Operating System

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Chapter 04

Threads

线程

Learning Objectives

- Understand the distinction between process and thread
- Describe the basic design issues for threads
- Explain the difference between user-level threads and kernel-level threads

Outline

- **Processes and Threads**
  - Multithreading
  - Thread Functionality
- **Types of Threads**
  - User-Level and Kernel-Level Threads
  - Other Arrangements

The basic idea is that the several components in any complex system will perform particular subfunctions that contribute to the overall function.

-- *THE SCIENCES OF THE ARTIFICIAL,*
Herbert Simon

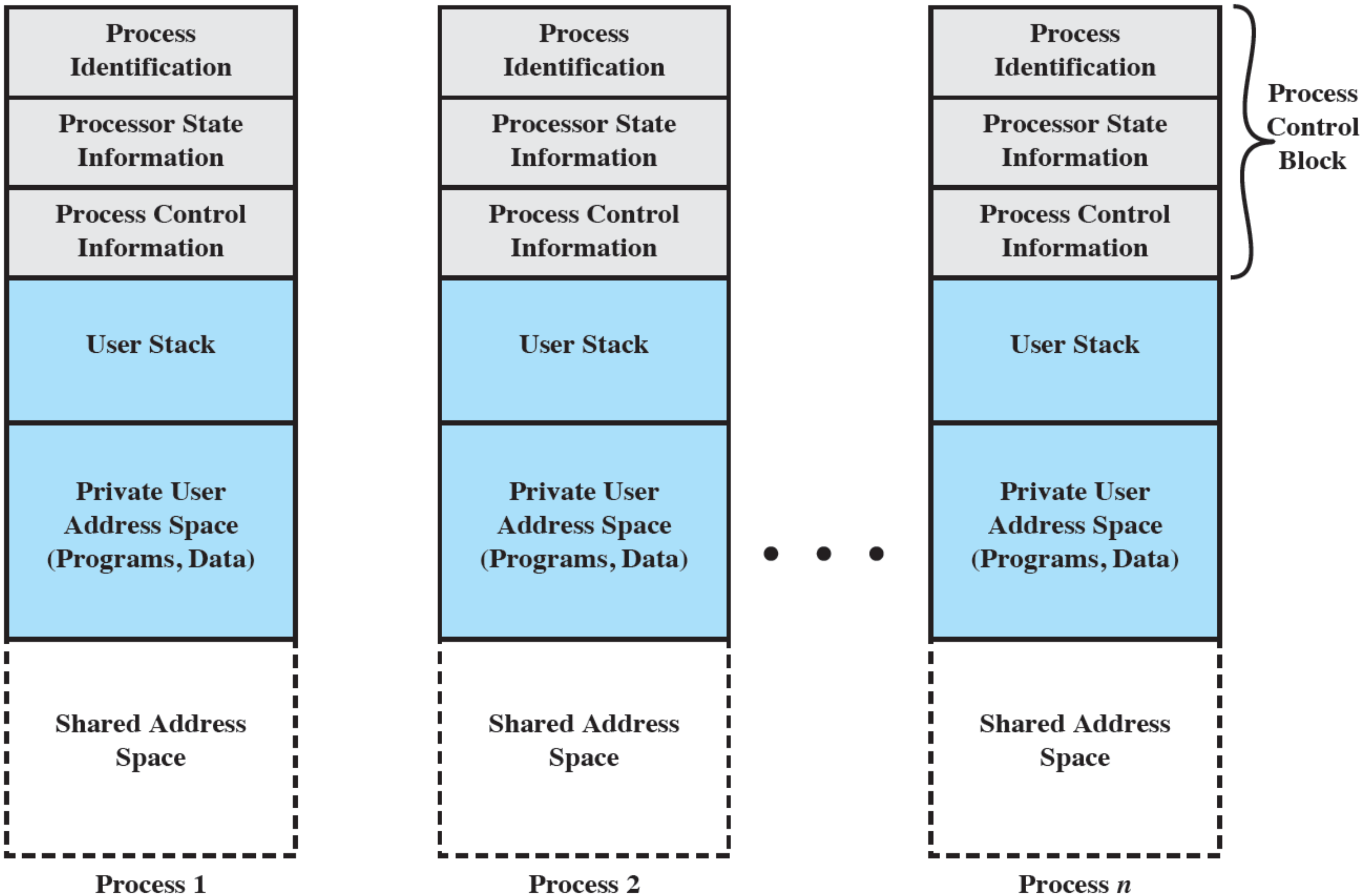
Turing Award	**1975**
Nobel Prize in Economics	**1978**
National Medal of Science	**1986**
von Neumann Theory Prize	**1988**

Processes and Threads

- **Resource Ownership**
  - **a virtual address space** to hold the **process image**
  - may be allocated **control** or **ownership** of resources
    - main memory
    - I/O channels and devices
    - files
  - OS performs **a protection function** to prevent unwanted interference between processes with respect to resources

- **Scheduling/Execution**
  - Follows an execution path that may be **interleaved** with other processes
  - an **execution state**
    - Running, Ready, etc.
  - a dispatching **priority**
  - is **the entity** that is scheduled and dispatched by the OS

Structure of Process Images

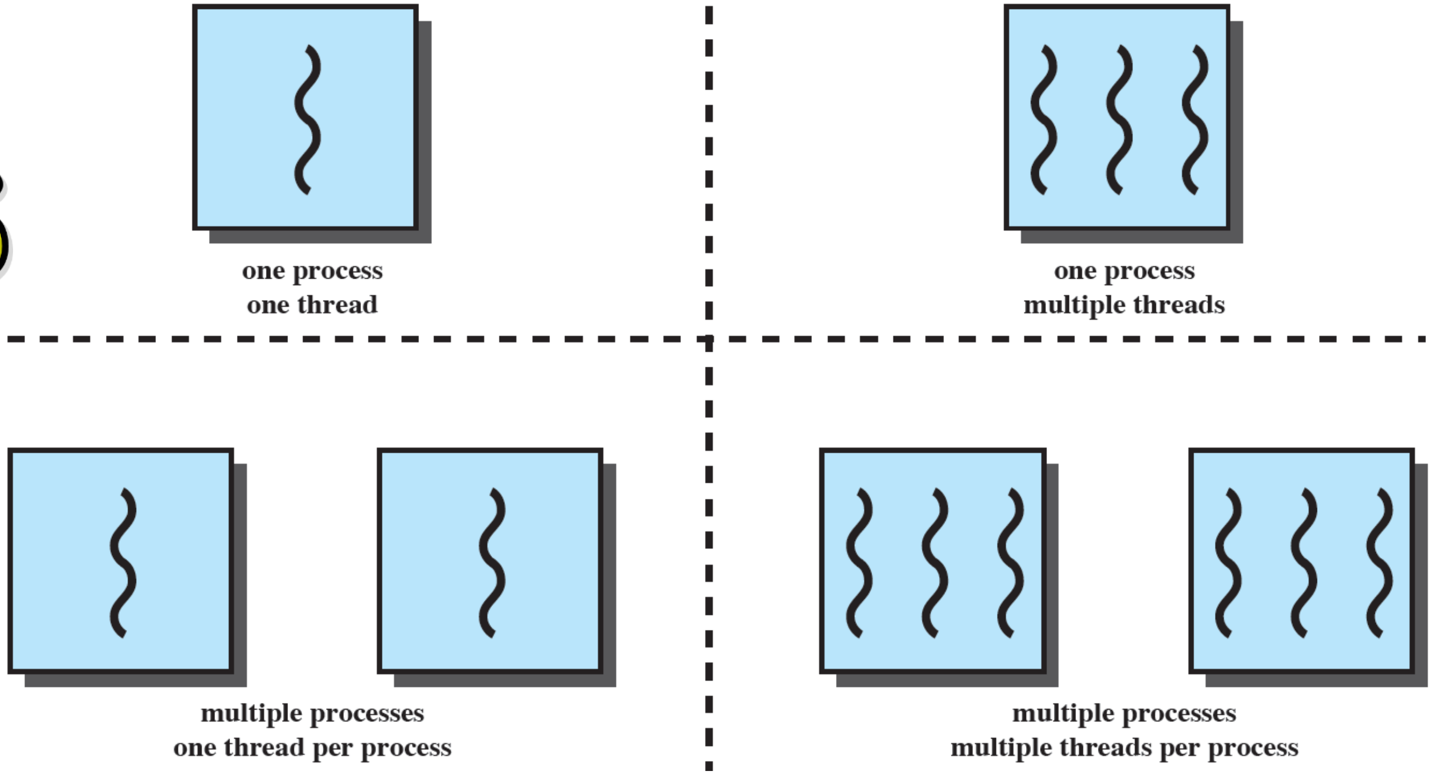


User Processes in Virtual Memory

Processes and Threads

- **Thread or lightweight process LWT**
  - The unit of **dispatching** is referred to as a thread or lightweight process
- **Process or Task**
  - The unit of **resource ownership** is referred to as a process or task
- **Multithreading**
  - The ability of an OS to support multiple, concurrent paths of execution within a single process

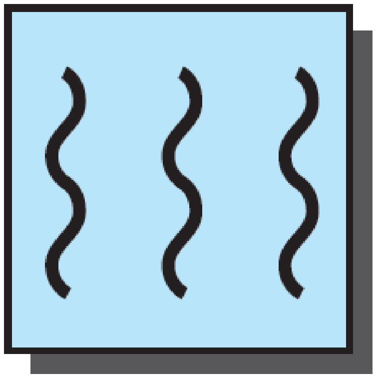
Threads and Processes



Processes

- **The unit of resource allocation**
  - **A virtual address space** that holds the **process image**

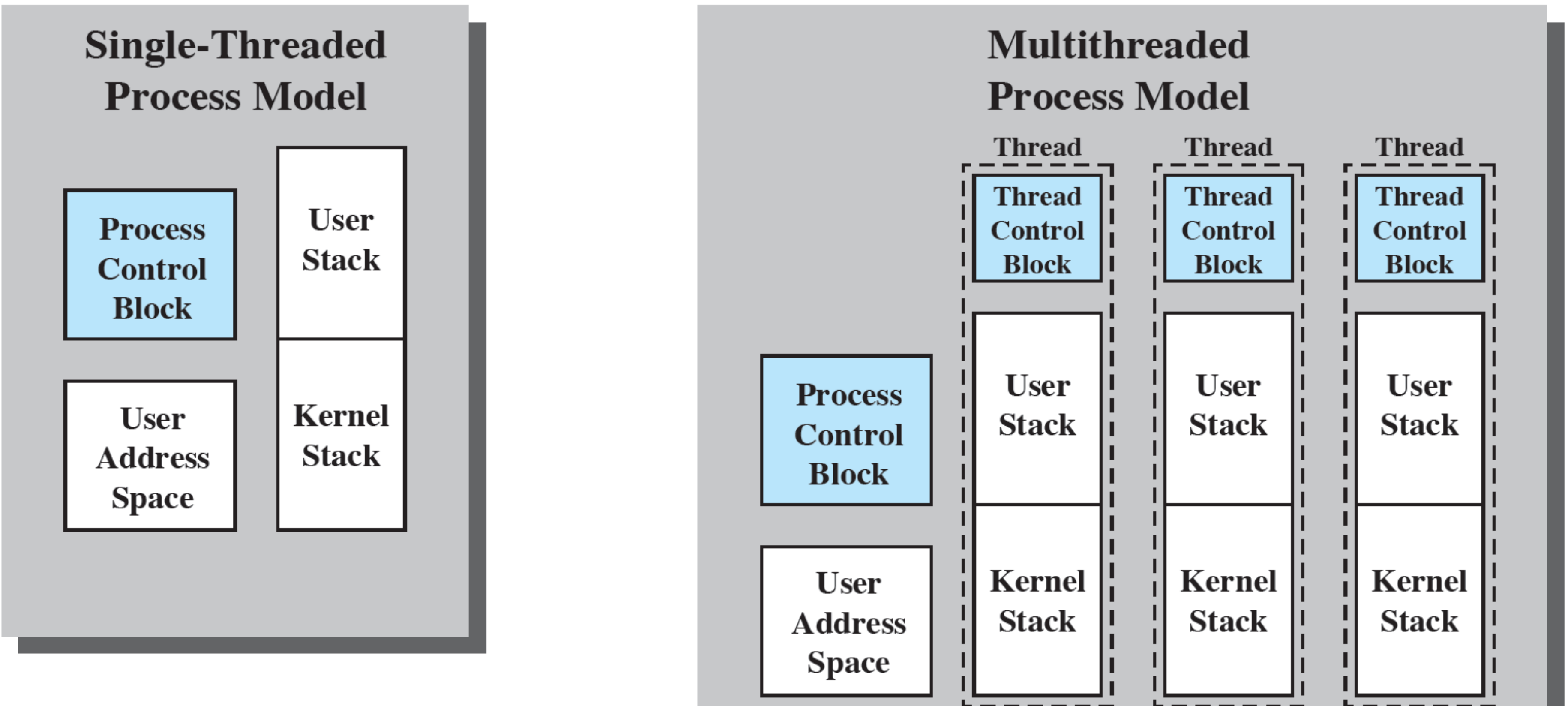
- **The unit of protection**
  - processors
  - other processes
    - for interprocess communication
  - files
  - I/O resources
    - devices and channels



One or More Threads in a Process

- **Each thread has**
  - an execution state
    - Running, Ready, etc.
  - saved **thread context** when not running
    - one way to view a thread is **as an independent program counter** operating within a process
  - 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

Threads vs. Processes



Key Benefits of Threads

why?

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 than switching between processes

Threads enhance efficiency in communication between programs

performance

Thread Use in a Single-User System

- **Foreground and background work**
  - a spreadsheet program
- **Asynchronous processing**
  - as a protection against power failure
- **Speed of execution**
  - A multithreaded process can compute one batch of data while reading the next batch from a device
- **Modular program structure**
  - Programs that involve a variety of activities or a variety of sources and destinations of input and output

Thread Functionality

- **Scheduling and dispatching is done on a thread basis**
- **Most of the state information dealing with execution is maintained in thread-level data structures**

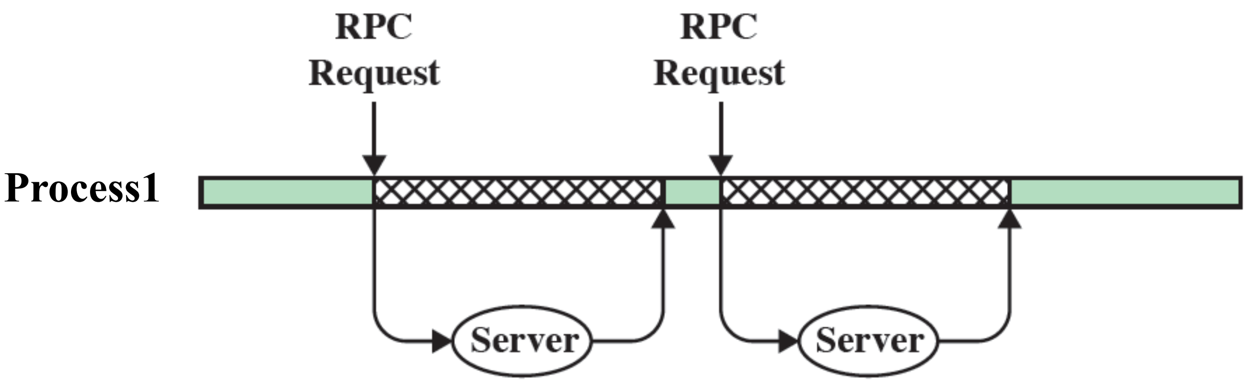
- **Several actions that affect all of the threads in a process**
  - the OS must manage at the **process level**
    - **suspending** a process involves suspending all threads of the process
    - **termination** of a process terminates all threads within the process

Thread Execution States

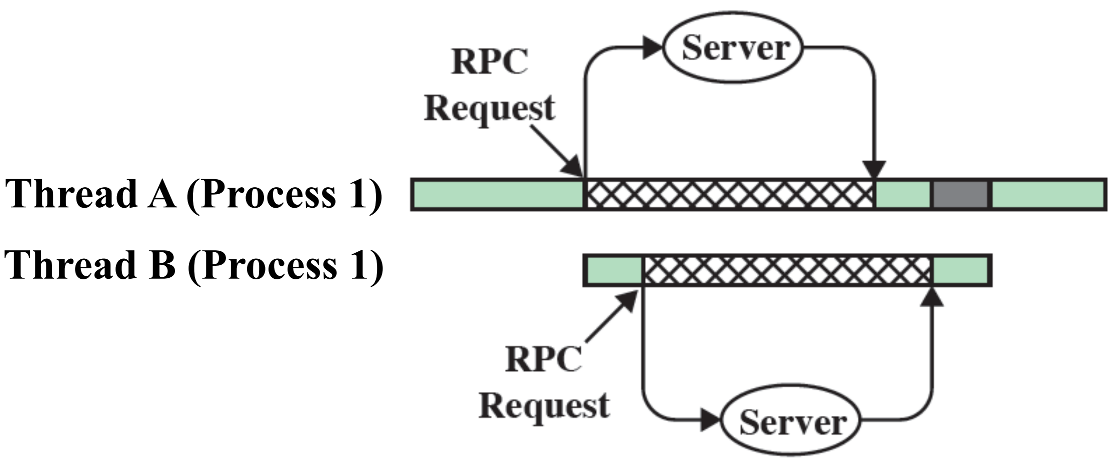
- **Key states for a thread**
  - Running
  - Ready
  - Blocked
- **Thread operations associated with a change in thread state**
  - **Spawn**
  - Block
  - Unblock
  - Finish

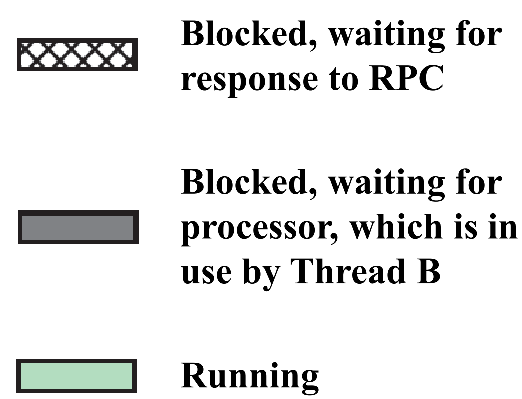
- **Spawn**
  - when a new process is spawned, a thread for that process is also spawned
  - a thread within a process may spawn another thread within the same process
  - The new thread is provided with its own register context and stack space and placed on the ready queue

Performance Benefits of Threads



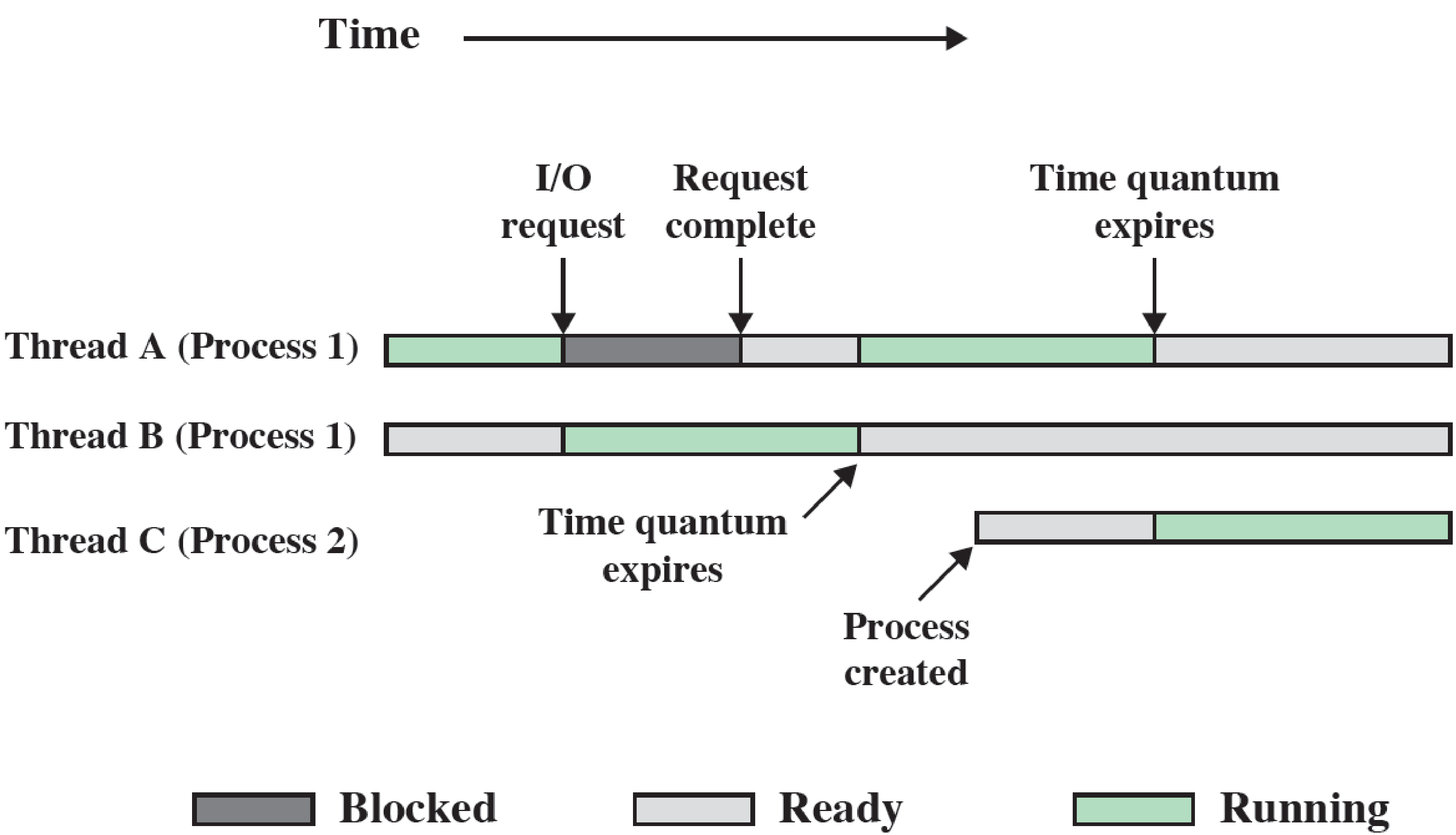
RPC Using Single Thread





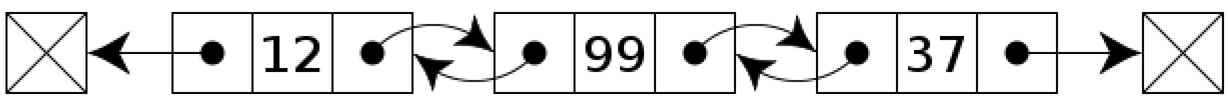
RPC Using One Thread per Server (on a uniprocessor)

Multithreading on a Uniprocessor



Thread Synchronization

- **It is necessary to synchronize the activities of the various threads**
  - all threads of a process share the same address space and other resources
  - any alteration of a resource by one thread affects the other threads in the same process



if two threads each try to add an element to a doubly linked list at the same time

- one element may be **lost**
- the list may end up **malformed**

Types of Threads

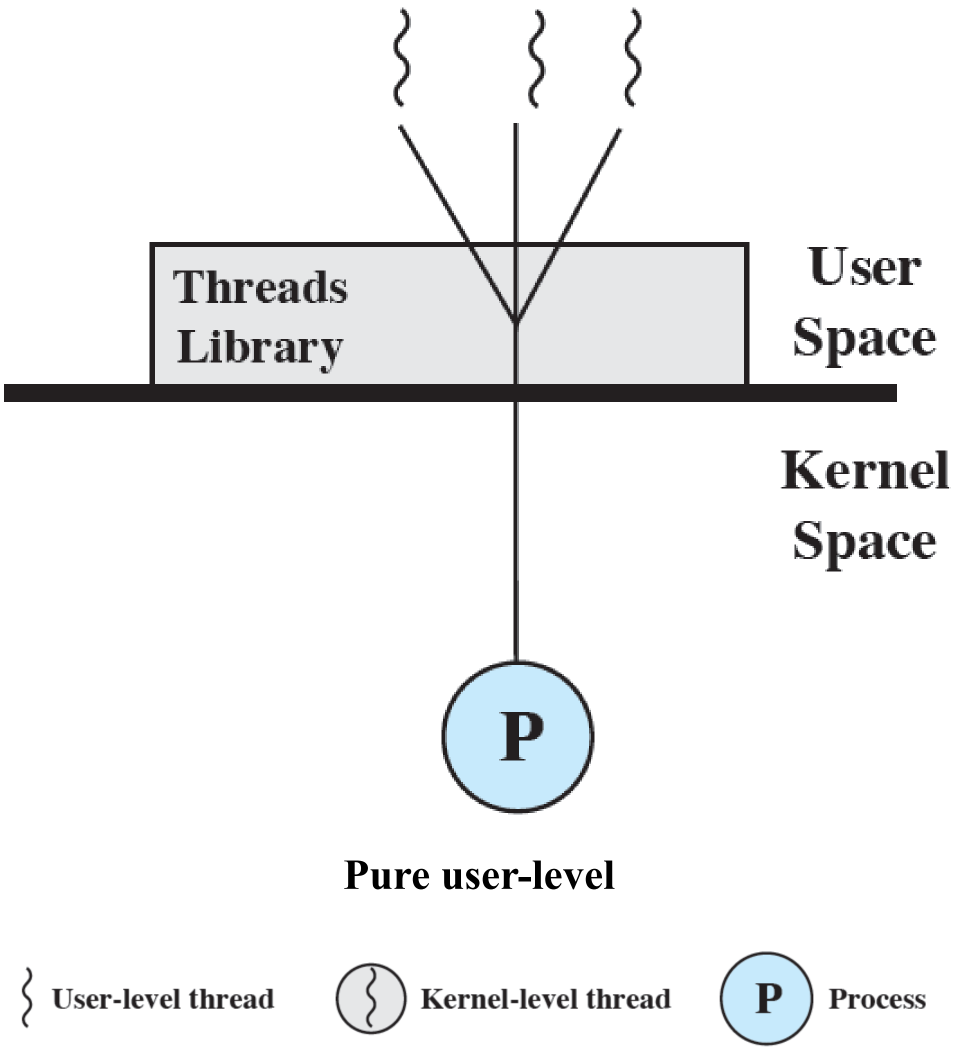
whether the blocking of a thread results in the blocking of the entire process ?

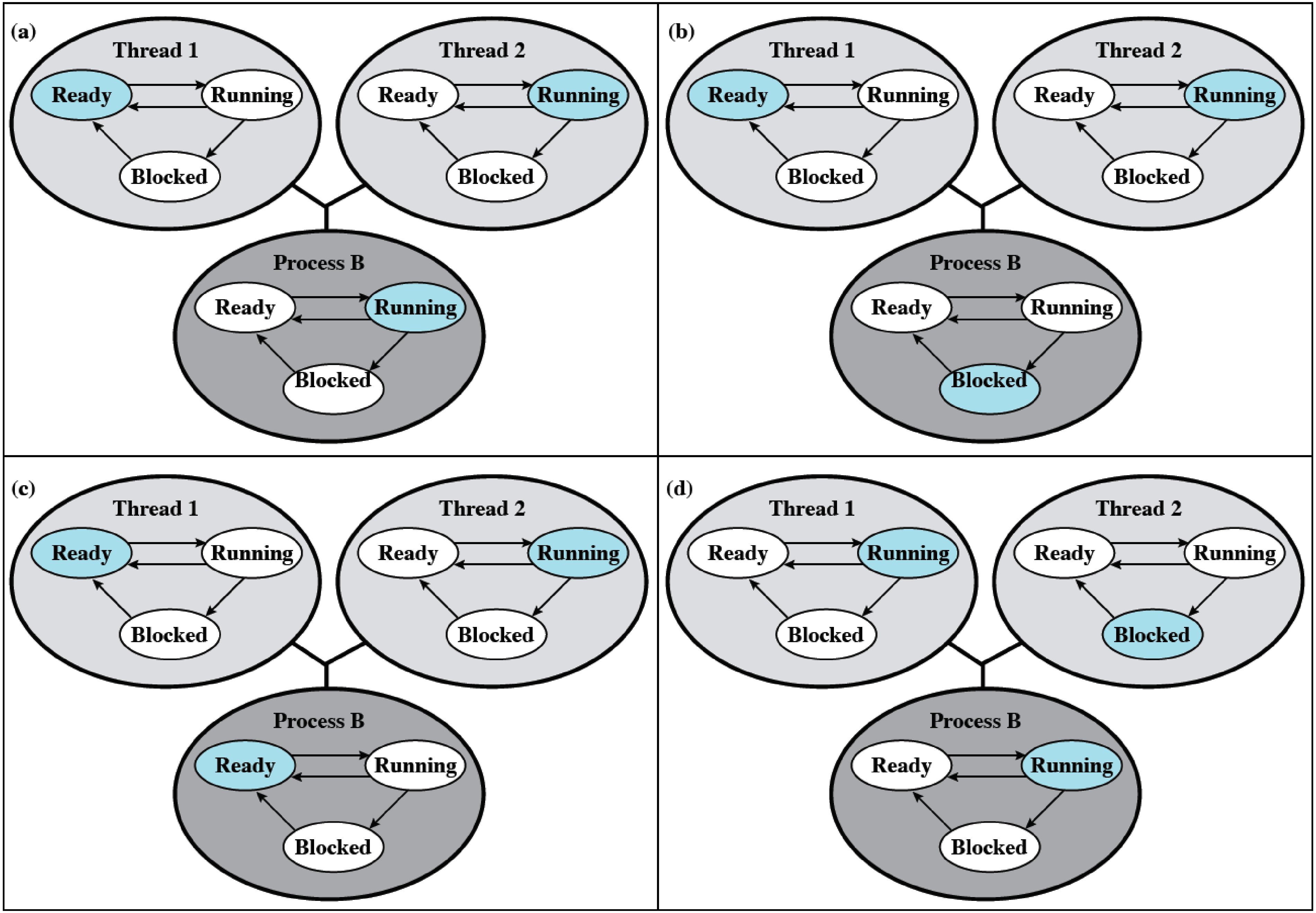
User Level Thread (ULT)

Kernel level Thread (KLT)

User-Level Threads (ULTs)

- **All thread management is done by the application**
  - in user space
  - within a single process
- **The kernel is not aware of the existence of threads**





Examples of the Relationships Between User-Level Thread States and Process States

Advantages of ULTs

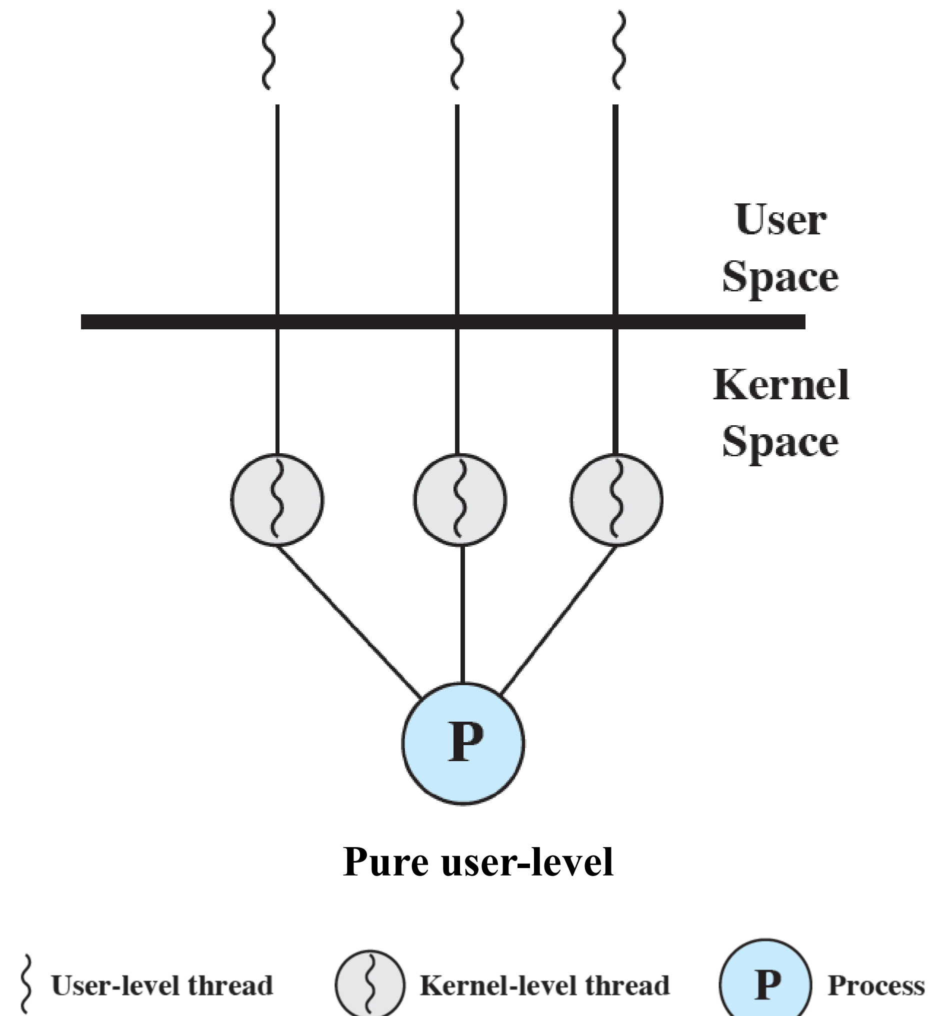
- **Thread switching does not require kernel mode privileges**
  - This saves the overhead of two mode switches
    - user to kernel; kernel back to user
- **Scheduling can be application specific**
  - The scheduling algorithm can **be tailored to the application** without disturbing the underlying OS scheduler
- **ULTs can run on any OS**
  - The threads library is a set of application-level functions shared by all applications

Disadvantages of ULTs

- **Disadvantages**
  - when a ULT executes a **system call**, not only is that thread blocked, but also all of the threads within the process are blocked
  - In a pure ULT strategy, a multithreaded application cannot take advantage of multiprocessing
- **Overcoming**
  - Writing an application as **multiple processes** rather than multiple threads
    - Each switch becomes a process switch rather than a thread switch, resulting in much greater overhead
  - **Jacketing**
    - converts a **blocking** system call into a **non-blocking** system call

Kernel-Level Threads (KLTs)

- **Thread management is done by the kernel**
  - no thread management is done by the application
  - Windows is an example of this approach



Advantages of KLTs

- 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 can be multithreaded

Disadvantage of KLTs

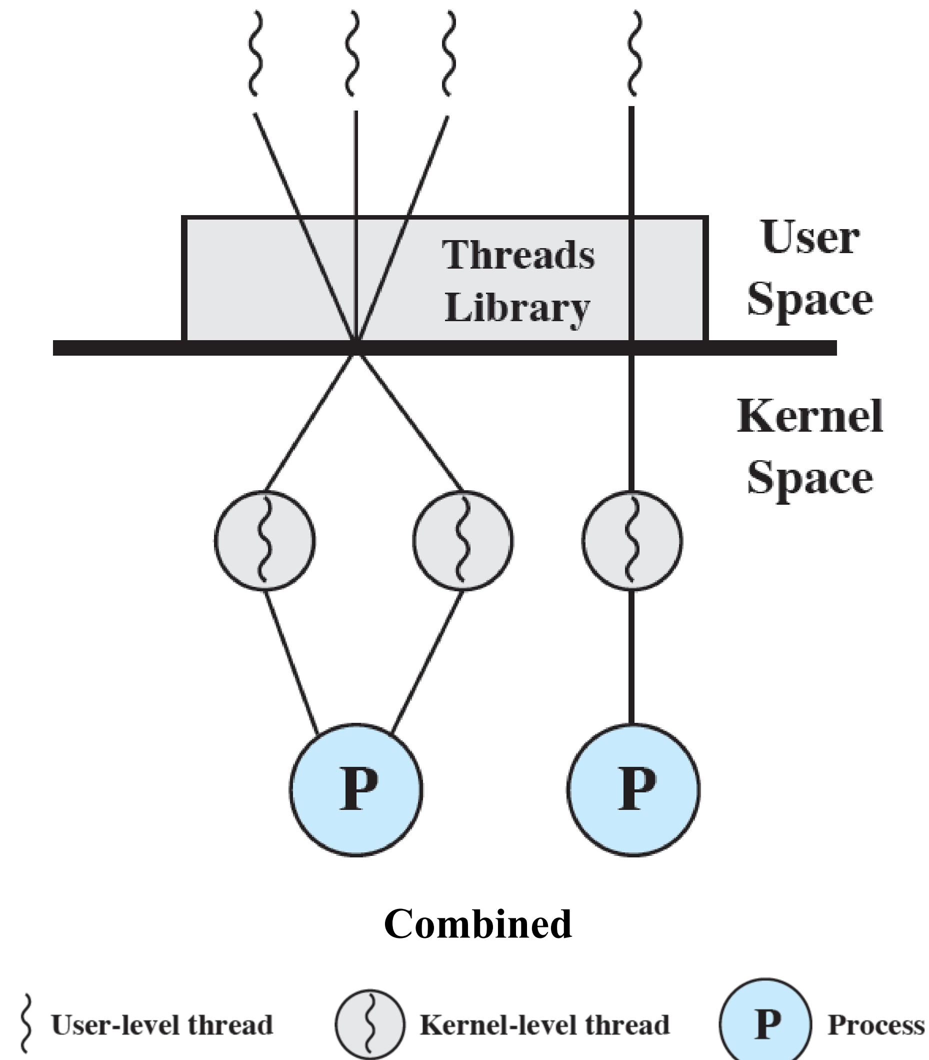
- The transfer of control from one thread to another within the same process requires a mode switch to the kernel

Table Thread and Process Operation Latencies (μs)

Operation	User-Level Threads	Kernel-Level Threads	Processes
Null Fork	34	948	11,300
Signal Wait	37	441	1,840

Combined Approaches

- **Thread creation** is done in the **user space**
- Bulk of **scheduling** and **synchronization** of threads is **by the application**
- The multiple ULTs are **mapped onto** some number of KLTs
- The programmer may **adjust the number of KLTs**



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

Summary

- **Process**
  - **resource ownership**
- **Thread**
  - **program execution**

- **User-level threads**
  - created and managed by a threads library that runs in the user space of a process
  - a mode switch is not required to switch from one thread to another
  - only a single user-level thread within a process can execute at a time
  - if one thread blocks, the entire process is blocked
- **Kernel-level threads**
  - threads within a process that are maintained by the kernel
  - a mode switch is required to switch from one thread to another
  - multiple threads within the same process can execute in parallel on a multiprocessor
  - blocking of a thread does not block the entire process