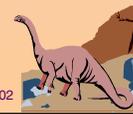




## Chapter 3: Operating-System Structures

- 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

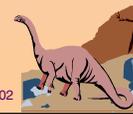
- Memory is a large array of words or bytes, each with its own address. It is a repository of quickly accessible data shared by the CPU and I/O devices.
- Main memory is a volatile storage device. It loses its contents in the case of system failure.
- The operating system is responsible for the following 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

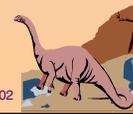
- The I/O system consists of:
  - ◆ A buffer-caching system
  - ◆ A general device-driver interface
  - ◆ Drivers for specific hardware devices





## 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.

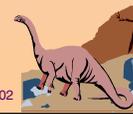




## Additional Operating System Functions

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

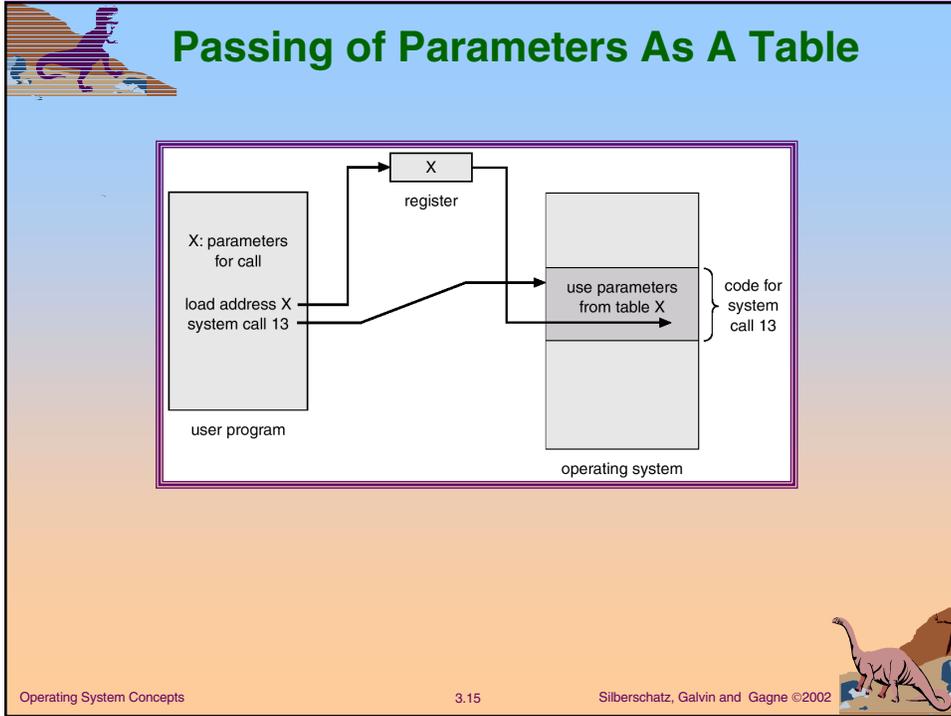
- Resource allocation – allocating resources to multiple users or multiple jobs running at the same time.
- Accounting – keep track of and record which users use how much and what kinds of computer resources for account billing or for accumulating usage statistics.
- Protection – ensuring that all access to system resources is controlled.



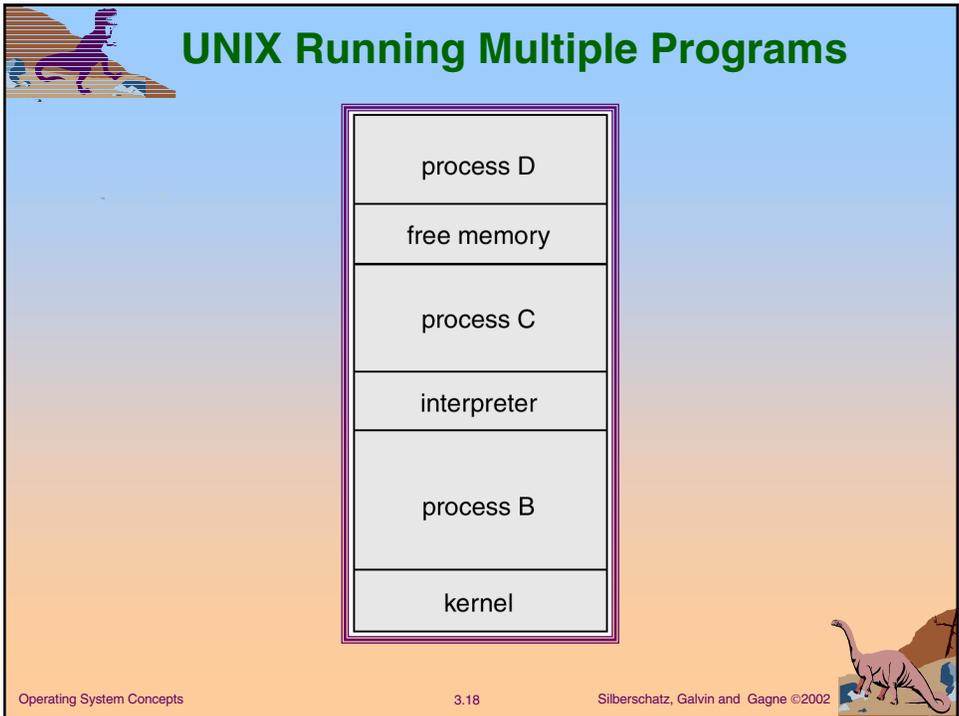
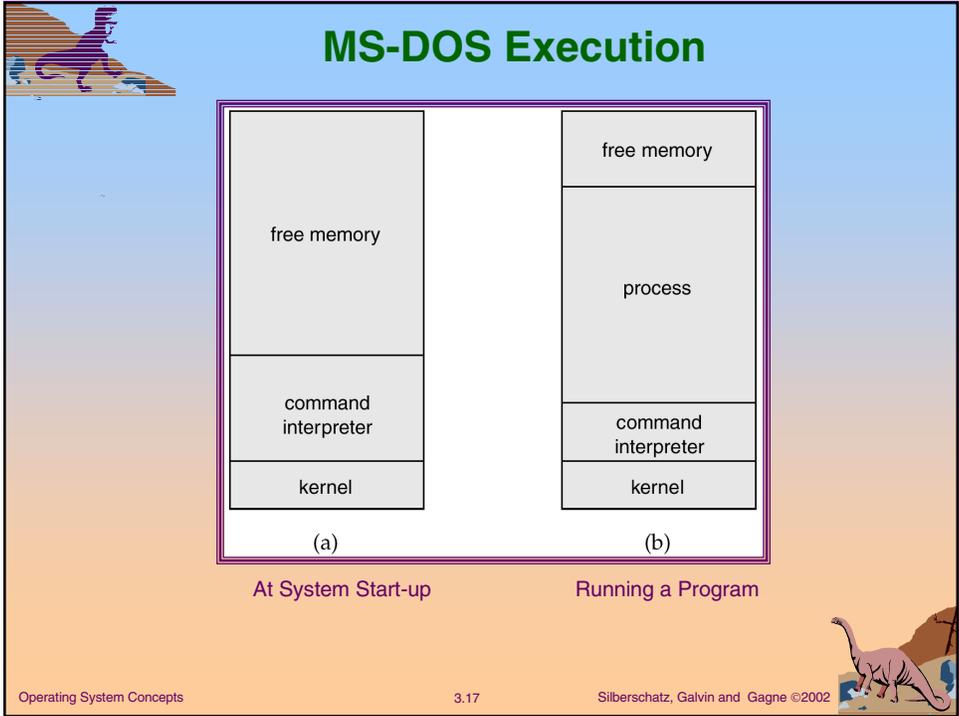
## System Calls

- 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.





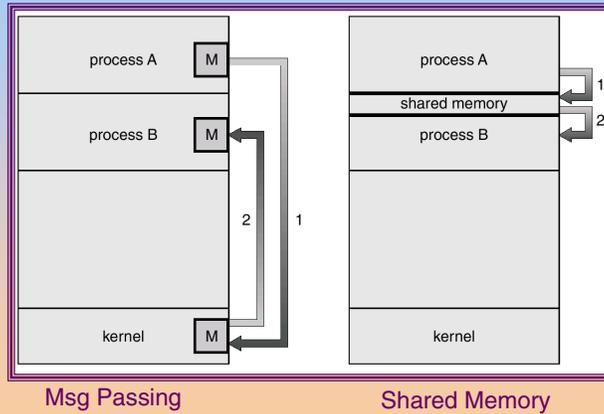
- ## Types of System Calls
- Process control
  - File management
  - Device management
  - Information maintenance
  - Communications
- Operating System Concepts 3.16 Silberschatz, Galvin and Gagne ©2002





## Communication Models

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



## System Programs

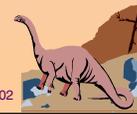
- System programs provide a convenient environment for program development and execution. They can be divided into:
  - ◆ File manipulation
  - ◆ Status information
  - ◆ File modification
  - ◆ Programming language support
  - ◆ Program loading and execution
  - ◆ Communications
  - ◆ Application programs
- Most users' view of the operation system is defined by system programs, not the actual system calls.



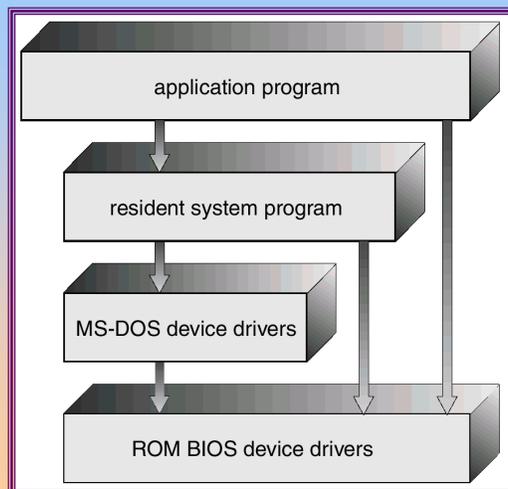


## MS-DOS System Structure

- 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



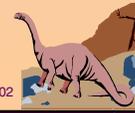
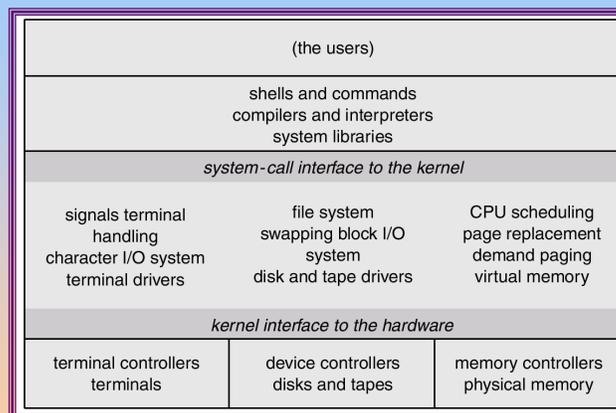


# UNIX System Structure

- 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



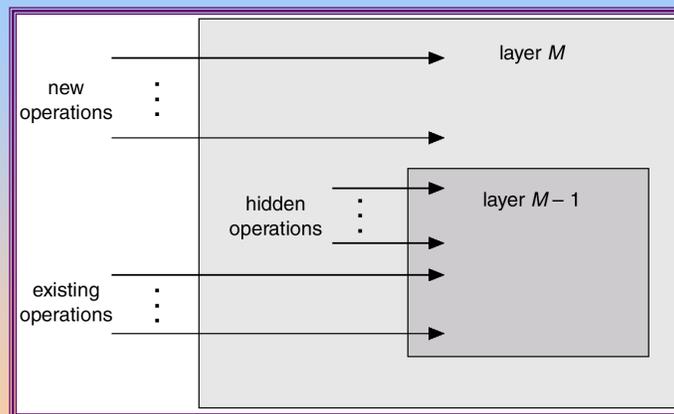


## Layered Approach

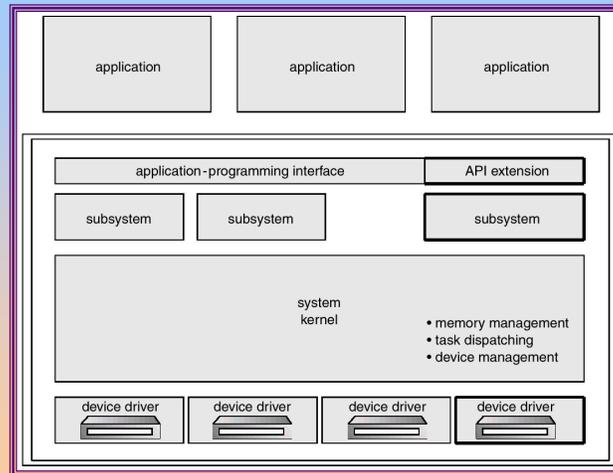
- The operating system is divided into a number of layers (levels), each built on top of lower layers. The bottom layer (layer 0), is the hardware; the highest (layer N) is the user interface.
- With modularity, layers are selected such that each uses functions (operations) and services of only lower-level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



## An Operating System Layer



## OS/2 Layer Structure

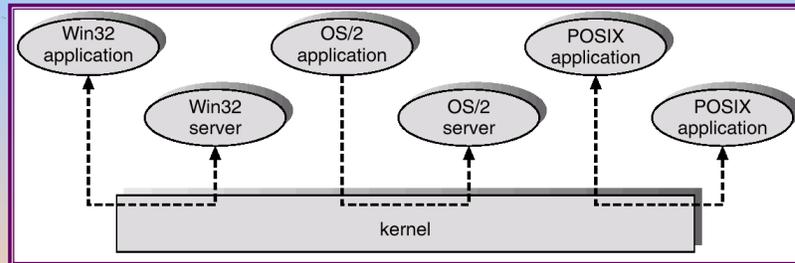


## Microkernel System Structure

- 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



## Windows NT Client-Server Structure



## Virtual Machines

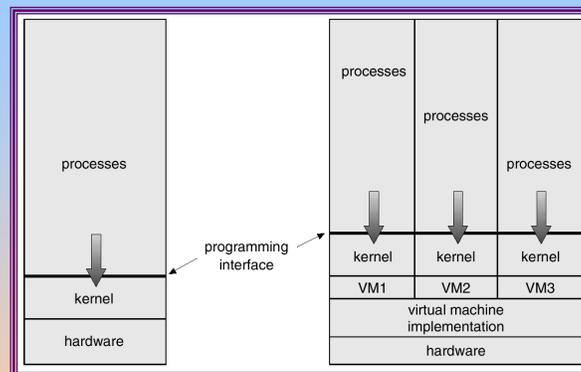
- A *virtual machine* takes the layered approach to its logical conclusion. It treats hardware and the operating system kernel as though they were all hardware.
- A virtual machine provides an interface *identical* to the underlying bare hardware.
- The operating system creates the illusion of multiple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



## Virtual Machines (Cont.)

- 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



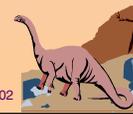
Non-virtual Machine

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.

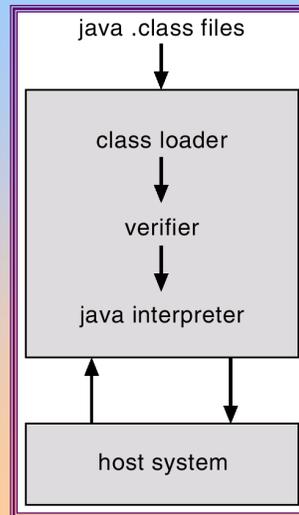


## Java Virtual Machine

- 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



## 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.



## 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.

