Chapter 4: Threads
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Single and Multithreaded Processes

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<thead>
<tr>
<th>code</th>
<th>data</th>
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thread

single-threaded process

multithreaded process
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
  - Win32 threads
  - Java 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

user thread

kernel thread

k
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

- user thread
- kernel thread
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
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 a 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.
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

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