CMSC 132: OBJECT-ORIENTED PROGRAMMING II

Threads in Java

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Problem

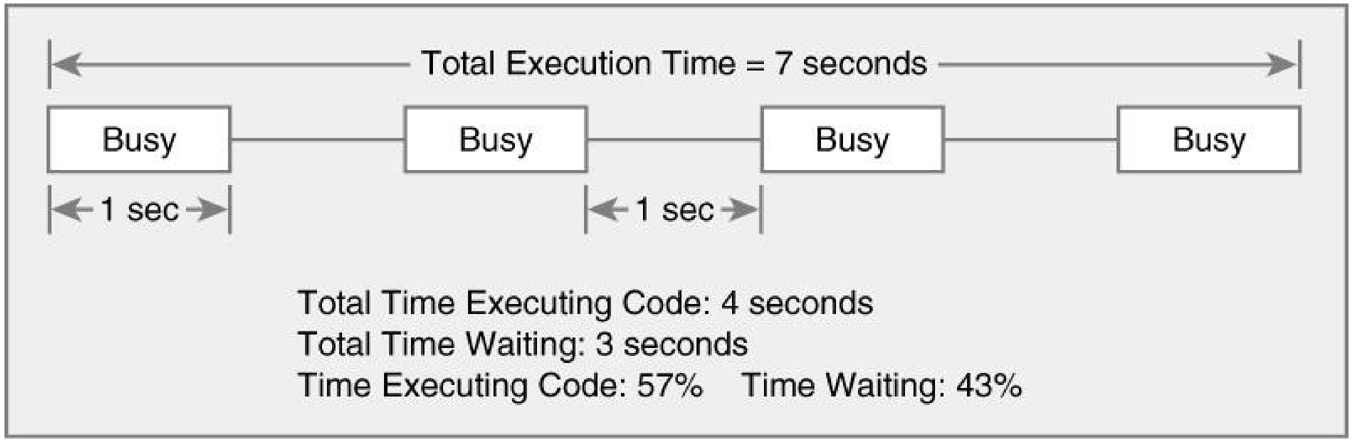
- **Multiple tasks for computer**
  - Draw & display images on screen
  - Check keyboard & mouse input
  - Send & receive data on network
  - Read & write files to disk
  - Perform useful computation (editor, browser, game)
- **How does computer do everything at once?**
  - Multitasking
  - Multiprocessing

Multitasking (Time-Sharing)

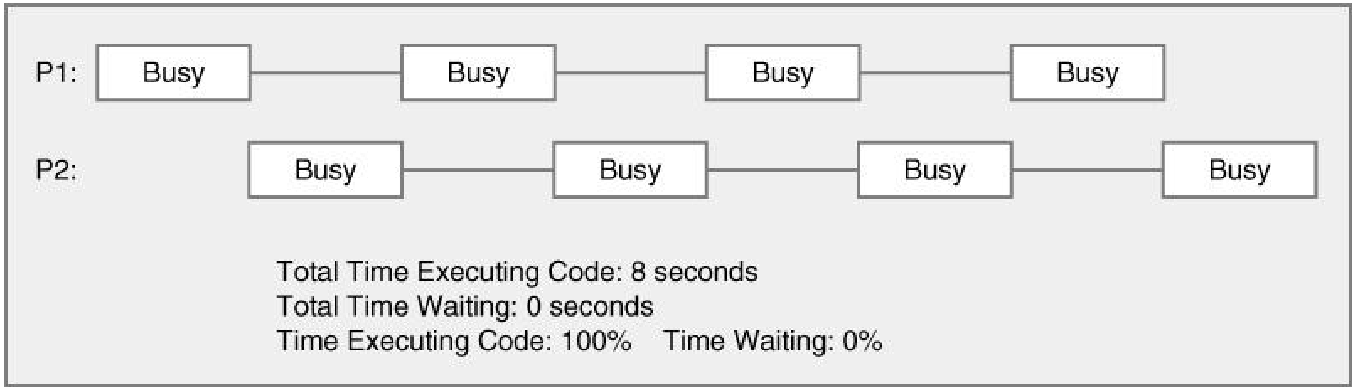
- Approach
  - Computer does some work on a task
  - Computer then quickly switch to next task
  - Tasks managed by operating system (scheduler)
- Computer seems to work on tasks concurrently
- Can improve performance by reducing waiting

Multitasking Can Aid Performance

- Single task


Total Execution Time = 7 seconds
Busy
Busy
Busy
Busy
1 sec
1 sec
Total Time Executing Code: 4 seconds
Total Time Waiting: 3 seconds
Time Executing Code: 57%
Time Waiting: 43%

- Two tasks


P1:
Busy
Busy
Busy
Busy
P2:
Busy
Busy
Busy
Busy
Total Time Executing Code: 8 seconds
Total Time Waiting: 0 seconds
Time Executing Code: 100%
Time Waiting: 0%

Multiprocessing

- Approach
  - Multiple processing units
  - **Computer works on several tasks in parallel**
  - Performance can be improved

Dual-core AMD Athlon X2

32 processor Pentium Xeon

4096 processor Cray X1

Beowulf computer cluster (Borg, 52-node cluster used by McGill University Image/Info from Wikipedia)

Perform Multiple Tasks Using Processes

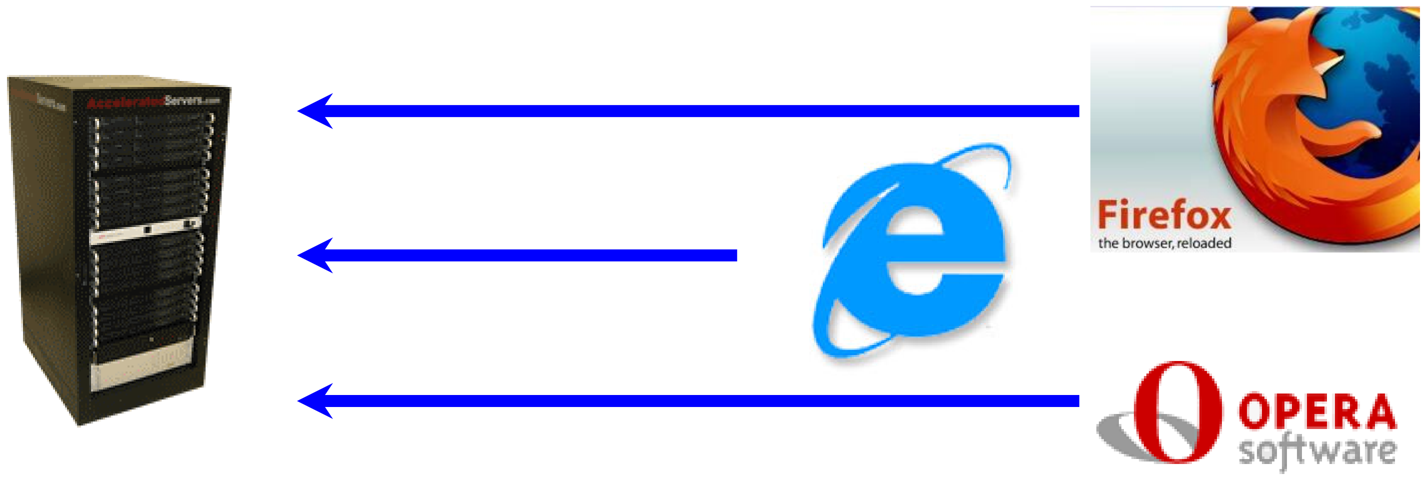
- Process
    - Definition - executable program loaded in memory
    - Has own address space
    - Address space - Variables & data structures (in memory)
    - Each process may execute a different program
    - Communicate via operating system, files, network
    - A process may contain multiple threads

Perform Multiple Tasks Using Threads

- Thread ("lightweight process")
  - Definition → sequentially executed stream of instructions
  - Has own execution context
    - Program counter, call stack (local variables)
  - Communicate via shared access to data
  - Also known as "lightweight process"
  - Let's see how memory is organized for a threaded environment
  - Diagram
    - http://blog.codecentric.de/wp-content/uploads/2009/12/java-memory-architecture.jpg

Motivation for Multithreading

- **Captures logical structure of problem**
  - May have concurrent interacting components
  - Can handle each component using separate thread
  - Simplifies programming for problem
- Example

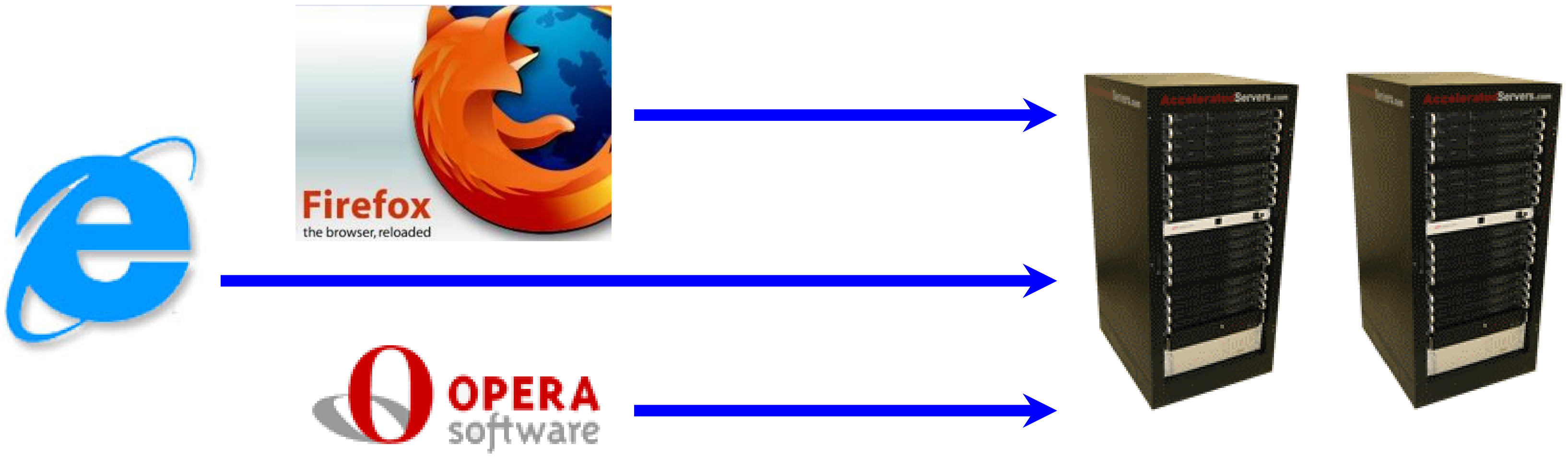


Web Server uses threads to handle …

Multiple simultaneous web browser requests

Motivation for Multithreading

- **Better utilization of hardware resources**
  - When a thread is delayed, execute other threads
  - Given extra hardware, execute threads in parallel
  - Reduce overall execution time
- Example



Multiple simultaneous web browser requests…

Handled faster by multiple web servers

Concurrent Programming

- Concurrent programming
    - Writing programs divided into independent tasks
    - Tasks may be executed in parallel on multiprocessors

Creating Threads in Java

- Two approaches to create threads
  - Extending Thread class (**NOT RECOMMENDED**)
  - Runnable interface approach (**PREFERED**)
- Approach 1: Extending Thread class
  - We override the Thread class **run()** method
  - The run() method defines the actual task the thread performs
  - **Example:**

```
public class MyT extends Thread {
    public void run( ) {
        …                    // Defines task for the thread
    }
}
MyT t = new MyT( ) ;   // Create thread
t.start( );            // Thread gets in line waiting to be executed
…
```

- **Example:** message, messageThreadExtends packages

Creating Threads in Java

- Approach 2: Runnable Interface
  - Define a class (worker) that implements the **Runnable** interface

```
public interface Runnable {
    public void run();   // work done by thread
}
```

  - Create thread to execute the **run()** method
    - **Alternative 1**: Create thread object and pass worker object to Thread constructor
    - **Alternative 2**: Hand worker object to an executor
  - **Example:**

```
public class Worker implements Runnable {
    public void run( )  { // work for thread }
}
Thread t = new Thread(new Worker( ));  // Create thread
t.start();                             // Thread gets in line waiting to be
                                       // executed
…
```

- **Example:** message, messageThreadRunnable packages

Why Extending Thread Not Recommended?

- Not a big problem for getting started
  - But a bad habit for industrial strength development
- Methods of worker and Thread class intermixed
- Hard to migrate to more efficient approaches
  - Thread Pools

Thread Class

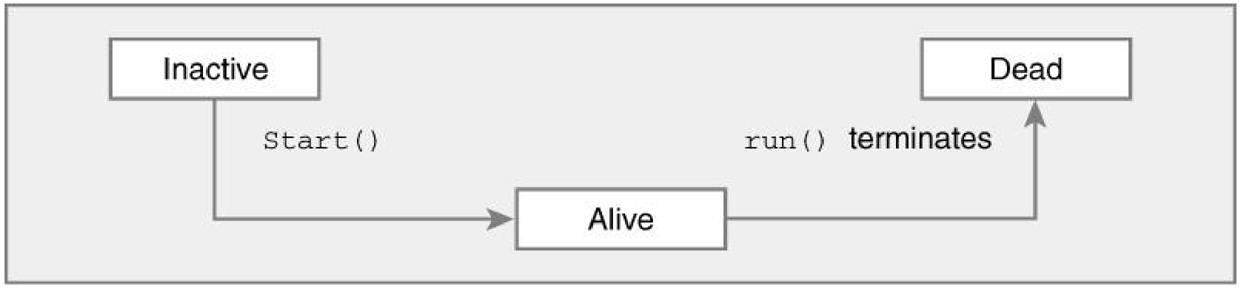
```
public class Thread extends Object implements Runnable {
    public Thread();
    public Thread(String name);   // Thread name
    public Thread(Runnable R);
    public Thread(Runnable R, String name);

    public void run();   // work for thread
    public void start(); // thread gets in line so it eventually it can run
    ...
}
```

More Thread Class Methods

```
public class Thread extends Object {
    …
    public static Thread currentThread()
    public String getName()
    public void interrupt()  // alternative to stop (deprecated)
    public boolean isAlive()
    public void join()
    public void setDaemon()
    public void setName()
    public void setPriority()
    public static void sleep()
    public static void yield()
}
```

Creating Threads in Java

- Note
  - Thread eventually starts executing only if start() is called
  - Calling start() does not mean the thread will start executing immediately



  - Runnable is an interface
    - Therefore, it can be implemented by any class
    - A class can implement the interface, but not used for threading
  - Do not call the run method directly
    - If using class instance as a thread

Threads – Thread States

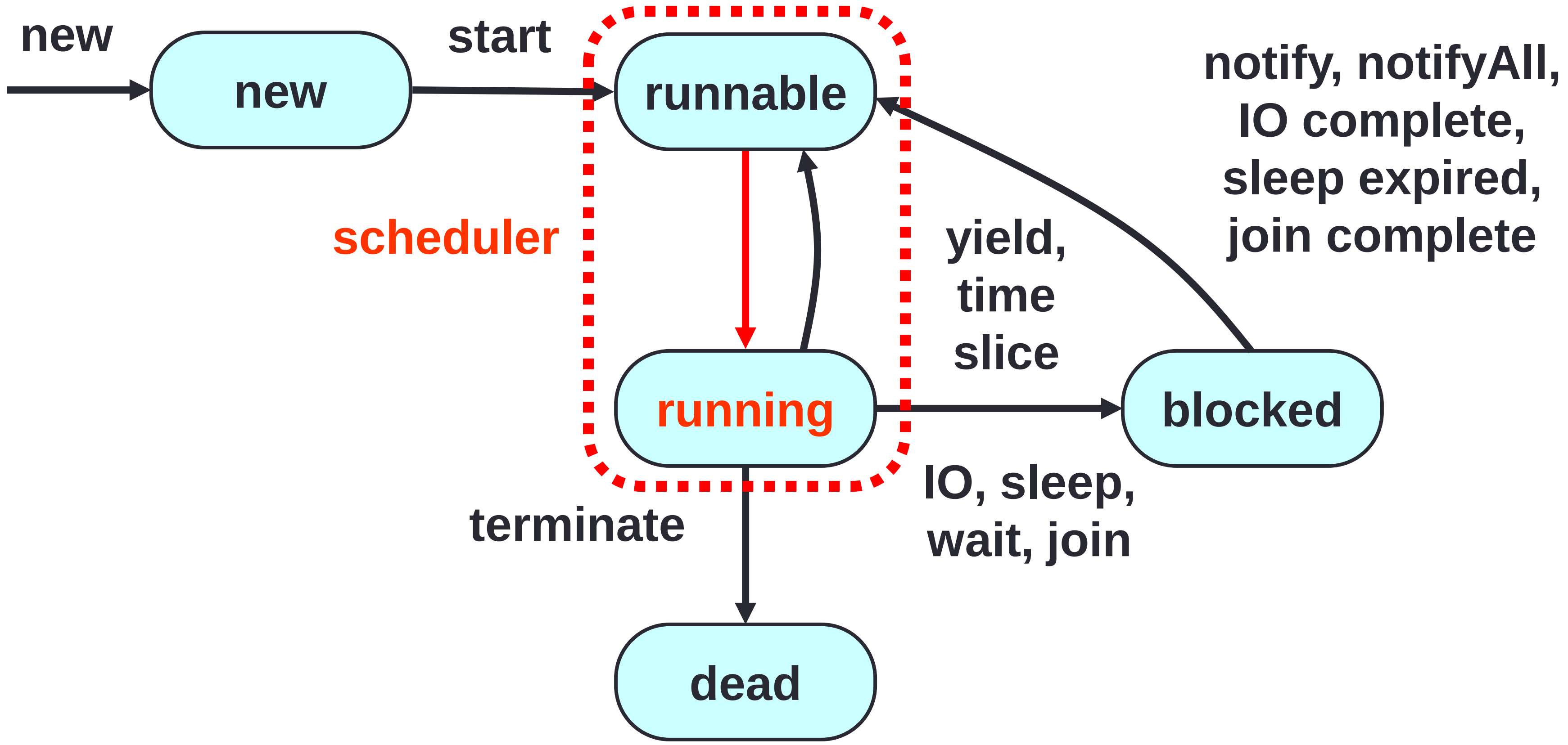
- Java thread can be in one of these states

New	→ thread allocated & waiting for start()
Runnable	→ thread can begin execution
Running	→ thread currently executing
Waiting/Blocked	→ thread waiting for event (I/O, etc.)
Terminated/Dead	→ thread finished/exited

- Transitions between states caused by
  - Invoking methods in class Thread
    - new(), start(), yield(), sleep(), wait(), notify()…
  - Other (external) events
    - Scheduler, I/O, returning from run()…
- In Java, states are defined by **Thread.State**
- https://docs.oracle.com/en/java/javase/11/docs/api/java.base/java/lang/Thread.State.html

Threads – Thread States

- State diagram



Running is a logical state → indicates runnable thread is actually running

Reference

- https://docs.oracle.com/javase/tutorial/essential/concurrency/index.html