# Benefits of threads

- Responsiveness - Interactive applications can be performing two tasks at the same time (rendering, spell checking)

- Resource Sharing - Sharing resources between threads is easy (too easy?)

- Economy - Resource allocation between threads is fast (no protection issues)

- Utilization of MP Architectures - seamlessly assign multiple threads to multiple processors (if available). Future appears to be multi-core anyway.

# Thread types

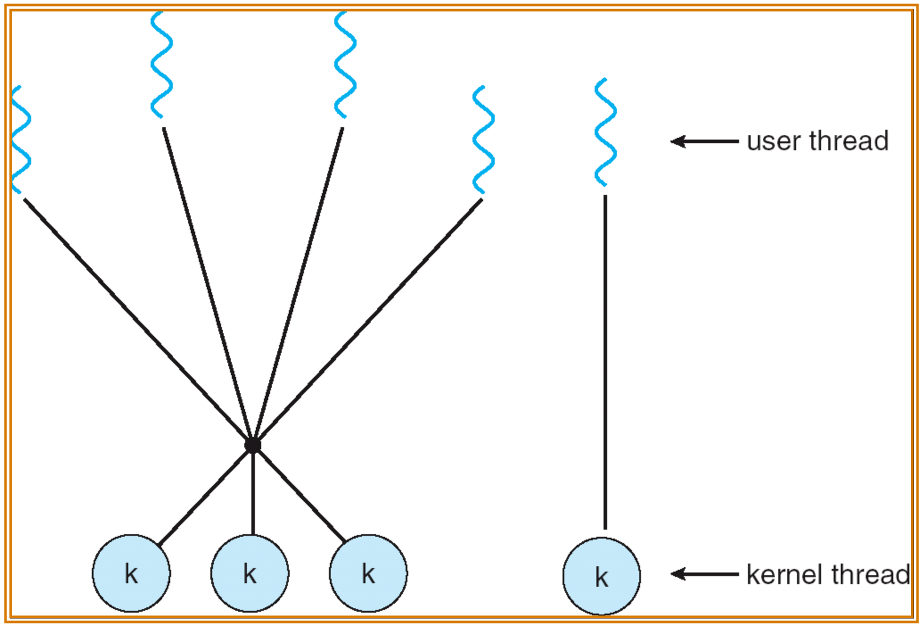
- User threads: thread management done by user-level threads library. Kernel does not know about these threads
  - Three primary thread libraries:
    - POSIX Pthreads
    - Win32 threads
    - Java threads
- Kernel threads: Supported by the Kernel and so more overhead than user threads
  - Examples: Windows XP/2000, Solaris, Linux, Mac OS X
- User threads map into kernel threads

# Multithreading Models

- Many-to-One: Many user-level threads mapped to single kernel thread
  - If a thread blocks inside kernel, all the other threads cannot run
  - Examples: Solaris Green Threads, GNU Pthreads
- One-to-One: Each user-level thread maps to kernel thread
- Many-to-Many: Allows many user level threads to be mapped to many kernel threads
  - Allows the  operating system to create a sufficient number of kernel threads

# 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



# Pthreads library

- Discuss the sample pthread program

# 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
  - Signal is generated by particular event
  - Signal is delivered to a process
  - 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 threa 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

# 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)

# 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:
  - ETHREAD (executive thread block)
  - KTHREAD (kernel thread block)
  - TEB (thread environment block)

# Linux Threads

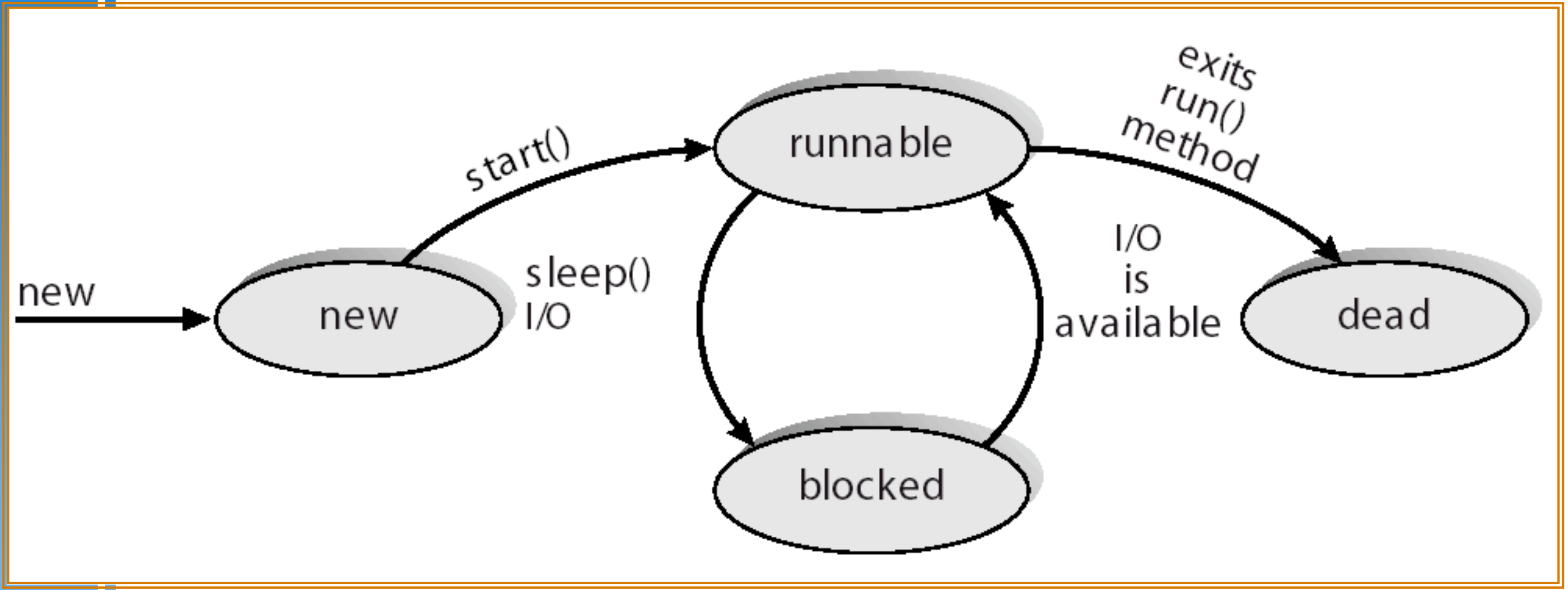
- Linux refers to them as tasks rather than threads
- Thread creation is done through clone() system call
- clone() allows a child task to share the address space of the parent task (process)

# Java Threads

- Java threads are managed by the JVM

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

# Java Thread States


new
new
start()
runnable
sleep()
I/O
blocked
I/O
is
available
exits
run()
method
dead