

# Unit 1

## Overviews

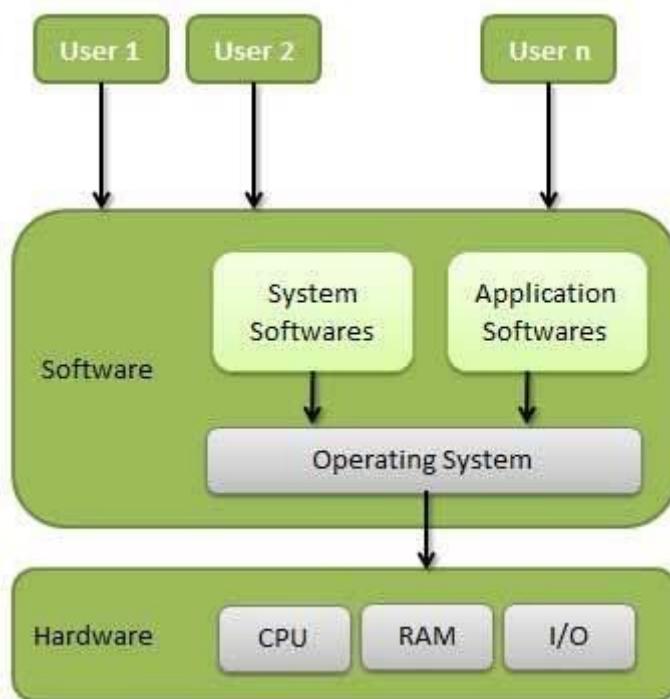
### Operating System

An Operating System (OS) is an interface between a computer user and computer hardware. An operating system is a software which performs all the basic tasks like file management, memory management, process management, handling input and output, and controlling peripheral devices such as disk drives and printers.

Some popular Operating Systems include Linux Operating System, Windows Operating System, VMS, OS/400, AIX, z/OS, etc.

### Definition

An operating system is a program that acts as an interface between the user and the computer hardware and controls the execution of all kinds of programs.



### Views of the Operating System

The operating system can be observed from the point of view of the user or the system. This is known as the user view and system view respectively. An operating system is a framework that enables user application programs to interact with system hardware. The operating system does not perform any functions on its own, but it provides an atmosphere in which various programs and apps can do useful work. The operating system may be observed from the point of view of the user or the system, and it is known as the user view and the system view.

The user viewpoint is all about how the user has to interact with the operating system with the help of various application programs and from the system point of view we see how the hardware has to interact with the operating system for accomplishing the various tasks.

## **Viewpoints of the Operating System**

There are mainly two types of views of the operating system.

- **User view**
- **System view**

### **User view**

The user viewpoint focuses on how the user interacts with the operating system through the usage of various application programs. Some systems are designed for a single user to monopolize the resources to maximize the user's task. Therefore the Operating system is designed primarily for ease of use with little emphasis on quality and none of resource utilization.

#### **Single user view point**

These systems are much more designed for a single user experience and meet the needs of single user where the performance is not given focus as the multiple user systems. Most computer users use a monitor, keyboard, printer, mouse and other accessories to operate their computer system. In some cases, the system is designed to maximize the output of a single user. As a result, more attention is laid on accessibility, and resource allocation is less important.

#### **Multiple user view point**

These systems are designed for multiple user experience and meet the needs of multiple user. when there is one mainframe computer and many users on their computer trying to interact with their kernels over the mainframe to each other.

The client server architecture is a good example where many clients may interact through a remote server, and the same constraints of effective use of server resources may arise.

#### **Handled user view point**

In the handled user viewpoint smartphones interact via wireless devices to perform numerous operations but they are not as efficient as a computer interface, limiting their usefulness. Smart phones have given you the best handheld technology ever. However, their operating system is a great example of creating a device focused on the user's point of view. The Touchscreen era has given you the best handheld technology ever.

### Embedded System user view Point

The embedded system lacks a user point of view. The remote control used to turn on or off the tv is all part of an embedded system in which the electronic device communicates with another program where the user view point is limited and allows the user to engage with the application.

### **System view**

An operating system can also be considered as a program running at all times in the background of a computer system known as the kernel and handling all the application programs. The operating system may also be viewed as just a resource allocator. A computer system comprises various sources, such as hardware and software which must be managed effectively. The operating system is responsible for managing hardware resources and allocating them to programs and users to ensure maximum performance. In the system viewpoint the operating system is more involved with hardware services -CPU time, memory space, I/O operation, and so on.

From the system point of view, we are more focused on how the hardware has to interact with the operating system than the user. The hardware and the operating system interact with each other for the various purpose some of them are

### Resource Allocation

There are many resources which present in the hardware such as register, cache, RAM, ROM, processors, I/O interaction, etc. These resources demanded by the operating system when it is asked by any application program. This resource allocation has to be done only by the operating system which has used many techniques and strategies such that it brings the most out of its processing and memory space. There are various techniques such as paging, virtual memory, caching, etc.

The operating system allocates resources when a program needs them. When the program terminates, the resources are unallocated and allocated to other programs that need them.

There are two resource allocation techniques

- **Resource partitioning approach** It divides the resources in the system to many resource partitions, where each partition may include various resources -for example ,1MB memory, disk blocks and a printer. Then it allocates one resource partition to each user program before the program's initiation. A resource table records the resource partition and its current allocation status.

In this approach the operating system decides beforehand what resources should be allocated to which user program.

- **Pool based approach:** in the pool-based approach there is a common pool of resources. The operating system checks the allocation status in the resource table whenever a program makes a request for a resource. If the resource is free, it allocates the resources to the program.

Control program

In the control programs it controls how input and output devices (hardware) interact with the operating system. The user may request an action that can only be done with I/O devices, The operating system must also have proper communication, control, detect, and handle such devices.

## History of the Operating System

It took years to evolve the Operating Systems and make them as modernised and advanced as they are today. Given below are the details about the evolution and history of Operating systems.

- Initially, the computers made did not have an Operating system and to run each program a different code was used. This had made the processing of data more complex and time taking
- In 1956, the first operating systems were developed by General Motors to run a single IBM computer
- It was in the 1960s that IBM had started installing OS in the devices they launched
- The first version of the UNIX operating system was launched in the 1960s and was written in the programming language C
- Later on, Microsoft came up with their OS on the request of IBM

- Today, all major computer devices have an operating system, each performing the same functions but with slightly different features

Following is some of important functions of an operating System.

- Memory Management
- Processor Management
- Device Management
- File Management
- Security
- Control over system performance
- Job accounting
- Error detecting aids
- Coordination between other software and users

## **Memory Management**

Memory management refers to management of Primary Memory or Main Memory. Main memory is a large array of words or bytes where each word or byte has its own address.

Main memory provides a fast storage that can be accessed directly by the CPU. For a program to be executed, it must be in the main memory. An Operating System does the following activities for memory management –

- Keeps tracks of primary memory, i.e., what part of it are in use by whom, what part are not in use.
- In multiprogramming, the OS decides which process will get memory when and how much.
- Allocates the memory when a process requests it to do so.
- De-allocates the memory when a process no longer needs it or has been terminated.

## **Processor Management**

In multiprogramming environment, the OS decides which process gets the processor when and for how much time. This function is called **process scheduling**. An Operating System does the following activities for processor management –

- Keeps tracks of processor and status of process. The program responsible for this task is known as **traffic controller**.
- Allocates the processor (CPU) to a process.
- De-allocates processor when a process is no longer required.

## **Device Management**

An Operating System manages device communication via their respective drivers. It does the following activities for device management –

- Keeps tracks of all devices. Program responsible for this task is known as the **I/O controller**.
- Decides which process gets the device when and for how much time.
- Allocates the device in the efficient way.
- De-allocates devices.

## File Management

A file system is normally organized into directories for easy navigation and usage. These directories may contain files and other directions.

An Operating System does the following activities for file management –

- Keeps track of information, location, uses, status etc. The collective facilities are often known as **file system**.
- Decides who gets the resources.
- Allocates the resources.
- De-allocates the resources.

## Other Important Activities

Following are some of the important activities that an Operating System performs –

- **Security** – By means of password and similar other techniques, it prevents unauthorized access to programs and data.
- **Control over system performance** – Recording delays between request for a service and response from the system.
- **Job accounting** – Keeping track of time and resources used by various jobs and users.
- **Error detecting aids** – Production of dumps, traces, error messages, and other debugging and error detecting aids.
- **Coordination between other software and users** – Coordination and assignment of compilers, interpreters, assemblers and other software to the various users of the computer systems.

## Types of Operating System

Operating systems are there from the very first computer generation and they keep evolving with time. In this chapter, we will discuss some of the important types of operating systems which are most commonly used.

### Batch operating system

The users of a batch operating system do not interact with the computer directly. Each user prepares his job on an off-line device like punch cards and submits it to the computer operator. To speed up processing, jobs with similar needs are batched together and run as a group. The programmers leave their programs with the operator and the operator then sorts the programs with similar requirements into batches.

The problems with Batch Systems are as follows –

- Lack of interaction between the user and the job.
- CPU is often idle, because the speed of the mechanical I/O devices is slower than the CPU.
- Difficult to provide the desired priority.

### **Time-sharing operating systems**

Time-sharing is a technique which enables many people, located at various terminals, to use a particular computer system at the same time. Time-sharing or multitasking is a logical extension of multiprogramming. Processor's time which is shared among multiple users simultaneously is termed as time-sharing.

The main difference between Multiprogrammed Batch Systems and Time-Sharing Systems is that in case of Multiprogrammed batch systems, the objective is to maximize processor use, whereas in Time-Sharing Systems, the objective is to minimize response time.

Multiple jobs are executed by the CPU by switching between them, but the switches occur so frequently. Thus, the user can receive an immediate response. For example, in a transaction processing, the processor executes each user program in a short burst or quantum of computation. That is, if  $n$  users are present, then each user can get a time quantum. When the user submits the command, the response time is in few seconds at most.

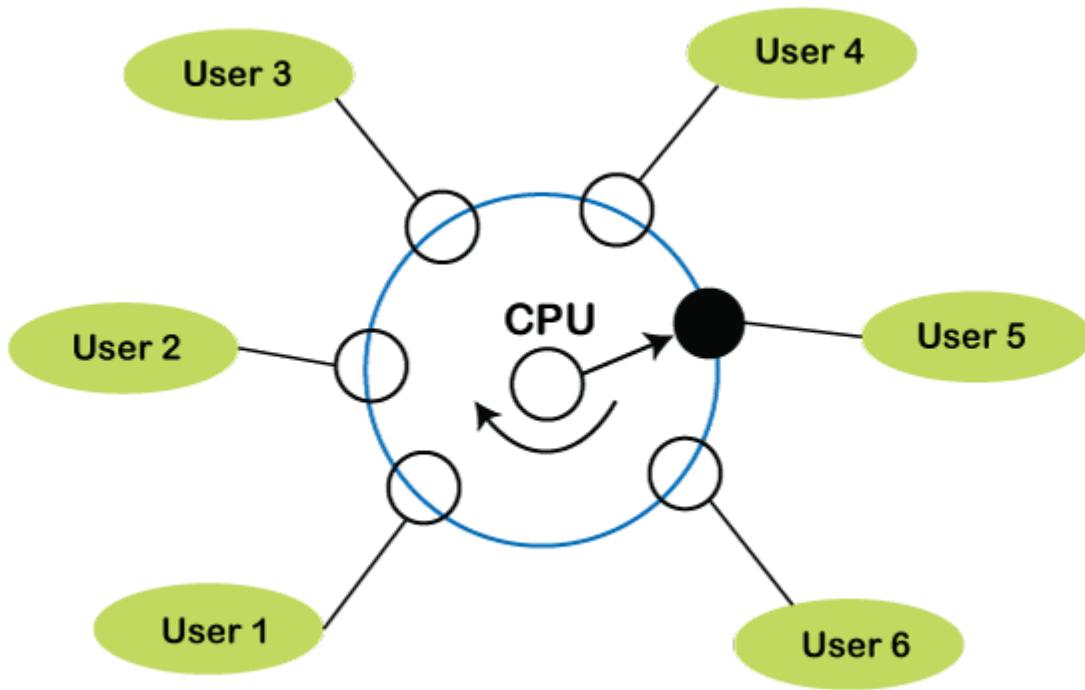
The operating system uses CPU scheduling and multiprogramming to provide each user with a small portion of a time. Computer systems that were designed primarily as batch systems have been modified to time-sharing systems.

Advantages of Timesharing operating systems are as follows –

- Provides the advantage of quick response.
- Avoids duplication of software.
- Reduces CPU idle time.

Disadvantages of Time-sharing operating systems are as follows –

- Problem of reliability.
- Question of security and integrity of user programs and data.
- Problem of data communication.



### Distributed operating System

Distributed systems use multiple central processors to serve multiple real-time applications and multiple users. Data processing jobs are distributed among the processors accordingly.

The processors communicate with one another through various communication lines (such as high-speed buses or telephone lines). These are referred as **loosely coupled systems** or distributed systems. Processors in a distributed system may vary in size and function. These processors are referred as sites, nodes, computers, and so on.

The advantages of distributed systems are as follows –

- With resource sharing facility, a user at one site may be able to use the resources available at another.
- Speedup the exchange of data with one another via electronic mail.
- If one site fails in a distributed system, the remaining sites can potentially continue operating.
- Better service to the customers.
- Reduction of the load on the host computer.
- Reduction of delays in data processing.

### Network operating System

A Network Operating System runs on a server and provides the server the capability to manage data, users, groups, security, applications, and other networking functions. The primary purpose of the network operating system is to allow shared file and printer access among multiple computers in a network, typically a local area network (LAN), a private network or to other networks.

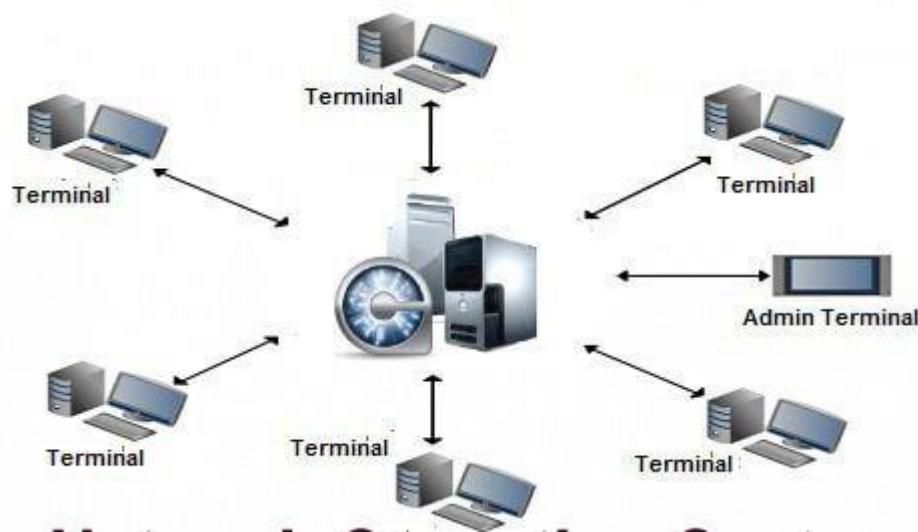
Examples of network operating systems include Microsoft Windows Server 2003, Microsoft Windows Server 2008, UNIX, Linux, Mac OS X, Novell NetWare, and BSD.

The advantages of network operating systems are as follows –

- Centralized servers are highly stable.
- Security is server managed.
- Upgrades to new technologies and hardware can be easily integrated into the system.
- Remote access to servers is possible from different locations and types of systems.

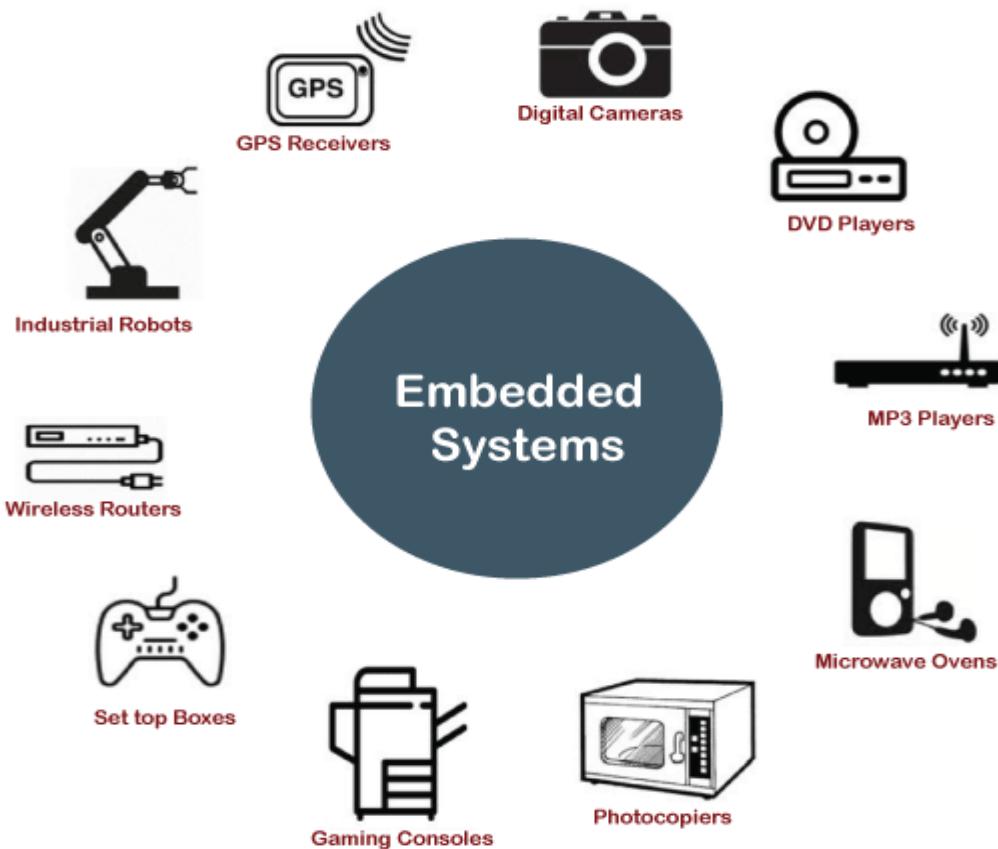
The disadvantages of network operating systems are as follows –

- High cost of buying and running a server.
- Dependency on a central location for most operations.
- Regular maintenance and updates are required.



## Embedded Operating System

The Embedded operating system is the specific purpose operating system used in the computer system's embedded hardware configuration. These operating systems are designed to work on dedicated devices like automated teller machines (ATMs), airplane systems, digital home assistants, and the internet of things (IoT) devices.



## Real Time operating System

A real-time system is defined as a data processing system in which the time interval required to process and respond to inputs is so small that it controls the environment. The time taken by the system to respond to an input and display of required updated information is termed as the **response time**. So in this method, the response time is very less as compared to online processing.

Real-time systems are used when there are rigid time requirements on the operation of a processor or the flow of data and real-time systems can be used as a control device in a dedicated application. A real-time operating system must have well-defined, fixed time constraints, otherwise the system will fail. For example, Scientific experiments, medical imaging systems, industrial control systems, weapon systems, robots, air traffic control systems, etc.

There are two types of real-time operating systems.

### Hard real-time systems

Hard real-time systems guarantee that critical tasks complete on time. In hard real-time systems, secondary storage is limited or missing and the data is stored in ROM. In these systems, virtual memory is almost never found.

### Soft real-time systems

Soft real-time systems are less restrictive. A critical real-time task gets priority over other tasks and retains the priority until it completes. Soft real-time systems have limited utility than hard real-time systems. For example, multimedia, virtual reality, Advanced Scientific Projects like undersea exploration and planetary rovers, etc.

## **Operating System - Services**

An Operating System provides services to both the users and to the programs.

- It provides programs an environment to execute.
- It provides users the services to execute the programs in a convenient manner.

Following are a few common services provided by an operating system –

- Program execution
- I/O operations
- File System manipulation
- Communication
- Error Detection
- Resource Allocation
- Protection

## **Program execution**

Operating systems handle many kinds of activities from user programs to system programs like printer spooler, name servers, file server, etc. Each of these activities is encapsulated as a process.

A process includes the complete execution context (code to execute, data to manipulate, registers, OS resources in use). Following are the major activities of an operating system with respect to program management –

- Loads a program into memory.
- Executes the program.
- Handles program's execution.
- Provides a mechanism for process synchronization.
- Provides a mechanism for process communication.
- Provides a mechanism for deadlock handling.

## **I/O Operation**

An I/O subsystem comprises of I/O devices and their corresponding driver software. Drivers hide the peculiarities of specific hardware devices from the users.

An Operating System manages the communication between user and device drivers.

- I/O operation means read or write operation with any file or any specific I/O device.
- Operating system provides the access to the required I/O device when required.

## **File system manipulation**

A file represents a collection of related information. Computers can store files on the disk (secondary storage), for long-term storage purpose. Examples of storage media include magnetic tape, magnetic disk and optical disk drives like CD, DVD. Each of these media has its own properties like speed, capacity, data transfer rate and data access methods.

A file system is normally organized into directories for easy navigation and usage. These directories may contain files and other directions. Following are the major activities of an operating system with respect to file management –

- Program needs to read a file or write a file.
- The operating system gives the permission to the program for operation on file.
- Permission varies from read-only, read-write, denied and so on.
- Operating System provides an interface to the user to create/delete files.
- Operating System provides an interface to the user to create/delete directories.
- Operating System provides an interface to create the backup of file system.

## **Communication**

In case of distributed systems which are a collection of processors that do not share memory, peripheral devices, or a clock, the operating system manages communications between all the processes. Multiple processes communicate with one another through communication lines in the network.

The OS handles routing and connection strategies, and the problems of contention and security. Following are the major activities of an operating system with respect to communication –

- Two processes often require data to be transferred between them
- Both the processes can be on one computer or on different computers, but are connected through a computer network.
- Communication may be implemented by two methods, either by Shared Memory or by Message Passing.

## **Error handling**

Errors can occur anytime and anywhere. An error may occur in CPU, in I/O devices or in the memory hardware. Following are the major activities of an operating system with respect to error handling –

- The OS constantly checks for possible errors.
- The OS takes an appropriate action to ensure correct and consistent computing.

## **Resource Management**

In case of multi-user or multi-tasking environment, resources such as main memory, CPU cycles and files storage are to be allocated to each user or job. Following are the major activities of an operating system with respect to resource management –

- The OS manages all kinds of resources using schedulers.
- CPU scheduling algorithms are used for better utilization of CPU.

## Protection

Considering a computer system having multiple users and concurrent execution of multiple processes, the various processes must be protected from each other's activities.

Protection refers to a mechanism or a way to control the access of programs, processes, or users to the resources defined by a computer system. Following are the major activities of an operating system with respect to protection –

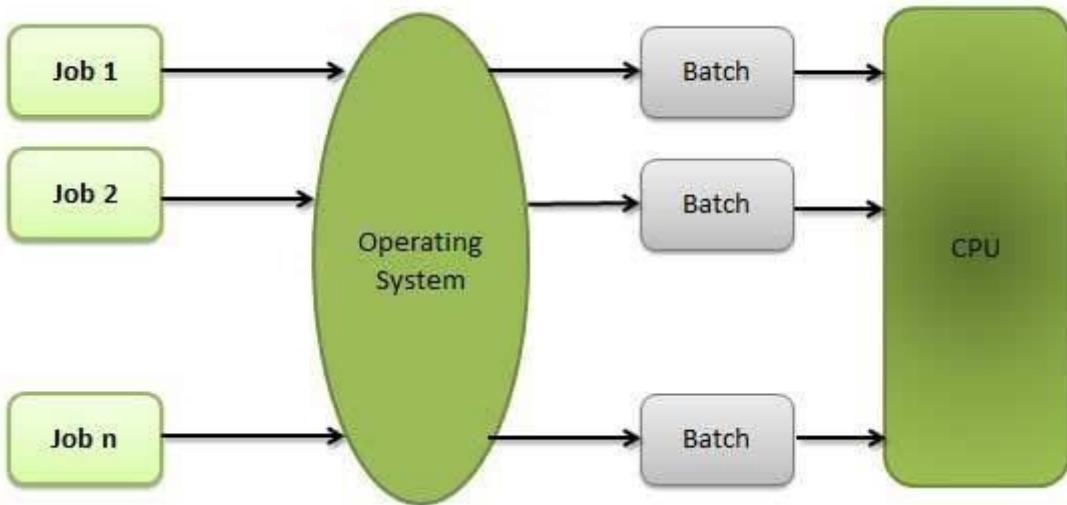
- The OS ensures that all access to system resources is controlled.
- The OS ensures that external I/O devices are protected from invalid access attempts.
- The OS provides authentication features for each user by means of passwords.

## Operating System - Properties

### Batch processing

Batch processing is a technique in which an Operating System collects the programs and data together in a batch before processing starts. An operating system does the following activities related to batch processing –

- The OS defines a job which has predefined sequence of commands, programs and data as a single unit.
- The OS keeps a number of jobs in memory and executes them without any manual intervention.
- Jobs are processed in the order of submission, i.e., first come first served fashion.
- When a job completes its execution, its memory is released and the output for the job gets copied into an output spool for later printing or processing.



### Advantages

- Batch processing takes much of the work of the operator to the computer.
- Increased performance as a new job gets started as soon as the previous job is finished, without any manual intervention.

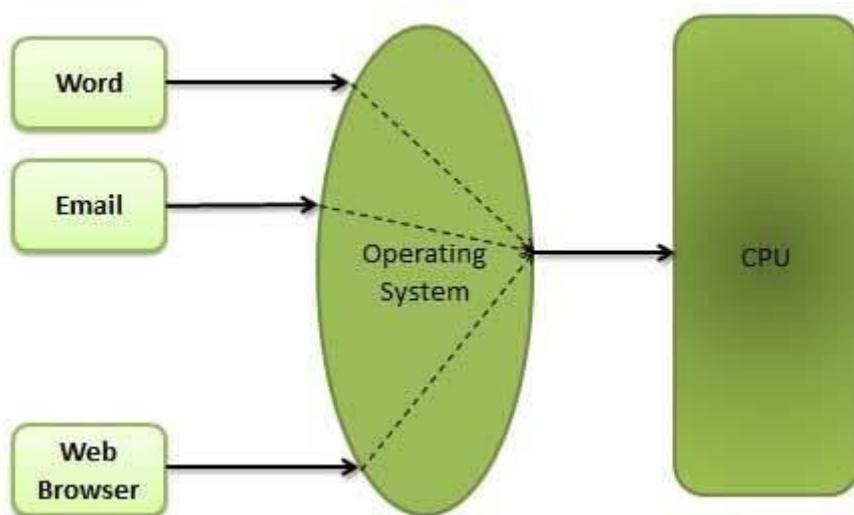
## Disadvantages

- Difficult to debug program.
- A job could enter an infinite loop.
- Due to lack of protection scheme, one batch job can affect pending jobs.

## Multitasking

Multitasking is when multiple jobs are executed by the CPU simultaneously by switching between them. Switches occur so frequently that the users may interact with each program while it is running. An OS does the following activities related to multitasking –

- The user gives instructions to the operating system or to a program directly, and receives an immediate response.
- The OS handles multitasking in the way that it can handle multiple operations/executes multiple programs at a time.
- Multitasking Operating Systems are also known as Time-sharing systems.
- These Operating Systems were developed to provide interactive use of a computer system at a reasonable cost.
- A time-shared operating system uses the concept of CPU scheduling and multiprogramming to provide each user with a small portion of a time-shared CPU.
- Each user has at least one separate program in memory.



- A program that is loaded into memory and is executing is commonly referred to as a **process**.
- When a process executes, it typically executes for only a very short time before it either finishes or needs to perform I/O.

- Since interactive I/O typically runs at slower speeds, it may take a long time to complete. During this time, a CPU can be utilized by another process.
- The operating system allows the users to share the computer simultaneously. Since each action or command in a time-shared system tends to be short, only a little CPU time is needed for each user.
- As the system switches CPU rapidly from one user/program to the next, each user is given the impression that he/she has his/her own CPU, whereas actually one CPU is being shared among many users.

## Multiprogramming

Sharing the processor, when two or more programs reside in memory at the same time, is referred as **multiprogramming**. Multiprogramming assumes a single shared processor. Multiprogramming increases CPU utilization by organizing jobs so that the CPU always has one to execute.

The following figure shows the memory layout for a multiprogramming system.



An OS does the following activities related to multiprogramming.

- The operating system keeps several jobs in 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 jobs in the memory.
- Multiprogramming operating systems monitor the state of all active programs and system resources using memory management programs to ensure that the CPU is never idle, unless there are no jobs to process.

## Advantages

- High and efficient CPU utilization.
- User feels that many programs are allotted CPU almost simultaneously.

## Disadvantages

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

## Interactivity

Interactivity refers to the ability of users to interact with a computer system. An Operating system does the following activities related to interactivity –

- Provides the user an interface to interact with the system.
- Manages input devices to take inputs from the user. For example, keyboard.
- Manages output devices to show outputs to the user. For example, Monitor.

The response time of the OS needs to be short, since the user submits and waits for the result.

## Real Time System

Real-time systems are usually dedicated, embedded systems. An operating system does the following activities related to real-time system activity.

- In such systems, Operating Systems typically read from and react to sensor data.
- The Operating system must guarantee response to events within fixed periods of time to ensure correct performance.

## Distributed Environment

A distributed environment refers to multiple independent CPUs or processors in a computer system. An operating system does the following activities related to distributed environment –

- The OS distributes computation logics among several physical processors.
- The processors do not share memory or a clock. Instead, each processor has its own local memory.
- The OS manages the communications between the processors. They communicate with each other through various communication lines.

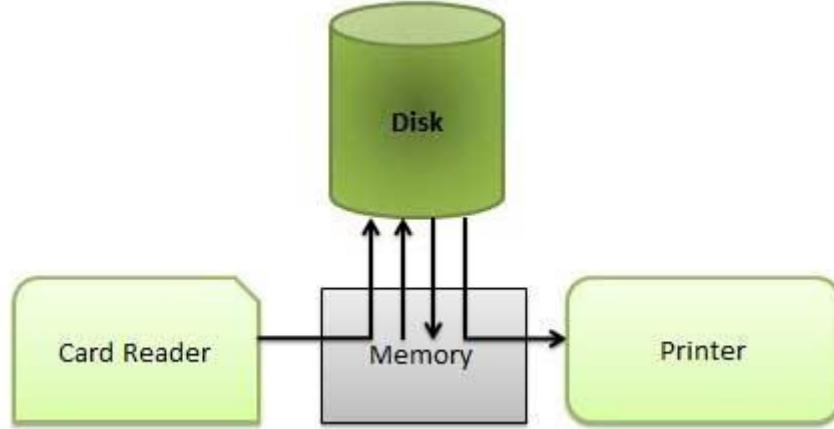
## Spooling

Spooling is an acronym for simultaneous peripheral operations on line. Spooling refers to putting data of various I/O jobs in a buffer. This buffer is a special area in memory or hard disk which is accessible to I/O devices.

An operating system does the following activities related to distributed environment –

- Handles I/O device data spooling as devices have different data access rates.

- Maintains the spooling buffer which provides a waiting station where data can rest while the slower device catches up.
- Maintains parallel computation because of spooling process as a computer can perform I/O in parallel fashion. It becomes possible to have the computer read data from a tape, write data to disk and to write out to a tape printer while it is doing its computing task.

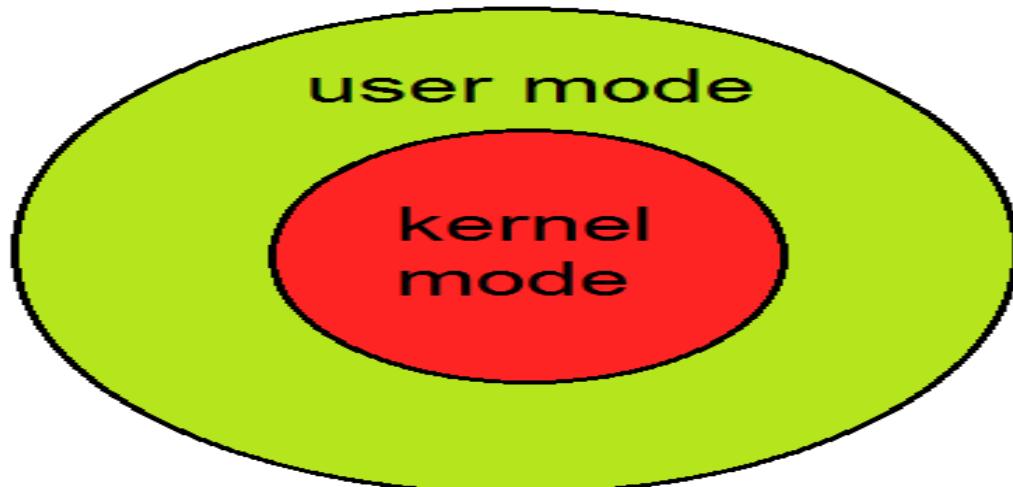


### Advantages

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

### Introduction to System Call

To understand system calls, first one needs to understand the difference between **kernel mode** and **user mode** of a CPU. Every modern operating system supports these two modes.



### Modes supported by the operating system

## Kernel Mode

- When CPU is in **kernel mode**, the code being executed can access any memory address and any hardware resource.
- Hence kernel mode is a very privileged and powerful mode.
- If a program crashes in kernel mode, the entire system will be halted.

## User Mode

- When CPU is in **user mode**, the programs don't have direct access to memory and hardware resources.
- In user mode, if any program crashes, only that particular program is halted.
- That means the system will be in a safe state even if a program in user mode crashes.
- Hence, most programs in an OS run in user mode.

## System Call

In computing, a **system call** is the programmatic way in which a computer program requests a service from the kernel of the operating system it is executed on. A system call is a way for programs to **interact with the operating system**. A computer program makes a system call when it makes a request to the operating system's kernel. System call **provides** the services of the operating system to the user programs via Application Program Interface (API). It provides an interface between a process and operating system to allow user-level processes to request services of the operating system. System calls are the only entry points into the kernel system. All programs needing resources must use system calls.

### Services Provided by System Calls:

1. Process creation and management
2. Main memory management
3. File Access, Directory and File system management
4. Device handling(I/O)
5. Protection
6. Networking, etc.

### Types of System Calls:

There are 5 different categories of system calls –

1. **Process control:** end, abort, create, terminate, allocate and free memory.
2. **File management:** create, open, close, delete, read file etc.
3. Device management
4. Information maintenance
5. Communication

In another word, when a program in user mode requires access to RAM or a hardware resource, it must ask the kernel to provide access to that resource. This is done via something called a **system call**.

When a program makes a system call, the mode is switched from user mode to kernel mode. This is called a **context switch**.

Then the kernel provides the resource which the program requested. After that, another context switch happens which results in change of mode from kernel mode back to user mode.

Generally, system calls are made by the user level programs in the following situations:

- Creating, opening, closing and deleting files in the file system.
- Creating and managing new processes.
- Creating a connection in the network, sending and receiving packets.
- Requesting access to a hardware device, like a mouse or a printer.

In a typical UNIX system, there are around 300 system calls. Some of them which are important ones in this context, are described below.

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

## **What Does Shell Mean?**

A shell is software that provides an interface for an operating system's users to provide access to the kernel's services.

On Unix-based or Linux-based operating systems, a shell can be invoked through the shell command in the command line interface (CLI), allowing users to direct operations through computer commands, text or script.

Shells also exist for programming languages, providing them with autonomy from the operating system and allowing cross-platform compatibility.

Shell is a UNIX term for the interactive user interface with an operating system. The shell is the layer of programming that understands and executes the commands a user enters. In some systems, the shell is called a command interpreter. A shell usually implies an interface with a command syntax (think of the DOS operating system and its "C:>" prompts and user commands such as "dir" and "edit").

As the outer layer of an operating system, a shell can be contrasted with the kernel, the operating system's inmost layer or core of services.

## **Open-Source Operating System**

Open source is a term that originally referred to open-source software (OSS). Open-source software is code that is designed to be publicly accessible—anyone can see, modify, and distribute the code as they see fit.

A software for which the original source code is made freely available and may be redistributed and modified according to the requirement of the user. Open-source software is that by which the source code or the base code is usually available for modification or enhancement by anyone for reusability and accessibility. Open-source code is the part of software that mostly users don't ever see. Anyone can manipulate and change a piece of software so that the program or application can work. Programmers who have access to a computer program source code can improve a program by adding features to it or fixing parts that don't always work correctly.

There are two kinds of software. One is open-source software and the other is proprietary software or closed source software. As the source code of an open-source program can be

modified by anyone without any licence to do the same, this is also free to download. The terms of use are often defined by the General Public Licence, which serves as the Software Licence Agreement (SLA) for many open-source programs. Many people prefer open-source software because they are interested in more control over these kinds of software. They can examine the code to make sure it's not doing anything they don't want it to do, and they can only change parts of it they don't like to do. Generic users who aren't programmers also took benefit from open-source software, because they can use this kind of software for any purpose without any prior notice to the proprietor as they wish—not merely the way someone else thinks they should. This is a common misconception about what open source implies. Generally, programmers can't charge money for the open-source software they create or to which they contribute. Many open-source software programmers find that charging users money for software services and support rather than for the software itself is more profitable. This way, their software remains free of charge and they make money by helping others to install, use and troubleshoot it.

Open-source software is developed in a decentralized and collaborative way, relying on peer review and community production. Open-source software is often cheaper, more flexible, and has more longevity than its proprietary peers because it is developed by communities rather than a single author or company.

Open source has become a movement and a way of working that reaches beyond software production. The open-source movement uses the values and decentralized production model of open-source software to find new ways to solve problems in their communities and industries.