OPERATING SYSTEMS

Threads

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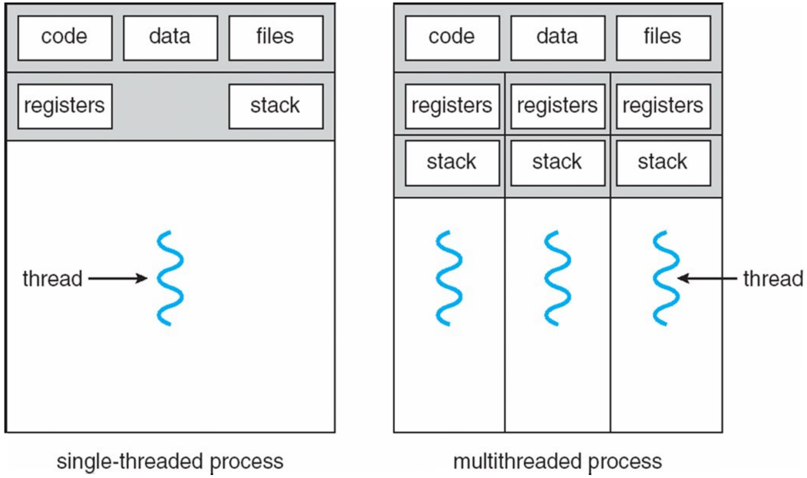
Thread

➢ A thread is a path of execution within a process.



- A thread contains -
  - Thread ID
  - Program Counter
  - Register Set
  - Stack
- Shares with other threads belonging to the same process -
  - Code Section
  - Data Section
  - OS resources

➢ A traditional process has a single thread of control (Single Threaded Process)

➢ Process with multiple threads of control, can perform more than one task at a time (Multi Threaded Process)

Benefits

There are four major categories of benefits to multi-threading:

1. **Responsiveness** - One thread may provide rapid response while other threads are blocked or slowed down doing intensive calculations.

1. **Resource sharing** - By default threads share common code, data, and other resources, which allows multiple tasks to be performed simultaneously in a single address space.

1. **Economy** - Creating and managing threads (and context switches between them) is much faster than performing the same tasks for processes.

1. **Scalability, i.e. Utilization of multiprocessor architectures** - A single threaded process can only run on one CPU, no matter how many may be available, whereas the execution of a multi-threaded application may be split amongst available processors. (Note that single threaded processes can still benefit from multi-processor architectures when there are multiple processes contending for the CPU, i.e. when the load average is above some certain threshold.)

Multicore Programming

Multicore or **multiprocessor** systems putting pressure on programmers, challenges include:

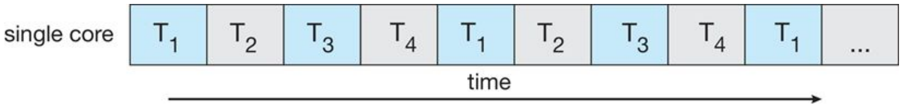
- ➔ Dividing activities
- ➔ Balance
- ➔ Data splitting
- ➔ Data dependency
- ➔ Testing and debugging

Parallelism implies a system can perform more than one task simultaneously

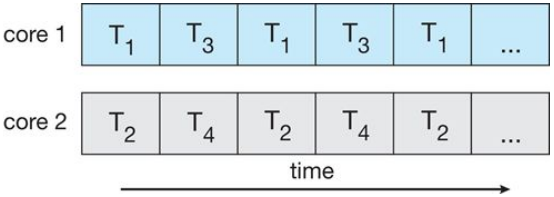
Concurrency supports more than one task making progress

- Single processor / core, scheduler providing concurrency

Concurrent execution on single-core system:



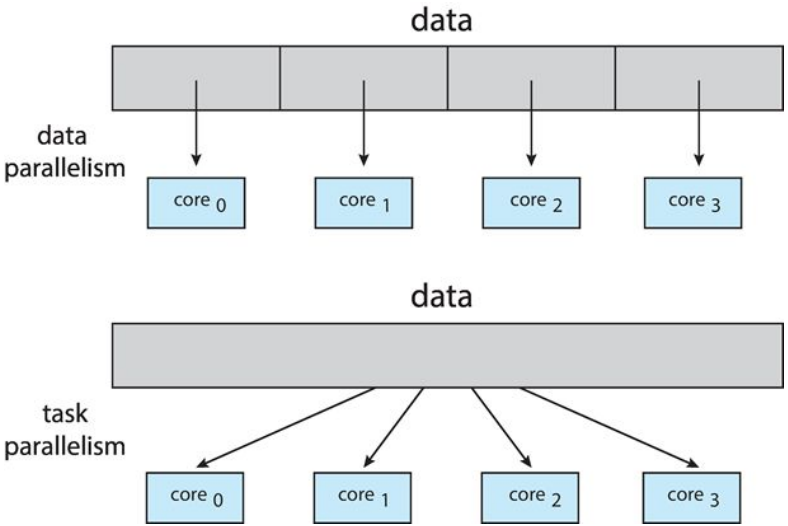
Parallelism on a multi-core system:



Multicore Programming

Data parallelism – distributes subsets of the same data across multiple cores, same operation on each

Task parallelism – distributes threads across cores, each thread performing unique operation



Amdahl's Law

Identifies performance gains from adding additional cores to an application that has both serial and parallel components

- S is serial portion
- N is number of processing cores

$$speedup \le \frac{1}{S + \frac{(1-S)}{N}}$$

- That is, if application is 75% parallel / 25% serial, moving from 1 to 2 cores results in speedup of 1.6 times
- As N approaches infinity, speedup approaches 1 / S

Serial portion of an application has disproportionate effect on performance gained by adding additional cores

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Multithreading Models

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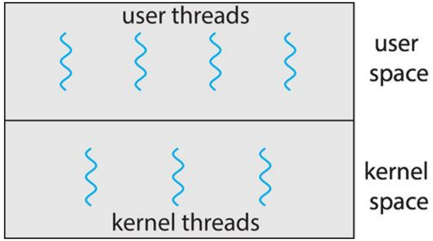
User and Kernel Threads

- There are two types of threads to be managed in a modern system: User threads and kernel threads.
- In a specific implementation, the user threads must be mapped to kernel threads.



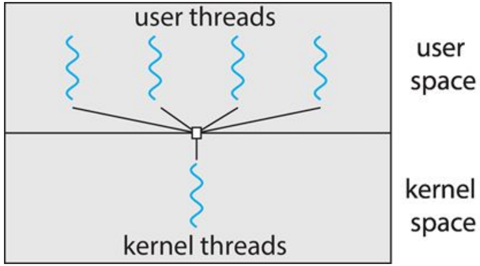
- **User threads** are supported above the kernel, without kernel support. These are the threads that application programmers would put into their programs.

- **Kernel threads** are supported within the kernel of the OS itself. All modern OS support kernel level threads, allowing the kernel to perform multiple simultaneous tasks and/or to service multiple kernel system calls simultaneously.

Multithreading Models

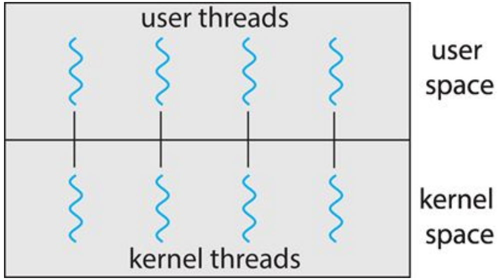
Many-to-One:

- Many user-level threads mapped to single kernel thread
- One thread blocking causes all to block
- Multiple threads may not run in parallel on multicore system because only one may be in kernel at a time
- Examples:
  - Solaris Green Threads
  - GNU Portable Threads



One to One:

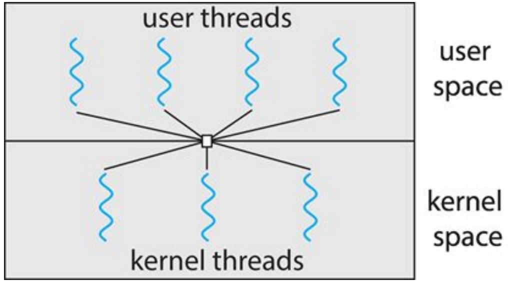
- Each user-level thread maps to kernel thread
- Creating a user-level thread creates a kernel thread
- More concurrency than many-to-one
- Number of threads per process sometimes restricted due to overhead
- Examples
  - Windows
  - Linux



Multithreading Models

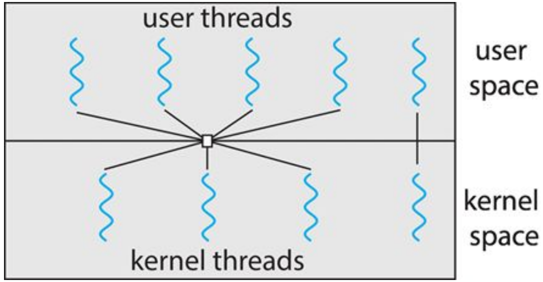
Many-to-Many:

- Allows many user level threads to be mapped to many kernel threads
- Allows the operating system to create a sufficient number of kernel threads
- Windows with the ThreadFiber package
- Otherwise not very common



Two-level Model:

- Similar to M:M, except that it allows a user thread to be bound to kernel thread



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Thread Libraries

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Thread library

- Thread libraries provide programmers with an API for creating and managing threads.
- Thread libraries may be implemented either in user space or in kernel space. The former involves API functions implemented solely within user space, with no kernel support. The latter involves system calls, and requires a kernel with thread library support.
- There are three main thread libraries in use today:
  - POSIX Pthreads - may be provided as either a user or kernel library, as an extension to the POSIX standard.
  - Win32 threads - provided as a kernel-level library on Windows systems.
  - Java threads - Since Java generally runs on a Java Virtual Machine, the implementation of threads is based upon whatever OS and hardware the JVM is running on, i.e. either Pthreads or Win32 threads depending on the system.

Pthreads

- The POSIX standard (IEEE 1003.1c) defines the specification for pThreads, not the implementation.
- pThreads are available on Solaris, Linux, Mac OSX, Tru64, and via public domain shareware for Windows.
- Global variables are shared amongst all threads.
- One thread can wait for the others to rejoin before continuing.
- pThreads begin execution in a specified function.
- Common in UNIX operating systems (Linux & Mac OS X)

Java Threads

- Java threads are managed by the JVM
- Typically implemented using the threads model provided by underlying OS
- Java threads may be created by:
  - Extending Thread class
  - Implementing the Runnable interface

```
public interface Runnable
{
    public abstract void run();
}
```

➔ Standard practice is to implement Runnable interface

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Threading Issues

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Threading Issues

- **fork() and exec() System Calls:** Duplicate all the threads or not?
- **Thread cancellation:** Thread cancellation is the task of terminating a thread before it has completed.
- **Signal Handling:** Where should a signal be delivered?
- **Thread Pool:** Create a number of threads at the process start-up.
- **Thread Specific data:** Each thread might need it’s own copy of certain data.