Chapter 4: Threads
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- Overview
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- Windows XP Threads
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Single and Multithreaded Processes

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<th>Multithreaded process</th>
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<tr>
<td>files</td>
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<tr>
<td>registers</td>
<td>registers</td>
</tr>
<tr>
<td>stack</td>
<td>stack</td>
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</table>

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

user thread

kernel thread

k

k

k
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 \texttt{fork()} and \texttt{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 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

- 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

The diagram illustrates the various states of a Java thread, including:

- **new**: The thread is newly created and not yet ready to run.
- **runnable**: The thread is ready to run but is not currently in execution.
- **blocked**: The thread is blocked due to I/O operations or other reasons.
- **dead**: The thread is no longer active.

Transitions between states can be triggered by method calls such as `start()` and `sleep()`, and by I/O operations. The thread can also exit a state by entering another through the `run()` method.
End of Chapter 4