Chapter 3: Operating-System Structures

- 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

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

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

I/O System Management

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

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

Command-Interpreter System (Cont.)

- 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

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

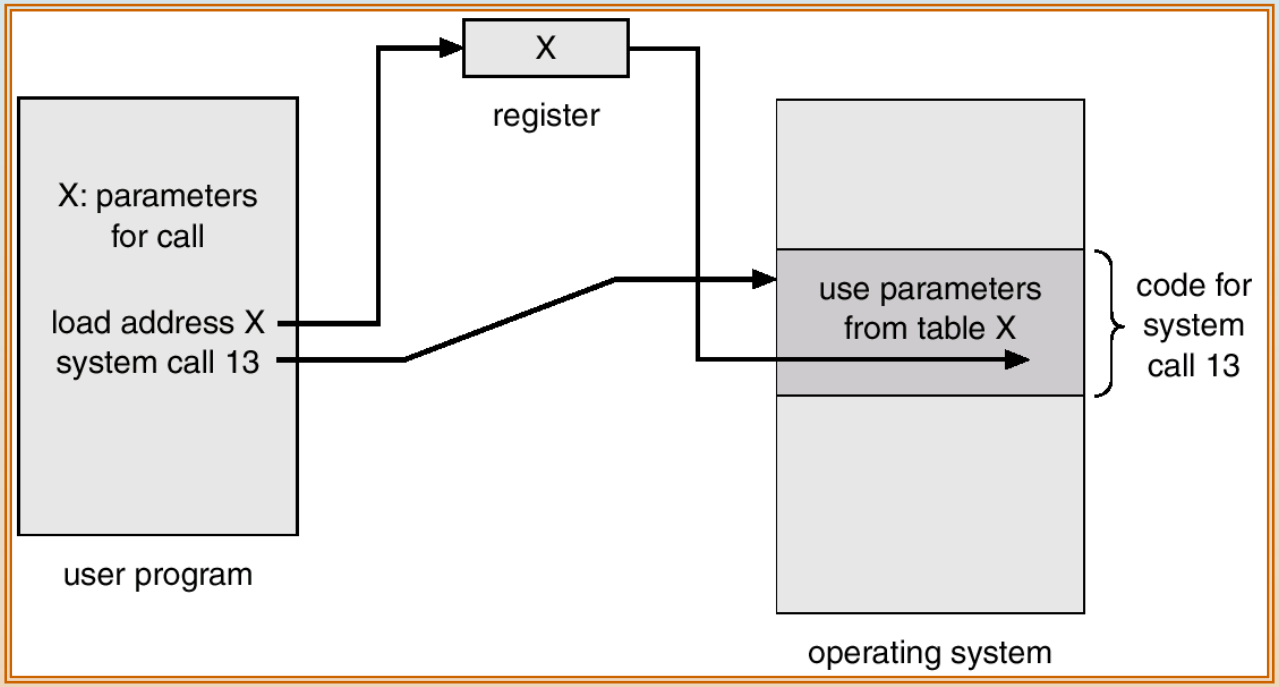
Additional functions exist not for helping the user, but rather for ensuring efficient system operations

- 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

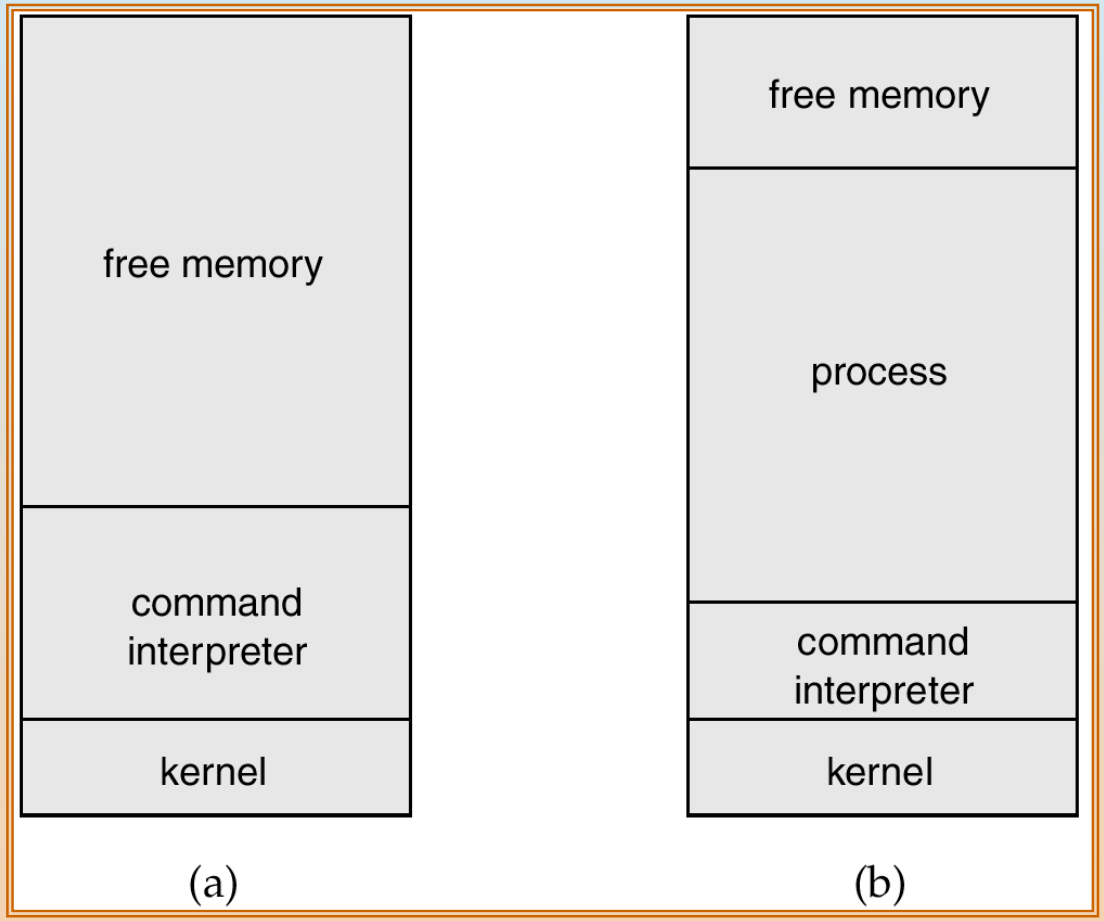
Passing of Parameters As A Table



Types of System Calls

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

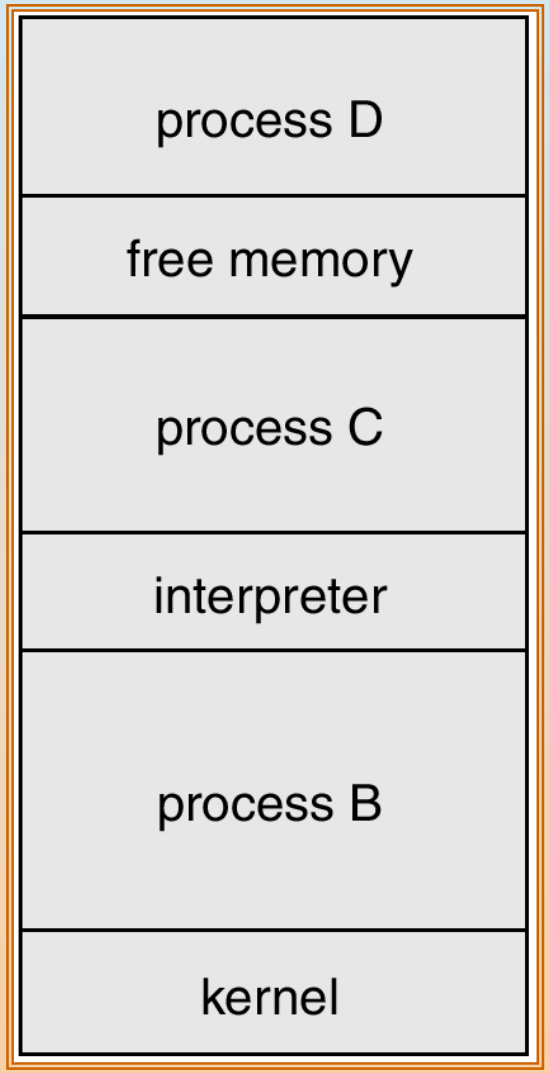
MS-DOS Execution



At System Start-up

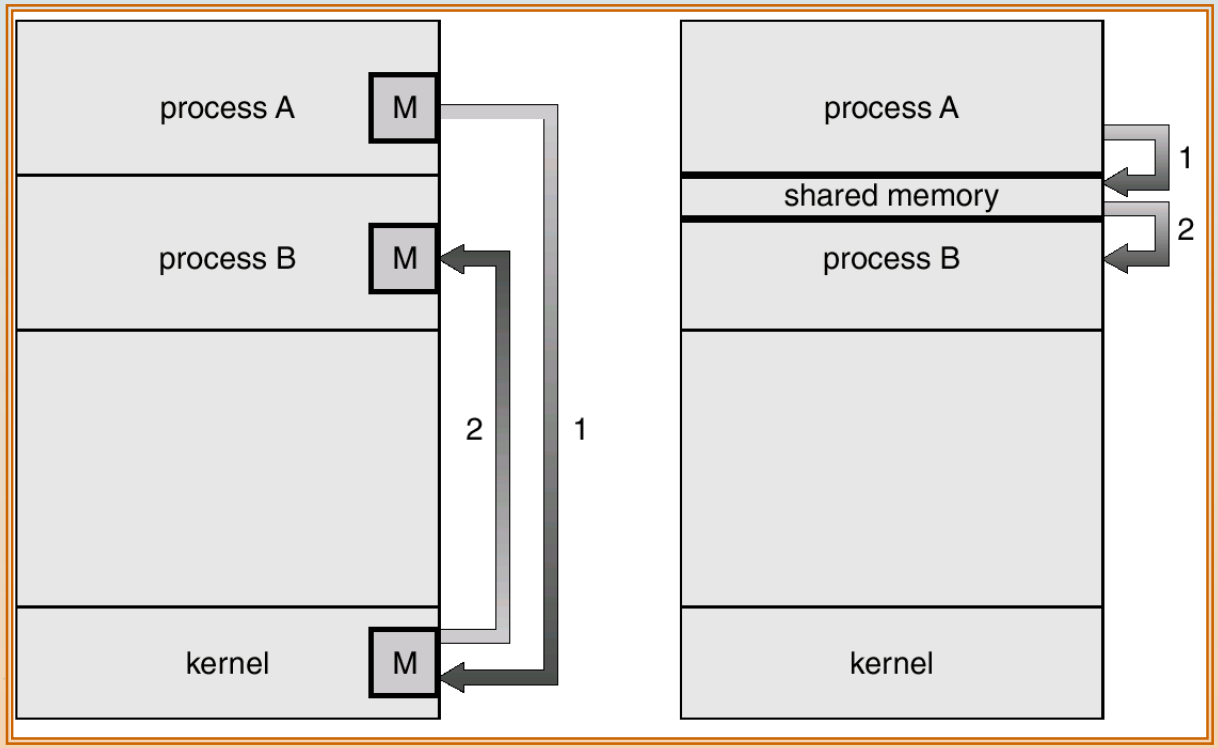
Running a Program

UNIX Running Multiple Programs



Communication Models

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



Message Passing

Shared Memory

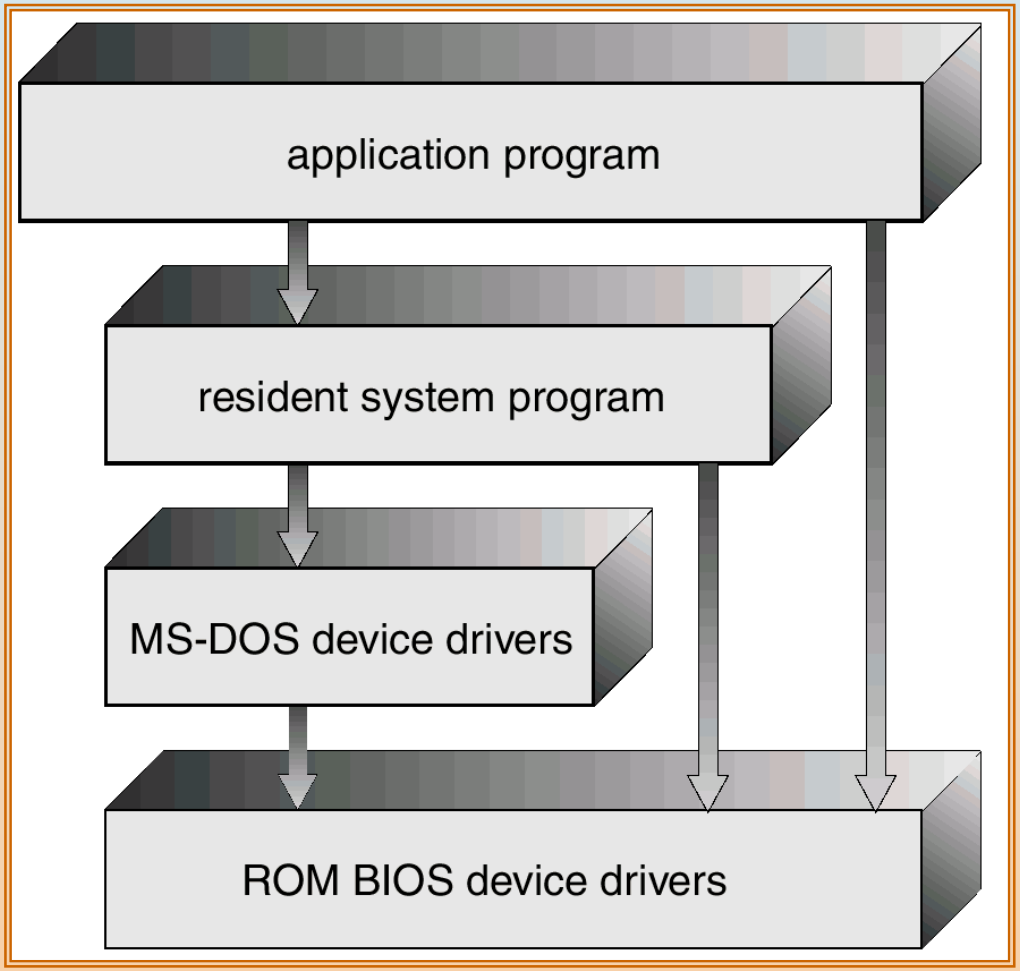
System Programs

- 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

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

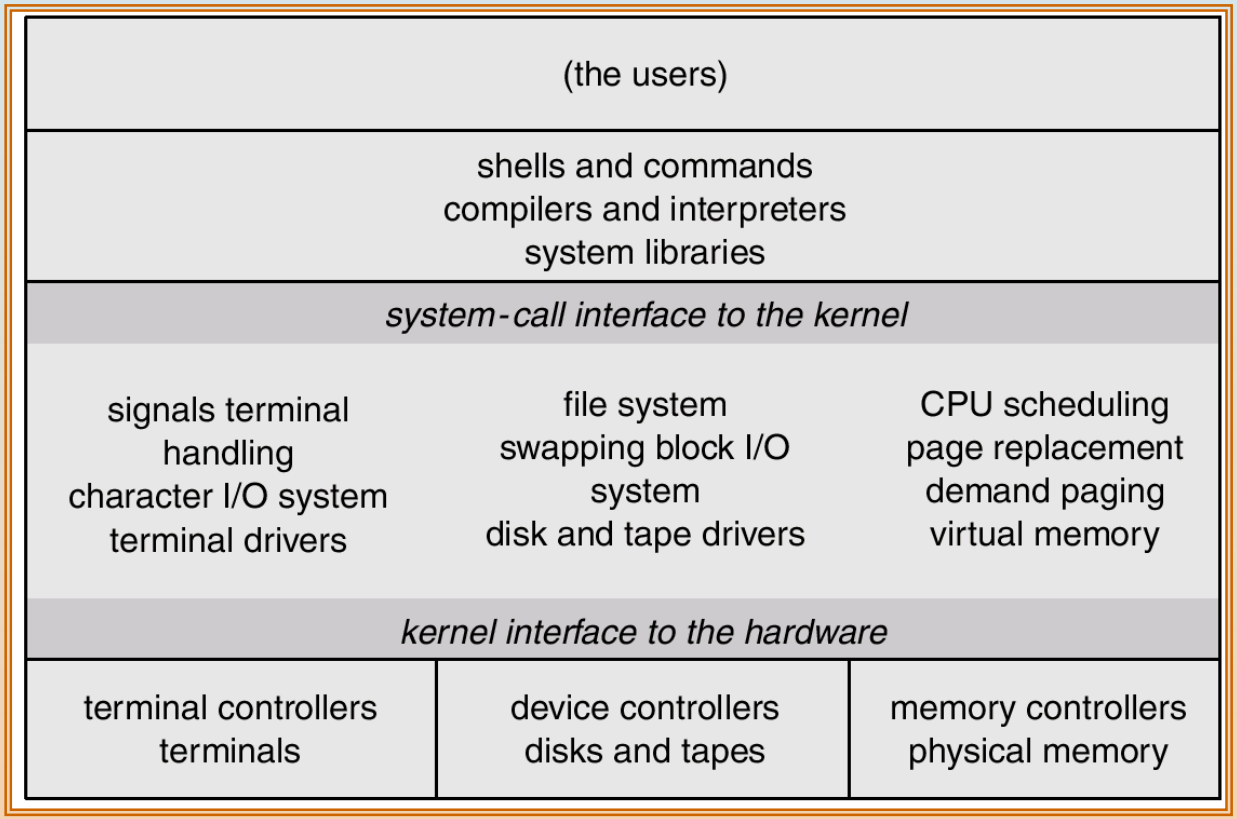
MS-DOS Layer Structure



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

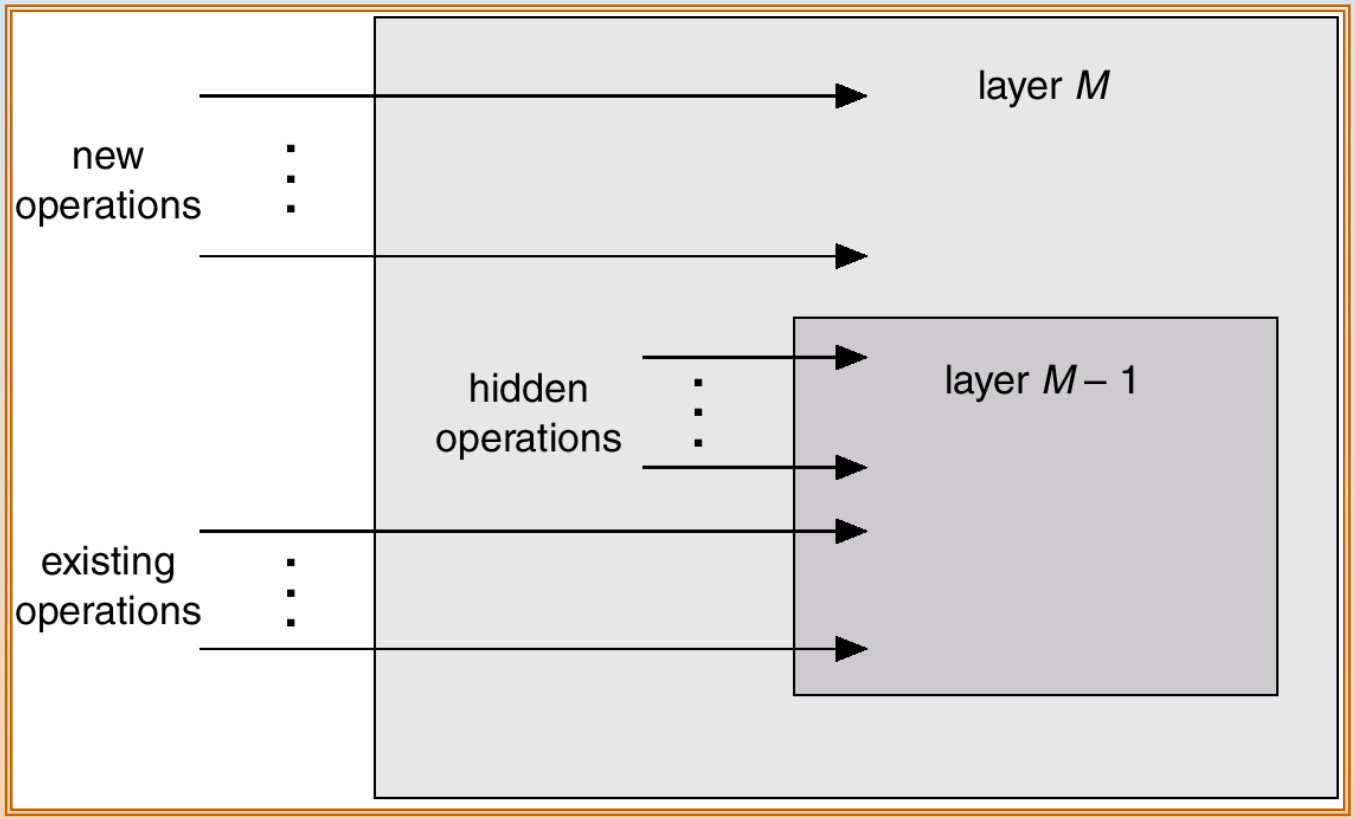
UNIX System Structure



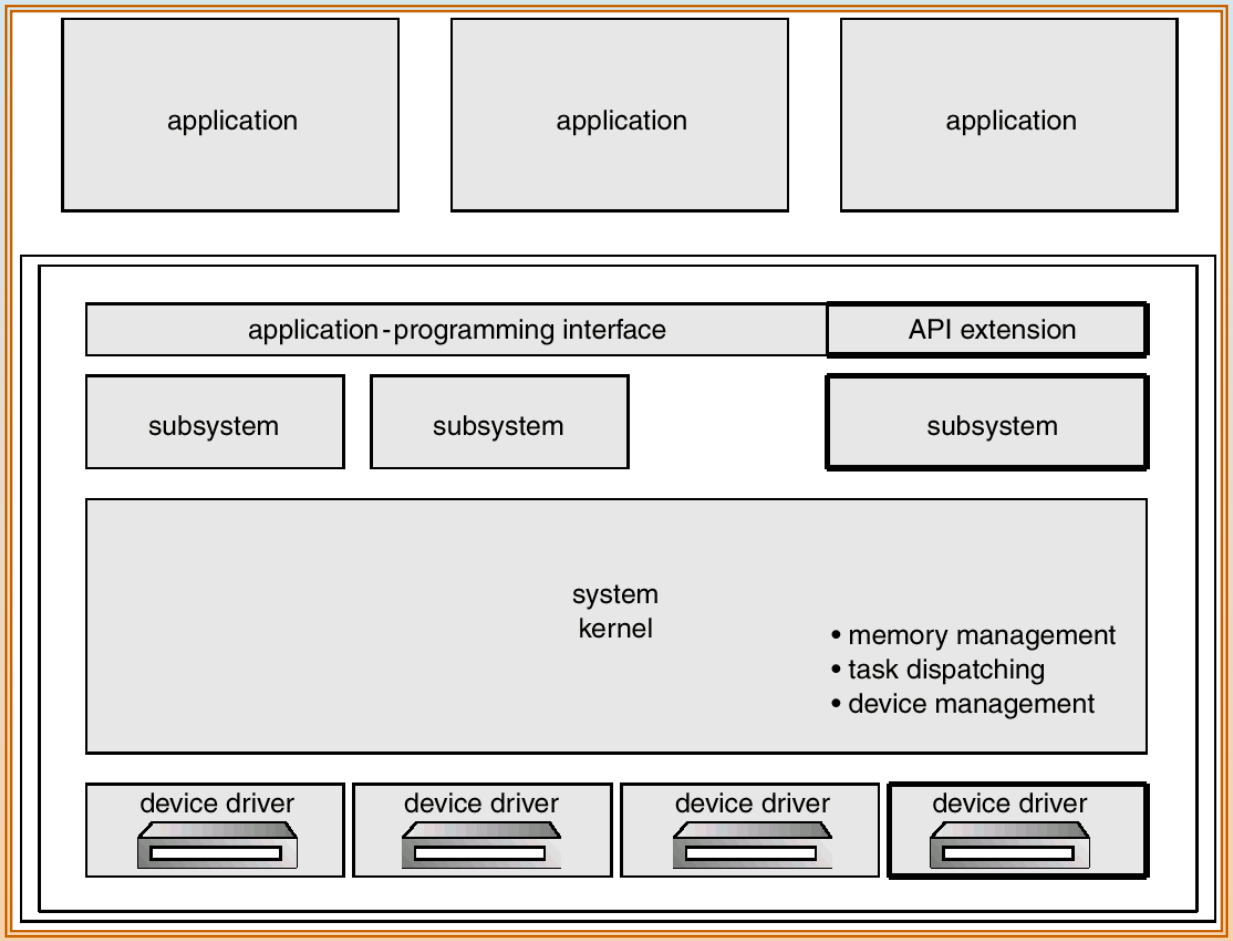
Layered Approach

- 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



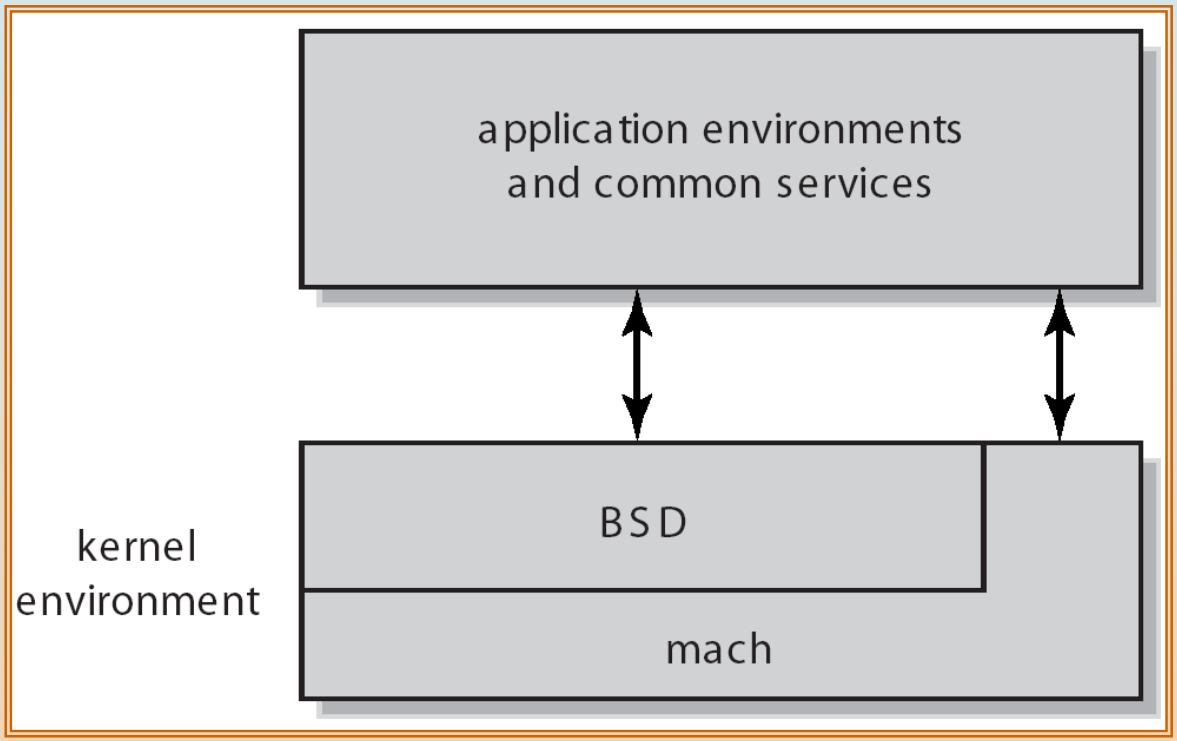
OS/2 Layer Structure



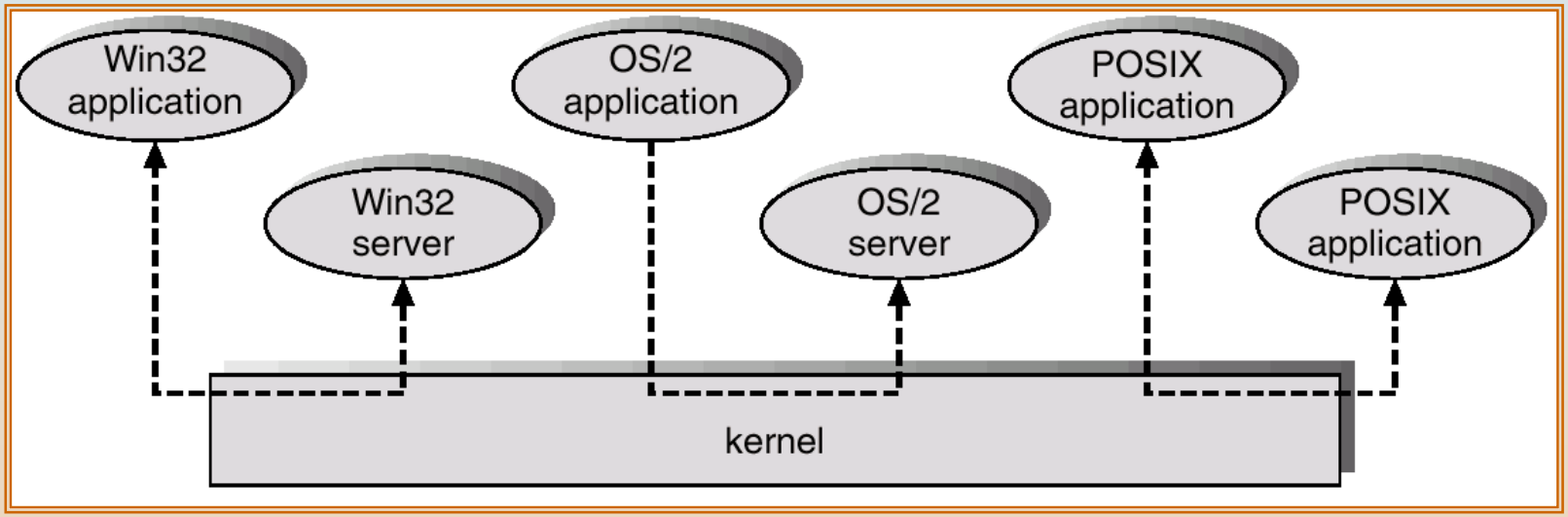
Microkernel System Structure

- 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
- Detriments:
  - Performance overhead of user space to kernel space communication

Mac OS X Structure



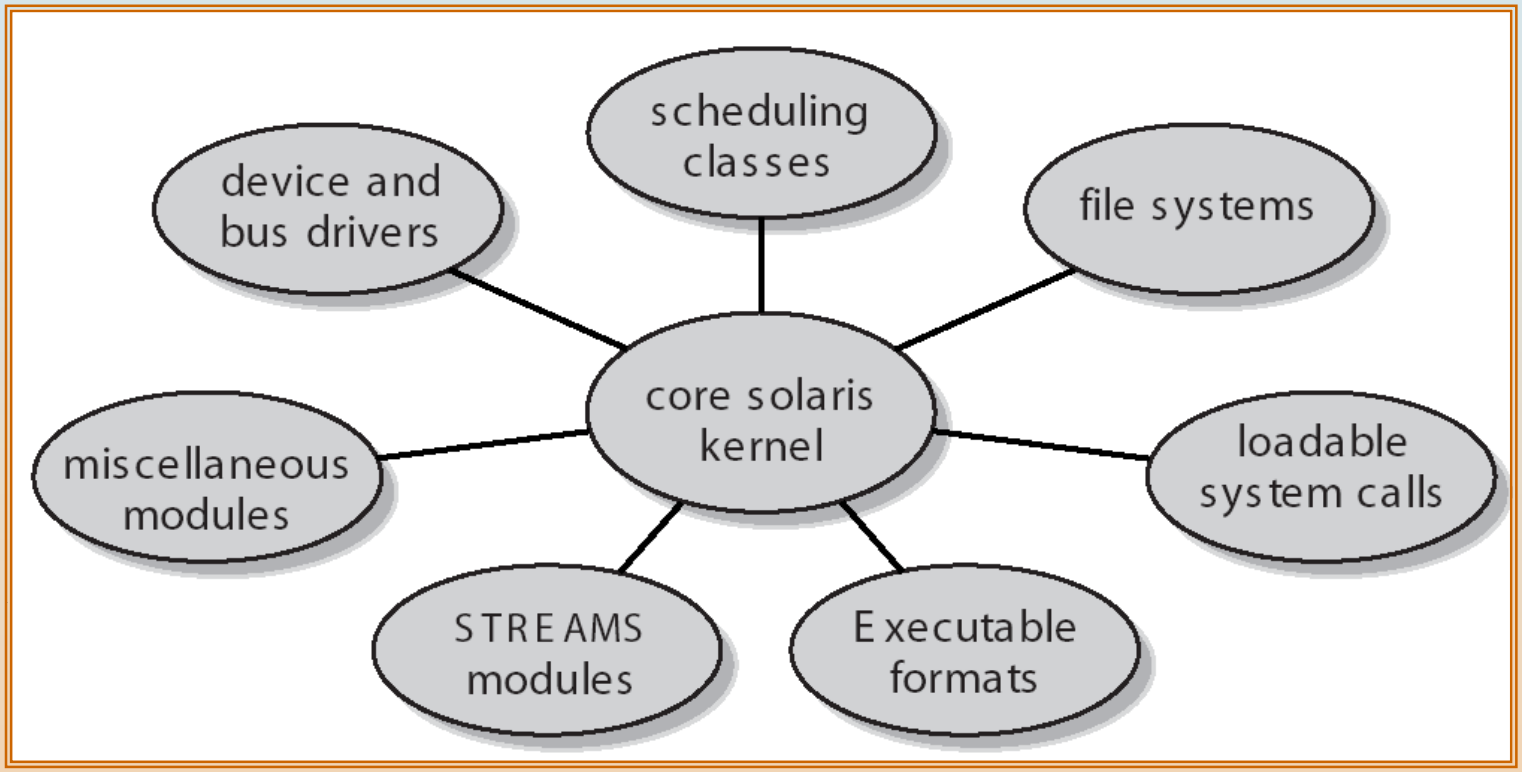
Windows NT Client-Server Structure



Modules

- Most modern operating systems implement kernel *modules*
  - Uses object-oriented approach
  - Each core component is separate
  - Each talks to the others over known interfaces
  - Each is loadable as needed within the kernel
- Overall, similar to layers but with more flexible

Solaris Modular Approach



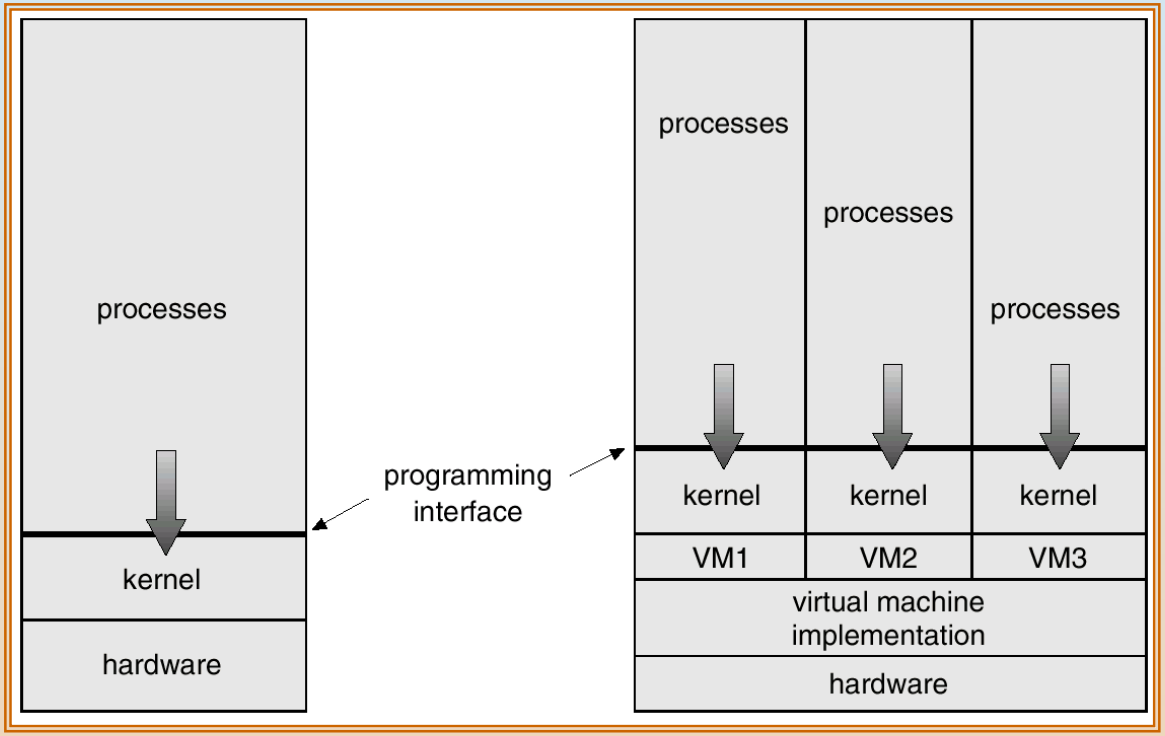
Virtual Machines

- 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.)

- 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

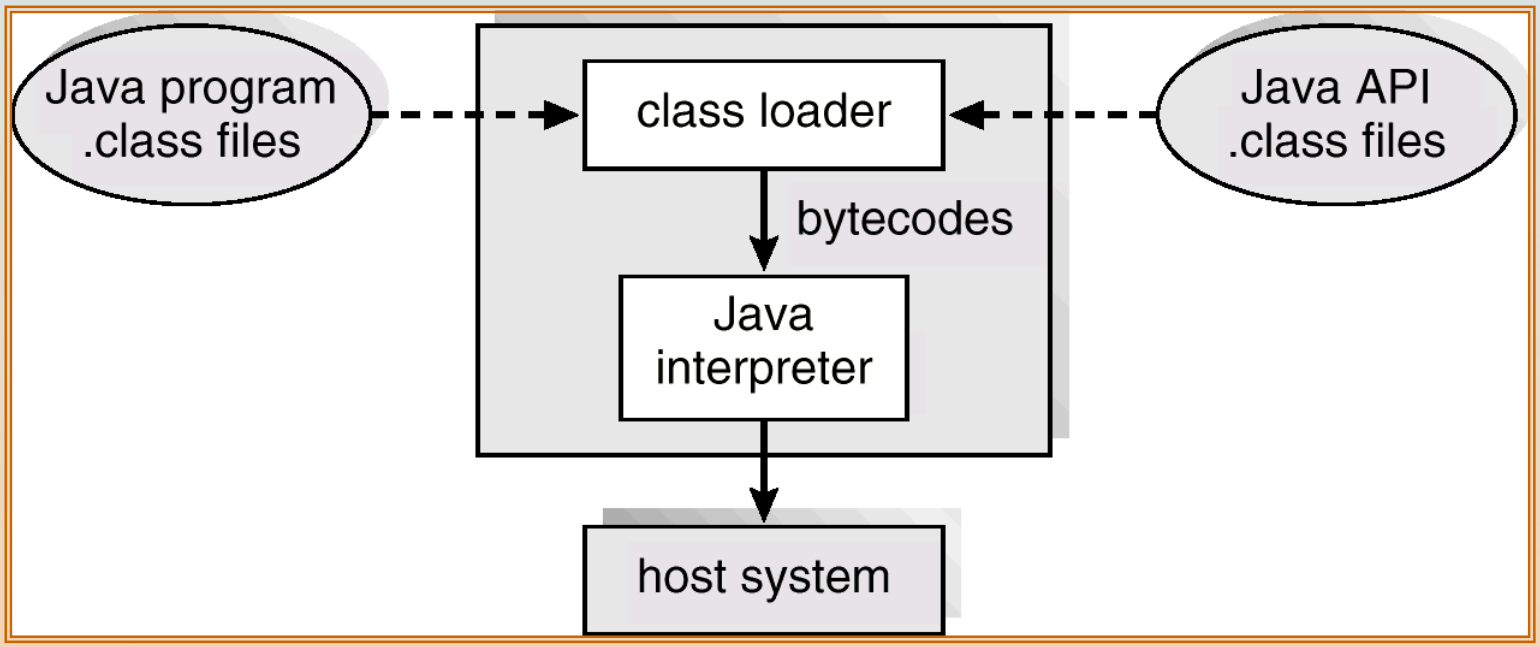
Advantages/Disadvantages of Virtual Machines

- 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

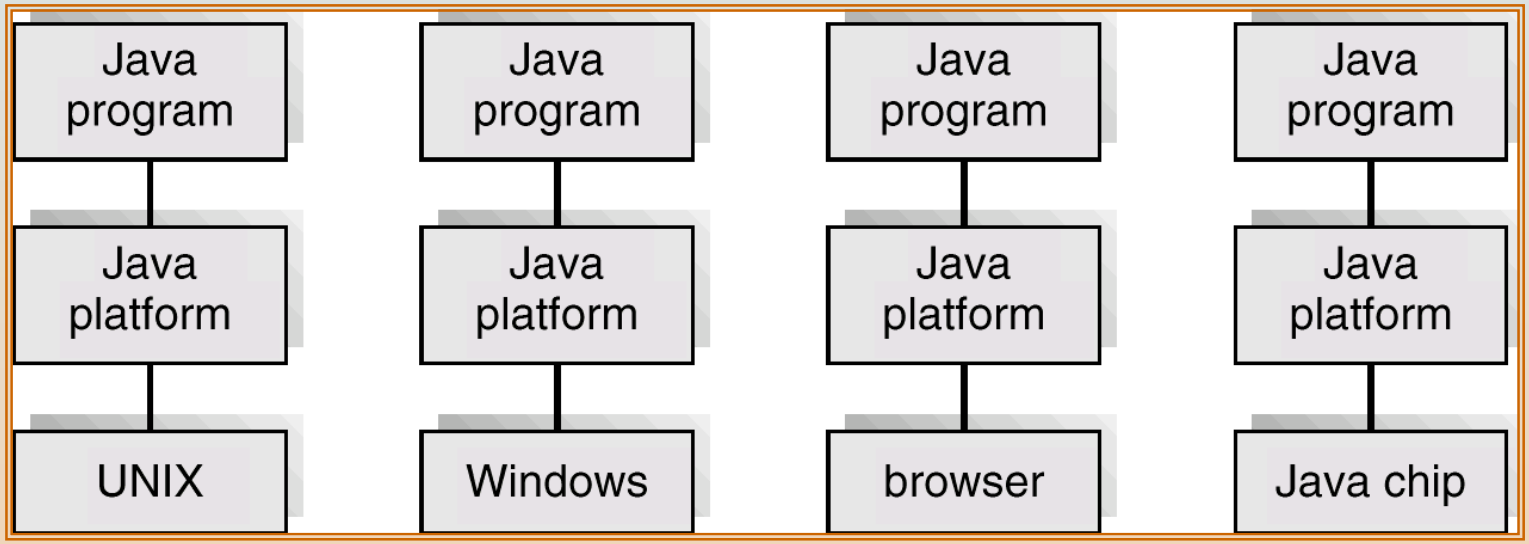
Java Virtual Machine

- Compiled Java programs are platform-neutral bytecodes executed by a Java Virtual Machine (JVM)
- JVM consists of
  - Class loader
  - Class verifier
  - Runtime interpreter
- Just-In-Time (JIT) compilers increase performance

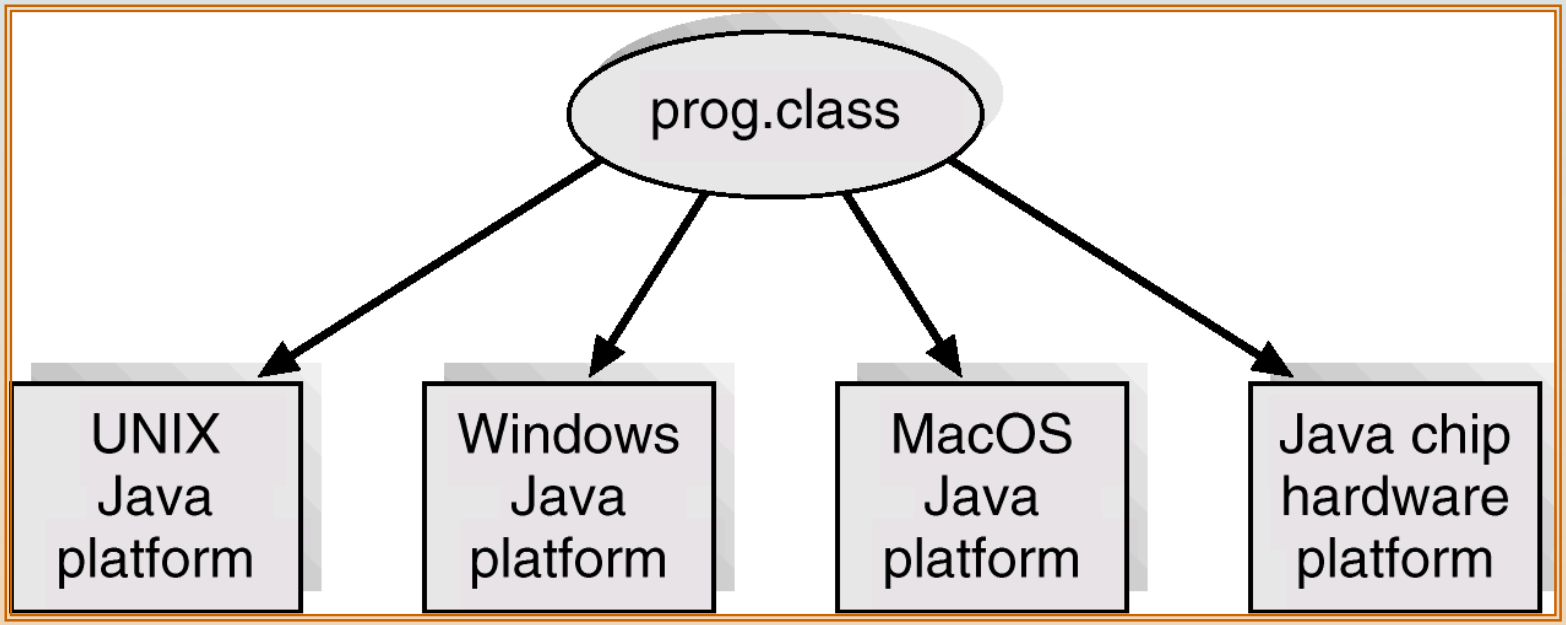
The Java Virtual Machine



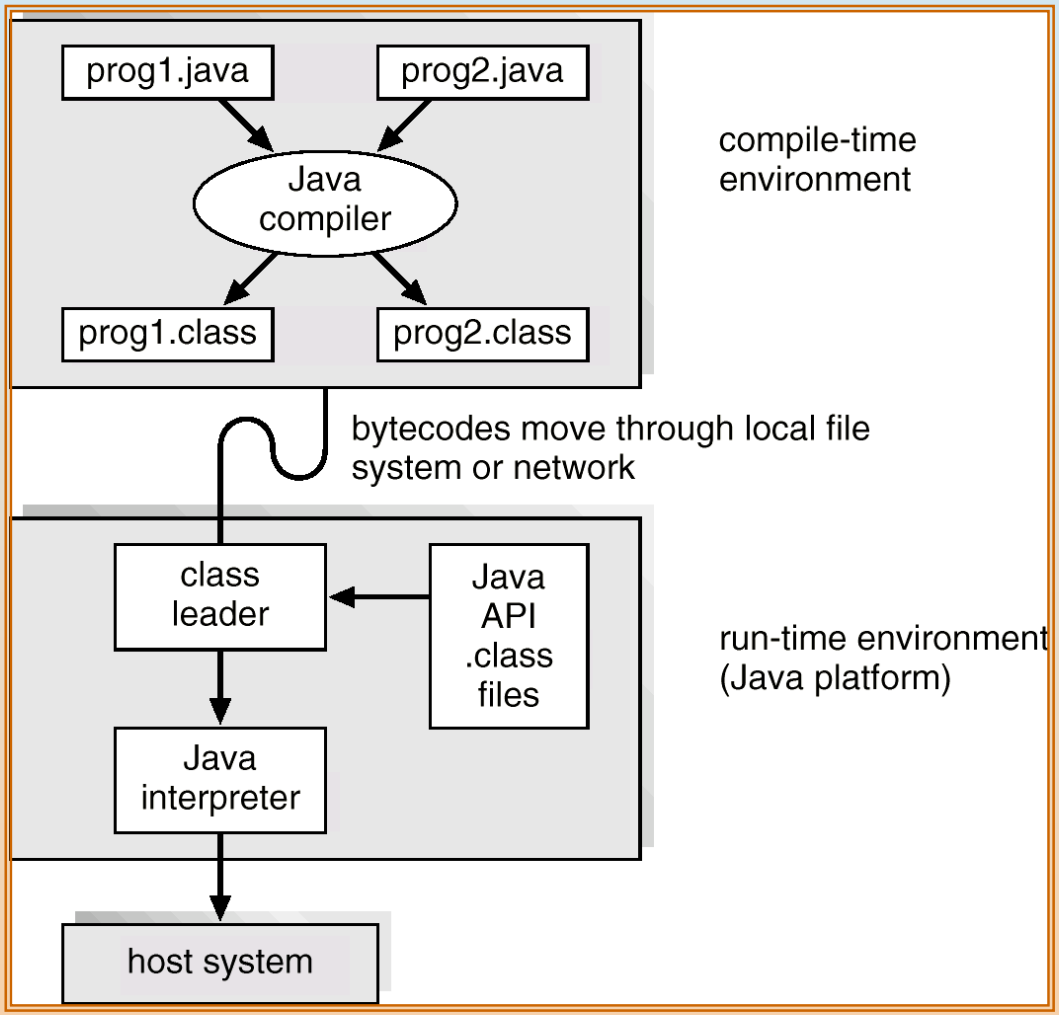
The Java Platform



Java .class File on Cross Platforms



Java Development Environment



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

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 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

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