Chapter 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
  - 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

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

One-to-One

- 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

One-to-one Model

Many-to-Many Model
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 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 of 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

![Java Thread States Diagram]

End of Chapter 4