OPERATING SYSTEMS

UNIT I

Operating Systems Overview: Operating system functions, Operating system structure, operating systems Operations, protection and security, Computing Environments, OpenSource Operating Systems System Structures: Operating System Services, User and Operating-System Interface, systems calls, Types of System Calls, system programs, operating system structure, operating system debugging, System Boot.

UNIT I

1.1 OPERATING SYSTEMS OVERVIEW

1.1.1 Operating systems functions What is an Operating System?

A program that acts as an intermediary between a user of a computer and the computer hardware Operating system goals:

- Execute user programs and make solving user problems easier
- Make the computer system convenient to use
- Use the computer hardware in an efficient manner

Computer System Structure

Computer system can be divided into four components

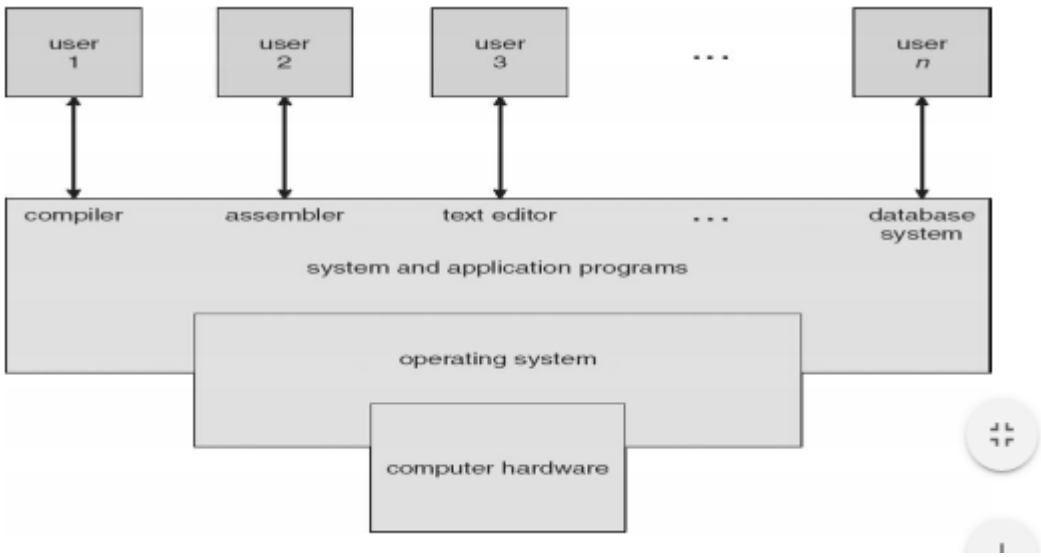
- Hardware – provides basic computing resources CPU, memory, I/O devices
- Operating system-Controls and coordinates use of hardware among various applications and users
- Application programs – define the ways in which the system resources are used to solve the computing problems of the users

-Word processors, compilers, web browsers, database systems, video games

Users

- People, machines, other computers

Four Components of a Computer System



A process is a program in execution. It is a unit of work within the system. Program is a passive entity, process is an active entity.

Process needs resources to accomplish its task

- CPU, memory, I/O, files
- Initialization data
- Process termination requires reclaim of any reusable resources
- Single-threaded process has one program counter specifying location of next instruction to
- execute Process executes instructions sequentially, one at a time, until completion
- Multi-threaded process has one program counter per thread
- Typically system has many processes, some user, some operating system running concurrently on
- one or more CPUs Concurrency by multiplexing the CPUs among the processes / threads

Process Management Activities

The operating system is responsible for the following activities in connection with process

- management: Creating and deleting both user and system processes
- Suspending and resuming processes
- Providing mechanisms for process synchronization
- Providing mechanisms for process communication
- Providing mechanisms for deadlock handling

Memory Management

All data in memory before and after processing

- All instructions in memory in order to execute
- Memory management determines what is in memory when
- Optimizing CPU utilization and computer response to users
- **Memory management activities**

- Keeping track of which parts of memory are currently being used and by whom
- Deciding which processes (or parts thereof) and data to move into and out of memory
- Allocating and deal locating memory space as needed

Storage Management

OS provides uniform, logical view of information storage

- Abstracts physical properties to logical storage unit – file
- Each medium is controlled by device (i.e., disk drive, tape drive)
- Varying properties include access speed, capacity, data-transfer rate, access method (sequential or random)
- File-System management
- Files usually organized into directories
- Access control on most systems to determine who can access what

OS activities include

- Creating and deleting files and directories
- Primitives to manipulate files and dirs
- 6 Mapping files onto secondary storage
- Backup files onto stable (non-volatile) storage media

Mass-Storage Management

- Usually disks used to store data that does not fit in main memory or data that must be kept for a "long" period of time
- Proper management is of central importance
- Entire speed of computer operation hinges on disk subsystem and its algorithms

MASS STORAGE activities

- Free-space management

- Storage allocation
- Disk scheduling
- Some storage need not be fast
- Tertiary storage includes optical storage, magnetic tape
- Still must be managed
- Varies between WORM (write-once, read-many-times) and RW (read-write)

1.1.2 Operating-System Structure

Simple Structure

Many commercial systems do not have well-defined structures. Frequently, such operating systems started as small, simple, and limited systems and then grew beyond their original scope. MS-DOS is an example of such a system.

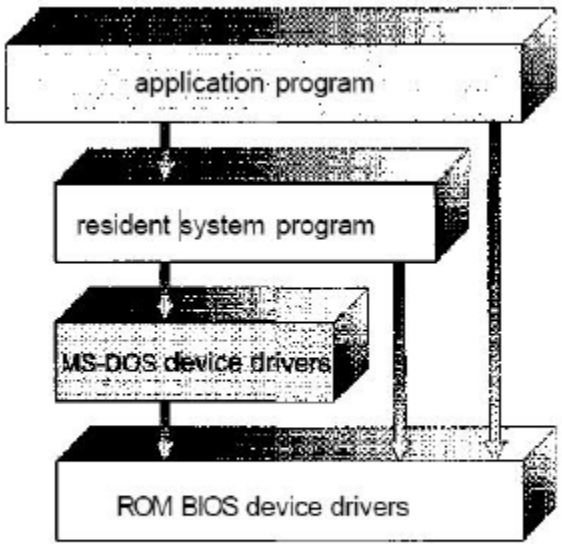


Figure 2.10 MS-DOS layer structure.

It was written to provide the most functionality in the least space, so it was not divided into modules carefully. In MS-DOS, the interfaces and levels of functionality are not well separated. For instance, application programs are able to access the basic I/O routines to write directly to the display and disk drives. Such freedom leaves MS-DOS vulnerable to errant (or malicious) programs, causing entire system crashes when user programs fail. Of course, MS-DOS was also

limited by the hardware of its era. Another example of limited structuring is the original UNIX operating system. UNIX is another system that initially was limited by hardware functionality.

It consists of two separable parts: the kernel and the system programs. The kernel is further separated into
a series of interfaces and device drivers, which have been added and expanded over the years as UNIX
has evolved.

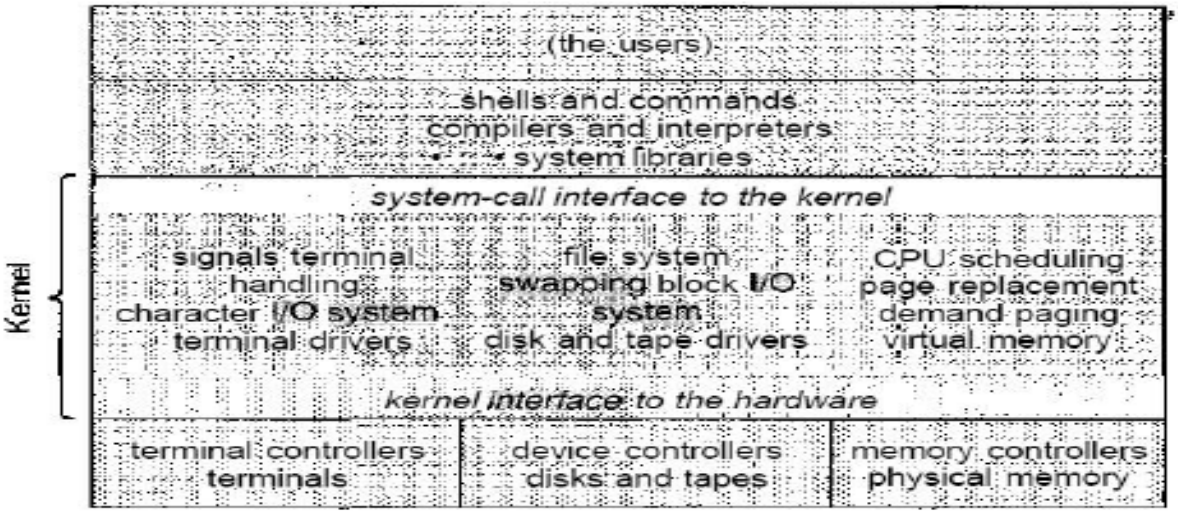
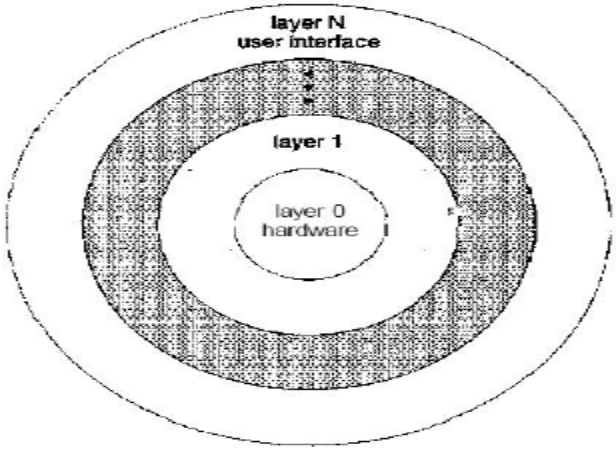


Figure 2.11 UNIX system structure.

Layered Approach

The operating system can then retain much greater control over the computer and over the applications that make use of that computer. Implementers have more freedom in changing the inner workings of the system and in creating modular operating systems. Under the top down approach, the overall functionality and features are determined and are separated into components. Information hiding is also important, because it leaves programmers free to implement the low-level routines as they see fit, provided that the external interface of the routine stays unchanged and that the routine itself performs the advertised task.

A system can be made modular in many ways. One method is the **layered approach,** in which the operating system is broken up into a number of layers (levels). The bottom layer (layer 0) is the hardware; the highest (layer N) is the user interface.



An operating-system layer is an implementation of an abstract object made up of data and the operations that can manipulate those data. A typical operating-system layer—say, layer M—consists of data structures and a set of routines that can be invoked by higher-level layers. Layer *M,* in turn, can invoke operations on lower-level layers.

The main advantage of the layered approach is simplicity of construction and debugging. The layers are selected so that each uses functions (operations) and services of only lower-level layers. This approach simplifies debugging and system verification. The first layer can be debugged without any
concern for the rest of the system, because, by definition, it uses only the basic hardware (which is assumed correct) to implement its functions. Once the first layer is debugged, its correct unctioning can be assumed while the second layer is debugged, and so on. If an error is found during the debugging of a particular layer, the error must be on that layer, because the layers below it are already debugged. Thus, the design and implementation of the system is simplified. Each layer is implemented with only those operations provided by lower level layers. A layer does not need to know how these operations are implemented; it needs to know only what these operations do. Hence, each layer hides the existence of certain data structures, operations, and hardware from higher-level layers.

The major difficulty with the layered approach involves appropriately defining the various layers. The backing-store driver would normally be above the CPU scheduler, because the driver may need to wait for I/O and the CPU can be rescheduled during this time. A final problem with layered implementations is that they tend to be less efficient than other types. For instance, when a user program executes an I/O operation, it executes a system call that is trapped to the I/O layer, which calls the memory-management layer, which in turn calls the CPU-scheduling layer, which is then passed to the hardware.

Micro kernels

The kernel became large and difficult to manage. In the mid-1980s, researchers at Carnegie Mellon University developed an operating system called **Mach** that modularized the kernel using the **microkernel** approach. This method structures the operating system by removing all nonessential components from the kernel and implementing them as system and user-level

programs. The result is a smaller kernel. microkernels provide minimal process and memory management, in addition to a communication facility.

The main function of the microkernel is to provide a communication facility between the client program and the various services that are also running in user space. One benefit of the microkernel approach is ease of extending the operating system. All new services are added to user space and consequently do not require modification of the kernel. When the kernel does have to be modified, the changes tend to be fewer, because the microkernel is a smaller kernel.

The resulting operating system is easier to port from one hardware design to another. The microkernel also provides more security and reliability, since most services are running as user rather than kernel processes. If a service fails, the rest of the operating system remains untouched.

Modules

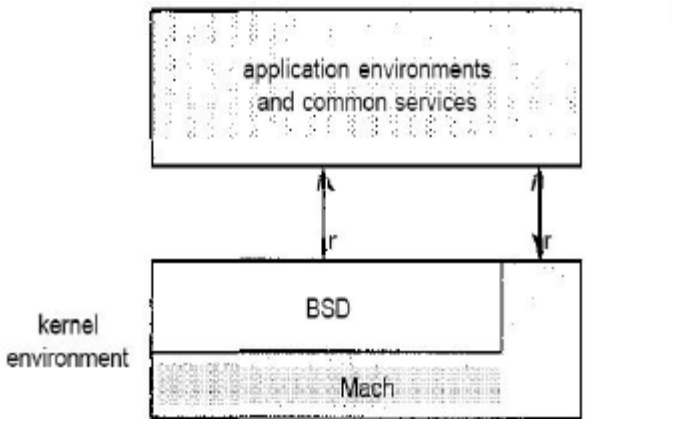
The best current methodology for operating-system design involves using object-oriented programming techniques to create a modular kernel. Here, the kernel has a set of core components and dynamically links in additional services either during boot time or during run time. Such a strategy uses dynamically loadable modules and is common in modern implementations of UNIX, such as Solaris, Linux, and Mac OS X.

A core kernel with seven types of loadable kernel modules:
1. Scheduling classes
2. File systems
3. Loadable system calls
4. Executable formats
5. STREAMS modules
6. Miscellaneous
7. Device and bus drivers

Such a design allows the kernel to provide core services yet also allows certain features to be implemented dynamically. The overall result resembles a layered system in that each kernel section has defined, protected interfaces; but it is more flexible than a layered system in that any module can call any other module. The approach is like the microkernel approach in that the primary module has only core functions and knowledge of how to load and communicate with other modules; but it is more efficient, because modules do not need to invoke message passing in order to communicate.

The Apple Macintosh Mac OS X operating system uses a hybrid structure. Mac OS X (also known as *Danvin)* structures the operating system using a layered technique where one layer consists of the Mach microkernel. The top layers include application environments and a set of services providing a graphical interface to applications. Below these layers is the kernel environment, which consists primarily of the Mach microkernel and the BSD kernel. Mach provides memory management; support for remote procedure calls (RPCs) and inter process communication (IPC) facilities, including message passing; and thread scheduling. The BSD

component provides a BSD command line interface, support for networking and file systems, and an implementation of POSIX APIs, including Pthreads.



1.1.2 Operating-System Operations

1. 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 almost always signaled by the occurrence of an interrupt or a trap

2. A **trap (or** an **exception)** is a software-generated interrupt caused either by an error or by a specific request from a user program that an operating-system service is performed.

3. The interrupt-driven nature of an operating system defines that system's general structure. 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.

4. The operating system and the users share the hardware and software resources of the computer system, we need to make sure that an error in a user program could cause problems only for the one program that was running. With sharing, many processes could be adversely affected by a bug in one program. For example, if a process gets stuck in an infinite loop, this loop could prevent the correct operation of many other processes.

5. Without protection against these sorts of errors, either the computer must execute only one process at a time or all output must be suspect.

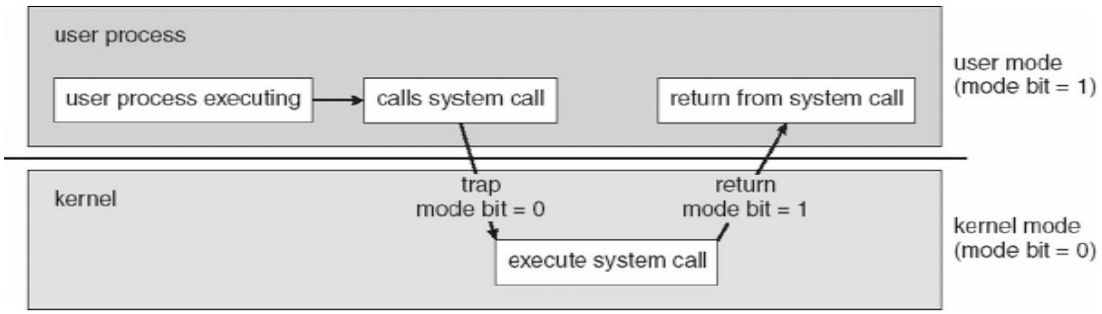
Dual-Mode Operation

Dual-mode operation allows OS to protect itself and other system components

User mode and **kernel mode**
Mode bit provided by hardware Provides ability to distinguish when system is running user code or kernel code Some instructions designated as **privileged**, only executable in kernel mode System call changes mode to kernel, return from call resets it to user

Transition from User to Kernel Mode

- Timer to prevent infinite loop / process hogging resources Set interrupt after specific period
- Operating system decrements counter
- When counter zero generate an interrupt
- Set up before scheduling process to regain control or terminate program that exceeds allotted time



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.

1.1.4 Protection and security

Protection is any 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 can improve reliability by detecting latent errors at the interfaces between component subsystems. Early detection of interface errors can often prevent contamination of a healthy subsystem by another subsystem that is malfunctioning. An unprotected resource cannot defend against use (or misuse) by an unauthorized or incompetent user. 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.

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 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).**

- User ID then associated with all files, processes of that user to determine access control

• Group identifier (**group ID**) allows set of users to be defined and controls managed, then also associated with each process, file **Privilege escalation** allows user to change to effective ID with more rights

1.1.5 Kernel Data Structures

The operating system must keep a lot of information about the current state of the system. As things happen within the system these data structures must be changed to reflect the current eality. For example, a new process might be created when a user logs onto the system. The kernel must create a data structure representing the new process and link it with the data structures representing all of the other processes in the system.

Mostly these data structures exist in physical memory and are accessible only by the kernel and its subsystems. Data structures contain data and pointers, addresses of other data structures, or the addresses of routines. Taken all together, the data structures used by the Linux kernel can look very confusing. Every data structure has a purpose and although some are used by several kernel subsystems, they are more simple than they appear at first sight.

Understanding the Linux kernel hinges on understanding its data structures and the use that the various functions within the Linux kernel makes of them. This section bases its description of the Linux kernel on its data structures. It talks about each kernel subsystem in terms of its algorithms, which are its
methods of getting things done, and their usage of the kernel's data structures.

1.1.6 Computing Environments

Traditional Computing

As computing matures, the lines separating many of the traditional computing environments are blurring. this environment consisted of PCs connected to a network, with servers providing file and print services.
Terminals attached to mainframes were prevalent at many companies as well, with even fewer remote access and portability options.

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.

Batch system processed jobs in bulk, with predetermined input. 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.

Client-Server Computing

Designers have shifted away from centralized system architecture. Terminals connected to centralized systems are now being supplanted by PCs. Correspondingly, user interface functionality once handled directly by the centralized systems is increasingly being handled by

the PCs. As a result, many of today's systems acts as **server systems to** satisfy requests generated by **client systems** 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 system.

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 web browsers.

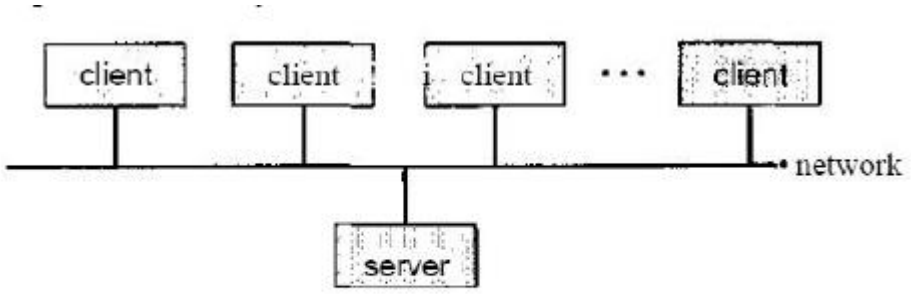


Figure 1.11 General structure of a client-server system.

Peer-to-Peer Computing

In this model, clients and servers are not distinguished from one another; instead, 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. Peer-to-peer systems offer an advantage over traditional client-server systems. In a client-server system, the server is a bottleneck; 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 first discover what 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

The Web has become ubiquitous, leading to more access by a wider variety of devices than was dreamt of a few years ago. Web computing has increased the emphasis on networking. Devices that were not previously networked now include wired or wireless access. Devices that were networked now have faster network connectivity, provided by either improved networking technology, optimized network implementation code, or both.

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.

1.1.7 Open-Source Operating Systems

- Operating systems made available in source-code format rather than just binary closed-source
- Counter to the copy protection and Digital Rights Management (DRM) movement
- Examples include GNU/Linux, BSD UNIX (including core of Mac OS X), and Sun Solaris

CHAPTER - 2
OPERATING SYSTEM STRUCTURE

1.2.1 Operating System Services

- One set of operating-system services provides functions that are helpful to the user
- Communications – Processes may exchange information, on the same computer or between computers over a network.

- Communications may be via shared memory or through message passing (packets moved by the
OS)

- Error detection – OS needs to be constantly aware of possible errors may occur in the CPU and memory hardware, in I/O devices, in user program

- For each type of error, OS should take the appropriate action to ensure correct and consistent computing.

- Debugging facilities can greatly enhance the user's and programmer's abilities to efficiently use
the system.

- Another set of OS functions exists for ensuring the efficient operation of the system itself via resource sharing

• **Resource allocation -** When multiple users or multiple jobs running concurrently, resources must be allocated to each of them

• Many types of resources - Some (such as CPU cycles, main memory, and file storage) may have
special allocation code, others (such as I/O devices) may have general request and release code

• **Accounting -** To keep track of which users use how much and what kinds of computer resources

• **Protection and security -** The owners of information stored in a multiuser or networked computer system may want to control use of that information, concurrent processes should not interfere with each other.

• **Protection** involves ensuring that all access to system resources is controlled.

• **Security** of the system from outsiders requires user authentication, extends to defending external
I/O devices from invalid access attempts.

• If a system is to be protected and secure, precautions must be instituted throughout it. A chain is
only as strong as its weakest link.

1.2.2 User and Operating System Interface - CLI

• Command Line Interface (CLI) or command interpreter allows direct command entry
Sometimes implemented in kernel, sometimes by systems program
- Sometimes multiple flavors implemented – shells
- Primarily fetches a command from user and executes it

• Sometimes commands built-in, sometimes just names of programs If the latter, adding new features doesn't require shell modification

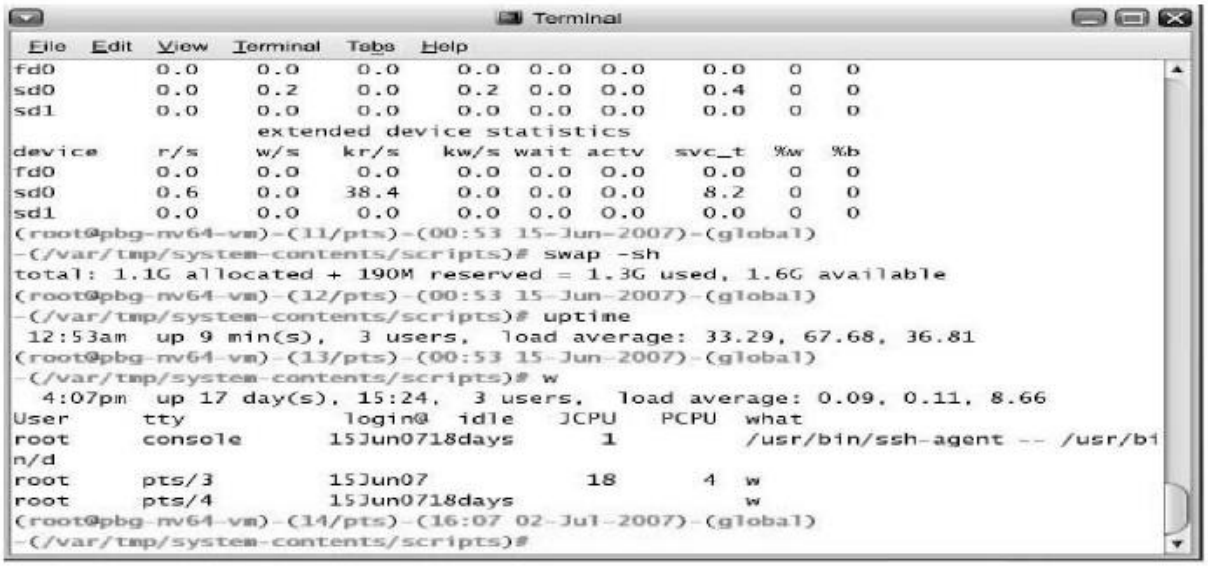
User Operating System Interface - GUI

• User-friendly desktop metaphor interface
• Usually mouse, keyboard, and monitor
• Icons represent files, programs, actions, etc
• Various mouse buttons over objects in the interface cause various actions (provide information, options, execute function, open directory (known as a folder)

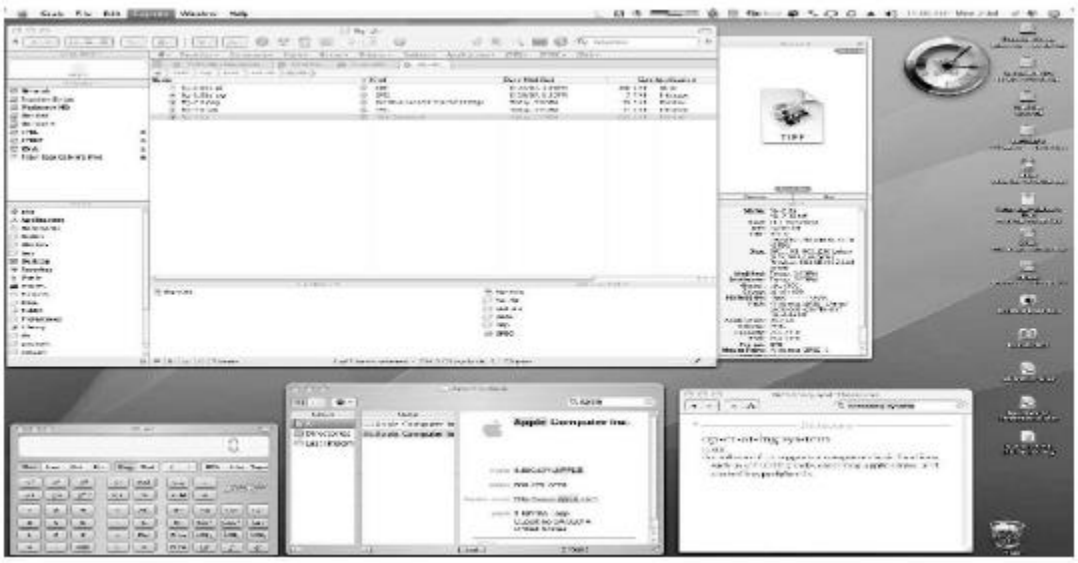
Invented at Xerox PARC

• Many systems now include both CLI and GUI interfaces
• Microsoft Windows is GUI with CLI "command" shell
• Apple Mac OS X as "Aqua" GUI interface with UNIX kernel underneath and shells available
• Solaris is CLI with optional GUI interfaces (Java Desktop, KDE)

Bourne Shell Command Interpreter



The Mac OS X GUI

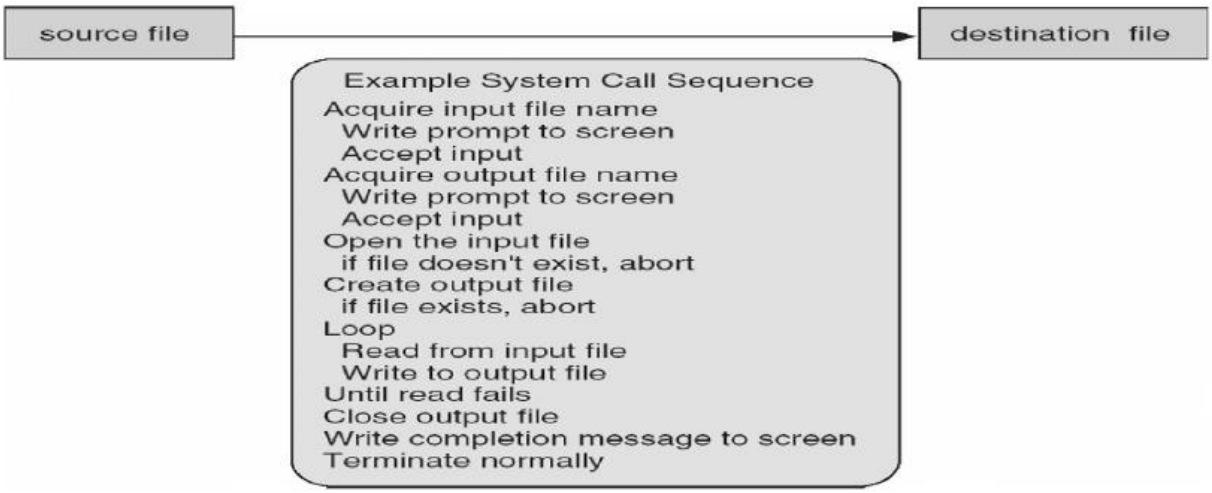


1.2.3 System Calls

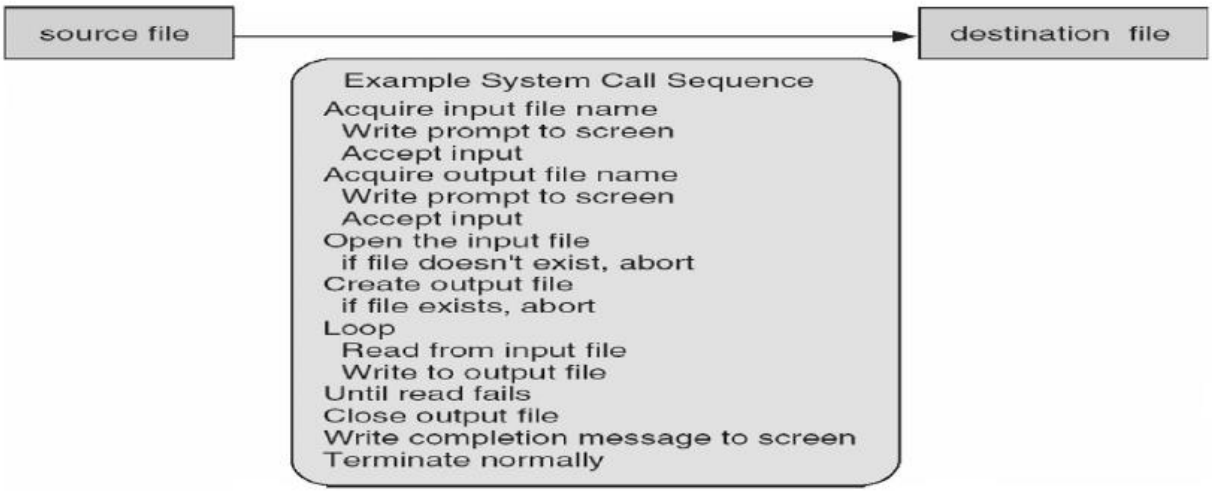
- Programming interface to the services provided by the OS
- Typically written in a high-level language (C or C++)

• Mostly accessed by programs via a high-level Application Program Interface (API) rather than direct system call usenThree most common APIs are Win32 API for Windows, POSIX API for POSIX-based systems (including virtually all versions of UNIX, Linux, and Mac OS X), and Java API for the Java virtual machine (JVM)
• Why use APIs rather than system calls?(Note that the system-call names used throughout this text are generic)

Example of System Calls



System Call Implementation



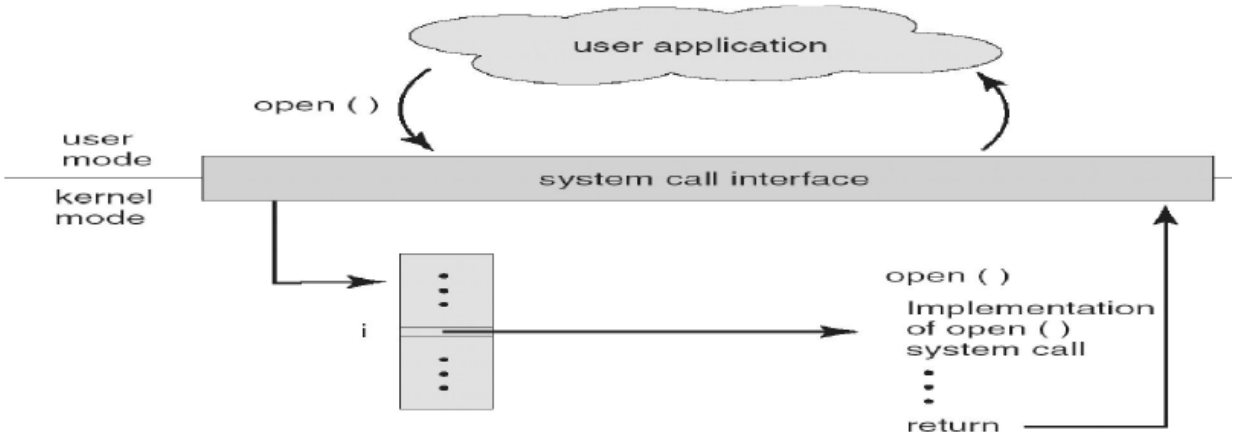
System Call Implementation

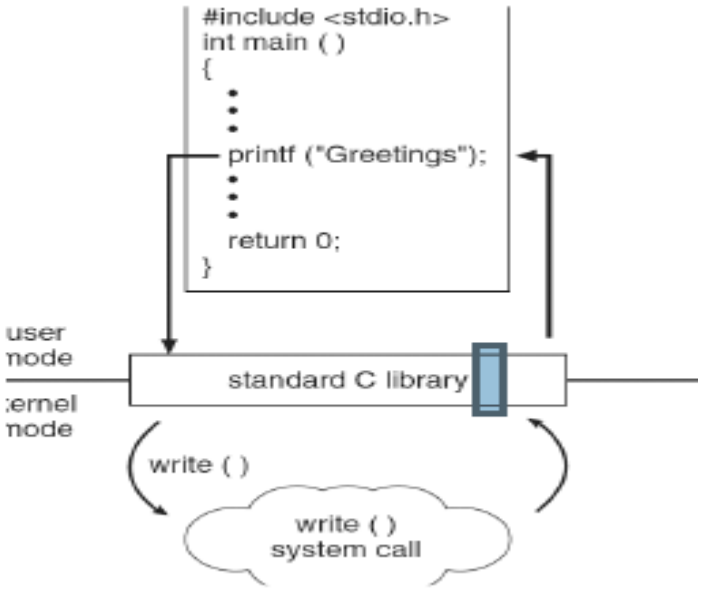
System Call Implementation

• Typically, a number associated with each system call
• System-call interface maintains a table indexed according to these numbers
• The system call interface invokes intended system call in OS kernel and returns status of the system call and any return values
• The caller need know nothing about how the system call is implemented

- Just needs to obey API and understand what OS will do as a result call
- Most details of OS interface hidden from programmer by API Managed by run-time support library (set of functions built into libraries included with compiler)

API — System Call – OS Relationship



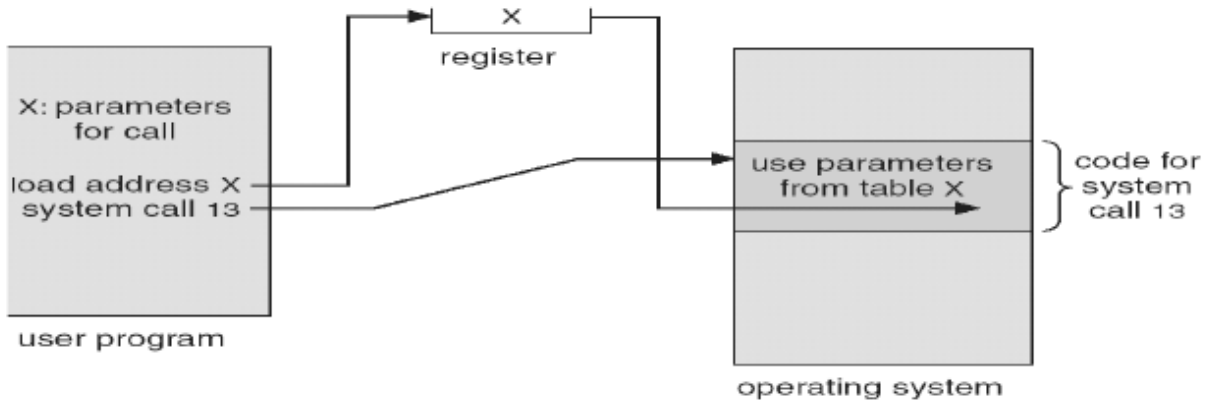


System Call Parameter Passing

- Often, more information is required than simply identity of desired system call
- Exact type and amount of information vary according to OS and call
- Three general methods used to pass parameters to the OS
- Simplest: pass the parameters in *registers*
  - In some cases, may be more parameters than registers

- Parameters stored in a *block,* or table, in memory, and address of block passed as a parameter in a register This approach taken by Linux and Solaris
- Parameters placed, or *pushed,* onto the *stack* by the program and *popped* off the stack by the operating system
- Block and stack methods do not limit the number or length of parameters being passed

Parameter Passing via Table



1.2.4 Types of System Calls

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

Process Control

A running program needs to be able to halt its execution either normally (end) or abnormally (abort). If a system call is made to terminate the currently running program abnormally, or if the program runs into a problem and causes an error trap, a dump of memory is sometimes taken and an error message generated.

The dump is written to disk and may be examined by a **debugger**—a system program designed to aid the programmer in finding and correcting bugs-—to determine the cause of the problem. Under either normal or abnormal circumstances, the operating system must transfer control to the invoking command interpreter. The command interpreter then reads the next command. In an interactive system, the command interpreter simply continues with the next command; it is assumed that the user will issue an appropriate command to respond to any error.

File Management

We first need to be able to create and delete files. Either system call requires the name of the file and perhaps some of the file's attributes. Once the file is created, we need to open it and to use it. We may also read, write, or reposition (rewinding or skipping to the end of the file, for example). Finally, we need to close the file, indicating that we are no longer using it. We may need these same sets of operations for directories if we have a directory structure for organizing files in the file system. In addition, for either files or directories, we need to be able to determine the values

of various attributes and perhaps to reset them if necessary. File attributes include the file name, a file type, protection codes, accounting information, and so on.

At least two system calls, get file attribute and set file attribute, are required for this function. Some operating systems provide many more calls, such as calls for file move and copy.

Device Management

A process may need several resources to execute—main memory, disk drives, access to files, and so on. If the resources are available, they can be granted, and control can be returned to the user process.

Otherwise, the process will have to wait until sufficient resources are available. The various resources controlled by the operating system can be thought of as devices. Some of these devices are physical devices (for example, tapes), while others can be thought of as abstract or virtual devices (for example, files). If there are multiple users of the system, the system may require us to first request the device, to ensure exclusive use of it. After we are finished with the device, we release it. These functions are similar to the open and close system calls for files.

Information Maintenance

Many system calls exist simply for the purpose of transferring information between the user program and the operating system. For example, most systems have a system call to return the current tim e and date . Other system calls may return information about the system, such as the number of current users, the version number of the operating system, the amount of free memory or disk space, and so on.

In addition, the operating system keeps information about all its processes, and system calls are used to access this information. Generally, calls are also used to reset the process information (get process attributes and set process attributes) .

Communication

There are two common models of inter process communication: the message passing model and the shared-memory model. In the message-passing model, the communicating processes exchange messages with one another to transfer information.

Messages can be exchanged between the processes either directly or indirectly through a common mailbox. Before communication can take place, a connection must be opened.

The name of the other communicator must be known, be it another process on the same system or a process on another computer connected by a communications network. Each computer in a network has a *host name* by which it is commonly known.

A host also has a network identifier, such as an IP address. Similarly, each process has a *process name,* and this name is translated into an identifier by which the operating system can refer to the process.

The get host id and get process id system calls do this translation. The identifiers are then passed to the general purpose open and close calls provided by the file system or to specific open connection and close connection system calls, depending on the system's model of communication.

In the shared-memory model, processes use shared memory creates and shared memory attaches system calls to create and gain access to regions of memory owned by other processes. Recall that, normally, the operating system tries to prevent one process from accessing another process's memory.

Shared memory requires that two or more processes agree to remove this restriction.

They can then exchange information by reading and writing data in the shared areas. The form of the data and the location are determined by the processes and are not under the operating system's control.

The processes are also responsible for ensuring that they are not writing to the same location simultaneously.

1.2.5 System Programs

At the lowest level is hardware. Next are the operating system, then the system programs, and finally the application programs. System programs provide a convenient environment for program development and execution. Some of them are simply user interfaces to system calls; others are considerably more complex. They can be divided into these categories:

• **File management.** These programs create, delete, copy, rename, print, dump, list, and generally manipulate files and directories.

• **Status information.** Some programs simply ask the system for the date, time, amount of available memory or disk space, number of users, or similar status information. Others are more complex, providing detailed performance, logging, and debugging information. Typically, these programs format and print the output to the terminal or other output devices or files or display it in a window of the GUI. Some systems also support a registry, which is used to store and retrieve configuration information.

• **File modification.** Several text editors may be available to create and modify the content of files stored on disk or other storage devices. There may also be special commands to search contents of files or perform transformations of the text.

• **Programming-language support.** Compilers, assemblers, debuggers and interpreters for common programming languages (such as C, C++, Java, Visual Basic, and PERL) are often provided to the user with the operating system.

• **Program loading and execution.** Once a program is assembled or compiled, it must be loaded into memory to be executed. The system may provide absolute loaders, relocatable loaders,

linkage editors, and overlay loaders. Debugging systems for either higher-level languages or machine language are needed as well.

• **Communications.** These programs provide the mechanism for creating virtual connections among processes, users, and computer systems. They allow users to send messages to one another's screens, to browse web pages, to send electronic-mail messages, to log in remotely, or to transfer files from one machine to another.

In addition to systems programs, most In addition to systems programs, most operating systems are supplied with programs that are useful in solving common problems or performing common operations. Such programs include web browsers, word processors and text formatters, spreadsheets, database systems, compilers, plotting and statistical-analysis packages, and games. These programs are known as system utilities or application programs.

1.2.6 Operating-System Structure

Refer above pages

1.2.7 Operating-System Debugging

- Debugging is finding and fixing errors, or bugs
- OS generate log files containing error information
- Failure of an application can generate core dump file capturing memory of the process
- Operating system failure can generate crash dump file containing kernel memory
- Beyond crashes, performance tuning can optimize system performance
- Kernighan's Law: "Debugging is twice as hard as writing the code in the rst place. Therefore, if you write the code as cleverly as possible, you are, by definition, not smart enough to debug it."
- DTrace tool in Solaris, FreeBSD, Mac OS X allows live instrumentation on production systems
- Probes fire when code is executed, capturing state data and sending it to consumers of those Probes

1.2.8 System Boot

The procedure of starting a computer by loading the kernel is known as *booting* the system. On most computer systems, a small piece of code known as the **bootstrap program** or **bootstrap loader** locates the kernel, loads it into main memory, and starts its execution. Some computer systems, such as PCs, use a two-step process in which a simple bootstrap loader fetches a more complex boot program from disk, which in turn loads the kernel.

When a CPU receives a reset event—for instance, when it is powered up or rebooted—the instruction register is loaded with a predefined memory location, and execution starts there. At that location is the initial bootstrap program. This program is in the form of **read-only memory (ROM),** because the RAM is in an unknown state at system startup. ROM is convenient because it needs no initialization and cannot be infected by a computer virus.

The bootstrap program can perform a variety of tasks. Usually, one task is to run diagnostics to determine the state of the machine. If the diagnostics pass, the program can continue with the booting steps. It can also initialize all aspects of the system, from CPU registers to device controllers and the contents of main memory.

Sooner or later, it starts the operating system.
Some systems—such as cellular phones, PDAs, and game consoles—store the entire operating system in ROM. Storing the operating system in ROM is suitable for small operating systems, simple supporting hardware, and rugged operation.

A problem with this approach is that changing the bootstrap code requires changing the ROM hardware chips. Some systems resolve this problem by using **erasable programmable read-only memory** (EPROM), which is read only except when explicitly given a command to become writable.

All forms of ROM are also known as **firmware,** since their characteristics fall somewhere between those of hardware and those of software. A problem with firmware in general is that executing code there is slower than executing code in RAM.
Some systems store the operating system in firmware and copy it to RAM for fast execution. A final issue with firmware is that it is relatively expensive, so usually only small amounts are available.
For large operating systems (including most general-purpose operating systems like Windows, Mac OS X, and UNIX) or for systems that change frequently, the bootstrap loader are stored in firmware, and the operating system is on disk. In this case, the bootstrap runs diagnostics and has a bit of code that can read a single block at a fixed location (say block zero) from disk into memory and execute the code from that **boot block.** The program stored in the boot block may be sophisticated enough to load the entire operating system into memory and begin its execution. More typically, it is simple code (as it fits in a single disk block) and only knows the address on disk and length of the remainder of the bootstrap program. All of the disk-bound bootstrap, and the operating system itself, can be easily changed by writing new versions to disk.

UNIT-II
CHAPTER -3
PROCESSES

1.3.1 Process concepts

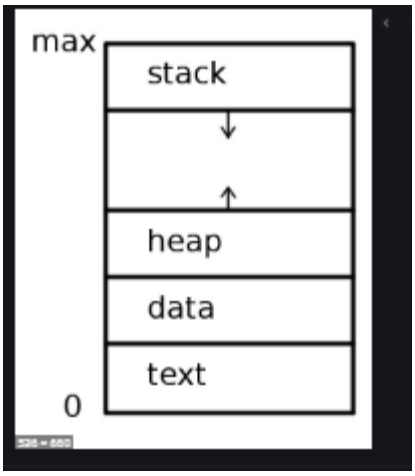
Process : A process is a program in execution. A process is more than the program code, which is sometimes known as the **text section.** It also includes the current activity, as represented by the value of the **program counter** and the contents of the processor's registers. A process generally also includes the process **stack,** which contains temporary data (such as function parameters, return addresses, and local variables), and a **data section,** which contains global variables. A process may also include a **heap,** which is memory that is dynamically allocated during process run time.

Structure of a process

We emphasize that a program by itself is not a process; a program is a *passive* entity, such as a file containing a list of instructions stored on disk (often called an **executable file),** whereas a process is an *active* entity, with a program counter specifying the next instruction to execute and a set of associated resources. A program becomes a process when an executable file is loaded into memory.

Two common techniques for loading executable files are double-clicking an icon representing the executable file and entering the name of the executable file on the command line (as in prog. exe or a.out.)

Process



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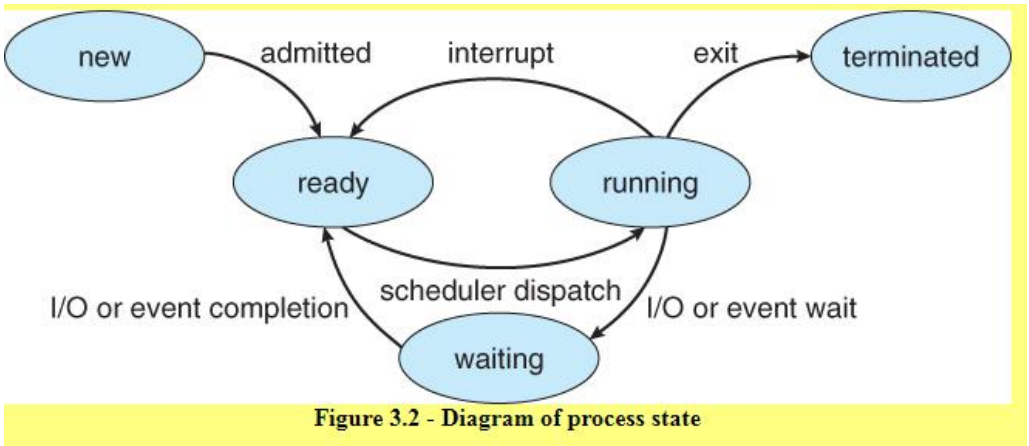

Figure 3.2 - Diagram of process state

Process State

As a process executes, it changes **state.** The state of a process is defined in part by the current activity of
that process. Each process may be in one of the following states:

• **New.** The process is being created.
• **Running.** Instructions are being executed.
• **Waiting.** The process is waiting for some event to occur (such as an I/O completion or reception of a signal).
• **Ready.** The process is waiting to be assigned to a processor.
• **Terminated.** The process has finished execution. These names are arbitrary, and they vary across operating systems. The states that they represent are fotind on all systems, however. Certain operating systems also more finely delineate process states. It is important to realize that only one process can be *running* on any processor at any instant.

Process Control Block

Each process is represented in the operating system by a **process control block (PCB)**—also called a *task control block.*

Process state. The state may be new, ready, running, and waiting, halted, and so on.

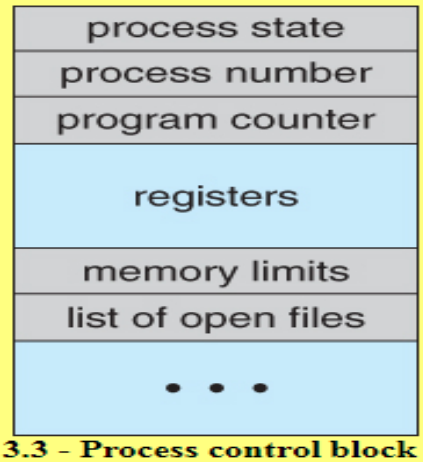

Figure 3.3 - Process control block (PCB)

Program counter-The counter indicates the address of the next instruction to be executed for this process.

• CPU **registers-** The registers vary in number and type, depending on the computer architecture. They include accumulators, index registers, stack pointers, and general-purpose registers, plus any condition code information.

CPU-scheduling information- This information includes a process priority, pointers to scheduling queues, and any other scheduling parameters.

Memory-management information- This information may include such information as the value of the base and limit registers, the page tables, or the segment tables, depending on the memory system used by the operating system

Accounting information-This information includes the amount of CPU and real time used, time limits, account members, job or process numbers, and so on.

I/O status information-This information includes the list of I/O devices allocated to the process, a list of open files, and so on.

1.3.2 Process Scheduling

The **process scheduler** selects an available process (possibly from a set of several available processes) for program execution on the CPU. As processes enter the system, they are put into a **job queue,** which consists of all processes in the system. The processes that are residing in main memory and are ready and waiting to execute are kept on a list called the **ready queue.**

This queue is generally stored as a linked list. A ready-queue header contains pointers to the first and final PCBs in the list. Each PCB includes a pointer field that points to the next PCB in the ready queue.

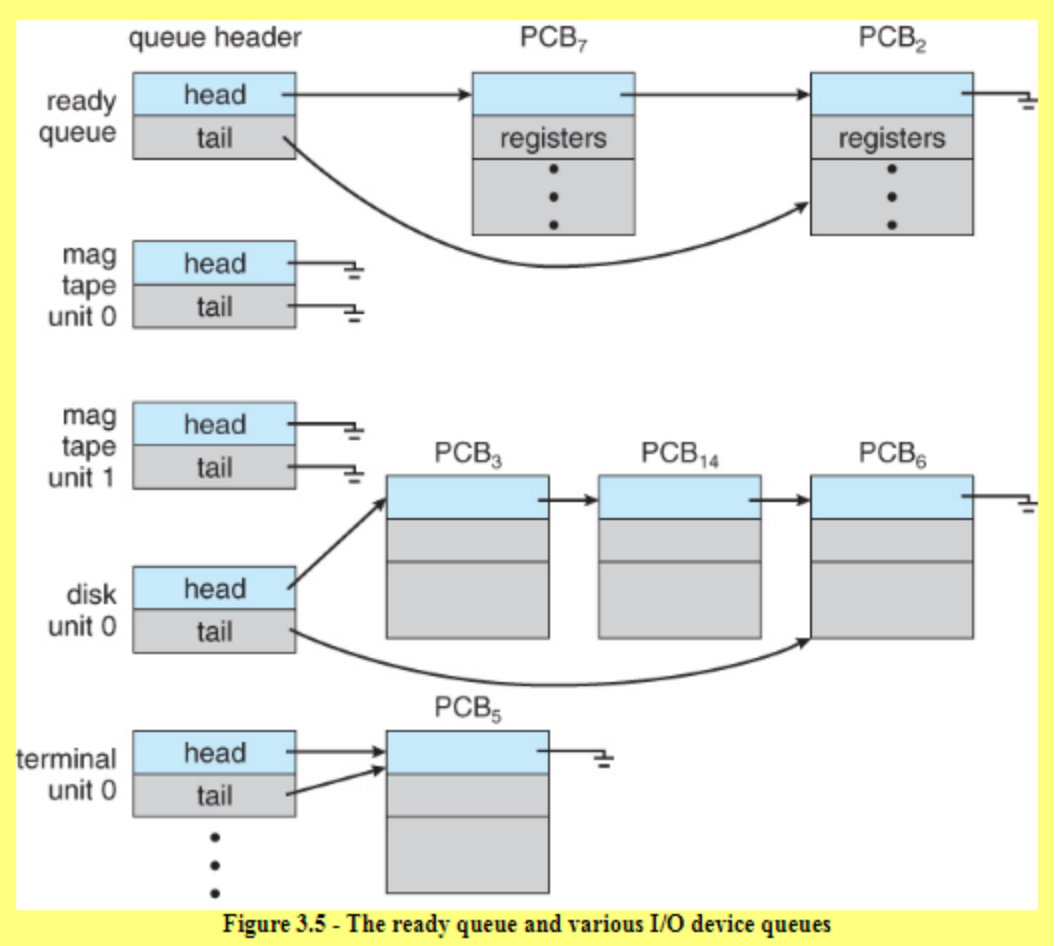

Figure 3.5 - The ready queue and various I/O device queues

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This queue is generally stored as a linked list. A ready-queue header contains pointers to the first and final PCBs in the list. Each PCB includes a pointer field that points to the next PCB in the ready queue.
Each rectangular box represents a queue. Two types of queues are present: the ready queue and a set of device queues. The circles represent the resources that serve the queues, and the arrows indicate the flow of processes in the system.

A new process is initially put in the ready queue. It waits there till it is selected for execution, or is **dispatched.** Once the process is allocated the CPU and is executing, one of several events could occur:
• The process could issue an I/O request and then be placed in an I/O queue.
• The process could create a new sub process and wait for the sub process's termination.
• The process could be removed forcibly from the CPU, as a result of an interrupt, and be put back in the
ready queue.

Schedulers
A process migrates among the various scheduling queues throughout its lifetime. The operating system must select, for scheduling purposes, processes from these queues in some fashion.

The selection process is carried out by the appropriate **scheduler.** The **long-term scheduler,** or **job scheduler,** selects processes from this pool and loads them into memory for execution. The **short-term scheduler, or** CPU **scheduler,** selects from among the processes that are ready to execute and allocates the CPU to one of them.

1.3.3 Operations on Processes
Process Creation
A process may create several new processes, via a create-process system call, during the course of execution. The creating process is called a **parent** process, and the new processes are called the **children** of that process. Each of these new processes may in turn create other processes, forming a **tree** of processes.

Most operating systems identify processes according to a unique **process identifier** (or **pid),** which is typically an integer number. These processes are responsible for managing memory and file systems. The sched process also creates the init process, which serves as the root parent process for all user processes.

When a process creates a new process, two possibilities exist in terms of execution:
1. The parent continues to execute concurrently with its children.
2. The parent waits until some or all of its children have terminated.
There are also two possibilities in terms of the address space of the new process:

1. The child process is a duplicate of the parent process (it has the same program and data as the parent).
2. The child process has a new program loaded into it.

```
#include <sys/types.h>
#include <stdio.h>
#include <unistd.h>
int main()
{
pid-t pid;
/* fork a child process */
pid = fork();
if (pid < 0) {/* error occurred */
fprintf(stderr, "Fork Failed");
exit (-1) ;
}
else if (pid == 0} {/* child process */
execlpf"/bin/Is","Is",NULL);
}
else {/* parent process */
/* parent will wait for the child to complete */
wait(NULL);
printf("Child Complete");
exit (0) ;
}
}
```

In UNIX, as we've seen, each process is identified by its process identifier, which is a unique integer. A new process is created by the fork() system call. The new process consists of a copy of the address space of the original process.

This mechanism allows the parent process to communicate easily with its child process. Both processes (the parent and the child) continue execution at the instruction after the fork(), with one difference: The return code for the fork() is zero for the new (child) process, whereas the (nonzero) process identifier of the child is returned to the parent. the exec() system call is used after a fork() system call by one of the two processes to replace the process's memory space with a new program.

The exec () system call loads a binary file into memory (destroying the memory image of the program containing the execO system call) and starts its execution.

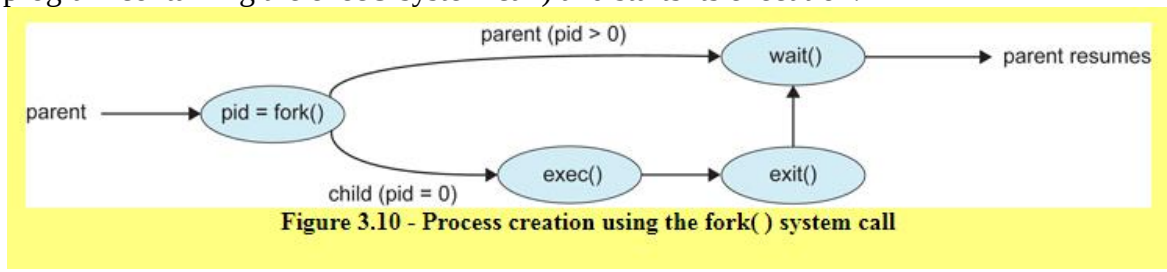

Figure 3.10 - Process creation using the fork( ) system call

Process Termination

A process terminates when it finishes executing its final statement and asks the operating system to delete it by using the exit () system call. At that point, the process may return a status value (typically an integer) to its parent process (via the wait() system call). All the resources of the process—including physical and virtual memory, open files, and I/O buffers—are deal located by the operating system.
Termination can occur in other circumstances as well. A process can cause the termination of another process via an appropriate system call (for example, TerminateProcessO in Win32). Usually, such a system call can be invoked only by the parent of the process that is to be terminated.
A parent may terminate the execution of one of its children for a variety of reasons, such as these:
• The child has exceeded its usage of some of the resources that it has been allocated.
• The task assigned to the child is no longer required.
• The parent is exiting, and the operating system does not allow a child to
continue if its parent terminates.
Consider that, in UNIX, we can terminate a process by using the exit() system call; its parent process may wait for the termination of a child process by using the wait() system call. The wait () system call returns the process identifier of a terminated child so that the parent can tell which of its possibly many children has terminated.
If the parent terminates, however, all its children have assigned as their new parent the init process.

1.3.4 Interprocess Communication

Processes executing concurrently in the operating system may be either independent processes or cooperating processes. A process is **independent** if it cannot affect or be affected by the other processes executing in the system.

Any process that does not share data with any other process is independent. A process is **cooperating** if **it** can affect or be affected by the other processes executing in the system.
There are several reasons for providing an environment that allows process cooperation:

• **Information sharing.** Since several users may be interested in the same piece of information (for instance, a shared file), we must provide an environment to allow concurrent access to such information.
• **Computation speedup.** If we want a particular task to run faster, we must break it into subtasks, each of
which will be executing in parallel with the others. Notice that such a speedup can be achieved only if the
computer has multiple processing elements (such as CPUs or I/O channels).
• **Modularity.** We may want to construct the system in a modular fashion, dividing the system functions into separate processes or threads. • **Convenience.** Even an individual user may work on many tasks at the same time. For instance, a user may be editing, printing, and compiling in parallel.
Cooperating processes require an **interprocess communication (IPC)** mechanism that will allow them to exchange data and information. There are two fundamental models of interprocess

communication:

(1) shared memory and (2) **message passing.** In the shared-memory model, a region of memory that is shared by cooperating processes is established. Processes can then exchange information by reading and writing data to the shared region. In the message passing model, communication takes place by means of messages exchanged between the cooperating processes.

Message passing is useful for exchanging smaller amounts of data, because no conflicts need be avoided. Message passing is also easier to implement than is shared memory for intercomputer communication. Shared memory allows maximum speed and convenience of communication, as it can be done at memory speeds when within a computer.

Shared memory is faster than message passing, as message-passing systems are typically implemented using system calls and thus require the more time consuming task of kernel intervention.

Shared-Memory Systems Interprocess communication using shared memory requires communicating processes to establish a region of shared memory.
Typically, a shared-memory region resides in the address space of the process creating the shared-memory segment. Other processes that wish to communicate using this shared-memory segment must attach it to their address space.
The operating system tries to prevent one process from accessing another process's memory. Shared memory requires that two or more processes agree to remove this restriction. They can then exchange information by reading and writing data in the shared areas.

The form of the data and the location are determined by these processes and are not under the operating system's control. The processes are also responsible for ensuring that they are not writing to the same location simultaneously.
Message-Passing Systems The scheme requires that these processes share a region of memory and that the code for accessing and manipulating the shared memory be written explicitly by the application programmer. Another way to achieve the same effect is for the operating system to provide the means for cooperating processes to communicate with each other via a message-passing facility.

Message passing provides a mechanism to allow processes to communicate and to synchronize their actions without sharing the same address space and is particularly useful in a distributed environment, where the communicating processes may reside on different computers connected by a network.
A message-passing facility provides at least two operations: send(message) and receive(message). Messages sent by a process can be of either fixed or variable size. If only fixed-sized messages can be sent, the system-level implementation is straightforward. This restriction, however, makes the task of programming more difficult. Conversely, variable-sized messages require a more complex system-level implementation, but the programming task becomes simpler. This is a common kind of tradeoff seen throughout operating system design.

Naming

Processes that want to communicate must have a way to refer to each other. They can use either direct or indirect communication.
Under direct communication, each process that wants to communicate must explicitly name the recipient or sender of the communication. In this scheme, the send.0 and receive() primitives are defined as:
• send(P, message)—Send a message to process P.
• receive (Q, message)—Receive a message from process Q.
A communication link in this scheme has the following properties:
• A link is established automatically between every pair of processes that want to communicate. The processes need to know only each other's identity to communicate.
• A link is associated with exactly two processes.
• Between each pair of processes, there exists exactly one link.
The disadvantage in both of these schemes (symmetric and asymmetric) is the limited modularity of the resulting process definitions. Changing the identifier of a process may necessitate examining all other process definitions.

Synchronization
Communication between processes takes place through calls to send() and receive () primitives. There are different design options for implementing each primitive. Message passing may be either **blocking** or **nonblocking**— also known as **synchronous** and **asynchronous.**

• **Blocking send-** The sending process is blocked until the message is received by the receiving process or by the mailbox.

• **Nonblocking send-** The sending process sends the message and resumes operation.
• **Blocking receive-** The receiver blocks until a message is available.

• **Nonblocking receive-** The receiver retrieves either a valid message or a null.
Buffering

Whether communication is direct or indirect, messages exchanged by communicating processes reside in a temporary queue. Basically, such queues can be implemented in three ways:

• **Zero capacity-** The queue has a maximum length of zero; thus, the link cannot have any messages waiting in it. In this case, the sender must block until the recipient receives the message.

• **Bounded capacity-** The queue has finite length *n;* thus, at most *n* messages can reside in it. If the queue is not full when a new message is sent, the message is placed in the queue (either the message is copied or a pointer to the message is kept), and the sender can continue execution without waiting. The links capacity is finite, however. If the link is full, the sender must block until space is available in the queue.

• **Unbounded capacity-** The queues length is potentially infinite; thus, any number of messages can wait in it. The sender never blocks.

1.3.5 Examples of IPC Systems

An Example: POSIX Shared Memory

Several IPC mechanisms are available for POSIX systems, including shared memory and message passing. A process must first create a shared memory segment using the shmget () system call (shmget () is derived from SHared Memory GET).

The following example illustrates the use of shmget ():
segment_id = shmget(IPCJPRIVATE, size, SJRUSR | SJVVUSR) ;
This first parameter specifies the key (or identifier) of the shared-memory segment. If this is set to IPCPRIVATE, a new shared-memory segment is created. The second parameter specifies the size (in bytes) of the shared memory segment. Finally, the third parameter identifies the mode, which indicates how the shared-memory segment is to be used—that is, for reading, writing, or both. By setting the mode to SJRUSR | SJVVUSR, we are indicating that the owner may read or write to the shared memory segment.

Processes that wish to access a shared-memory segment must attach it to their address space using the shmat () (SHared Memory ATtach) system call.
The call to shmat () expects three parameters as well. The first is the integer identifier of the shared-memory segment being attached, and the second is a pointer location in memory indicating where the shared memory will be attached.
If we pass a value of NULL, the operating system selects the location on the user's behalf. The third parameter identifies a flag that allows the shared memory region to be attached in read-only or read-write mode; by passing a parameter of 0, we allow both reads and writes to the shared region.

The third parameter identifies a mode flag. If set, the mode flag allows the shared-memory region to be attached in read-only mode; if set to 0, the flag allows both reads and writes to the shared region.

We attach a region of shared memory using shmat () as follows:
shared_memory = (char *) shmat(id, NULL, 0);
If successful, shmat () returns a pointer to the beginning location in memory where the shared-memory region has been attached.

An Example: Windows XP

The Windows XP operating system is an example of modern design that employs modularity to increase functionality and decrease the time needed to implement new features. Windows XP provides support for multiple operating environments, or *subsystems,* with which application programs communicate via a message-passing mechanism. The application programs can be considered clients of the Windows XP subsystem server.

The message-passing facility in Windows XP is called the **local procedure call (LPC)** facility. The LPC in Windows XP communicates between two processes on the same machine. It is similar to the standard RPC mechanism that is widely used, but it is optimized for and specific to

Windows XP. Windows XP uses a port object to establish and maintain a connection between two processes. Every client that calls a subsystem needs a communication channel, which is provided by a port object and is never inherited.
Windows XP uses two types of ports: connection ports and communication ports. They are really the same but are given different names according to how they are used. Connection ports are named *objects* and are visible to all processes

The communication works as follows:
• The client opens a handle to the subsystem's connection port object.
• The client sends a connection request.
• The server creates two private communication ports and returns the handle to one of them to the client.
• The client and server use the corresponding port handle to send messages or callbacks and to listen for replies.
Windows XP uses two types of message-passing techniques over a port that the client specifies when it establishes the channel.

The simplest, which is used for small messages, uses the port's message queue as intermediate storage and copies the message from one process to the other. Under this method, messages of up to 256 bytes can be sent. If a client needs to send a larger message, it passes the message through a section object, which sets up a region of shared memory. The client has to decide when it sets up the channel whether or not it will need to send a large message. If the client determines that it does want to send large messages, it asks for a section object to be created. Similarly, if the server decides that replies will be large, it creates a section object. So that the section object can be used, a small message is sent that contains a pointer and size information about the section object. This method is more complicated than the first method, but it avoids data copying. In both cases, a callback mechanism can be used when either the client or the server cannot respond immediately to a request.