

CSMC 412

Operating Systems

Prof. Ashok K Agrawala

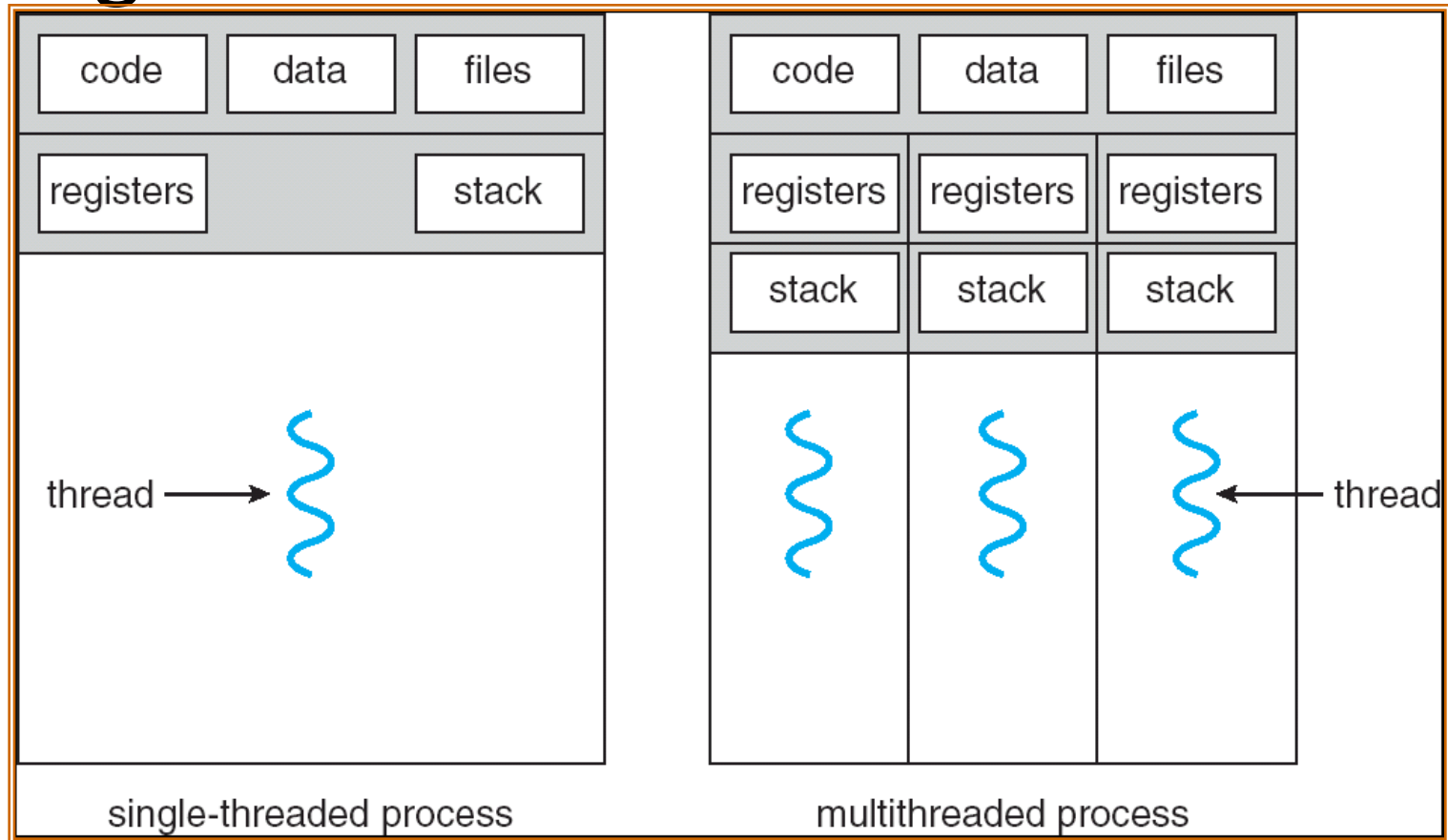
© 2005 Ashok Agrawala

Set 4

Threads

- Overview
- Multithreading Models
- Threading Issues
- Pthreads
- Windows XP Threads
- Linux Threads
- Java Threads

Single and Multithreaded Processes



Benefits

- Responsiveness
- Resource Sharing
- Economy
- Utilization of MP Architectures

User Threads

- Thread management done by user-level threads library
- Three primary thread libraries:
 - POSIX Pthreads
 - Java threads
 - Win32 threads

Kernel Threads

- Supported by the Kernel
- Examples
 - Windows XP/2000
 - Solaris
 - Linux
 - Tru64 UNIX
 - Mac OS X

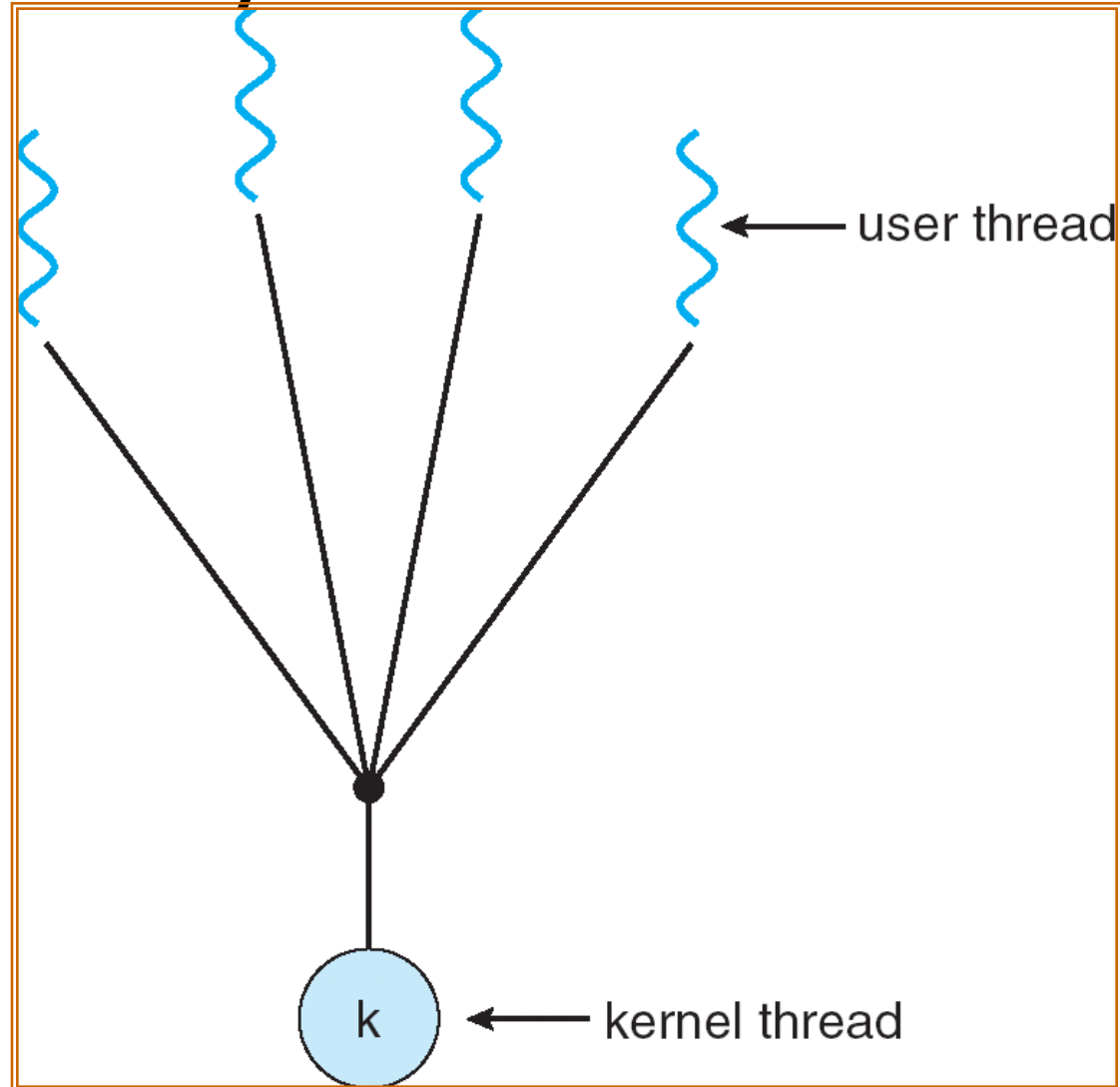
Multithreading Models

- Many-to-One
- One-to-One
- Many-to-Many

Many-to-One

- Many user-level threads mapped to single kernel thread
- Examples
 - Solaris Green Threads
 - GNU Portable Threads

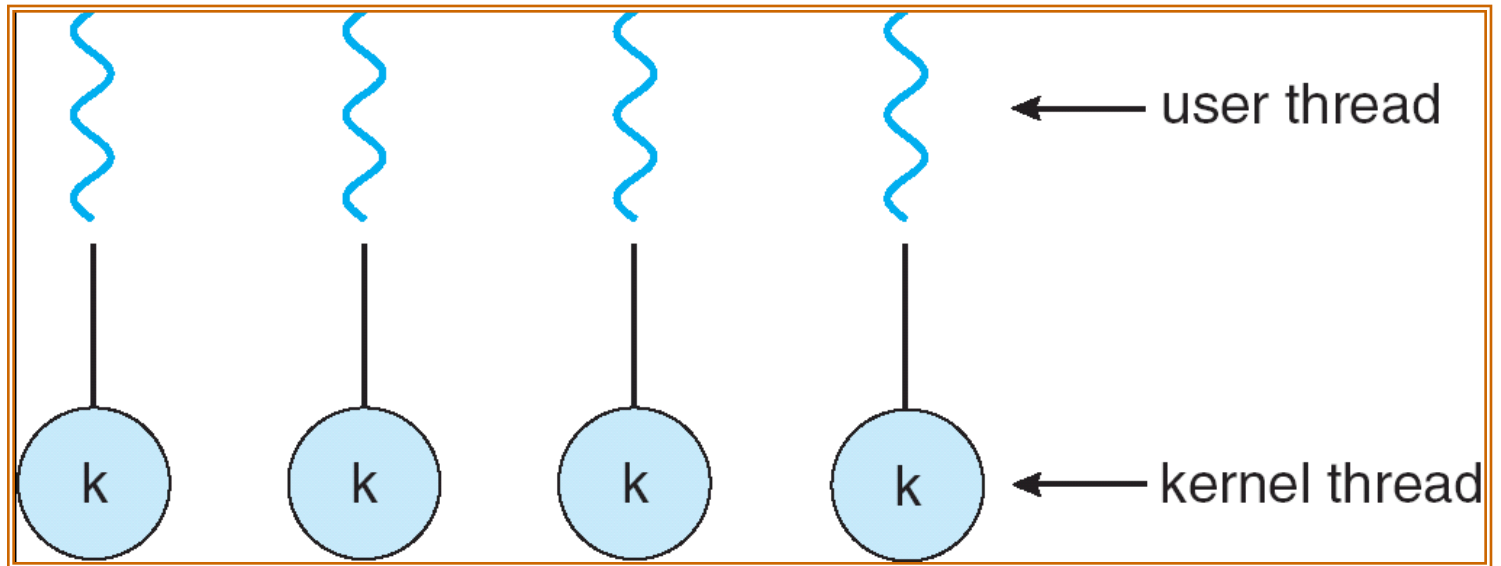
Many-to-One Model



One-to-One

- Each user-level thread maps to kernel thread
- Examples
 - Windows NT/XP/2000
 - Linux
 - Solaris 9 and later

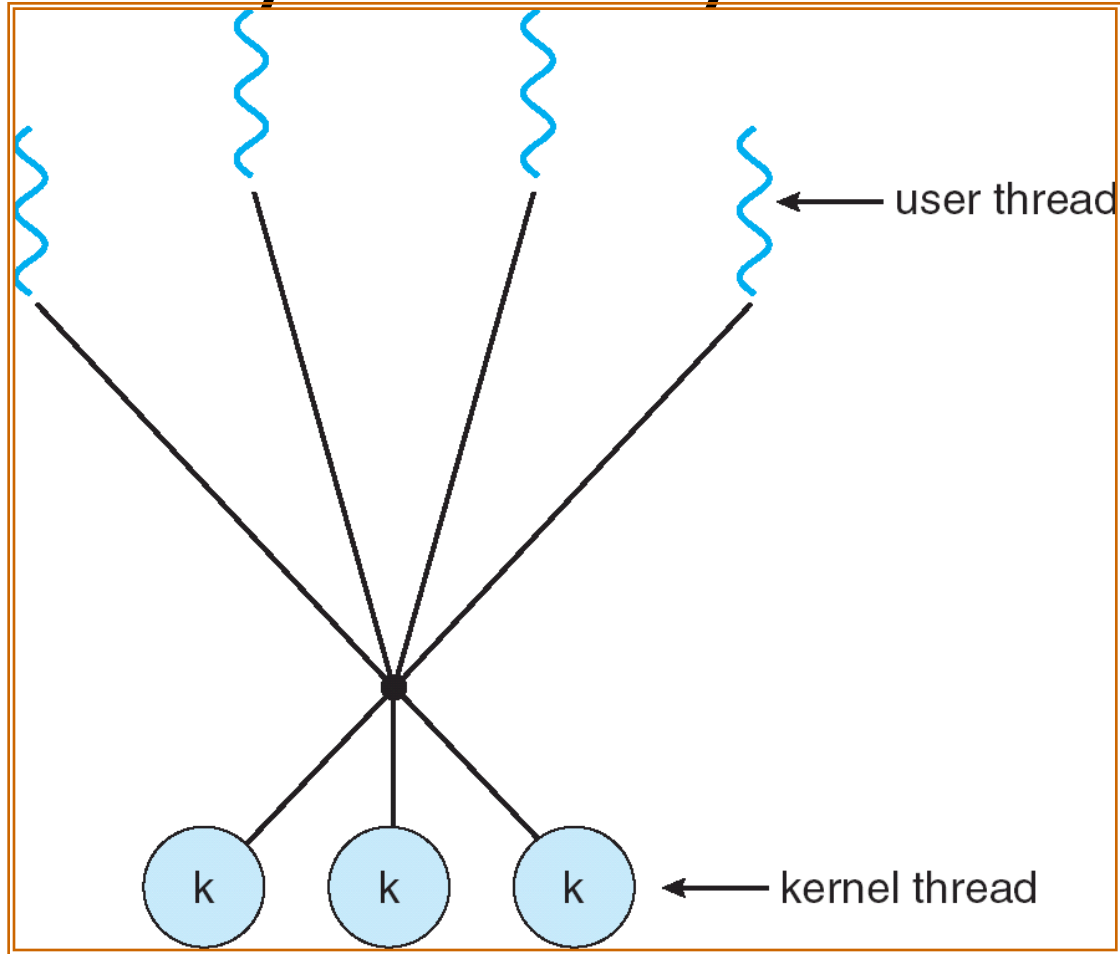
One-to-one Model



Many-to-Many Model

- Allows many user level threads to be mapped to many kernel threads
- Allows the operating system to create a sufficient number of kernel threads
- Solaris prior to version 9
- Windows NT/2000 with the *ThreadFiber* package

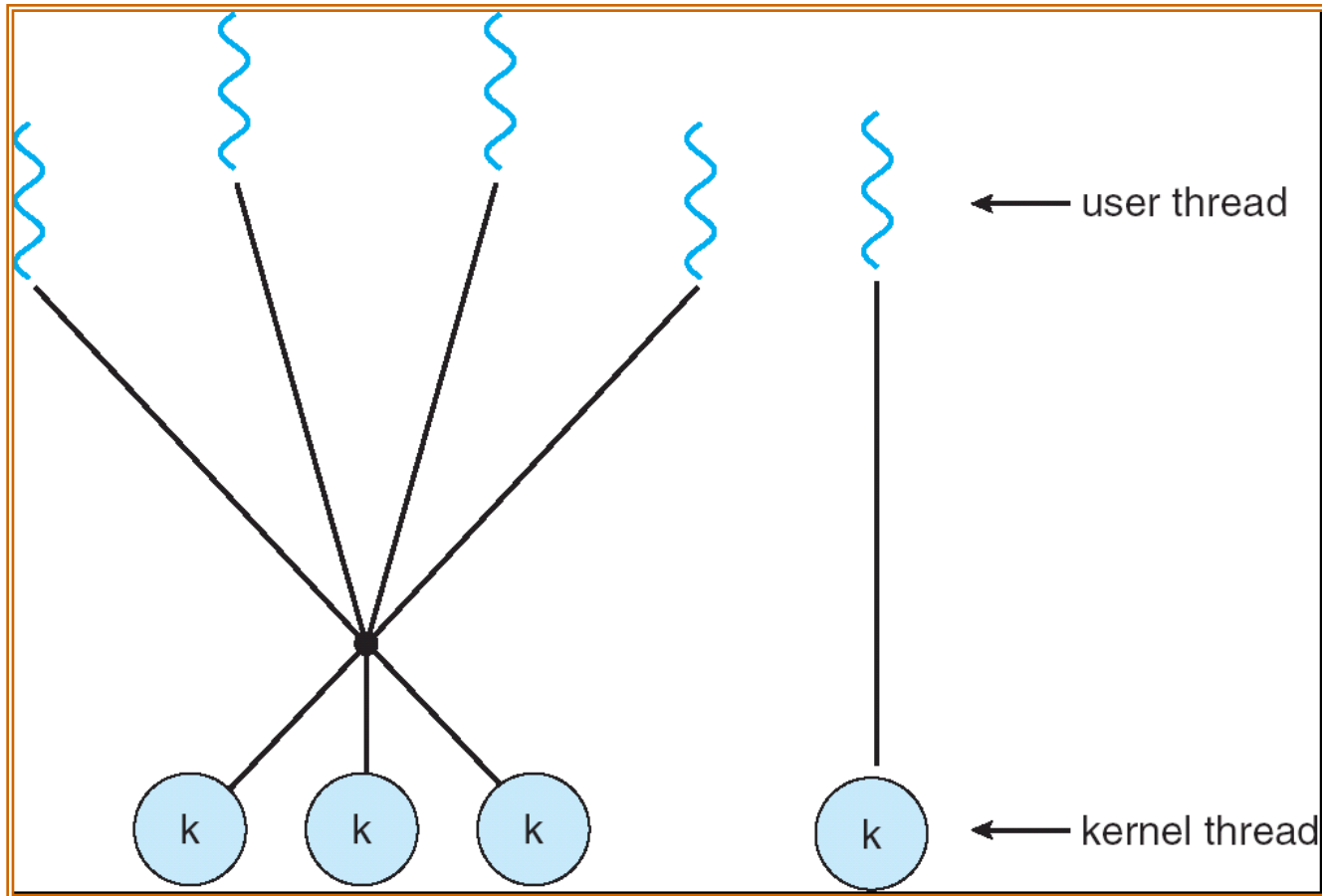
Many-to-Many Model



Two-level Model

- Similar to M:M, except that it allows a user thread to be **bound** to kernel thread
- Examples
 - IRIX
 - HP-UX
 - Tru64 UNIX
 - Solaris 8 and earlier

Two-level Model



Threading Issues

- Semantics of **fork()** and **exec()** system calls
- Thread cancellation
- Signal handling
- Thread pools
- Thread specific data
- Scheduler activations

Semantics of `fork()` and `exec()`

- Does **`fork()`** duplicate only the calling thread or all threads?

Thread Cancellation

- Terminating a thread before it has finished
- Two general approaches:
 - **Asynchronous cancellation** terminates the target thread immediately
 - **Deferred cancellation** allows the target thread to periodically check if it should be cancelled

Signal Handling

- Signals are used in UNIX systems to notify a process that a particular event has occurred
- A **signal handler** is used to process signals
 1. Signal is generated by particular event
 2. Signal is delivered to a process
 3. Signal is handled
- Options:
 - Deliver the signal to the thread to which the signal applies
 - Deliver the signal to every thread in the process
 - Deliver the signal to certain threads in the process
 - Assign a specific thread to receive all signals for the process

Thread Pools

- Create a number of threads in a pool where they await work
- Advantages:
 - Usually slightly faster to service a request with an existing thread than create a new thread
 - Allows the number of threads in the application(s) to be bound to the size of the pool

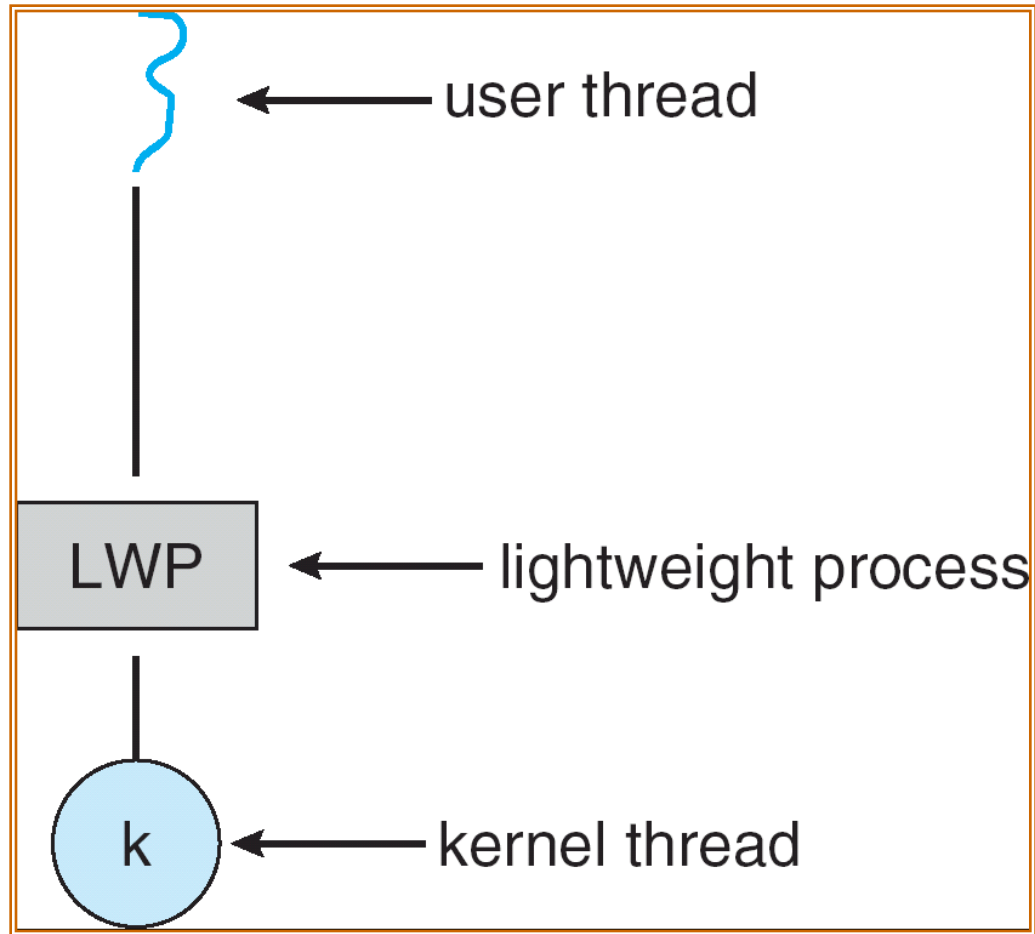
Thread Specific Data

- Allows each thread to have its own copy of data
- Useful when you do not have control over the thread creation process (i.e., when using a thread pool)

Scheduler Activations

- Both M:M and Two-level models require communication to maintain the appropriate number of kernel threads allocated to the application
- Scheduler activations provide **upcalls** - a communication mechanism from the kernel to the thread library
- This communication allows an application to maintain the correct number kernel threads

Light Weight Process



Pthreads

- A POSIX standard (IEEE 1003.1c) API for thread creation and synchronization
- API specifies behavior of the thread library, implementation is up to development of the library
- Common in UNIX operating systems (Solaris, Linux, Mac OS X)

Pthreads

```
int sum; /* this data is shared by the thread(s) */
void *runner(void *param); /* the thread */

main(int argc, char *argv[])
{
    pthread_t tid; /* the thread identifier */
    pthread_attr_t attr; /* set of attributes for the thread */
    /* get the default attributes */
    pthread_attr_init(&attr);
    /* create the thread */
    pthread_create(&tid,&attr,runner,argv[1]);
    /* now wait for the thread to exit */
    pthread_join(tid,NULL);
    printf("sum = %d\n",sum);
}

void *runner(void *param) {
    int upper = atoi(param);
    int i;
    sum = 0;
    if (upper > 0) {
        for (i = 1; i <= upper; i++)
            sum += i;
    }
    pthread_exit(0);
}
```

Java Threads

- Java threads are managed by the JVM
- Java threads may be created by:
 - Extending Thread class
 - Implementing the Runnable interface

Extending the Thread Class

```
class Worker1 extends Thread
{
    public void run() {
        System.out.println("I Am a Worker Thread");
    }
}

public class First
{
    public static void main(String args[]) {
        Worker1 runner = new Worker1();
        runner.start();

        System.out.println("I Am The Main Thread");
    }
}
```

The Runnable Interface

```
public interface Runnable  
{  
    public abstract void run();  
}
```

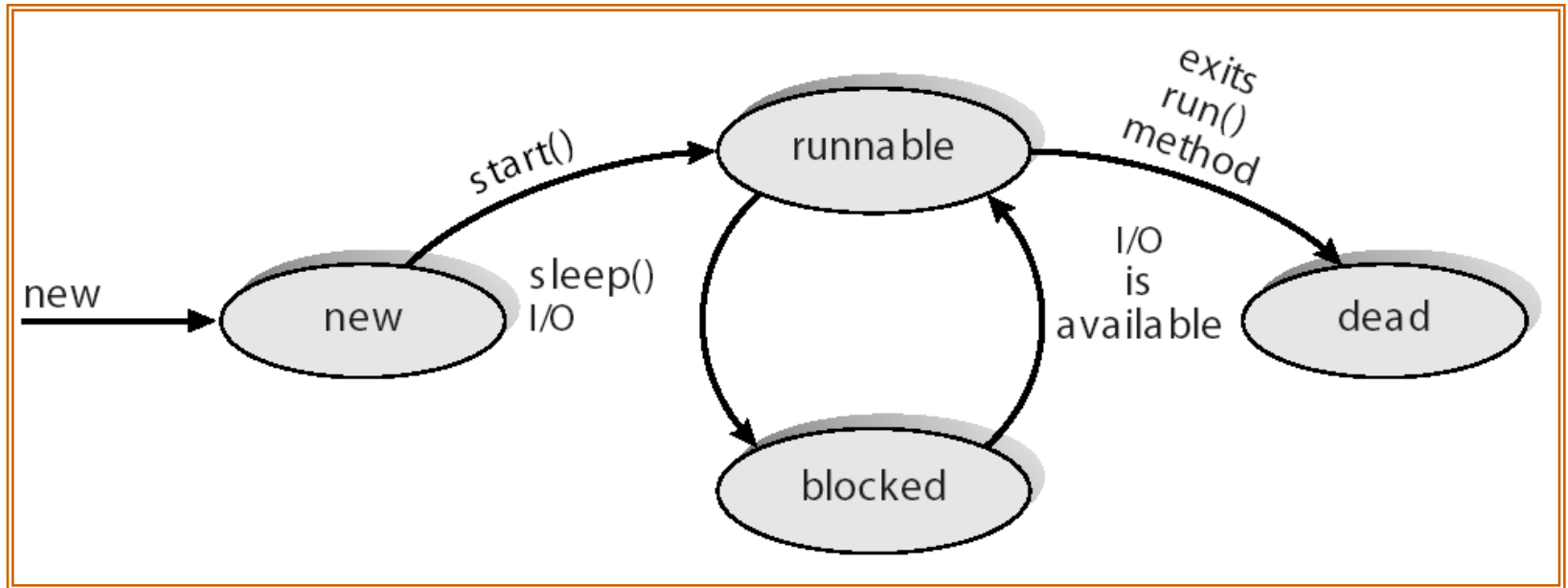
Implementing the Runnable Interface

```
class Worker2 implements Runnable
{
    public void run() {
        System.out.println("I Am a Worker Thread ");
    }
}

public class Second
{
    public static void main(String args[]) {
        Runnable runner = new Worker2();
        Thread thrd = new Thread(runner);
        thrd.start();

        System.out.println("I Am The Main Thread");
    }
}
```

Java Thread States



Joining Threads

```
class JoinableWorker implements Runnable
{
    public void run() {
        System.out.println("Worker working");
    }
}

public class JoinExample
{
    public static void main(String[] args) {
        Thread task = new Thread(new JoinableWorker());
        task.start();

        try { task.join(); }
        catch (InterruptedException ie) { }

        System.out.println("Worker done");
    }
}
```

Thread Cancellation

```
Thread thrd = new Thread (new InterruptibleThread());  
Thrd.start();
```

```
...
```

```
// now interrupt it  
Thrd.interrupt();
```

Thread Cancellation

```
public class InterruptibleThread implements Runnable
{
    public void run() {
        while (true) {
            /**
             * do some work for awhile
             */

            if (Thread.currentThread().isInterrupted()) {
                System.out.println("I'm interrupted!");
                break;
            }
        }

        // clean up and terminate
    }
}
```

Thread Specific Data

```
class Service
{
    private static ThreadLocal errorCode = new ThreadLocal();

    public static void transaction() {
        try {
            /**
             * some operation where an error may occur
             */
            catch (Exception e) {
                errorCode.set(e);
            }
        }

        /**
         * get the error code for this transaction
         */
        public static Object getErrorCode() {
            return errorCode.get();
        }
    }
}
```

Thread Specific Data

```
class Worker implements Runnable
{
    private static Service provider;

    public void run() {
        provider.transaction();
        System.out.println(provider.getErrorCode());
    }
}
```

Producer-Consumer Problem

```
public class Factory
{
    public Factory() {
        // first create the message buffer
        Channel mailBox = new MessageQueue();

        // now create the producer and consumer threads
        Thread producerThread = new Thread(new Producer(mailBox));
        Thread consumerThread = new Thread(new Consumer(mailBox));

        producerThread.start();
        consumerThread.start();
    }

    public static void main(String args[]) {
        Factory server = new Factory();
    }
}
```

Producer Thread

```
class Producer implements Runnable
{
    private Channel mbox;

    public Producer(Channel mbox) {
        this.mbox = mbox;
    }

    public void run() {
        Date message;

        while (true) {
            SleepUtilities.nap();
            message = new Date();
            System.out.println("Producer produced " + message);

            // produce an item & enter it into the buffer
            mbox.send(message);
        }
    }
}
```

Consumer Thread

```
class Consumer implements Runnable
{
    private Channel mbox;

    public Consumer(Channel mbox) {
        this.mbox = mbox;
    }

    public void run() {
        Date message;

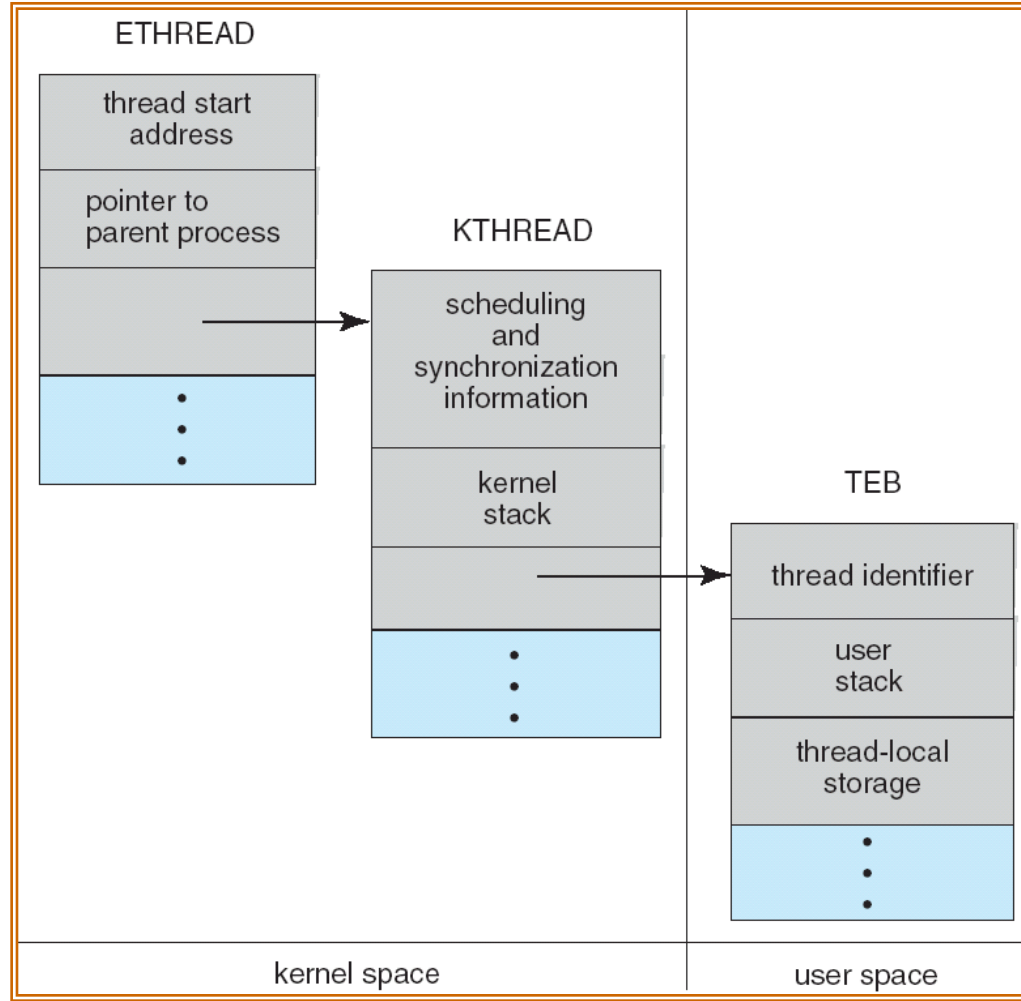
        while (true) {
            SleepUtilities.nap();
            // consume an item from the buffer
            System.out.println("Consumer wants to consume.");

            message = (Date)mbox.receive();
            if (message != null)
                System.out.println("Consumer consumed " + message);
        }
    }
}
```

Windows XP Threads

- Implements the one-to-one mapping
- Each thread contains
 - A thread id
 - Register set
 - Separate user and kernel stacks
 - Private data storage area
- The register set, stacks, and private storage area are known as the **context** of the threads
- The primary data structures of a thread include:

Windows XP Threads



Linux Threads

- Linux refers to them as *tasks* rather than *threads*
- Thread creation is done through **clone()** system call
- **clone()** allows a child task to share the address space of the parent task (process)

Flags

flag	meaning
CLONE_FS	File-system information is shared.
CLONE_VM	The same memory space is shared.
CLONE_SIGHAND	Signal handlers are shared.
CLONE_FILES	The set of open files is shared.