CHAPTER 3: OPERATING-SYSTEM STRUCTURES

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

Most operating systems support the following types of system components:

- Process Management
- Main-Memory Management
- Secondary-Storage Management
- I/O System Management
- File Management
- Protection System
- Networking
- 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 connection 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.

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

I/O System Management

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

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 connection 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.

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.

Networking (Distributed Systems)

- A *distributed* system is a collection of 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.*

- A distributed system provides user access to various system resources.

- Access to a shared resource allows:

  - Computation speed-up

  - Increased data availability

  - Enhanced reliability

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:
  - control-card interpreter
  - 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 exist not for helping the user, but rather for ensuring efficient system operation.

- 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, Bliss, PL/360).

- 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 the operating system.

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.

System Structure – Simple Approach

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

- UNIX – limited by hardware functionality, the original UNIX operating system had limited structuring. The UNIX OS consists of two separable parts:
  - the systems programs.
  - the kernel, which 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.

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.

- A layered design was first used in the THE operating system. Its six layers are as follows:

Level 5:	user programs
Level 4:	buffering for input and output devices
Level 3:	operator-console device driver
Level 2:	memory management
Level 1:	CPU scheduling
Level 0:	hardware

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.

- 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.

Advantages and 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 of the underlying 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.