

OBJECT ORIENTED PROGRAMMING WITH JAVA

Multithreaded Programming in Java – I

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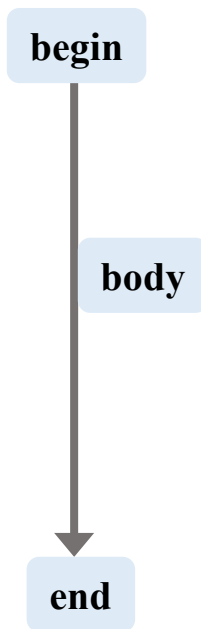


What is Multithreading?



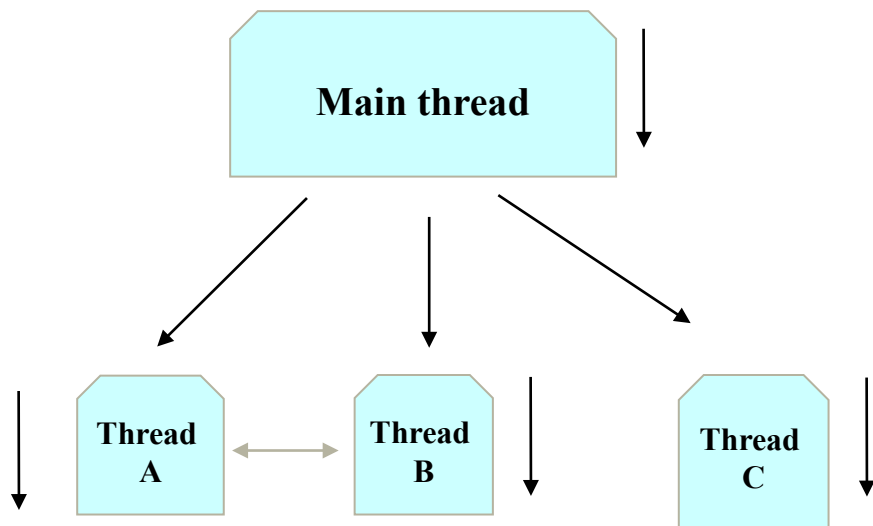
A single threaded program

```
class ABC
{
    ...
    public void main(..)
    {
        ...
        ...
    }
}
```





A multithreaded program



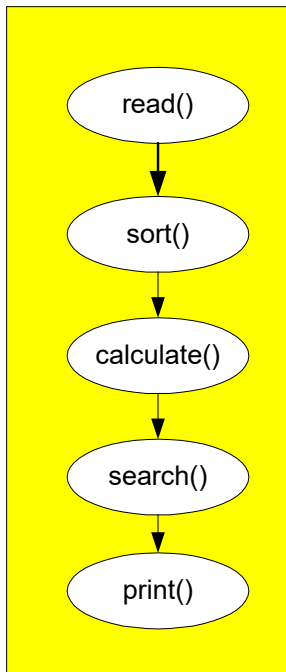
Threads may switch or exchange data/ results among them



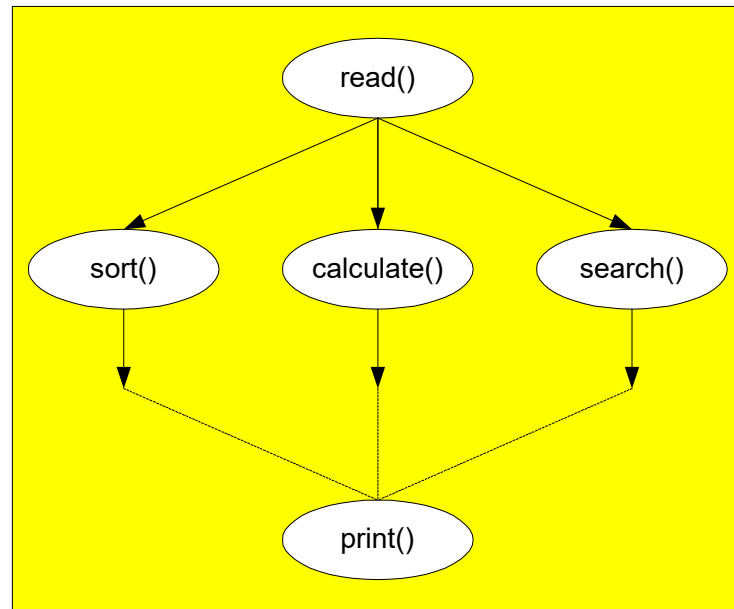
A multithreaded program

```
public class X {  
    main () {  
        . read()  
            { ... };  
        . sort()  
            { ... };  
        . calculate()  
            { ... };  
        . search()  
            { ... };  
        . print()  
            { ... };  
    }  
}
```

main



main





The concept

Multiple tasks in computer

- Draw and display images on screen
- Check keyboard and mouse input
- Send and receive data on network
- Read and write files to disk
- Perform useful computation (editor, browser, game)

How does computer do everything at once?

- Multitasking
- Multiprocessing



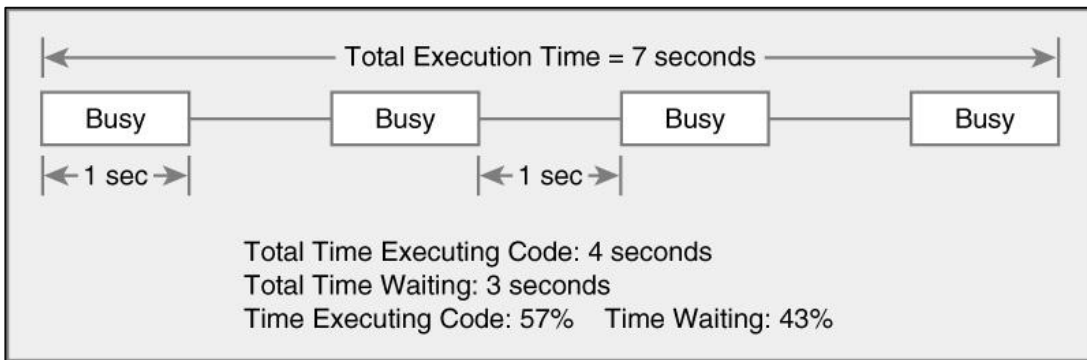
Multitasking (time-sharing)

- 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 improve performance

Single task →



Single task →

Two tasks →

Two tasks →



Multiprocessing (multi-threading)

- Multiple processing units (multiprocessor).
- Computer works on several tasks in parallel.
- Performance can be improved.



**Dual-core AMD
Athlon X2**



**32 processor
Pentium Xeon**



**4096 processor
Cray X1**



Perform multiple tasks using...

Process

- Definition – executable program loaded in memory
- Has own address space : [Variables and data structures \(in memory\)](#)
- Each process may execute a different program
- Communicate via operating system, files, network
- May contain **multiple threads**

Thread

- Definition – sequentially executed stream of instructions
- Shares address space with other threads
- Has own execution context : [Program counter, call stack \(local variables\)](#)
- Communicate via shared access to data
- Multiple threads in process execute same program
- Also, known as "**lightweight process**"



Why Multithreading?



Motivation for multithreading

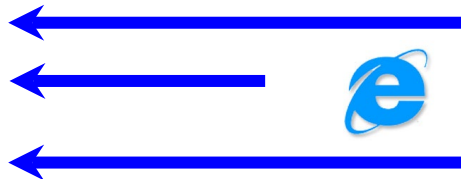
1. Captures logical structure of problem

- 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**

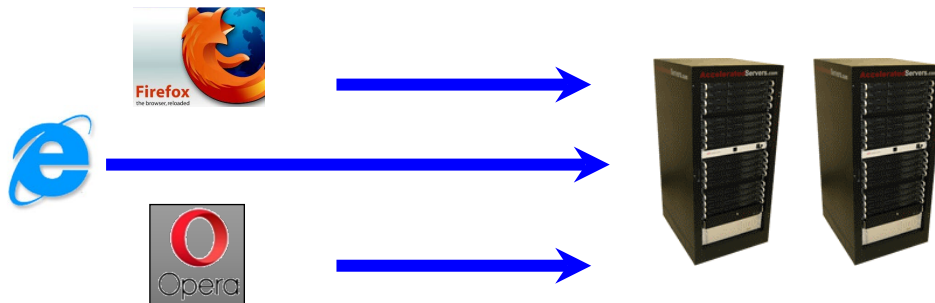


Motivation for multithreading

2. Better utilize hardware resources

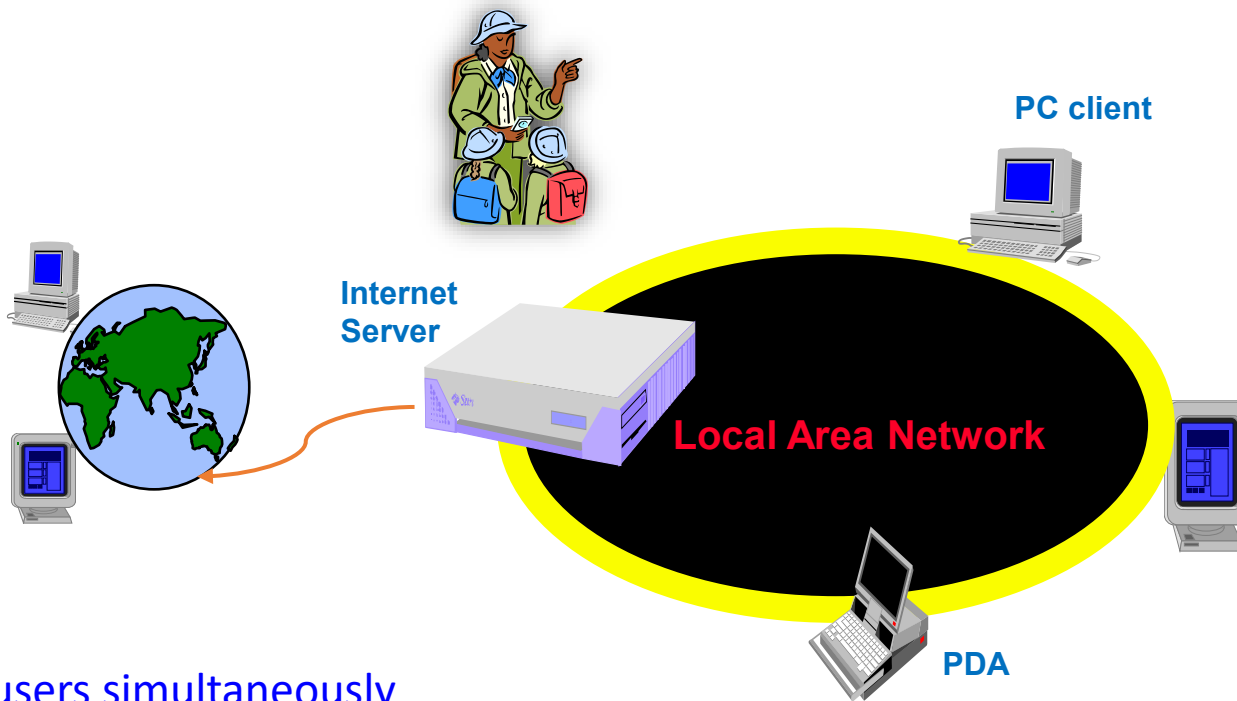
- When a thread is delayed, compute other threads
- Given extra hardware, compute threads in parallel
- Reduce overall execution time

Example



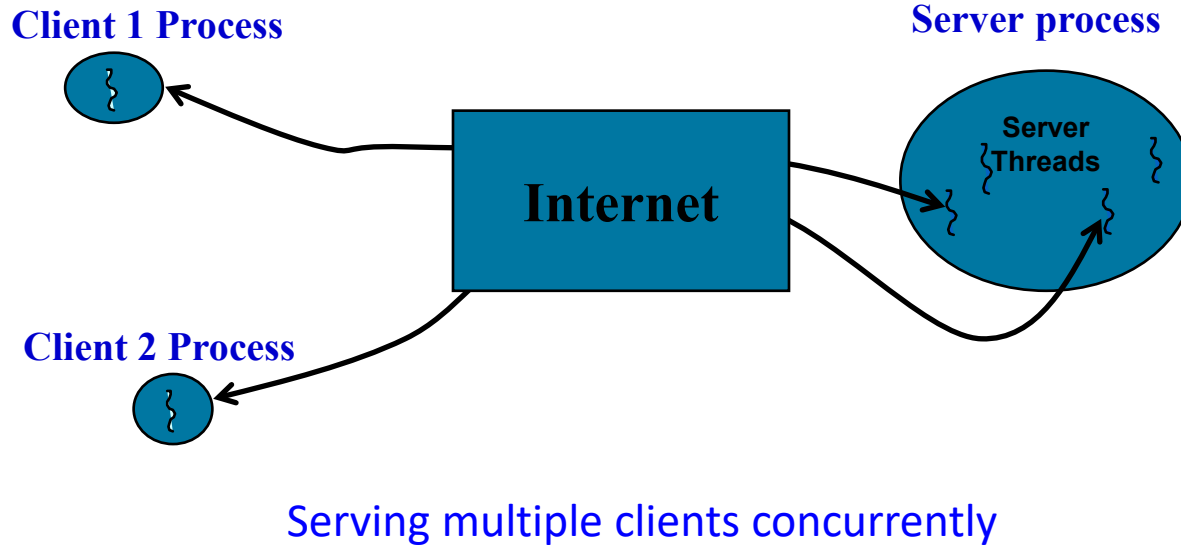


Web/ Internet applications



Serving many users simultaneously

Multithreaded server



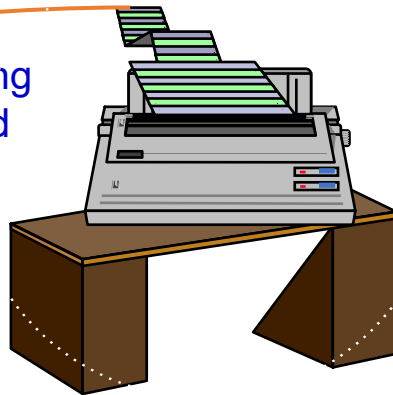


Modern applications need threads

Editing
thread



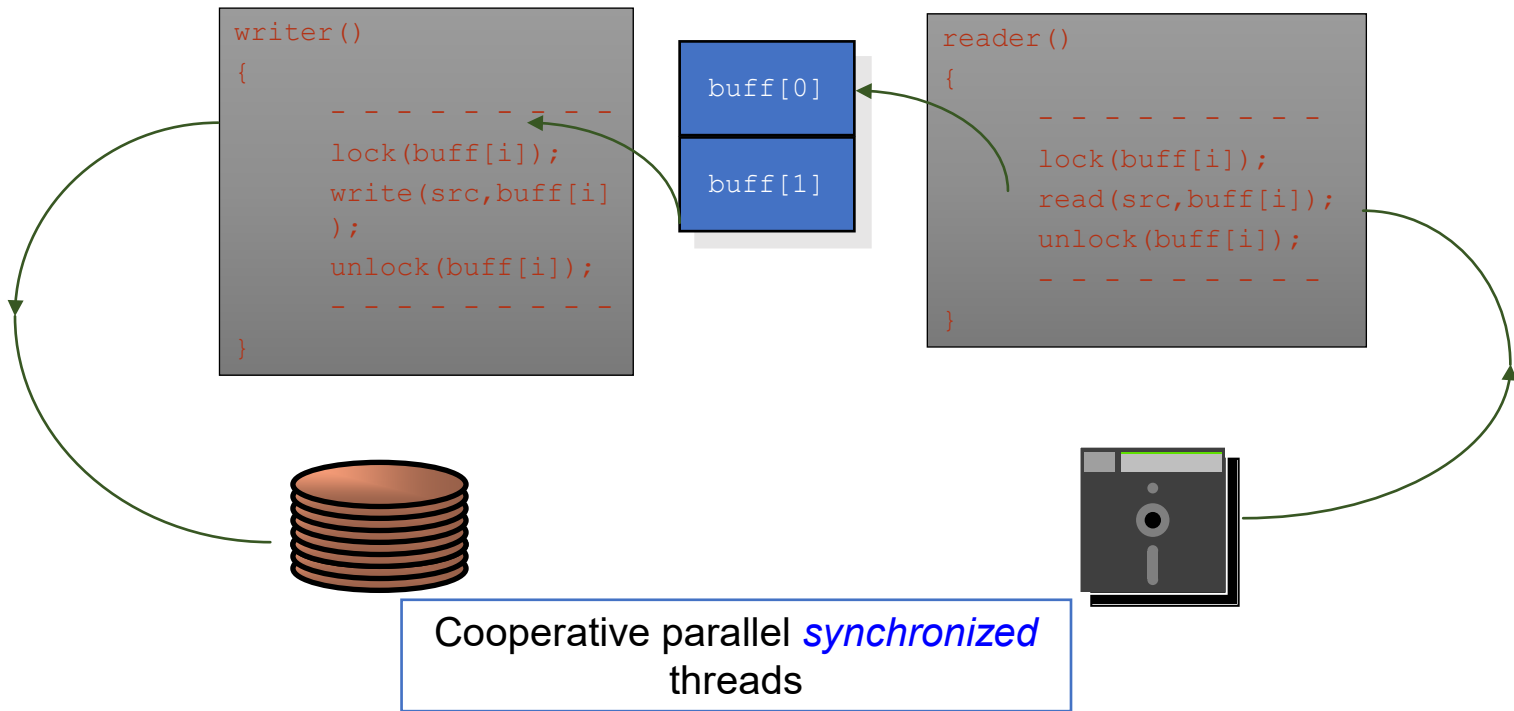
Printing
thread



“Editing” and “Printing” documents are in background



Multithreaded/ Parallel file copy

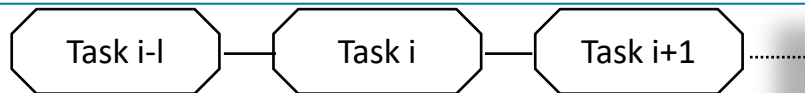




How Multithreading?

Levels of parallelism

Sockets



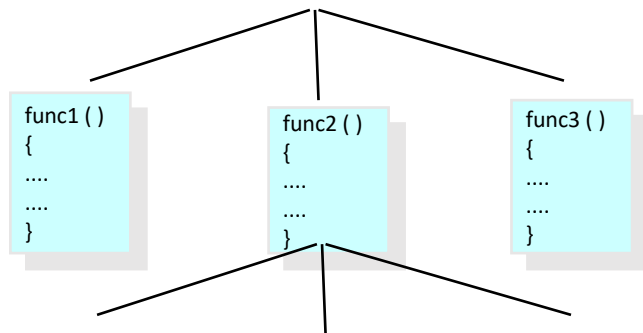
Code-granularity

Code Item

Large grain
(task level)

Program

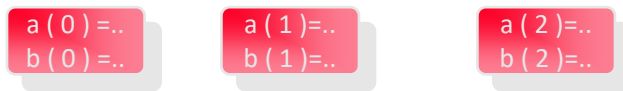
Threads



Medium grain
(control level)

Function (thread)

Compilers



Fine grain
(data level)

Loop (Compiler)

CPU



Very fine grain
(multiple issue)

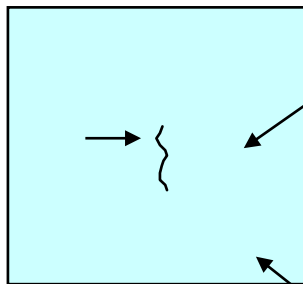
With hardware



Single and multithreaded processes

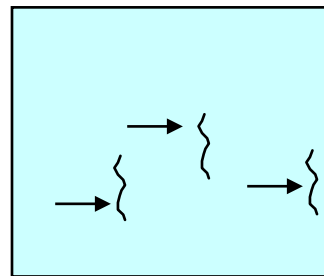
Threads are light-weight processes within a process

Single-threaded process



Threads of execution

Multipletreaded process



Single instruction stream

Multiple instruction stream

**Common
Address Space**



A thread is ...

- A piece of code that runs concurrently with other threads.
- Each thread is a statically ordered sequence of instructions.
- Threads are being extensively used to express concurrency on both single and multiprocessor machines.
- Programming a task having multiple threads of control
 - [Multithreading or multithreaded programming.](#)



Multithreading in Java



Java threads

- Java has built in support for multithreading.

- Synchronization
- Thread scheduling
- Inter-thread communication:

currentThread	start	setPriority
yield	run	getPriority
sleep	stop	suspend
resume		

Everything about thread is readily defined in the package *java.lang* and in a class **Thread** and interface **Runnable** in it.



Running a thread in Java

Note:

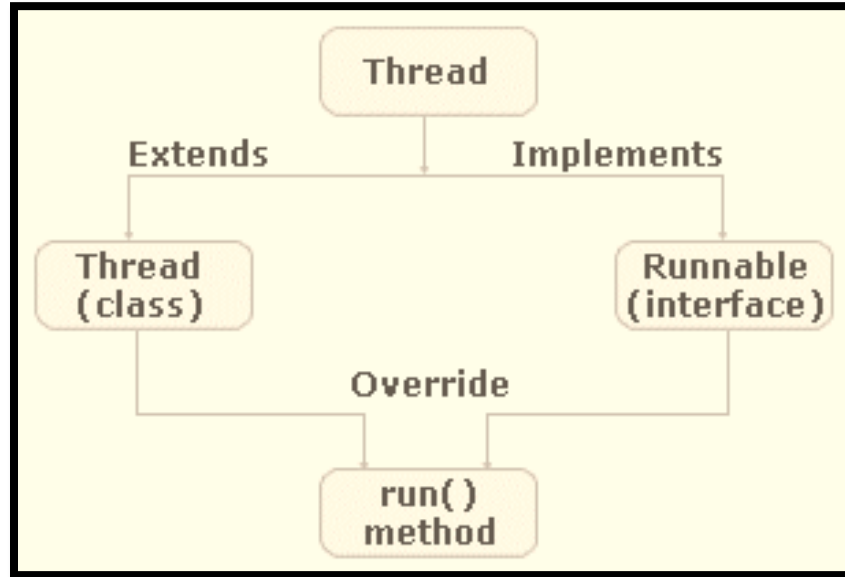
➤ Thread starts executing only if start() is called



➤ Runnable is interface

- So it can be multiply inherited
- Required for multithreading in applets

Running a thread in Java





Creating Threads with Threa



Creating threads in Java

There are two ways to create and run a thread:

➤ Thread class

```
public class Thread extends Object { ...  
}
```

➤ Runnable interface

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



Thread class

```
public class Thread extends Object implements Runnable {  
    public Thread();  
    public Thread (String name); //Thread name  
    public Thread (Runnable R); //Thread R.run()  
    public Thread (Runnable R, String name);  
    public void run(); //if no R, work for thread  
    public void start(); //begin thread execution  
    ...  
}
```



More Thread class methods

```
public class Thread extends Object {  
    ...  
    public static Thread currentThread();  
    public String getName();  
    public void interrupt();  
    public boolean isAlive();  
    public void join();  
    public void setDaemon();  
    public void setName();  
    public void setPriority();  
    public static void sleep();  
    public static void yield();  
}
```



Creating thread in Java programs

1. Thread class

- Extend Thread class and override the run method

Example:

```
public class MyT extends Thread {  
    public void run() {  
        ...                // work for thread  
    }  
}  
  
MyT T = new MyT () ;      // create thread  
T.start () ;              // begin running thread  
...                       // thread executing in parallel
```



Creating thread : An example

```
class ThreadA extends Thread  
{  
    public void run( ) {
```

```
class ThreadA extends Thread{  
    public void run( ) {  
        for(int i = 1; i <= 5; i++) {  
            System.out.println("From Thread A with i = "+ -1*i);  
        }  
        System.out.println("Exiting from Thread A ...");  
    }  
}  
  
class ThreadB extends Thread {  
    public void run( ) {  
        for(int j = 1; j <= 5; j++) {  
            System.out.println("From Thread B with j= "+2* j);  
        }  
        System.out.println("Exiting from Thread B ...");  
    }  
}
```

```
class ThreadC extends Thread
```

```
    public void run( ) {  
        for(int k = 1; k <= 5; k++) {  
            System.out.println("From Thread C with k = "+ 2*k-1);  
        }  
        System.out.println("Exiting from Thread C ...");  
    }  
}
```

```
class ThreadC extends Thread  
{  
    public void run( ) {  
        for(int k = 1; k <= 5; k++) {  
            System.out.println("From Thread C with k = "+  
                2*k-1);  
        }  
        System.out.println("Exiting from Thread C  
        ...");  
    }  
}  
  
class MultiThreadClass  
{  
    public static void main(String args[]) {  
        ThreadA a = new ThreadA();  
        ThreadB b = new ThreadB();  
        ThreadC c = new ThreadC();  
        a.start();  
        b.start();  
        c.start();  
        System.out.println("... Multithreading is over ");  
    }  
}
```

THANK YOU

OBJECT ORIENTED PROGRAMMING WITH JAVA

Multithreaded Programming in Java – II

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Creating Threads with Runnable



2. Runnable interface

- Create object implementing Runnable interface
- Pass it to Thread object via Thread constructor

Example

```
public class MyT implements Runnable {
    public void run() {
        ... // work for thread
    }
}

Thread T = new Thread(new MyT); // create thread
T.start(); // begin running thread
... // thread executing in parallel
```



Creating thread : Example

```
class ThreadX implements Runnable
{
    public void run( ) {
        for(int i = 1; i <= 5; i++) {
            System.out.println("Thread X with i = "+ -1*i);
        }
        System.out.println("Exiting Thread X ...");
    }
}

class ThreadY implements Runnable {
    public void run( ) {
        for(int j = 1; j <= 5; j++) {
            System.out.println("Thread Y with j = "+ 2*j);
        }
        System.out.println("Exiting Thread Y ...");
    }
}
```

nable

```
5; k++) {
    println("Thread Z with k = "+ 2*k-1);
    println("Exiting Thread Z ...");
}
```

St

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```
class ThreadZ implements Runnable
{
    public void run( ) {
        for(int k = 1; k <= 5; k++) {
            System.out.println("Thread Z with k = "+ 2*k-1);
        }
        System.out.println("Exiting Thread Z ...");
    }
}

class MultiThreadRunnable {
    public static void main(String args[]) {
        ThreadX x = new ThreadX();
        Thread t1 = new Thread(x);
        ThreadY y = new ThreadY();
        Thread t2 = new Thread(y);
        Thread t3 = new Thread(new ThreadZ());
        t1.start();
        t2.start();
        t3.start();
        System.out.println("... Multithreading is over ");
    }
}
```



States of a Thread



Threads : Thread states of a thread

Java thread can be in one of these states :

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

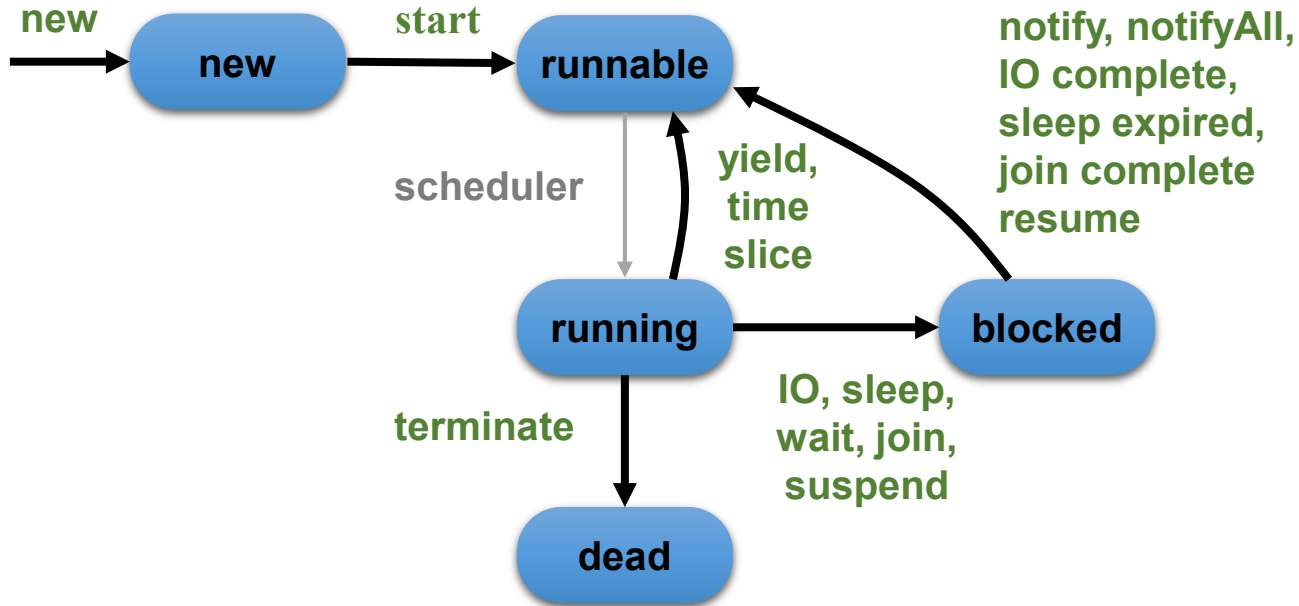
Transitions between states caused by

- Invoking methods in class Thread
 - ❖ new(), start(), yield(), sleep(), wait(), notify()...
- Other (external) events
 - ❖ Scheduler, I/O, returning from run()...



Thread States

State diagram





Thread control methods

- `start ()` :→ A newborn thread with this method enter into **Runnable** state and Java run time create a system thread context and starts it running. **This method for a thread object can be called once only**
- `suspend()` :→ This method is different from **stop()** method. It takes the thread and causes it to stop running and later on can be restored (by **resume()**)
- `resume()` :→ This method is used to revive a suspended thread. There is no gurantee that the thread will start running right way, since there might be a higher priority thread running already, but, `resume()` causes the thread to become eligible for running
- `sleep(int n):`→ This method causes the run time to put the current thread to sleep for **n milliseconds**
- `yield()` :→ This method causes the run time to switch the context from the current thread to the next available runnable thread. This is one way **to ensure that the threads at lower priority do not get started**



Scheduling of Threads



Daemon threads

Java threads types

- User
- Daemon
 - Provide general services.
 - Typically never terminate.
 - Call `setDaemon()` before `start()`.

Program termination

- All user threads finish.
- Daemon threads are terminated by JVM.
- Main program finishes.



Threads : Scheduling

Scheduler

- Determines which runnable threads to run.
- Can be based on thread **priority**.
- Part of OS or Java Virtual Machine (JVM) .

Scheduling policy

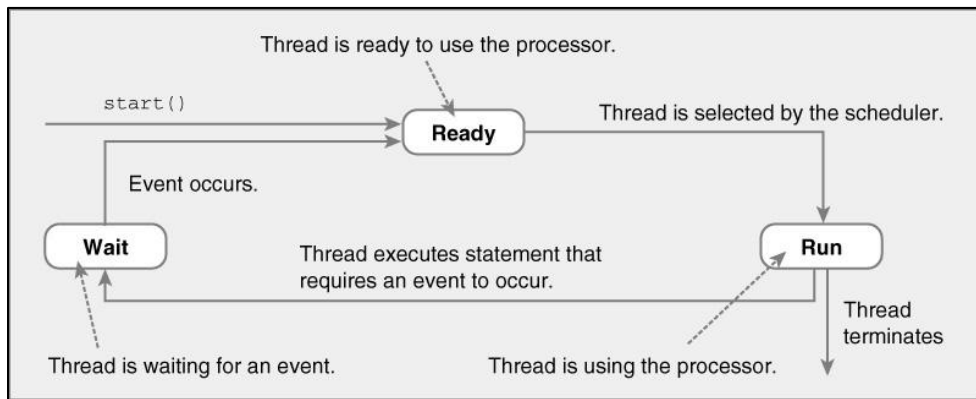
- Nonpreemptive (cooperative) scheduling.
- Preemptive scheduling.



Threads: Non-preemptive scheduling

Threads continue execution until

- Thread terminates.
- Executes instruction causing wait (e.g., IO).
- Thread volunteering to stop (invoking yield or sleep).

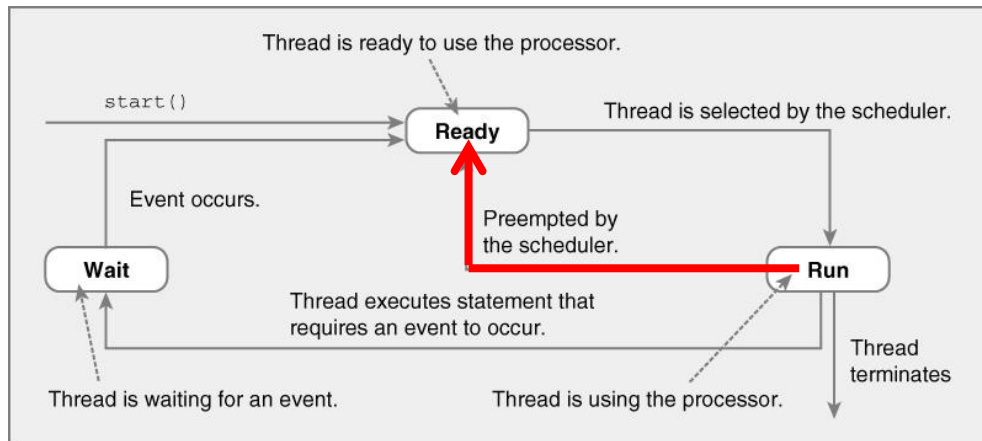




Threads: Preemptive scheduling

Threads continue execution until

- Same reasons as non-preemptive scheduling.
- **Preempted** by scheduler.





Java thread : An example

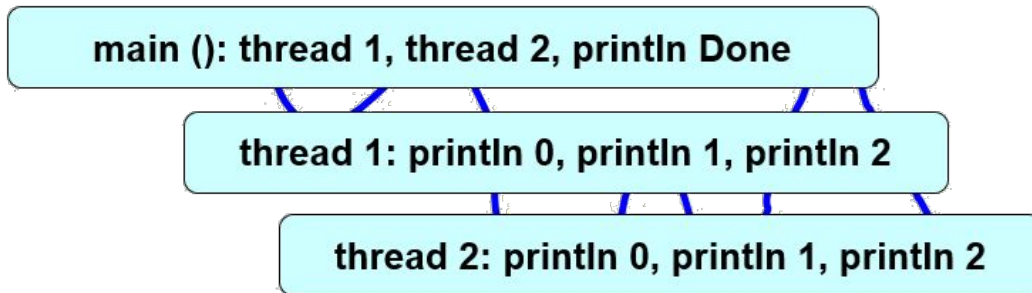
```
public class ThreadExample extends Thread {
    public void run() {
        for (int i = 0; i < 3; i++) {
            try {
                sleep ((int)(Math.random() * 5000)); // 5 secs
            }
            catch (InterruptedException e) {
                System.out.println (i);
            }
        }
    }
    public static void main(String[] args) {
        new ThreadExample().start();
        new ThreadExample().start();
        System.out.println ("Done");
    }
}
```



Java Thread Example

Possible outputs

- 0,1,2,0,1,2,Done // thread 1, thread 2, main()
- 0,1,2,Done,0,1,2 // thread 1, main(), thread 2
- Done,0,1,2,0,1,2 // main(), thread 1, thread 2
- 0,0,1,1,2,Done,2 // main() & threads interleaved





Data races

```
public class DataRace extends Thread {
    static int x;
    public void run() {
        for (int i = 0; i < 100000; i++) {
            x = x + 1;
            x = x - 1;
        }
    }
    public static void main(String[] args) {
        x = 0;
        for (int i = 0; i < 100000; i++)
            new DataRace().start();
        System.out.println(x); // x not always 0!
    }
}
```



Thread scheduling observations

The order in which threads are selected for execution is indeterminate.

- Depends on scheduler.

Thread can block indefinitely (starvation).

- If other threads always execute first.

Thread scheduling may cause data races.

- Modifying same data from multiple threads.
- Result depends on thread execution order.

Synchronization

- Control thread execution order.
- Eliminate data races.



Priority of Threads



Thread priority

- In **J**ava, each thread is assigned priority, which affects the order in which it is scheduled for running.
- The threads so far had same default priority (`NORM_PRIORITY`) and they are served using FCFS policy.
- **J**ava allows users to change priority:

`ThreadName.setPriority (int Number)`

❑ `MIN_PRIORITY` = 1

❑ `NORM_PRIORITY` = 5

❑ `MAX_PRIORITY` = 10



Thread priority : An example

```
class A extends Thread
{
    public void run()
    {
        System.out.println ("Thread A
started");
        for (int i=1;i<=4;i++)
        {
            System.out.println ("\t From
ThreadA: i= "+i);
        }
        System.out.println ("Exit from A");
    }
}
```

```
class B extends Thread
{
    public void run()
    {
        System.out.println ("Thread B started");
        for (int j=1;j<=4;j++)
        {
            System.out.println ("\t From
ThreadB: j= "+j);
        }
        System.out.println ("Exit from B");
    }
}
```

```
class C extends Thread
{
    public void run()
    {
        System.out.println ("Thread C started");
        for (int k=1;k<=4;k++)
        {
            System.out.println ("\t From ThreadC:
k= "+k);
        }
        System.out.println ("Exit from C");
    }
}
```

```
class B extends Thread
{
    public void run()
    {
        System.out.println ("Thread B started");
        for (int j=1;j<=4;j++)
        {
            System.out.println ("\t From ThreadB: j= "+j);
        }
        System.out.println ("Exit from B");
    }
}
```



Thread priority : An example

```
class ThreadPriority
{
    public static void main (String args[])
    {
        A threadA=new A();
        B threadB=new B();
        C threadC=new C();
        threadC.setPriority (Thread.MAX_PRIORITY);
        threadB.setPriority (threadA.getPriority()+1);
        threadA.setPriority (Thread.MIN_PRIORITY);
        System.out.println ("Started Thread A");
        threadA.start();
        System.out.println ("Started Thread B");
        threadB.start();
        System.out.println ("Started Thread C");
        threadC.start();
        System.out.println ("End of main thread");
    }
}
```



Thread class : Join

```
public class Test1 {  
    static void main(String[] args){  
        Thread t1 = new Thread(new R(1));  
        Thread t2 = new Thread(new R(2));  
        t1.start();  
        t2.start();  
        try {  
            t1.join();           // waits until t1 has terminated  
            t2.join();           // waits until t2 has terminated  
        }  
        catch (InterruptedException e){ }  
        System.out.println("done");  
    }  
}
```



Synchronization of Threads

Thread synchronization

When two or more processes attempts to access a shared resource, it should be synchronized to avoid conflicts.

Java supports methods to be synchronized.

Following is the syntax by which methods can be made to protect from simultaneous access:

```
synchronized (object) { block of statement(s) }
```



Thread synchronization : An example

```
class Account {
    private int balance;
    public int accountNo;
    void displayBalance( ) {
        System.out.println ( "Account No : " + accountNo
+ "Balance : " + balance );
    }
    synchronized void deposit (int amount ) {
        // Method to deposit an amount
        balance = balance + amount;
        System.out.print( amount + " is deposited " );
        displayBalance( ) ;
    }
    synchronized void withdraw (int amount ) {
        // method to withdraw an amount
        balance = balance - amount;
        System.out.print (amount + " is withdrawn" );
        displayBalance ( );
    }
}
```

```
// To implement a thread for deposit
class TransactionDeposite implements
Runnable {
    Account accountX;
    TransactionDeposite (Account x,
int amount ) {
        // Constructor to initiate this thread
        accountX = x;
        this.amount = amount;
        new Thread (this).start ( );
    }
    public void run( ) {
        accountX.deposit (amount);
    }
}
```



Thread synchronization : An example

```
// To implement a thread for withdraw
class TransactionWithdraw implements
Runnable {      Account accountY;
    int amount;
    TransactionWithdraw (Account y;
    int amount ) {
        accountY = y ;
        this.amount = amount;
        new Thread (this).start( );
    }
    public void run ( )      {
        accountY.withdraw (amount);
    }
}
```

```
class Transaction {
    public static void main (String,
    args[ ] ) {
        Account ABC = new Account ( );
        // Create an account
        ABC.balance = 1000;
        // initialize the account by Rs 1000
        TransactionDeposite t1;
        // A thread for deposit
        TransactionWithdraw t2
        // Another thread for withdraw
        t1 = new TransactionDeposite (ABC ,
        500 );
        t2 = new TransactionWithdraw (ABC,
        900 );
        // Two threads are started
    }
}
```



Thread synchronization : Stack example

Example: Stack

```
public class Stack {  
    private int top = 0;  
    private int[] data = new int [10];  
    public void push(int x) {  
        data[top] = x;  
        top++;  
    }  
    public int pop() {  
        top--;  
        return data[top];  
    }  
}
```

Two threads, one is pushing, the other popping objects



Using blocks

Synchronized blocks

- every object contains a single lock
- lock is taken when **synchronized** section is entered
- if lock is not available, thread enters a waiting queue
- if lock is returned any (longest waiting?) thread is resumed

```
public void push(int x) {  
    synchronized(this) {  
        data[top] = x;  
        top++;  
    }  
}
```



Instance methods

➤ Often a method is synchronized on “this”:

```
public void push(int x) {synchronized(this) {.....}}
```

➤ Short form:

```
public synchronized void push(int x) {.....}
```

Question to think...

- In any software, Input-Output is a great concern. How Java facilitates I-O handling?
- What makes Java suitable for network programming?

Thank You