How ClassLoader Works in Java? Example

Java class loaders are used to load classes at runtime. ClassLoader in Java works on three principles: `delegation`, `visibility`, and `uniqueness`. Delegation principle forward request of class loading to parent class loader and only loads the class if the parent is not able to find or load the class. The visibility principle allows the child class loader to see all the classes loaded by the parent ClassLoader, but the parent class loader can not see classes loaded by a child. The uniqueness principle allows one to load a class exactly once, which is basically achieved by delegation and ensures that child ClassLoader doesn't reload the class already loaded by a parent. Correct understanding of class loader is a must to resolve issues like NoClassDefFoundError in Java and java.lang.ClassNotFoundException, which is related to class loading.

ClassLoader is also an important topic in advanced Java Interviews, where a good knowledge of the working of Java ClassLoader and How classpath works in Java is expected from Java programmers.

I have always seen questions like, **Can one class be loaded by two different ClassLoader in Java** on various Java Interviews. In this Java programming tutorial, we will learn what is ClassLoader in Java, How ClassLoader works in Java and some specifics about Java ClassLoader.

What is ClassLoader in Java

ClassLoader in Java is a class that is used to load class files in Java. Java code is compiled into a class file by `javac` compiler and JVM executes the Java program, by executing byte codes written in the class file. ClassLoader is responsible for loading class files from file systems, networks, or any other source.

There is three default class loader used in Java, **Bootstrap**, **Extension,** and **System or Application class loader**.

Every class loader has a predefined location, from where they load class files. The bootstrap class loader is responsible for loading standard JDK class files from `rt.jar` and it is the parent of all class loaders in Java.

The bootstrap class loader doesn't have any parents if you call `String.class.getClassLoader()` it will return `null and any code based on that may throw NullPointerException in Java`. The bootstrap class loader is also known as **Primordial ClassLoader** in Java.

Extension ClassLoader delegates class loading request to its parent, `Bootstrap,` and if unsuccessful, loads class form `jre/lib/ext` directory or any other directory pointed by `java.ext.dirs` system property. Extension ClassLoader in JVM is implemented by `sun.misc.Launcher$ExtClassLoader.`

The third default class loader used by JVM to load Java classes is called System or Application class loader and it is responsible for loading application-specific classes from CLASSPATH environment variable, `-classpath` or `-cp` command line option, `Class-Path` attribute of Manifest file inside JAR.

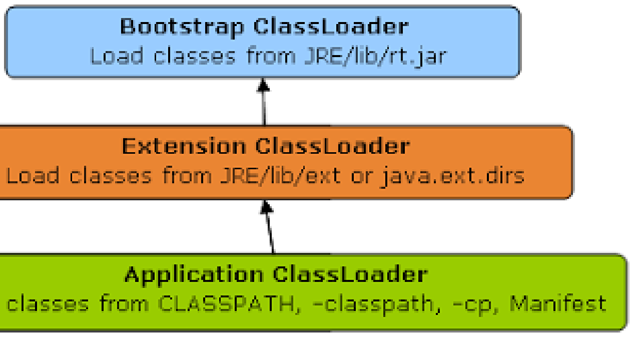
Application class loader is a child of Extension ClassLoader and its implemented by `sun.misc.Launcher$AppClassLoader` class. Also, except for the Bootstrap class loader, which is implemented in the native language mostly in C, all Java class loaders are implemented using `java.lang.ClassLoader`.

In short here is the location from which Bootstrap, Extension, and Application ClassLoader load Class files.

1) Bootstrap ClassLoader - JRE/lib/rt.jar

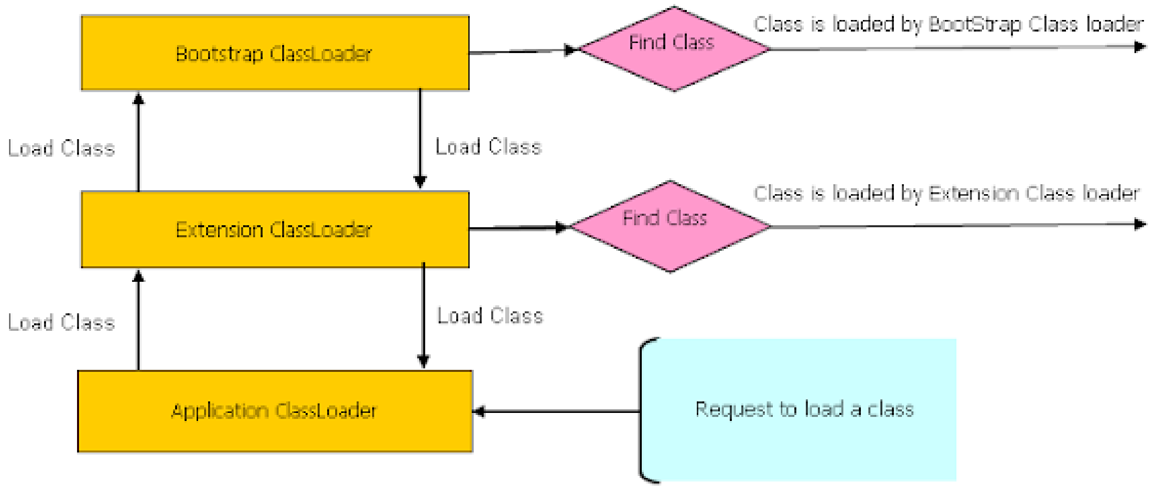
2) Extension ClassLoader - JRE/lib/ext or any directory denoted by `java.ext.dirs`

3) Application ClassLoader - `CLASSPATH` environment variable, `-classpath` or `-cp` option, Class-Path attribute of Manifest inside JAR file.


Bootstrap ClassLoader
Load classes from JRE/lib/rt.jar
Extension ClassLoader
Load classes from JRE/lib/ext or java.ext.dirs
Application ClassLoader
Load classes from CLASSPATH, -classpath, -cp, Manifest

How ClassLoader works in Java?

As I explained earlier Java ClassLoader works in three principles: `delegation`, `visibility`, and `uniqueness`. In this section, we will see those rules in detail and understand the working of Java ClassLoader with example. By the way here is a diagram that explains How ClassLoader loads class in Java using delegation.



1. Delegation principles

As discussed on when a class is loaded and initialized in Java, a class is loaded in Java, when it's needed. Suppose you have an application-specific class called `Abc.class`, the first request of loading this class will come to Application ClassLoader which will delegate to its parent Extension ClassLoader which further delegates to `Primordial` or `Bootstrap` class loader.

Primordial will look for that class in `rt.jar` and since that class is not there, a request comes to Extension class loader which looks on `jre/lib/ext` directory and tries to locate this class there, if the class is found there then Extension class loader will load that class and Application class loader will never load that class but if it's not loaded by extension class-loader than Application class loader loads it from Classpath in Java. Remember `Classpath` is used to load class files while PATH is used to locate executables like javac or java command.

2. Visibility Principle

According to the visibility principle, Child ClassLoader can see class loaded by Parent ClassLoader but vice-versa is not true. This means if class `Abc` is loaded by Application class loader than trying to load class ABC explicitly using extension ClassLoader will throw either java.lang.ClassNotFoundException. as shown in the below Example

```
package test;

import java.util.logging.Level;
import java.util.logging.Logger;

/**
 * Java program to demonstrate How ClassLoader works in Java,
 * in particular about the visibility principle of ClassLoader.
 *
 * @author Javin Paul
 */

public class ClassLoaderTest {

    public static void main(String args[]) {
        try {
            //printing ClassLoader of this class

  System.out.println("ClassLoaderTest.getClass().getClassLoader() : "
                                                +
ClassLoaderTest.class.getClassLoader());


            //trying to explicitly load this class again using Extension
class loader
            Class.forName("test.ClassLoaderTest", true
                                                ,
ClassLoaderTest.class.getClassLoader().getParent());
        } catch (ClassNotFoundException ex) {

  Logger.getLogger(ClassLoaderTest.class.getName()).log(Level.SEVERE, null,
ex);
        }
    }

}

Output:
ClassLoaderTest.getClass().getClassLoader() :
sun.misc.Launcher$AppClassLoader@601bb1
```

```
16/08/2012 2:43:48 AM test.ClassLoaderTest main
SEVERE: null
java.lang.ClassNotFoundException: test.ClassLoaderTest
        at java.net.URLClassLoader$1.run(URLClassLoader.java:202)
        at java.security.AccessController.doPrivileged(Native Method)
        at java.net.URLClassLoader.findClass(URLClassLoader.java:190)
        at sun.misc.Launcher$ExtClassLoader.findClass(Launcher.java:229)
        at java.lang.ClassLoader.loadClass(ClassLoader.java:306)
        at java.lang.ClassLoader.loadClass(ClassLoader.java:247)
        at java.lang.Class.forName0(Native Method)
        at java.lang.Class.forName(Class.java:247)
        at test.ClassLoaderTest.main(ClassLoaderTest.java:29)
```

3. Uniqueness Principle

According to this principle, a class loaded by a Parent should not be loaded by Child ClassLoader again. Though it's completely possible to write a class loader that violates Delegation and Uniqueness principles and loads class by itself, it's not something which is beneficial. You should follow all class loader principles while writing your own ClassLoader.

How to load class explicitly in Java

Java provides API to explicitly load a class by `Class.forName(classname)` and `Class.forName(classname, initialized, classloader)`, remember JDBC code which is used to load JDBC drives we have seen in Java program to Connect Oracle database.

As shown in the above example you can pass the name of ClassLoader which should be used to load that particular class along with the binary name of the class. Class is loaded by calling `loadClass()` method of `java.lang.ClassLoader` class which calls `findClass()` method to locate bytecodes for the corresponding class.

In this example, Extension ClassLoader uses `java.net.URLClassLoader` which searches for class files and resources in JAR and directories. any search path which is ended using "/" is considered a directory.

If `findClass()` does not found the class then it throws java.lang.ClassNotFoundException and if it finds it calls `defineClass()` to convert bytecodes into a .class instance which is returned to the caller.

Where to use ClassLoader in Java?

ClassLoader in Java is a powerful concept and is used in many places. One of the *popular examples of ClassLoader* is `AppletClassLoader` which is used to load a class by `Applet` since `Applets` are mostly loaded from the internet rather than a local file system.

By using separate ClassLoader you can also load the same class from multiple sources and they will be treated as different classes in JVM. J2EE uses multiple class loaders to load a class from a different location like classes from the WAR file will be loaded by Web-app ClassLoader while classes bundled in EJB-JAR are loaded by another classloader.

Some web server also supports hot deploy functionality which is implemented using ClassLoader. You can also use ClassLoader to load classes from a database or any other persistent store.

That's all about **What is ClassLoader in Java** and **How ClassLoader works in Java**. We have seen delegation, visibility, and uniqueness principles which are quite important to debug or troubleshoot any ClassLoader related issues in Java. In summary knowledge of How ClassLoader works in Java is a must for any Java developer or architect to design Java applications and packaging.