北京邮电大学软件学院

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Operating Systems

Lecture 3 Threads

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Catalog Description

- Overview
- Multithreading Models
- Threading Issues

Why Threads?

- 自从60年代提出进程概念以来，在操作系统中一直都是以进程作为独立运行的基本单位，直到80年代中期，人们又提出了更小的能独立运行的基本单位—线程。

Why Threads?

- [案例]编写一个MP3播放软件，核心功能模块有三个：
  - 从MP3音频文件中读取数据；
  - 对数据进行解压缩；
  - 把解压缩后的音频数据播放出来。

Why Threads?

- 单进程的实现方法：

```
Main()
{
While(true)
{read();
decompress();
Play();
}
}
read(){...};
decompress(){...};
Play(){...};
```

I/O

CPU

问题：

- ✓ 播放出来的声音是否连贯？
- ✓ 各个函数之间不是并发执行，影响资源的使用效率？

Youtube的状态栏

Why Threads?

- 多进程的实现方法：

```
程序1
Main()
{
While(true)
{read();
}
}
read(){…};
```

```
程序2
Main()
{
While(true)
{decompress();
}
}
decompress(){…};
```

```
程序3
Main()
{
While(true)
{Play();
}
}
Play(){…};
```

Why Threads?

- 怎么解决这些问题：

需要提出一种新的实体，满足以下特性：
实体之间可以并发地执行；
实体之间共享相同的地址空间；

这种实体就是：线程（Thread）

Thread concept overview

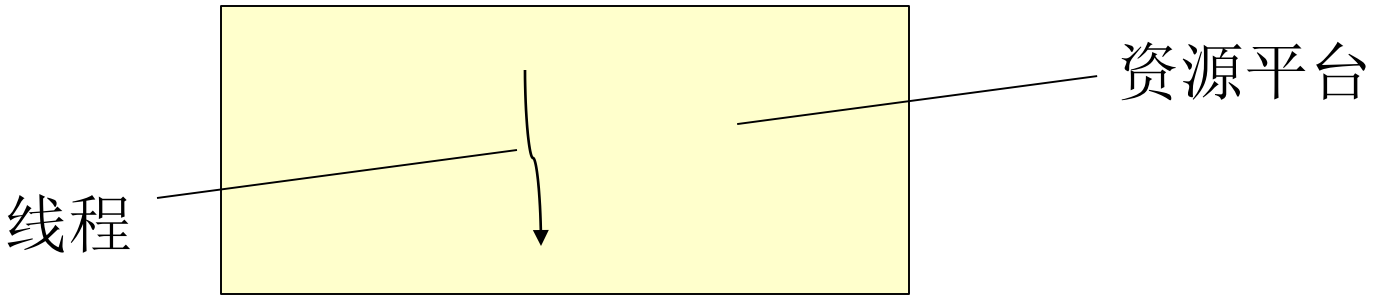
- What is the thread?
  - Thread:
    - ✓ A sequential execution stream within a process
    - ✓ a thread of execution
    - ✓ 进程当中的一条执行流程

Thread concept overview

- A thread is a basic unit of CPU utilization;
  - it comprises a thread ID, a program counter, a register set, and a stack.
  - it shares with other threads belonging to the same process, the code section, the data section, and other OS resources, such as open files, signals, etc
- A traditional process has a single thread of control: heavyweight process.

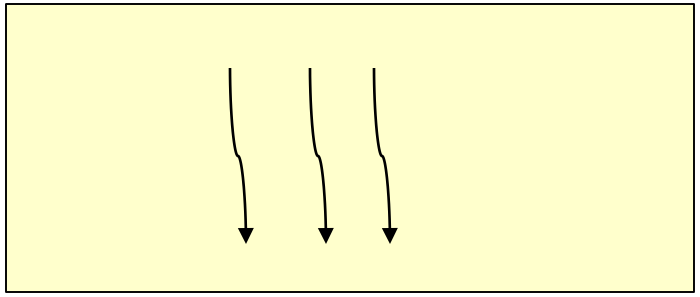
Thread concept overview

- 从两个方面来理解进程
  - 从资源组合的角度：进程把一组相关的资源组合起来，构成一个资源平台（环境），包括地址空间（代码段、数据段）、打开的文件等各种资源
  - 从运行的角度：代码在这个平台上的一条执行流程（线程）



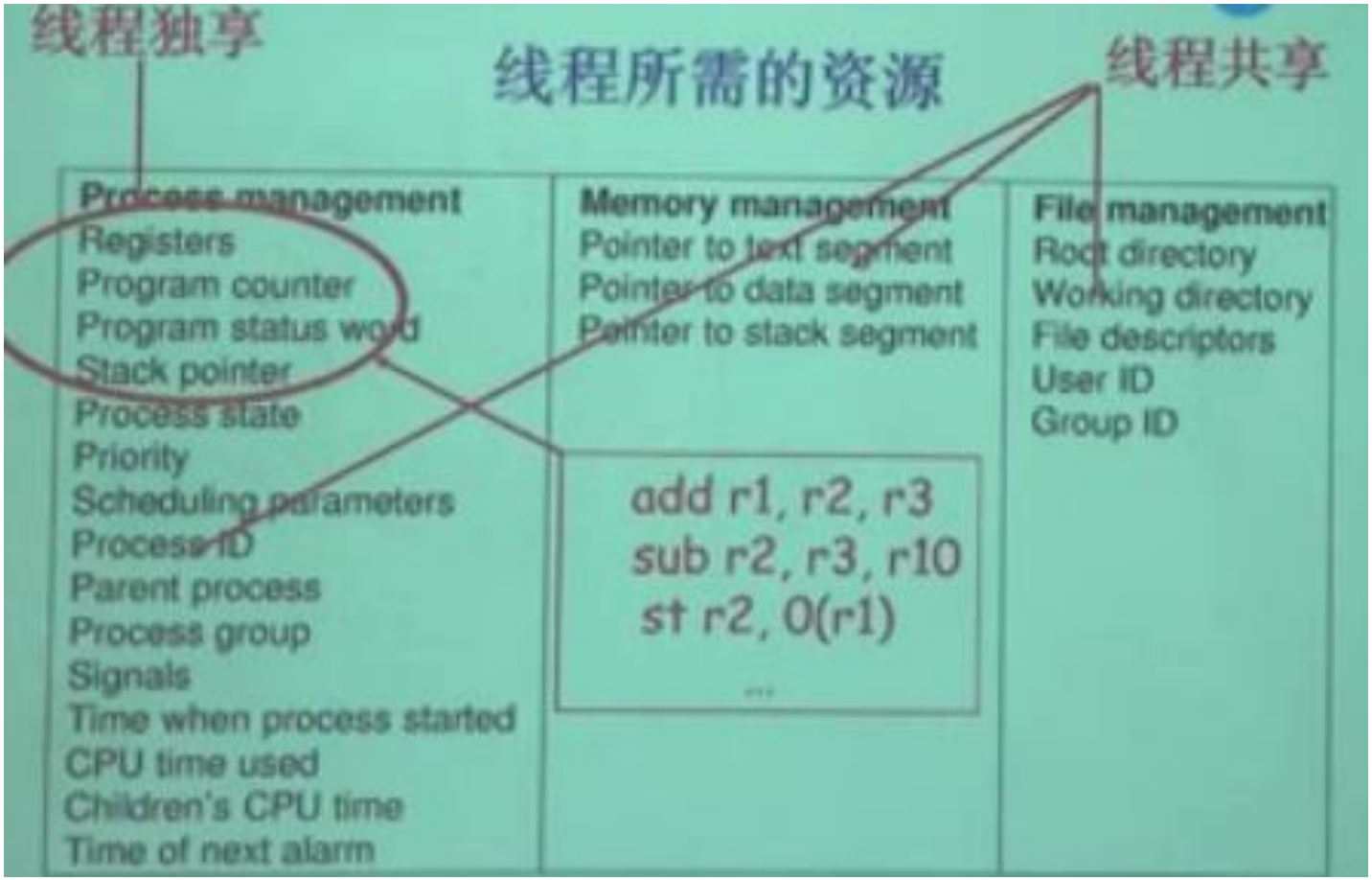
Thread concept overview

- 进程 = 线程 + 资源平台
  - 优点：
  - ✓ 一个进程中可以同时存在多个线程
  - ✓ 各个线程之间可以并发地执行
  - ✓ 各个线程之间可以共享地址空间



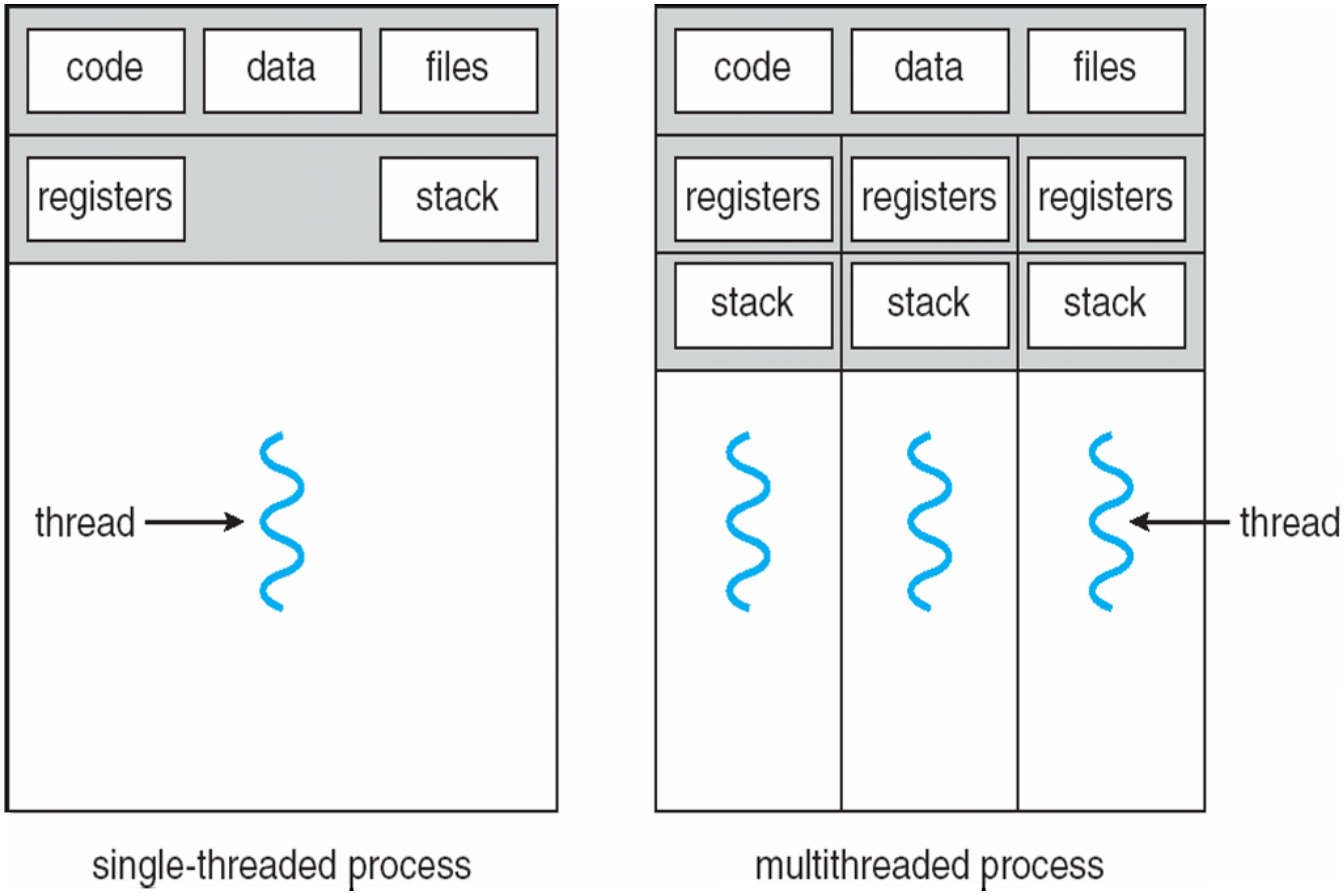
Thread concept overview

- Single and Multithreaded Processes



Thread concept overview

- Single-threaded and Multithreaded Processes



Thread concept overview

- 线程与进程的比较
  - 进程是资源分配单位,线程是CPU分配单位
  - 进程拥有一个完整的资源平台，而线程值独享必不可少的资源，如寄存器和栈
  - 线程同样具有就绪、阻塞和执行三种状态，同样具有状态之间的转换关系
  - 线程能减少并发执行的时间和空间开销
  - 线程=轻量级进程（lightweight process）

Thread concept overview

- Motivation
  - On modern desktop PC, many APPs are multithreaded.
  - a separate process with several threads
  - Example 1: A web browser
    - ✓ one for displaying images or text;
    - ✓ another for retrieving data from network
  - Example 2: A word processor
    - ✓ one for displaying graphics;
    - ✓ another for responding to keystrokes from the user;
    - ✓ and a third for performing spelling & grammar checking in the background

Thread concept overview

- Motivation
  - In certain situations, a single application may be required to perform several similar tasks. Example: a web server
  - Allow a server to service several concurrent requests. Example: a RPC server and Java's RMI systems
  - The OS itself needs to perform some specific tasks in kernel, such as managing devices or interrupt handling.
    - ✓ PARTICULAR, many OS systems are now multithreaded.
    - ✓ Example: Solaris, Linux

Thread concept overview

- Benefits
  - Responsiveness (响应度高)
    - ✓ Example: an interactive application such as web browser, while one thread loading an image, another thread allowing user interaction
  - Resource Sharing
    - ✓ address space, memory, and other resources
  - Economy
    - ✓ Solaris:

      creating a process is about 30 times slower than creating a thread;

      context switching is about 5 times slower
  - Utilization of MP Architectures
    - ✓ parallelism and concurrency ↑

Catalog Description

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Two methods to support threads

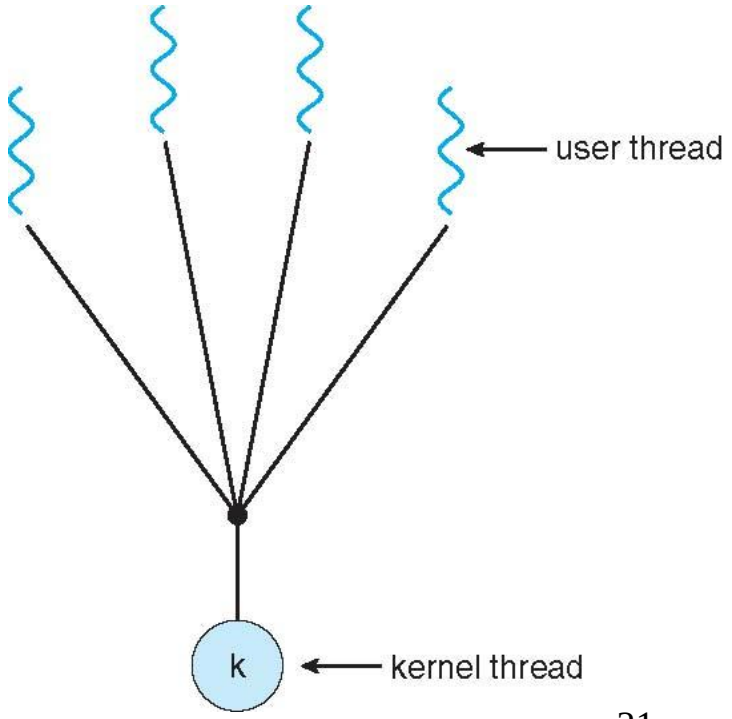
- User threads VS. Kernel threads
  - User threads
    - ✓ Thread management done by user-level threads library without kernel support
    - --Kernel may be multithreaded or not.
  - Three primary thread libraries:
    - ✓ POSIX Pthreads
    - ✓ Win32 threads
    - ✓ Java threads

Two methods to support threads

- User threads VS. Kernel threads
  - Kernel threads
    - ✓ Supported by the Kernel, usually may be slower than user thread
  - Examples:
    - ✓ Windows XP/2000
    - ✓ Solaris
    - ✓ Linux
    - ✓ Tru64 UNIX (formerly Digital UNIX)
    - ✓ Mac OS X

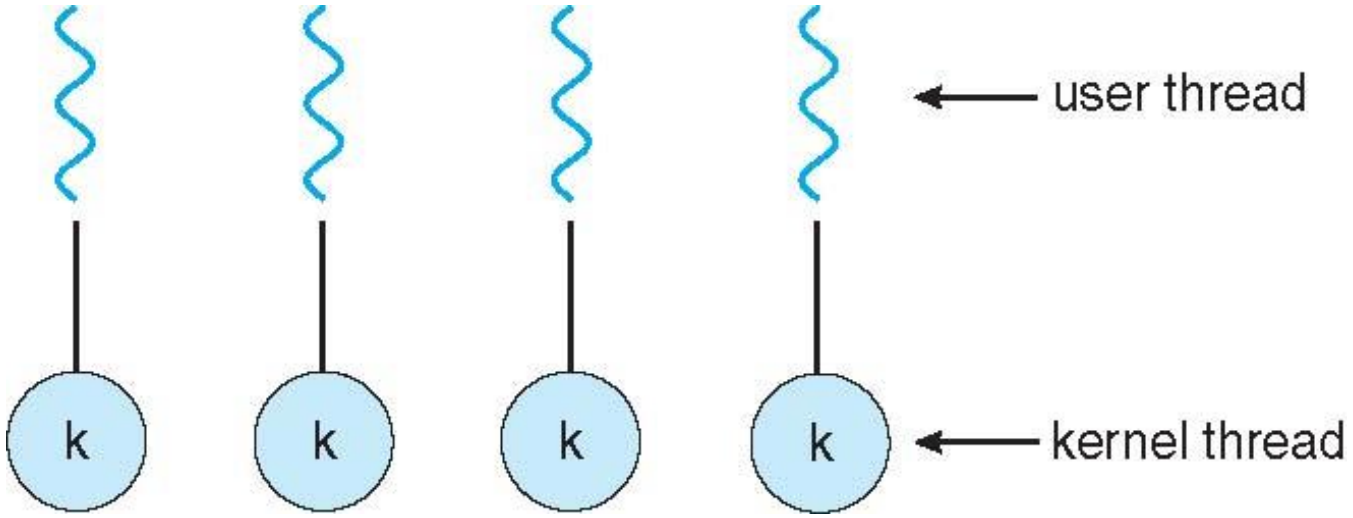
Multithreading Models

- The relationship between user threads and kernel threads
  - Many-to-One [n:1]
  - One-to-One [1:1]
  - Many-to-Many [n:m]
- Many-to-One [n:1]
  - Map many user-level threads single kernel thread
  - Examples:
    - ✓ Solaris Green Threads
    - ✓ GNU Portable Threads



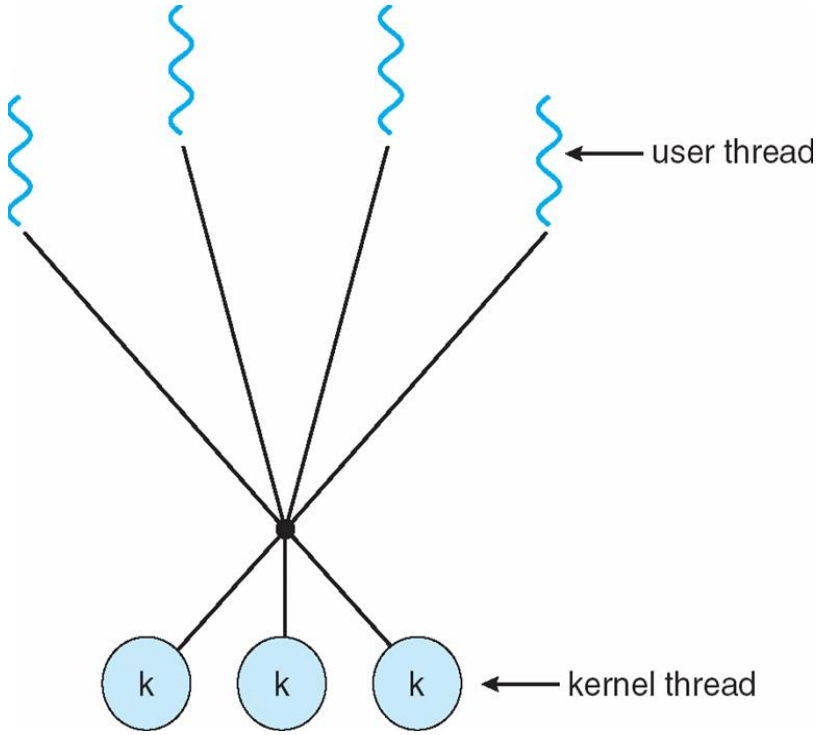
Multithreading Models

- One-to-One [1:1]
  - Map each user-level thread to a kernel thread
  - Examples:
    - ✓ Windows NT/XP/2000
    - ✓ Linux
    - ✓ Solaris 9 and later



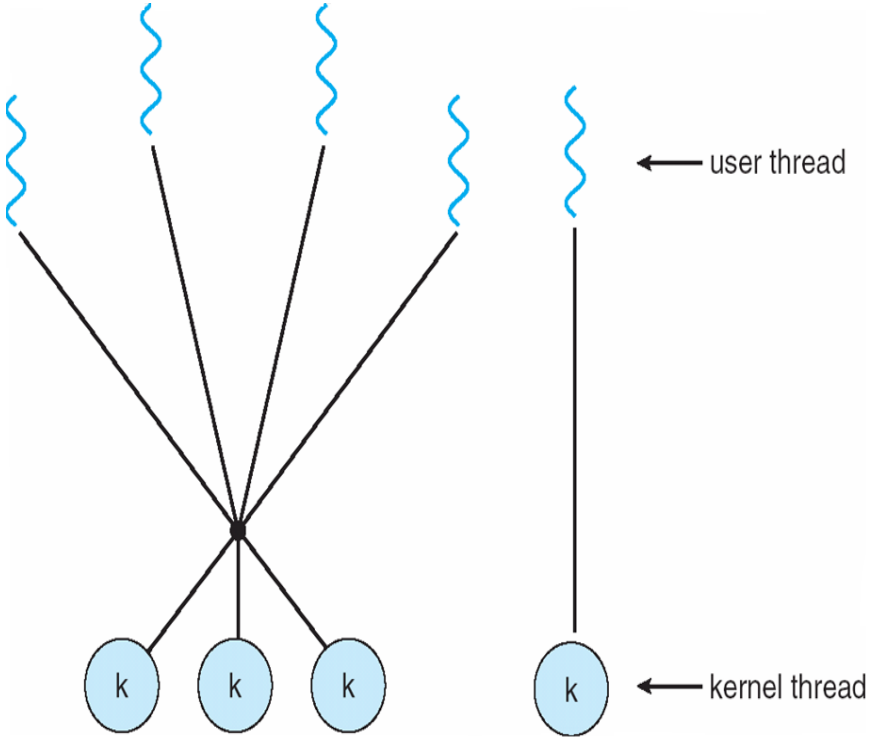
Multithreading Models

- Many-to-Many [n:m]
  - Allows many user level threads to be mapped to many kernel threads
  - Allows the operating system to create a sufficient number of kernel threads
  - Examples:
    - ✓ Solaris prior to version 9
    - ✓ Windows NT/2000 with the ThreadFiber package



Multithreading Models

- Two-level Model, a popular variation on many-to-many model
  - Similar to n:m, except that it allows a user thread to be bound to a kernel thread
  - Examples:
    - ✓ IRIX
    - ✓ HP-UX
    - ✓ Tru64 UNIX
    - ✓ Solaris 8 and earlier



Catalog Description

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Threading Issues

- Semantics of fork() and exec() system calls
  - Does fork() duplicate only the calling thread or all threads?
  - Some UNIX systems have chosen to have two versions
  - Which one version to use? Depend on the APP.
- Thread cancellation
  - Terminating a thread before it has finished
  - Two general approaches:
    - ✓ Asynchronous（异步）cancellation terminates the target thread immediately
    - ✓ Deferred（延时）cancellation allows the target thread to periodically check if it should be cancelled

Threading Issues

- Signal Handling
  - Signals are used in UNIX systems to notify a process that a particular event has occurred:
    - ✓ Synchronous: illegal memory access, division by 0
    - ✓ Asynchronous: Ctrl+C
  - All signals follow the same pattern:
    - ✓ Signal is generated by particular event
    - ✓ Signal is delivered to a process
    - ✓ Signal is handled
  - Signal handler may be handled by
    - ✓ a default signal handler, or
    - ✓ a user-defined signal handler

Threading Issues

- Signal Handling
  - When multithread, where should a signal be delivered?
    - ✓ Deliver the signal to the thread 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

Threading Issues

- Thread Pools
  - Create a number of threads in a pool where they sit and wait for 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)

Threading Issues

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

End of Chapter 4