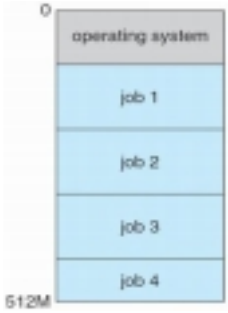
Module - I : Introduction to OS, System Structures

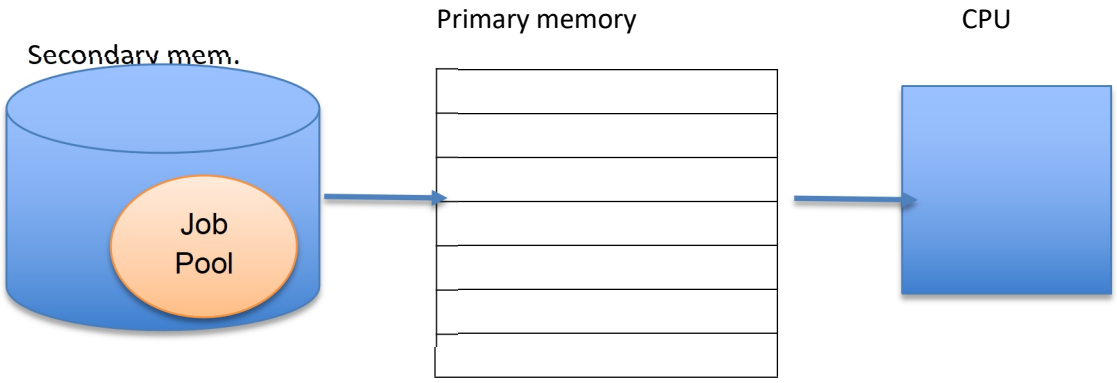
Unit I

Operating-System Structure

One of the most important aspects of operating systems is the ability to multiprogram. A single user cannot keep either the CPU or the I/O devices busy at all times. **Multiprogramming** increases CPU utilization by organizing jobs, so that the CPU always has one to execute.



The operating system keeps several jobs in memory simultaneously as shown in figure. This set of jobs is a subset of the jobs kept in the job pool. Since the number of jobs that can be kept simultaneously in memory is usually smaller than the number of jobs that can be kept in the job pool(in secondary memory). The operating system picks and begins to execute one of the jobs in memory. Eventually, the job may have to wait for some task, such as an I/O operation, to complete. In a non-multiprogrammed system, the CPU would sit idle. In a multiprogrammed system, the operating system simply switches to, and executes, another job. When *that* job needs to wait, the CPU is switched to *another* job, and so on. Eventually, the first job finishes waiting and gets the CPU back. Thus the CPU is never idle.



Multiprogrammed systems provide an environment in which the various system resources (for example, CPU, memory, and peripheral devices) are utilized effectively, but they do not provide for user interaction with the computer system.

In **Time sharing** (or **multitasking) systems,** a single CPU executes multiple jobs by switching among them, but the switches occur so frequently that the users can interact with each program while it is running. The user feels that all the programs are being executed at the same time. Time sharing requires an **interactive** (or **hands-on) computer system,** which provides direct communication between the user and the system. The user gives instructions to the operating system or to a program directly, using a input device such as a keyboard or a mouse,

and waits for immediate results on an output device. Accordingly, the **response time** should be short—typically less than one second.

A time-shared operating system allows many users to share the computer simultaneously. As the system switches rapidly from one user to the next, each user is given the impression that the entire computer system is dedicated to his use only, even though it is being shared among many users.

A **multiprocessor system** is a computer system having two or more CPUs within a single computer system, each sharing main memory and peripherals. Multiple programs are executed by multiple processors parallel.

Distributed Systems

Individual systems that are connected and share the resource available in network is called Distributed system. Access to a shared resource increases computation speed, functionality, data availability, and reliability.

A **network** is a communication path between two or more systems. Distributed systems depend on networking for their functionality. Networks vary by the protocols used, the distances between nodes, and the transport media. TCP/IP is the most common network protocol. Most operating systems support TCP/IP.

Networks are characterized based on the distances between their nodes. A **local-area network (LAN)** connects computers within a room, a floor, or a building. A **wide-area network (WAN)** usually links buildings, cities, or countries. A global company may have a WAN to connect its offices worldwide. A **metropolitan-area network** (MAN) links buildings within a city. A **small-area network** connects systems within a several feet using wireless technology. Eg. BlueTooth and 802.11.

The media to carry networks also vary - copper wires, fiber strands, and wireless transmissions between satellites, microwave dishes, and radios.

A **network operating system** is an operating system that provides features such as file sharing across the network and that allows different processes on different computers to exchange messages.A computer running a network operating system acts autonomously from all other computers on the network, although it is aware of the network and is able to communicate with other networked computers.

Operating-System Operations

Modern operating systems are **interrupt driven.** If there are no processes to execute, no I/O devices to service, and no users to whom to respond, an operating system will sit quietly, waiting for something to happen. Events are signaled by the occurrence of an interrupt or a trap. A **trap (or** an **exception)** is a software-generated interrupt. For each type of interrupt, separate segments of code in the operating system determine what action should be taken. An interrupt service routine is provided that is responsible for dealing with the interrupt.

a) Dual-Mode Operation

Since the operating system and the user programs share the hardware and software resources of the computer system, it has to be made sure that an error in a user program cannot cause problems to other programs and the Operating System running in the system.

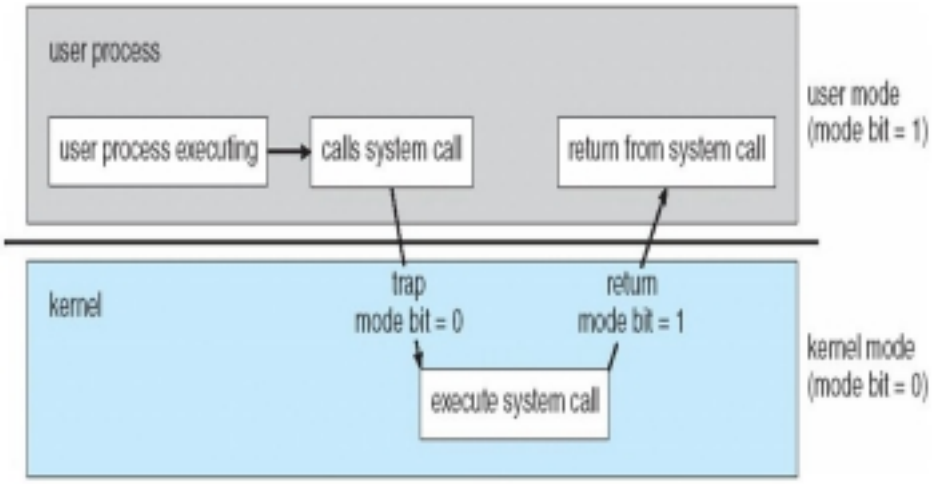
The approach taken is to use a hardware support that allows us to differentiate among various modes of execution.

The system can be assumed to work in two separate **modes** of operation:

- **user mode** and
- **kernel mode** (**supervisor mode, system mode, or privileged mode).**

A hardware bit of the computer, called the **mode bit**, is used to indicate the current mode: kernel (0) or user (1). With the mode bit, we are able to distinguish between a task that is executed by the operating system and one that is executed by the user.

When the computer system is executing a user application, the system is in user mode. When a user application requests a service from the operating system (via a system call), the transition from user to kernel mode takes place.



At system boot time, the hardware starts in kernel mode. The operating system is then loaded and starts user applications in user mode. Whenever a trap or interrupt occurs, the hardware switches from user mode to kernel mode (that is, changes the mode bit from 1 to 0). Thus, whenever the operating system gains control of the computer, it is in kernel mode.

The dual mode of operation provides us with the means for protecting the operating system from errant users—and errant users from one another.

The hardware allows privileged instructions to be executed only in kernel mode. If an attempt is made to execute a privileged instruction in user mode, the hardware does not execute the instruction but rather treats it as illegal and traps it to the operating system. The instruction to switch to user mode is an example of a privileged instruction.

Initial control is within the operating system, where instructions are executed in kernel mode. When control is given to a user application, the mode is set to user mode. Eventually, control is switched back to the operating system via an interrupt, a trap, or a system call.

b) Timer

Operating system uses timer to control the CPU. A user program cannot hold CPU for a long time, this is prevented with the help of timer.

A timer can be set to interrupt the computer after a specified period. The period may be **fixed** (for example, 1/60 second) or **variable** (for example, from 1 millisecond to 1 second).

Fixed timer – After a fixed time, the process under execution is interrupted.

Variable timer – Interrupt occurs after varying interval. This is implemented using a fixed-rate clock and a counter. The operating system sets the counter. Every time the clock ticks, the counter is decremented. When the counter reaches 0, an interrupt occurs.

Before changing to the user mode, the operating system ensures that the timer is set to interrupt. If the timer interrupts, control transfers automatically to the operating system, which may treat the interrupt as a fatal error or may give the program more time.

Process Management

A program under execution is a process. A process needs resources like CPU time, memory, files, and I/O devices for its execution. These resources are given to the process when it is created or at run time. When the process terminates, the operating system reclaims the resources.

The program stored on a disk is a **passive entity** and the program under execution is an **active entity**. A single-threaded process has one **program counter** specifying the next instruction to execute. The CPU executes one instruction of the process after another, until the process completes. A multithreaded process has multiple program counters, each pointing to the next instruction to execute for a given thread.
The operating system is responsible for the following activities in connection with process management:

- Scheduling process and threads on the CPU
- Creating and deleting both user and system processes
- Suspending and resuming processes
- Providing mechanisms for process synchronization
- Providing mechanisms for process communication

Memory Management

Main memory is a large array of words or bytes. Each word or byte has its own address. Main memory is the storage device which can be easily and directly accessed by the CPU. As the program executes, the central processor reads instructions and also reads and writes data from main memory.

To improve both the utilization of the CPU and the speed of the computer's response to its users, general-purpose computers must keep several programs in memory, creating a need for memory management.

The operating system is responsible for the following activities in connection with memory management:

- Keeping track of which parts of memory are currently being used by user. • Deciding which processes and data to move into and out of memory.
- Allocating and deallocating memory space as needed.

Storage Management

There are three types of storage management i) File system management ii) Mass-storage management iii) Cache management.

File-System Management

File management is one of the most visible components of an operating system. Computers can store information on several different types of physical media. Magnetic disk, optical disk, and magnetic tape are the most common. Each of these media has its own characteristics and physical organization. Each medium is controlled by a device, such as a disk drive or tape drive, that also has its own unique characteristics.

A file is a collection of related information defined by its creator. Commonly, files represent programs and data. Data files may be numeric, alphabetic, alphanumeric, or binary. Files may be free-form (for example, text files), or they may be formatted rigidly (for example, fixed fields).

The operating system implements the abstract concept of a file by managing mass storage media. Files are normally organized into directories to make them easier to use. When multiple users have access to files, it may be desirable to control by whom and in what ways (read, write, execute) files may be accessed.

The operating system is responsible for the following activities in connection with file management:

- Creating and deleting files
- Creating and deleting directories to organize files
- Supporting primitives for manipulating files and directories
- Mapping files onto secondary storage
- Backing up files on stable (nonvolatile) storage media

Mass-Storage Management

As the main memory is too small to accommodate all data and programs, and as the data that it holds are erased when power is lost, the computer system must provide secondary storage to back up main memory. Most modern computer systems use disks as the storage medium for both programs and data.

Most programs—including compilers, assemblers, word processors, editors, and formatters—are stored on a disk until loaded into memory and then use the disk as both the source and destination of their processing. Hence, the proper management of disk storage is of central importance to a computer system. The operating system is responsible for the following activities in connection with disk management:

- Free-space management
- Storage allocation
- Disk scheduling

As the secondary storage is used frequently, it must be used efficiently. The entire speed of operation of a computer may depend on the speeds of the disk. Magnetic tape drives and their tapes, CD, DVD drives and platters are **tertiary storage** devices. The functions that operating systems provides include mounting and unmounting media in devices, allocating and freeing the devices for exclusive use by processes, and migrating data from secondary to tertiary storage.

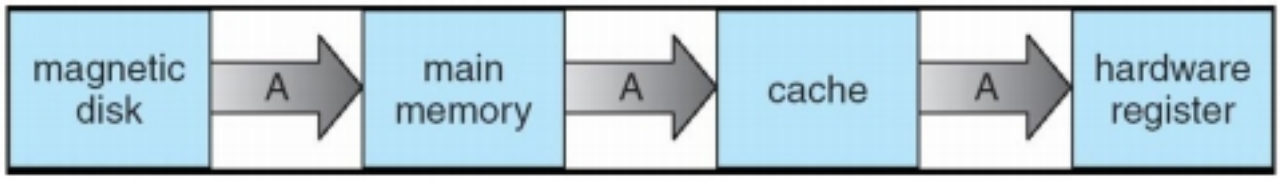
Caching

Caching is an important principle of computer systems. Information is normally kept in some storage system (such as main memory). As it is used, it is copied into a faster storage system—the cache—as temporary data. When a particular piece of information is required, first we check whether it is in the cache. If it is, we use the information directly from the cache; if it is not in cache, we use the information from the source, putting a copy in the cache under the assumption that we will need it again soon.

Because caches have limited size, **cache management** is an important design problem. Careful selection of the cache size and page replacement policy can result in greatly increased performance.

The movement of information between levels of a storage hierarchy may be either explicit or implicit, depending on the hardware design and the controlling operating-system software. For instance, data transfer from cache to CPU and registers is usually a hardware function, with no operating-system intervention. In contrast, transfer of data from disk to memory is usually controlled by the operating system.

In a hierarchical storage structure, the same data may appear in different levels of the storage system. For example, suppose to retrieve an integer A from magnetic disk to the processing program. The operation proceeds by first issuing an I/O operation to copy the disk block on which A resides to main memory. This operation is followed by copying A to the cache and to an internal register. Thus, the copy of A appears in several places: on the magnetic disk, in main memory, in the cache, and in an internal register.



In a multiprocessor environment, in addition to maintaining internal registers, each of the CPUs also contains a local cache. In such an environment, a copy of A may exist simultaneously in several caches. Since the various CPUs can all execute concurrently, any update done to the value of A in one cache is immediately reflected in all other caches where A resides. This situation is called **cache coherency,** and it is usually a hardware problem (handled below the operating-system level).

I/O Systems

One of the purposes of an operating system is to hide the peculiarities of specific hardware devices from the user. The I/O subsystem consists of several components: • A memory-management component that includes buffering, caching, and spooling

- A general device-driver interface
- Drivers for specific hardware devices

Only the device driver knows the peculiarities of the specific device to which it is assigned.

Protection and Security

If a computer system has multiple users and allows the concurrent execution of multiple processes, then access to data must be regulated. For that purpose, mechanisms ensure that files, memory segments, CPU, and other resources can be operated on by only those processes that have gained proper authorization from the operating system.

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processes, then access to data must be regulated. For that purpose, there are mechanisms which ensure that files, memory segments, CPU, and other resources can be operated on by only those processes that have gained proper authorization from the operating system.

For example, memory-addressing hardware ensures that a process can execute only within its own address space. The timer ensures that no process can gain control of the CPU for a long time. Device-control registers are not accessible to users, so the integrity of the various peripheral devices is protected.

Protection is a mechanism for controlling the access of processes or users to the resources defined by a computer system. This mechanism must provide means for specification of the controls to be imposed and means for enforcement.

Protection improves reliability. A protection-oriented system provides a means to distinguish between authorized and unauthorized usage. A system can have adequate protection but still be prone to failure and allow inappropriate access.

Consider a user whose authentication information is stolen. Her data could be copied or deleted, even though file and memory protection are working. It is the job of **security** to defend a system from external and internal attacks. Such attacks spread across a huge range and include viruses and worms, denial-of service attacks etc.

Protection and security require the system to be able to distinguish among all its users. Most operating systems maintain a list of user names and associated **user identifiers (user IDs).** When a user logs in to the system, the authentication stage determines the appropriate user ID for the user.

Distributed Systems

A distributed system is a collection of systems that are networked to provide the users with access to the various resources in the network. Access to a shared resource increases computation speed, functionality, data availability, and reliability.

A **network** is a communication path between two or more systems. Networks vary by the protocols used(TCP/IP,UDP,FTP etc.), the distances between nodes, and the transport media(copper wires, fiber-optic,wireless).

TCP/IP is the most common network protocol. The operating systems support of protocols also varies. Most operating systems support TCP/IP, including the Windows and UNIX operating systems.

Networks are characterized based on the distances between their nodes. A **local-area network (LAN)** connects computers within a room, a floor, or a building. A **wide-area network (WAN)** usually links buildings, cities, or countries. A global company may have a WAN to connect its offices worldwide. These networks may run one protocol or several protocols. A **metropolitan-area network** (MAN) connects buildings within a city. BlueTooth and 802.11 devices use wireless technology to communicate over a distance of several feet, in essence creating a **small-area network** such as might be found in a home.

The transportation media to carry networks are also varied. They include copper wires, fiber strands, and wireless transmissions between satellites, microwave dishes, and radios. When computing devices are connected to cellular phones, they create a network.

Special-Purpose Systems

There are different classes of computer systems, whose functions are more limited and specific and it deal with limited computation domains. The systems can be classified as Real-Time Embedded Systems, Multimedia Systems and Handheld Systems.

Real-Time Embedded Systems

Embedded computers are the most prevalent form of computers in existence. These devices are found everywhere, from car engines and manufacturing robots to VCRs and microwave ovens. They tend to have very specific tasks. Usually, they have little user interface, and more time is spent for monitoring and managing hardware devices, eg. automobile engines and robotic arms.

The Operating Systems, in these embedded systems vary considerably. Some systems have standard operating systems—such as UNIX—with special-purpose applications. Others have special-purpose embedded operating system providing just the functionality desired.

Embedded systems always run **real-time operating systems.** A real-time system is used when there is restricted time for an operation or for the flow of data. A real-time system functions

correctly only if it returns the correct result within its time constraints. Sensors bring data to the computer. The computer must analyze the data and perform certain action.

Some medical imaging systems, automobile-engine fuel-injection systems, home appliance controllers, and weapon systems are real-time systems. A real-time system has well defined, fixed time constraints. Processing **mustbe** done within the defined constraints, or the system will fail. For instance, the robot arm should be halted before it has smashed into the car, it was building.

Entire houses can be computerized, so that a computer —can control heating and lighting, alarm systems, and even coffee makers. Web access can enable a home owner to tell the house to heat up before she arrives home.

Multimedia Systems

Multimedia data consist of audio and video files as well as conventional files. These data differ from conventional data in that multimedia data—such as frames of video—must be delivered (streamed) according to certain time restrictions (for example, 30 frames per second).

Multimedia describes a wide range of applications like audio files - MP3, DVD movies, video conferencing, and short video clips of movie previews or news. Multimedia applications may also include live webcasts of speeches or sporting events and even live webcams. Multimedia applications can be either audio or video or combination of both. For example, a movie may consist of separate audio and video tracks.

Handheld Systems

Handheld systems include personal digital assistants (PDAs), such as Palm and Pocket-PCs, and cellular telephones. Developers of these systems face many challenges, due to the limited memory, slow processors and small screens in such devices.

The amount of physical memory in a handheld depends upon the device, the operating system and applications must manage memory efficiently. This includes returning all allocated memory back to the memory manager when the memory is not being used. A second issue of concern to developers of handheld devices is the speed of the processor used in the devices. Processors for most handheld devices run at faster speed than the processor in a PC. Faster processors require more power and so, a larger battery is required. Another issue is the usage of I/O devices.

Generally, the limitations in the functionality of PDAs are balanced by their convenience and portability. Their use continues to expand as network connections become more available and other options, such as digital cameras and MP3 players, expand their utility.

Computing Environments

The different computing environments are -

Traditional Computing

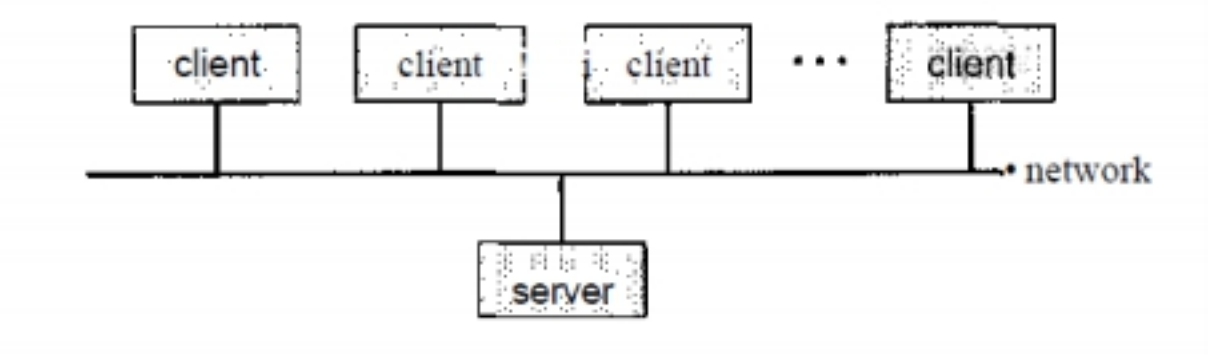
The current trend is toward providing more ways to access these computing environments. Web technologies are stretching the boundaries of traditional computing. Companies establish **portals,** which provide web accessibility to their internal servers. **Network computers** are essentially terminals that understand web-based computing. Handheld computers can synchronize with PCs to allow very portable use of company information. Handheld PDAs can also connect to **wireless networks** to use the company's web portal. The fast data connections are allowing home computers to serve up web pages and to use networks. Some homes even have **firewalls** to protect their networks.

In the latter half of the previous century, computing resources were scarce. Years before, systems were either batch or interactive. Batch system processed jobs in bulk, with predetermined input (from files or other sources of data). Interactive systems waited for input from users. To optimize the use of the computing resources, multiple users shared time on these systems. Time-sharing systems used a timer and scheduling algorithms to rapidly cycle processes through the CPU, giving each user a share of the resources.

Today, traditional time-sharing systems are used everywhere. The same scheduling technique is still in use on workstations and servers, but frequently the processes are all owned by the same user (or a single user and the operating system). User processes, and system processes that provide services to the user, are managed so that each frequently gets a slice of computer time.

Client-Server Computing

Designers shifted away from centralized system architecture to - terminals connected to centralized systems. As a result, many of today’s systems act as **server systems to** satisfy requests generated by **client systems.** This form of specialized distributed system, called **client server** system.



General Structure of Client – Server System

Server systems can be broadly categorized as compute servers and file servers: • The **compute-server system** provides an interface to which a client can send a request to perform an action (for example, read data); in response, the server executes the action and sends back results to the client. A server running a database that responds to client requests for data is an example of such a svstem.

- The **file-server system** provides a file-system interface where clients can create, update, read, and delete files. An example of such a system is a web server that delivers files to clients running the web browsers.

Peer-to-Peer Computing

In this model, clients and servers are not distinguished from one another; here, all nodes within the system are considered peers, and each may act as either a client or a server, depending on whether it is requesting or providing a service.

In a client-server system, the server is a bottleneck, because all the services must be served by the server. But in a peer-to-peer system, services can be provided by several nodes distributed throughout the network.

To participate in a peer-to-peer system, a node must first join the network of peers. Once a node has joined the network, it can begin providing services to—and requesting services from—other nodes in the network. Determining what services are available is accomplished in one of two general ways:

- When a node joins a network, it registers its service with a centralized lookup service on the network. Any node desiring a specific service first contacts this centralized lookup service to determine which node provides the service. The remainder of the communication takes place between the client and the service provider.
- A peer acting as a client must know, which node provides a desired service by broadcasting a request for the service to all other nodes in the network. The node (or nodes) providing that service responds to the peer making the request. To support this approach, a *discovery protocol* must be provided that allows peers to discover services provided by other peers in the network.

Web-Based Computing

Web computing has increased the importance on networking. Devices that were not previously networked now include wired or wireless access. Devices that were networked now have faster network connectivity.

The implementation of web-based computing has given rise to new categories of devices, such as **load balancers,** which distribute network connections among a pool of similar servers. Operating systems like Windows 95, which acted as web clients, have evolved into Linux and Windows XP, which can act as web servers as well as clients. Generally, the Web has increased the complexity of devices, because their users require them to be web-enabled.

The design of an operating system is a major task. It is important that the goals of the new system be well defined before the design of OS begins. These goals form the basis for choices among various algorithms and strategies.

2.1 Operating-System Services

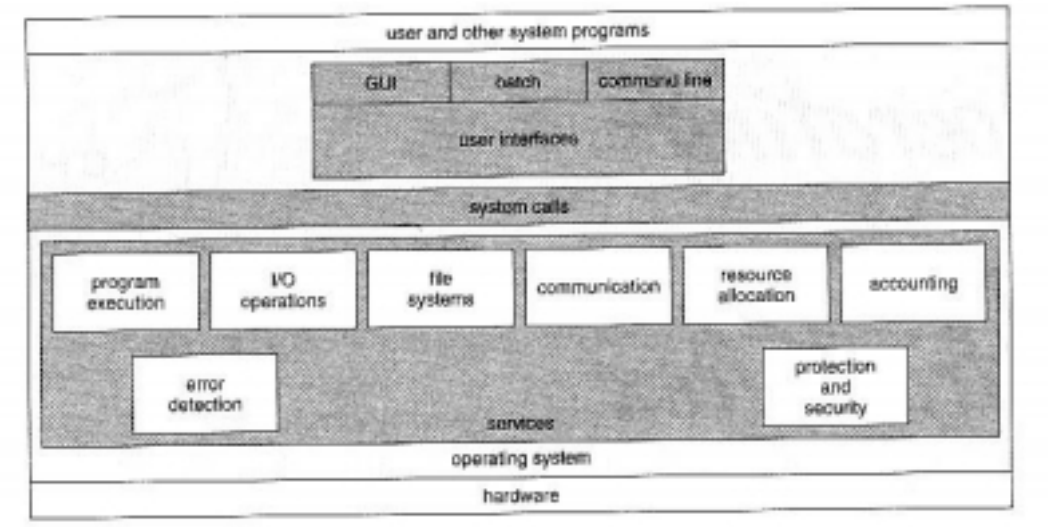


Figure 2.1 A view of operating system services.

An operating system provides an environment for the execution of programs. It provides certain services to programs and to the users of those programs. OS provide services for the users of the system, including:

- **User Interfaces** - Means by which users can issue commands to the system. Depending on the operating system these may be a **command-line interface** (e.g. sh, csh, ksh, tcsh, etc.), a **Graphical User Interface** (e.g. Windows, X-Windows, KDE, Gnome, etc.), or a **batch command systems**. In Command Line Interface(CLI)- commands are given to the system. In Batch interface – commands and directives to control these commands are put in a file and then the file is executed. In GUI systems- windows with pointing device to get inputs and keyboard to enter the text.
- **Program Execution** - The OS must be able to load a program into RAM, run the program, and terminate the program, either normally or abnormally.
- **I/O Operations** - The OS is responsible for transferring data to and from I/O devices, including keyboards, terminals, printers, and files. For specific devices, special functions are provided(device drivers) by OS.

- **File-System Manipulation** – Programs need to read and write files or directories. The services required to create or delete files, search for a file, list the contents of a file and change the file permissions are provided by OS.

- **Communications** - Inter-process communications, IPC, either between processes running on the same processor, or between processes running on separate processors or separate machines. May be implemented by using the service of OS- like shared memory or message passing.
- **Error Detection** - Both hardware and software errors must be detected and handled appropriately by the OS. Errors may occur in the CPU and memory hardware (such as power failure and memory error), in I/O devices (such as a parity error on tape, a connection failure on a network, or lack of paper in the printer), and in the user program (such as an arithmetic overflow, an attempt to access an illegal memory location).

OS provide services for the efficient operation of the system, including:

- **Resource Allocation** – Resources like CPU cycles, main memory, storage space, and I/O devices must be allocated to multiple users and multiple jobs at the same time.
- **Accounting** – There are services in OS to keep track of system activity and resource usage, either for billing purposes or for statistical record keeping that can be used to optimize future performance.
- **Protection and Security** – The owners of information(file) in multiuser or networked computer system may want to control the use of that information. When several separate processes execute concurrently, one process should not interfere with other or with OS. Protection involves ensuring that all access to system resources is controlled. Security of the system from outsiders must also be done, by means of a password.

2.2 User Operating-System Interface

There are several ways for users to interface with the operating system.

1) Command-line interface, or command interpreter, allows users to directly enter commands to be performed by the operating system.
2) Graphical user interface(GUI), allows users to interface with the operating system using pointer device and menu system.

Command Interpreter

Command Interpreters are used to give commands to the OS. There are multiple command interpreters known as shells. In UNIX and Linux systems, there are several different shells, like the *Bourne shell, C shell, Bourne-Again shell, Korn shell,* and others.

The main function of the command interpreter is to get and execute the user-specified command. Many of the commands manipulate files: create, delete, list, print, copy, execute, and so on.

The commands can be implemented in two general ways

1) The command interpreter itself contains the code to execute the command. For example, a command to delete a file may cause the command interpreter to jump to a particular section of its

code that sets up the parameters and makes the appropriate system call.

2) The code to implement the command is in a function in a separate file. The interpreter searches for the file and loads it into the memory and executes it by passing the parameter. Thus by adding new functions new commands can be added easily to the interpreter without disturbing it.

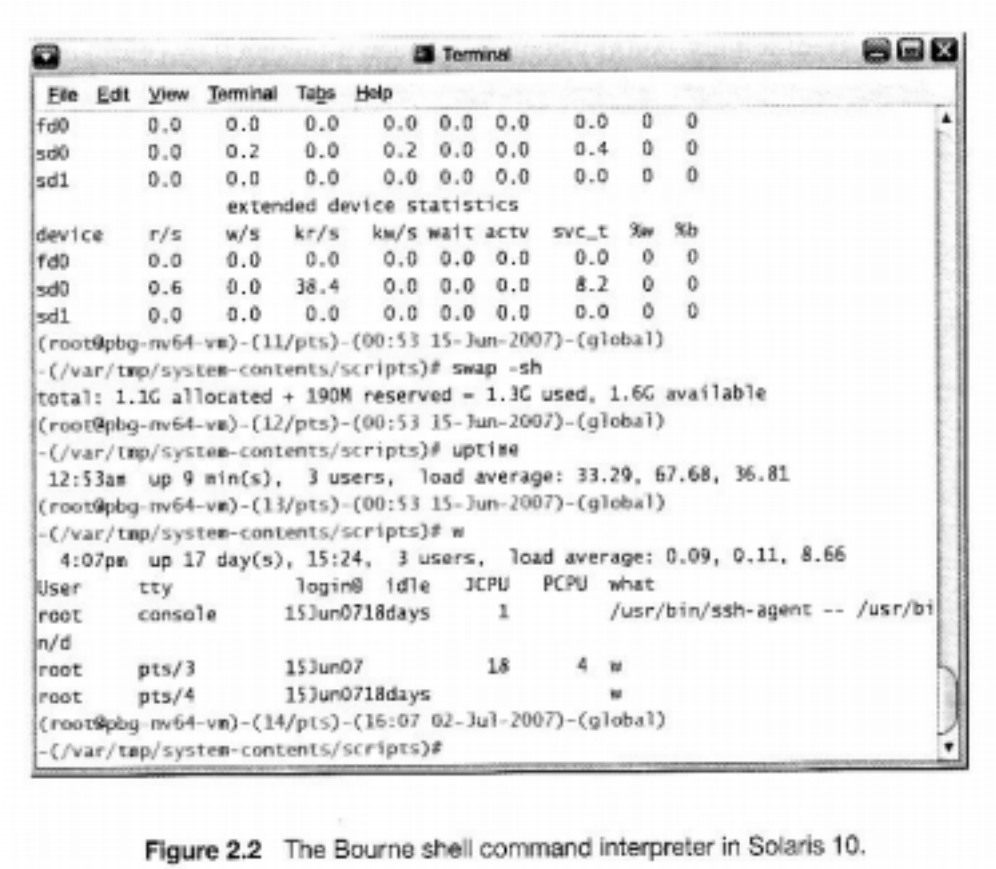


Figure 2.2 The Bourne shell command interpreter in Solaris 10.

Graphical User Interface, GUI

Another way of interfacing with the operating system is through a user friendly graphical user interface, or GUI. Here, rather than entering commands directly via a command-line interface, users employ a mouse-based window and menu system. The user moves the mouse to position its

pointer on images, or icons on the screen (the desktop) that represent programs, files, directories, and system functions. Depending on the mouse pointer's location, clicking a button on the mouse can invoke a program, select a file or directory-known as a folder-or pull down a menu that contains commands.

Graphical user interfaces first appeared on the Xerox Alto computer in 1973.

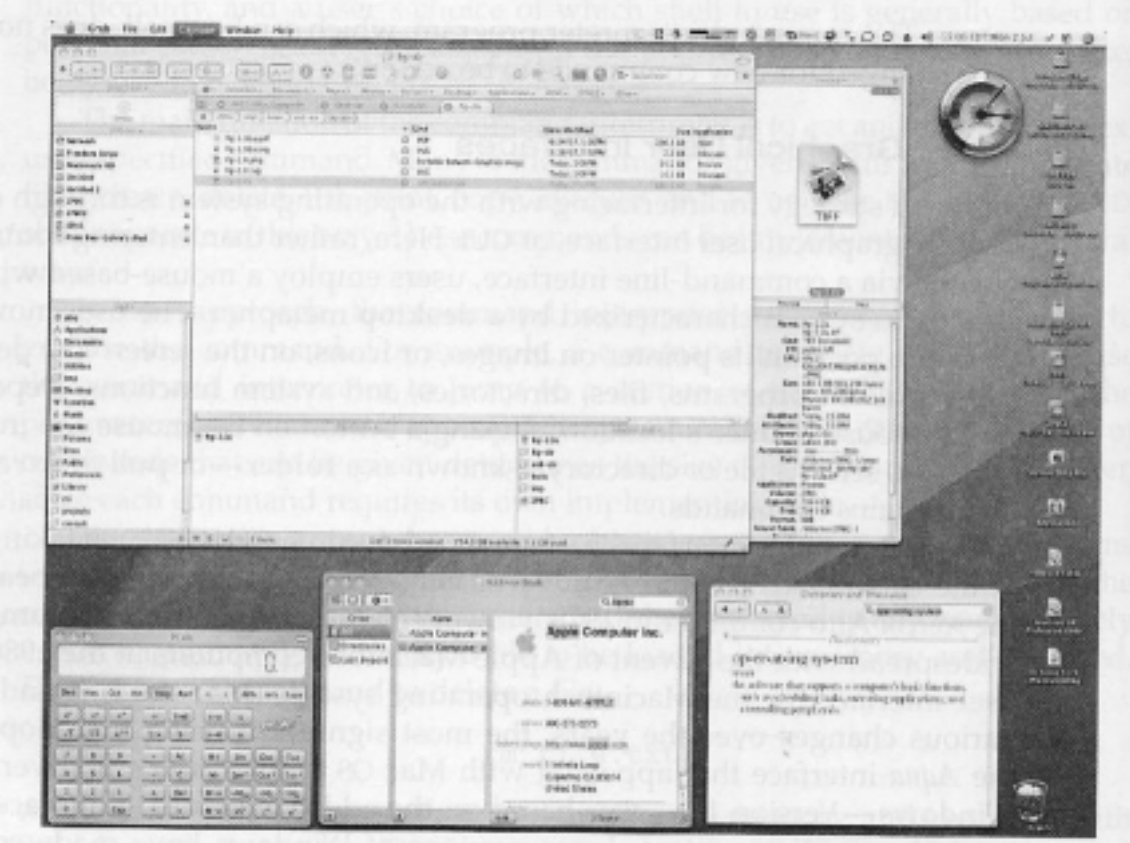


Figure 2.3 The Mac OS X GUI.

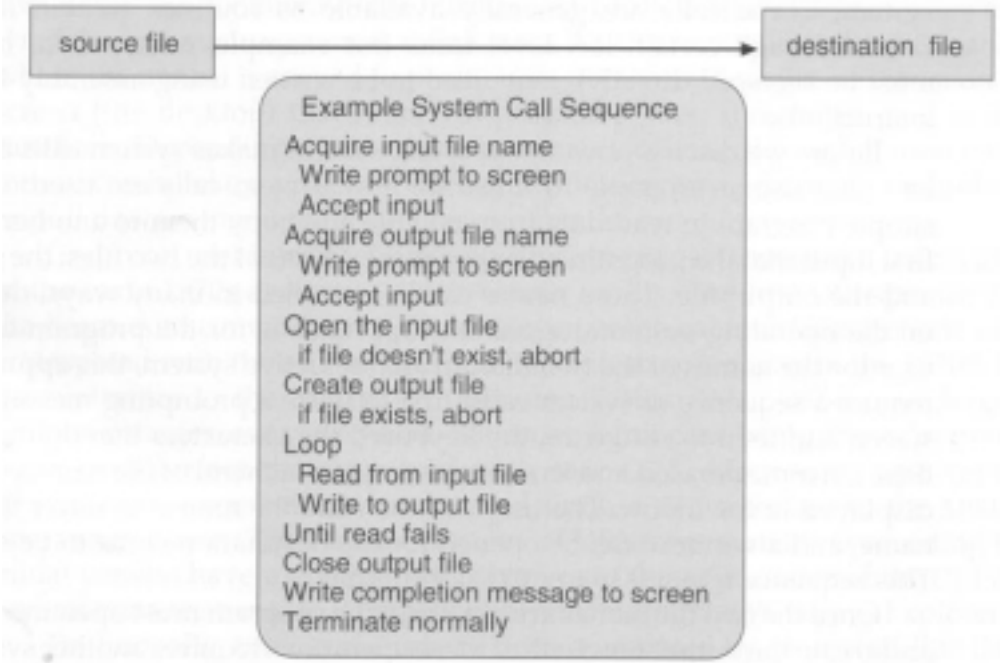
Most modern systems allow individual users to select their desired interface, and to customize its operation, as well as the ability to switch between different interfaces as needed.

2.3 System Calls

- System calls is a means to access the services of the operating system.

- Generally written in C or C++, although some are written in assembly for optimal performance.

- The below figure illustrates the sequence of system calls required to copy a file content from one file(input file) to another file (output file).



There are number of system calls used to finish this task. The first system call is to write a message on the screen (monitor). Then to accept the input filename. Then another system call to write message on the screen, then to accept the output filename. When the program tries to open the input file, it may find that there is no file of that name or that the file is protected against access. In these cases, the program should print a message on the console(another system call) and then terminate abnormally (another system call) and create a new one (another system call).

Now that both the fileas are opened, we enter a loop that reads from the input file(another system call) and writes to output file (another system call).

Finally, after the entire file is copied, the program may close both files (another system call), write a message to the console or window(system call), and finally terminate normally (final system call).

- Most programmers do not use the low-level system calls directly, but instead use an "Application Programming Interface", API.

- The APIs instead of direct system calls provides for greater program portability between different systems. The API then makes the appropriate system calls through the system call interface, using a system call table to access specific numbered system calls, as shown in Figure 2.6.
- Each system call has a specific numbered system call. The system call table (consisting of system call number and address of the particular service) invokes a particular service routine for a specific system call.
- The caller need know nothing about how the system call is implemented or what it does during execution.

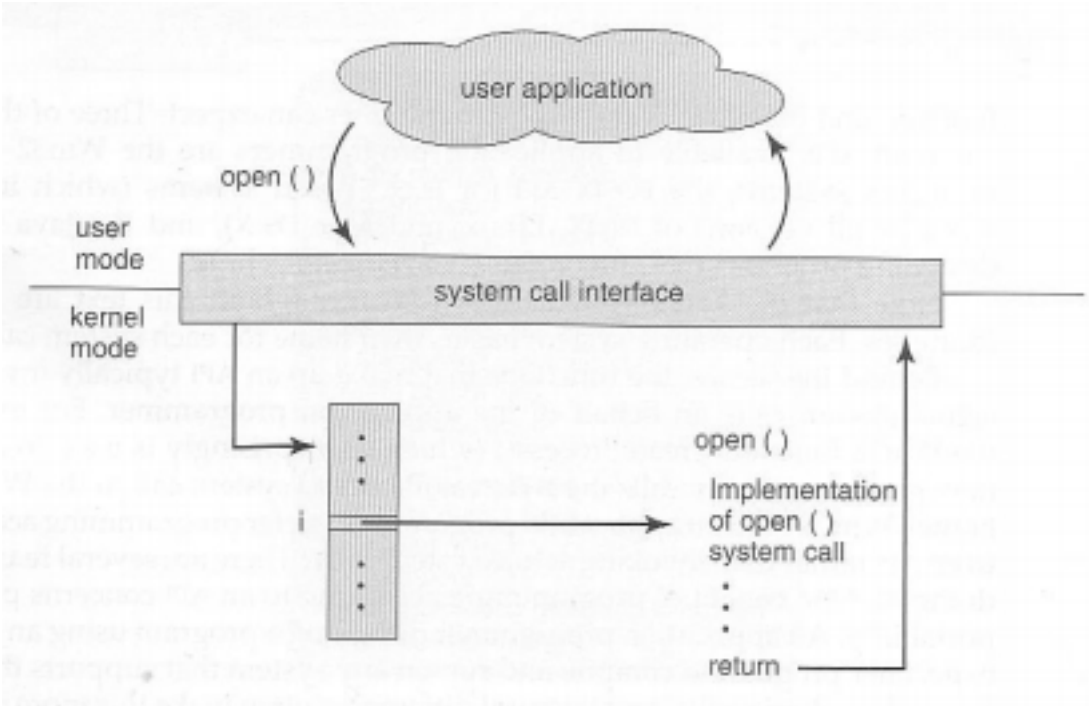
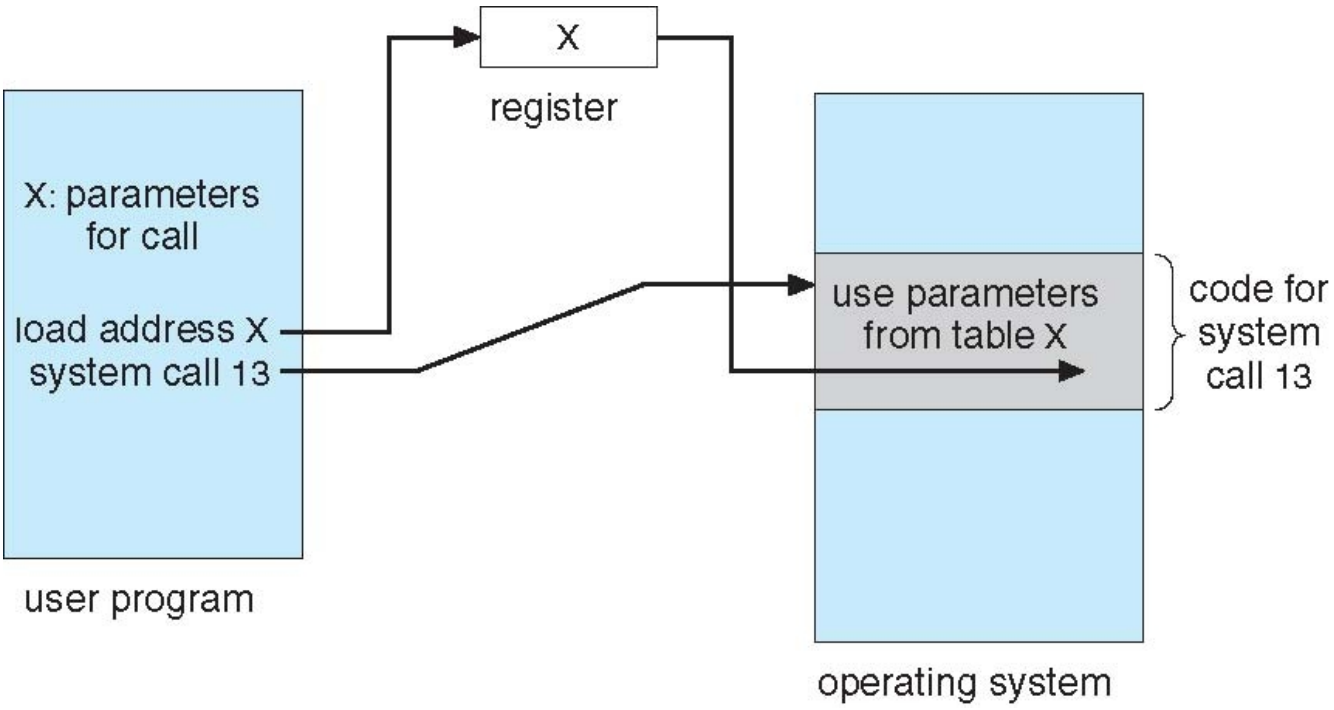


Figure 2.6 The handling of a user application invoking the open() system call.



Three general methods used to pass parameters to OS are –

- To pass parameters in registers
- If parameters are large blocks, address of block (where parameters are stored in memory) is sent to OS in the register. (Linux & Solaris).
- Parameters can be pushed onto the stack by program and popped off the stack by OS.

2.3.1 Types of System Calls

The system calls can be categorized into six major categories:

- Process Control
- File management
- Device management
- Information management
- Communications
- Protection

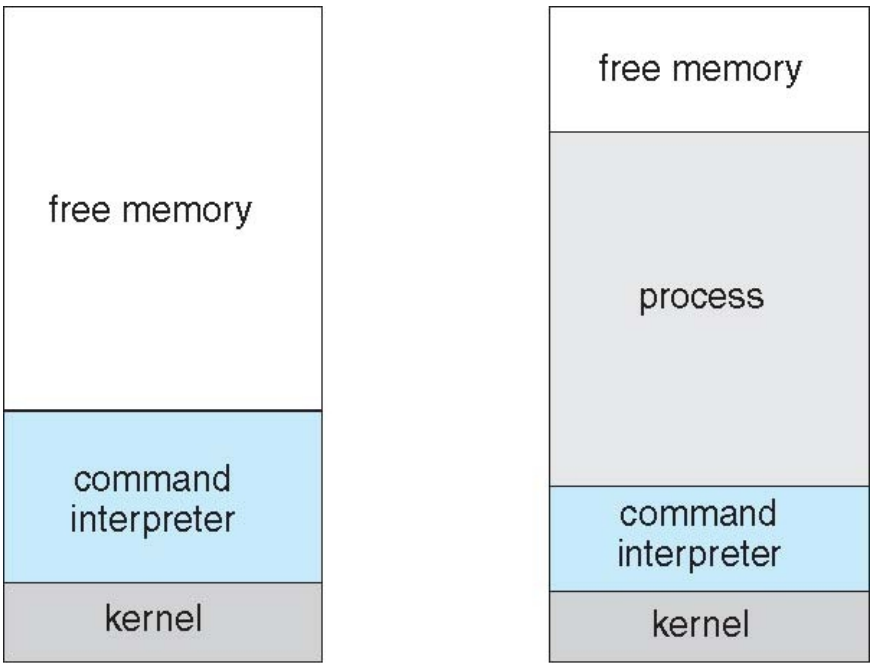
	Windows	Unix
Process Control	CreateProcess() ExitProcess() WaitForSingleObject()	fork() exit() wait()
File Manipulation	CreateFile() ReadFile() WriteFile() CloseHandle()	open() read() write() close()
Device Manipulation	SetConsoleMode() ReadConsole() WriteConsole()	ioctl() read() write()
Information Maintenance	GetCurrentProcessID() SetTimer() Sleep()	getpid() alarm() sleep()
Communication	CreatePipe() CreateFileMapping() MapViewOfFile()	pipe() shmget() mmap()
Protection	SetFileSecurity() InitlializeSecurityDescriptor() SetSecurityDescriptorGroup()	chmod() umask() chown()

a) Process Control

- Process control system calls include end, abort, load, execute, create process, terminate process, get/set process attributes, wait for time or event, signal event, and allocate and free memory.
- Processes must be created, launched, monitored, paused, resumed, and eventually stopped.
- When one process pauses or stops, then another must be launched or resumed
- Process attributes like process priority, max. allowable execution time etc. are set and retrieved by OS.
- After creating the new process, the parent process may have to wait (wait time), or wait for an event to occur(wait event). The process sends back a signal when the event has occurred (signal event).

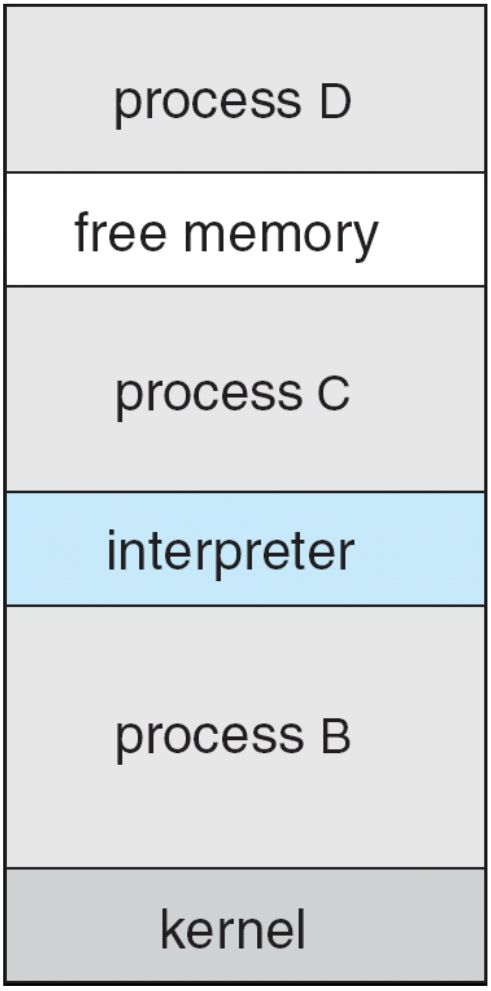
  - In DOS, the command interpreter loaded first.Then loads the process and transfers control to it. The interpreter does not resume until the process has completed, as shown in Figure

At system startup running a program



(a) (b)

- Because UNIX is a multi-tasking system, the command interpreter remains completely resident when executing a process, as shown in Figure 2.11 below. ▪ The user can switch back to the command interpreter at any time, and can place the running process in the background even if it was not originally launched as a background process.
  - ▪ In order to do this, the command interpreter first executes a "fork" system call, which creates a second process which is an exact duplicate (clone) of the original command interpreter. The original process is known as the parent, and the cloned process is known as the child, with its own unique process ID and parent ID.
  - ▪ The child process then executes an "exec" system call, which replaces its code with that of the desired process.
  - ▪ The parent (command interpreter) normally waits for the child to complete before issuing a new command prompt, but in some cases it can also issue a new prompt right away, without waiting for the child process to complete. (The child is then said to be running "in the background", or "as a background process".)



b) File Management

The file management functions of OS are –

- File management system calls include create file, delete file, open, close, read, write, reposition, get file attributes, and set file attributes.
- After **creating** a file, the file is **opened**. Data is **read** or **written** to a file. •

The file pointer may need to be **repositioned** to a point.

- The file **attributes** like filename, file type, permissions, etc. are set and retrieved using system calls.
- These operations may also be supported for directories as well as ordinary files. **c)**

Device Management

- Device management system calls include **request device**, **release** device, **read**, **write**, **reposition**, **get/set** device attributes, and logically **attach** or **detach** devices. • When a process

needs a resource, a request for resource is done. Then the control is granted to the process. If requested resource is already attached to some other process, the requesting process has to wait.

- In multiprogramming systems, after a process uses the device, it has to be returned to OS, so that another process can use the device.
- Devices may be physical (e.g. disk drives), or virtual / abstract (e.g. files, partitions, and RAM disks).

d) Information Maintenance

- Information maintenance system calls include calls to get/set the time, date, system data, and process, file, or device attributes.
- These system calls care used to transfer the information between user and the OS. Information like current time & date, no. of current users, version no. of OS, amount of free memory, disk space etc. are passed from OS to the user.

e) Communication

- Communication system calls create/delete communication connection, send/receive messages, transfer status information, and attach/detach remote devices.
- The **message passing** model must support calls to:
    - Identify a remote process and/or host with which to communicate.
    - Establish a connection between the two processes.
    - Open and close the connection as needed.
    - Transmit messages along the connection.
    - Wait for incoming messages, in either a blocking or non-blocking state.
    - Delete the connection when no longer needed.
- The **shared memory** model must support calls to:
    - Create and access memory that is shared amongst processes (and threads.)
    - Free up shared memory and/or dynamically allocate it as needed.
- Message passing is simpler and easier, (particularly for inter-computer communications), and is generally appropriate for small amounts of data. It is easy to implement, but there are system calls for each read and write process.
- Shared memory is faster, and is generally the better approach where large amounts of data are to be shared. This model is difficult to implement, and it consists of only few system calls.

f) Protection

- Protection provides mechanisms for controlling which users / processes have access to which system resources.
- System calls allow the access mechanisms to be adjusted as needed, and for non priveleged users to be granted elevated access permissions under carefully controlled temporary circumstances.

2.4 System Programs

A collection os programs that provide a convenient environment for program development and execution (other than OS) are called system programs or system utilities.

- It is not a part of the kernel or command interpreters.
- System programs may be divided into five categories:
    - **File management** - programs to create, delete, copy, rename, print, list, and generally manipulate files and directories.
    - **Status information** - Utilities to check on the date, time, number of users, processes running, data logging, etc. System **registries** are used to store and recall configuration information for particular applications.
    - **File modification** - e.g. text editors and other tools which can change file contents.
    - **Programming-language support** - E.g. Compilers, linkers, debuggers, profilers, assemblers, library archive management, interpreters for common languages, and support for make.
    - **Program loading and execution** - loaders, dynamic loaders, overlay loaders, etc., as well as interactive debuggers.

    - **Communications** - Programs for providing connectivity between processes and users, including mail, web browsers, remote logins, file transfers, and remote command execution.

2.5 Operating-System Design and Implementation

2.5.1 Design Goals

Any system to be designed must have its own goals and specifications. Similarly the OS to be built will have its own goals depending on the type of system in which it will be used, the type of hardware used in the system etc.

- **Requirements** define properties which the finished system must have, and are a necessary steps in designing any large complex system. The requirements may be of two basic groups:

    1. User goals (User requirements)
    2. System goals (system requirements)

    - **User requirements** are features that users care about and understand like system should be convenient to use, easy to learn,reliable, safe and fast.
    - **System requirements** are written for the developers, ie. People who design the OS. Their requirements are like easy to design, implement and maintain, flexible,

reliable, error free and efficient.

2.5.2 Mechanisms and Policies

- Policies determine *what* is to be done. Mechanisms determine *how* it is to be implemented.
- Example: in timer, counter and decrementing counter is the mechanism and deciding how long the time has to be set is the policies.
- Policies change overtime. In the worst case, each change in policy would require a change in the underlying mechanism.
- If properly separated and implemented, policy changes can be easily adjusted without re writing the code, just by adjusting parameters or possibly loading new data / configuration files.

2.5.3 Implementation

- Traditionally OS were written in assembly language.
- In recent years, Os are written in C, or C++. Critical sections of code are still written in assembly language.
- The first OS that was not written in assembly language was the Master Control Program (MCP).
- The advantages of using a higher-level language for implementing operating systems are: The code can be written faster, more compact, easy to port to other systems and is easier to understand and debug.
- The only disadvantages of implementing an operating system in a higher-level language are reduced speed and increased storage requirements.

2.7 Operating-System Structure

OS structure must be carefully designed. The task of OS is divided into small components and then interfaced to work together.

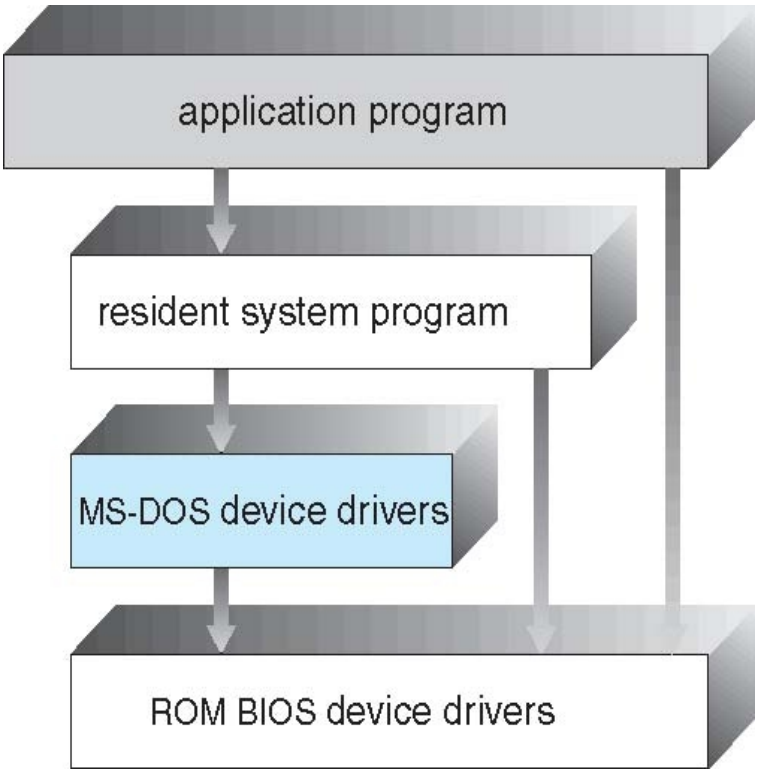
2.7.1 Simple Structure

Many operating systems do not have well-defined structures. They started as small, simple, and limited systems and then grew beyond their original scope. Eg: MS-DOS.

In MS-DOS, the interfaces and levels of functionality are not well separated. Application programs can access basic I/O routines to write directly to the display and disk drives. Such freedom leaves MS-DOS in bad state and the entire system can crash down when user programs fail.

UNIX OS consists of two separable parts: the kernel and the system programs. The kernel is

further separated into a series of interfaces and device drivers. The kernel provides the file system, CPU scheduling, memory management, and other operating-system functions through system calls.



MS-DOS Layer Structure

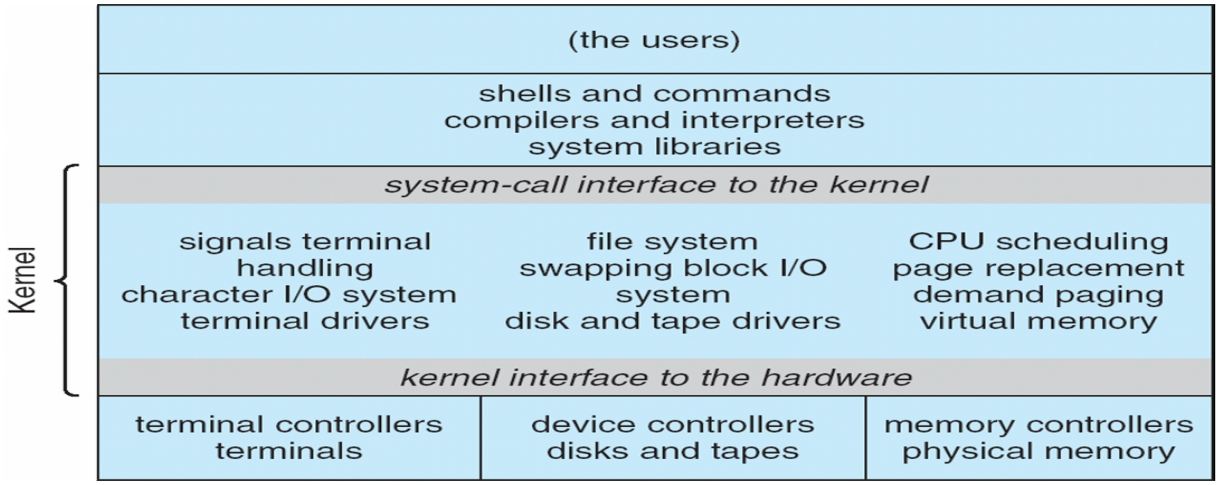


Figure 2.13 UNIX System Structure

2.7.2 Layered Approach

• The OS is broken into number of layers (levels). Each layer rests on the layer below it, and relies on the services provided by the next lower layer.

• Bottom layer(layer 0) is the hardware and the topmost layer is the user interface. • A typical layer, consists of data structure and routines that can be invoked by higher-level layer.

Advantage of layered approach is simplicity of construction and debugging.

The layers are selected so that each uses functions and services of only lower-level layers. So simplifies debugging and system verification. The layers are debugged one by one from the lowest and if any layer doesn't work, then error is due to that layer only, as the lower layers are already debugged. Thus the design and implementation is simplified.

A layer need not know how its lower level layers are implemented. Thus hides the operations from higher layers.

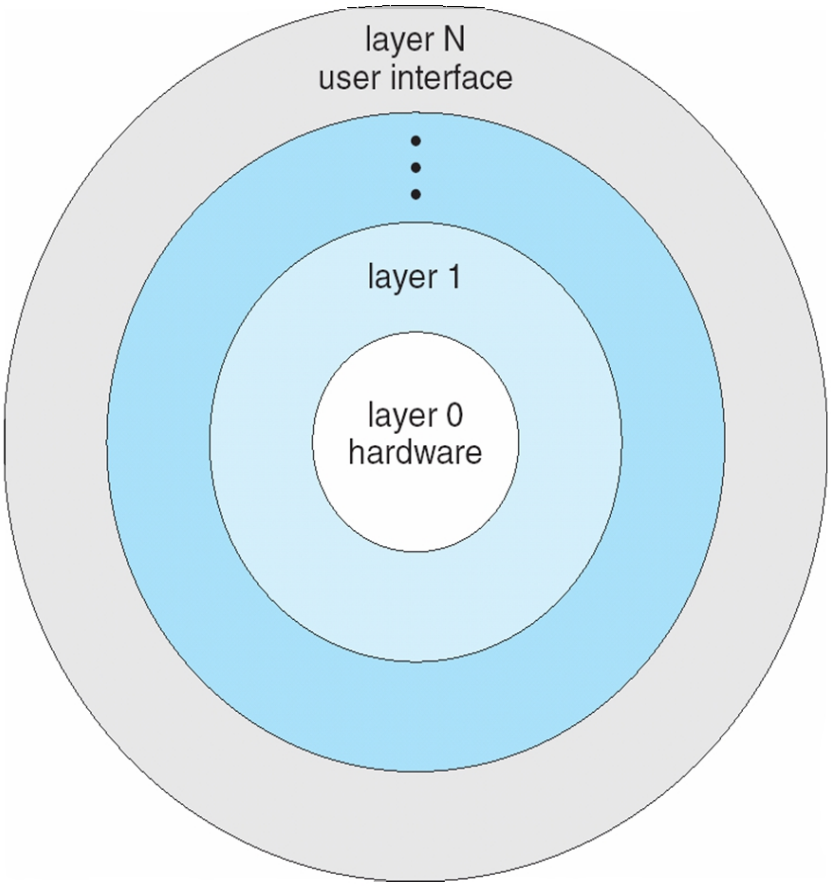


Figure 2.14 A layered Operating System

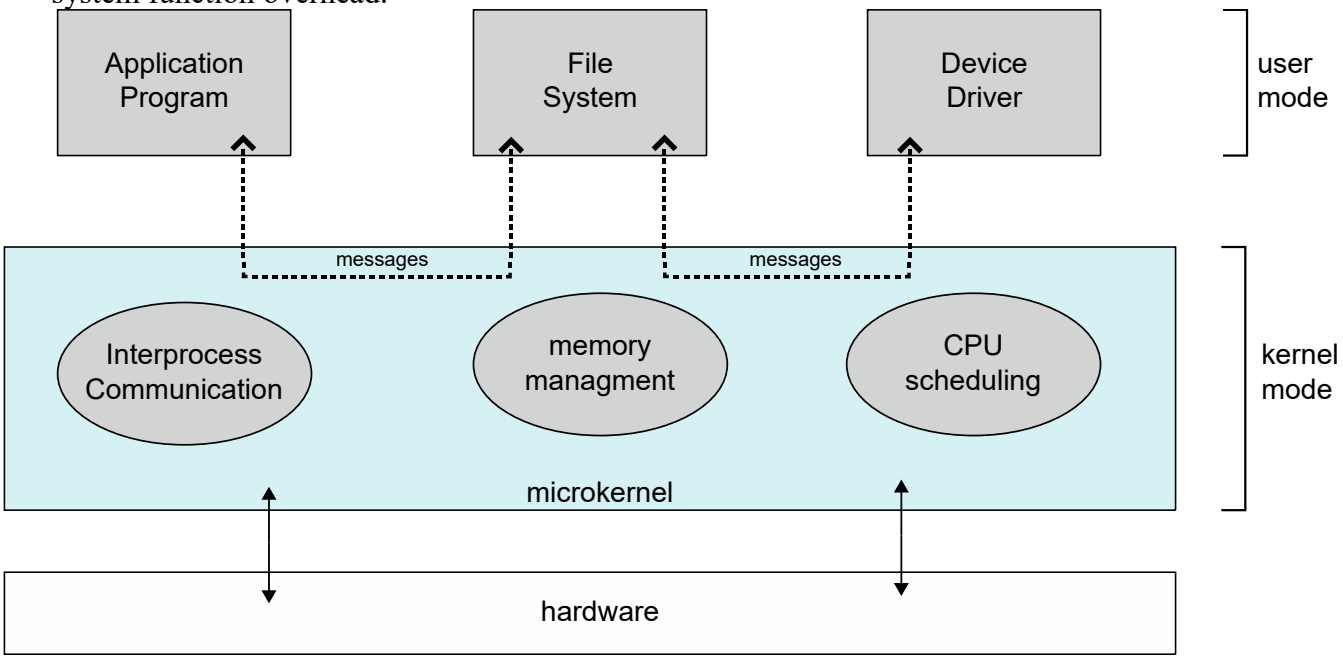
Disadvantages of layered approach:

• The various layers must be appropriately defined, as a layer can use only lower level layers.

• Less efficient than other types, because any interaction with layer 0 required from top layer. The system call should pass through all the layers and finally to layer 0. This is an overhead.

2.7.3 Microkernels

• The basic idea behind micro kernels is to **remove all non-essential** services from the kernel, thus making the kernel as small and efficient as possible.
• The removed services are implemented as system applications.
• Most microkernels provide basic process and memory management, and message passing between other services.
• **Benefit** of microkernel - System expansion can also be easier, because it only involves adding more system applications, not rebuilding a new kernel.
• Mach was the first and most widely known microkernel, and now forms a major component of Mac OSX.
• Disadvantage of Microkernel is, it suffers from reduction in performance due to increases system function overhead.



2.7.4 Modules

• Modern OS development is object-oriented, with a relatively small core kernel and a set of ***modules*** which can be linked in dynamically.
• Modules are similar to layers in that each subsystem has clearly defined tasks and interfaces, but any module is free to contact any other module, eliminating the problems of going through multiple intermediary layers.
• The kernel is relatively small in this architecture, similar to microkernels, but the kernel does not have to implement message passing since modules are free to contact each other directly. Eg: Solaris, Linux and MacOSX.

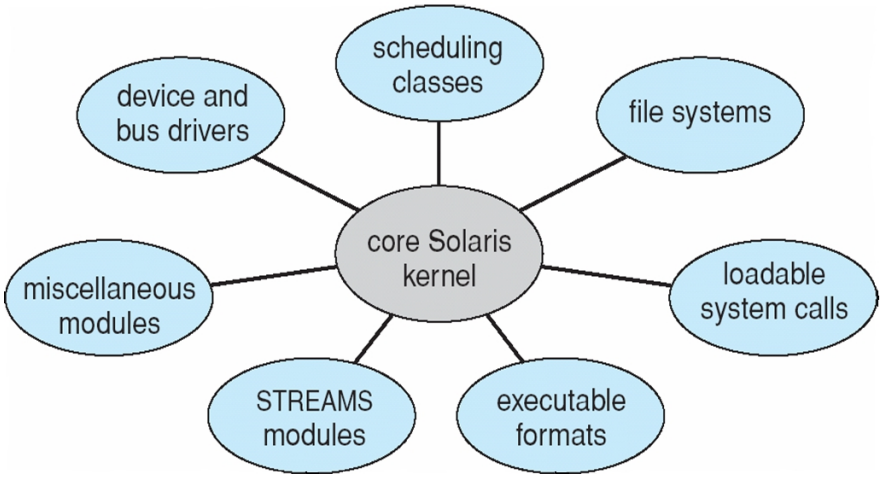


Figure 2.15 Solaris loadable modules

- The Max OSX architecture relies on the Mach microkernel for basic system management services, and the BSD kernel for additional services. Application services and dynamically loadable modules (kernel extensions) provide the rest of the OS functionality.
- Resembles layered system, but a module can call any other module.
- Resembles microkernel, the primary module has only core functions and the knowledge of how to load and communicate with other modules.

2.8 Virtual Machines

The fundamental idea behind a virtual machine is to abstract the hardware of a single computer (the CPU, memory, disk drives, network interface cards, and so forth) into several different execution environments, thereby creating the illusion that each separate execution environment is running its own private computer.

Creates an illusion that a process has its own processor with its own memory. Host OS is the main OS installed in system and the other OS installed in the system are called guest OS.

Benefits

• Able to share the same hardware and run several different execution environments(OS). • Host system is protected from the virtual machines and the virtual machines are protected from one another. A virus in guest OS, will corrupt that OS but will not affect the other guest systems and host systems.

- Even though the virtual machines are separated from one another, software resources can be shared among them. Two ways of sharing s/w resource for communication are: a)To share a file system volume(part of memory). b)To develop a virtual communication

network to communicate between the virtual machines.

- The operating system runs on and controls the entire machine. Therefore, the current system must be stopped and taken out of use while changes are made and tested. This period is commonly called *system development time.* In virtual machines such problem is eliminated. User programs are executed in one virtual machine and system development is done in another environment.
- Multiple OS can be running on the developer's system **concurrently**. This helps in rapid porting and testing of programmers code in different environments.
- **System consolidation** – two or more systems are made to run in a single system.

2.10 Operating-System Generation

- OS may be designed and built for a specific HW configuration at a specific site, but more commonly they are designed with a number of variable parameters and components, which are then configured for a particular operating environment.
- Systems sometimes need to be re-configured after the initial installation, to add additional resources, capabilities, or to tune performance, logging, or security.

- At one extreme the OS source code can be edited, re-compiled, and linked into a new kernel.
- More commonly configuration tables determine which modules to link into the new kernel, and what values to set for some key important parameters. This approach may require the configuration of complicated makefiles, which can be done either automatically or through interactive configuration programs; Then make is used to actually generate the new kernel specified by the new parameters.
- At the other extreme a system configuration may be entirely defined by table data, in which case the "rebuilding" of the system merely requires editing data tables. • Once a system has been regenerated, it is usually required to reboot the system to activate the new kernel. Because there are possibilities for errors, most systems provide some mechanism for booting to older or alternate kernels.

2.11 System Boot

The general approach when most computers boot up goes something like this:

- When the system powers up, an interrupt is generated which loads a memory address into the program counter, and the system begins executing instructions found at that address. This address points to the "bootstrap" program located in ROM chips (or EPROM chips) on the motherboard.
- The ROM bootstrap program first runs hardware checks, determining what physical resources are present and doing power-on self tests (POST) of all HW for which this is applicable. Some devices, such as controller cards may have their own on-board diagnostics, which are called by the ROM bootstrap program.

- The user generally has the option of pressing a special key during the POST process, which will launch the ROM BIOS configuration utility if pressed. This utility allows the user to specify and configure certain hardware parameters as where to look for an OS and whether or not to restrict access to the utility with a password.
    - Some hardware may also provide access to additional configuration setup programs, such as for a RAID disk controller or some special graphics or networking cards.
- Assuming the utility has not been invoked, the bootstrap program then looks for a non volatile storage device containing an OS. Depending on configuration, it may look for a floppy drive, CD ROM drive, or primary or secondary hard drives, in the order specified by the HW configuration utility.
- Assuming it goes to a hard drive, it will find the first sector on the hard drive and load up the fdisk table, which contains information about how the physical hard drive is divided up into logical partitions, where each partition starts and ends, and which partition is the "active" partition used for booting the system.
- There is also a very small amount of system code in the portion of the first disk block not occupied by the fdisk table. This bootstrap code is the first step that is not built into the hardware, i.e. the first part which might be in any way OS-specific. Generally this code knows just enough to access the hard drive, and to load and execute a (slightly) larger boot program.
- For a single-boot system, the boot program loaded off of the hard disk will then proceed to locate the kernel on the hard drive, load the kernel into memory, and then transfer control over to the kernel. There may be some opportunity to specify a particular kernel to be loaded at this stage, which may be useful if a new kernel has just been generated and doesn't work, or if the system has multiple kernels available with different configurations for different purposes. (Some systems may boot different configurations automatically, depending on what hardware has been found in earlier steps.)
- For dual-boot or multiple-boot systems, the boot program will give the user an opportunity to specify a particular OS to load, with a default choice if the user does not pick a particular OS within a given time frame. The boot program then finds the boot loader for the chosen single-boot OS, and runs that program as described in the previous bullet point.
- Once the kernel is running, it may give the user the opportunity to enter into single-user mode, also known as maintenance mode. This mode launches very few if any system services, and does not enable any logins other than the primary log in on the console. This mode is used primarily for system maintenance and diagnostics.