3. Operating-System Structures

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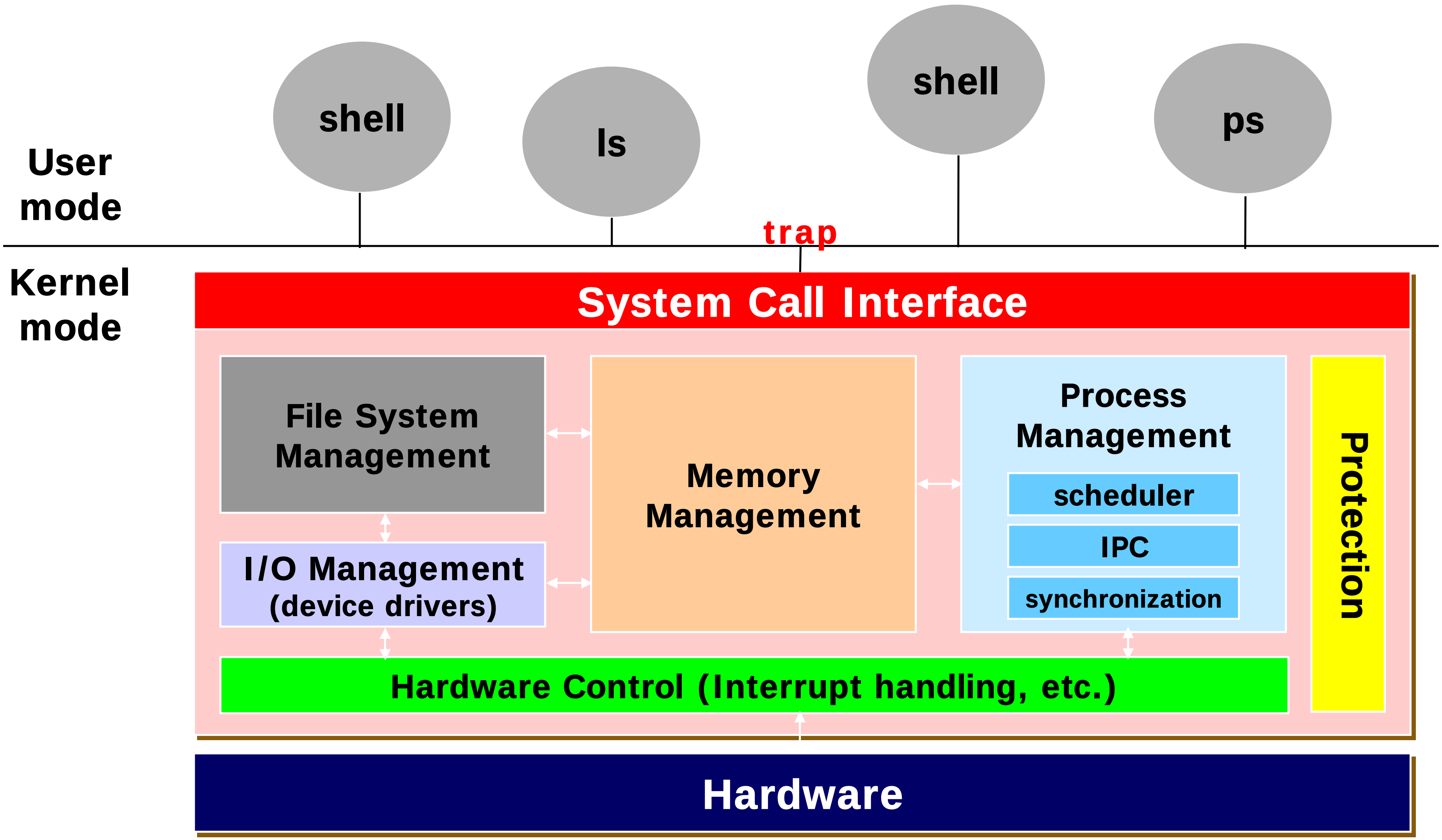
Contents

- *System Components*
- *Operating System Services*
- *System Calls*
- *System Programs*
- *System Structure*
- *Virtual Machines*
- *System Design and Implementation*
- *System Generation*

Common System Components

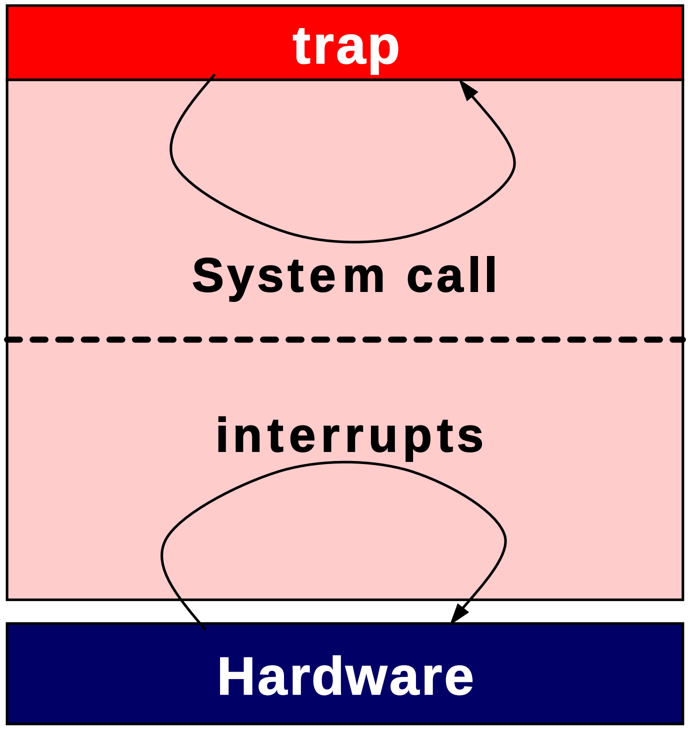
- Process Management
- Main Memory Management
- File Management
- I/O System Management
- Secondary Management
- Networking
- Protection System
- Command-Interpreter System

Operating System Structure



Taking Control of the System

- Bootstrapping
- System calls
- Interrupts



Process Management

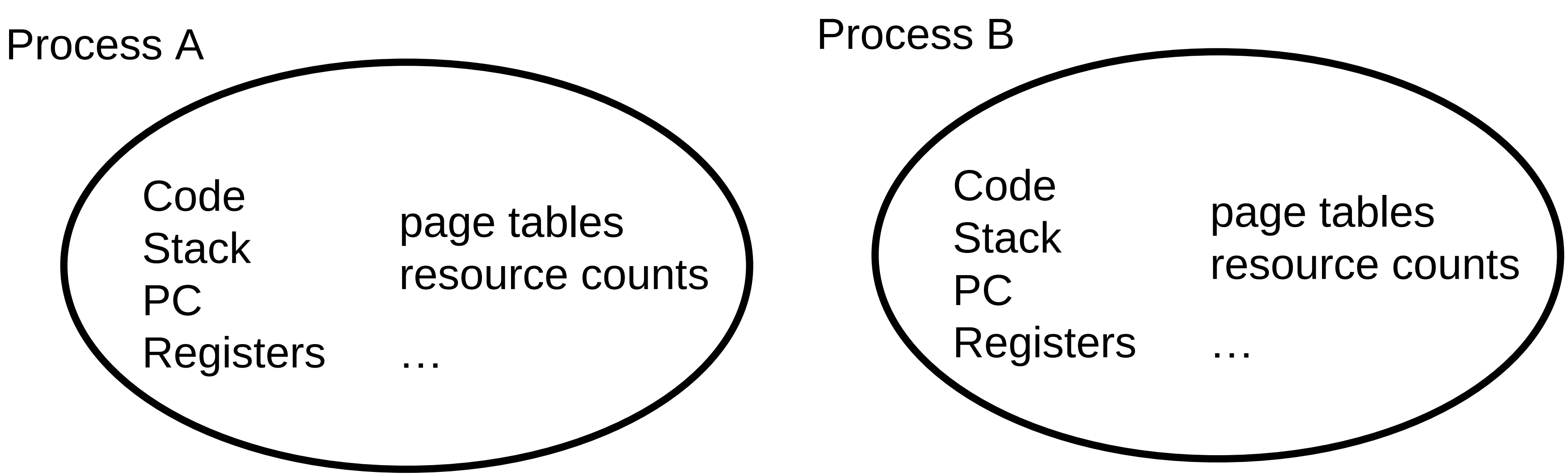
- A *process* is a program in execution
  - A process needs certain resources, including CPU time, memory, files, and I/O devices, to accomplish its task

- 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 <u>program</u> is a passive thing – just a file on the disk with code that is *potentially* runnable

- A <u>process</u> 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

Protection System

- Protection is a general mechanism throughout the OS

- All resources objects need to protection
  - Memory
  - Processes
  - Files
  - Devices

- Protection mechanisms help to detect errors as well as to prevent malicious destruction

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

- 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

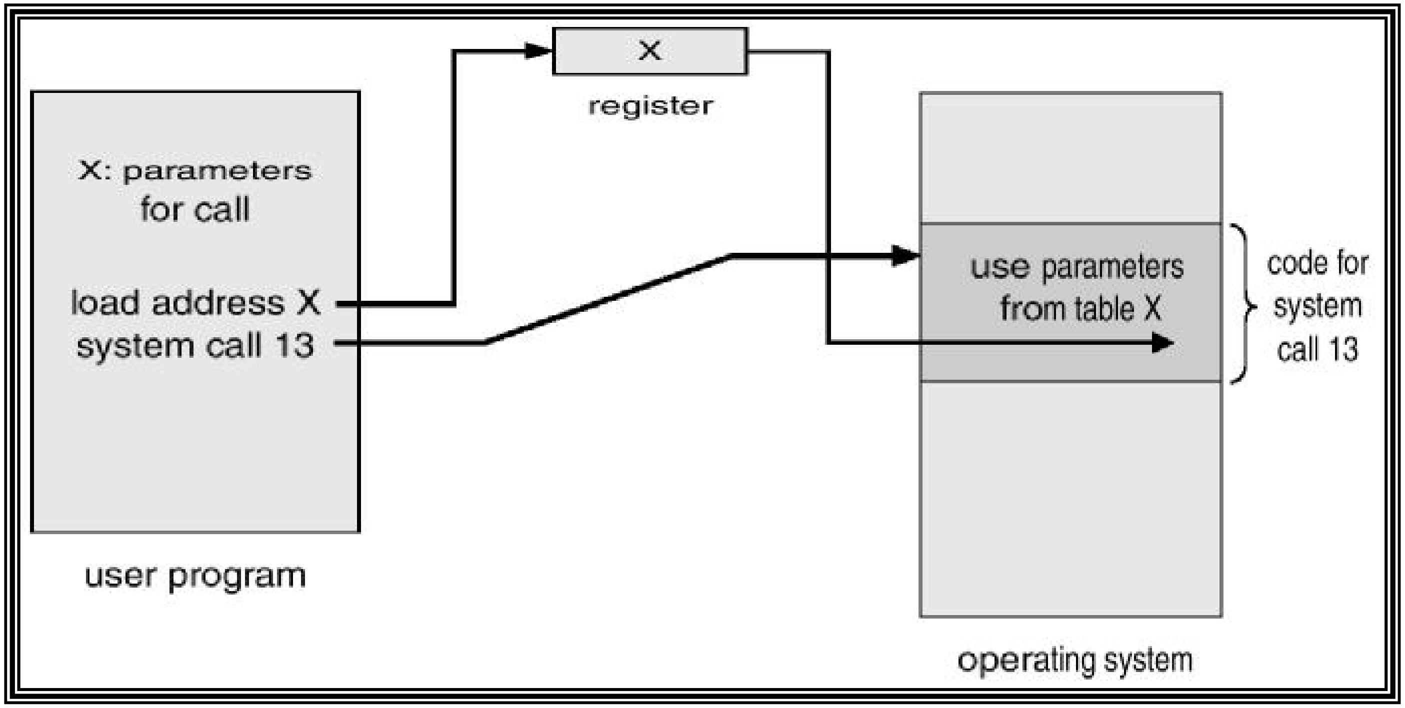
Additional Operating System Functions

- 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

Passing of Parameters As A Table



Types of System Calls

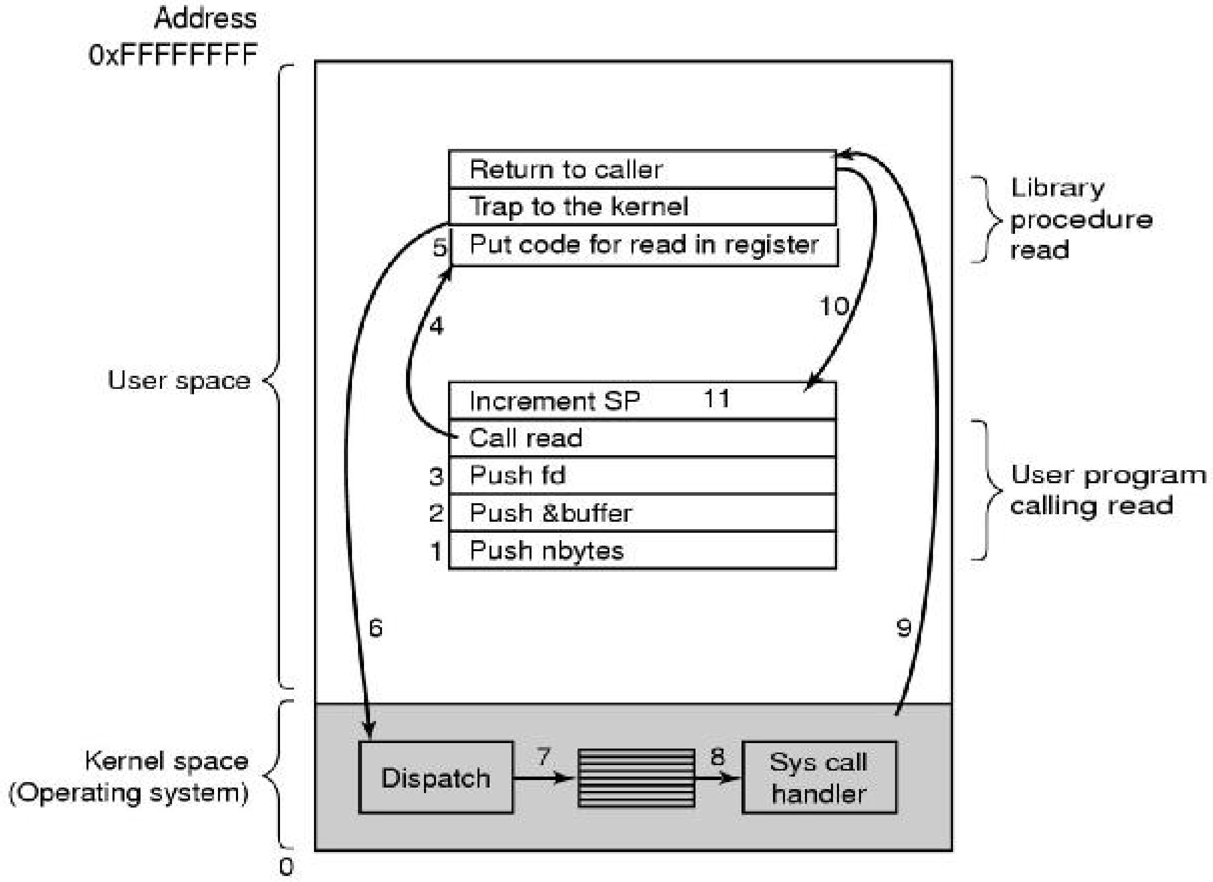
- Process control
- File management
- Device management
- Information maintenance
- Communications

System Calls

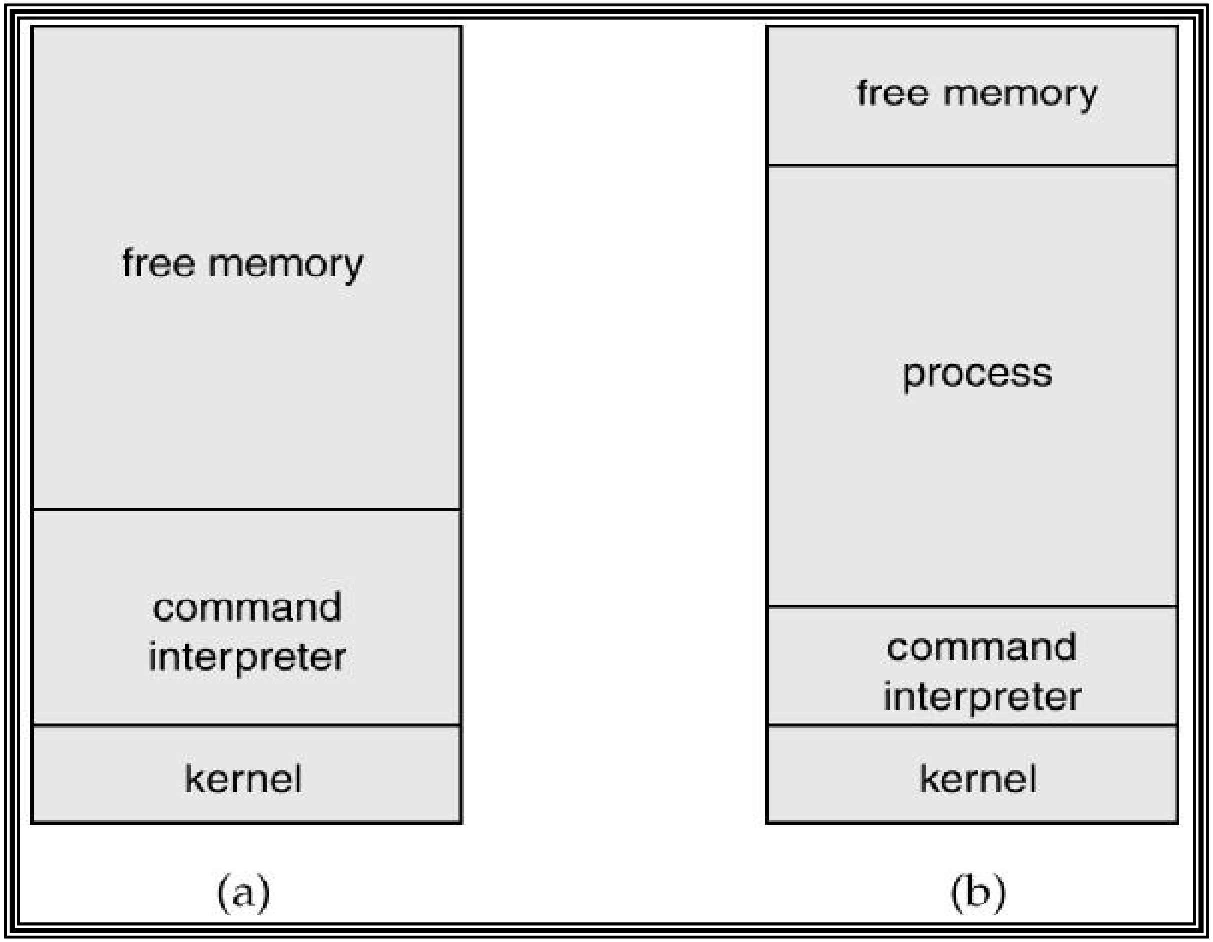
Process Management	fork	CreateProcess	Create a new process
	waitpid	WaitForSingleObject	Wait for a process to exit
	execve	(none)	CreateProcess = fork + execve
	exit	ExitProcess	Terminate execution
	kill	(none)	Send a signal
File Management	open	CreateFile	Create a file or open an existing file
	close	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);

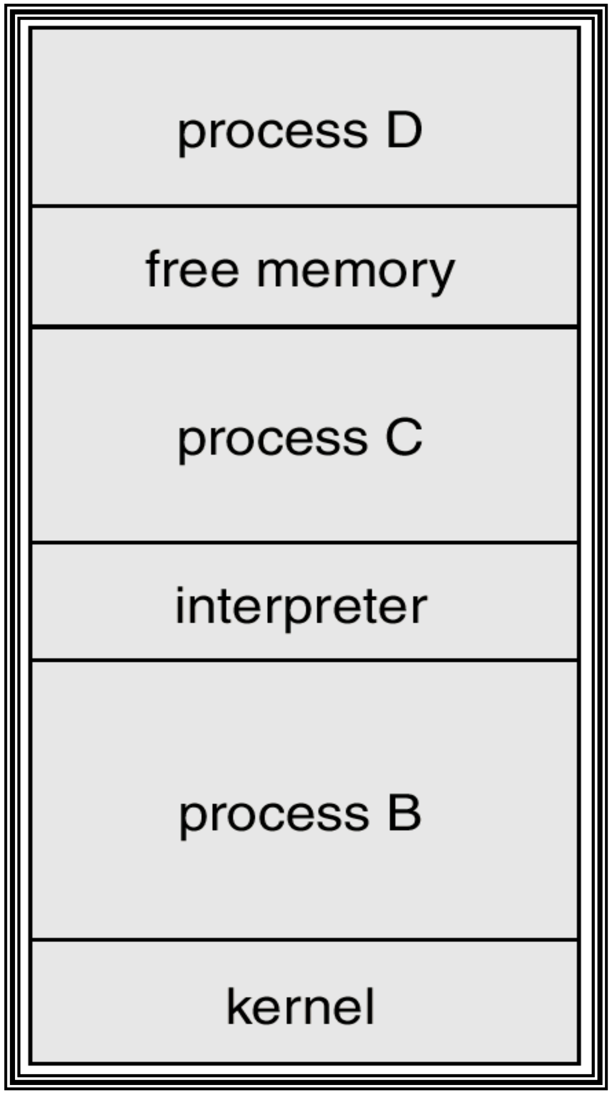


MS-DOS Execution



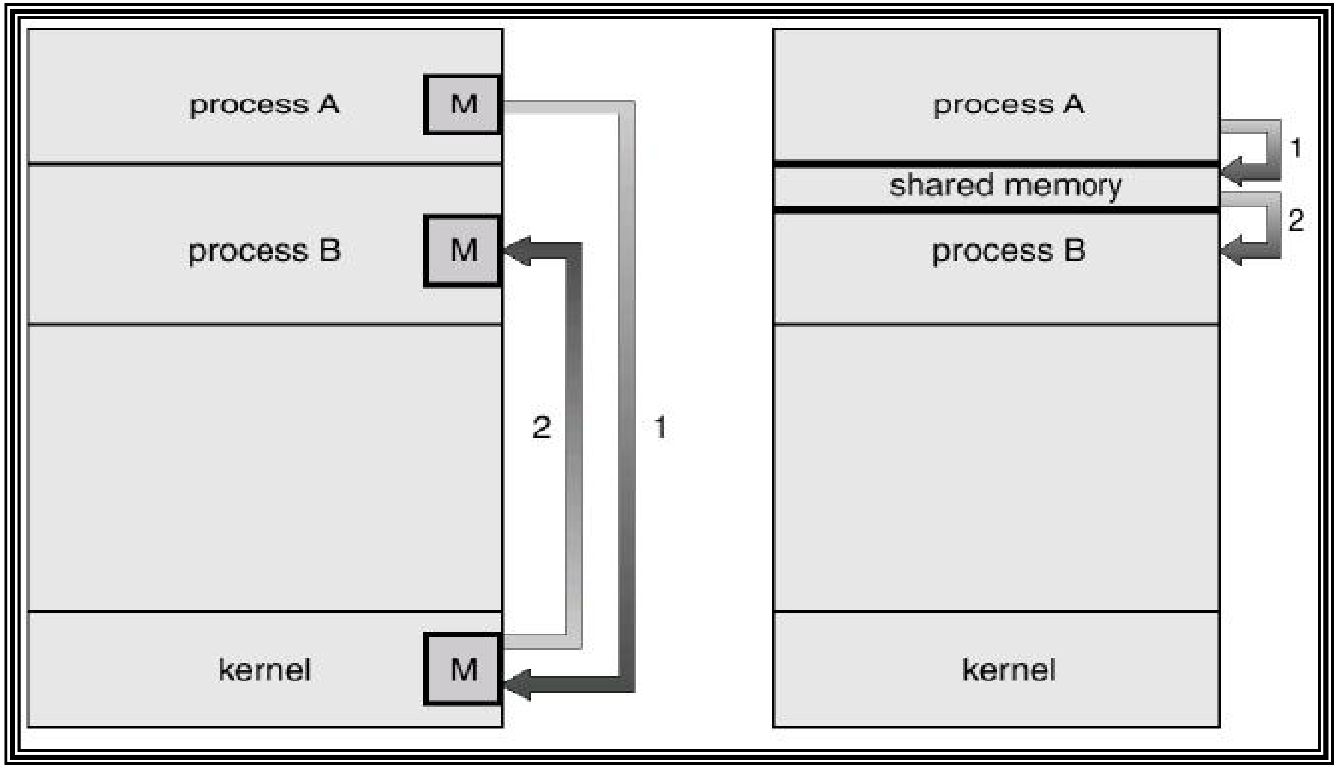
At System Start-up **Running a Program**

UNIX Running Multiple Programs



Communication Models

- Communication may take place using either message passing or shared memory



Msg Passing

Shared Memory

System Programs

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

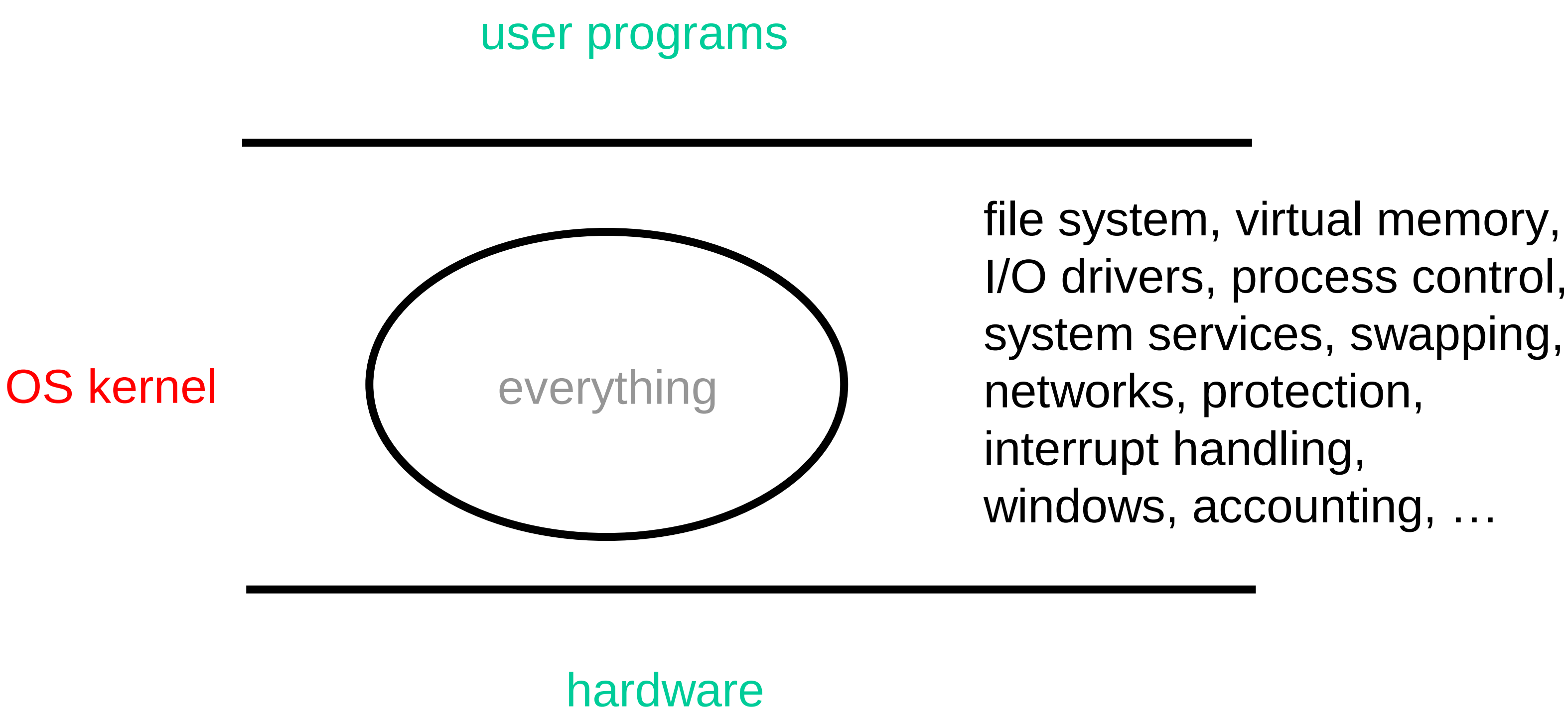
- Most users' view of the operation system is defined by system programs, not the actual system calls

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

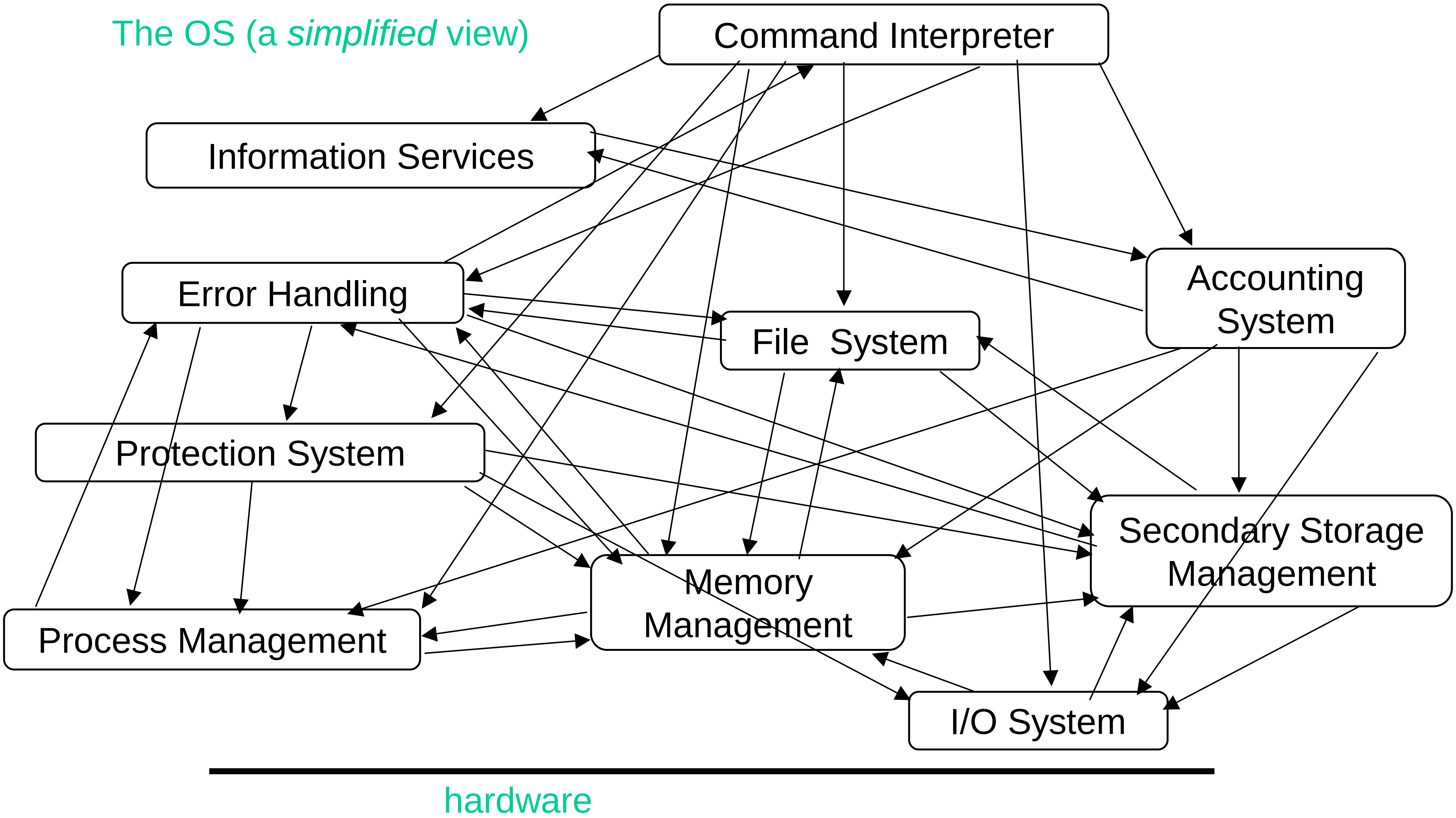
OS Structure (Cont'd)

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



OS Structure (Cont'd)

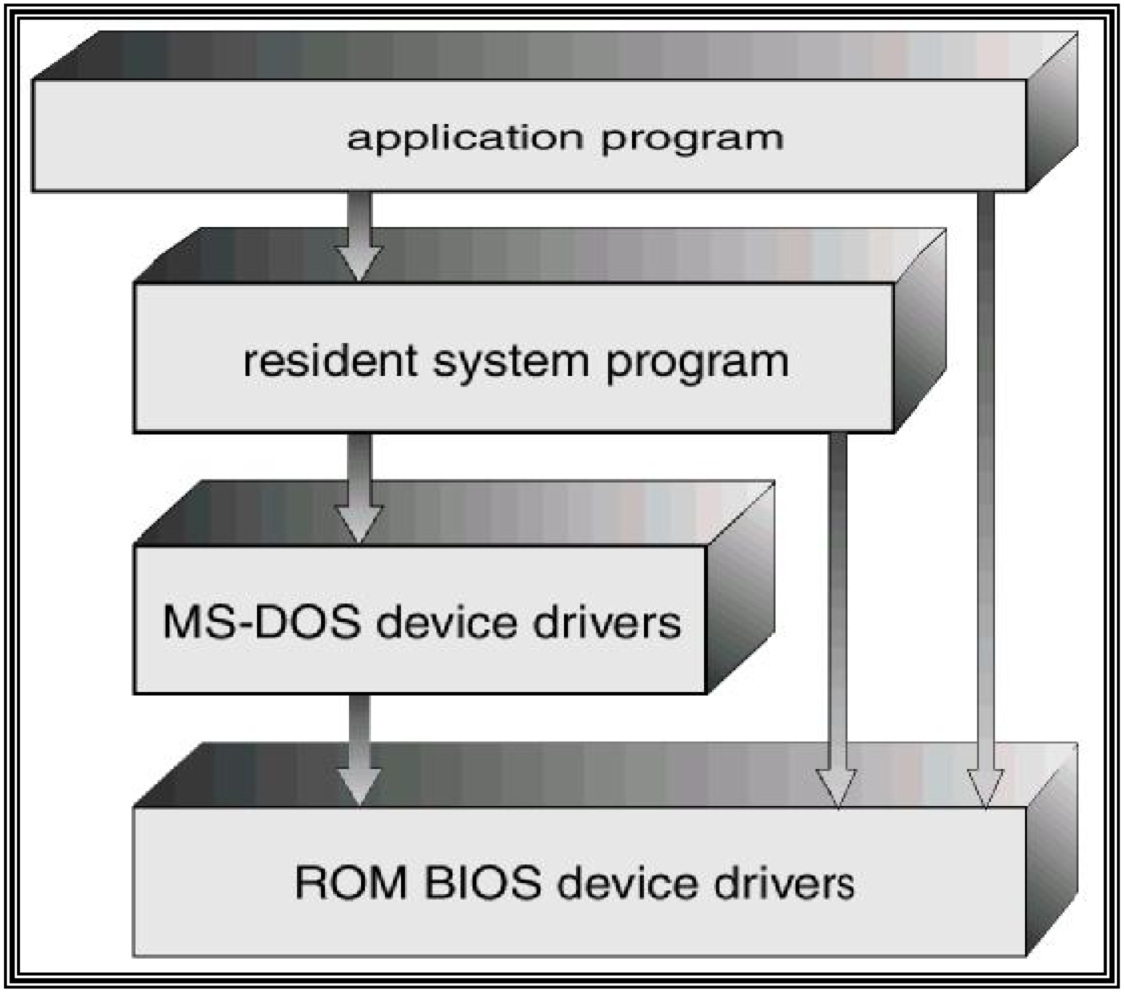
The OS (a *simplified* view)



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

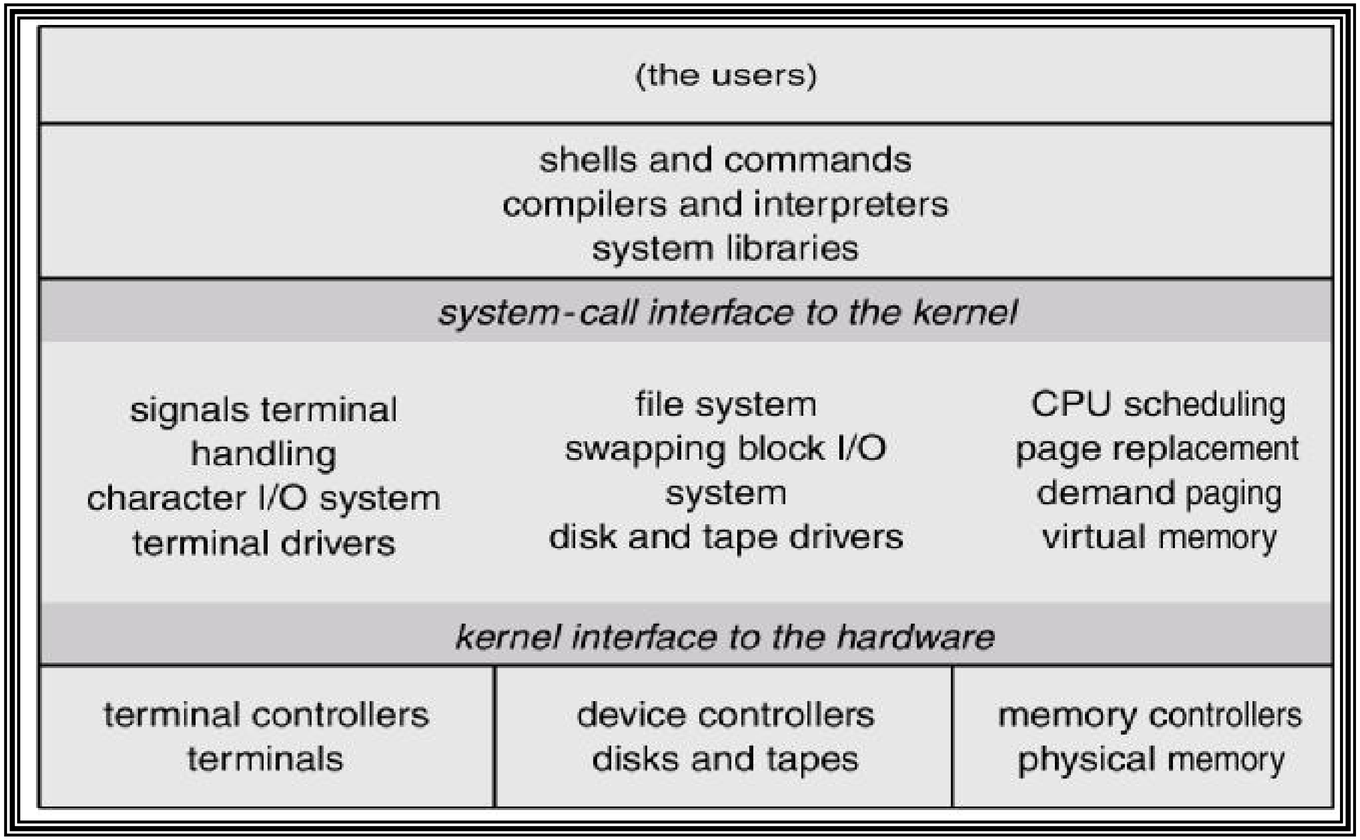
MS-DOS Layer Structure



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

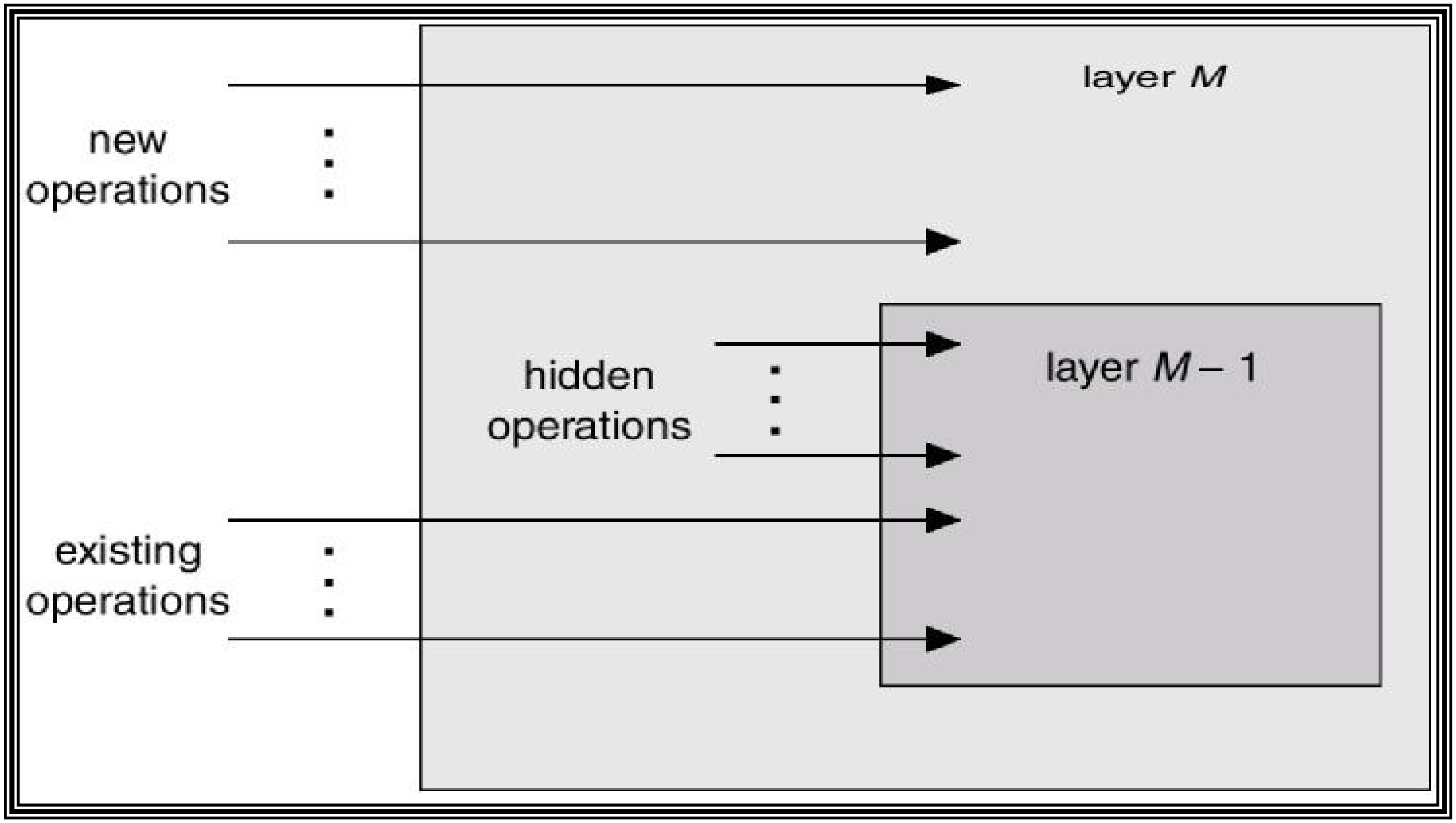
UNIX System Structure (Cont'd)



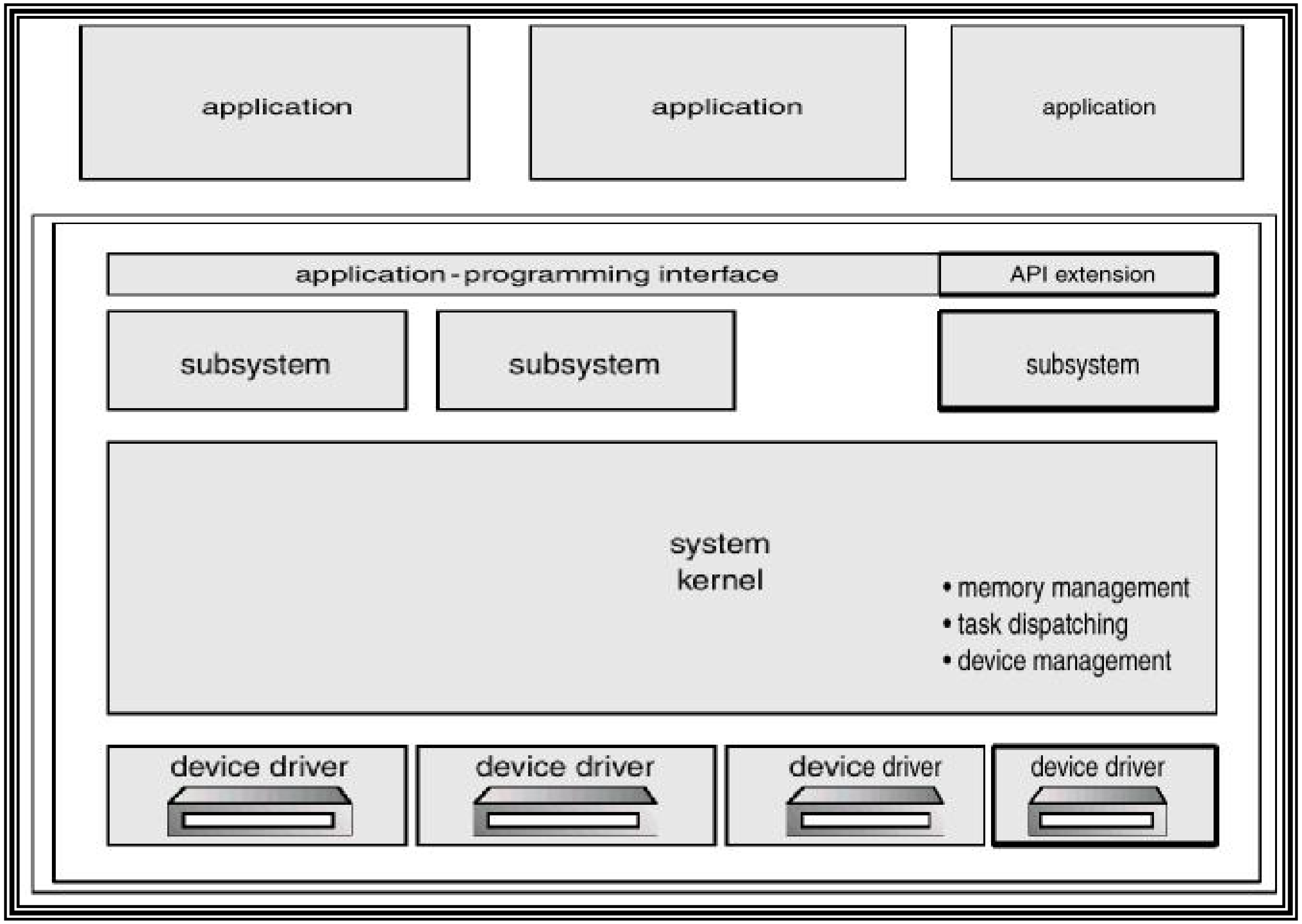
Layered Approach

- The operating system is divided into a number of layers (levels), each built on top of lower layers
- The bottom layer (layer 0), is the hardware; the highest (layer N) is the user interface
- With modularity, layers are selected such that each uses functions (operations) and services of only lower-level layers

An Operating System Layer



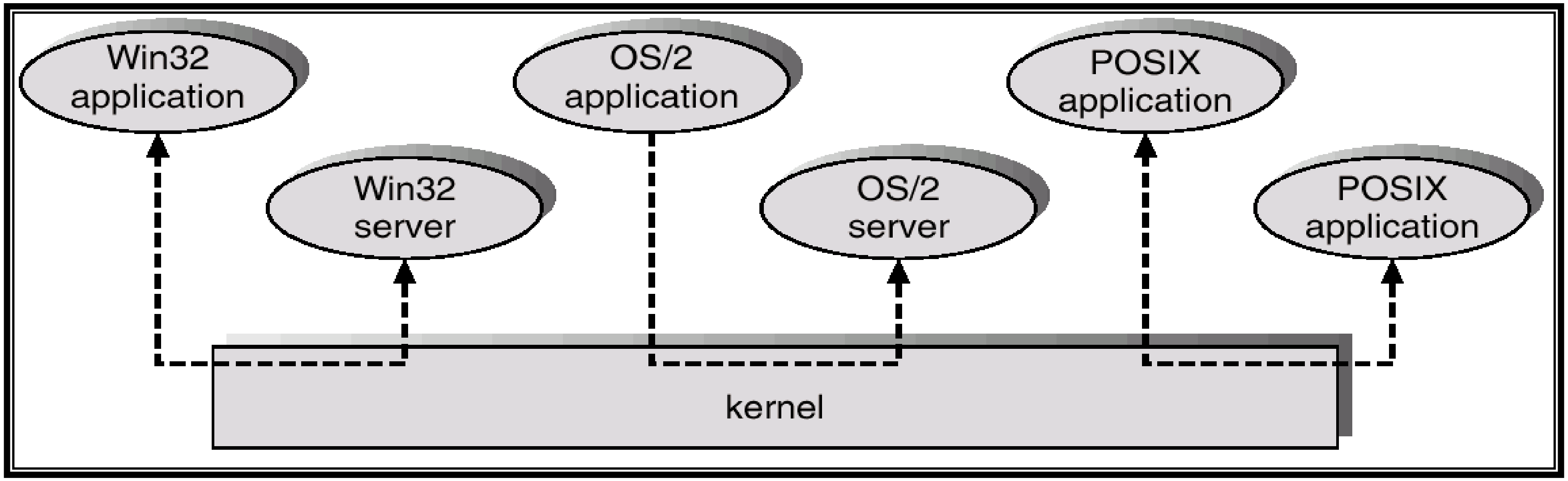
OS/2 Layer Structure



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



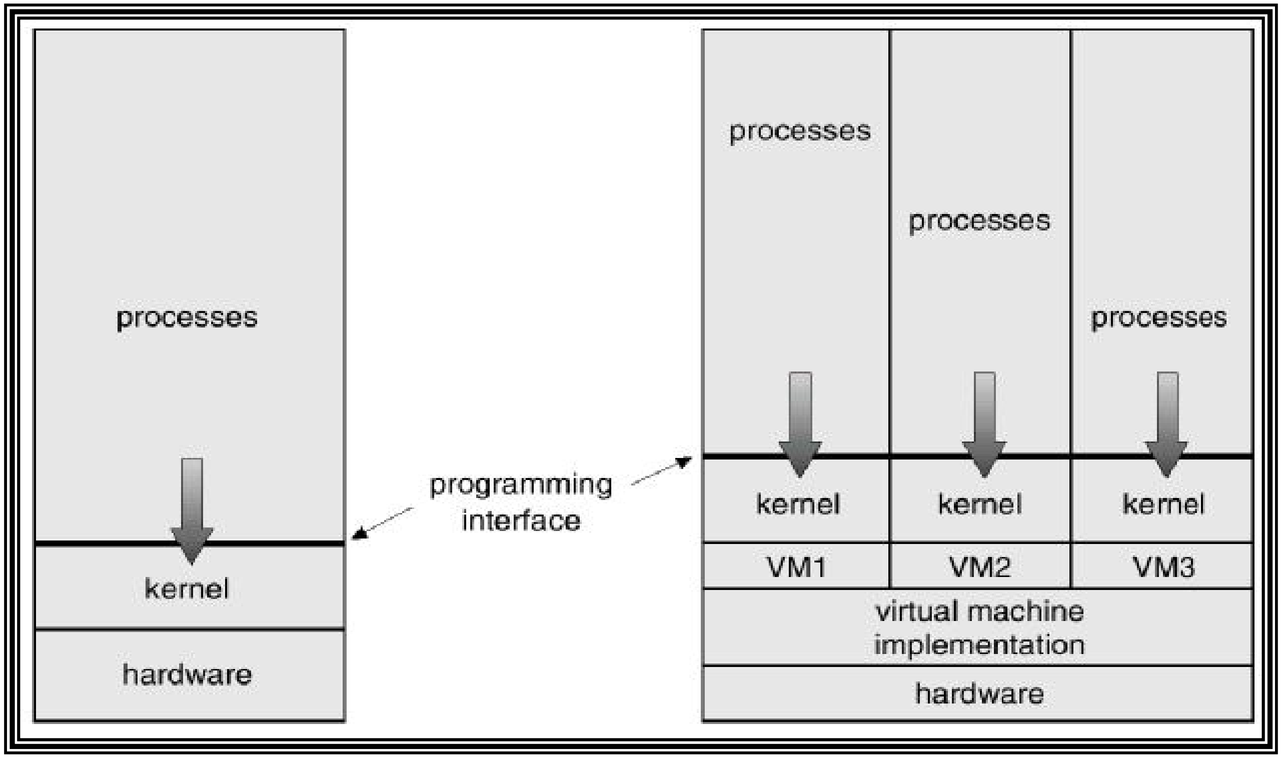
Virtual Machines

- 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

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

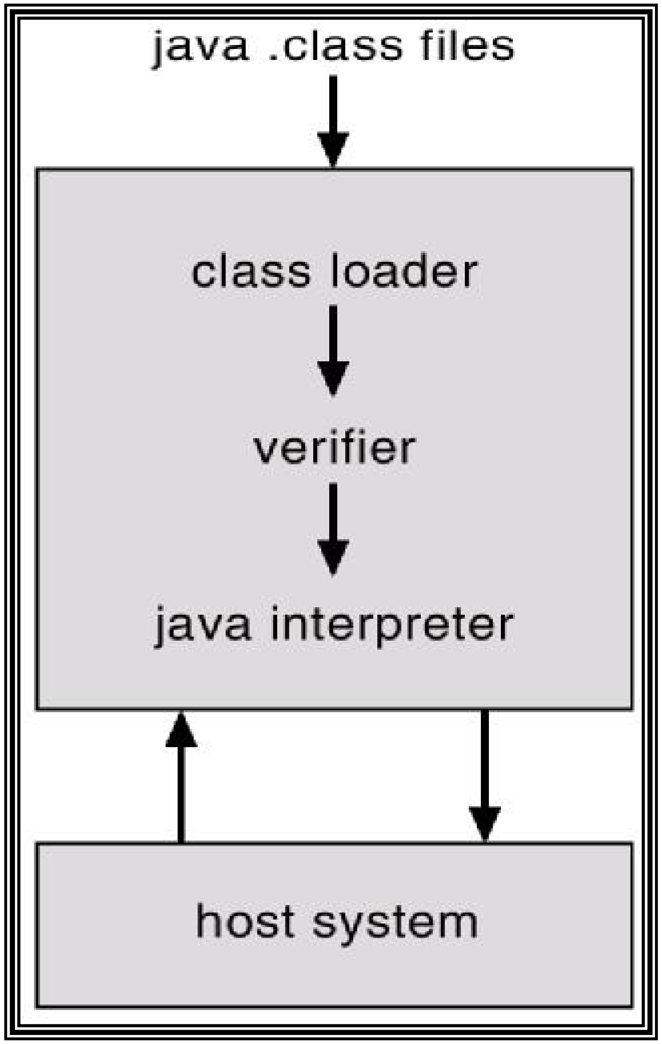
- Compiled Java programs are platform-neutral byte-codes executed by a Java Virtual Machine (JVM)
- JVM consists of

  - class loader

  - class verifier

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

Java Virtual Machine



System Design Goals

- User goals
  - operating system should be convenient to use, easy to learn, reliable, safe, and fast

- System goals
  - operating system should be easy to design, implement, and maintain, as well as flexible, reliable, error-free, and efficient

Mechanisms and Policies

- Mechanisms determine how to do something, policies decide what will be done
- The separation of policy from mechanism is a very important principle, it allows maximum flexibility if policy decisions are to be changed later

Mechanisms and Policies

- Policy
  - *What* should be done?
- Mechanism
  - *How* to do something?

- Policies are likely to change across places or over time.
- A general mechanism is desirable.
- A change in policy would then require redefinition of only certain parameters of the system instead of resulting in a change in the mechanism.

System Implementation

- Traditionally written in assembly language, operating systems can now be written in higher-level languages

- Code written in a high-level language:
  - can be written faster
  - is more compact
  - is easier to understand and debug

- An operating system is far easier to *port* (move to some other hardware) if it is written in a high-level language

System Generation (SYSGEN)

- Operating systems are designed to run on any of a class of machines; the system must be configured for each specific computer site

- SYSGEN program obtains information concerning the specific configuration of the hardware system

- *Booting*
  - starting a computer by loading the kernel

- *Bootstrap program*
  - code stored in ROM that is able to locate the kernel, load it into memory, and start its execution

Bootstrapping

- Linux Booting Process
  - The CPU initializes itself and then execute an instruction at a fixed location (0xfffffff0).
  - 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.