Java and C# in depth

Carlo A. Furia, Marco Piccioni, Bertrand Meyer

Java: framework overview and in-the-small features

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Java: framework overview

What’s in a name

Initially was “Oak” (James Gosling, 1991), then “Green”

- Ruled out by the trademark lawyers

Twelve people locked in a room together with a “naming consultant”

- “How does this thing make you feel?”
- “What else makes you feel that way?”

After listing and sorting, 12 names were sent to the lawyers

- #1 was “Silk”
- Gosling’s favorite was “Lyric” (#3)
- “Java” was # 4

Version 1.0: 1995, latest stable version: 7 Update 51 (14.1.14)

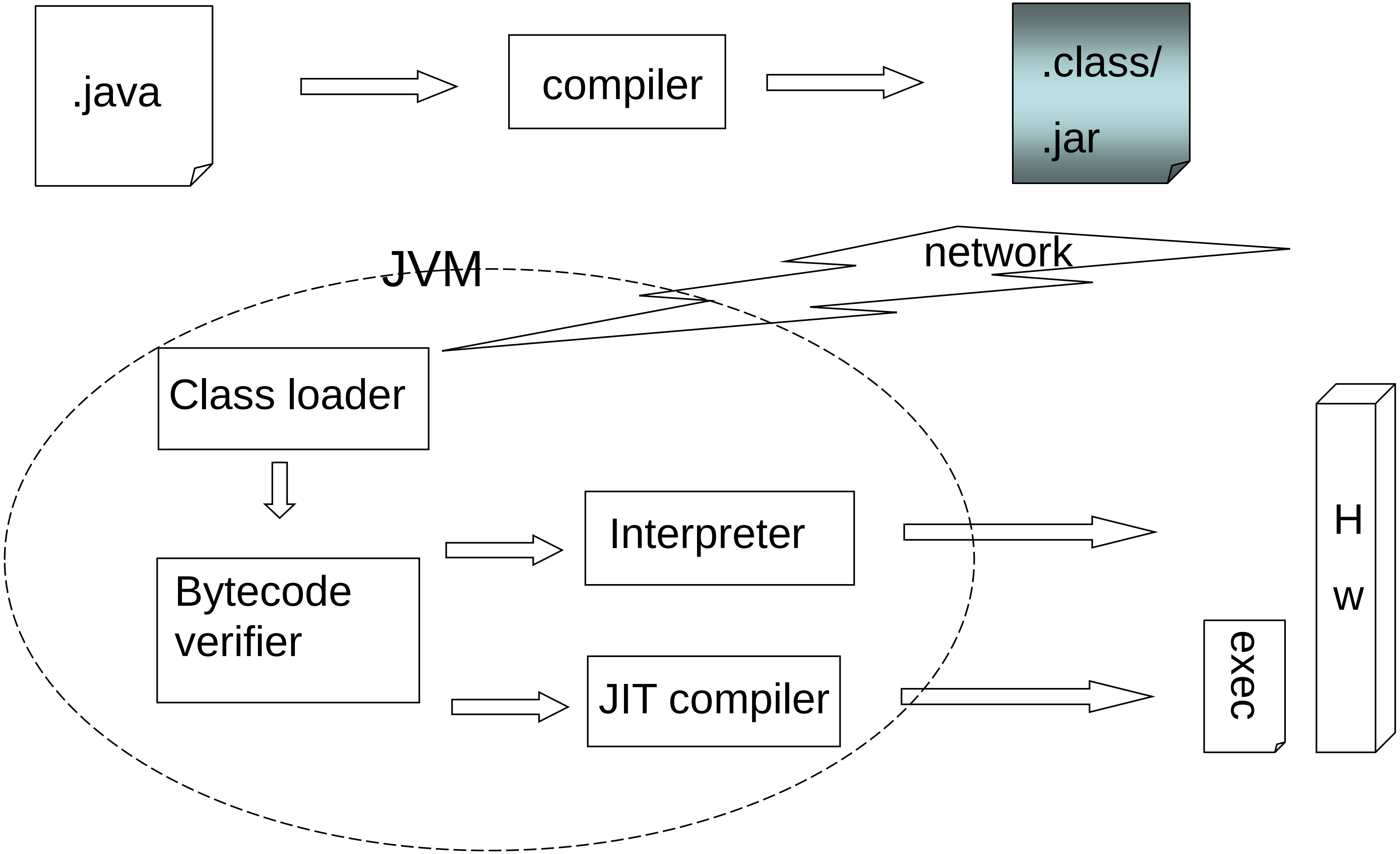
Coming next (Java SE 8, 18.3.2014):

- lambda expressions (closures)
- embedded JavaScript

Java platform goals

- Write Once, Run Anywhere
- Built-in security
- Automatic memory management
- API + documentation generation
- Object-Oriented
- Familiar C/C++ syntax

Write once, run anywhere



Bytecode

- Intermediate format resulting from Java compilation

- Instruction set of an architecture that
  - is stack-oriented (no registers)
  - provides capability (object access rights)

- 1 bytecode instruction = 1 byte

- Executed by any platform-specific Virtual Machine (VM)

Bytecode format

- JVM loads class file → gets a stream of bytecodes
- One bytecode instruction: opcode + ≥0 operands
- Each opcode is associated with a mnemonic
  - 03 → iconst_0 // pushes int 0 on stack
  - 3b → istore_0 // pops int from stack to local in pos 0
  - 84 00 01 → iinc 0, 1 // increments local in pos 0 by 1
  - 1a → iload_0 // pushes int from local in pos 0 on stack
  - 05 → iconst_2 // pushes int 2 on stack
  - 68 → imul // pops 2 int values, multiplies them and puts the result on the stack

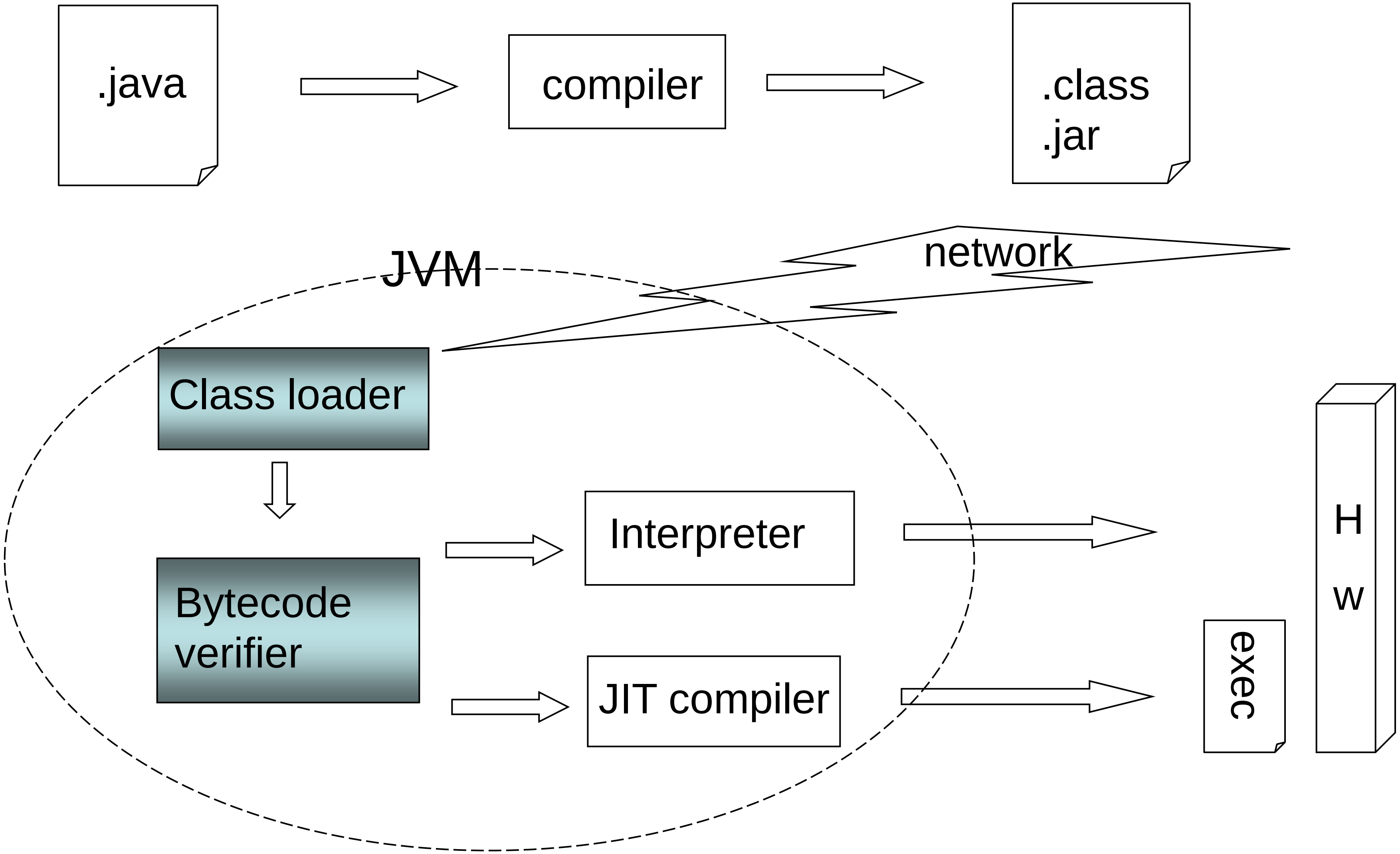
Example of bytecode translation

```
class SimpleMath{
     byte inflexible_add(){
          byte x = 2;
          byte y = 2;
          byte z = (byte) (x + y);
          return z;
     }
}
```

Bytecode example

Opcode mnemonics	Meaning
iconst_2	push an integer constant 2 into the stack
istore_1	pop into local in pos 1 (x)
iconst_2	push an integer constant 2 into the stack
istore_2	pop into local in pos 2 (y)
iload_1	push x into the stack
iload_2	push y into the stack
iadd	sum the two top values on the stack and push the result
int2byte	convert result into byte
istore_3	pop into local in pos 3 (z)
iload_3	push z into the stack
ireturn	return result (z)

JVM overview



Security: language restrictions and support

- No pointers, no explicit memory de-allocation
- Checked type casts (at compile time and runtime)
- Enforced array bounds (at runtime)
- Security APIs
  - SecurityManager (standard security)
  - XML digital signature, Public Key Infrastructure, cryptographic services, authentication

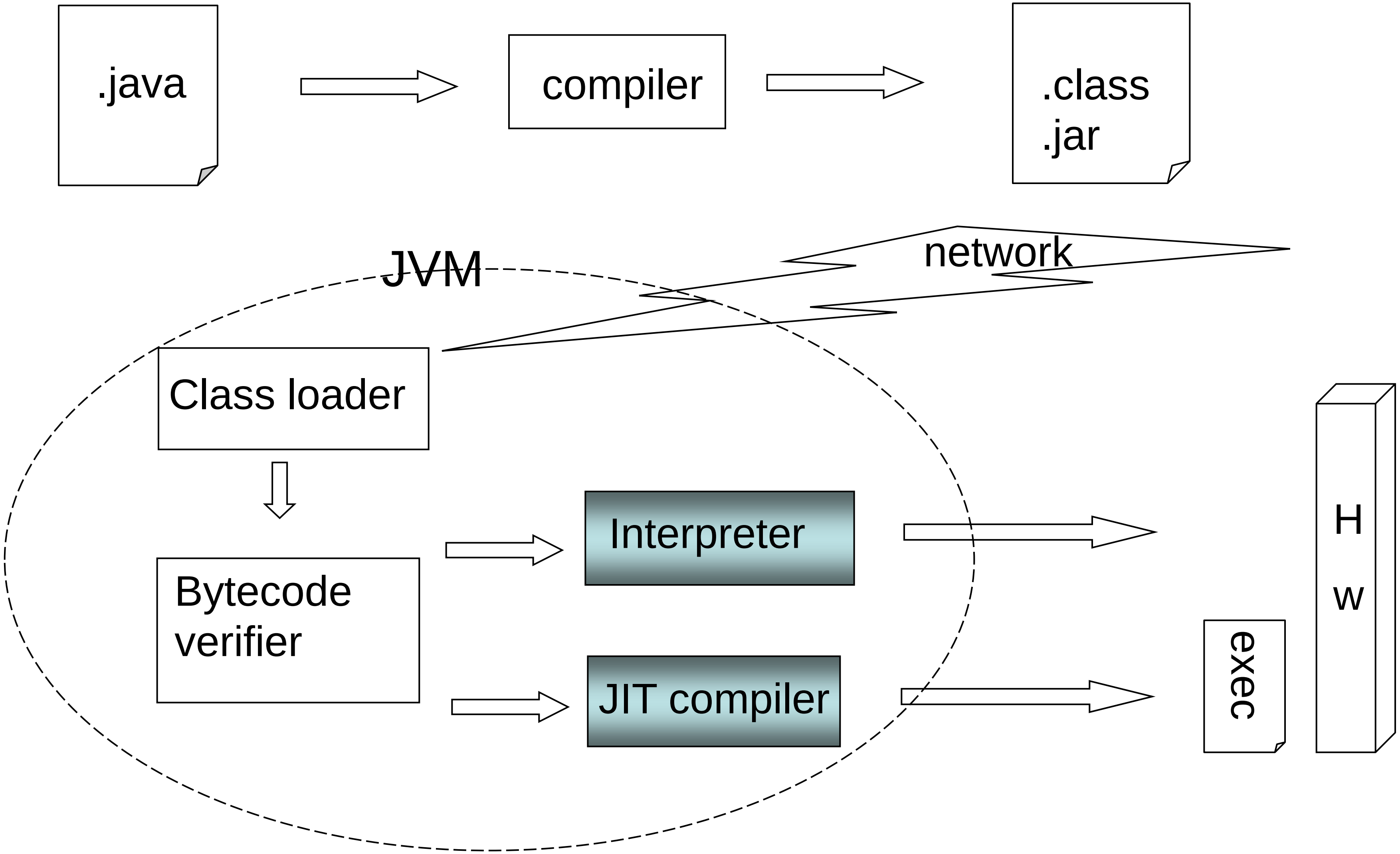
Security: class loaders

- Take care of files and file systems
- Locate libraries and dynamically load classes
- Partition classes into realms (e.g. local machine, local network, all the rest) and restrict what they can do

Security: Bytecode verifier

- Verifier checks bytecode using a “theorem prover”
  - Branches always to valid locations
  - Data always initialized
  - Types of parameters of bytecode instructions always correct
  - Data and methods access checked for visibility
  - Arbitrary bit patterns cannot get used as an address
  - No operand stack overflows and underflows

JVM: code generation



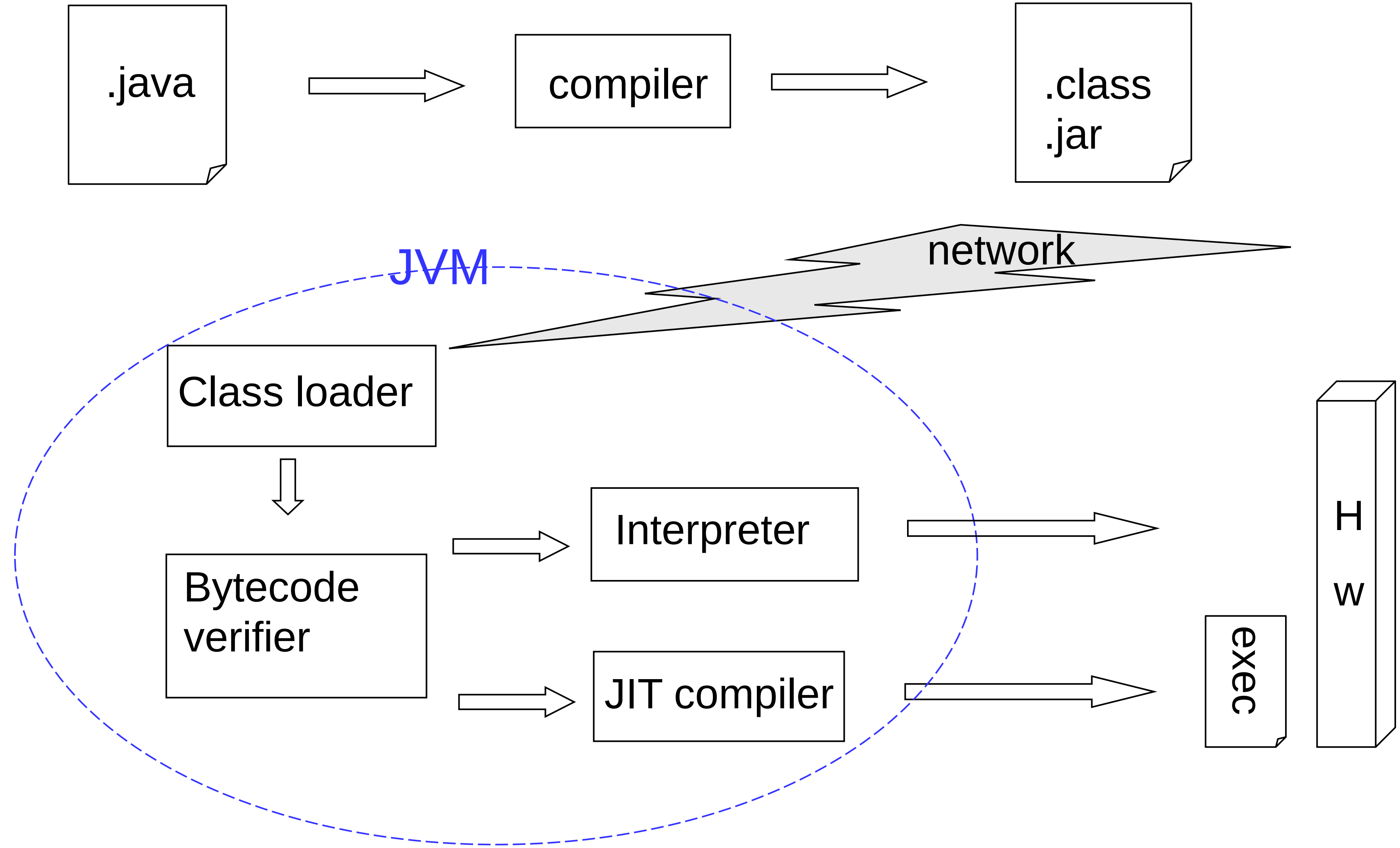
Code generation: HotSpot

- The interpreter is the software CPU of the JVM
  - Examines each bytecode and executes a unique native procedure
  - No native code is produced
- A JIT “compiler” converts the bytecode into native code just before running it
  - Keeps a log (cache) of the native code that it has to run to execute each bytecode
  - May optimize substituting often occurring short sets of instructions (“hot spots”) with shorter/faster ones
  - Like the back-end of a traditional compiler, the java compiler being the front-end
- HotSpot is the default SUN JVM since 2000

HotSpot client and server

- HotSpot client VM
  - For platforms typically used for client applications (e.g. GUI)
  - Tuned for reducing start-up time and memory footprint
  - Invoked by using –*client* when launching an app
- HotSpot server VM
  - For all platforms
  - Tuned for max program execution speed
  - Invoked by using –*server* when launching an app
- Both use an interpreter to launch applications, and an adaptive compiler optimizing code hot spots
- They use different code inline policies and heap defaults

JVM Overview



JVM: more features

- Automated exception handling
  - Provides “root cause” debugging info for every exception

- Responsible for garbage collection

- Ships as JRE (VM + libraries)

- Can have other languages run on top of it, e.g.
  - JRuby (Ruby)
  - Rhino (JavaScript)
  - Jython (Python)
  - Scala

- From 6.0 scripting languages can be mixed with Java code

Command-line Java

- Compile

  ```
  javac MainClass.java
  ```

- Execute

  ```
  java MainClass
  ```

- Generate documentation

  ```
  javadoc MainClass.java
  ```

- Generate an archive from `.class` files in current dir

  ```
  jar cf myarchive.jar *.class
  ```

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Java: in-the-small language features

Encoding and formatting

- Uses unicode as encoding system: www.unicode.org

- Free format
  - Blanks, tabs, new lines, form feeds are only used to keep tokens separate

- Comments
  - Single line: `//Single line comment`
  - Multiple lines:
    ```
    /* non-nested, multi-line
                        comment*/
    ```
  - Javadoc comment: `/** processed by javadoc */`

Identifiers

- No restriction on length
- Case sensitive
- Cannot start with a digit
- Cannot include `/` or `-`
- Cannot be a keyword

Annotations

Meta-data about programs

- Compiler flags

  e.g: `@Deprecated, @Override, @SuppressWarnings`
- Information that can be used for compilation (or other forms of code analysis)

  e.g.: `@Inherited,` application-defined such as `@RevisionId`
- Some runtime processing

  e.g.: application-defined

Keywords

`abstract`
`boolean`
`break`
`byte`
`case`
`catch`
`char`
`class`
`(const)`
`continue`
`default`
`do`
`double`
`else`
`extends`
`final`
`finally`
`float`
`for`
`(goto)`
`if`
`implements`
`import`
`instanceof`
`int`
`interface`
`long`
`native`
`new`
`package`
`private`
`protected`
`public`
`return`
`short`
`super`
`switch`
`synchronized`
`this`
`throw`
`throws`
`transient`
`try`
`void`
`volatile`
`while`

- Literals `null`, `true`, `false` are also reserved

Operators

- Access, method call: `.`, `[]`, `()`
- Postfix: ***`expr++`***, ***`expr--`*** (R to L)
- Other unary: ***`++expr`***, ***`--expr`***, `+`, `-`, `~`, `!`, **`new`**, `(`***`aType`***`)`
- Arithmetic: `*`, `/`, `%`
- Additive: `+`, `-`
- Shift: <<, >>, >>>
- Relational: `<`, `>`, `<=`, `>=`, **`instanceof`**
- Equality: `==`, `!=`
- Logical (L to R): `&`, `^`, `|`, `&&`, `||`
- Ternary: ***`condition ? (expr1):(expr2)`*** (R to L)
- Assignment: `=`, `+=`, `-=`, `*=`, `/=`, `%=`, `&=`, `^=`, `|=`, `<<=`, `>>=`, `>>>=`
- Precedence: from top to bottom
- Tip: don't rely too much on precedence rules: use parentheses

Type system basics

- Primitive types
  - `boolean, byte, short, int, long, char, float, double`
- Reference types
  - `class`, `interface`, `[]`
- `null`
- Automatic widening conversions (no precision loss)
  - `byte` to `short` to `int` to `long`
  - `char` to `int, int` to `double, float` to `double`
- Automatic widening conversions (possible precision loss)
  - `int` to `float`, `long` to `float`, `long` to `double`
- A cast is required for narrowing conversions

```
int i = 3; long j = 5; i = (int) j
```

Widening conversions with precision loss

```
float g(int x){
     return x;
}
...
int i = 1234567890;
float f = g(i);
System.out.println(i - (int)f)
// output: -46
...
```

Wrapper types and autoboxing

- For each primitive type there is a wrapper type
  - `Boolean, Byte, Short, Integer, Long, Character, Float, Double`
- Starting from 5.0, autoboxing provides automatic conversions between primitive and wrapper types
- Pro: reduces code complexity
- Cons: not efficient, sometimes unexpected behavior

Some surprises of autoboxing

```
new Integer(7).equals(7)     // true

new Long(7).equals(7) //false. True if equals(7L)

new Integer(7).equals(new (Long(7))) // false

new Integer(7) == 7  // true

new Long(7) == 7  // true

new Integer(7) == new Long(7)  // compiler error
```

Control flow: conditional branch

Same syntax as in C/C++

```
if  (booleanExpr)
{
     // do something
}
else // else is optional
{
     // do something else
}
```

Control flow: loops

```
while (booleanExpr)
{
      // execute body
      // until booleanExpr becomes false
}



do
{
      // execute body (at least once)
      // until booleanExpr becomes false
}
while (booleanExpr);
```

Control flow: for loop

```
for (int i=0; i < n; i++)
{
     // execute loop body n times
}

// equivalent to the following
int i=0;
while (i < n)
{
      // executes loop body n times
      i++;
}
```

Control flow: enhanced `for` loop

Introduced in Java 5.0

```
for (variable : collection)
{
      // loop body
}
```

- `collection` is an array or an object of a class that implements `interface Iterable`
  - more on classes and interfaces later

- Executes the loop body for every element of the `collection`, assigned iteratively to `variable`

Control flow: `switch` selector

```
switch  (Expr)
{
     case Value1: instructions;
          break;
     case Value2: instructions;
          break;
     // ...
     default: instructions;
}
```

Expr can be of type:

- **byte, short, int, char** (or wrapped counterparts)
- **enum** types
- **String** (compared with **equals**) (new in Java 7)

Breaking the control flow: `break`

`label: [while | do | for]`

- Identifies a loop
- (Or a code block)

`break optionalLabel;`

- Within a loop or a `switch`
- No label: exit the loop or switch
- With label:
  - within loop: jump out of the loop to label `optionalLabel`
  - within `switch`: jump out of `switch` block to label `optionalLabel`

Breaking the control flow: `continue`

```
label: [while | do | for]
```

- Identifies a loop
- (Or a code block)

```
continue optionalLabel;
```

- Within a loop
- No label: skip the remainder of the current iteration and continue with the next iteration
- With label:
    - skip the remainder of the current iteration and continue with the next iteration of the loop with label `optionalLabel`