Multithreaded Programming using Java Threads

61FIT3NPR -Network Programming

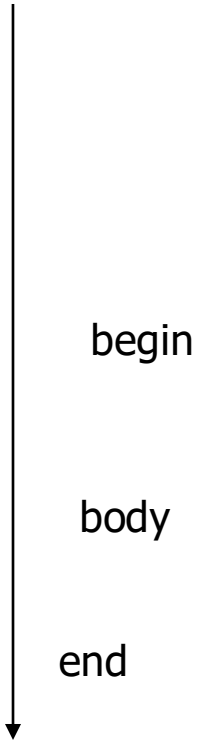
Faculty of Information Technology
Hanoi University
Fall 2020

Agenda

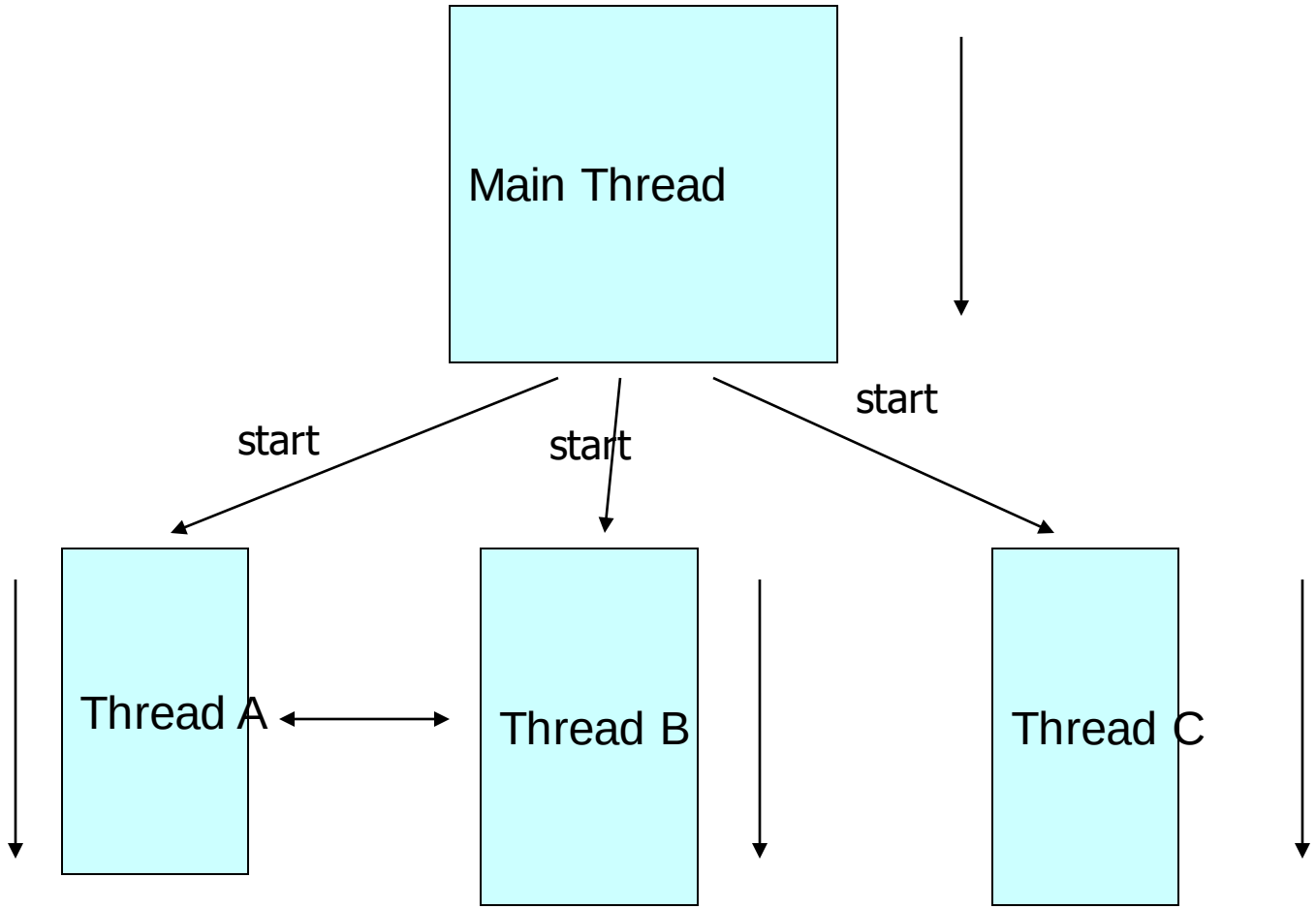
- Introduction
- Thread Applications
- Defining Threads
- Java Threads and States
  - Priorities
- Accessing Shared Resources
  - Synchronisation
- Assignment 1:
  - Multi-Threaded Math Server
- Advanced Issues:
  - Concurrency Models: master/worker, pipeline, peer processing
  - Multithreading Vs multiprocessing

A single threaded program

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



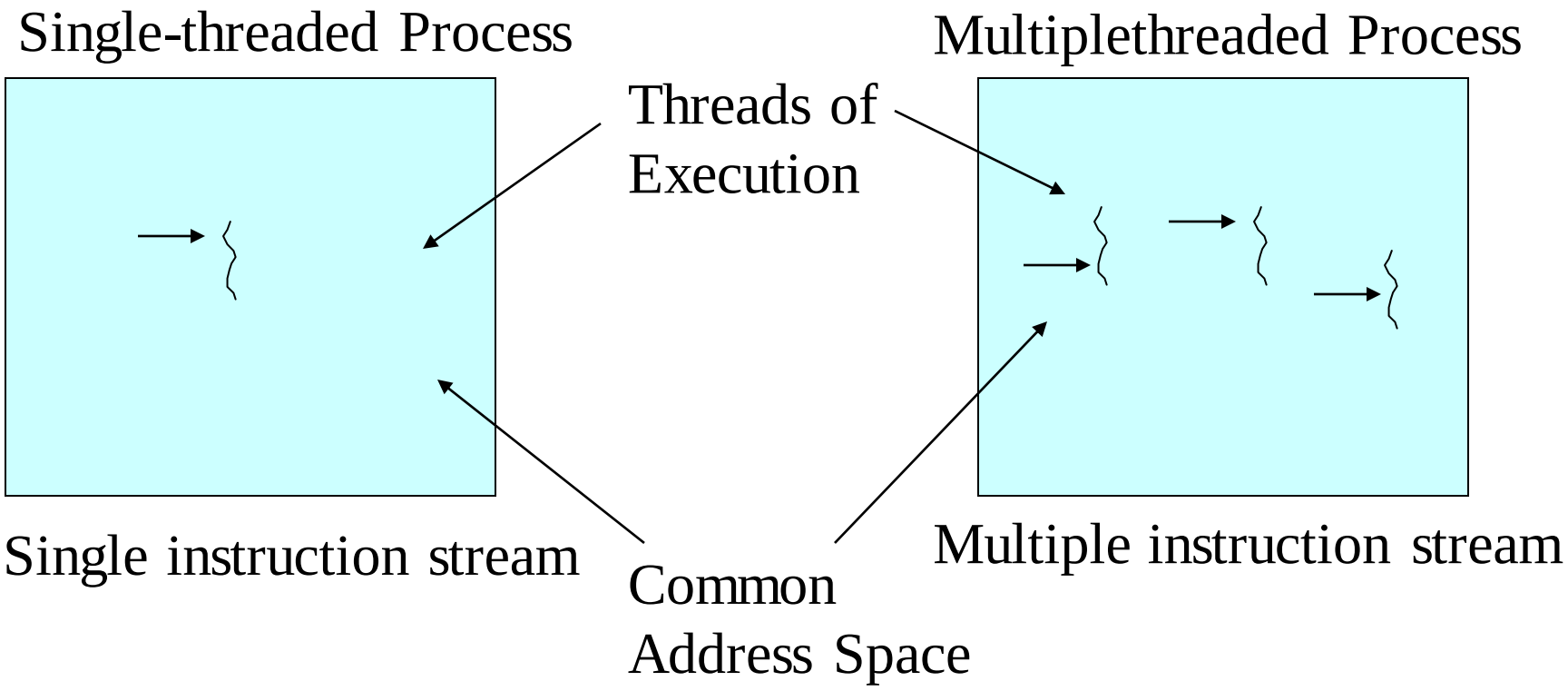
A Multithreaded Program



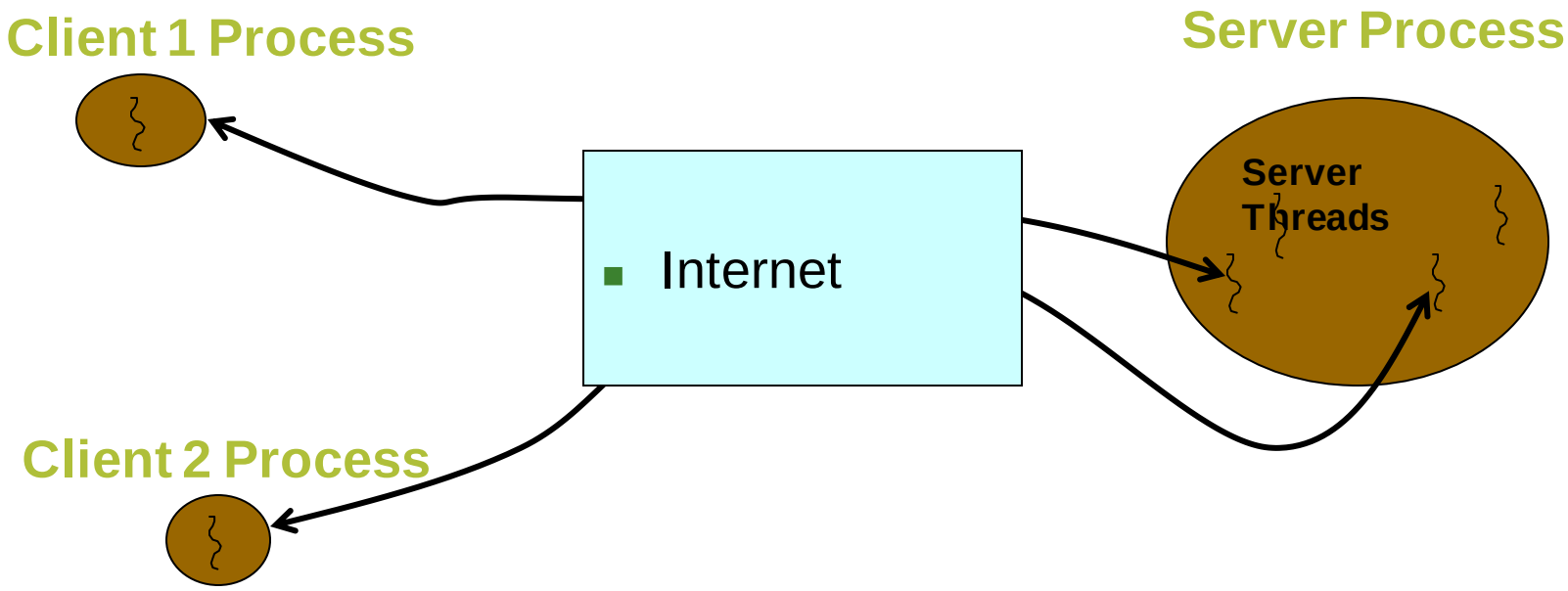
Threads may switch or exchange data/results

Single and Multithreaded Processes

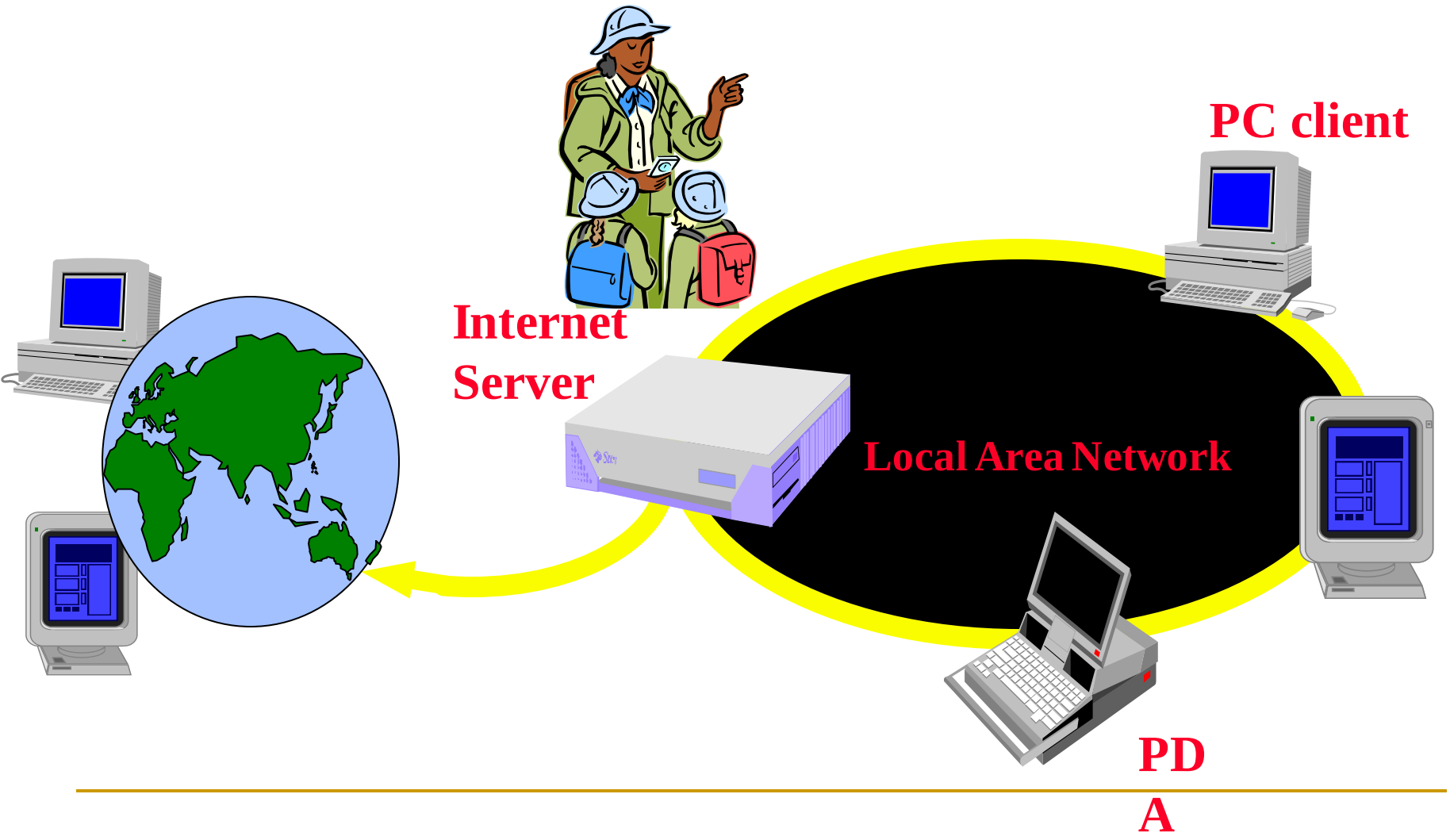
threads are light-weight processes within a process



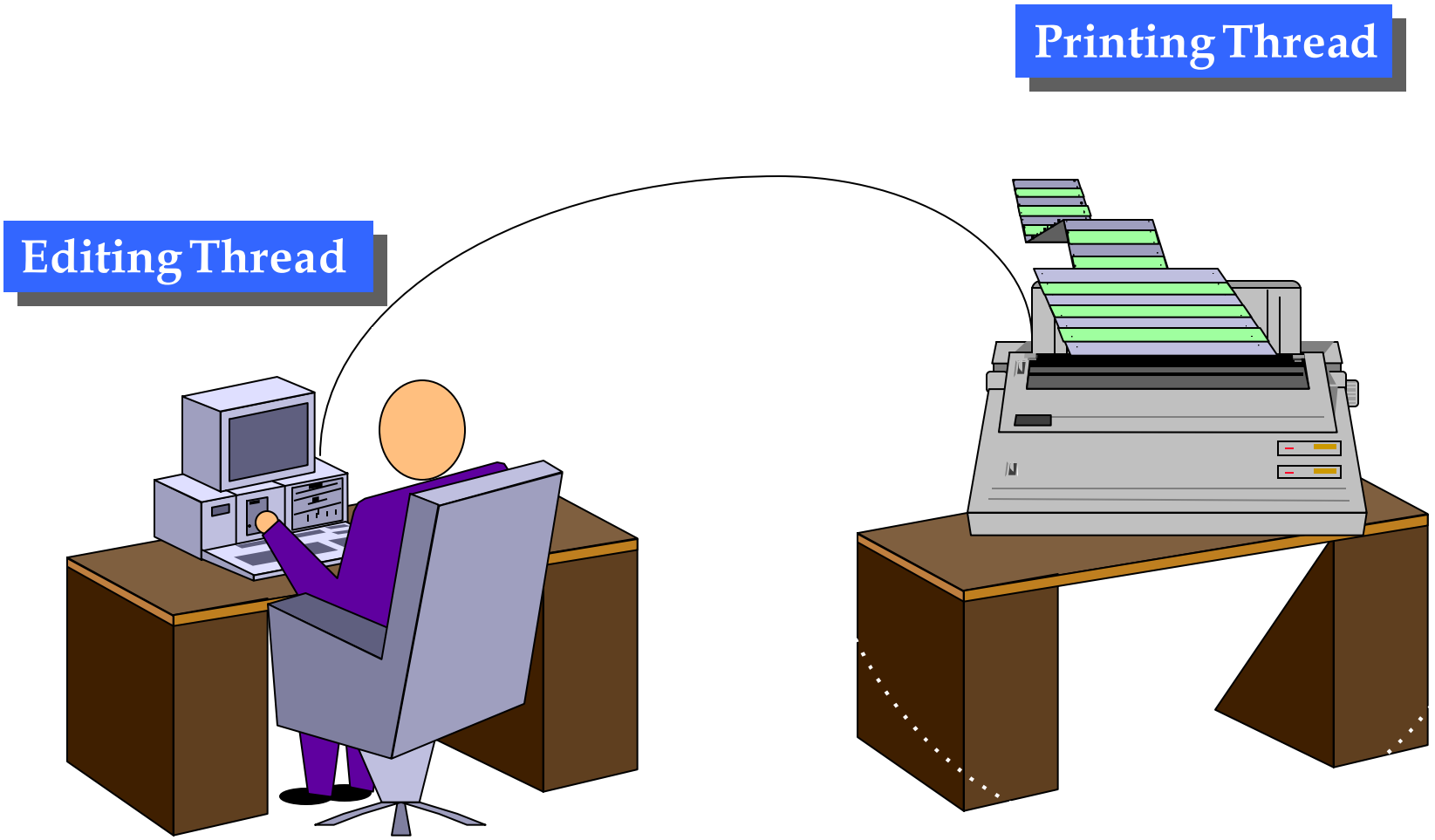
Multithreaded Server: For Serving Multiple Clients Concurrently



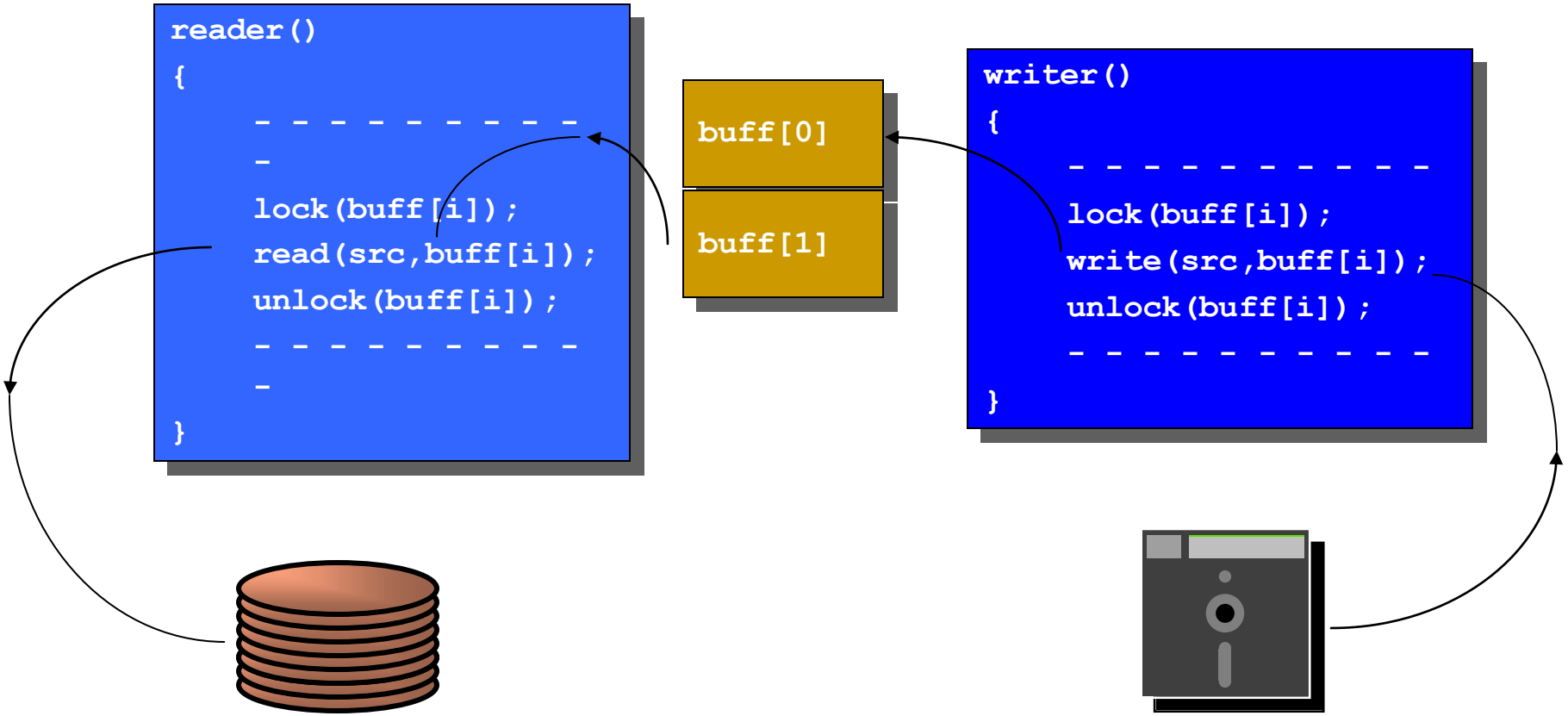
Web/Internet Applications: Serving Many Users Simultaneously



Modern Applications need Threads (ex1): Editing and Printing documents in background.

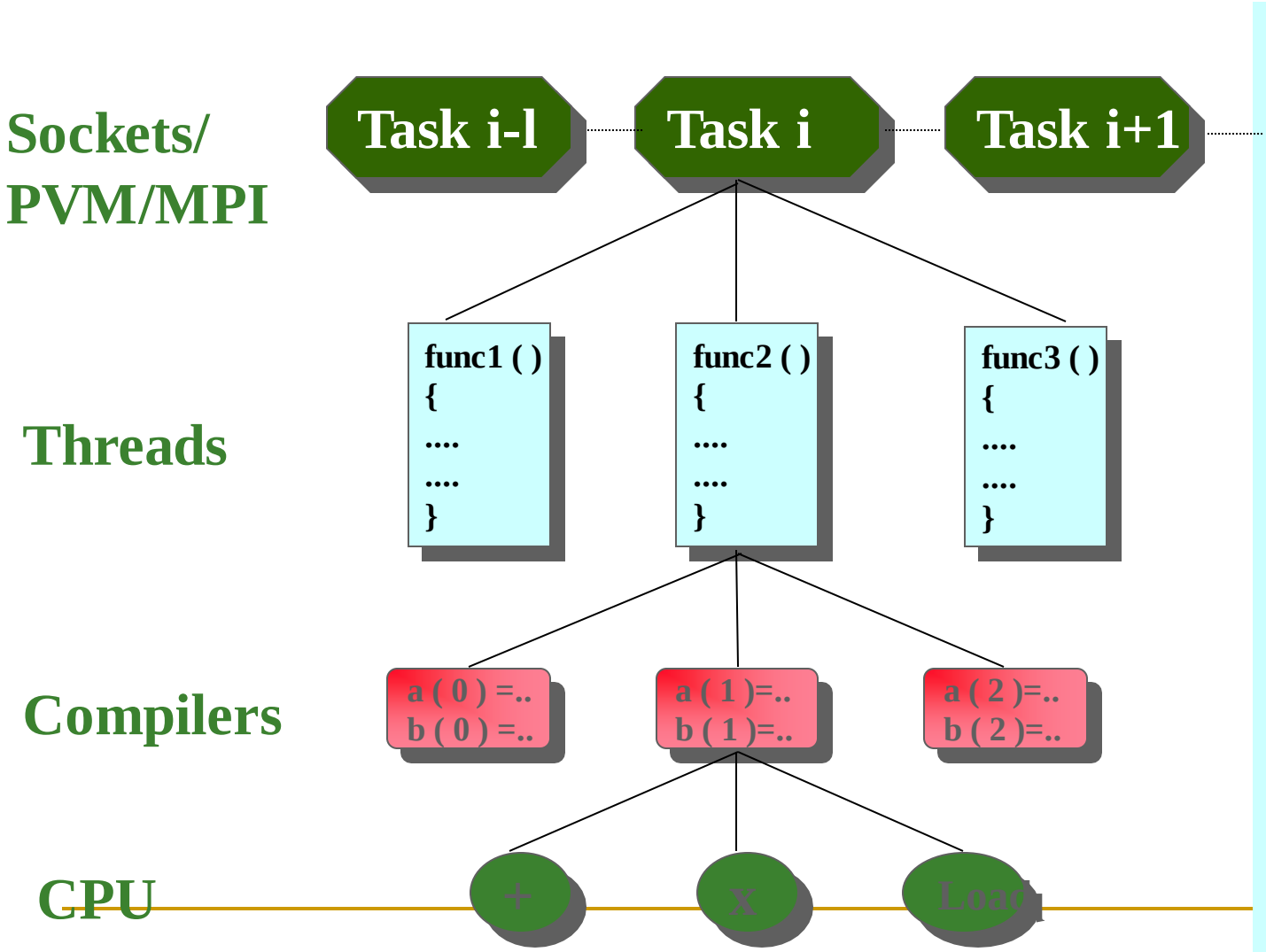


Multithreaded/Parallel File Copy



Cooperative Parallel Synchronized Threads

Levels of Parallelism



Code-Granularity

Code Item

Large grain (task level)

Program

Medium grain (control level)

Function (thread)

Fine grain (data level)

Loop (Compiler)

Very fine grain (multiple issue)

With hardware

What are Threads?

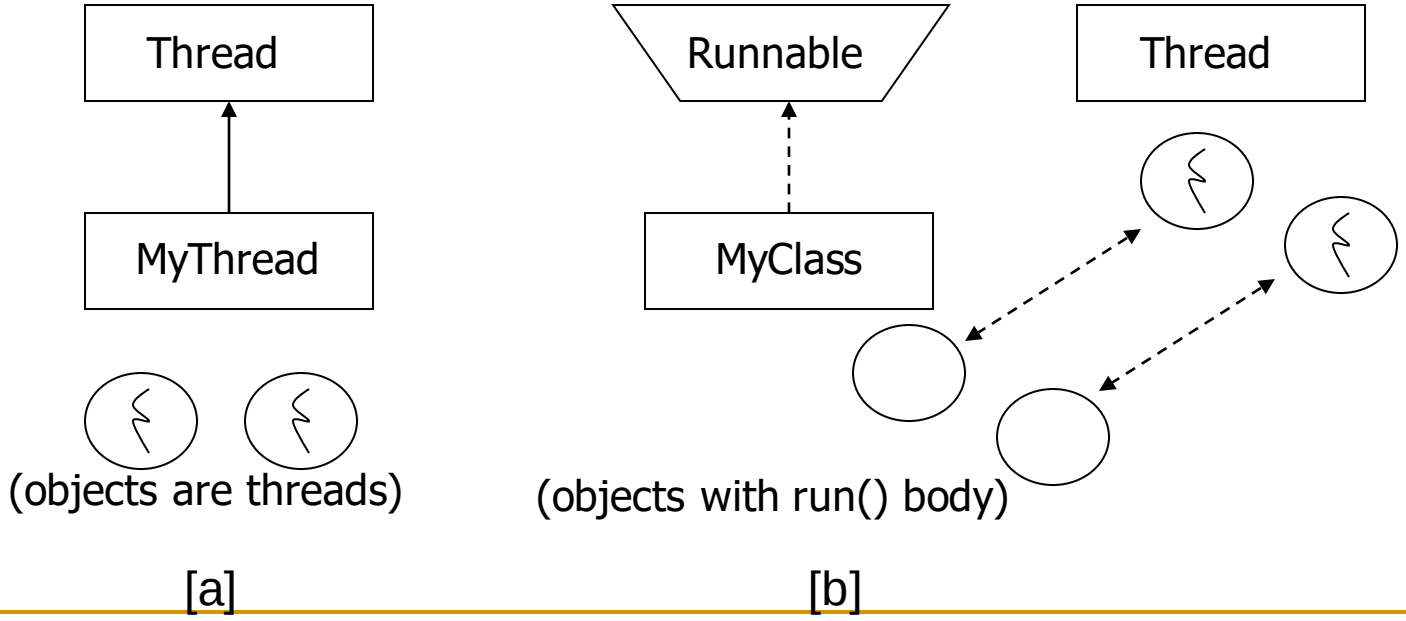
- A piece of code that run in concurrent with other threads.
- Each thread is a statically ordered sequence of instructions.
- Threads are being extensively used express concurrency on both single and multiprocessors machines.
- Programming a task having multiple threads of control – Multithreading or Multithreaded Programming.

Java Threads

- Java has built in thread support for Multithreading
- Synchronization
- Thread Scheduling
- Inter-Thread Communication:
  - currentThread
  - yield
  - sleep
  - resume
  - start
  - run
  - stop
  - setPriority
  - getPriority
  - suspend
- Java Garbage Collector is a low-priority thread.

Threading Mechanisms...

- Create a class that extends the Thread class
- Create a class that implements the Runnable interface



1st method: Extending Thread class

- Create a class by extending Thread class and override run() method:

```
class MyThread extends Thread
{
     public void run()
    {
        // thread body of execution
    }
}
```

- Create a thread:

```
MyThread thr1 = new MyThread();
```

- Start Execution of threads:

```
thr1.start();
```

- Create and Execute:

```
new MyThread().start();
```

An example

```
class MyThread extends Thread {
        public void run() {
                System.out.println(" this thread is running … ");
        }
}

class ThreadEx1 {
        public static void main(String [] args  ) {
            MyThread t = new MyThread();
             t.start();
       }
}
```

2nd method: Threads by implementing Runnable interface

- Create a class that implements the interface Runnable and override run() method:

```
class MyThread implements Runnable
{
   .....
   public void run()
   {
      // thread body of execution
   }
}
```

- Creating Object:

```
MyThread myObject = new MyThread();
```

- Creating Thread Object:

```
Thread thr1 = new Thread( myObject );
```

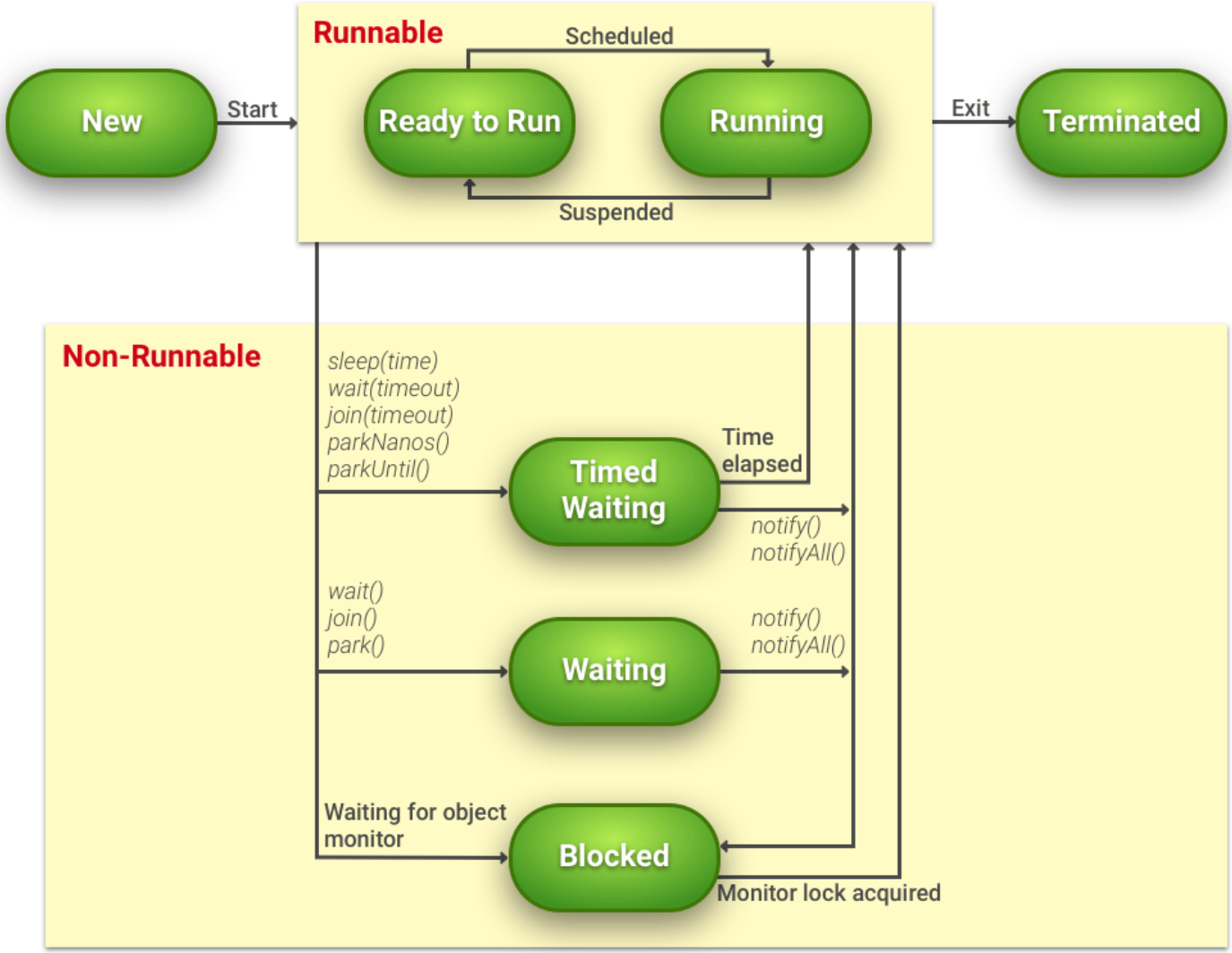
- Start Execution:

```
thr1.start();
```

An example

```
class MyThread implements Runnable  {
        public void run() {
                System.out.println(" this thread is running … ");
        }
}

class ThreadEx2 {
        public static void main(String [] args  ) {
                Thread t = new Thread(new MyThread());
                 t.start();
        }
}
```

Life Cycle of Thread



A Program with Three Java Threads

- Write a program that creates 3 threads

Three threads example

```
class A extends Thread
{
      public void run()
       {
           for(int i=1;i<=5;i++)
            {
                System.out.println("\t From ThreadA: i= "+i);
            }
             System.out.println("Exit from A");
       }
}

class B extends Thread
{
      public void run()
       {
           for(int j=1;j<=5;j++)
            {
                System.out.println("\t From ThreadB: j= "+j);
            }
             System.out.println("Exit from B");
       }
}
```

```
class C extends Thread
{
      public void run()
       {
           for(int k=1;k<=5;k++)
            {
                System.out.println("\t From ThreadC: k= "+k);
            }

             System.out.println("Exit from C");
       }
}

class ThreadTest
{
        public static void main(String args[])
        {
                new A().start();
                new B().start();
                new C().start();
        }
}
```

Run 1

- [raj@mundroo] threads [1:76] java ThreadTest
  From ThreadA: i= 1
  From ThreadA: i= 2
  From ThreadA: i= 3
  From ThreadA: i= 4
  From ThreadA: i= 5

Exit from A

  From ThreadC: k= 1
  From ThreadC: k= 2
  From ThreadC: k= 3
  From ThreadC: k= 4
  From ThreadC: k= 5

Exit from C

  From ThreadB: j= 1
  From ThreadB: j= 2
  From ThreadB: j= 3
  From ThreadB: j= 4
  From ThreadB: j= 5

Exit from B

Run2

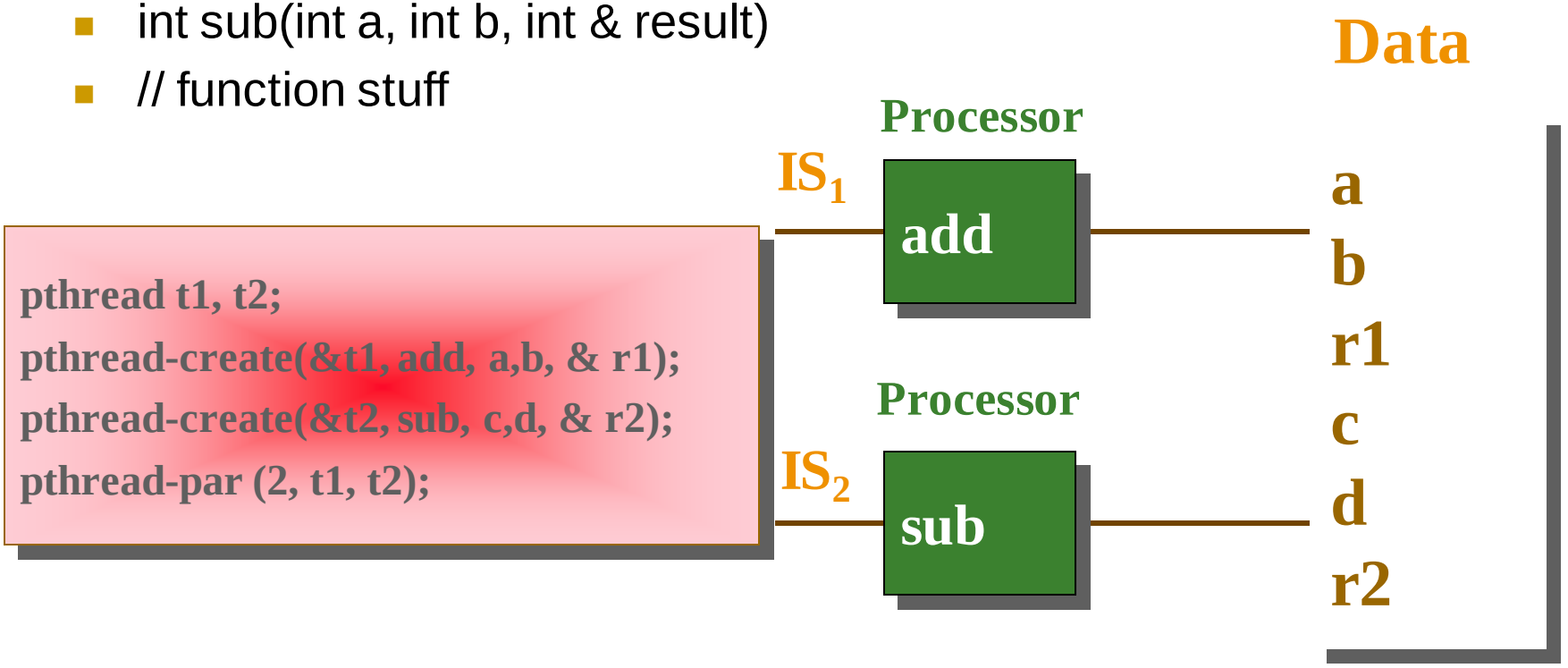
- [raj@mundroo] threads [1:77] java ThreadTest
  From ThreadA: i= 1
  From ThreadA: i= 2
  From ThreadA: i= 3
  From ThreadA: i= 4
  From ThreadA: i= 5
  From ThreadC: k= 1
  From ThreadC: k= 2
  From ThreadC: k= 3
  From ThreadC: k= 4
  From ThreadC: k= 5

Exit from C
  From ThreadB: j= 1
  From ThreadB: j= 2
  From ThreadB: j= 3
  From ThreadB: j= 4
  From ThreadB: j= 5

Exit from B
Exit from A

Process Parallelism

- int add (int a, int b, int & result)
- // function stuff
- int sub(int a, int b, int & result)
- // function stuff

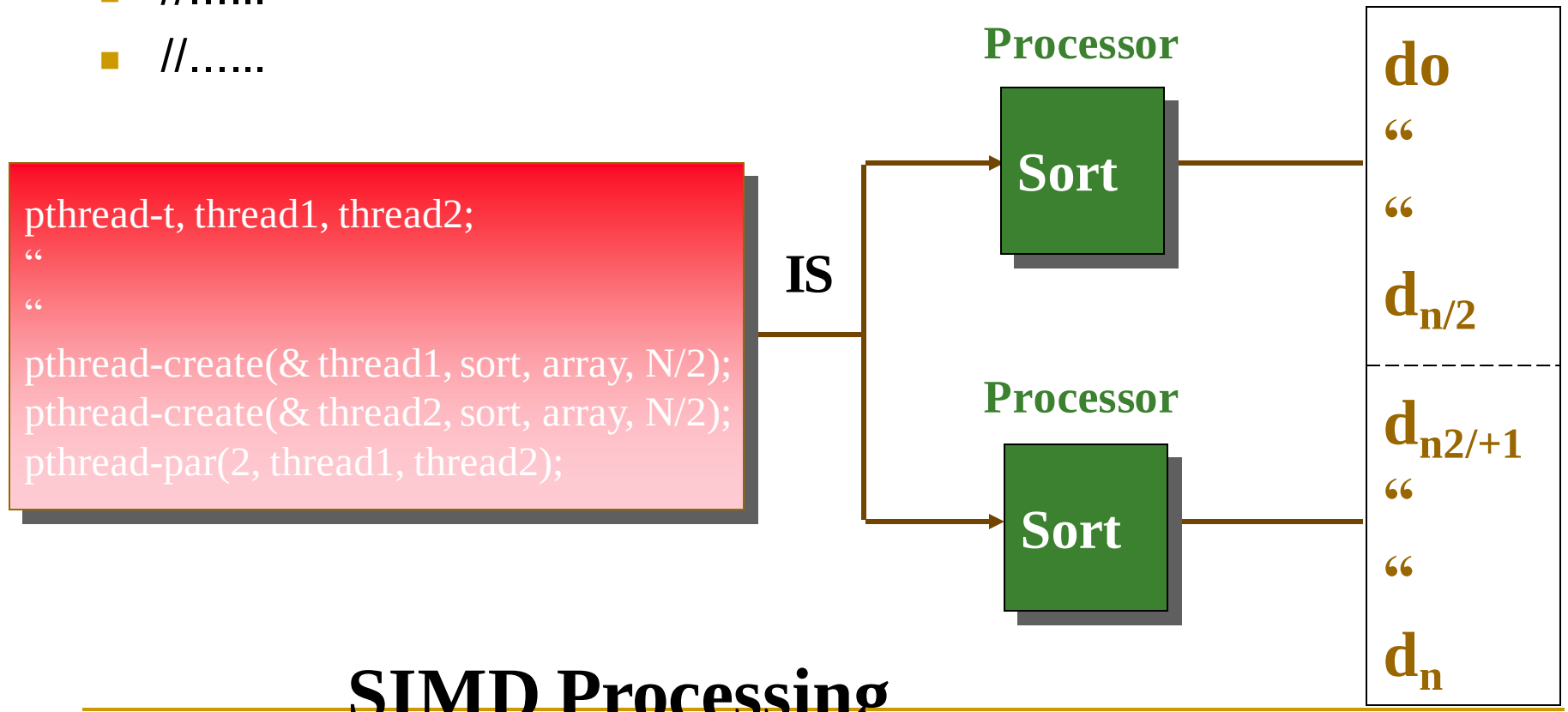


MISD and MIMD Processing

Data Parallelism

- sort(int *array, int count)
- //.....
- //.....

```
pthread-t, thread1, thread2;
“
“
pthread-create(& thread1, sort, array, N/2);
pthread-create(& thread2, sort, array, N/2);
pthread-par(2, thread1, thread2);
```



SIMD Processing

Thread Priority

- In Java, 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.
  - Java allows users to change priority:
    - ThreadName.setPriority(intNumber)
      - MIN_PRIORITY = 1
      - NORM_PRIORITY=5
      - MAX_PRIORITY=10

Thread Priority 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");
       }
}
```

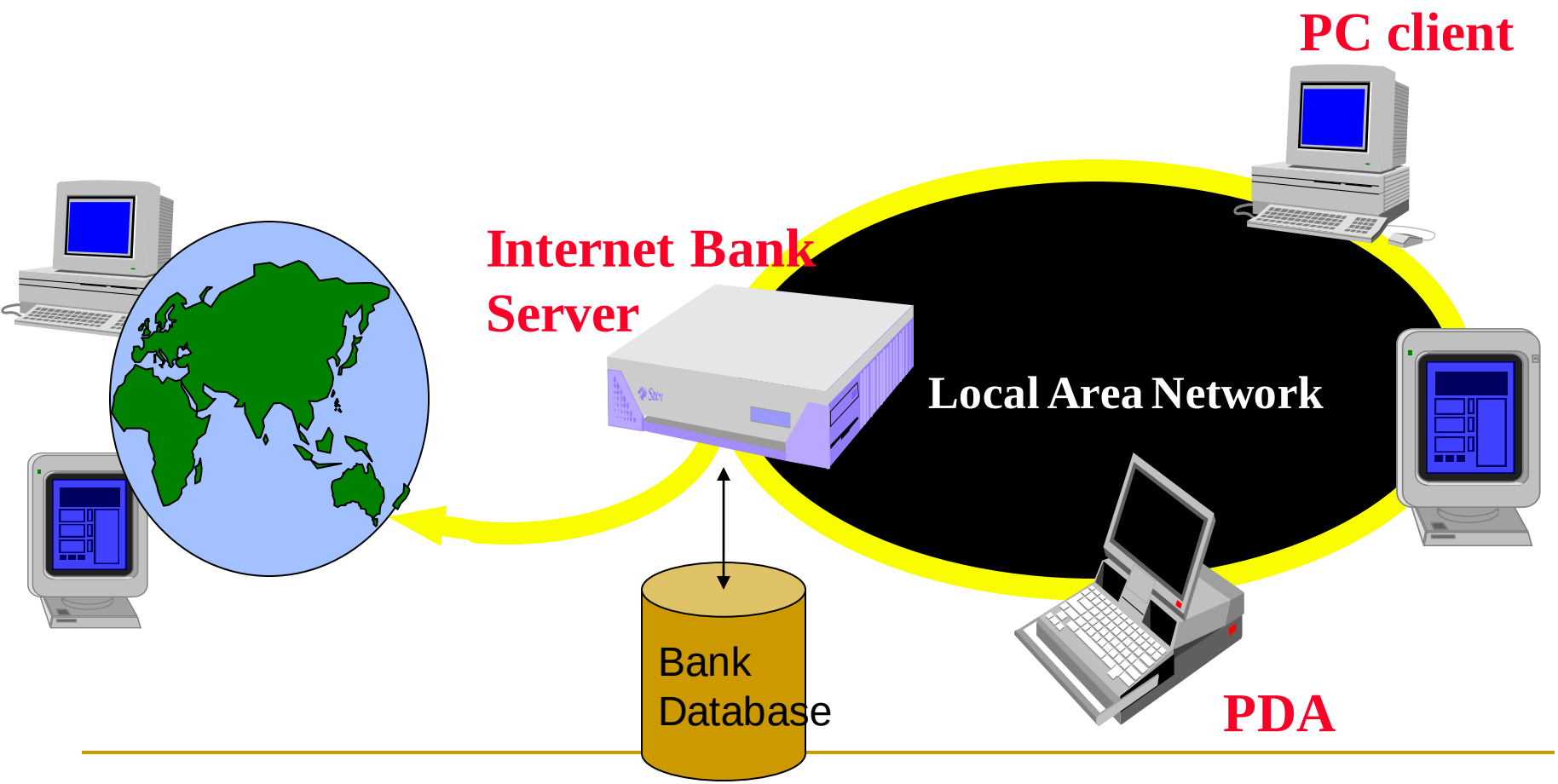
Thread Priority Example

```
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 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");
       }
}
```

Accessing Shared Resources

- Applications Access to Shared Resources need to be coordinated.
  - Printer (two person jobs cannot be printed at the same time)
  - Simultaneous operations on your bank account.
  - Can the following operations be done at the same time on the same account?
    - Deposit()
    - Withdraw()
    - Enquire()

Online Bank: Serving Many Customers and Operations



Shared Resources

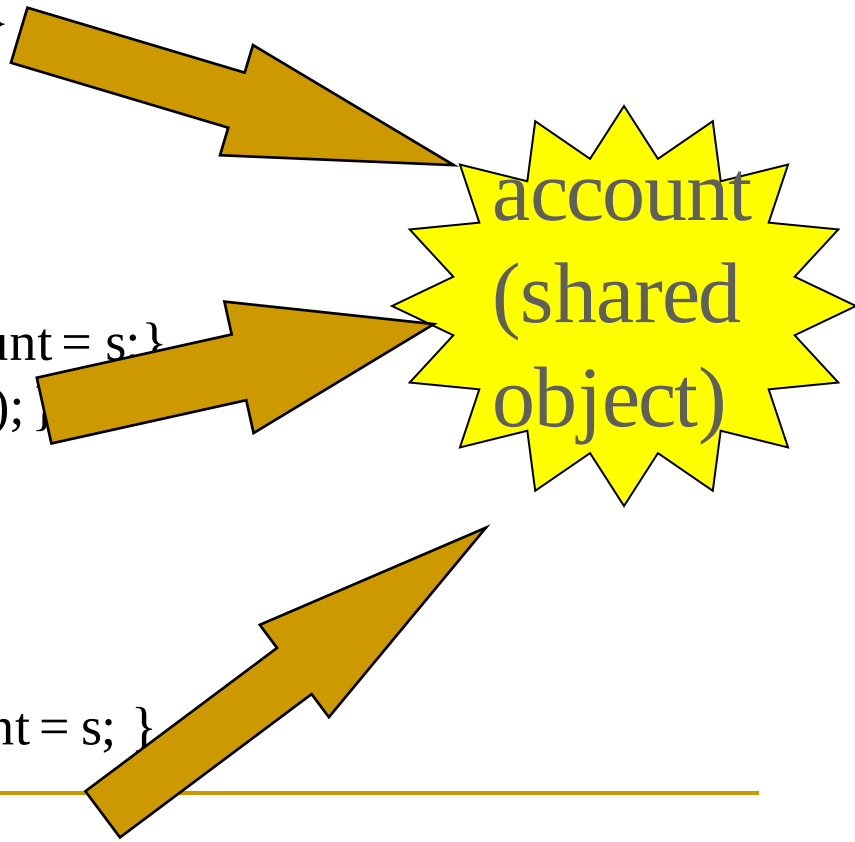
- If one thread tries to read the data and other thread tries to update the same data, it leads to inconsistent state.
- This can be prevented by synchronising access to the data.
- Use “Synchronized” method:
  - public synchronized void update()
  - {
    - …
  - }

the driver: 3rd Threads sharing the same object

```
class InternetBankingSystem {
        public static void main(String [] args  ) {
            Account accountObject = new Account ();
            Thread t1 = new Thread(new MyThread(accountObject));
            Thread t2 = new Thread(new YourThread(accountObject));
            Thread t3 = new Thread(new HerThread(accountObject));
            t1.start();
            t2.start();
            t3.start();
          // DO some other operation
       } // end main()
}
```

Shared account object between 3 threads

```
class MyThread implements Runnable  {
 Account account;
        public MyThread (Account s) {  account = s;}
        public void run() { account.deposit(); }
} // end class MyThread

class YourThread implements Runnable  {
 Account account;
        public YourThread (Account s) { account = s;}
        public void run() { account.withdraw(); }
} // end class YourThread

class HerThread implements Runnable  {
 Account account;
        public HerThread (Account s) { account = s; }
        public void run() {account.enquire(); }
} // end class HerThread
```

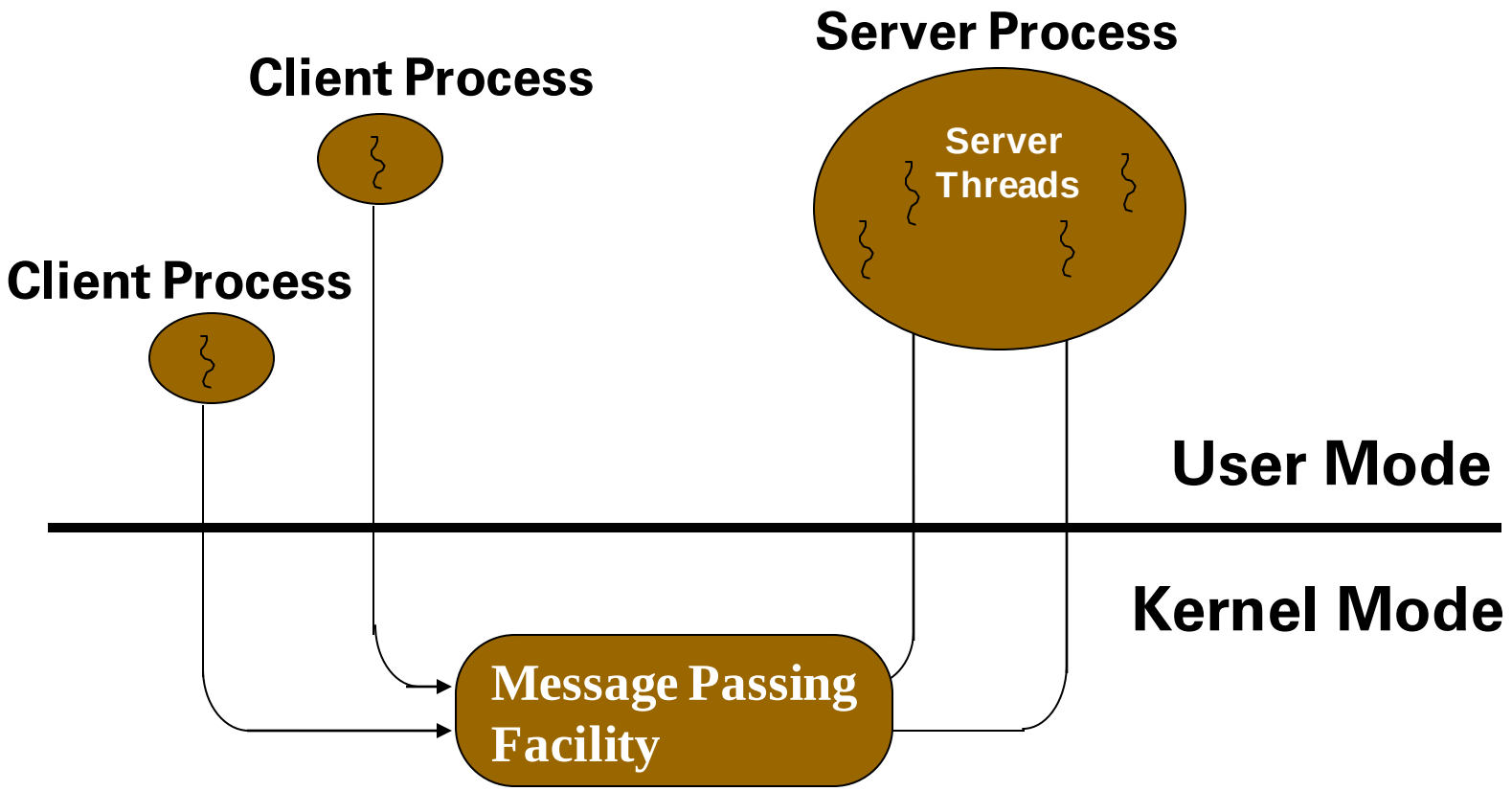


Monitor (shared object access): serializes operation on shared object

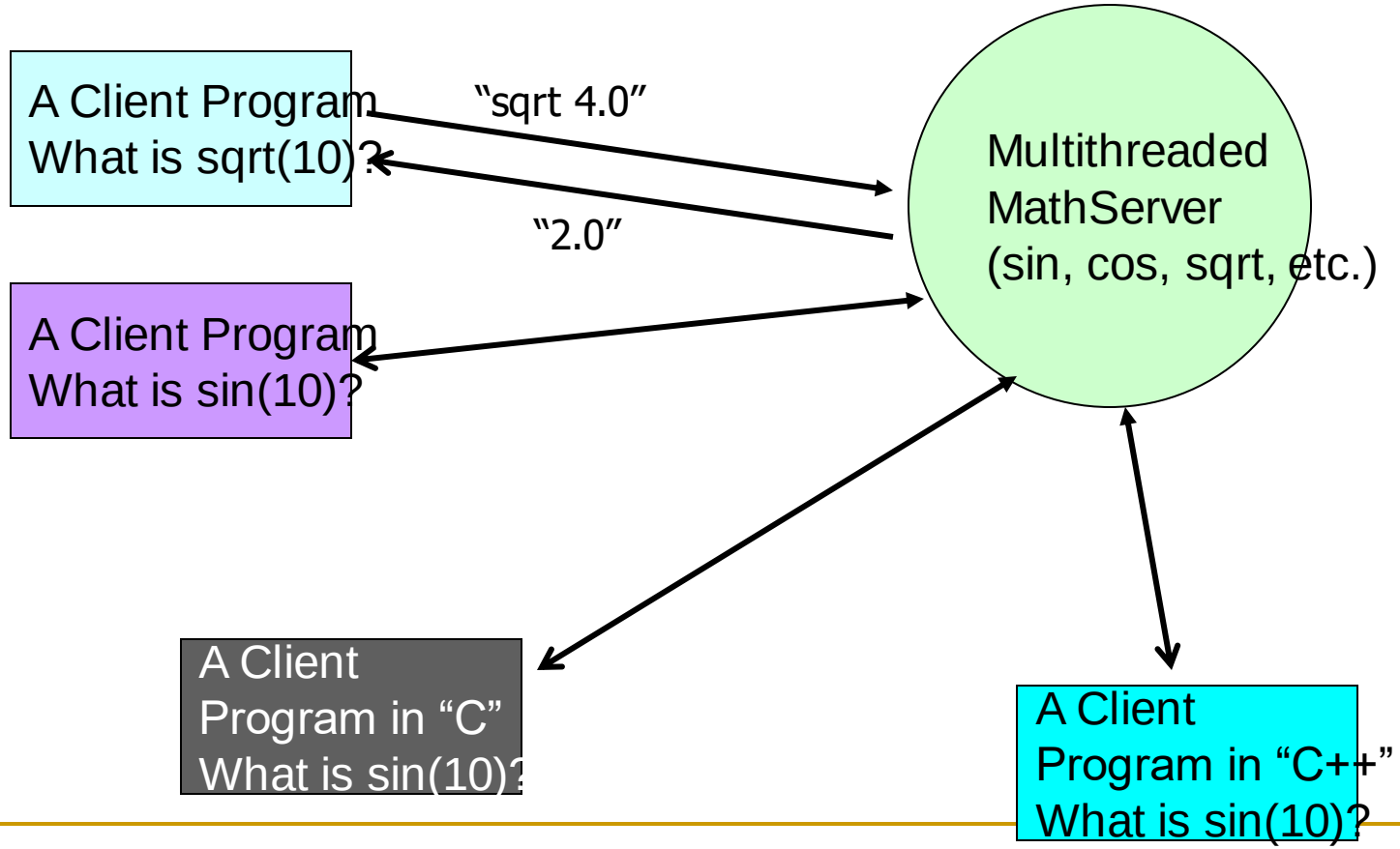
```
class Account {   // the 'monitor'
   int balance;

     // if 'synchronized' is removed, the outcome is unpredictable
      public synchronized void deposit( ) {
         // METHOD BODY : balance += deposit_amount;
       }

        public synchronized void withdraw( ) {
           // METHOD BODY: balance -= deposit_amount;
        }
        public synchronized void enquire( ) {
           // METHOD BODY: display balance.
        }
}
```

Multithreaded Server

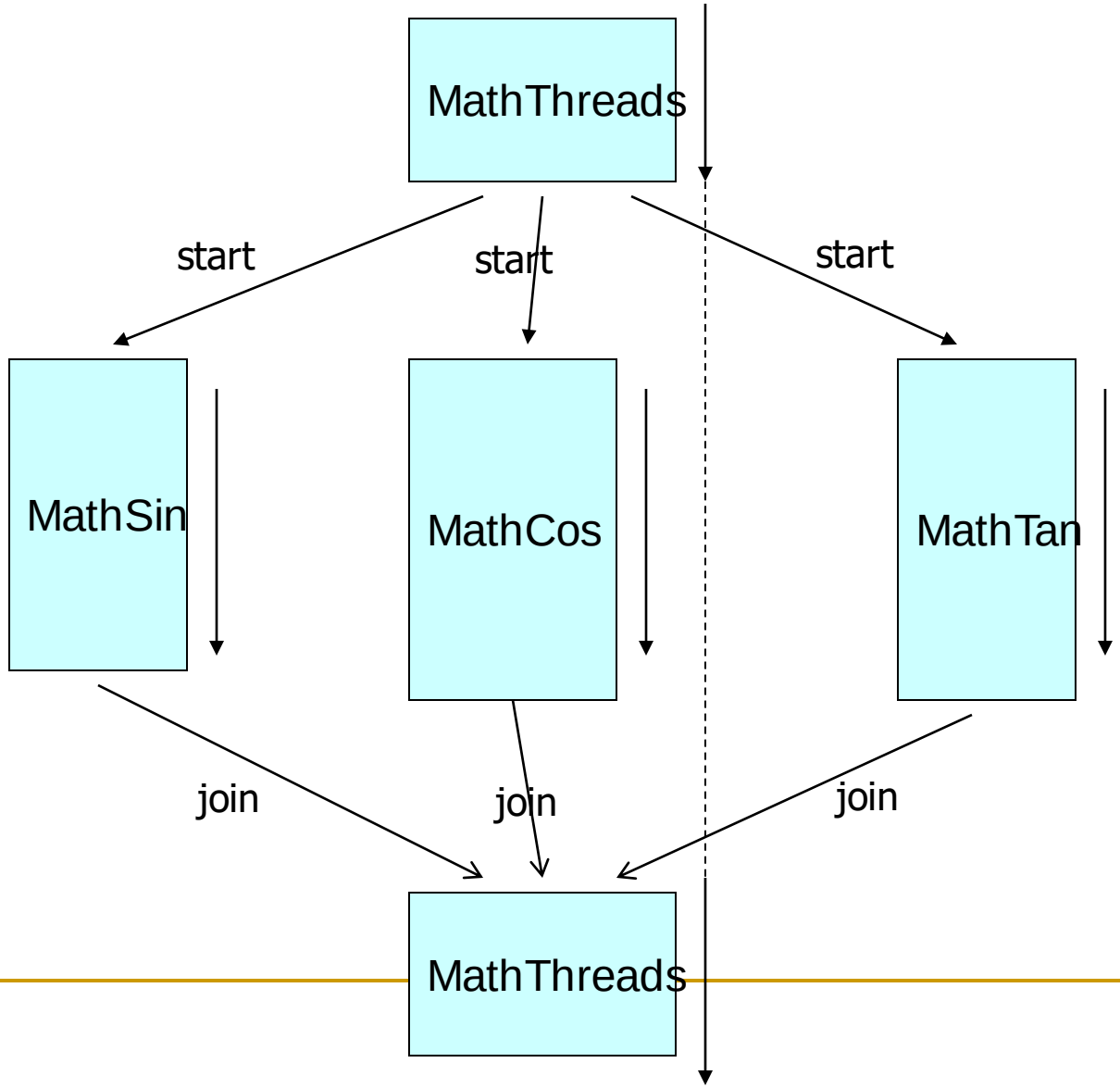
Multithreaded Server



Assignment 1: Multithreaded MathServer – Demonstrates the use of Sockets and Threads



A Multithreaded Program

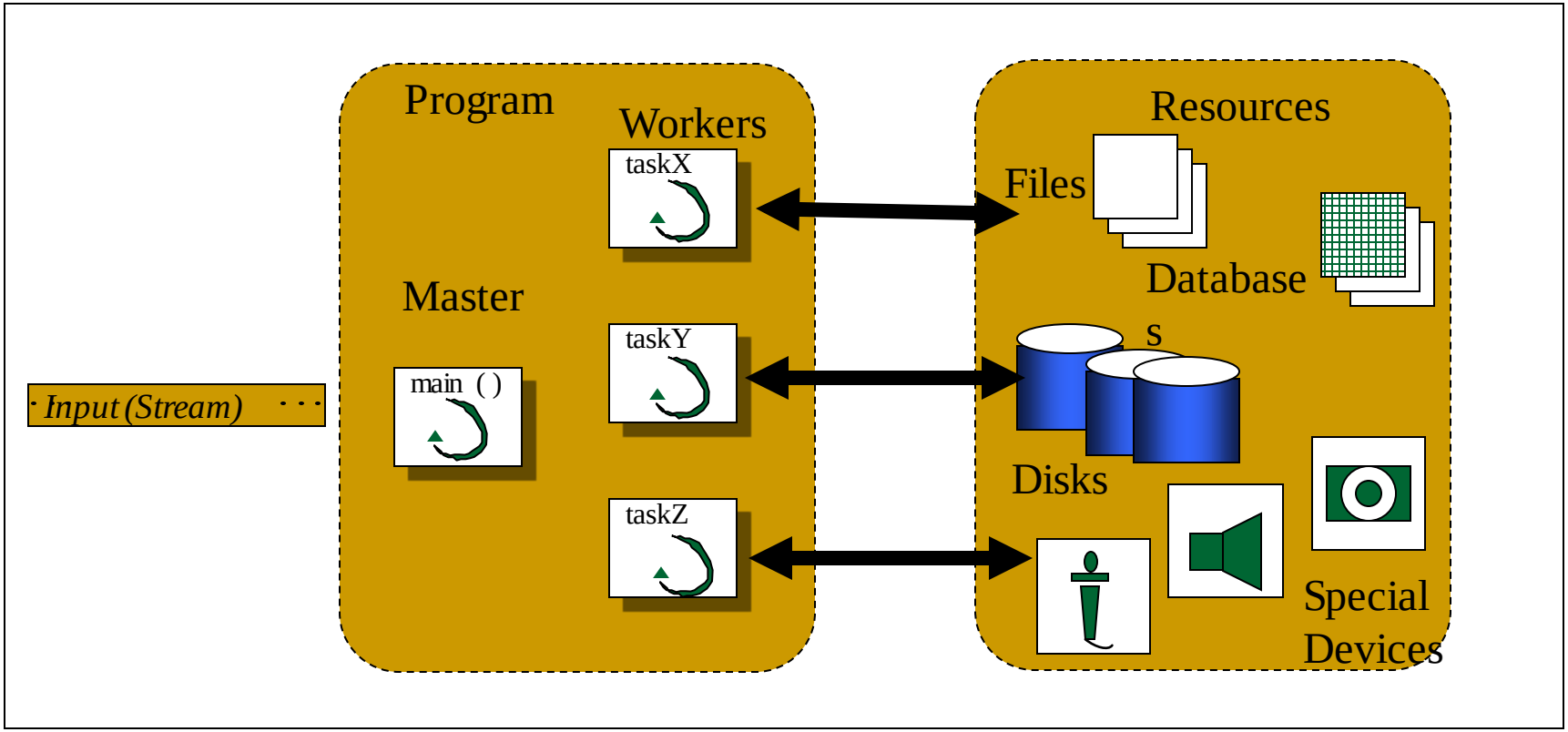


Thread concurrency/operation models

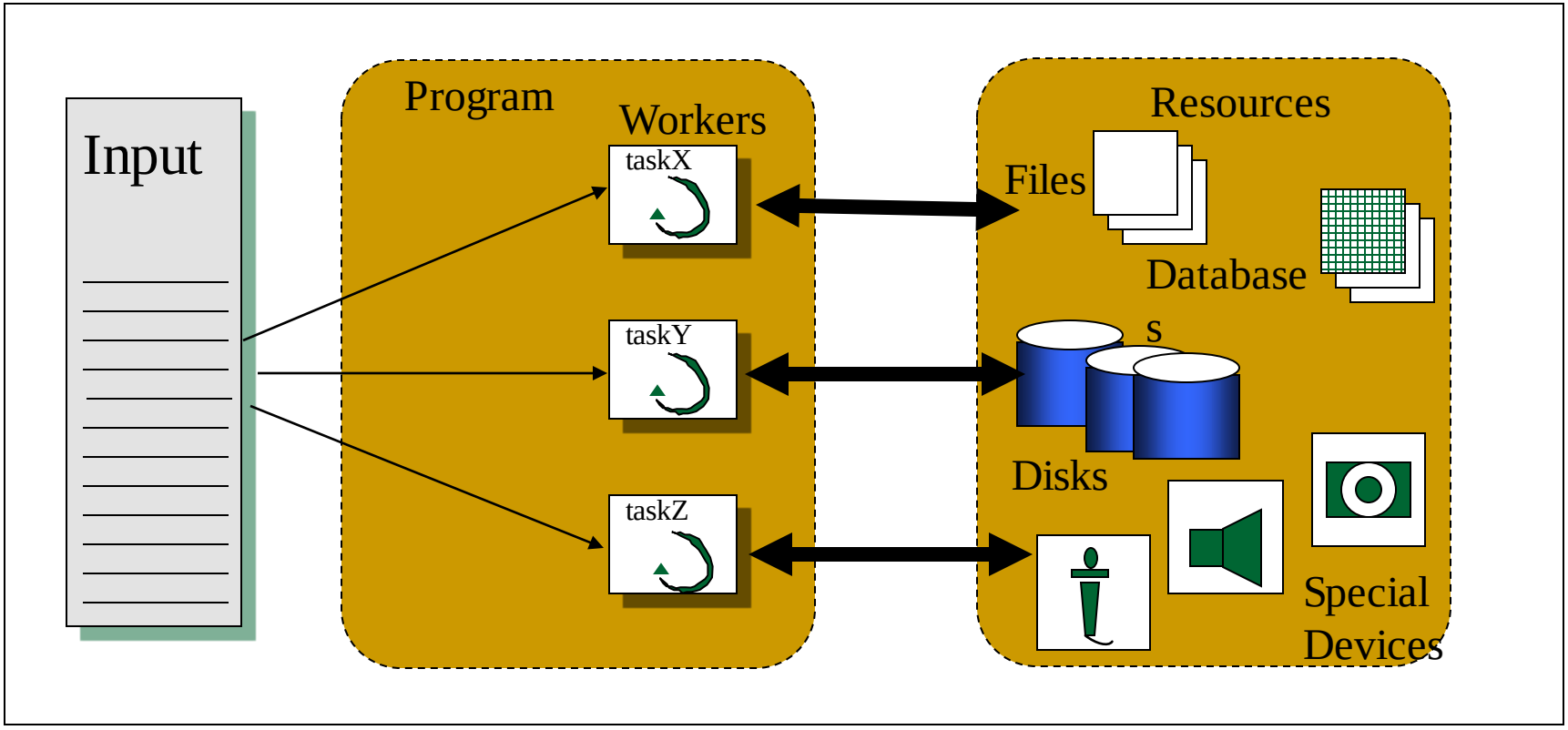
- The master/worker model
- The peer model
- A thread pipeline

Thread Programming models

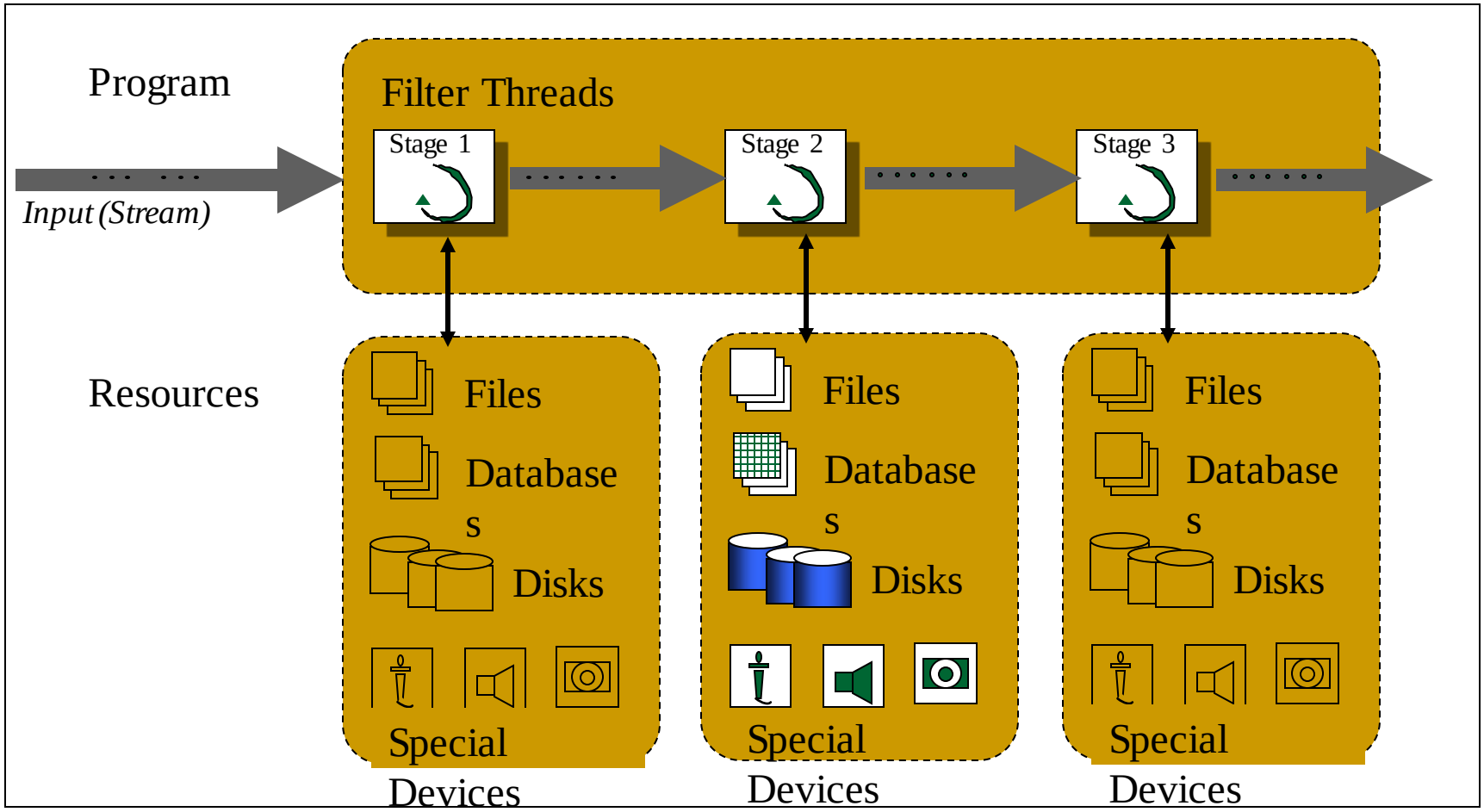
The master/worker model



The peer model



A thread pipeline

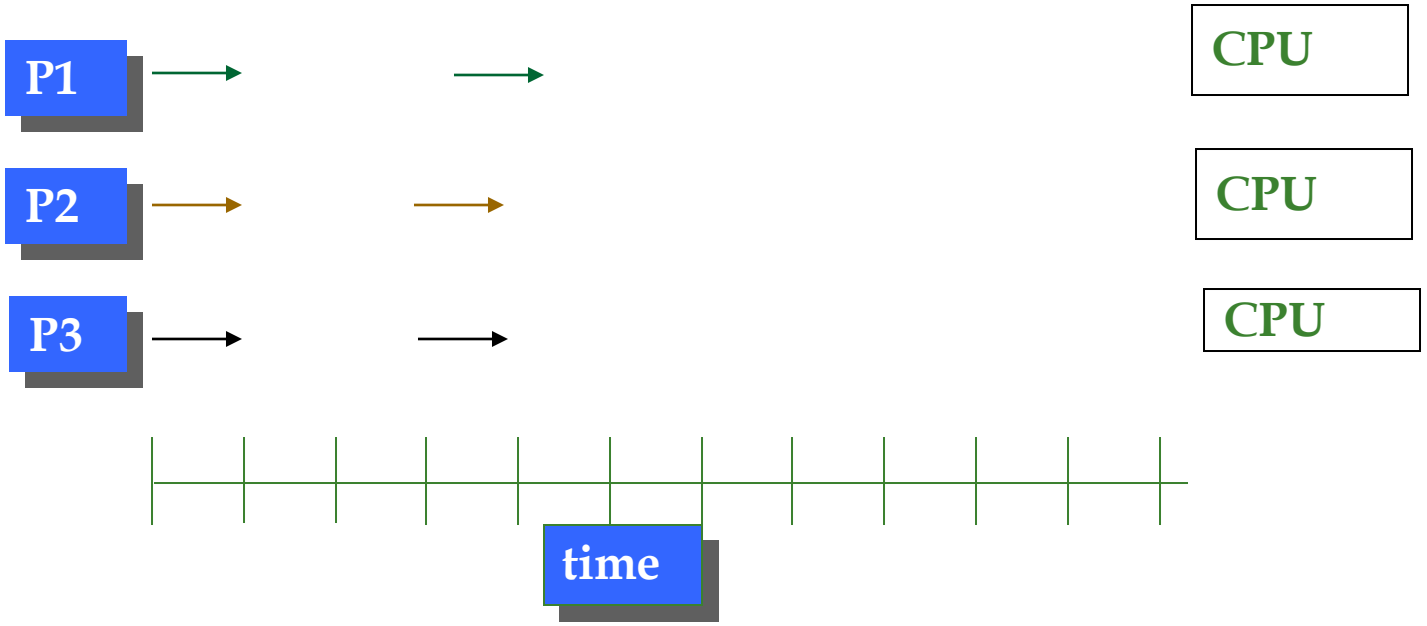


Multithreading and Multiprocessing Deployment issues

On Shared and distributed memory systems

Multithreading - Multiprocessors

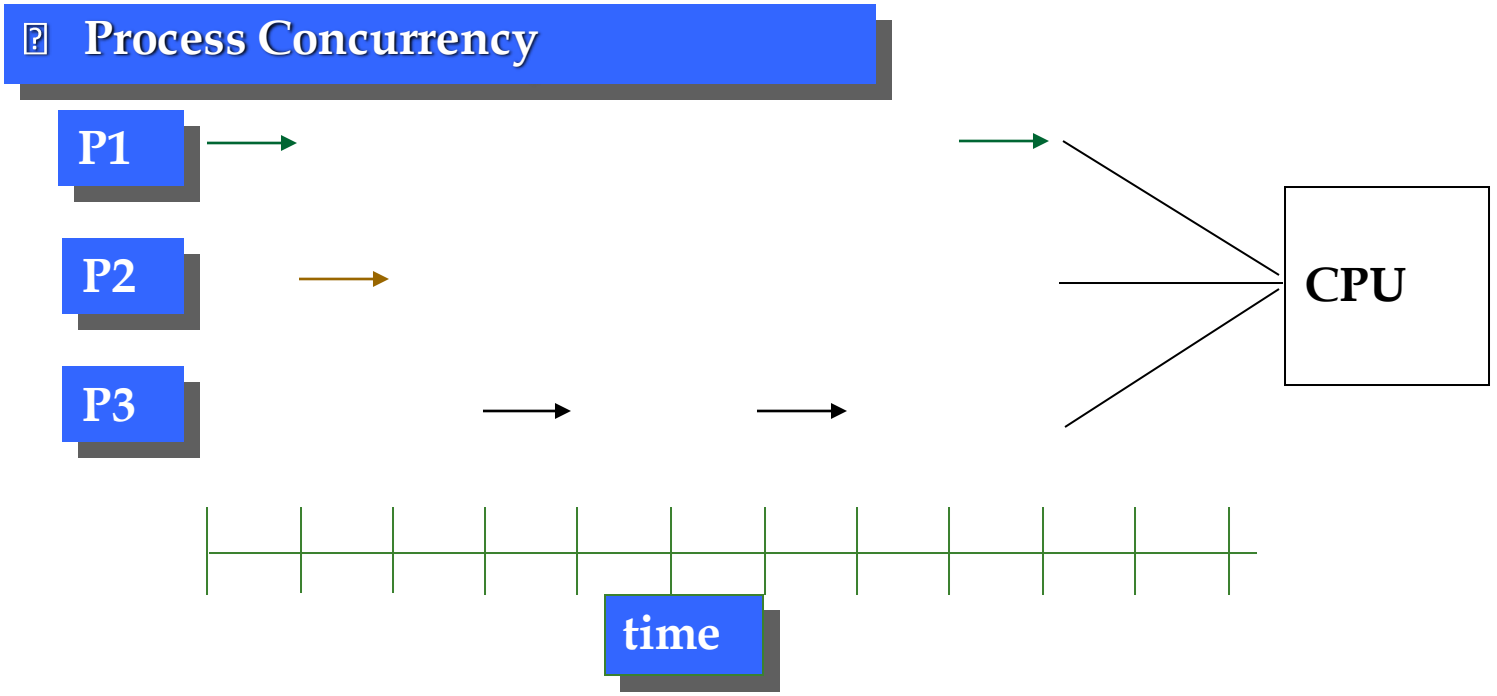
Process Parallelism



No of execution processes <= the number of CPUs

Multithreading on Uni-processor

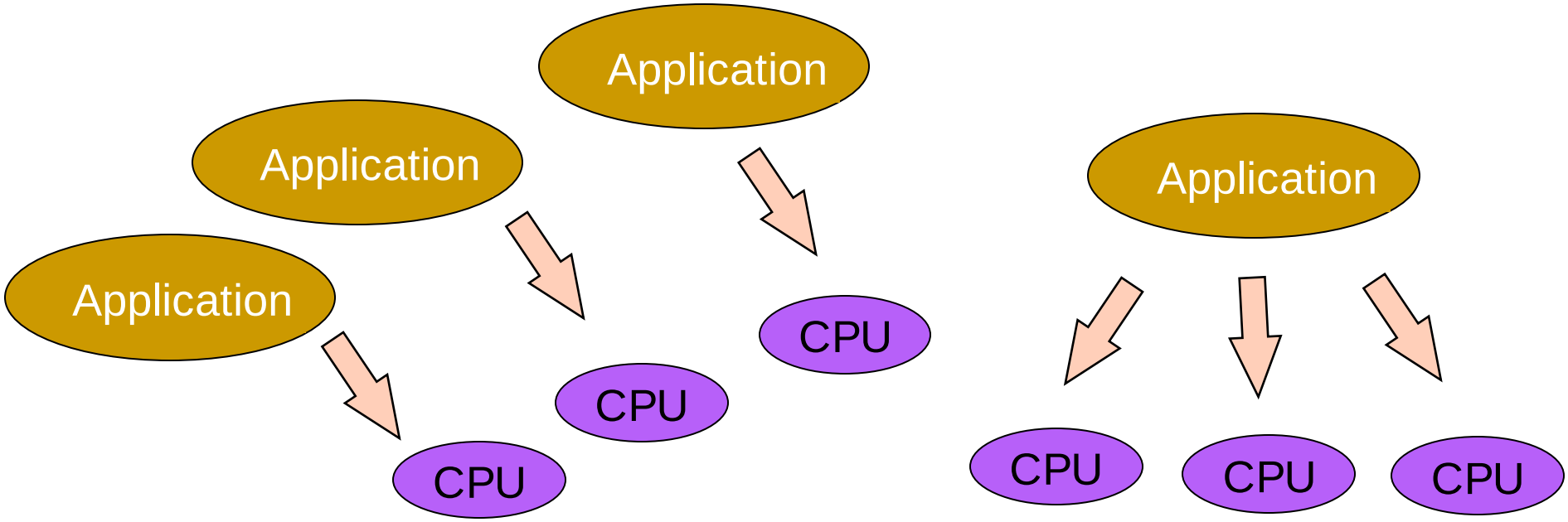
- Concurrency Vs Parallelism



Number of Simultaneous execution units > number of CPUs

Multi-Processing (clusters & grids) and Multi-Threaded Computing

Threaded Libraries, Multi-threaded I/O



Better Response Times in Multiple Application Environments

Higher Throughput for Parallelizeable Applications

References

- Rajkumar Buyya, Thamarai Selvi, Xingchen Chu, **Mastering OOP with Java**, McGraw Hill (I) Press, New Delhi, India, 2009.
- Sun Java Tutorial – Concurrency:
  - http://java.sun.com/docs/books/tutorial/essential/concurrency/