Chap. 2) System Structures

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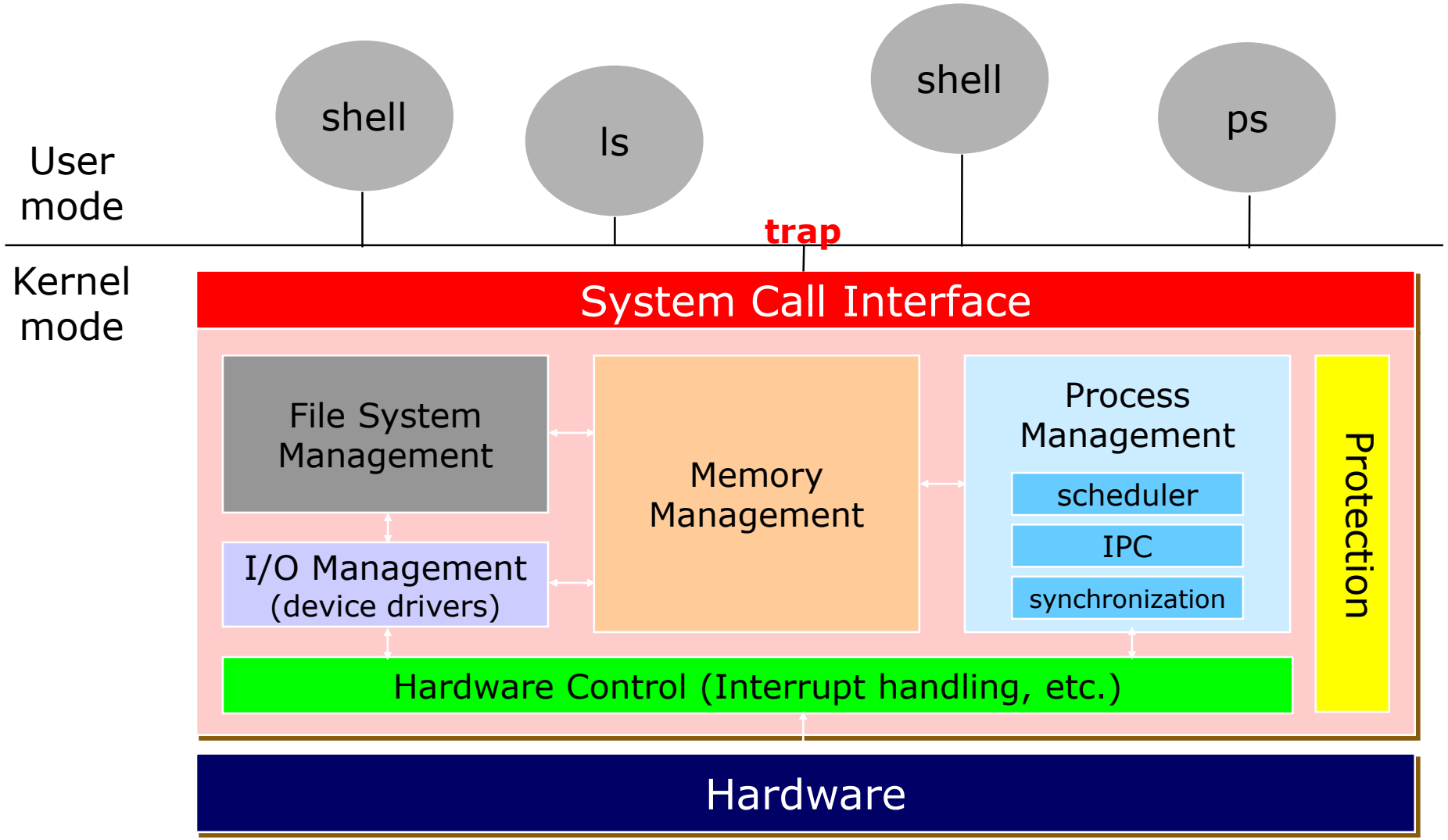
Common System Components

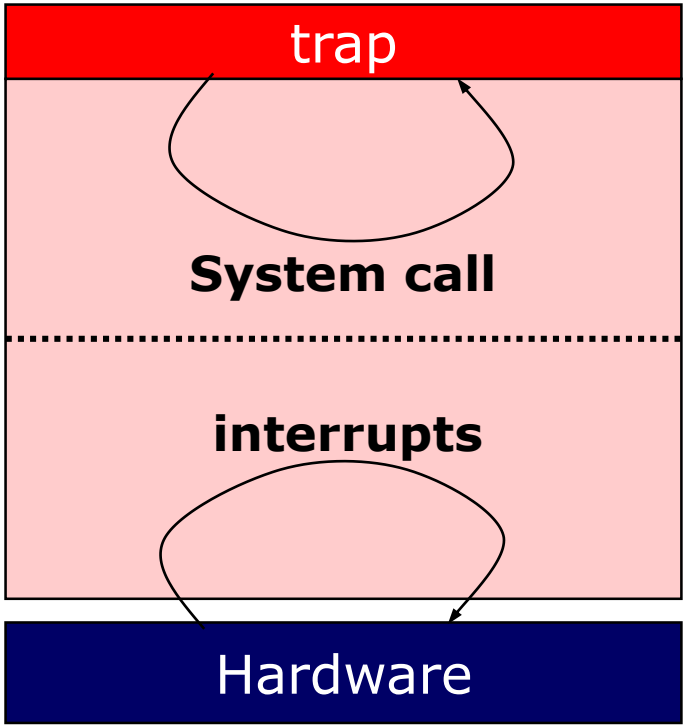
- Process Management
- Main Memory Management
- I/O System Management
- Secondary Storage Management
- File Management
- Networking
- Protection System
- Command-Interpreter System

Operating System Structure



Taking Control of the System

- Bootstrapping
- System calls
- Interrupts



Bootstrapping

- Linux Booting Process
  - ✓ The CPU initializes itself and then execute an instruction at a fixed location (0xffffff0).
  - ✓ This instruction jumps into the BIOS.
  - ✓ The BIOS finds a boot device and fetches its MBR (Master Boot Record), which points to LILO (Linux Loader).
  - ✓ The BIOS loads and transfers control to LILO.
  - ✓ LILO loads the compressed kernel.
  - ✓ The compressed kernel decompresses itself and transfers control to the uncompressed kernel.

Process Management

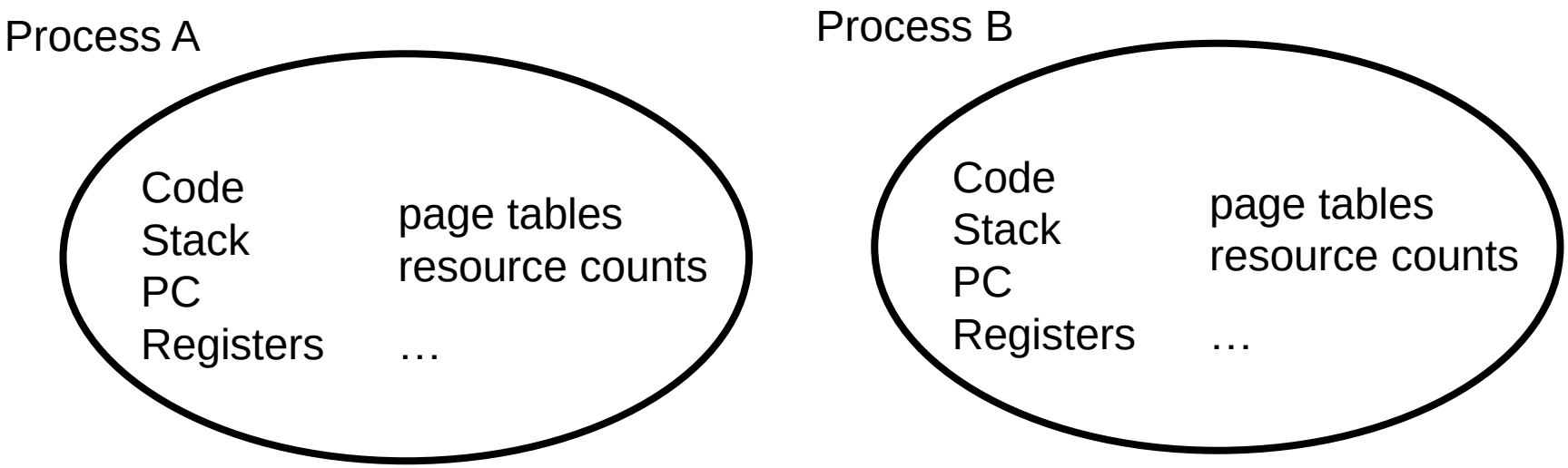
- A *process* is a program in execution
  - ✓ A process needs certain resources, including CPU time, memory, files, and I/O devices, to accomplish its task

- The operating system is responsible for the following activities in connection with process management
  - ✓ Process creation and deletion
  - ✓ process suspension and resumption
  - ✓ Provision of mechanisms for:
    - process synchronization
    - process communication

Program vs. Process

- A program is a passive thing – just a file on the disk with code that is *potentially* runnable

- A process is one instance of a program *in execution*;
at any instance, there may be many processes running copies of a single program (e.g., an editor): each is a *separate, independent* process



Main-Memory Management

- Memory is a large array of words or bytes, each with its own address
  - ✓ It is a repository of quickly accessible data shared by the CPU and I/O devices
- Main memory is a volatile storage device
  - ✓ It loses its contents in the case of system failure
- The operating system is responsible for the following activities in connections with memory management:
  - ✓ Keep track of which parts of memory are currently being used and by whom
  - ✓ Decide which processes to load when memory space becomes available
  - ✓ Allocate and deallocate memory space as needed

File Management

- A file is a collection of related information defined by its creator
  - ✓ Commonly, files represent programs (both source and object forms) and data

- The operating system is responsible for the following activities in connections with file management:
  - ✓ File creation and deletion
  - ✓ Directory creation and deletion
  - ✓ Support of primitives for manipulating files and directories
  - ✓ Mapping files onto secondary storage
  - ✓ File backup on stable (nonvolatile) storage media

File System

- A convenient abstraction for the secondary storage
  - ✓ Defines logical objects (files, directories)
  - ✓ Defines logical operations

- File
  - ✓ Named collection of persistent information
  - ✓ The basic long-term storage unit

- Directory (folder)
  - ✓ Named file that contains names of other files and metadata about those files

I/O System Management

- The I/O system consists of:
  - ✓ A buffer-caching system
  - ✓ A general device-driver interface
  - ✓ Drivers for specific hardware devices

- *I/O Abstraction*
  - ✓ The OS provides a standard interface between programs and devices
  - ✓ File system, Sockets, I/O devices, etc.

Secondary-Storage Management

- Since main memory (*primary storage*) is volatile and too small to accommodate all data and programs permanently, the computer system must provide *secondary storage* to back up main memory

- Most modern computer systems use disks as the principle on-line storage medium, for both programs and data

- The operating system is responsible for the following activities in connection with disk management:
  - ✓ Free space management
  - ✓ Storage allocation
  - ✓ Disk scheduling

Networking (Distributed Systems)

- A *distributed* system is a collection processors that do not share memory or a clock
- Each processor has its own local memory
- The processors in the system are connected through a communication network
- Communication takes place using a *protocol*
- A distributed system provides user access to various system resources
- Access to a shared resource allows:
  - ✓ Computation speed-up
  - ✓ Increased data availability
  - ✓ Enhanced reliability

Protection System

- *Protection* refers to a mechanism for controlling access by programs, processes, or users to both system and user resources

- The protection mechanism must:
  - ✓ distinguish between authorized and unauthorized usage
  - ✓ specify the controls to be imposed
  - ✓ provide a means of enforcement

Command-Interpreter System

- Many commands are given to the operating system by control statements which deal with:
  - ✓ process creation and management
  - ✓ I/O handling
  - ✓ secondary-storage management
  - ✓ main-memory management
  - ✓ file-system access
  - ✓ protection
  - ✓ networking

- The program that reads and interprets control statements is called variously:
  - ✓ command-line interpreter
  - ✓ shell (in UNIX)

- Its function is to get and execute the next command statement

Command-Interpreter System

- Shell
  - ✓ A particular program that handles the interpretation of users' commands
  - ✓ Helps to manage processes

- Types
  - ✓ A standard part of the OS
    - MS-DOS, Apple II
  - ✓ A non-privileged process
    - sh / csh / tcsh / zsh / ksh on UNIX
  - ✓ No command interpreter
    - MacOS

Operating System Services

- User interface
  - ✓ Command-line interface (CLI) vs. Graphical user interface (GUI)
- Program execution
  - ✓ system capability to load a program into memory and to run it
- I/O operations
  - ✓ since user programs cannot execute I/O operations directly, the operating system must provide some means to perform I/O
- File-system manipulation
  - ✓ program capability to read, write, create, and delete files
- Communications
  - ✓ exchange of information between processes executing either on the same computer or on different systems tied together by a network (Implemented via *shared memory* or *message passing)*
- Error detection
  - ✓ ensure correct computing by detecting errors in the CPU and memory hardware, in I/O devices, or in user programs

Additional Operating System Functions

- Additional functions exist not for helping the user, but rather for ensuring efficient system operations
  - ✓ Resource allocation
    - allocating resources to multiple users or multiple jobs running at the same time
  - ✓ Accounting
    - keep track of and record which users use how much and what kinds of computer resources for account billing or for accumulating usage statistics
  - ✓ Protection
    - ensuring that all access to system resources is controlled

System Calls

- System calls provide the interface between a running program and the operating system
  - ✓ Generally available as assembly-language instructions
  - ✓ Languages defined to replace assembly language for systems programming allow system calls to be made directly (e.g., C, C++)

- Three general methods are used to pass parameters between a running program and the operating system
  - ✓ Pass parameters in *registers*
  - ✓ Store the parameters in a table in memory, and the table address is passed as a parameter in a register
  - ✓ *Push* (store) the parameters onto the *stack* by the program, and *pop* off the stack by operating system

Types of System Calls

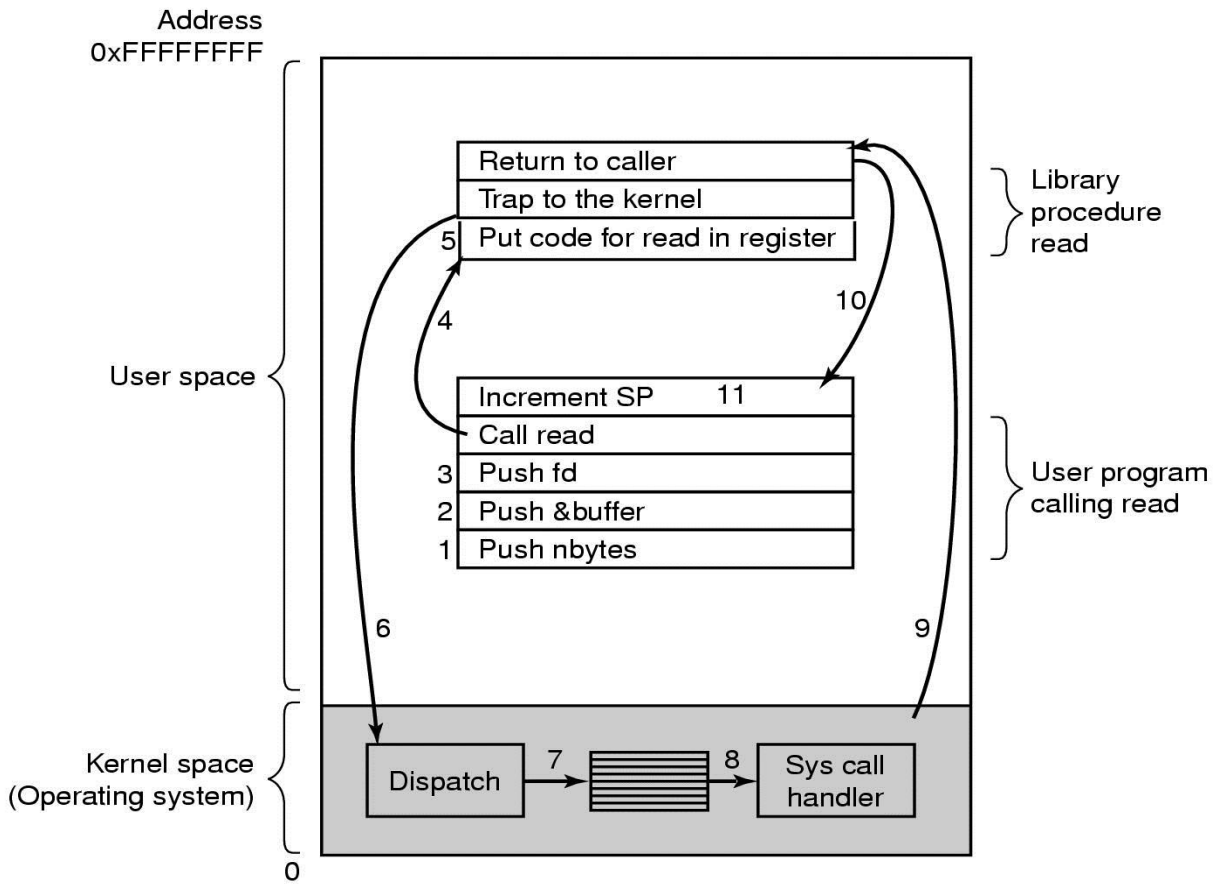
- Process control
- File management
- Device management
- Information maintenance
- Communications

System Calls

Process Management	**fork**	**CreateProcess**	Create a new process
	waitpid	**WaitForSingleObject**	Wait for a process to exit
	execve	**(none)**	CreateProcess = fork + execve
	exit	**ExitProcess**	Terminate execution
	kill	**(none)**	Send a signal
File Management	**open**	**CreateFile**	Create a file or open an existing file
	close	**CloseHandle**	Close a file
	read	**ReadFile**	Read data from a file
	write	**WriteFile**	Write data to a file
	lseek	**SetFilePointer**	Move the file pointer
	stat	**GetFileAttributesEx**	Get various file attributes
	chmod	**(none)**	Change the file access permission
File System Management	**mkdir**	**CreateDirectory**	Create a new directory
	rmdir	**RemoveDirectory**	Remove an empty directory
	link	**(none)**	Make a link to a file
	unlink	**DeleteFile**	Destroy an existing file
	mount	**(none)**	Mount a file system
	umount	**(none)**	Unmount a file system
	chdir	**SetCurrentDirectory**	Change the curent working directory

Invoking a System Call

```
count = read (fd, buffer, nbytes);
```



System Programs

- System programs provide a convenient environment for program development and execution. They can be divided into:
  - ✓ File manipulation
  - ✓ Status information
  - ✓ File modification
  - ✓ Programming language support
  - ✓ Program loading and execution
  - ✓ Communications
  - ✓ Application programs

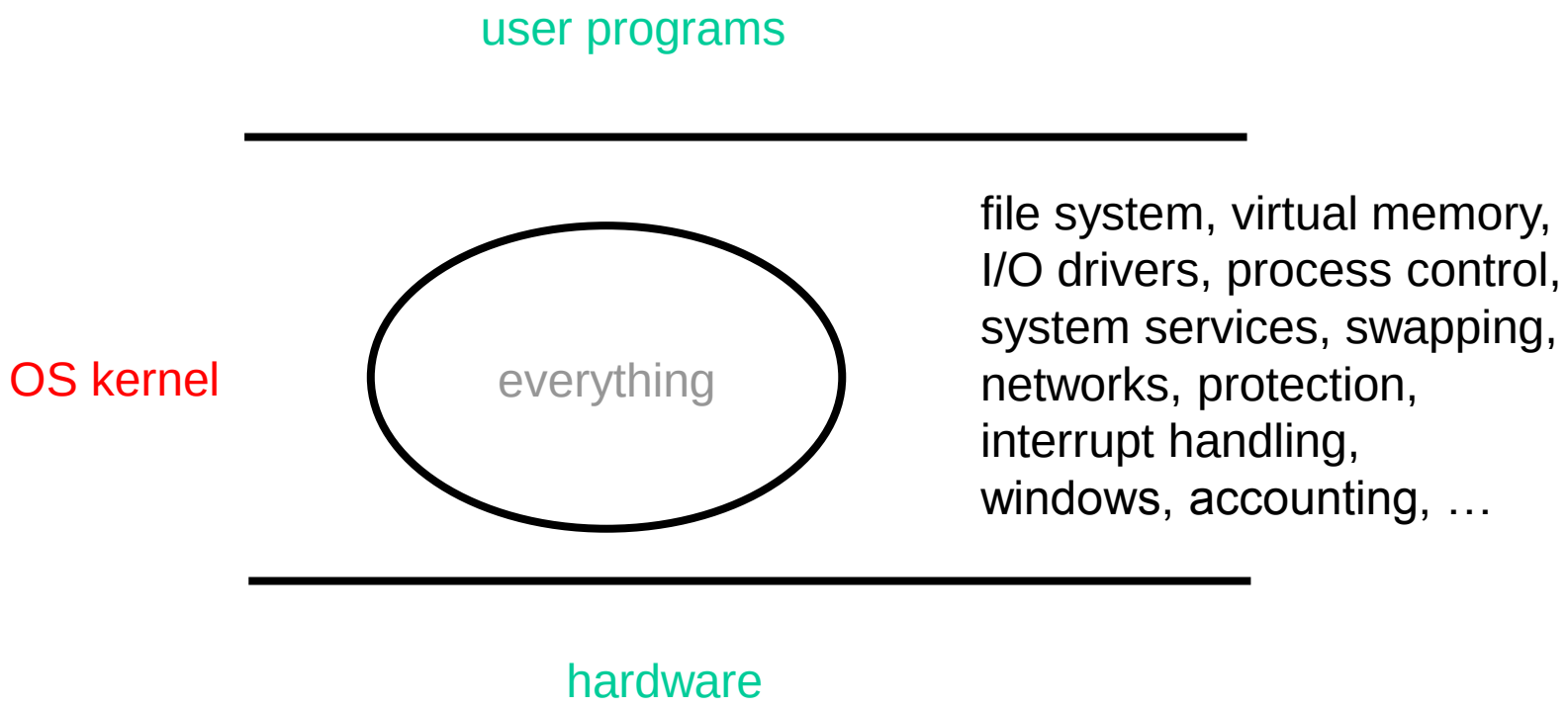
- Most users' view of the operation system is defined by system programs, not the actual system calls

OS Structure

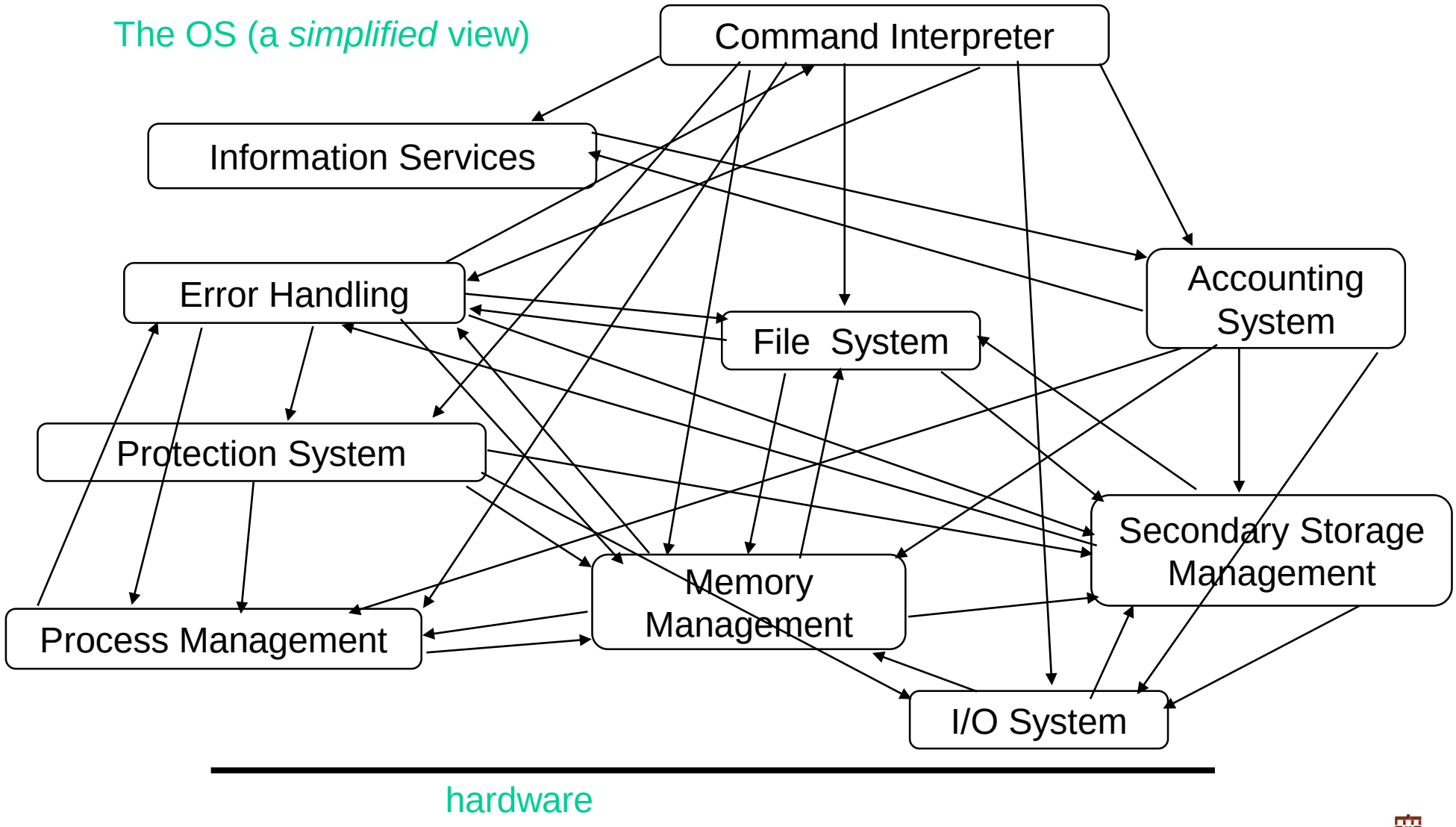
- An OS consists of all of these components, plus lots of others, plus system service routines, plus system programs(privileged and non-privileged), plus …
- The big issue:
  - ✓ How do we organize all of this?
  - ✓ What are the entities and where do they exist?
  - ✓ How does these entities cooperate?
- Basically, how do we build a complex system that's:
  - ✓ Performance
  - ✓ Reliable
  - ✓ Extensible

OS Structure (Cont'd)

- Traditionally, systems such as Unix were built as a *monolithic* kernel:



OS Structure (Cont'd)



MS-DOS System Structure

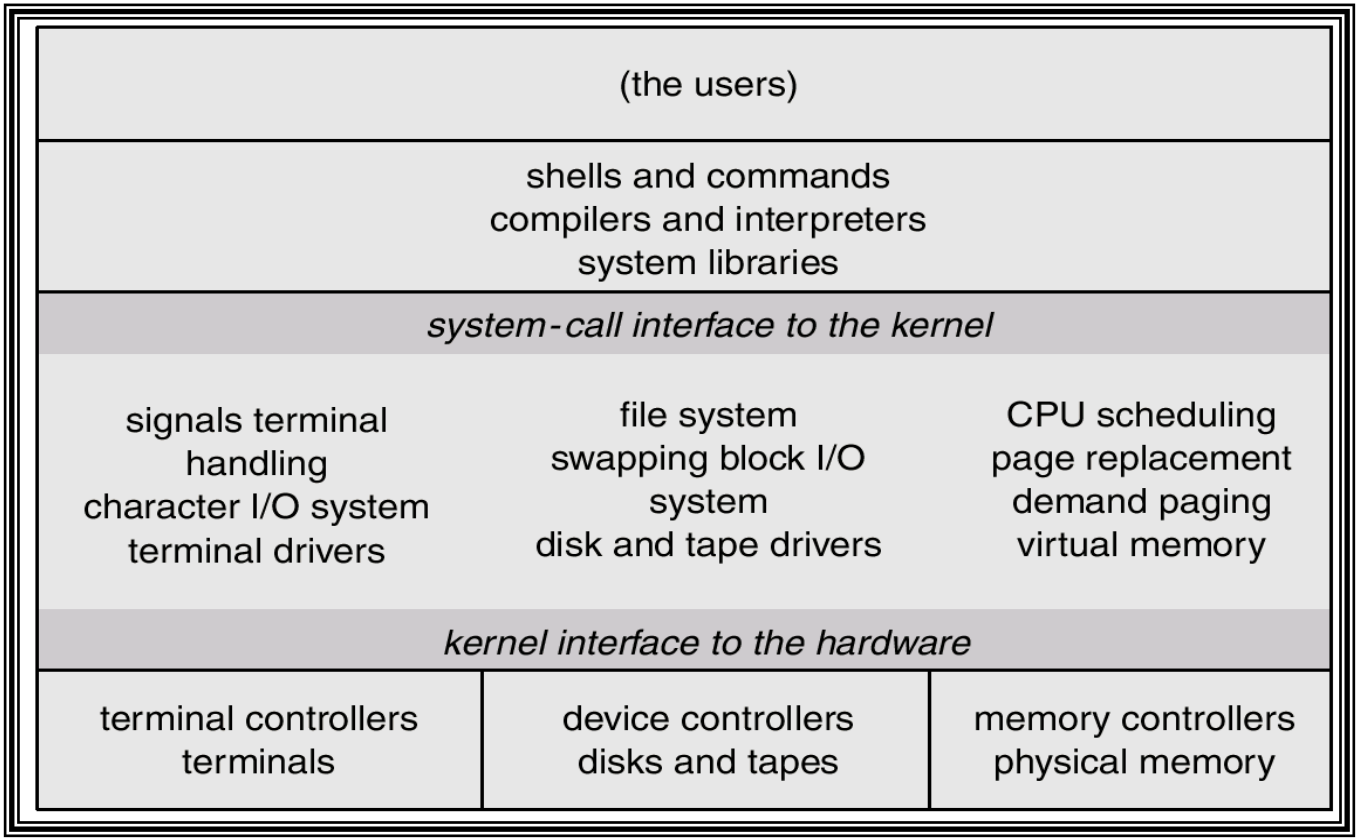
- MS-DOS – written to provide the most functionality in the least space
  - ✓ not divided into modules
  - ✓ Although MS-DOS has some structure, its interfaces and levels of functionality are not well separated

UNIX System Structure

- UNIX – limited by hardware functionality, the original UNIX operating system had limited structuring

- The UNIX OS consists of two separable parts
  - ✓ Systems programs
  - ✓ The kernel
    - Consists of everything below the system-call interface and above the physical hardware
    - Provides the file system, CPU scheduling, memory management, and other operating-system functions; a large number of functions for one level

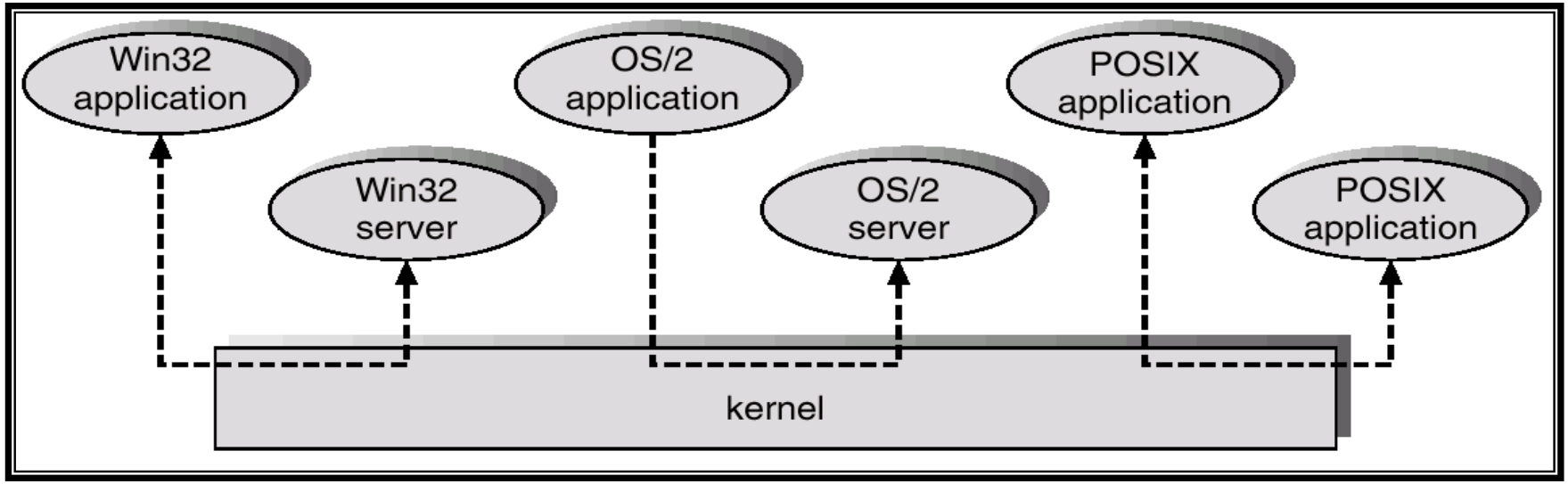
UNIX System Structure (Cont'd)



Microkernel System Structure

- Moves as much from the kernel into "*user*" space
- Communication takes place between user modules using message passing
- Benefits:
  - ✓ easier to extend a microkernel
  - ✓ easier to port the operating system to new architectures
  - ✓ more reliable (less code is running in kernel mode)
  - ✓ more secure

Windows NT Client-Server Structure



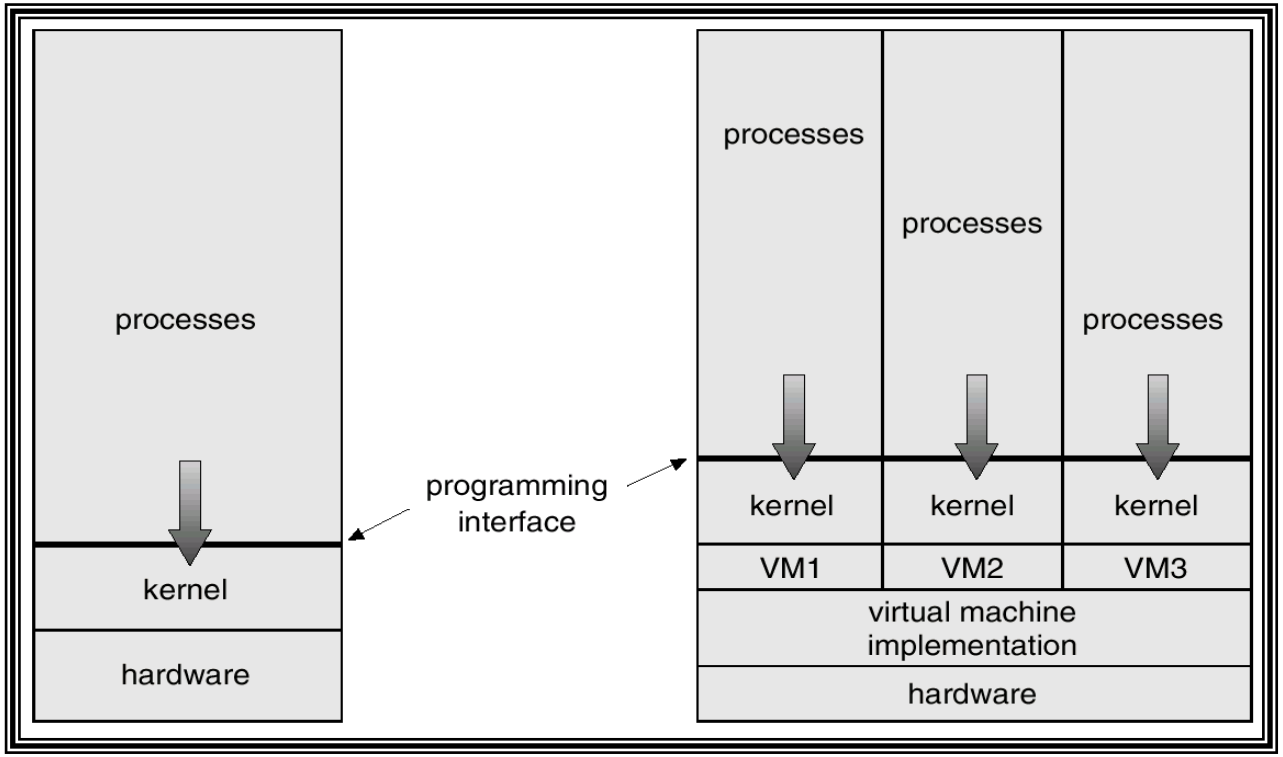
Virtual Machines

- A *virtual machine* takes the layered approach to its logical conclusion
  - ✓ It treats hardware and the operating system kernel as though they were all hardware
- A virtual machine provides an interface *identical* to the underlying bare hardware
- The operating system creates the illusion of multiple processes, each executing on its own processor with its own (virtual) memory

Virtual Machines (Cont'd)

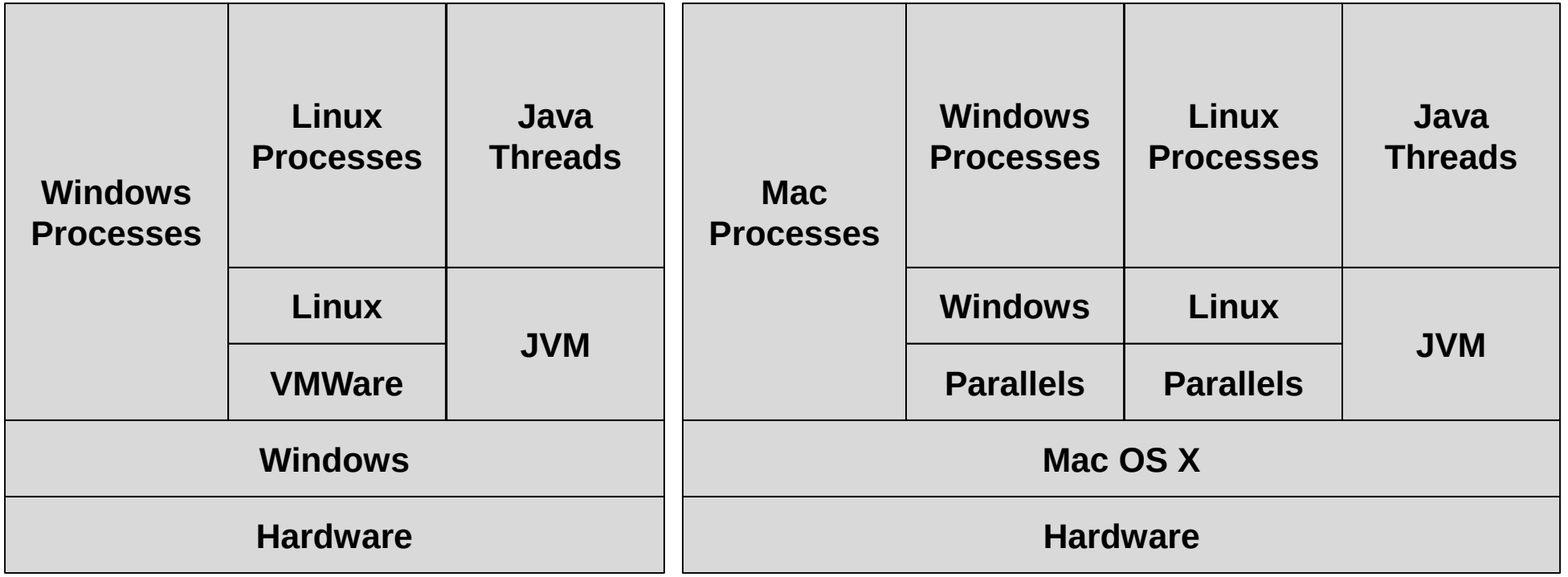
- The resources of the physical computer are shared to create the virtual machines
  - ✓ CPU scheduling can create the appearance that users have their own processor
  - ✓ Spooling and a file system can provide virtual card readers and virtual line printers
  - ✓ A normal user time-sharing terminal serves as the virtual machine operator's console

System Models



Non-virtual Machine Virtual Machine

Virtual Machine Examples



Advantages/Disadvantages of Virtual Machines

- The virtual-machine concept provides complete protection of system resources since each virtual machine is isolated from all other virtual machines
- This isolation, however, permits no direct sharing of resources
- A virtual-machine system is a perfect vehicle for operating-systems research and development
- System development is done on the virtual machine, instead of on a physical machine and so does not disrupt normal system operation
- The virtual machine concept is difficult to implement due to the effort required to provide an *exact* duplicate to the underlying machine

Java Virtual Machine

- Compiled Java programs are platform-neutral byte-codes executed by a Java Virtual Machine (JVM)

- JVM consists of
  - class loader
  - class verifier
  - runtime interpreter

- Just-In-Time (JIT) compilers increase performance

Summary

- Operating system component
  - ✓ Process management
  - ✓ Main memory management
  - ✓ File management
  - ✓ Secondary storage management
  - ✓ I/O system management
  - ✓ Protection system
  - ✓ Command-interpreter system
  - ✓ Networking system
- Operating system implementation
  - ✓ Monolithic-kernel
    - All the OS components are implemented into one big image
  - ✓ Micro-kernel
    - Only primitive functions are implemented into a small kernel
    - A lot of components are moved from the kernel to user server processes

Summary (Cont'd)

- Virtual machine
  - ✓ Provides an interface identical to the underlying bare hardware
  - ✓ The operating system creates the illusion of multiple processes of which each is executing on its own (virtual) processor with its own (virtual) memory