Threads, SMP, and Microkernels

Chapter 4

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- Processes and threads
- Symmetric multiprocessing
- Microkernels
- Window 2000 thread and SMP management
- Solaris thread and SMP management
- Linux process and thread management

Processes of yesterday

- Unit of resource ownership
  - process is allocated a virtual address space to hold the process image
- Unit of dispatching
  - scheduled and dispatched by the OS
  - execution may be interleaved with other processes
- These two characteristics are treated independently by today's operating system

Processes of today

- Process or task
  - unit of resource ownership
  - virtual address space, main memory, I/O devices, and files
- Thread or light weight process
  - unit of dispatching
  - scheduled and dispatched by the OS

Multithreading

- Refers to the ability of an OS to support multiple threads of execution within a single process
- MS-DOS supports a single user process and a single thread
- UNIX supports multiple user processes but only supports one thread per process
- Windows 2000, Solaris, Linux, Mach, and OS/2 support multiple threads

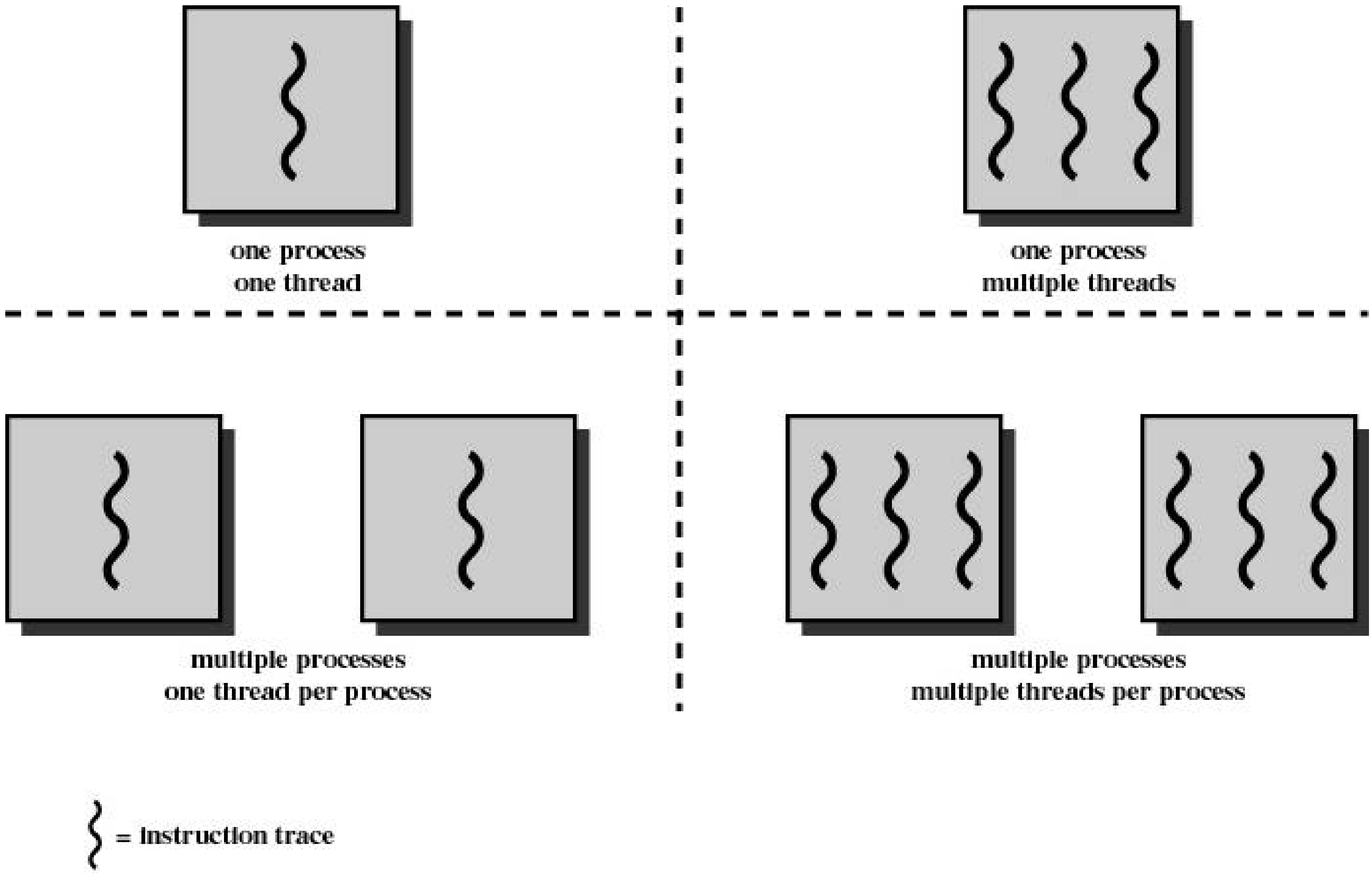


Figure 4.1 Threads and Processes [ANDE97]

Processes in Multithreaded environment

- A process is the unit of resource allocation and a unit of protection
  - have a virtual address space that holds the process image
  - protected access to processors, other processes, files, and I/O resources
  - Per Process Items
    - address space, global variable, open files, child processes, timers, signals, semaphores, account

Threads

- Within a process, there may be one or more threads, each with the followings
  - thread execution state(running, ready,...)
  - saved thread context
    - program counter, stack, register set, child threads, memory for local variables
  - access to the memory and resources of its process
    - all threads of a process share this

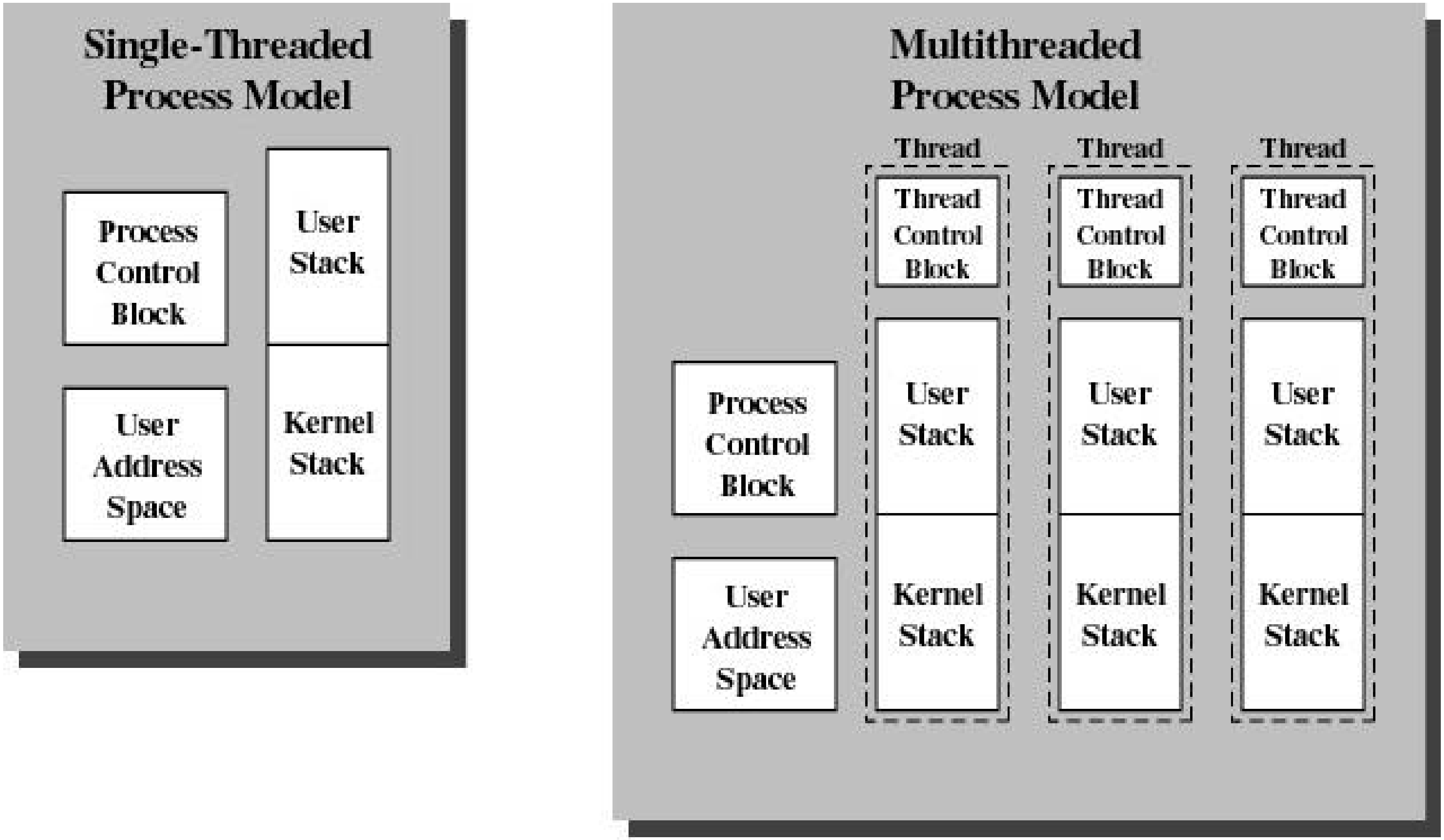


Figure 4.2 Single Threaded and Multithreaded Process Models

Benefits of Threads

- Takes less time to create a new thread than a process
  - no need to allocate a virtual address space
- Less time to terminate a thread than a process
- Less time to switch between two threads within the same process
- Since threads within the same process share memory and files, they can communicate with each other without invoking the kernel

Uses of Threads in a Single-User Multiprocessing System

- Foreground and background work
  - one thread displays menus and read user input
  - another thread executes user commands
- Asynchronous elements in the program can be implemented as threads
- Speed execution
  - on a multiprocessor system, multiple threads from the same process may be able to execute simultaneously
- Modular program structure

Threads

- Actions that affect all of the threads in a process
  - Suspending a process involves suspending all threads of the process since all threads share the same address space
  - Termination of a process terminates all threads within that process

Thread States

- Operations associated with a change in thread state
  - Spawn
    - a thread within a process may spawn another thread within the same process
  - Block
  - Unblock
  - Finish
    - Deallocate register context and stacks

Remote Procedure Call Using Threads

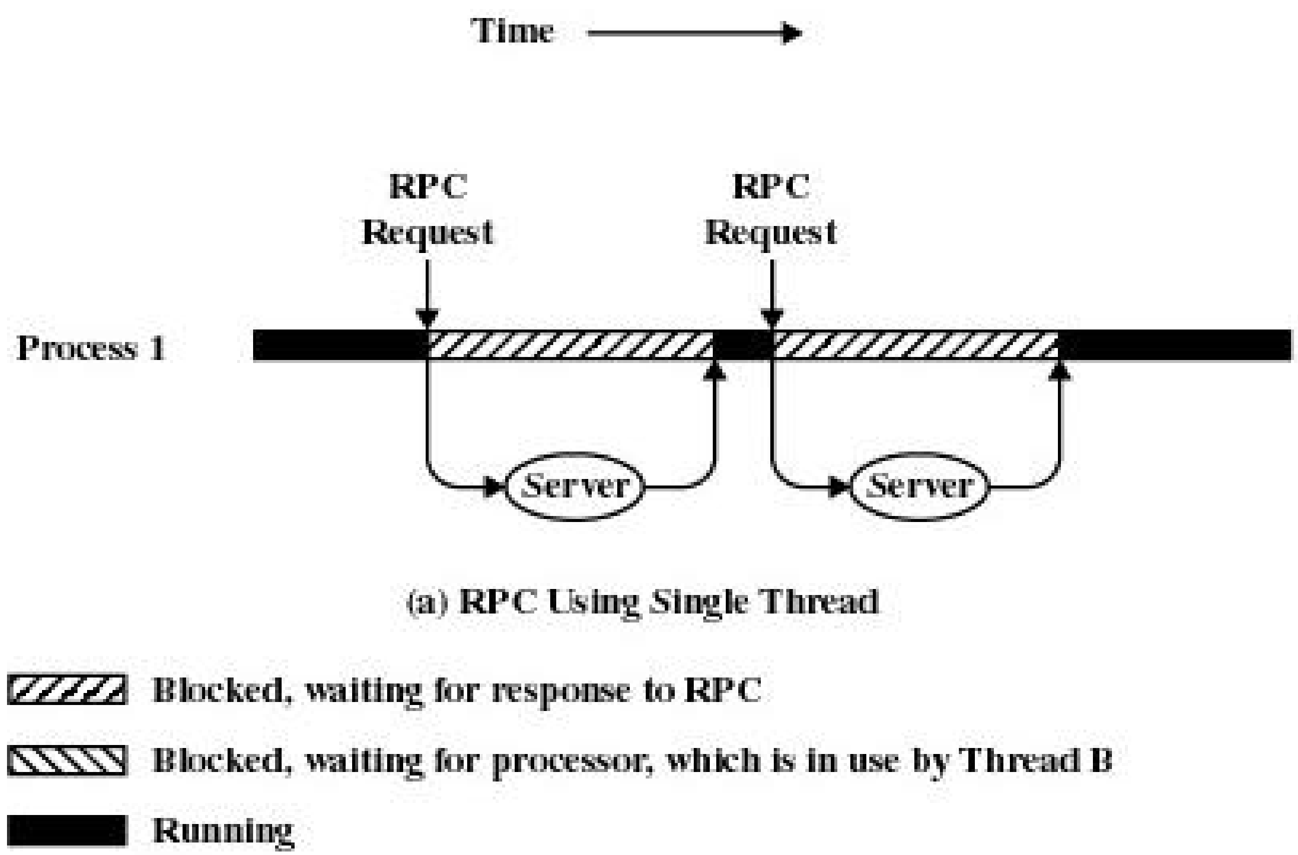
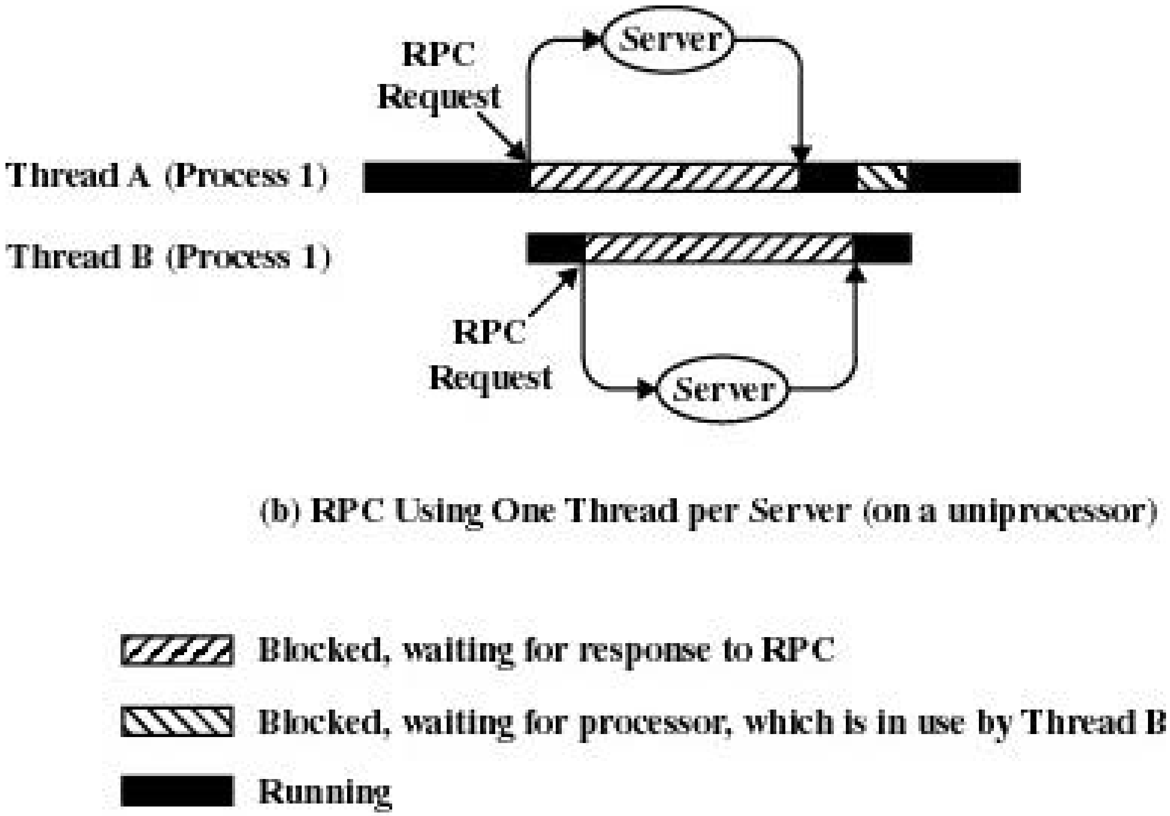


Figure 4.3 Remote Procedure Call (RPC) Using Threads

Remote Procedure Call Using Threads



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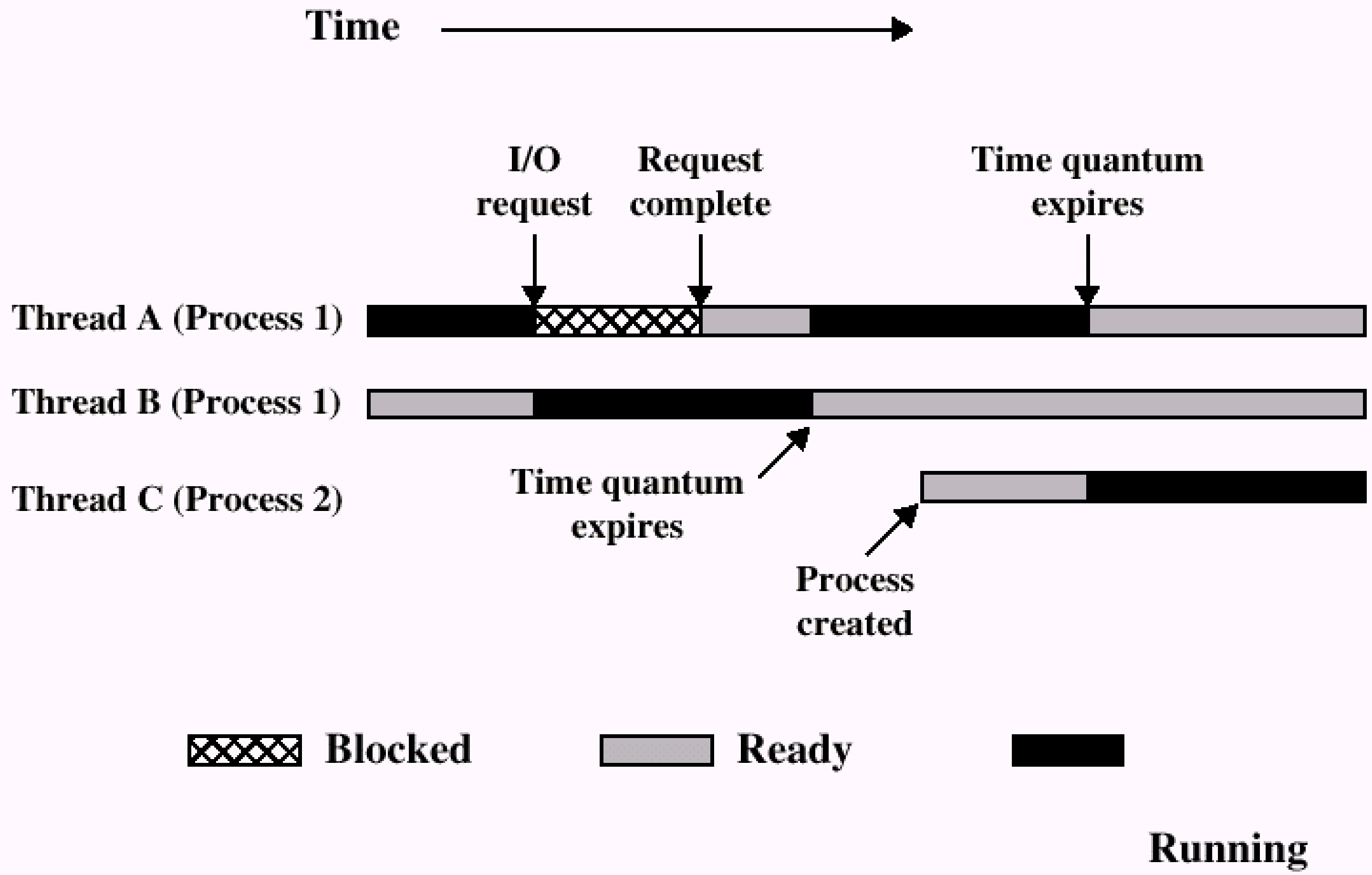


Figure 4.4 Multithreading Example on a Uniprocessor

Implementation of Threads

- User-level threads(ULTs)
- Kernel-level threads(KLTs)
  - also referred to as kernel-supported threads or lightweight processes
- Combined approaches

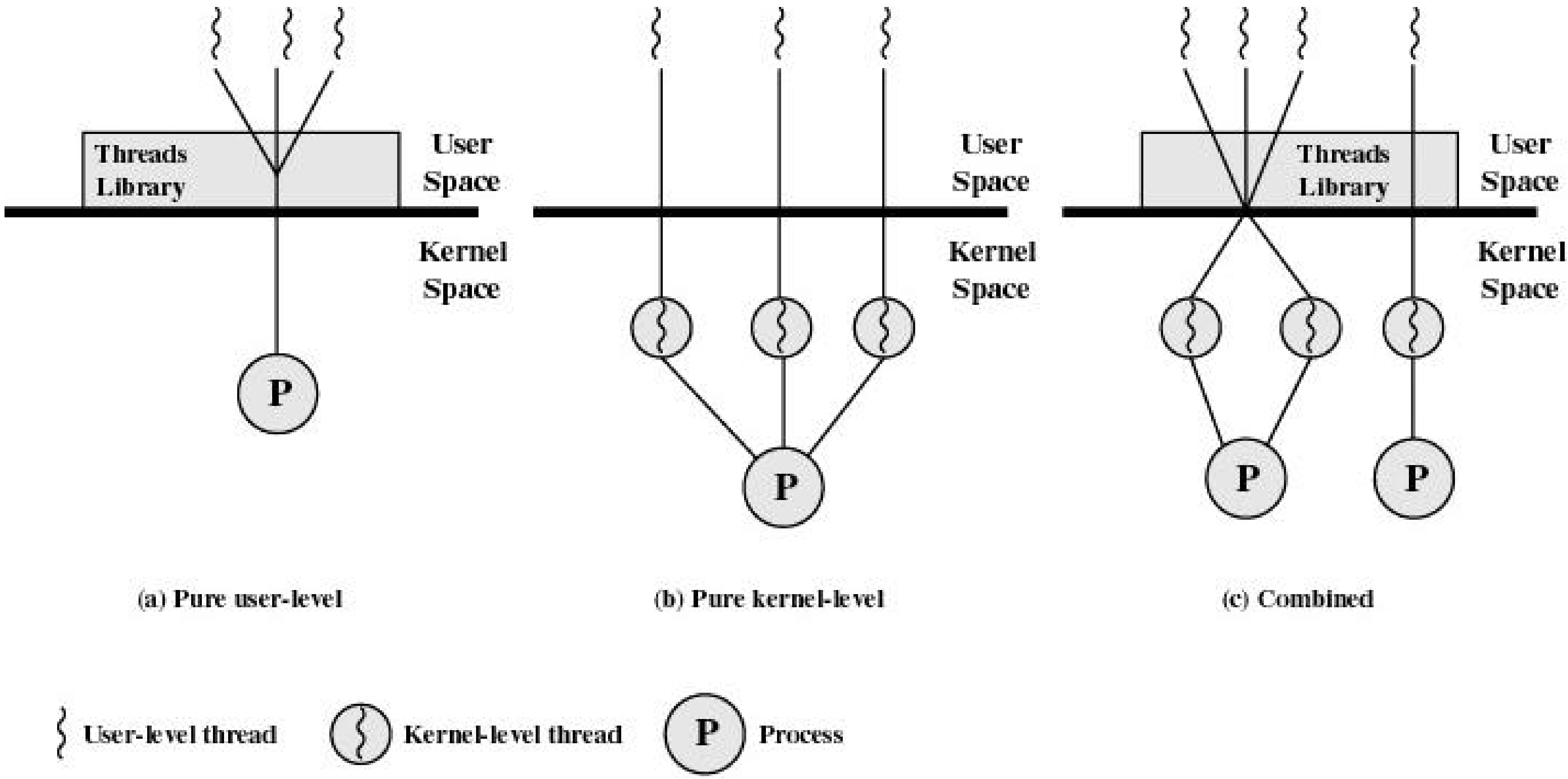


Figure 4.6 User-Level and Kernel-Level Threads

User-Level Threads

- All thread management is done by the application
  - kernel is not aware of the existence of threads
- Advantages of ULTs
  - thread switching does not require kernel mode privileges
  - scheduling is application specific
  - ULTs can run on any OS

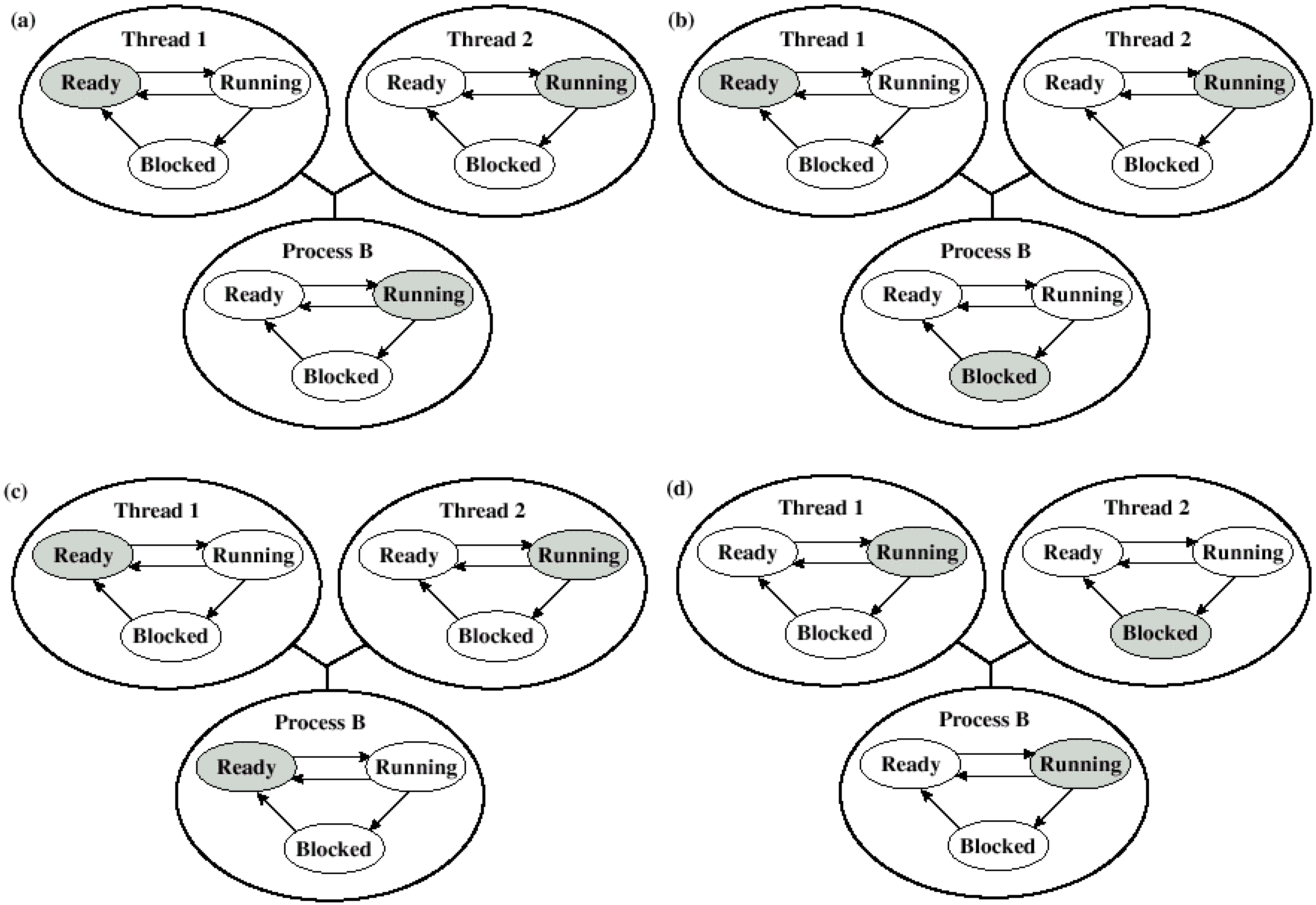


Figure 4.7 Examples of the relationship between User-level thread states and process states

User-Level Threads

- Disadvantages of ULTs
  - when a thread is blocked, all of the threads within that process are blocked
  - cannot take advantage of multiprocessing
    - kernel assigns one process to only one processor at a time

Kernel-Level Threads

- Windows 2000 and OS/2 are examples of this approach
- Kernel maintains the context information for the process and the threads
- Scheduling by the kernel is done on a thread basis

Combined Approaches for Threads

- Example is Solaris
- Thread creation done in the user space
  - as is bulk of scheduling and synchronization
- Multiple ULTs from a single application are mapped onto some(smaller or equal) 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

Relationship Between Threads and Processes

Threads:Process	Description	Example Systems
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:M	Combines attributes of M:1 and 1:M cases	TRIX

Categories of Computer Systems(by Flynn)

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

Categories of Computer Systems

- Multiple Instruction Single Data (MISD)
  - a sequence of data is transmitted to a set of processors, each of which executes a different instruction sequence. Never implemented
- Multiple Instruction Multiple Data (MIMD)
  - a set of processors simultaneously execute different instruction sequences on different data sets

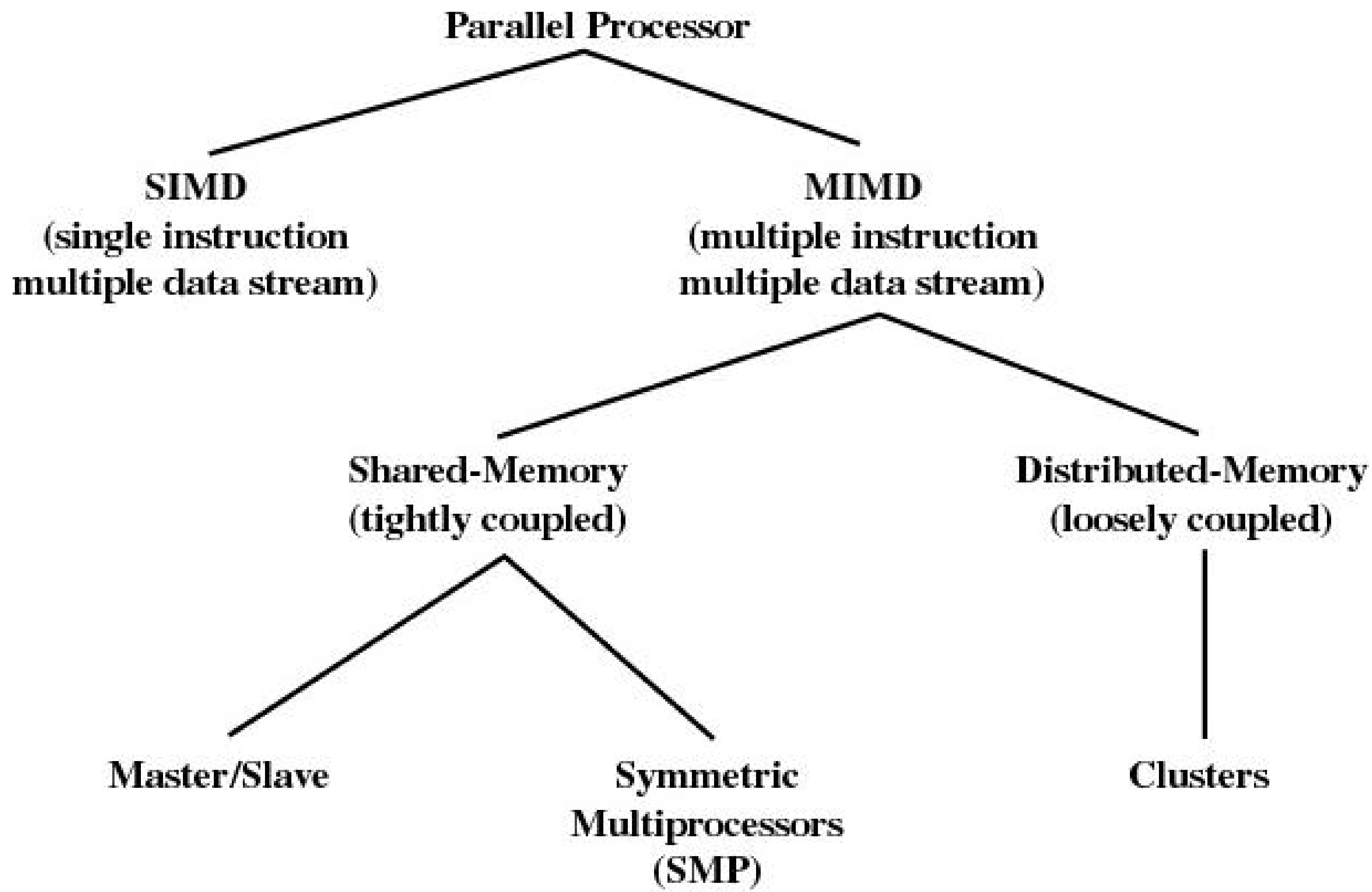


Figure 4.7 Parallel Processor Architectures

Symmetric Multiprocessing

- Kernel can execute on any processor
- Typically each processor does self-scheduling from the pool of available processes or threads

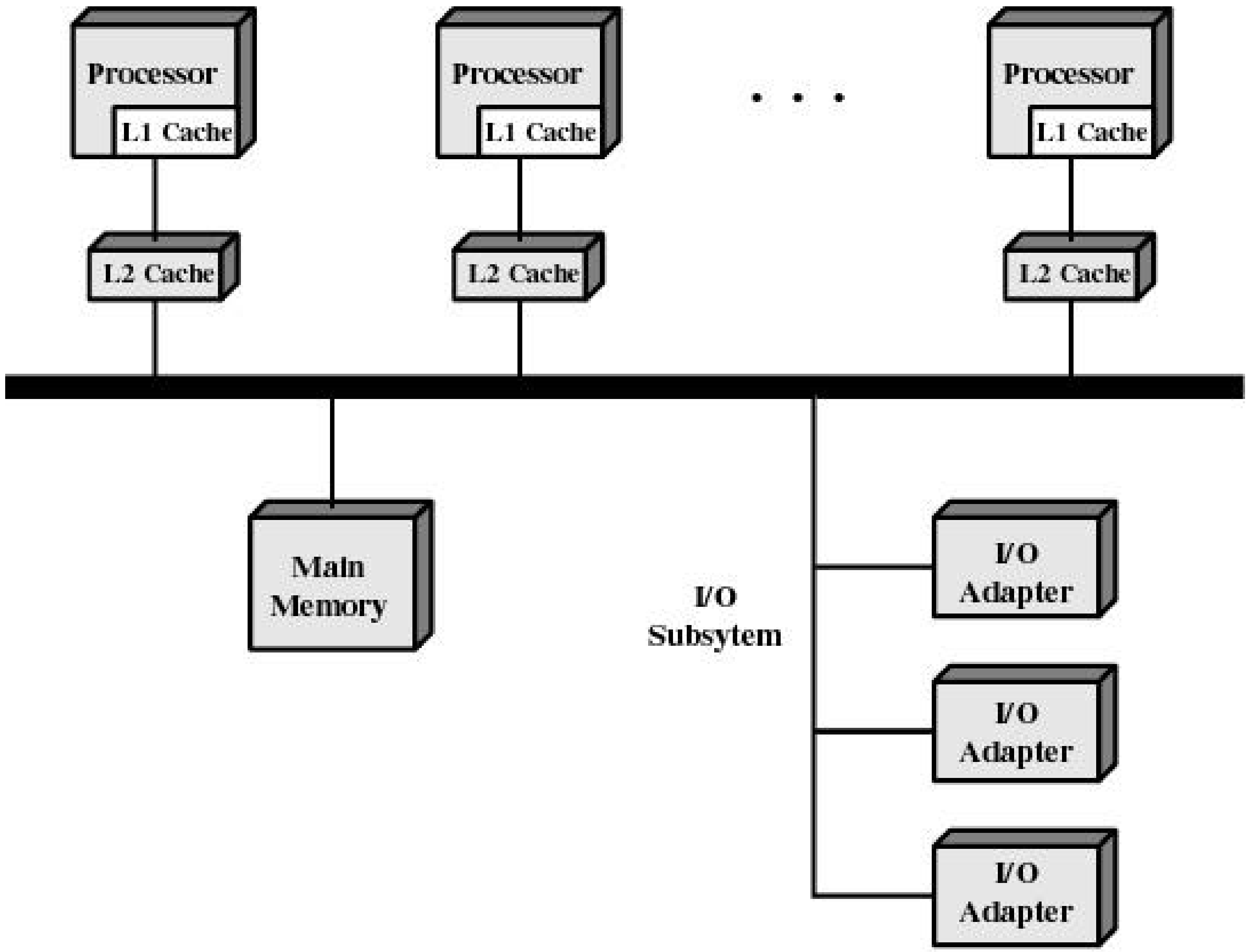


Figure 4.9 Symmetric Multiprocessor Organization

Multiprocessor Operating System Design Considerations

- Simultaneous concurrent processes or threads
  - kernel routines need to be reentrant
- Scheduling
  - may be performed by any processor
- Synchronization
- Memory Management
- Reliability and Fault Tolerance

Microkernel

- Small operating system core
- Contains only essential operating systems functions
- Many services traditionally included in the operating system are now external subsystems
  - device drivers
  - file systems
  - virtual memory manager
  - windowing system
  - security services

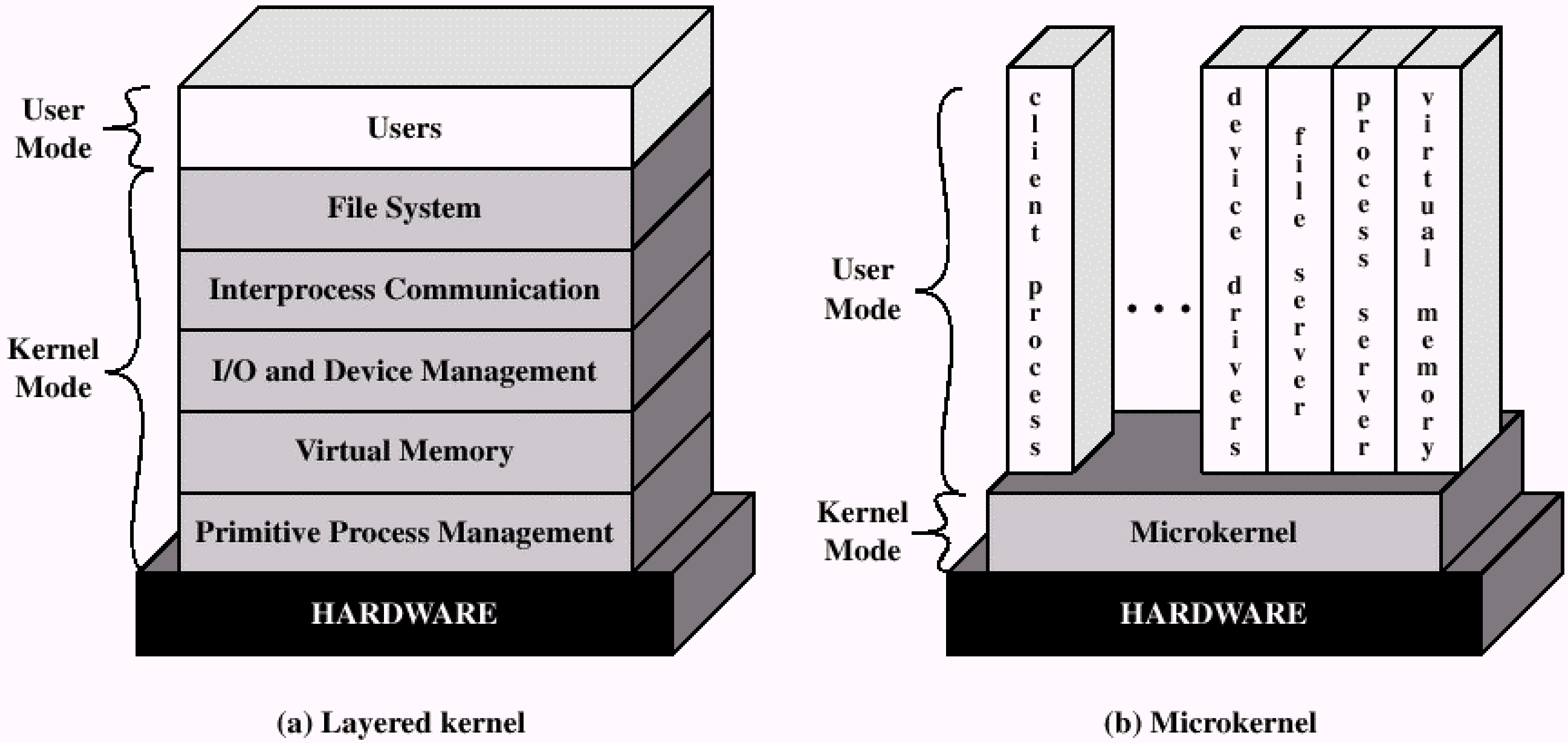


Figure 4.10 Kernel Architecture

Benefits of a Microkernel Organization

- Uniform interface on request made by a process
  - all services are provided by means of message passing
- Extensibility
  - allows the addition of new services
- Flexibility
  - not only can new features be added to OS, but existing features can be subtracted

Benefits of a Microkernel Organization

- Portability
  - almost all processor-specific code is in the microkernel
    - changes needed to port the system to a new processor are fewer and tend to be arranged in logical groupings
- Reliability
  - modular design
  - small microkernel can be rigorously tested

Benefits of Microkernel Organization

- Distributed system support
  - message can be sent without knowing what the target machine is
- Object-oriented operating system
  - components are objects with clearly defined interfaces that can be interconnected to form software

Microkernel Design

- Functions that must be included
  - Low-level memory management
    - mapping each virtual page to a physical page frame
  - Inter-process communication
    - message is the basic form
    - message passing between separate processes involves memory-to-memory copying
      - current research on thread-based IPC and memory sharing scheme
  - I/O and interrupt management

Windows 2000 Processes

- Implemented as objects
- An executable process may contain one or more threads
- Both process and thread objects have built-in synchronization capabilities

Process and its Resources

- Security access token
  - used to validate the user's ability to access secured objects
- Virtual address space
  - a series of blocks
- Object table
  - have handles to other objects known to this process
  - one handle exists for each thread contained in this object

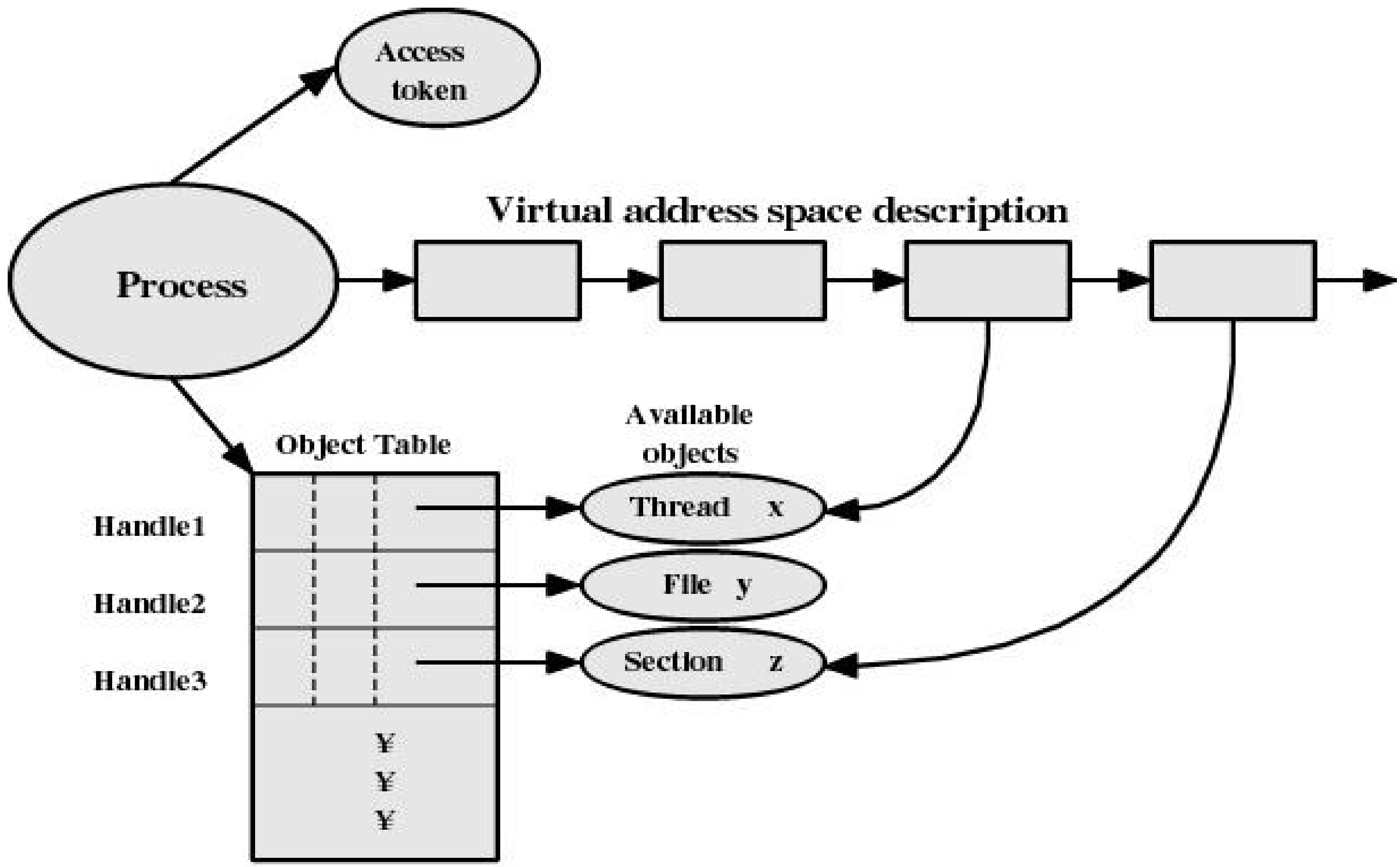
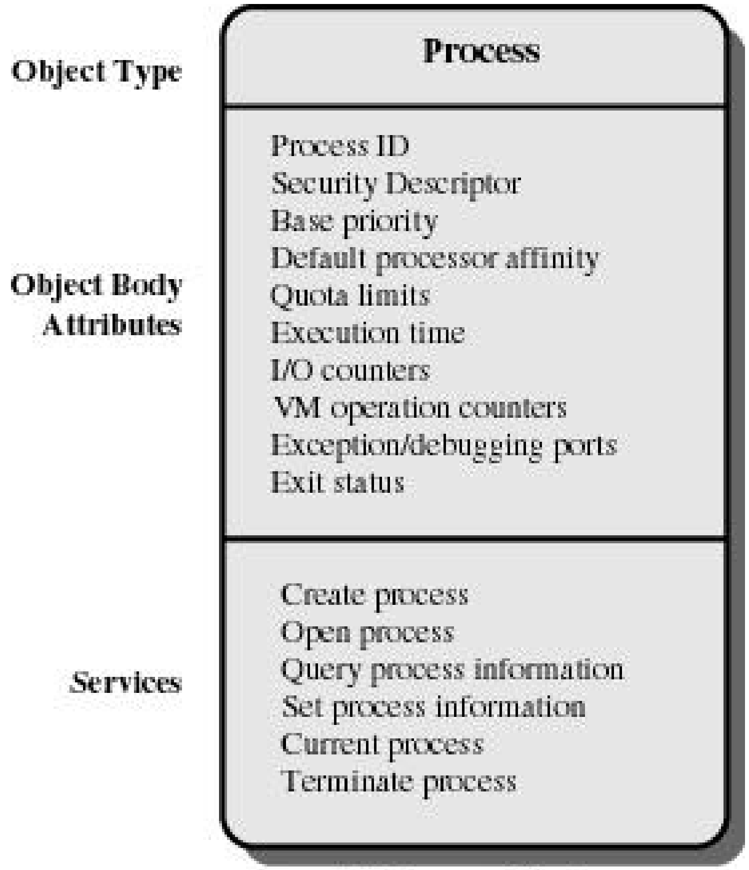


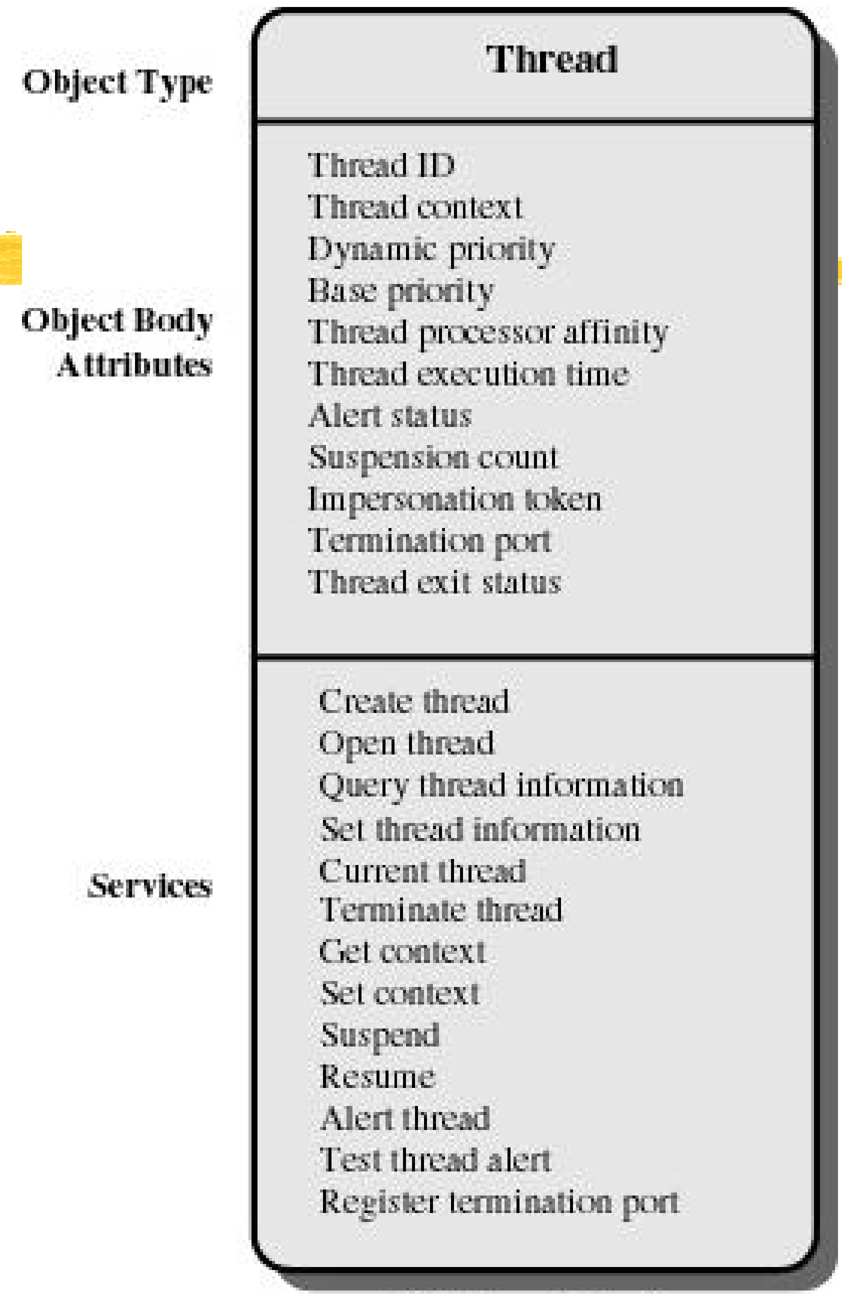
Figure 4.12 Windows 2000 Process and Its Resources

Windows 2000 Process Object



(a) Process object

Windows 2000 Thread Object



(b) Thread object

Multithreading

- Threads in different processes may execute concurrently
- Multiple threads within the same process may be allocated to separate processors and execute concurrently
- Threads in different processes can exchange information through shared memory that has been set up between the two processes

Windows 2000 Thread States

- Ready
- Standby : selected to run next
- Running
- Waiting : blocked
- Transition : ready to run but the resources are not available(e.g: stack may be paged out of memory)
- Terminated

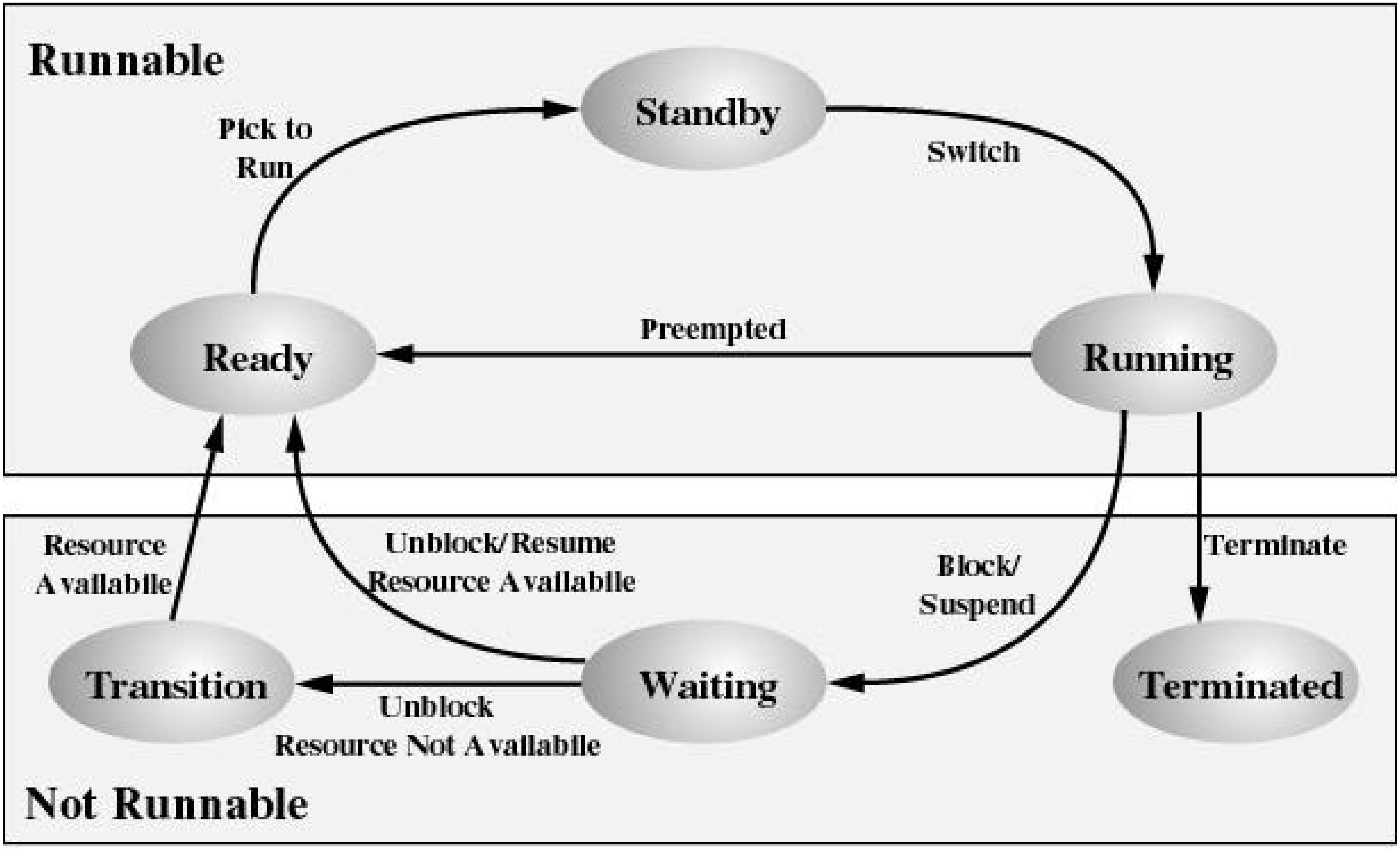


Figure 4.14 Windows 2000 Thread States

Solaris

- Thread-related concepts used by Solaris
  - Process
    - includes the user’s address space, stack, and process control block
  - User-level threads
    - implemented through a threads library
  - Lightweight processes
    - can be viewed as a mapping between ULTs and kernel threads
  - Kernel threads

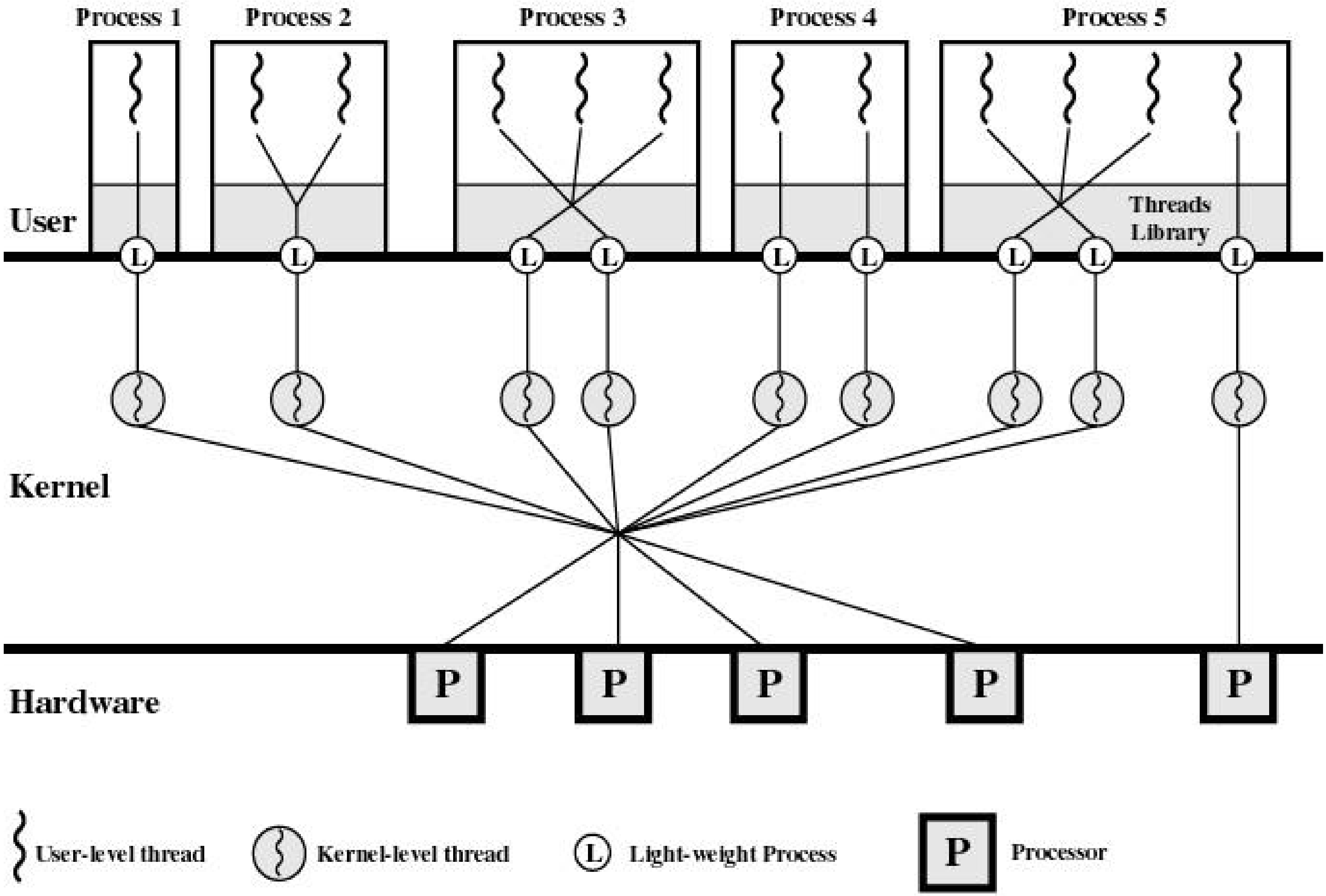


Figure 4.15 Solaris Multithreaded Architecture Example

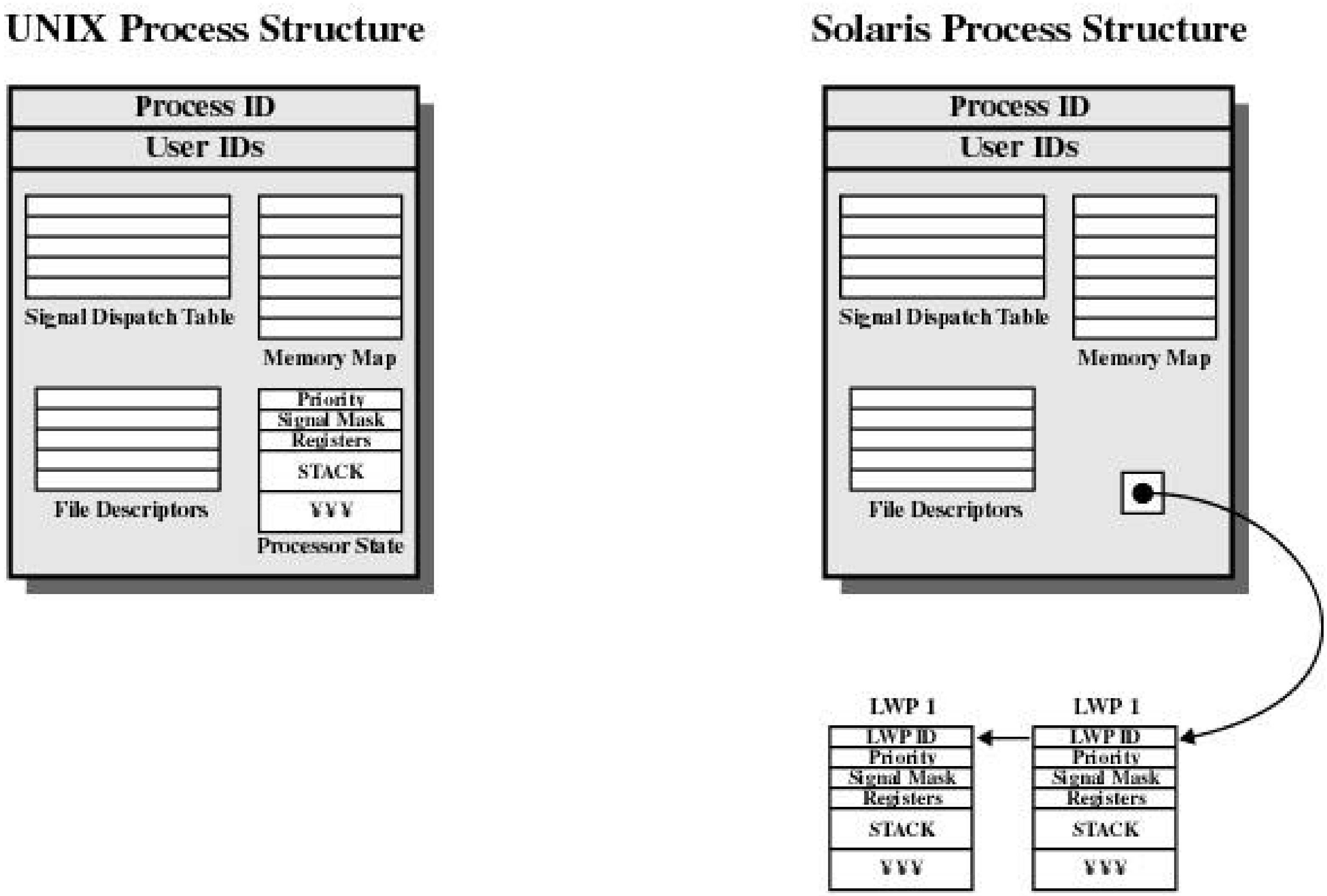


Figure 4.16 Process Structure in Traditional UNIX and Solaris [LEWI96]

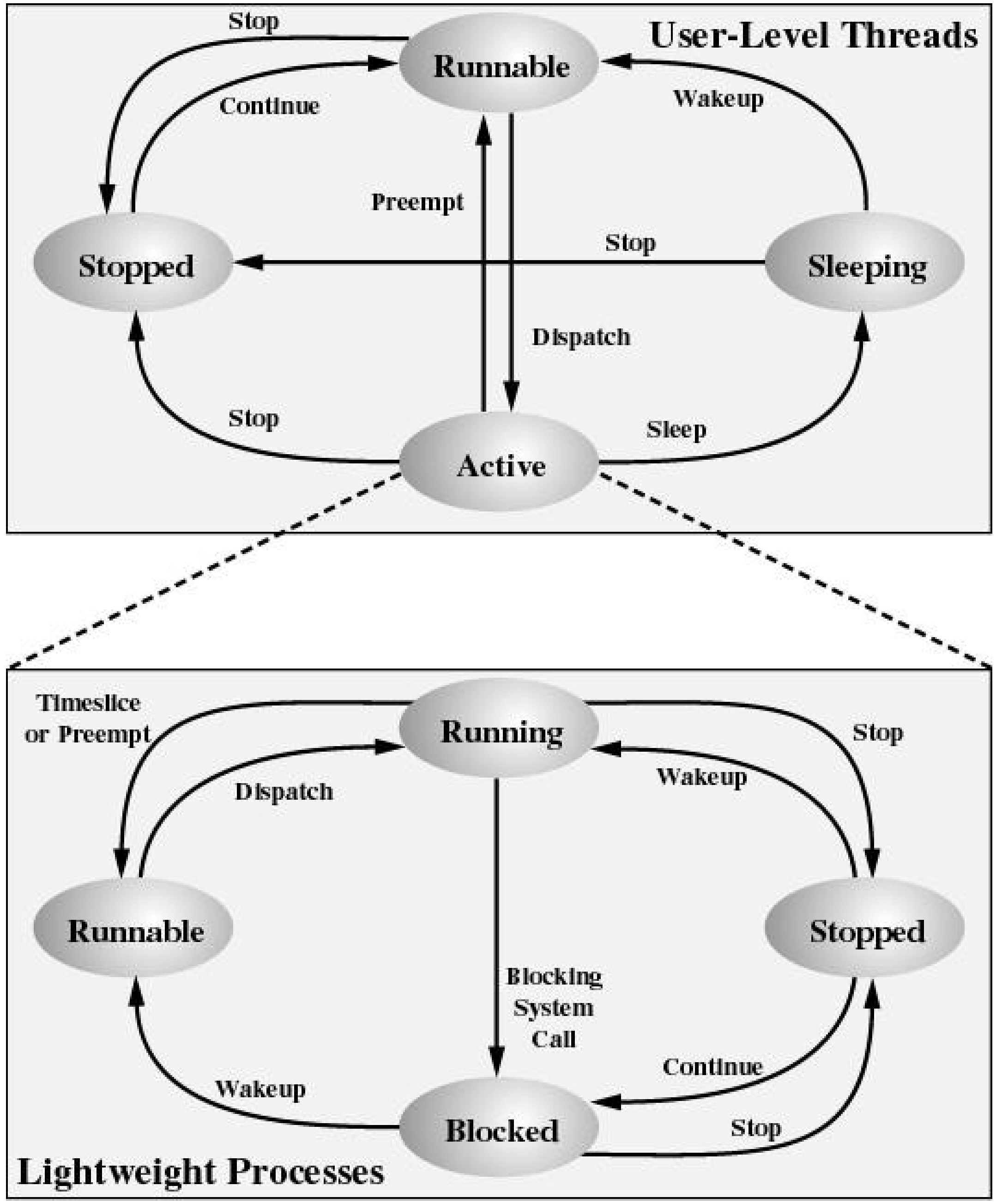


Figure 4.17 Solaris User-Level Thread and LWP States

Solaris Thread Execution

- Events of some transitions
  - Synchronization
    - invoke a concurrency action and go into the sleeping state
  - Suspension
    - go into the stopped state
  - Preemption
    - go into the runnable state
  - Yielding
    - yield to another runnable thread

Linux Process

- State
- Scheduling information
- Identifiers
- Interprocess communication : SVR4 is supported
- Links
- Times and timers
- File system
- Virtual memory
- Processor-specific context

Linux States of a Process

- Running
- Interruptable
  - blocked state
- Uninterruptable
  - another blocked state, but will not accept any signals
- Stopped
  - halted, and can only resume by positive action from another process
- Zombie

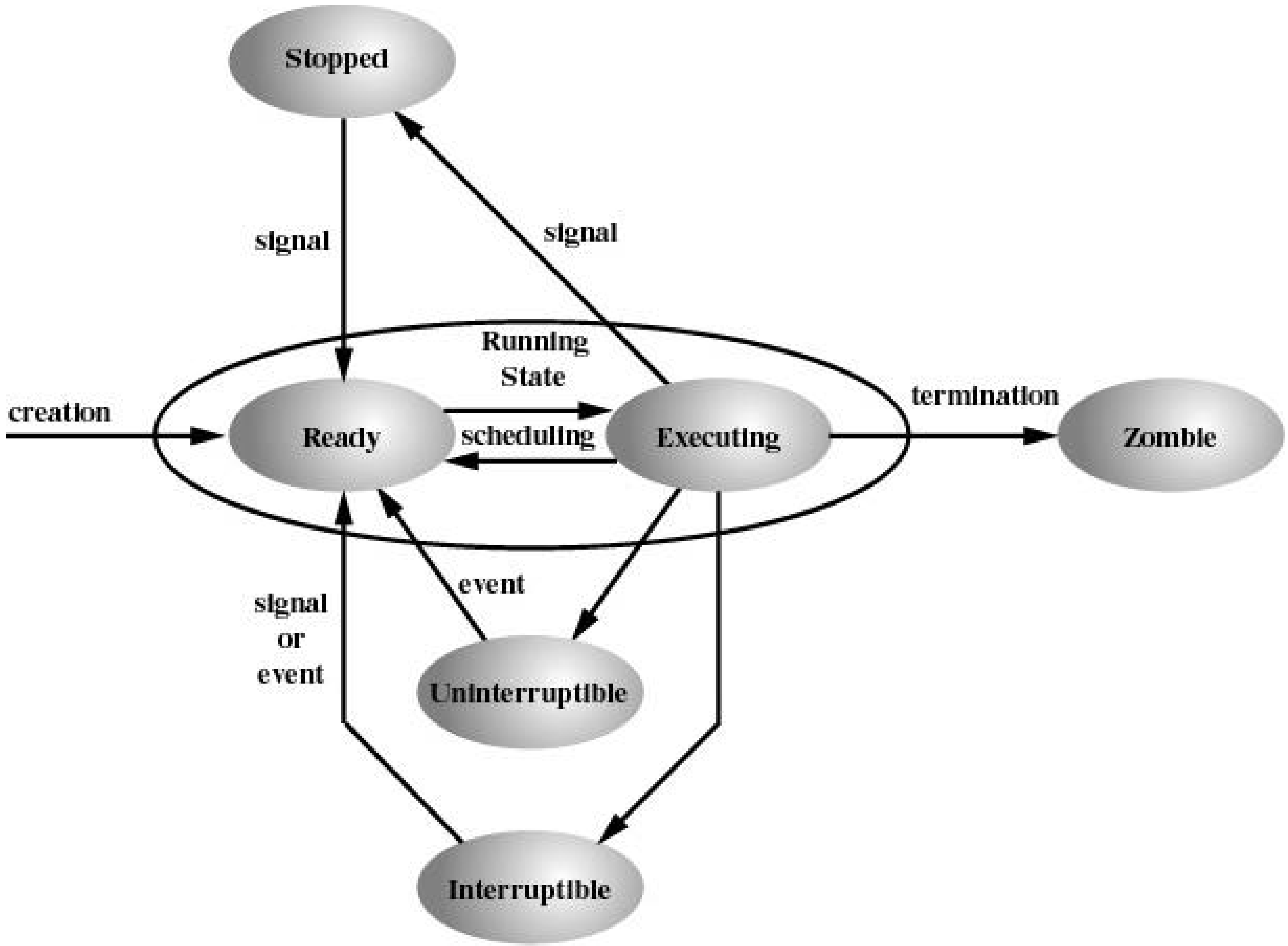


Figure 4.18 Linux Process/Thread Model