**Operating Systems**

# "Threads, SMP, and Microkernels"

## Roadmap

- Threads: Resource ownership and execution
- Symmetric multiprocessing (SMP).
- Microkernel
- Case Studies of threads and SMP:
  - Windows
  - Solaris
  - Linux

# Processes and Threads

- Processes have two characteristics:
  - **Resource ownership** - process includes a virtual address space to hold the process image
  - **Scheduling/execution** - follows an execution path that may be interleaved with other processes
- These two characteristics are treated independently by the operating system

# Processes and Threads

- The dispatching unit is referred to as a ***thread*** or lightweight process
- The entity that owns a resource is referred to as a process or ***task***
- One process / task can have one or more threads

# Multithreading

- The ability of an OS to support multiple, concurrent paths of execution within a single process.

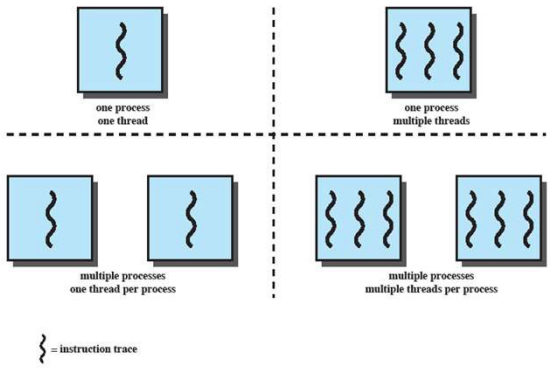



Figure 4.1 Threads and Processes [ANDE97]

# Single Thread Approaches

- MS-DOS supports a single user process and a single thread.
- Some UNIX, support multiple user processes but only support one thread per process

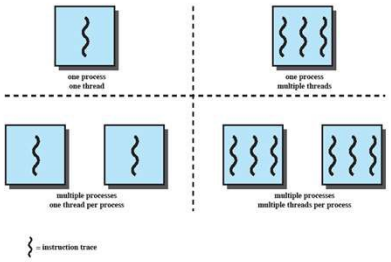



Figure 4.1 Threads and Processes [ANDE97]

# Multithreading

- Java run-time environment is a single process with multiple threads
- Multiple processes ***and*** threads are found in Windows, Solaris, and many modern versions of UNIX

  →**the main topic**

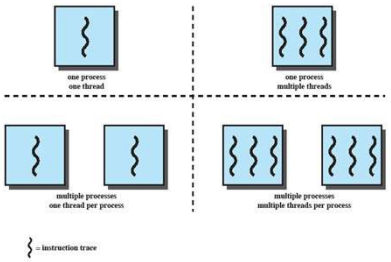



Figure 4.1 Threads and Processes [ANDE97]

# Processes

- A virtual address space which holds the process image
- Protected access to
  - Processors,
  - Other processes,
  - Files,
  - I/O resources

# One or More Threads in Process

- Each thread has
  - An execution state (running, ready, etc.)
  - Saved thread context when not running
  - An execution stack
  - Some per-thread static storage for local variables
  - Access to the memory and resources of its process (all threads of a process share this)

# One view…

- *One way to view a thread is as an independent program counter operating **within** a process.*

# Threads vs. processes

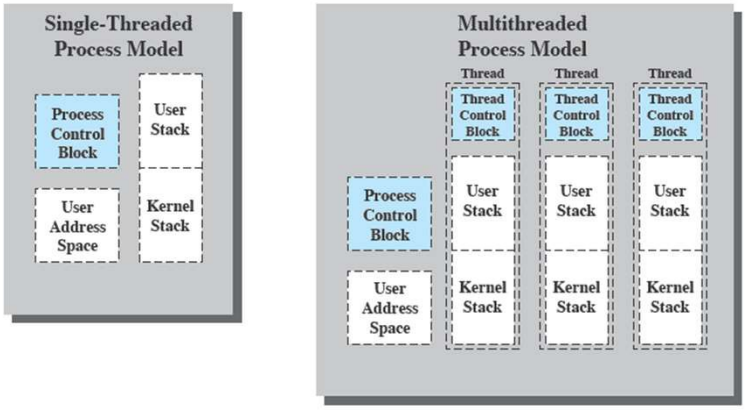



Figure 4.2 Single Threaded and Multithreaded Process Models

# Benefits of Threads

- Takes less time to create a new thread than a process
- Less time to terminate a thread than a process
- Switching between two threads takes less time that switching processes
- Threads can communicate with each other
  - without invoking the kernel

# Thread use in a Single-User System

- Foreground and background work
- Asynchronous processing
- Speed of execution
- Modular program structure

# Threads

- Several actions that affect all of the threads in a process
  - The OS must manage these at the process level.
- Examples:
  - Suspending a process involves suspending all threads of the process
  - Termination of a process, terminates all threads within the process

# Activities similar to Processes

- Threads have execution states and may synchronize with one another.
  - Similar to processes
- We look at these two aspects of thread functionality in turn.
  - States
  - Synchronisation

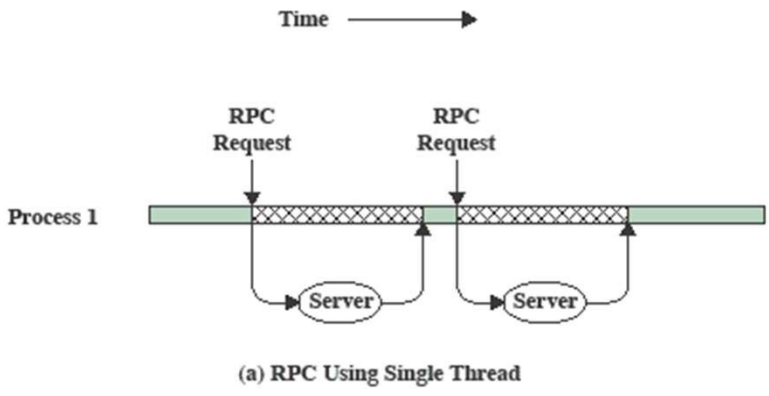
# Thread Execution States

- States associated with a change in thread state
  - Spawn (another thread)
  - Block
    - Issue: will blocking a thread block other, or all threads
  - Unblock
  - Finish (thread)
    - Deallocate register context and stacks

# Example: Remote Procedure Call

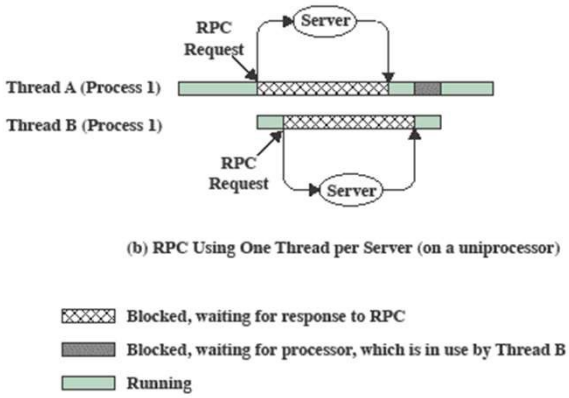
- Consider:
  - A program that performs two remote procedure calls (RPCs)
  - to two different hosts
  - to obtain a combined result.

# RPC Using Single Thread




(a) RPC Using Single Thread

# RPC Using One Thread per Server




# Multithreading on a Uniprocessor

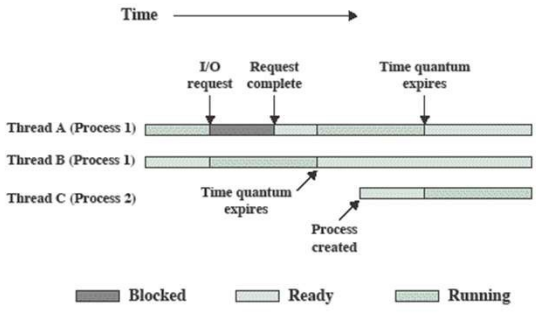


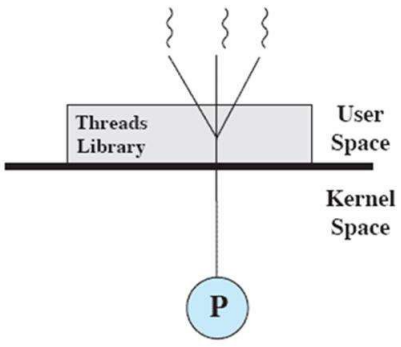

Figure 4.4 Multithreading Example on a Uniprocessor

# Categories of Thread Implementation

- User Level Thread (ULT)
  - thread that are managed entirely by user-level code
  - Not requiring any support from the operating system kernel.
- Kernel level Thread (KLT) also called:
  - kernel-supported threads
  - lightweight processes.

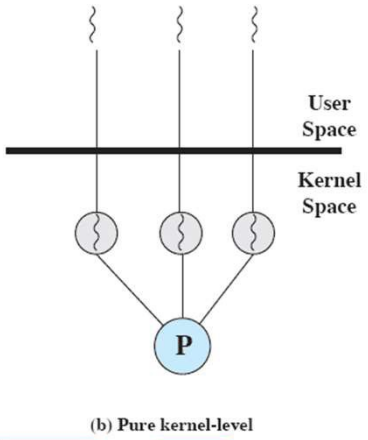
# User-Level Threads

- All thread management is done by the application
- The kernel is not aware of the existence of threads




(a) Pure user-level

# Kernel-Level Threads




(b) Pure kernel-level

- Kernel maintains context information for the process and the threads
  - No thread management done by application
- Scheduling is done on a thread basis
- Windows is an example of this approach

# Advantages of KLT

- The kernel can simultaneously schedule multiple threads from the same process on multiple processors.
- If one thread in a process is blocked, the kernel can schedule another thread of the same process.
- Kernel routines themselves can be multithreaded.

# Disadvantage of KLT

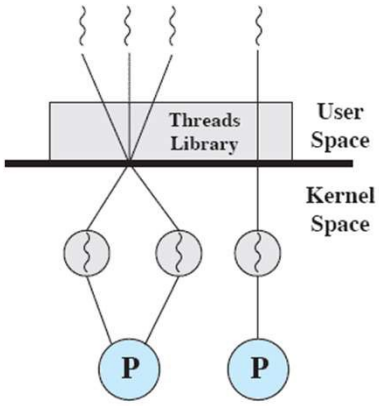
- The transfer of control from one thread to another within the same process requires a mode switch to the kernel

# Comparison ULT and KLT

| Criteria | User-Level Threads (ULTs) | Kernel-Level Threads (KLTs) |
|---|---|---|
| Management | Managed entirely by user-level code, without kernel support | Managed by the operating system kernel |
| Scheduling | Scheduled by a user-level thread library or application, without kernel intervention | Scheduled by the operating system kernel, which may provide advanced scheduling algorithms and policies |
| Context Switching | Context switching occurs entirely in user space, without requiring a system call or trap into kernel mode | Context switching requires a system call or trap into kernel mode, which can incur overhead |
| Resources | ULTs share the same process address space and resources as the parent process | KLTs have their own kernel-level data structures, which can result in higher overhead and memory usage |
| Scalability | ULTs are limited to a single processor core and cannot take full advantage of multicore systems | KLTs can be assigned to different processor cores and can take full advantage of multicore systems |
| Synchronization | ULTs must use user-level synchronization mechanisms, which can be more efficient but may be subject to priority inversion and other issues | KLTs can use both user-level and kernel-level synchronization mechanisms, providing more flexibility and better enforcement of policies |
| Portability | ULTs are highly portable across different operating systems, as long as a compatible user-level thread library is available | KLTs may be less portable, as different operating systems may have different thread APIs and scheduling mechanisms |

# Combined Approaches

- Thread creation done in the user space
- Bulk of scheduling and synchronization of threads by the application
- Example is Solaris




(c) Combined

# Relationship Between Thread and Processes

Table 4.2 Relationship Between Threads and Processes

| Threads:Processes | Description | Example Systems |
|---|---|---|
| 1:1 | Each thread of execution is a unique process with its own address space and resources. | Traditional UNIX implementations |
| M:1 | A process defines an address space and dynamic resource ownership. Multiple threads may be created and executed within that process. | Windows NT, Solaris, Linux, OS/2, OS/390, MACH |
| 1:M | A thread may migrate from one process environment to another. This allows a thread to be easily moved among distinct systems. | Ra (Clouds), Emerald |
| M:N | Combines attributes of M:1 and 1:M cases. | TRIX |

# Roadmap

- Threads: Resource ownership and execution
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- Microkernel
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# Traditional View

- Traditionally, the computer has been viewed as a sequential machine.
  - A processor executes instructions one at a time in sequence
  - Each instruction is a sequence of operations
- Two popular approaches to providing parallelism
  - Symmetric Multi Processors (SMPs)
  - Clusters (ch 16)

# Categories of Computer Systems

- Single Instruction Single Data (SISD) stream
  - Single processor executes a single instruction stream to operate on data stored in a single memory
- Single Instruction Multiple Data (SIMD) stream
  - Each instruction is executed on a different set of data by the different processors

# Categories of Computer Systems

- Multiple Instruction Single Data (MISD) stream
  - A sequence of data is transmitted to a set of processors, each of execute a different instruction sequence
- Multiple Instruction Multiple Data (MIMD)
  - A set of processors simultaneously execute different instruction sequences on different data sets

# Parallel Processor Architectures

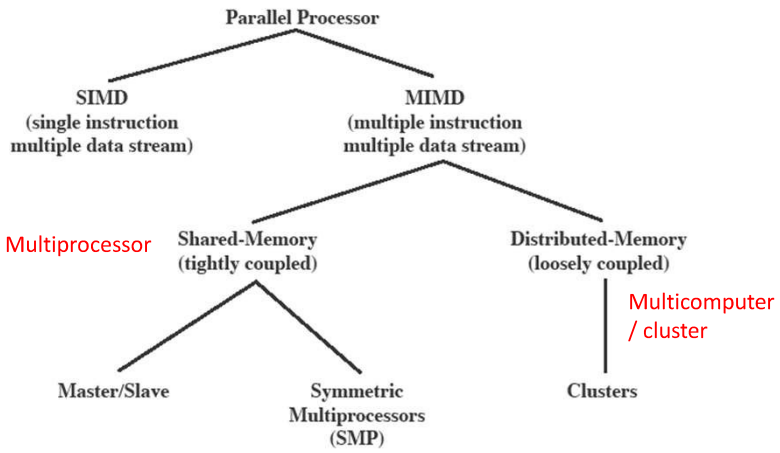


Figure 4.8 Parallel Processor Architectures

# Symmetric Multiprocessing

- Kernel can execute on any processor
  - Allowing portions of the kernel to execute in parallel
- Typically, each processor does self-scheduling from the pool of available process or threads

# Typical SMP Organization

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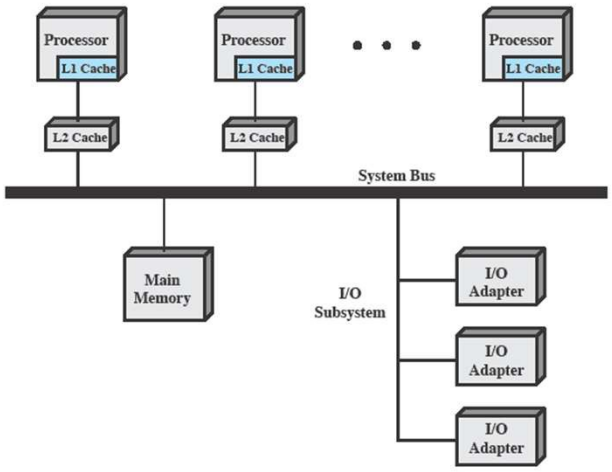


Figure 4.9 Symmetric Multiprocessor Organization

# Multiprocessor OS Design Considerations

- The key design issues include
  - Simultaneous concurrent processes or threads
  - Scheduling
  - Synchronization
  - Memory Management
  - Reliability and Fault Tolerance

# Roadmap

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# Microkernel

- A microkernel is a small OS core that provides the foundation for modular extensions.
- Big question is how small must a kernel be to qualify as a microkernel
  - *Must* drivers be in user space?
- In theory, this approach provides a high degree of flexibility and modularity.