System Programming
Second Class
مدرس مساعد: منال مطلوب
CHAPTER EIGHT (Introduction to Operating System)

Definition: An operating system is a program that control the execution of application programs and acts as an interface between the user of a computer and the computer hardware.

Introduction:

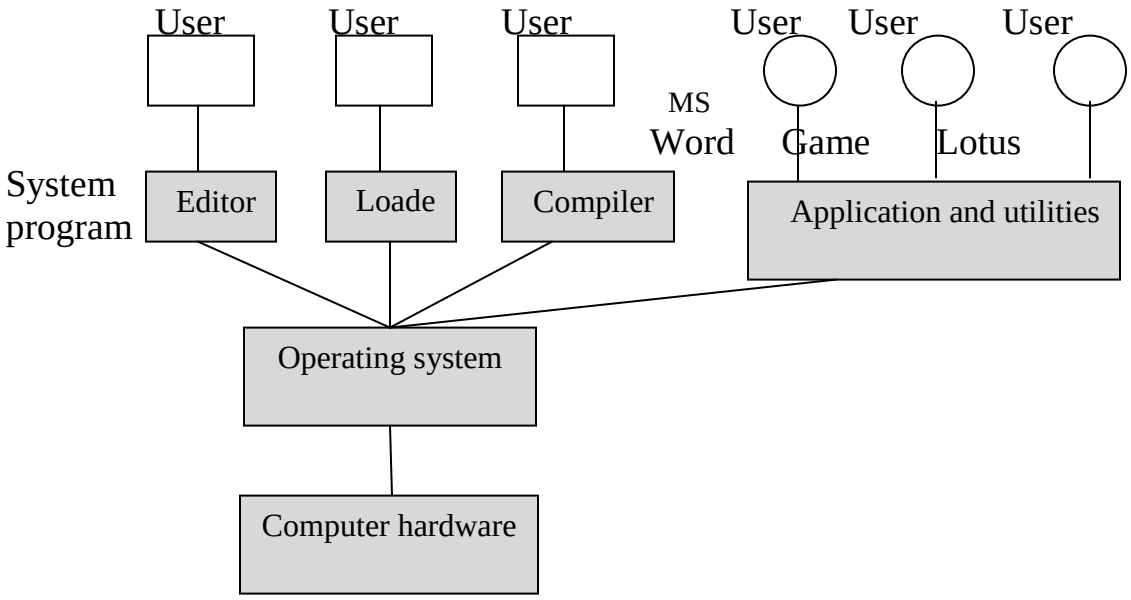
• Operating system performs three functions:

1. Convenience: An as makes a computer more convenient to use.
2. Efficiency: An as allows the computer system resources to be used in an efficient manner.
3. Ability to evolve : An as should be constructed in such a way as to permit the effective development, testing and introduction of new system functions without at the same time interfaring with service .

Operating System as a User Interface:

- Every general purpose computer consists of the hardware, operating system, system programs, application programs. The hardware consists of memory, CPU, ALU, I/O devices, peripheral device and storage device. System program consists of compilers, loaders, editors, as etc. The application program consists of business program, database program.
- The Figure below shows the conceptual view of a computer system.

Every computer must have an operating system to run other programs. The operating system controls and co-ordinates the use of the hardware among the various system programs and application program for a various users. It simply provides an environment within which other programs can do useful work.



(Conceptual view of a computer system)

- The operating system is a set of special programs that run on a computer system that allow it to work properly. It performs basic tasks such as recognizing input from the keyboard, keeping track of files and directories on the disk, sending output to the display screen and controlling a peripheral devices.
- OS is designed to serve two basic purposes :

1. It controls the allocation and use of the computing system's resources among the various users and tasks.
2. It provides an interface between the computer hardware and the programmer that simplifies and makes feasible for coding, creation, debugging of application programs.

- The operating system must support the following tasks. The tasks are:

1. Provides the facilities to create, modification of program and data files using an editor.
2. Access to the compiler for translating the user program from high level language to machine language.
3. Provide a loader program to move the compiled program code to the computer's memory for execution.
4. Provide routines that handle the details of I/O programming.

Operating System Services:

- An operating system provides services to programs and to the users of those programs. It provides an environment for the execution of programs. The services provided by one operating system is different than other operating system.
- Operating system makes the programming task easier. The common services
  Provided by the operating system is listed below.

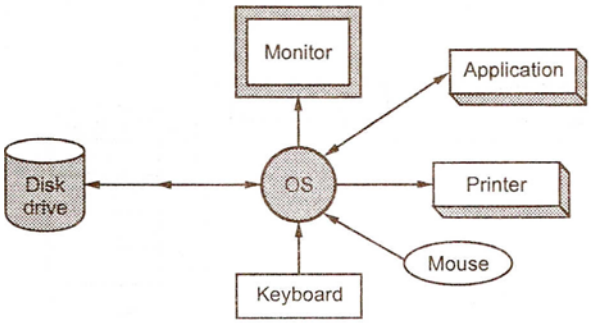
1. Program execution
2. I/O operation
3. File system manipulation
4. Communications
5. Error detection.

1. **Program execution**: Operating system loads a program into memory and executes the program. The program must be able to end its execution, either normally or abnormally.
2. ***I/O* operation:** I/O means any file or any specific I/O device. Program may require any I/O device while running. So operating system must provide the required I/O.
3. **File system manipulation**: Program needs to read a file or write a file. The operating system gives the permission to the program for operation on file.
4. **Communication:** Data transfer between two processes is required for some time. The both processes are on the one computer or on different computer but connected through computer network. Communication may be implemented by two methods: shared memory and message passing.
5. **Error detection:** Error may occur in CPU, in I/O devices or in the memory hardware. The operating system constantly needs to be aware of possible errors. It should take the appropriate action to ensure correct and consistent computing.

Operating system with multiple users provides following services.

1. Resource allocation
2. Accounting
3. Protection

• Figure below shows the view of OS with components.

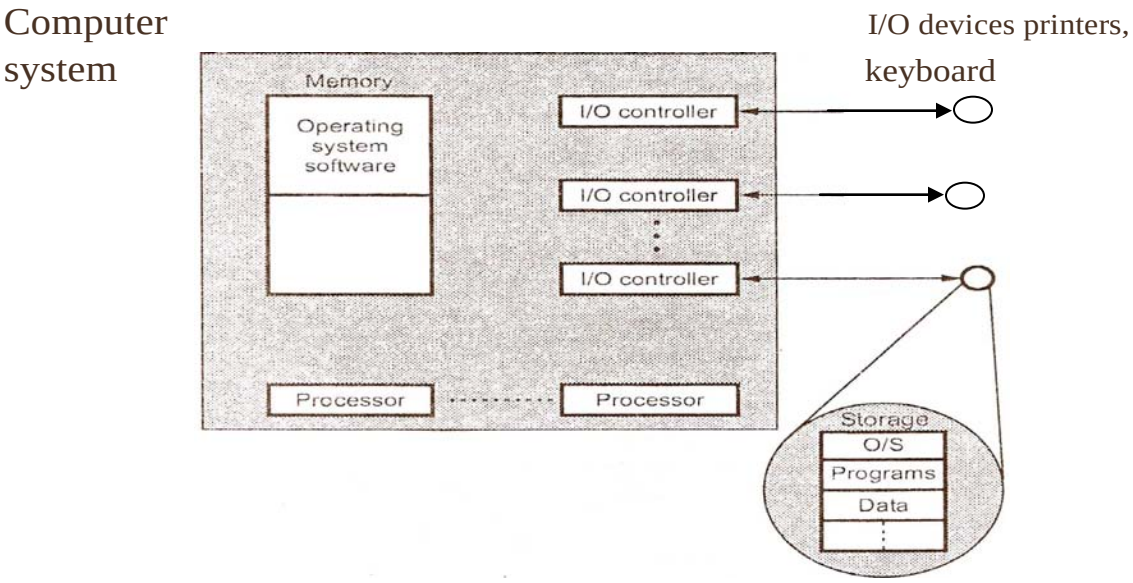


(view of OS with components)

- An operating system is a lower level of software that user programs run on.
  OS is built directly on the hardware interface and provides an interface between the hardware and the user program. It shares characteristics 'with both software and hardware.
- We can view an operating system as a resource allocator. OS keeps track of the status of each resource and decides who gets a resource, for how long, and when. as makes sure that different programs and users running at the same time but do not interfere with each other. It is also responsible for security, ensuring that unauthorized users do not access the system.
- The primary objective of operating systems is to increase productivity of a processing resource, such as computer hardware or users.
- The operating system is the first program nm on a computer when the computer boots up. The services of the as are invoked with a system call instruction that is used just like any other hardware instruction.
- Name of the operating systems are: DOS, Windows 95, Windows NT/2000, Unix, Linux etc.

Operating System as Resource Manager

- A computer is a set of resources for the movement, storage and processing of data and for the control of these functions. The as is responsible for managing these resources.
- Figure below shows as a resource manager.



(OS as a resource manager)

- Main resources that are managed by the operating system. A portion of the operating system is in main memory. This includes the Kernel, which contains the most frequently used functions in the operating system and at a given time, other portions of the OS currently in use.
- The remainder of main memory contains other user programs and data. The allocation of main memory is controlled jointly by the OS and memory management hardware in the processor.
- The operating system decides when an I/O device can be used by a program in execution and controls access to and use of files. The processor itself is a resource, and the operating system must determine how much processor time is to be devoted to the execution of a particular user program.

History of Operating System

- Operating systems have been evolving through the years. Following table shows the history of OS.

Generation	**Year**	**Electronic devices used**	**Types of OS and devices**
First	1945-55	Vacuum tubes	Plug boards
Second	1955-1965	Transistors	Batch system
Third	1965-1980	Integrated circuit (IC)	Multiprogramming
Fourth	Since 1980	Large scale integration	PC

Mainframe System: An operating system may process its workload serially or concurrently. That is resources of the computer system may be dedicated to a single program until its completion, or they may be dynamically reassigned among a collection of active programs in different stages of execution.

- Several variations of both serial and multiprogrammed operating systems exist.

Characteristics of mainframe systems

1. The first computers used to tackle various applications and still found today in corporate data centers.
2. Room-sized, high I/O capacity, reliability, security, technical support.
3. Mainframes focus on I/O bound business data applications.

Mainframes provide three main functions:

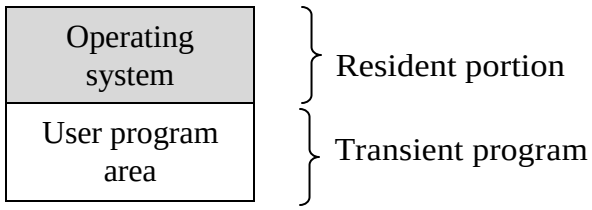
a. Batch processing: insurance claims, store sales reporting, etc.

b. Transaction processing: credit card, bank account, etc.

c. Time-sharing: multiple users querying a database.

Batch Systems

- Some computer systems only did one thing at a time. They had a list of instructions to carry out and these would be carried out one after the other. This is called a **serial system.** The mechanics of development and preparation of programs in such environments are quite slow and numerous manual operations involved in the process.
- Batch operating system is one where programs and data are collected together in a batch before processing starts. A job is predefined sequence of commands, programs and data that are combined into a single unit called **job.**
- Figure below shows the memory layout for a simple batch system. Memory management in batch system is very simple. Memory is usually divided into two areas: Operating system and user program area.

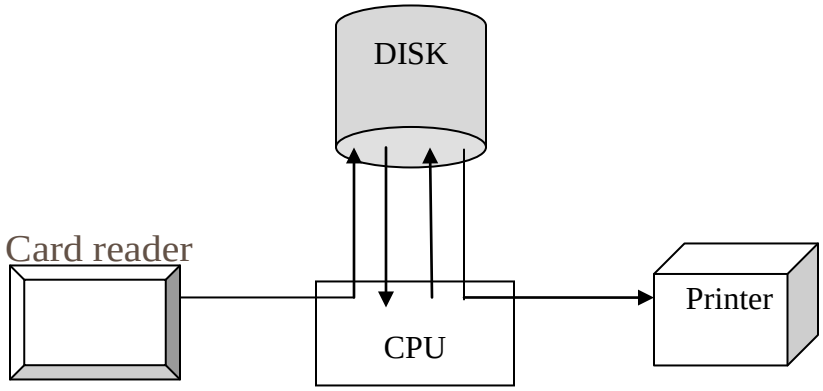


(Memory layout for a simple batch system)

- Scheduling is also simple in batch system. Jobs are processed in the order of submission i.e. first come first served fashion.
- When a job completes execution, its memory is released and the output for the job gets copied into an output **spool** for later printing.
- Spooling an acronym for **simultaneous peripheral operation on line.** Spooling uses the disk as a large buffer for outputting data to printers and other devices. It can also be used for input, but is generally used for output. Its main use is to prevent two users from alternating printing lines to the line printer on the same page, getting their output completely mixed together. It also helps in reducing idle time and overlapped I/O and CPU.
- Batch system often provides simple forms of file management. Access ·to file is serial. Batch systems do not require any time critical device management.
- Batch systems are inconvenient for users because users can not interact with their jobs to fix problems. There may also be long turnaround times. Example of this system is generating monthly bank statement.

Spooling:

- Acronym for simultaneous peripheral operations on line. Spooling refers to putting jobs in a buffer, a special area in memory or on a disk where a device can access them when it is ready.
- Spooling is useful because device access data at different rates. The buffer provides a waiting station where data can rest while the slower device catches up. Figure below shows the spooling.



(Spooling)

- Computer can perform I/O in parallel with computation, it becomes possible to have the computer read a deck of cards to a tape, drum or disk and to write out to a tape printer while it was computing. This process is called **spooling.**
- The most common spooling application is print spooling. In print spooling, documents are loaded into a buffer and then the printer pulls them off the buffer at its own rate.
- Spooling is also used for processing data at remote sites. The CPU sends the data via communications path to a remote printer. Spooling overlaps the I/O of one job with the computation of other jobs.
- One difficulty with simple batch systems is that the computer still needs to read the deck of cards before it can begin to execute the job. This means that the CPU is idle during these relatively slow operations.
- Spooling batch systems were the first and are the simplest of the multiprogramming systems.

Advantages of Spooling:

1. The spooling operation uses a disk as a very large buffer.
2. Spooling is however capable of overlapping I/O operation for one job with processor operations for another job.

Advantages of Batch System:

1. Move much of the work of the operator to the computer.
2. Increased performance since it was possible for job to start as soon as the previous job finished.

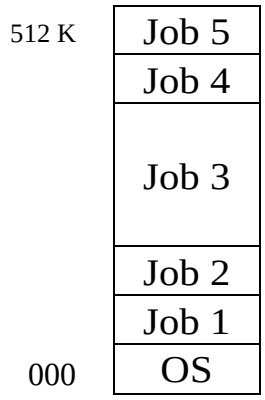
Disadvantages of Bach System:

1. Turn around time can be large from user standpoint.
2. Difficult to debug program.
3. A job could enter an infinite loop.
4. A job could corrupt the monitor, thus affecting pending jobs.
5. Due to lack of protection scheme, one batch job can affect pending jobs.

Multiprogramming Operating System:

When two or more programs are in memory at the same time, sharing the processor is referred to the multiprogramming operating system. Multiprogramming assumes a single processor that is being shared. It increases CPU utilization by organizing jobs so that the CPU always has one to execute.

Figure below shows the memory layout for a multiprogramming system.



(Memory layout for a multiprogramming system)

- The operating system keeps several jobs 111 memory at a time. This set of jobs is a subset of the jobs kept in the job pool. The operating system picks and begins to execute one of the job in the memory.
- Multiprogrammed systems provide an environment in which the various system resources are utilized effectively, but they do not provide for user interaction with the computer system.
- Jobs entering into the system are kept into the memory. Operating system picks the job and begins to execute one of the jobs in the memory. Having several programs in memory at the same time requires some form of memory management.
- Multiprogramming operating system monitors the state of all active programs and system resources. This ensures that the CPU is never idle unless there are no jobs.

Advantages

1. High CPU utilization.
2. It appears that many programs are allotted CPU almost simultaneously.

Disadvantages

1. CPU scheduling is required.
2. To accommodate many jobs in memory, memory management is required.

Time Sharing Systems:

- Time sharing system supports interactive users. Time sharing is also called **multitasking.** It is logical extension of multiprogramming. Time sharing system uses CPU scheduling and multiprogramming to provide an economical interactive system of two or more users.
- In time sharing, each user is given a time-slice for executing his job in round-robin fashion. Job continues until the time-slice ends.
- Time sharing systems are more complex than multiprogramming operating system. Memory management in time sharing system provides for isolation and protection of **co-resident** programs.
- Time sharing uses medium-term scheduling such as round-robin for the foreground. Background can use a different scheduling technique.
- Time sharing system can run several programs at the same time, so it is also a multiprogramming system. But multiprogramming operating system is not a time sharing system.
- Difference between both the systems is that, time sharing system allows more frequent context switches. This gives each user the impression that the entire computer is dedicated to his use. In multiprogramming system a context switch occurs only when the currently executing process stalls for some reason.

Desktop System:

During the late 1970, computers had faster CPU, thus creating an even greater disparity between their rapid processing speed and slower I/O access time. Multiprogramming schemes to increase CPU use were limited by the physical capacity of the main memory, which was a limited resource and very expensive. These system includes PC running MS window and the Apple Macintosh. The Apple Macintosh OS support new advance hardware i.e. virtual memory and multitasking with virtual memory, the entire program did not need to reside in memory before execution could begin.

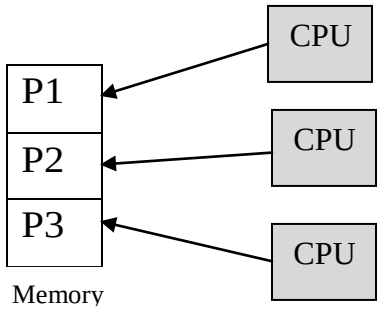
- Linux, a unix like OS available for PC, has also become popular recently. The microcomputer was developed for single users in the late 1970. Physical size was smaller than the minicomputers of that time, though larger than the microcomputers of today.
- Microcomputer grew to accommodate software with large capacity and greater speeds. The distinguishing characteristics of a

microcomputer is its single user status. MS-DOS is an example of a microcomputer operating system.

- The most powerful microcomputers used by commercial; educational, government enterprises. Hardware cost for microcomputers are sufficiently low that a single user (individuals) have sole use of a computer. Networking capability has been integrated into almost every system.

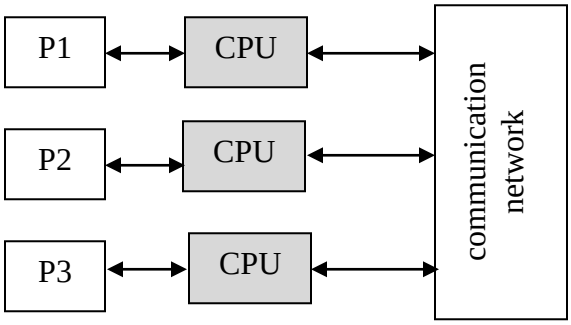
Multiprocessor System:

- Multiprocessor system have more than one processor in close communication. They share the computer bus, system clock and input-output devices and sometimes memory. In multiprocessing system, it is possible for two processes to run in parallel.
- Multiprocessor systems are of two types: symmetric multiprocessing and asymmetric multiprocessing.
- In symmetric multiprocessing, each processor runs an identical copy of the operating system and they communicate with one another as needed. All the CPU shared the common memory. Figure below shows the symmetric multiprocessing system.



Symmetric multiprocessing system (shared memory)

- In asymmetric multiprocessing, each processor is assigned a specific task. It uses master-slave relationship. A master processor controls the system. The master processor schedules and allocates work to the slave processors. Figure below shows the asymmetric multiprocessor.



Asymmetric multiprocessors (NO shared memory)

Features of multiprocessor systems

1. If one processor fails, then another processors should retrive the interrupted process state so that executation of the process can continue.
2. The processors should support efficient context switching operation.
3. Multiprocessor system supports large physical address space & large virtual address sapce.
4. The IPC mechanism should be provided & implemented in hardware as it becomes efficient & easy.

Distributed System:

Distributed operating systems depend on networking for their operation. Distributed as runs on and controls the resources of multiple machines. It provides resource sharing across the boundaries of a single computer system. It looks to users like a single machine as. Distributing as owns the whole network and makes it look like a virtual uniprocessor or may be a virtual multiprocessor.

- Definition: A distributed operating system is one that looks to its users like an ordinary operating system but runs on multiple, independent CPU.

Advantages of distributed OS:

1. Resource sharing: Sharing of software resources such as software libraries, database and hardware resources such as hard disks, printers and CDROM can also be done in a very effective way among all the computers and the users.
2. Higher reliability: Reliability refers to the degree of tolerance against errors and component failures. Availability is one of the important aspect of reliability. Availability refers to the fraction of time for which a system is available for use. Availability of a hard disk can be increased by having multiple hard disks located at different sites. If one hard disk fails or is unavailable, the program can use some other hard disk.
3. Better price performance ratio. Reduction in the price of microprocessor and increasing computing power gives good price-performance ratio.
4. Shorter responses times and higher throughput.
5. Incremental growth: To extend power and functionality of a system by simply adding additional resources to the system.

Difficulties in distributed OS are:

1. There are no current commercially successful examples.
2. Protocol overhead can dominate computation costs.
3. Hard to build well.
4. Probably impossible to build at the scale of the Internet.

Cluster System:

- It is a group of computer system connected with a high speed communication link. Each computer system has its own memory and peripheral devices. Clustering is usually performed to provide high availability. Clustered systems are integrated with hardware cluster and software cluster. Hardware cluster means sharing of high performance disks. Software cluster is in the form of unified control of the computer system in a cluster.
- A layer of software cluster runs on the cluster nodes. Each node can monitor one or more of the others. If the monitoring machine fails, the monitoring machine can take ownership of its storage and restart the application that were running on the failed machine.
- Clustered system can be categorized into two groups: asymmetric clustering and symmetric clustering.
- In asymmetric clustering, one machine is in hot standy mode while the other is running the applications. Hot standy mode monitors the active server and sometimes becomes the active server when the original server fails.
- In symmetric clustering mode, two or more than two hosts are running applications and they are monitoring each other.
- Parallel clusters and clustering over a WAN is also available in clustering.
  Parallel clusters allow multiple hosts to access the same data on the shared storage. A cluster provides all the key advantages of distributed systems. A cluster provides better reliability than the symmetrical multiprocessor system.
- Cluster technology is rapidly changing. Clustered system use and features should expand greatly as storage area networks. Storage area network allows easy attachment of multiple hosts to multiple storage units.

Real Time System:

- Real time systems which were originally used to control autonomous systems such as satellites, robots and hydroelectric dams. A real time operating system is one that must react to inputs and responds to them quickly. A real time system can not afford to be late with a response to an event.
- A real time system has well defined, fixed time constraints. Deterministic scheduling algorithms are used in real time systems. Real time systems are divided into two groups : **Hard real time system** and **soft real time system.**
- A hard real time system guarantees that the critical tasks be completed on time. This goal requires that all delay in the system be bounded. Soft real time system is a less restrictive type. In this, a critical r.eal time task gets priority over other tasks, and retains that priority until it completes.
- Real time operating system uses priority scheduling algorithm to meet the response requirement of a real time application.
- General real time applications with some examples are listed below.

Sr. No.	Real Time Application	Examples
1.	Detection	Radar system Burglar alarm
2.	Process monitoring and control	Petroleum, Paper mill.
3.	Communication	Telephone switching system
4.	Flight simulation and control	Auto pilot shuttle mission simulator
5.	transportation	Traffic light system, Air traffic control

- Memory management in real time system is comparatively less demanding than in other types of multiprogramming systems. Time-critical device management is one of the main characteristics of real time systems. The primary objective of file management in real time system is usually speed of access, rather than efficient utilization of secondary storage.

Comparison between Hard and Soft Real Time System

- Hard real time system guarantees that critical tasks complete on time. To achieve this, all delays in the system must be bounded i.e. the retrieval of stored data to the time that it takes the operating system to finish any request made of it. Soft real time system are less restrictive than the hard real time system. In soft real time, a critical real time task gets priority over other tasks and retains that priority until it complete.

- Time constraints are the main properties for the hard real time systems.
  Since none of the operating system support hard real time system, Kernal delays need to be bounded in soft real time system. Soft real time systems are useful in the area of multimedia, virtual reality and advance scientific projects. Soft real time systems can not be used in -robotics and industrial control because of their lack of deadline support. Soft real time system requires two conditions to implement. CPU scheduling must be priority based and dispatch latency must be small.

Handheld System:

- Personal Digital Assistants (PDA) is one type of handheld systems.
  Developing such device is the complex job and many challenges will face by developers. Size of these system is small i.e. height is 5 inches and width is 3 inches.
- Due to the limited size, most handheld devices have a small amount of memory, include slow processors and small display screen. Memory of handheld system is in the range of 512 kB to 8 MB. Operating system and applications must manage memory efficiently. This includes returning all allocated memory back to the memory manager once the memory is no longer needed. Developers are working only on confines of limited physical memory because any handheld devices not using virtual memory.
- Speed of the handheld system is major factor. Faster processors require for handheld systems. Processors for most handheld devices often run at a fraction of the speed of a processor in a Pc. Faster processors require more power. Larger battery requires for faster processors.
- For mimimum size of handheld devices, smaller, slower processors which consumes less power are used. Typically small display screen is available in these devices. Display size of handheld device is not more than 3 inches square.
- At the same time, display size of monitor is up to 21 inches. But these handheld device provides the facility for reading email, browsing web pages on smaller display. Web clipping is used for displaying web page on the handheld devices.
- Wireless technology is also used in handheld devices. Bluetooth protocol is used for remote access to email and web browsing. Cellular telephones with connectivity to the Internet fall into this category.

Computing Environments:

- Different types of computing environments are:

a. Traditional computing

b. Web based computing

c. Embedded computing

- Typical office environment uses traditional computing. Normal PC is used in traditional computing.
- Web technology also uses traditional computing environment. Network computers are essentially terminals that understand web based computing. In domastic application, most of user had a single computer with Internet connection. Cost of the accessing Internet is high.
- Web based computing has increased the emphasis on networking. Web based computing uses PC, handheld PDA and cell phones. One of the features of this type is load balancing. In load balancing, network connection is distributed among a pool of similar servers.
- Embedded computing uses realtime operating systems. Application of embedded computing is car engines, manufacturing robots to VCR and microwave ovens. This type of system provides limited features.

Essential Properties of the Operating System

1. **Batch:** Jobs with similar needs are batched together and run through the computer as a group by an operator or automatic job sequencer. Performance is increased by attempting to keep CPU and I/O devices busy at all times through buffering, off line operation, spooling and multiprogramming. A Batch system is good for executing large jobs that need little interaction, it can be submitted and picked up latter.
2. **Time sharing:** Uses CPU scheduling and multiprogramming to provide economical interactive use of a system. The CPU switches rapidly from one user to another i.e. the CPU is shared between a number of interactive users. Instead of having a job defined by spooled card images, each program reads its next control instructions from the terminal and output is normally printed immediately on the screen.
3. **Interactive:** User is on line with computer system and interacts with it via an interface. It is typically composed of many short transactions where the result of the next transaction may be unpredictable. Response time needs to be short since the user submits and waits for the result.

4. **Real time system**: Real time systems are usually dedicated, embedded systems. They typically read from and react to sensor

data. The system must guarantee response to events within fixed periods of time to ensure correct performance.

5. **Distributed:** Distributes computation among several physical processors. The processors do not share memory or a clock. Instead, each processor has its own local memory. They communicate with each other through various communication lines.

System Components:

Modern operating systems share the goal of supporting the system components. The system components are:

1. Process management
2. Main memory management
3. File management
4. Secondary storage management
5. I/O system management
6. Networking
7. Protection system
8. Command interpreter system.

Process Management

- Process refers to a program in execution. The process abstraction is a fundamental operating system mechanism for management of concurrent program execution. The operating system responds by creating a process.
- A process needs certain resources, such as CPU time, memory, files and I/O devices. These resources are either given to the process when it is created or allocated to it while it is running.
- When the process terminates, the operating system will reclaim any reusable resources.
- The term process refers to an executing set of machine instructions. Program by itself is not a process. A program is a passive entity.
- The operating system is responsible for the following activities of the process management.

1. Creating and destroying the user and system processes.
2. Allocating hardware resources among the processes.
3. Controlling the progress of processes.
4. Providing mechanisms for process communications.
5. Also provides mechanisms for deadlock handling.

Main Memory Management

- The memory management modules of an operating system are concerned with the management of the primary (main memory) memory. Memory management is concerned with following functions:

1. Keeping track of the status of each location of main memory. i.e. each memory location is either free or allocated.
2. Determining allocation policy for memory.
3. Allocation technique i.e. the specific. location must be selected and allocation information updated.
4. Deallocation technique and policy. After deallocation, status information must be updated.

- Memory management is primarily concerned with allocation of physical memory of finite capacity to requesting processes. The overall resource utilization and other performance criteria of a computer system are affected by performance of the memory management module. Many memory management schemes are available and the effectiveness of the different algorithms depends on the particular situation.

File Management

- Logically related data items on the secondary storage are usually organized into named collections called files. In short, file is a logical collection of information. Computer uses physical media for storing the different information.
- A file may contain a report, an executable program or a set of commands to the operating system. A file consists of a sequence of bits, bytes, lines or records whose meanings are defined by their creators. For storing the files, physical media (secondary storage device) is used.
- Physical media are of different types. These are magnetic disk, magnetic tape and optical disk. All the media has its own characteristics and physical organization. Each medium is controlled by a device.
- The operating system is responsible for the following in connection with file management.

1. Creating and deleting of files.
2. Mapping files onto secondary storage.
3. Creating and deleting directories.
4. Backing up files on stable storage media.
5. Supporting primitives for manipulating files and directories.
6. Transmission of file elements between main and secondary

storage.

- The file management subsystem can be implemented as one or more layers of the operating system.

Secondary Storage Management

- A storage device is a mechanism by which the computer may store information in such a way that this information may be retrieved at a later time. Secondary storage device is used for storing all the data and programs. These programs and data access by computer system must be kept in main memory. Size of main memory is small to accommodate all data and programs. It also lost the data when power is lost. For this reason secondary storage device is used. Therefore 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 the· disk management.

1. Free space management 2. Storage allocation 3. Disk scheduling

- The entire speed and performance of a computer may hinge on the speed of the disk subsystem.

I/O System Management :

II The module that keeps track of the status of devices is called the I/O traffic controller. Each I/O device has a device handler that resides in a separate process associated with that device.

- The I/O subsystem consists of

1. A memory management component that includes buffering, caching and spooling.
2. A general device driver interface.
3. Drivers for specific hardware devices.

Networking:

Networking enables computer users to share resources and speed up computations. the processors communicate with one another through various communication lines. For example, a distributed system. A distributed system is a collection of processors. Each processor has its own local memory and clock. The processors in the system are connected through a communication network, which can be configured in a number of different ways.

- Following parameter are considered while designing the networks.

1. Topology of network
2. Type of network
3. Physical media
4. Communication protocols
5. Routing algorithm.

Protection System:

- Modern computer systems support many users and allow the concurrent execution of multiple processes. Organizations rely on computers to store information. It is necessary that the information and devices must be protected from unauthorised users or processors. The protoction is any mechanism for controlling the access of programs, processes or users to the resources defined by a computer system.
- Protection mechanisms are implemented in operating systems to support various security policies. The goal of the security system is to authenticate subjects and to authorise their access to any object.
- Protection can improve reliability by detecting latent errors at the interfaces between compoent subsystems. Protection domains are extensions of the hardware supervisor mode ability

Command Interpreter System:

- Command interpreter is the interface between user and the operating system.

  It is system programs for an operating system. Command interpreter is a special program in Unix and MS-DOS operating system.
- When users login first time or when a job is initiated, the command interpreter is initially some operating system is included in the Kernel. A control statement is processed by the command interpreter. Command interpreter reads the control statement, analyses it and carries out the required action.

Operating System Services:

- An operating system provides services to programs and to the users of those programs. It provides an environment for the execution of programs. The services provided by one operating system is different than other operating system. Operating system makes the programming task easier.
- The common services provided by the operating system is listed below.

1. Program execution
2. I/O operation
3. File system manipulation
4. Communications
5. Error detection.

1. **Program execution**: Operating system loads a program into memory and executes the program. The program must be able to end its execution, either normally or abnormally.
2. **I/O Operation**: I/O means any file or any specific I/O device. Program may require any I/O device while running. So operating system must provide the required I/O.
3. **File system manipulation**: Program needs to read a file or write a file. The operating system gives the permission to the program for operation on file.
4. **Communication**: Data transfer between two processes is required for some time. The both processes are on the one computer or on different computer but connected through computer network. Communication may be implemented by two methods : shared memory and message passing.
5. **Error detection:** Error may occur in CPU, in I/O devices or in the memory hardware. The operating system constantly needs to be aware of possible errors. It should take the appropriate action to ensure correct and consistent computing.

- Operating system with multiple users provides following services.

1. Resource allocation
2. Accounting
3. Protection

A) Resource allocation:

If there are more than one user or jobs running at the same time, then resources must be allocated to each of them. Operating system manages different types of resources. Some resources require special allocation code, i.e., main memory, CPU cycles and file storage.

- There are some resources which require only general request and release code. For allocating CPU, CPU scheduling algorithms are used for better utilization of CPU. CPU scheduling routines consider the speed of the CPU, number of available registers and other required factors.

B) Accounting:

- Logs of each user must be kept. It is also necessary to keep record of which user uses how much and what kinds of computer resources. This log is used for accounting purposes.
- The accounting data may be used for statistics or for the billing. It also used to improve system efficiency.

C) System Calls:

- Protection involves ensuring that all access to system resources is controlled.
  Security starts with each user having to authenticate to the system, usually by means of a password. External I/O devices must be also protected from invalid access attempts.
- In protection, all the access to the resources is controlled. In multiprocess environment, it is possible that, one process to interface with the other, or with the operating system, so protection is required.

System Calls:

- Modern processors provide instructions that can be used as system calls.
  System calls provide the interface between a process and the operating system. A system call instruction is an instruction that generates an interrupt that cause the operating system to gain

control of the processor.

- System call works in following ways :

1. First the program executes the system call instructions.
2. The hardware saves the current (instruction) and PSW register in the ii and iPSW register.
3. 0 value is loaded into PSW register by hardware. It keeps the machine in system mode with interrupt disabled.
4. The hardware loads the i register from the system call interrupt vector location. This completes the execution of the system call instruction by the hardware.
5. Instruction execution continues at the beginning of the system call interrupt handler.
6. The system call handler completes and executes a return from interrupt (rti) instructions. This restores the i and PSW from the ii and iPSW.
7. The process that executed the system call instruction continues at the instruction after the system call.

Types of System Call:

A system call is made using the system call machine language instruction. System calls can be grouped into five major categories.

1. File management
2. Interprocess communication
3. Process management
4. I/O device management
5. Information maintenance.

Hardware Protection:

- For single-user programmer operating systems, programmer has the complete control over the system. They operate the system from the console. When new operating systems developed with some additional features, the system control transfers from programmer to the operating system.

- Early operating systems were called resident monitors, and starting with the resident monitor, the operating system began to perform many of the functions, like input-output operation.

- Before the operating system, programmer is responsible for the controls of input-output device operations. As the requirements of programmers from computer systems go on increasing and development in the field of communication helps to the operating system.

•Sharing of resource among different programmers is possible without increasing cost. It improves the system utilization but problems increase. If single system was used without share, an error occurs, that could cause problems for only the one program which was running on that machine.

•In sharing, other programs also affected by single program. For example, batch operating system faces the problem of infinite loop. This loop could prevent the correct operation of many jobs. In multiprogramming system, one erroreous program affects the other program or data of that program.

- For proper operation and error free result, protection of error is required. Without protection, only single process will execute one at a time otherwise the output of each program is separated. While designing the operating system, this type of care must be taken into consideration.

  - Many programming errors are detected by the computer hardware.

  Operating system handled this type of errors. Execution of illegal instruction or access of memory that is not in the user's address space, this type of operation found by the hardware and will trap to the operating system.

  - The trap transfers control through the interrupt vector to the operating system. Operating system must abnormally terminate the program when program error occurs. To handle this type of situation, different types of hardware protection is used.