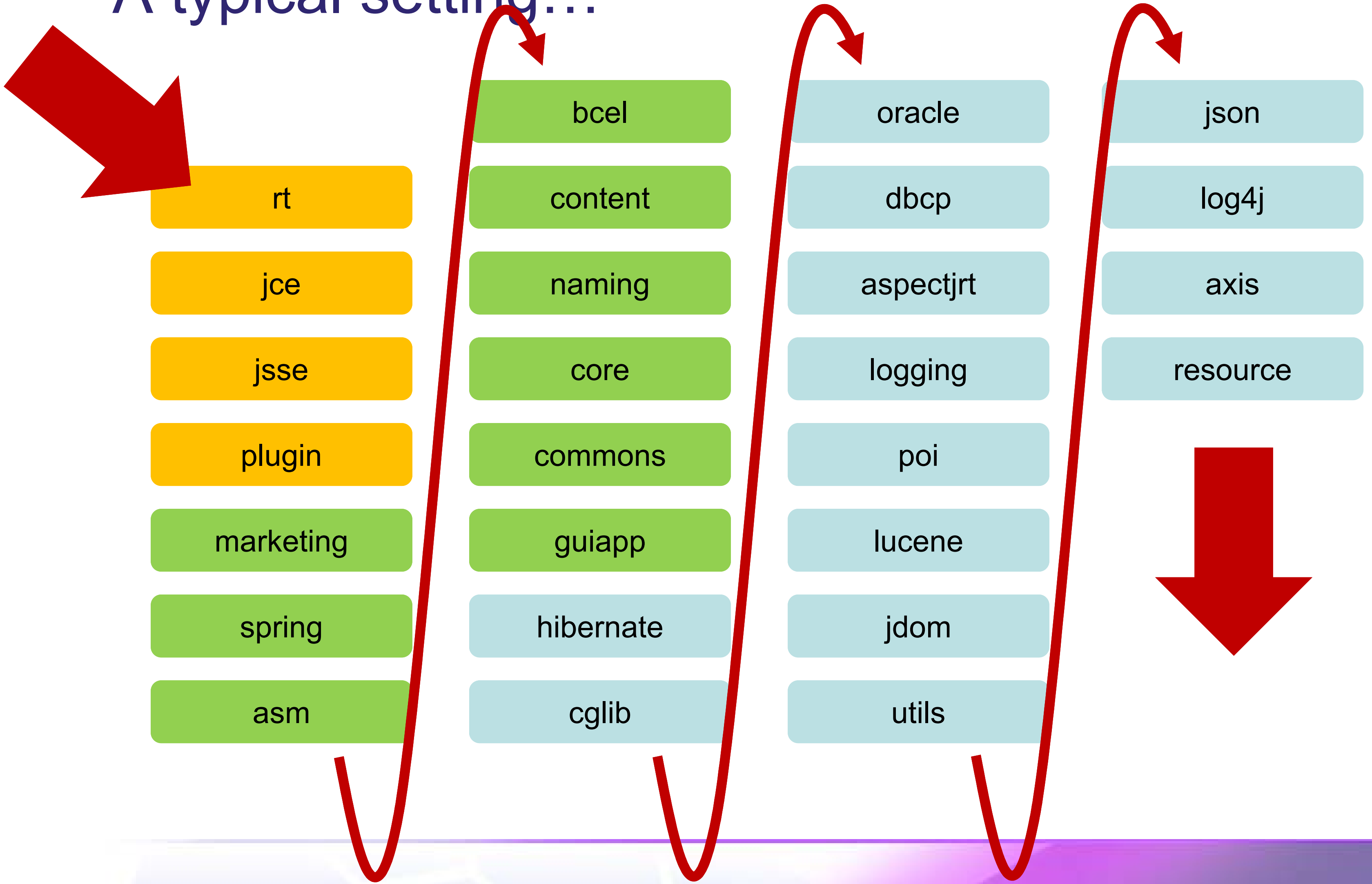


loads JVM classes (rt.jar)

loads classes from the JRE ext folder

loads classes from your application classpath

A typical setting…



Threads context classloader

```
Thread.currentThread().getContextClassLoader()
Thread.currentThread().setContextClassLoader(..)
```

- Typically used in libraries to access the context in which the library is called

Classloader.loadClass vs. Class.forName

- `Classloader.loadClass()` caches the loaded class object and returns always the same class object
  - **This is done by the defining classloader**
  - This ensures that each classloader loads the same class only once
- `Class.forName()` calls the normal classloader hierarchy to load the class (same happens as above)
  - **But caches the class object within the initiating classloader**
  - In standard cases no problem but can be tricky in dynamic environments

Classloading is dynamic

- You can create classloaders at runtime
- You can trigger them to load a specific class

- For example:
  - What app/web servers do for hot deployment

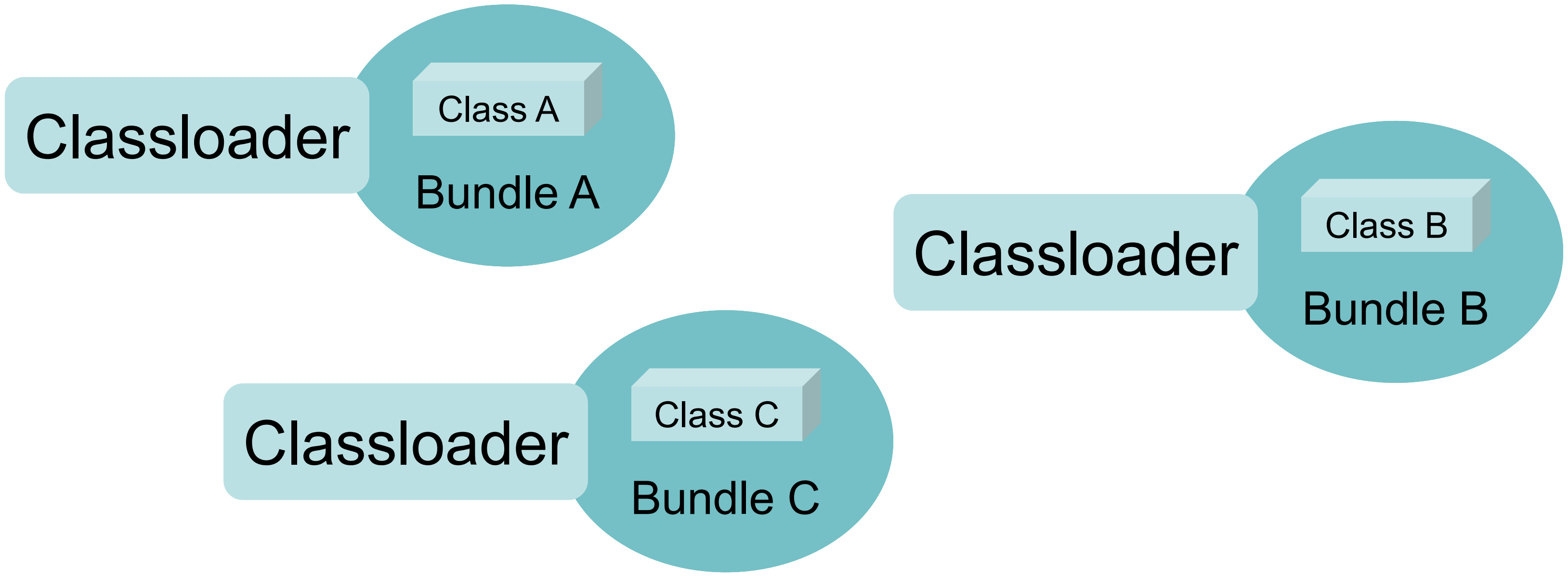
- Some people say the classloading mechanism is the only real innovation in the Java programming language

Classloading in OSGi

- “OSGi is a service framework”
- What is necessary:
  - Dependencies between bundles
    - Import- and Export-Package, Require-Bundle
  - Dynamic Bundle Lifecycle
    - Install, Update, Uninstall bundles
- Realized via specialized classloading

Classloader per bundle

- One classloader per bundle
  - Controls what is visible from the bundle
  - Controls what is visible from other bundles

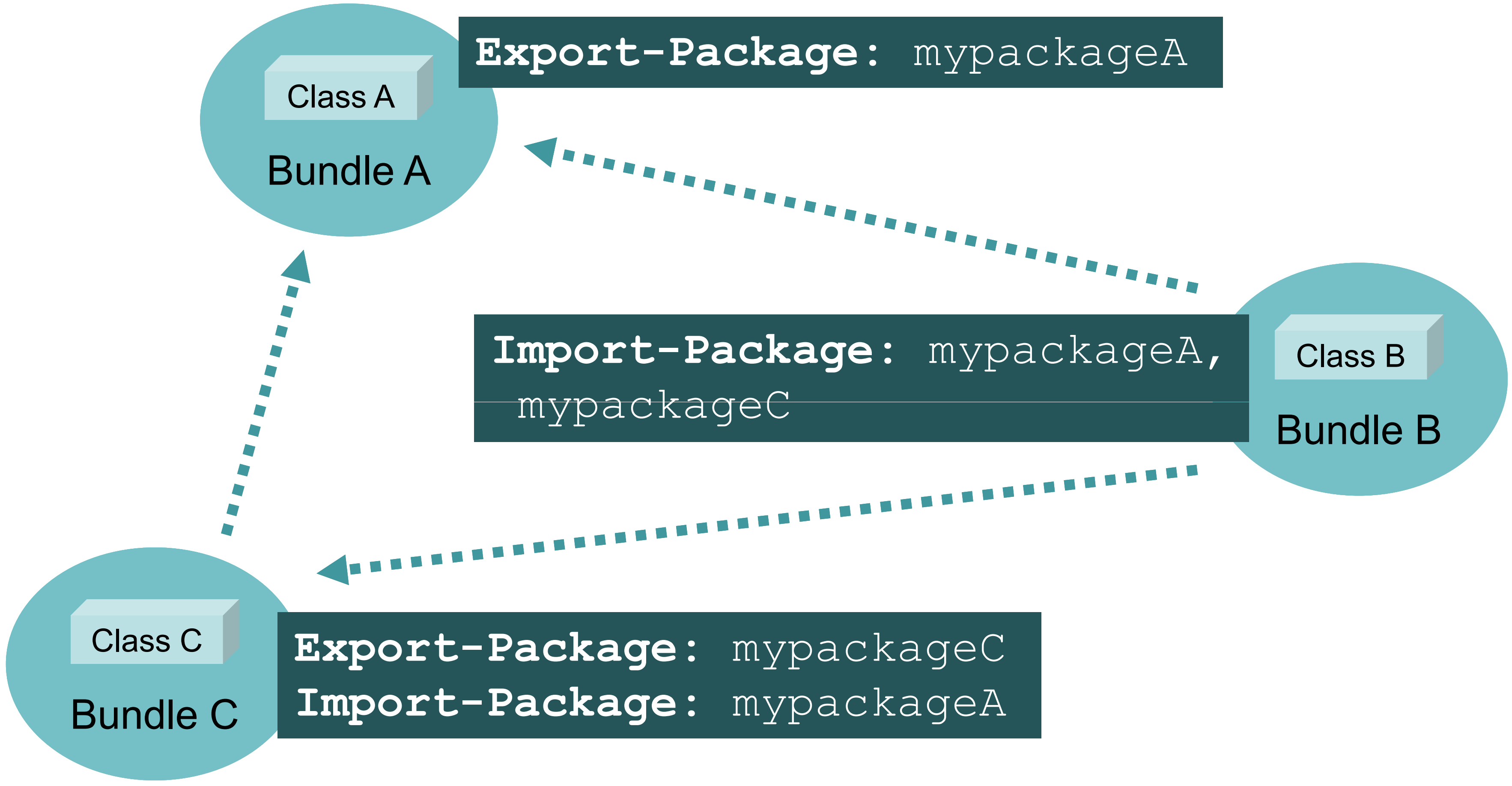


Classloader per bundle

- Effects
  - No linear class path for your application anymore
  - Instead class path per bundle
  - No real parent hierarchy anymore

- Classloader parent setting
  - Default: Bootstrap classloader
  - Can be parameterized via system property

Dependencies via delegation

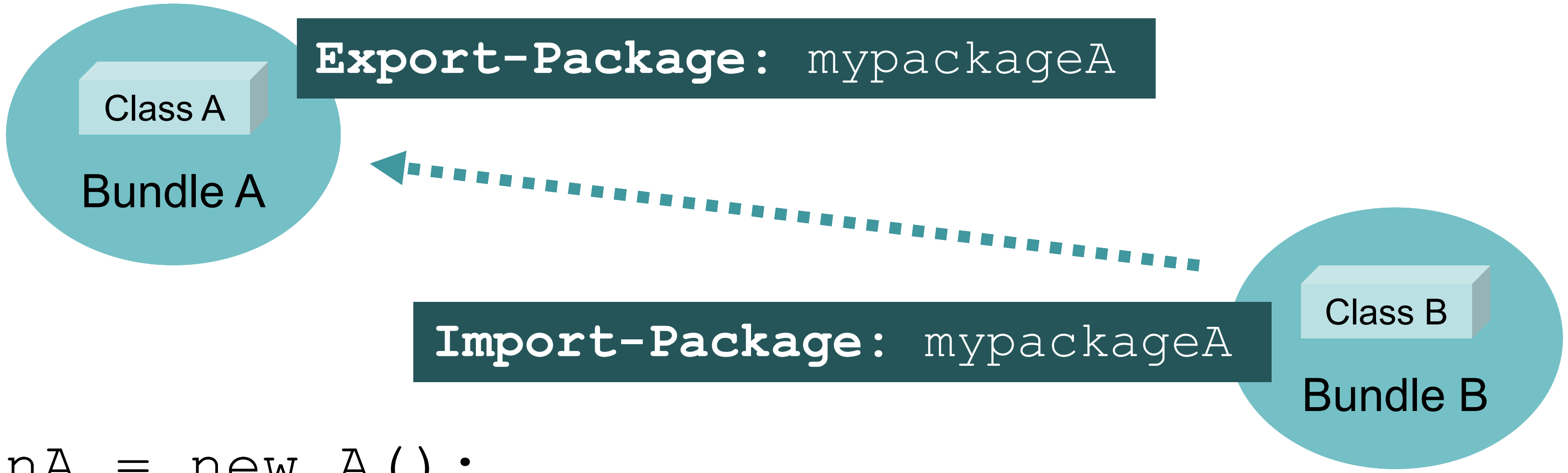


```
Export-Package: mypackageA
```

```
Import-Package: mypackageA,
 mypackageC
```

```
Export-Package: mypackageC
Import-Package: mypackageA
```

Type Visibility I

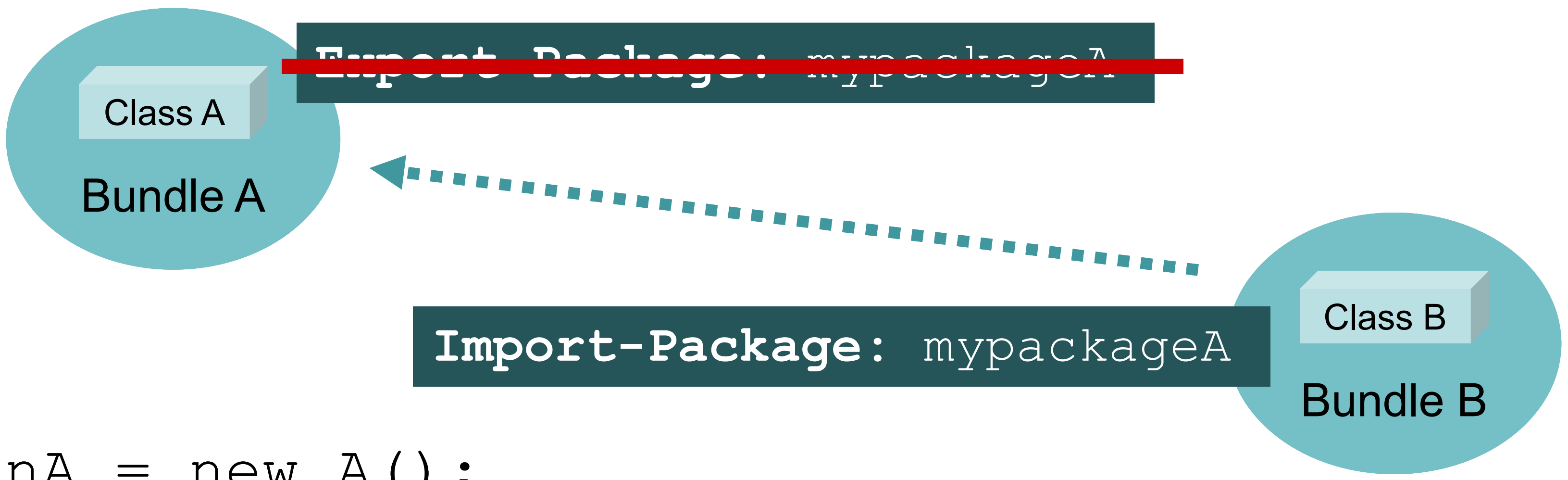


```
A anA = new A();
```

```
A anA = new A();
```

class A is loaded only once by bundle A (its defining classloader)

Type Visibility II



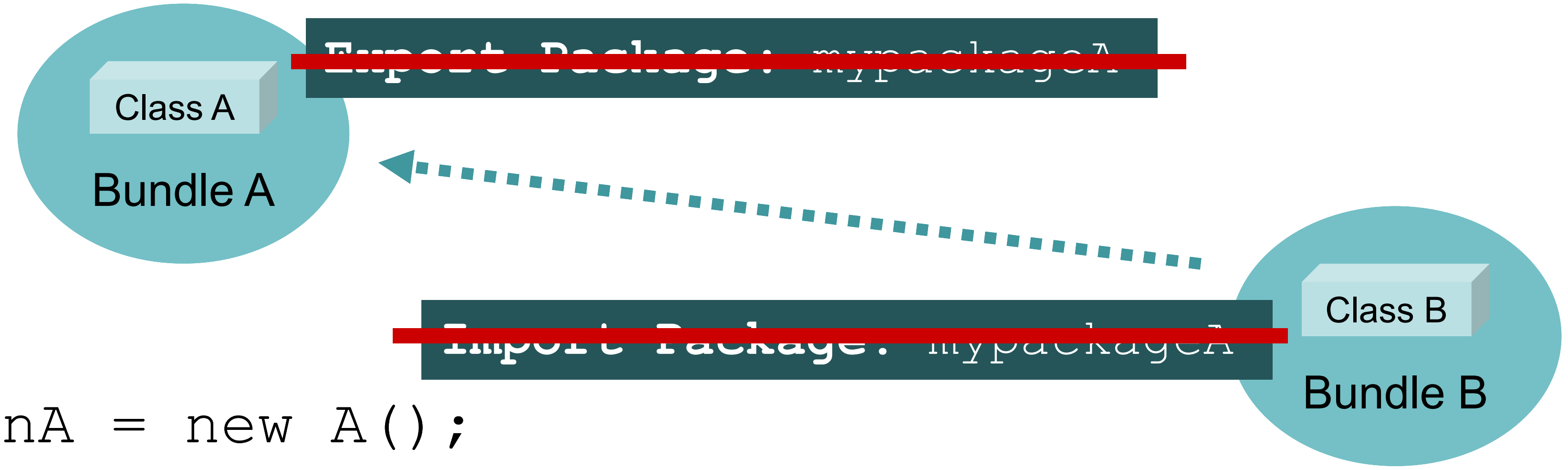
```
A anA = new A();
```

class is loaded successfully (if requested inside bundle A)

```
A anA = new A();
```

bundle B remains in state “installed” (not resolved), no loading of type A possible

Type Visibility III


~~Export-Package: mypackageA~~
Class A
Bundle A
~~Import-Package: mypackageA~~
Class B
Bundle B

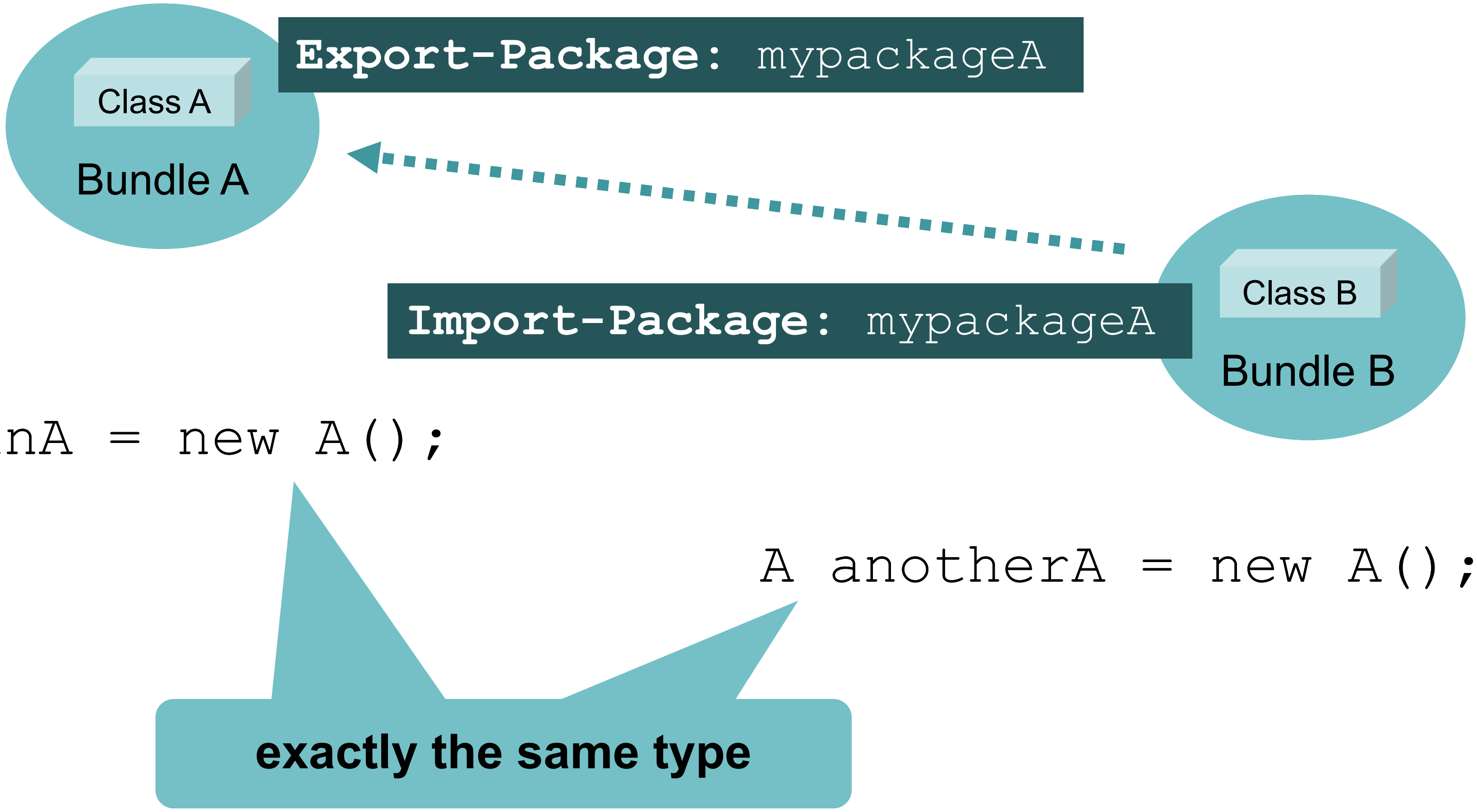
```
A anA = new A();
```

class is loaded successfully

```
A anA = new A();
```

ClassNotFoundException

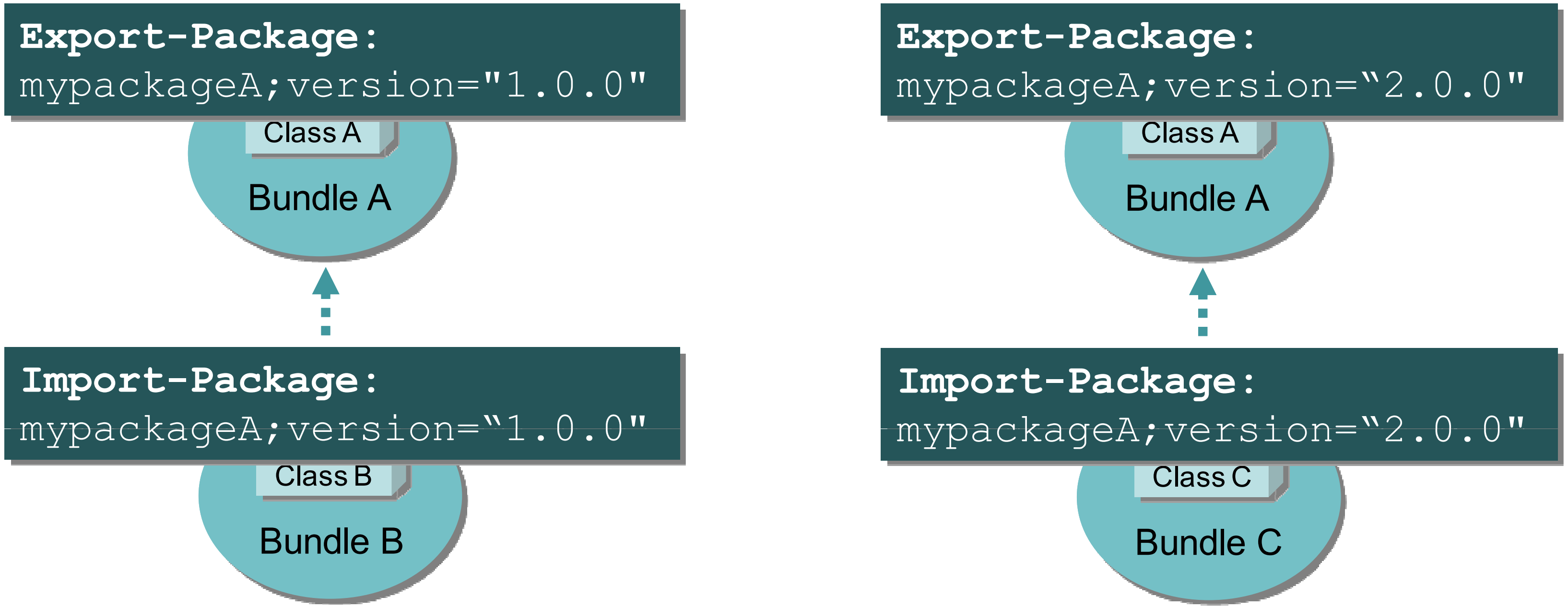
Type Compatibility revisited I



```
A anA = new A();
```

```
A anotherA = new A();
```

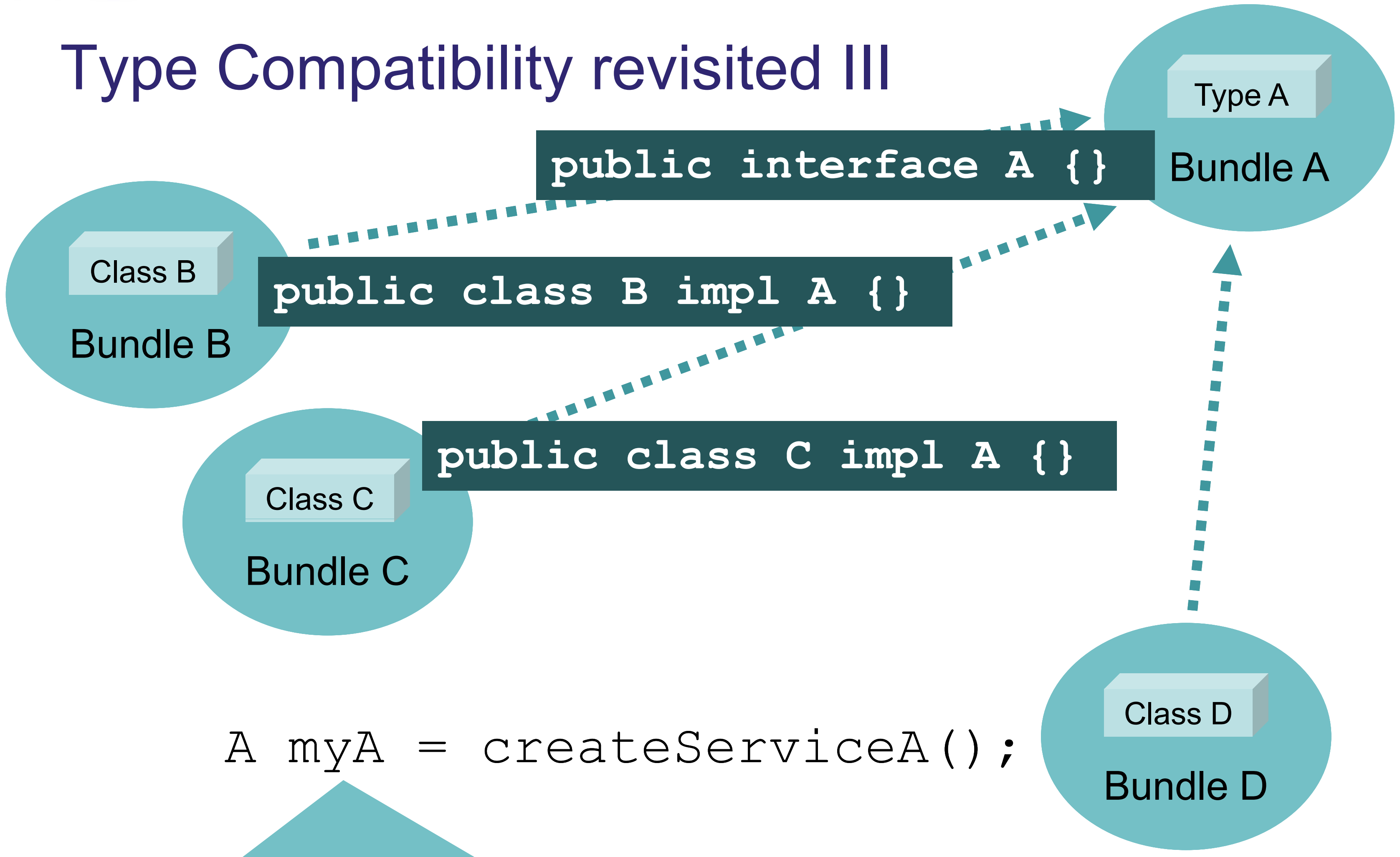
Type Compatibility revisited II



```
A anA = new A();                A anA = new A();
```

Completely different and incompatible types

Type Compatibility revisited III



```
public interface A {}
public class B impl A {}
public class C impl A {}
```

```
A myA = createServiceA();
```

Static type of myA is A, dynamic type of myA could be B or C

ClassNotFoundException

- Typical reasons for a ClassNotFoundException:
    - Dependency to declaring bundle not defined
    - Type is not visible (not exported)

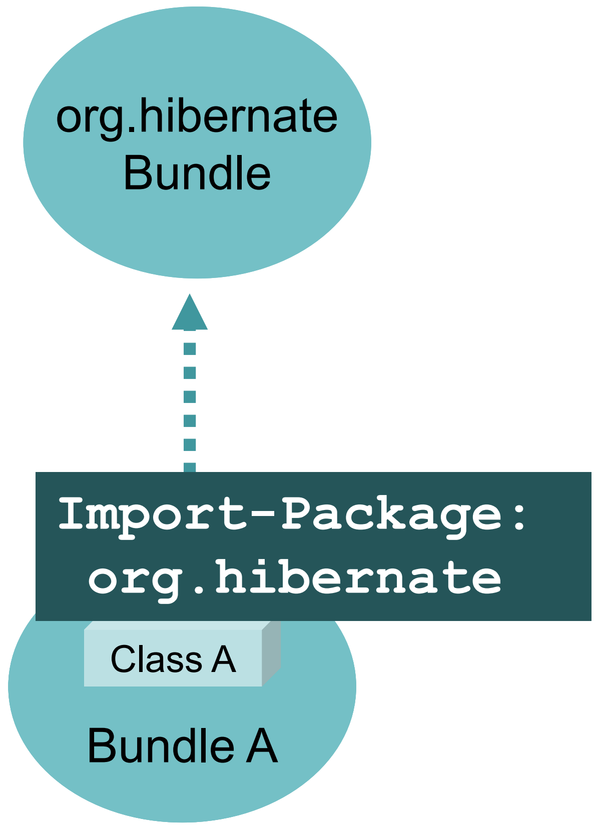
- Dynamically generated classes
    - Proxies
    - CGLib
    - …

- Serialisation

Libraries

- What happens if a library needs to load classes from its clients?
  - e.g. persistence libraries?

- Cyclic dependencies are not allowed and maybe even not what you want



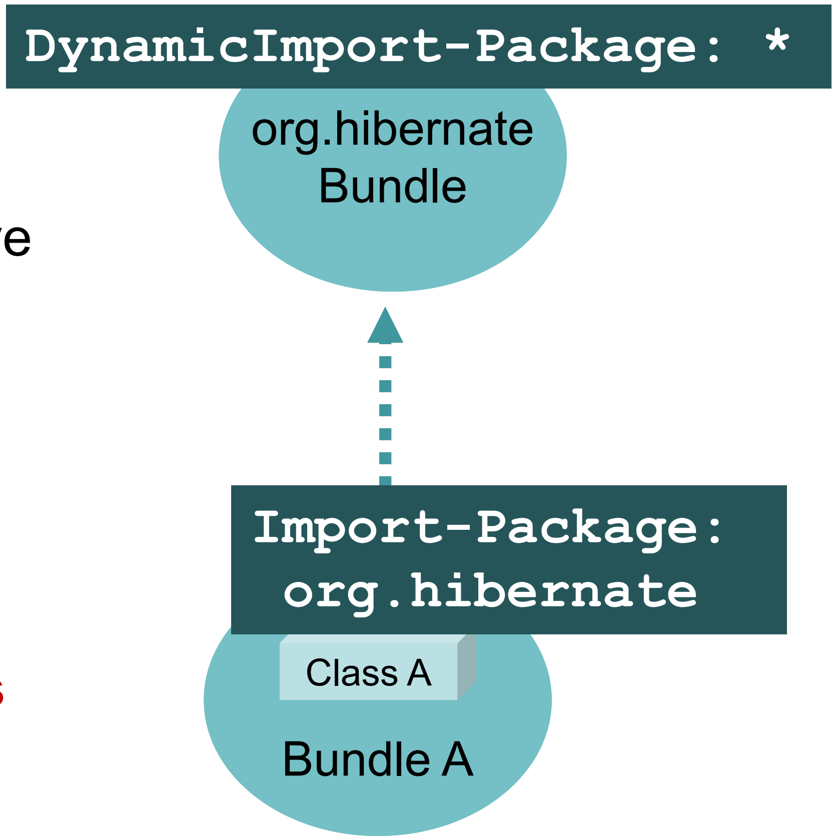
Register classes

- Register types the library need via an API
  - E.g. `Hibernate.registerClass(Class clientClass)`

- This allows the lib to create objects of those types without loading those classes directly

DynamicImport-Package

- Works similar to Import-Package, but
  - wiring does not happen at resolve
  - instead at first access to such a type
- Wildcards possible
  - * allows a bundle to see "everything"
  - **Should be used very rarely, as a "last resort"**



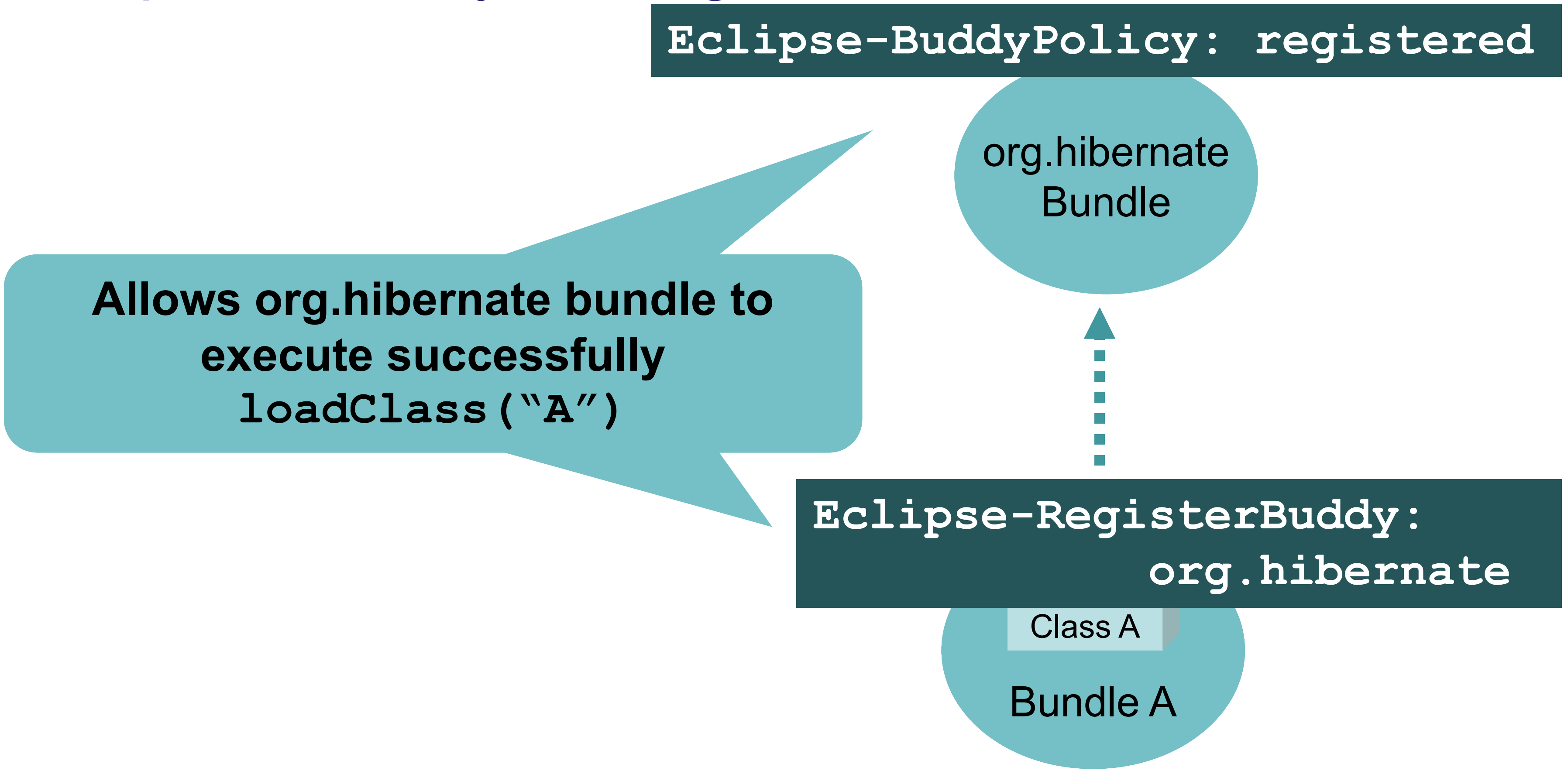
specific to Equinox

Equinox buddy loading I

- Equinox provides so called “Buddy Loading”
  - **“I am a buddy of hibernate. Hibernate is allowed to access my types”**

specific to Equinox

Equinox buddy loading II



```
Eclipse-BuddyPolicy: registered
```

Allows org.hibernate bundle to execute successfully `loadClass("A")`

```
Eclipse-RegisterBuddy:
                 org.hibernate
```

```
A anA = new A();
```

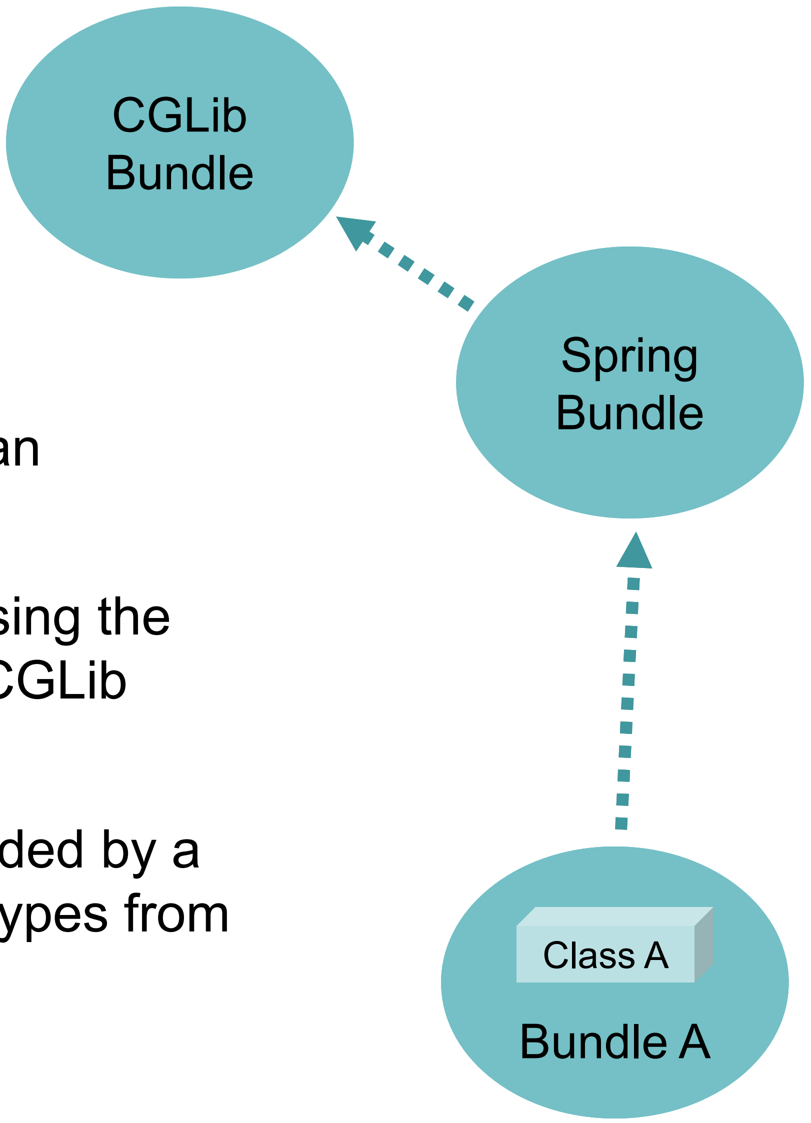
specific to Equinox

Equinox buddy loading III

- Important difference:
  - Buddy loading can load **all** classes from a buddy bundle
  - not only exported types
- Its just a workaround for libraries and other existing code that does not behave correctly within the OSGi world
- **Take care: you could loose consistency**

Generated Proxies

- Situation:
  - Ask the Spring bundle for a bean
- What does Spring?
  - Creates a proxy for the bean using the classloader of bundle A using CGLib
- The result
  - The proxy type needs to be loaded by a classloader that is able to see types from bundle A **and** CGLib



The loading sequence

1. Try the parent for “java.” packages
2. Try the parent for boot delegation packages
3. Try to find it from imported packages
4. Try to find it from required bundles
5. Try to find it from its own class path
6. Try to find it from dynamic import
7. Try to find it via buddy loading

Garbage Collection for Classloaders

- You could expect that the classloader of a bundle gets garbage collected if the bundle is stopped or uninstalled

- **This is not automatically the case!!!**

- You need to ensure that all objects from those classes loaded by this classloader are no longer referenced

What does this mean?

- Example:
    - You request an OSGi service and get an OSGi service back
    - The service you get is provided by bundle A
    - Next you uninstall bundle A

- If you stay with your object reference to the service, the classloader of A can never be collected

Service Tracker helps

- Use a Service-Tracker

- Takes care of …
  - holding the reference for performance reasons
  - As long as the service is available
  - **But no longer!**

“High Performance Classloading”

- Classloading consumes a remarkable amount of time at startup
- OSGi allows to highly optimize classloading
  - Finding the right class
  - Highly optimized implementations available
  - Avoid dynamic import

specific to Equinox

Classloading Hooks

- Equinox provides a hook mechanism
  - To enhance and modify the behavior of the runtime
- Examples
  - Modify bytecode at load-time
  - Intercept bundle data access
- Eat your own dog food
  - Some Equinox features are implemented using those hooks
  - e.g. Eclipse-LazyStart

Conclusions

- Changing the viewpoint from the linear classpath to a per-bundle classpath
- Clearly defined dependencies and visibilities
  - Real modularity
  - Classloading only implementation detail

- **Use OSGi in a clean and correct way and you never need to think about classloading at all**

Thank you for your attention!

Q&A

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