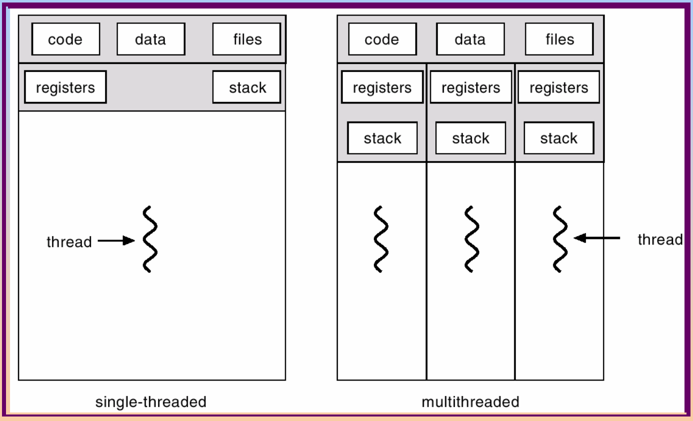
Chapter 5: Threads

Single and Multithreaded Processes

Threads are lightweight processes – have own thread ID, PC, registers, stack



Benefits

- Responsiveness
  - Can run even if one thread blocked or busy
  - Web browser example – one thread per client
- Resource Sharing
- Economy
  - Creating and context switching threads is low cost
  - Solaris 2 : creating 30x, context switch 5x slower for procs
- Utilization of MP Architectures
  - Run each thread on different CPU

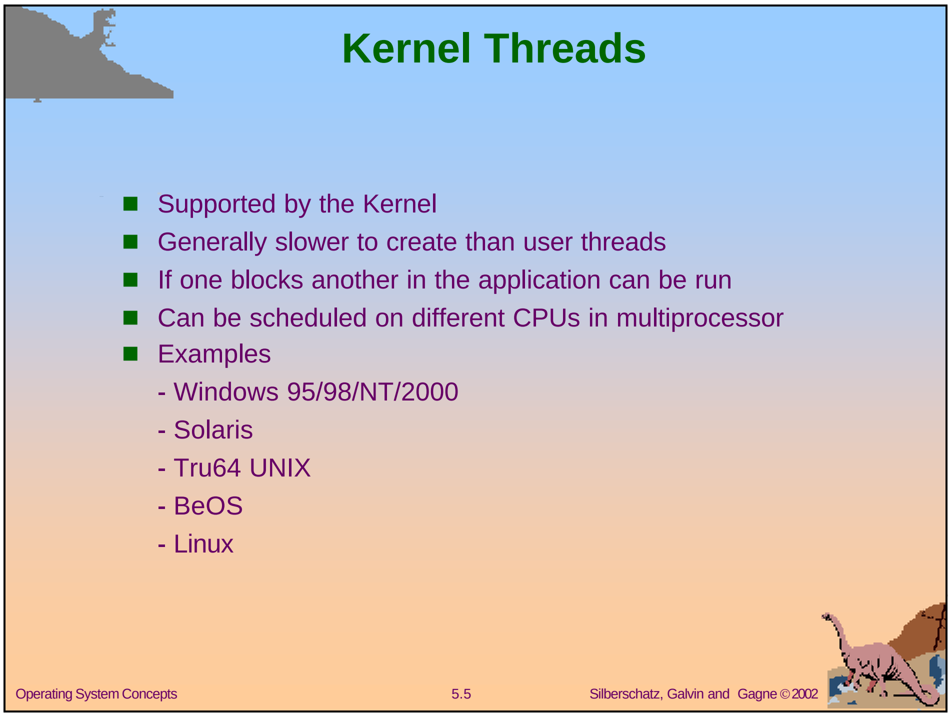
User Threads

- Thread management done by user-level threads library
- No need for kernel intervention
- Drawback : all may run in single process. If one blocks, all block.
- Examples

  - POSIX *Pthreads*

  - Mach *C-threads*

  - Solaris *threads*



Kernel Threads

- Supported by the Kernel
- Generally slower to create than user threads
- If one blocks another in the application can be run
- Can be scheduled on different CPUs in multiprocessor
- Examples

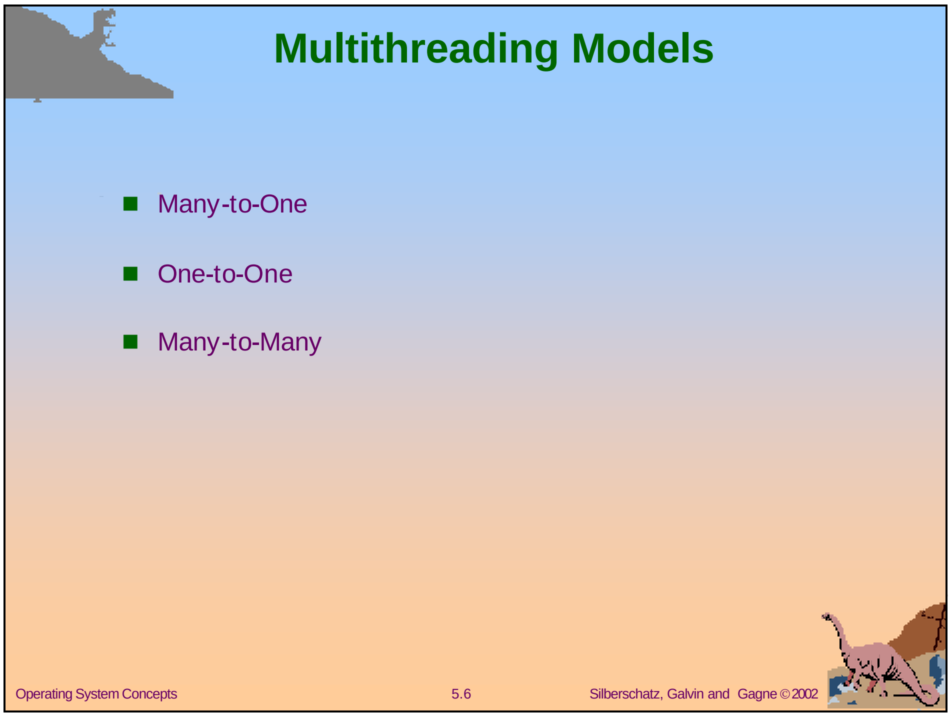
  - Windows 95/98/NT/2000

  - Solaris

  - Tru64 UNIX

  - BeOS

  - Linux



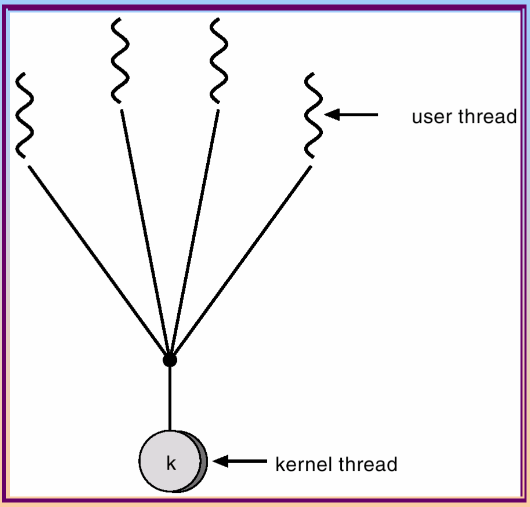
Multithreading Models

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

Many-to-One

- Many user-level threads mapped to single kernel thread.
- Used on systems that do not support kernel threads.

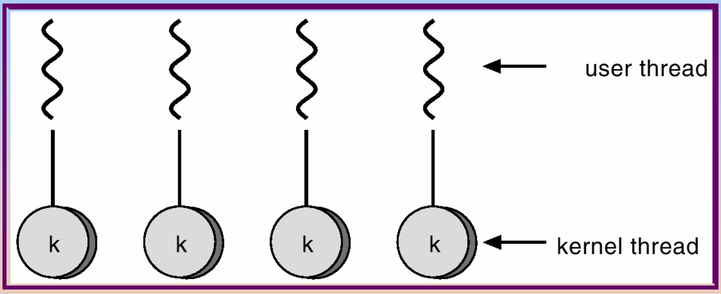
Many-to-One Model



One-to-One

- Each user-level thread maps to kernel thread.
- Examples
  - Windows 95/98/NT/2000
  - OS/2

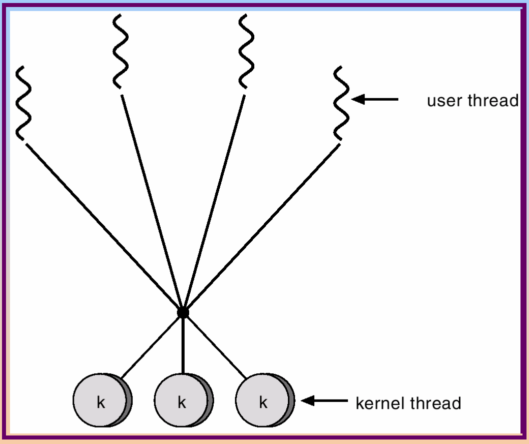
One-to-one Model

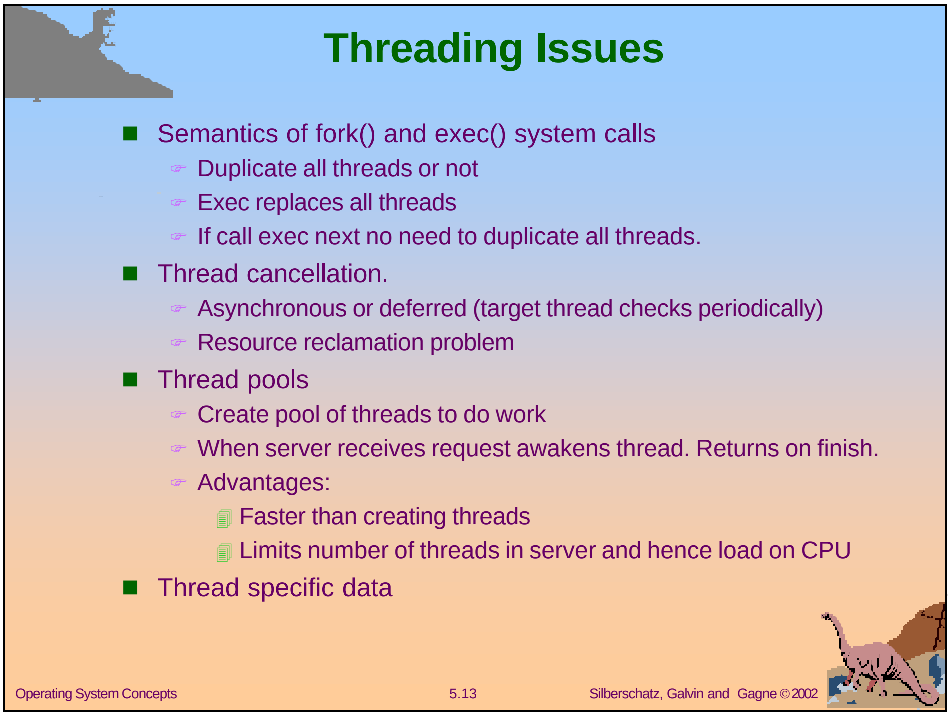


Many-to-Many Model

- 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 2
- IRIX
- HP-UX
- Tru64 Unix
- Windows NT/2000 with the *ThreadFiber* package

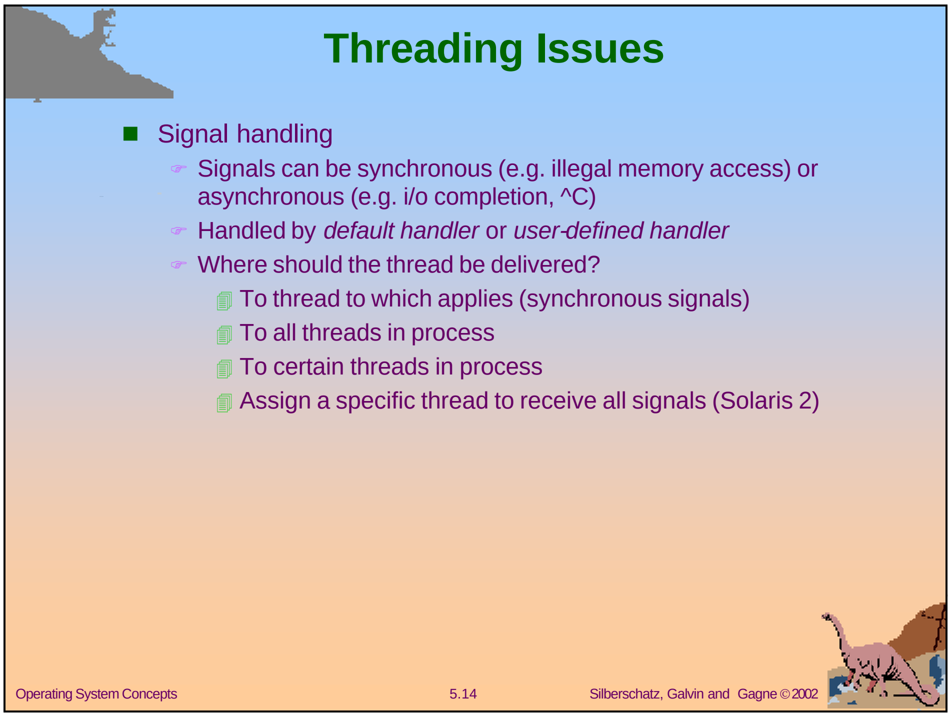
Many-to-Many Model





Threading Issues

- Semantics of fork() and exec() system calls
  - Duplicate all threads or not
  - Exec replaces all threads
  - If call exec next no need to duplicate all threads.
- Thread cancellation.
  - Asynchronous or deferred (target thread checks periodically)
  - Resource reclamation problem
- Thread pools
  - Create pool of threads to do work
  - When server receives request awakens thread. Returns on finish.
  - Advantages:
    - Faster than creating threads
    - Limits number of threads in server and hence load on CPU
- Thread specific data



Threading Issues

- Signal handling
  - Signals can be synchronous (e.g. illegal memory access) or asynchronous (e.g. i/o completion, ^C)
  - Handled by *default handler* or *user-defined handler*
  - Where should the thread be delivered?
    - To thread to which applies (synchronous signals)
    - To all threads in process
    - To certain threads in process
    - Assign a specific thread to receive all signals (Solaris 2)

Pthreads

- a POSIX standard (IEEE 1003.1c) API for thread creation and synchronization.
- API specifies behavior of the thread library, implementation is up to developer of the library.
- Common in UNIX operating systems.

Pthreads example

```
#include <pthread.h>
#include <stdio.h>
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 */
if (argc != 2) {
          fprintf(stderr,"usage: a.out <integer value>\n");
          exit();
}
if (atoi(argv[1]) < 0) {
          fprintf(stderr,"Argument %d must be non-negative\n",atoi(argv[1]));
          exit();
}
pthread_attr_init(&attr);                        /* get the default attributes */
pthread_create(&tid,&attr,runner,argv[1]);        /* create the thread */
pthread_join(tid,NULL);                /* now wait for the thread to exit */
printf("sum = %d\n",sum);
}
```

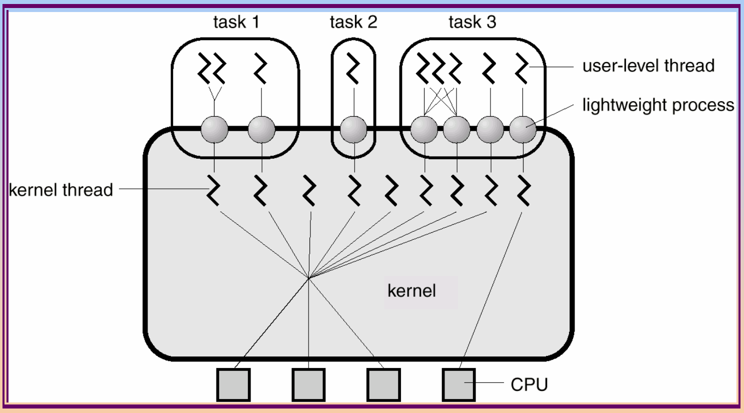
Pthreads example (ctd.)

```
/**
 * The thread will begin control in this function
 */
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);
}
```

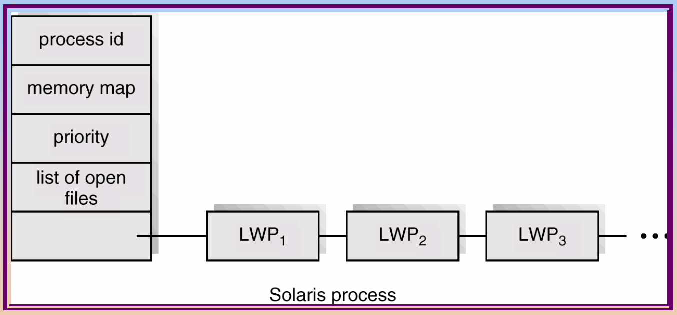
Solaris 2 Threads

- User and Kernel level threads, Light weight processes (LWP)
- Process : one or more LWPs
- Each LWP has kernel thread
- One LWP is needed for each user thread that may block
- If kernel thread blocks, LWP, and user level thread also block
- If all LWPs in process block, but there are user level threads which could run, kernel creates new LWP
- Kernel “ages” LWPs and deletes unused ones after +-5 min
- Kernel threads may be *bound* to particular CPU

Solaris 2 Threads



Solaris Process



Windows 2000 Threads

- Implements the one-to-one mapping.
- Each thread contains
  - a thread id
  - register set
  - separate user and kernel stacks
  - private data storage area

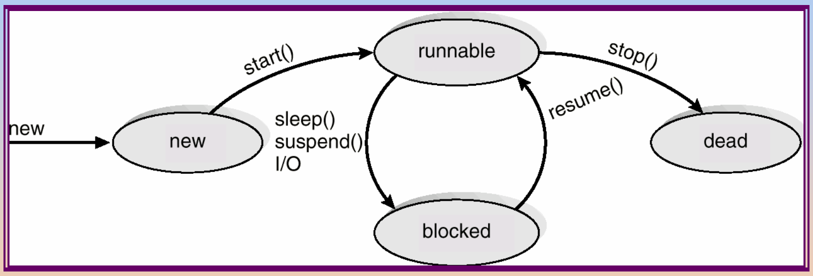
Linux Threads

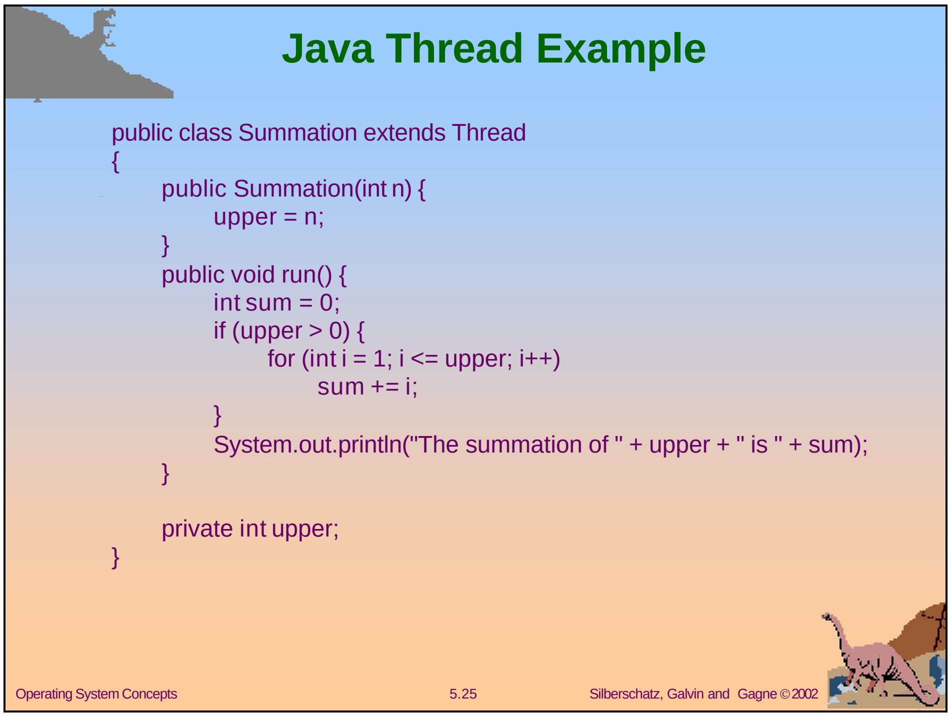
- Linux refers to them as *tasks* rather than *threads*.
- Thread creation is done through clone() system call.
- Clone() allows a child task to share the address space of the parent task (process)
- The amount of parent process shared is determined by a set of flags passed as parameter in clone() call
  - None set, no sharing clone() is fork()
  - All set, everything shared

Java Threads

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

Java Thread States

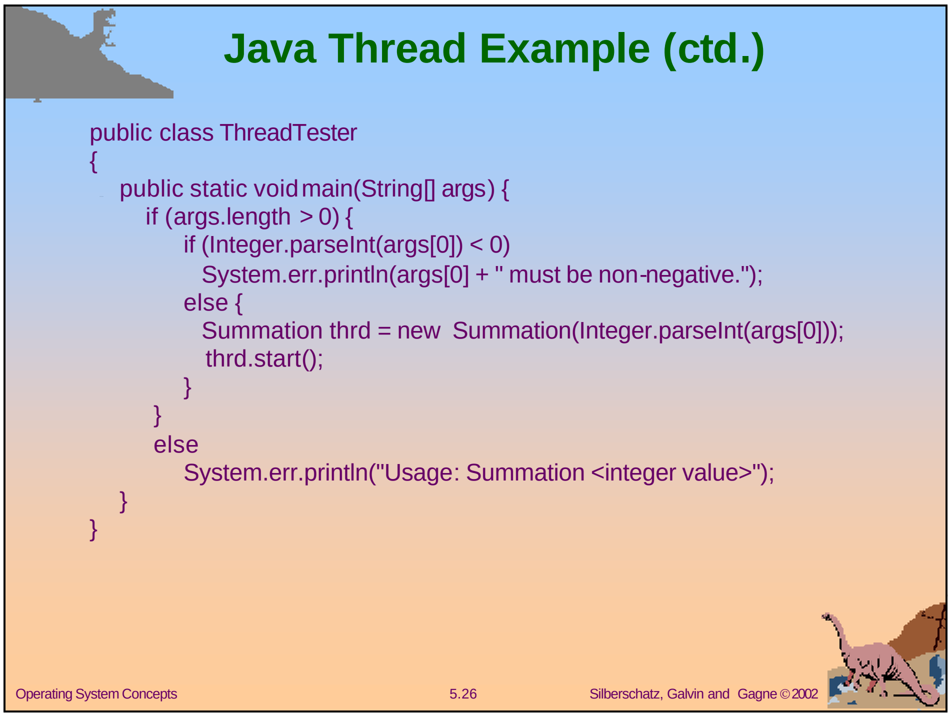




Java Thread Example

```
public class Summation extends Thread
{
        public Summation(int n) {
                upper = n;
        }
        public void run() {
                int sum = 0;
                if (upper > 0) {
                        for (int i = 1; i <= upper; i++)
                                sum += i;
                }
                System.out.println("The summation of " + upper + " is " + sum);
        }

        private int upper;
}
```



Java Thread Example (ctd.)

```
public class ThreadTester
{
    public static void main(String[] args) {
        if (args.length > 0) {
            if (Integer.parseInt(args[0]) < 0)
              System.err.println(args[0] + " must be non-negative.");
            else {
              Summation thrd = new  Summation(Integer.parseInt(args[0]));
              thrd.start();
            }
        }
        else
            System.err.println("Usage: Summation <integer value>");
    }
}
```