Java 9 features

1. Improved Javadoc:

We no longer need to use Google to find the right documentation. The new Javadoc came with search right in the API documentation itself.

2. Factory methods for collections(like List, Map, Set and Map.Entry):

List and Set interfaces have “of()” methods to create an empty or no-empty Immutable List or Set objects as shown below:

```
List immutableList = List.of();

List immutableList = List.of("one", "two", "three");


jshell> Map emptyImmutableMap = Map.of()
emptyImmutableMap ==> {}

jshell> Map nonemptyImmutableMap = Map.of(1, "one", 2, "two", 3,
"three")

nonemptyImmutableMap ==> {2=two, 3=three, 1=one}
```

3. JShell: the interactive Java REPL (Read Evaluate Print Loop):

It is used to execute and test any Java Constructs like class, interface, enum, object, statements etc. very easily.

4. Private methods in Interfaces:

In Java 8, we can provide method implementation in Interfaces using Default and Static methods. However we cannot create private methods in Interfaces. To avoid redundant code and more re-usability, Oracle Corp. introduced private methods in Java SE 9 Interfaces. From Java SE 9 on-wards, we can write private and private static methods too in an interface using ‘private’ keyword.

```
public interface Card{

  private Long createCardID(){
    // Method implementation goes here.
  }

  private static void displayCardDetails(){
    // Method implementation goes here.
  }

}
```

5. HTTP/2 Client

A new way of performing HTTP calls arrives with Java 9.

6. The Java(9) Platform module system:

7. Improvements in Process API:

8. Stream API Improvements:

9. Multi-Resolution Image API:

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Java Platform Module System (JPMS)

Java 9 Platform Module System (JPMS), the most important new software engineering technology in Java since its inception. Modularity—the result of Project Jigsaw—helps developers at all levels be more productive as they build, maintain, and evolve software systems, especially large systems.

What Is a Module?

Modularity adds a higher level of aggregation above packages.

module—a uniquely named, reusable group of related packages, as well as resources (such as images and XML files) and a *module descriptor* specifying

- the module's *name*
- the module's *dependencies* (that is, other modules this module depends on)
- the packages it explicitly makes available to other modules (all other packages in the module are *implicitly unavailable* to other modules)
- the *services it offers*
- the *services it consumes*
- to what other modules it allows *reflection*

History:

The Java SE platform has been around since 1995.

It is used to build everything from small apps for resource-constrained devices—like those in the Internet of Things (IoT) and other embedded devices—to large-scale business-critical and mission-critical systems. There are massive amounts of legacy code out there, but until now, the Java platform has primarily been a monolithic one-size-fits-all solution. Over the years, there have been various efforts geared to modularizing Java, but none is widely used—and none could be used to modularize the Java platform.

Modularizing the Java SE platform has been challenging to implement, and the effort has taken many years (12 years).
JSR 277: Java Module System was originally proposed in 2005 for Java 7. This JSR was later superseded by JSR 376: Java Platform Module System and targeted for Java 8. The Java SE platform is now modularized in Java 9, but only after Java 9 was delayed until September 2017.

Goals:

Each module must explicitly state its dependencies.

According to JSR 376, the key goals of modularizing the Java SE platform are

- Reliable configuration—Modularity provides mechanisms for explicitly declaring dependencies between modules in a manner that's recognized both at compile time and execution time. The system can walk through these dependencies to determine the subset of all modules required to support your app.

- Strong encapsulation—The packages in a module are accessible to other modules only if the module explicitly exports them. Even then, another module cannot use those packages unless it explicitly states that it requires the other module's capabilities. This improves platform security because fewer classes are accessible to potential attackers. You may find that considering modularity helps you come up with cleaner, more logical designs.

- Scalable Java platform—Previously, the Java platform was a monolith consisting of a massive number of packages, making it challenging to develop, maintain and evolve. It couldn't be easily subsetted. The platform is now modularized into 95 modules (this number might change as Java evolves). You can create custom runtimes consisting of only modules you need for your apps or the devices you're targeting. For example, if a device does not support GUIs, you could create a runtime that does not include the GUI modules, significantly reducing the runtime's size.

- Greater platform integrity—Before Java 9, it was possible to use many classes in the platform that were not meant for use by an app's classes. With strong

encapsulation, these internal APIs are truly encapsulated and hidden from apps using the platform. This can make migrating legacy code to modularized Java 9 problematic if your code depends on internal APIs.

- Improved performance—The JVM uses various optimization techniques to improve application performance. JSR 376 indicates that these techniques are more effective when it's known in advance that required types are located only in specific modules.

Listing the JDK's Modules:

JEP 200: THE MODULAR JDK

JEP 201: MODULAR SOURCE CODE

JEP 220: MODULAR RUN-TIME IMAGES

JEP 260: ENCAPSULATE MOST INTERNAL APIS

JEP 261: MODULE SYSTEM

JEP 275: MODULAR JAVA APPLICATION PACKAGING

JEP 282: JLINK: THE JAVA LINKER

JSR 376: JAVA PLATFORM MODULE SYSTEM

JSR 379: JAVA SE 9

Table 1. Java Modularity JEPs and JSRs

A crucial aspect of Java 9 is dividing the JDK into modules to support various configurations. Using the java command from the JDK's bin folder with the `--list-modules` option, as in:

`java --list-modules`
lists the JDK's set of modules, which includes the standard modules that implement the Java Language SE Specification (names starting with `java`),

JavaFX modules (names starting with `javafx`),

JDK-specific modules (names starting with `jdk`) and

Oracle-specific modules (names starting with `oracle`). Each module name is followed by a version string—`@9` indicates that the module belongs to Java 9.

Module Types:

There are four types of modules in the new module system:

- **System Modules** – These are the modules listed when we run the *list-modules* command above. They include the Java SE and JDK modules.
- **Application Modules** – These modules are what we usually want to build when we decide to use Modules. They are named and defined in the compiled *module-info.class* file included in the assembled JAR.
- **Automatic Modules** – We can include unofficial modules by adding existing JAR files to the module path. The name of the module will be derived from the name of the JAR. Automatic modules will have full read access to every other module loaded by the path.
- **Unnamed Module** – When a class or JAR is loaded onto the classpath, but not the module path, it's automatically added to the unnamed module. It's a catch-all module to maintain backward compatibility with previously-written Java code.

Module Declarations:

As we mentioned, a module must provide a module descriptor—metadata that specifies the module's dependencies, the packages the module makes available to other modules, and more. A module descriptor is the compiled version of a module declaration that's defined in a file named `module-info.java`. Each module declaration begins with the keyword `module`, followed by a unique module name and a module body enclosed in braces, as in:

A key motivation of the module system is strong encapsulation.

```
module modulename {
}
```

The module declaration's body can be empty or may contain various *module directives*, including `requires`, `exports`, `provides…with`, `uses` and `opens` (each of which we discuss). As you'll see later, compiling the module declaration creates the module descriptor, which is stored in a file named `module-info.class` in the module's root folder. Here we briefly introduce each module directive. After that, we'll present actual module declarations.

The keywords `exports`, `module`, `open`, `opens`, `provides`, `requires`, `uses`, `with`, as well as `to` and `transitive`, which we introduce later, are restricted keywords. They're keywords only in module declarations and may be used as identifiers anywhere else in your code.

requires. A `requires` module directive specifies that this module depends on another module—this relationship is called a *module dependency*. Each module must explicitly state its dependencies. When module A `requires` module B, module A is said to *read* module B and module B is *read by* module A. To specify a dependency on another module, use `requires`, as in:

```
requires modulename;
```

There is also a `requires static` directive to indicate that a module is required at compile time, but is optional at runtime. This is known as an *optional dependency* and won't be discussed in this introduction.

requires transitive—implied readability. To specify a dependency on another module and to ensure that other modules reading your module also read that dependency—known as *implied readability*—use `requires transitive`, as in:

```
requires transitive modulename;
```

Consider the following directive from the `java.desktop` module declaration:

```
requires transitive java.xml;
```

In this case, any module that reads `java.desktop` also implicitly reads `java.xml`. For example, if a method from the `java.desktop` module returns a type from the `java.xml` module, code in modules that read `java.desktop` becomes dependent on `java.xml`. Without the `requires transitive` directive in `java.desktop`'s module declaration, such dependent modules will not compile unless they *explicitly* read `java.xml`.

According to JSR 379 Java SE's standard modules must grant implied readability in all cases like the one described here. Also, though a Java SE standard module may depend on non-standard modules, it *must not* grant implied readability to them. This ensures that code depending only on Java SE standard modules is portable across Java SE implementations.

exports and exports…to. An `exports` module directive specifies one of the module's packages whose `public` types (and their nested `public` and `protected` types) should be accessible to code in all other modules. An `exports…to` directive enables you to specify in a comma-separated list precisely which module's or modules' code can access the exported package—this is known as a *qualified* export.

uses. A `uses` module directive specifies a service used by this module—making the module a service consumer. A *service* is an object of a class that implements the interface or extends the `abstract` class specified in the `uses` directive.

provides…with. A `provides…with` module directive specifies that a module provides a service implementation—making the module a *service provider*. The `provides` part of the directive specifies an interface or `abstract` class listed in a module's `uses` directive and the `with` part of the directive specifies the name of the service provider class that `implements` the interface or `extends` the `abstract` class.

open, opens, and opens…to. Before Java 9, reflection could be used to learn about all types in a package and all members of a type—even its `private` members—whether you wanted to allow this capability or not. Thus, nothing was truly encapsulated.

A key motivation of the module system is strong encapsulation. By default, a type in a module is not accessible to other modules unless it's a public type *and* you export its package. You expose only the packages you want to expose. With Java 9, this also applies to reflection.

Allowing runtime-only access to a package. An opens module directive of the form

`opens` *`package`*
indicates that a specific *package*'s `public` types (and their nested `public` and `protected` types) are accessible to code in other modules at runtime only. Also, all the types in the specified package (and all of the types' members) are accessible via reflection.

Allowing runtime-only access to a package by specific modules. An `opens…to` module directive of the form

```
opens package to comma-separated-list-of-modules
```
indicates that a specific *package*'s `public` types (and their nested `public` and `protected` types) are accessible to code in the listed modules at runtime only. All of the types in the specified package (and all of the types' members) are accessible via reflection to code in the specified modules.

Allowing runtime-only access to all packages in a module. If all the packages in a given module should be accessible at runtime and via reflection to all other modules, you may `open` the entire module, as in:

```
open module modulename {
   // module directives
}
```

Reflection Defaults

By default, a module with runtime reflective access to a package can see the package's `public` types (and their nested `public` and `protected` types). However, the code in other modules can access *all* types in the exposed package and *all* members within those types, including `private` members via `setAccessible`, as in earlier Java versions.

we can package our Java application and our Java packages into Java modules. By the help of the Java module, we can specify which of the packages of the module should be visible to other Java modules. A Java module must also specify which other Java modules is requires to do its job.
The main intent of developing JPMS is to make the JRE more modular i.e. have smaller jars which are optional and/or we can download/upgrade only the functionality as per need.

JPMS/Project Jigsaw is going to address few major problems:

1. ClassPath/JAR Hell
2. Massive Monolithic JDK
3. Version conflicts
4. Security Problems

ClassPath/JAR Hell:

Java searches for classes and packages on the classpath at the run time. At the compile time, the compiler will not check that the required class files are present inside the jar or not. It will run the application and at the run time it will goto the classpath and check that required classes are there inside the jar files or not. If it is there then our application will execute fine. But for any reason if any one of the class file is not present inside the jar then it will throw NoClassDefFound error. This is not good for us.

Apart from **.class files**, a Java module contains one more file i.e. **module-info.Java file**. Each Java module needs a Java module descriptor named module-info.Java which has to be located in the corresponding module root directory. Creating a module is relatively simple, however. A module is typically just a jar file that has a module-info.class file at the root – known as a modular jar file.

Using a modular jar file involves adding the jar file to the modulepath instead of the classpath. In module-info.Java, we can mention all the dependencies/which modules are needed at the run time.
Now at the compile time with the help of module-info.Java, compiler will get to know what classes are needed to run the application and at the compilation time only compiler will check that the corresponding classes/packages are present inside the module or not.
If the required classes are present then the code will compile successfully otherwise it will throw compilation errors at the compile time only. This is how Java module system resolve the classPath/JAR Hell problem.

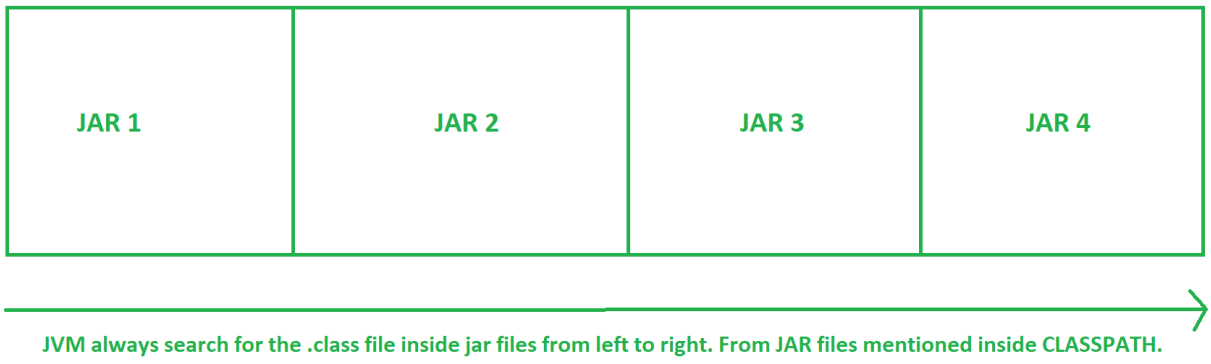
Massive Monolithic JDK:

Monolithic means formed of a single large block of stone.
The big monolithic nature of JDK causes several problems. It doesn't fit on small devices. Small devices do not necessarily have the memory to hold all of the JDK, especially, when the application only uses a small part of it.

```
class Geeksforgeeks {
    public static void main(String[] args)
    {
        System.out.println("Hello, "
            + "Welcome to JPMS!!!");
    }
}
```

To run the above code, we need a few classes like String, System, Object etc. But we have to hold the entire JDK. With this approach to run even 1KB of file, we need to have a minimum 60MB of rt.jar file. We can resolve this issue with JPMS. Jigsaw breaks up the JDK itself into many modules e.g. Java.sql contains the familiar SQL classes, Java.io contains the familiar IO classes etc. As per requirement, we can use the appropriate module. No need to use the entire JDK.

Version conflicts:



Suppose JAR 4 requires a **.class file** with name xyz of JAR 3 and JAR 2 also contains the .class file with the name xyz. Now JVM will search for xyz class file from left to right and it will get the .class file named with xyz from JAR 2. Now the JVM will assign xyz.class file of JAR 2 inside JAR 4. But JAR 4 requires xyz.class file of JAR 3. Here we will get a version conflict. With the help of JPMS, we can specify inside module-info.Java that we want a .class file of a particular JAR file.

```
module module4
{
    requires module3;
}
```

Security Problems:

`demo.api`
`demo.enhancement`

Both packages are public in nature. At some point, If we decide that our team should use the demo.api package and not use `demo.enhancement`. However, there is no way to enforce that on the classpath.
In JPMS, a module contains a module-info.Java file which allows us to explicitly state what is public to other modules.

```
module demo
{
     exports demo.api;
     exports demo.enhancement;
}
```