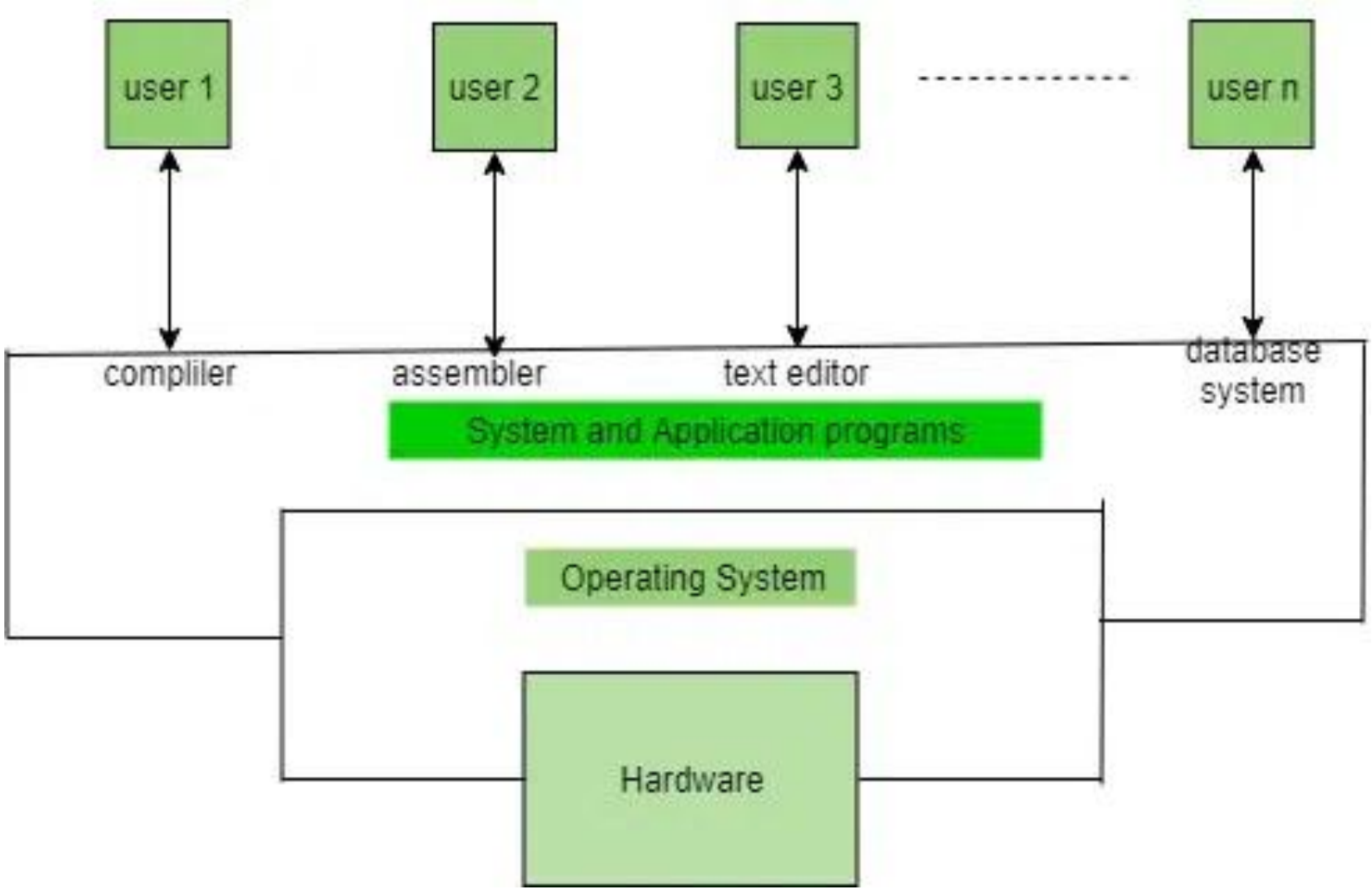
Operating System

UNIT-1

Operating System

- **Operating System** lies in the category of system software. It basically manages all the resources of the computer.
- An operating system acts as an interface between the software and different parts of the computer or the computer hardware.
- The operating system is designed in such a way that it can manage the overall resources and operations of the computer.
- Examples of Operating Systems are Windows, Linux, Mac OS, etc.


user 1
user 2
user 3
user n
compliler
assembler
text editor
database system
System and Application programs
Operating System
Hardware

Functions of the Operating System

- **Resource Management:** The operating system manages and allocates memory, CPU time, and other hardware resources among the various programs and processes running on the computer.
- **Process Management:** The operating system is responsible for starting, stopping, and managing processes and programs. It also controls the scheduling of processes and allocates resources to them.
- **Memory Management:** The operating system manages the computer's primary memory and provides mechanisms for optimizing memory usage.
- **Security:** The operating system provides a secure environment for the user, applications, and data by implementing security policies and mechanisms such as access controls and encryption.

Functions of OS (contd…)

- **Job Accounting:** It keeps track of time and resources used by various jobs or users.
- **File Management:** The operating system is responsible for organizing and managing the file system, including the creation, deletion, and manipulation of files and directories.
- **Device Management:** The operating system manages input/output devices such as printers, keyboards, mice, and displays. It provides the necessary drivers and interfaces to enable communication between the devices and the computer.
- **Networking:** The operating system provides networking capabilities such as establishing and managing network connections, handling network protocols, and sharing resources such as printers and files over a network.

Functions of OS (contd…)

- **User Interface**: The operating system provides a user interface that enables users to interact with the computer system. This can be a Graphical User Interface (GUI), a Command-Line Interface (CLI), or a combination of both.
- **Backup and Recovery:** The operating system provides mechanisms for backing up data and recovering it in case of system failures, errors, or disasters.
- **Virtualization:** The operating system provides virtualization capabilities that allow multiple operating systems or applications to run on a single physical machine. This can enable efficient use of resources and flexibility in managing workloads.
- **Performance Monitoring:** The operating system provides tools for monitoring and optimizing system performance, including identifying bottlenecks, optimizing resource usage, and analyzing system logs and metrics.

Functions of OS (contd…)

- **Time-Sharing:** The operating system enables multiple users to share a computer system and its resources simultaneously by providing time-sharing mechanisms that allocate resources fairly and efficiently.
- **System Calls:** The operating system provides a set of system calls that enable applications to interact with the operating system and access its resources. System calls provide a standardized interface between applications and the operating system, enabling portability and compatibility across different hardware and software platforms.
- **Error-detecting Aids:** These contain methods that include the production of dumps, traces, error messages, and other debugging and error-detecting methods.

Objectives of Operating Systems

- **Convenient to use:** One of the objectives is to make the computer system more convenient to use in an efficient manner.
- **User Friendly:** To make the computer system more interactive with a more convenient interface for the users.
- **Easy Access:** To provide easy access to users for using resources by acting as an intermediary between the hardware and its users**.**

Objectives of OS (Contd…)

- **Management of Resources:** For managing the resources of a computer in a better and faster way.
- **Controls and Monitoring:** By keeping track of who is using which resource, granting resource requests, and mediating conflicting requests from different programs and users.
- **Fair Sharing of Resources:** Providing efficient and fair sharing of resources between the users and programs.

Types of Operating Systems

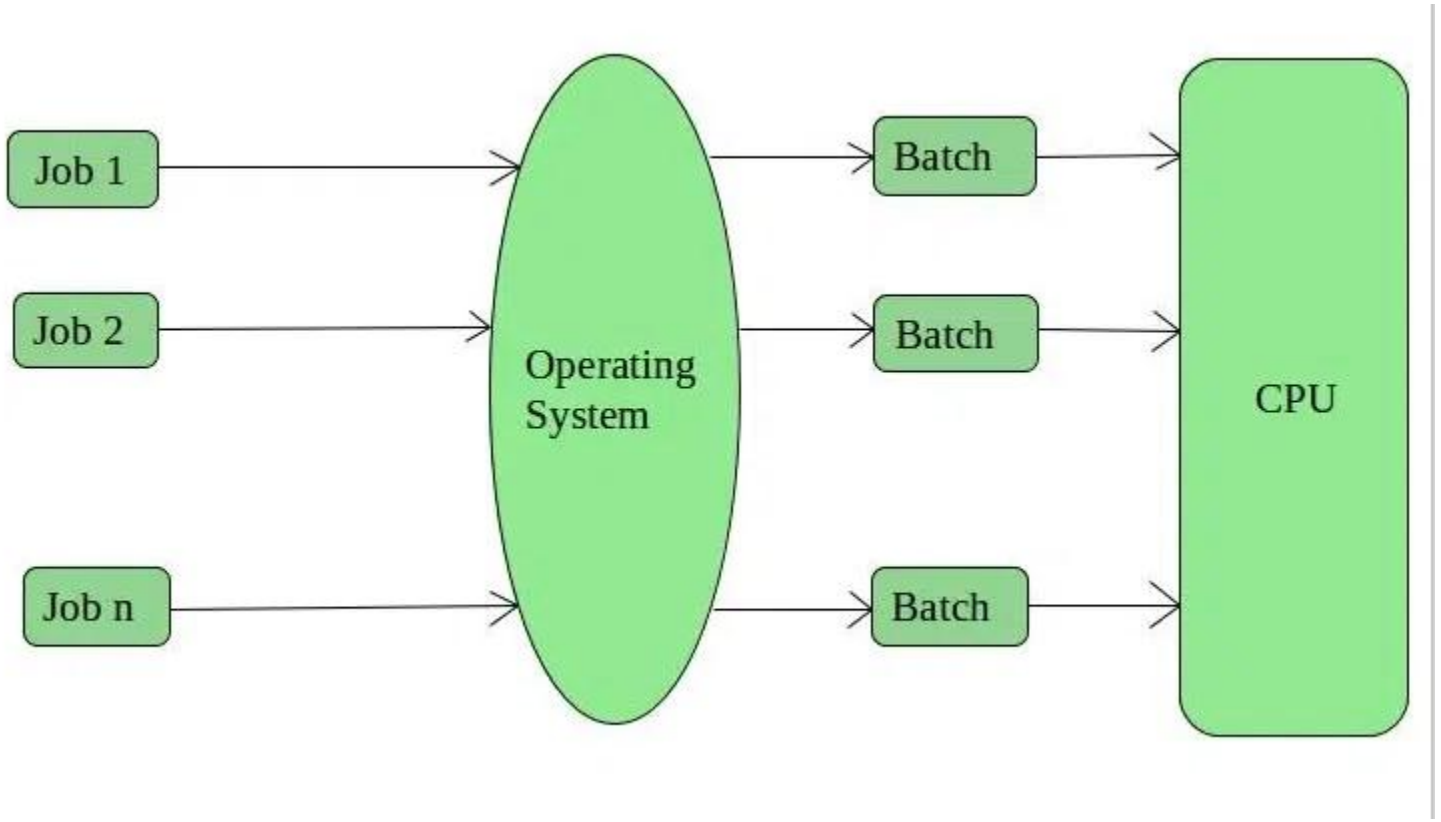
- There are several types of Operating Systems which are mentioned below.

  - ❑ Batch Operating System
  - ❑ Multi-Programming System
  - ❑ Multi-Processing System
  - ❑ Multi-Tasking Operating System
  - ❑ Time-Sharing Operating System
  - ❑ Distributed Operating System
  - ❑ Real-Time Operating System

1. Batch Operating System

- This type of operating system does not interact with the computer directly. There is an operator which takes similar jobs having the same requirement and groups them into batches. It is the responsibility of the operator to sort jobs with similar needs.
- **Examples of Batch Operating Systems:** Payroll Systems, Bank Statements, etc.

Batch Operating System



Advantages of Batch Operating System

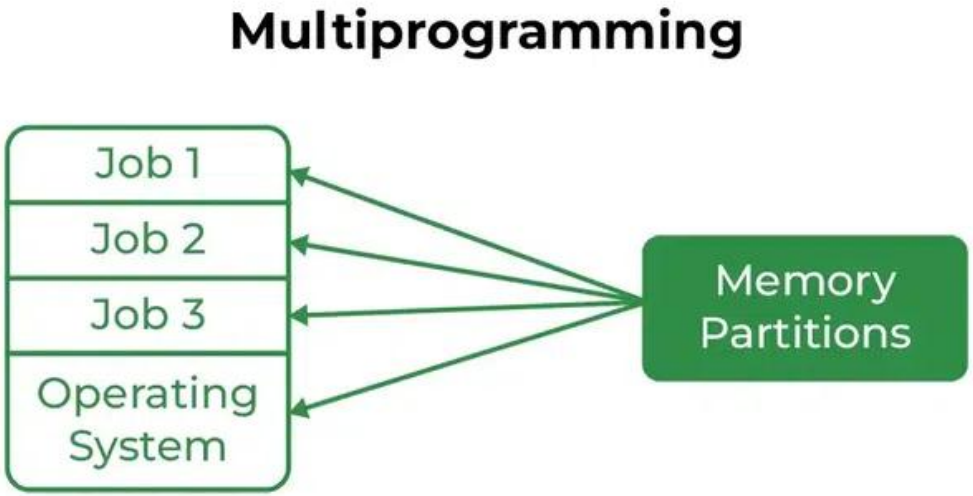
- It is very difficult to guess or know the time required for any job to complete. Processors of the batch systems know how long the job would be when it is in the queue.
- Multiple users can share the batch systems.
- The idle time for the batch system is very less.
- It is easy to manage large work repeatedly in batch systems.

Disadvantages of Batch Operating System

- The computer operators should be well known with batch systems.
- Batch systems are hard to debug.
- It is sometimes costly.
- The other jobs will have to wait for an unknown time if any job fails.

2. Multi-Programming Operating System

- It can be defined as more than one program is present in the main memory and any one of them can be kept in execution. This is basically used for better execution of resources.



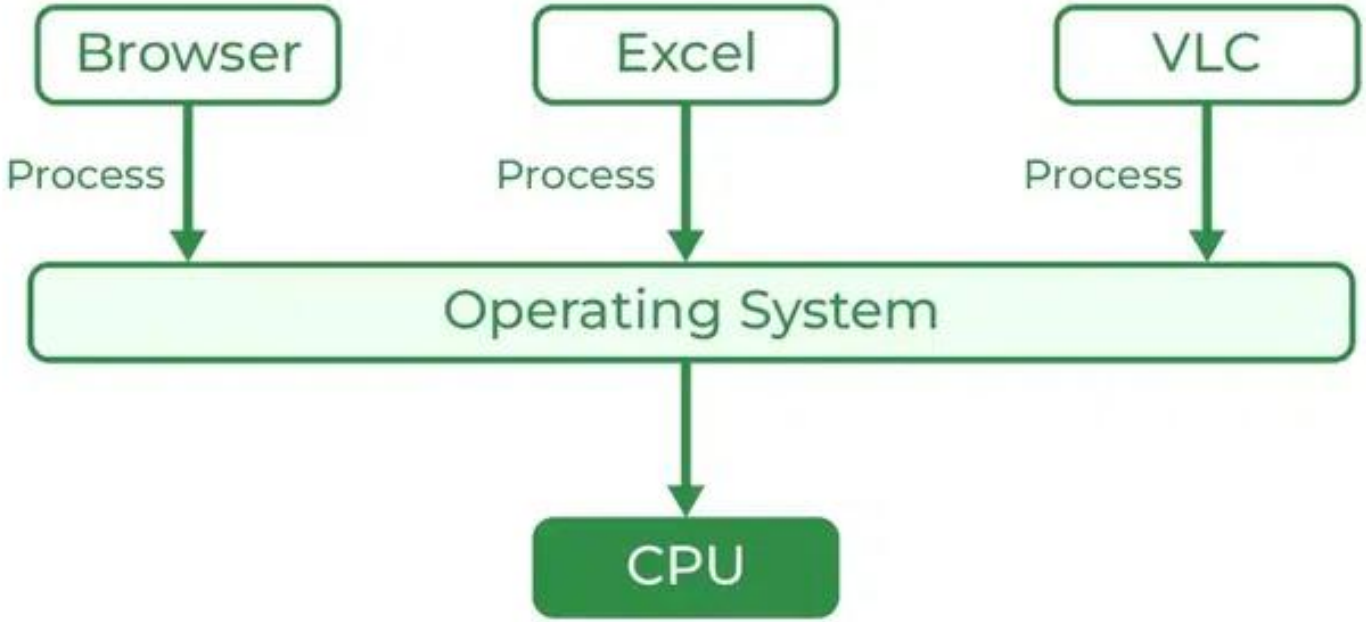
Multi-Programming Operating System

- **Advantages of Multi-Programming Operating System**
  - Multi Programming increases the Throughput of the System.
  - It helps in reducing the response time.
- **Disadvantages of Multi-Programming Operating System**
  - There is not any facility for user interaction of system resources with the system.

4. Multi-Tasking Operating System

- Multitasking Operating System is simply a multiprogramming Operating System with having facility of a Round-Robin Scheduling Algorithm. It can run multiple programs simultaneously.
- There are two types of Multi-Tasking Systems which are listed below.
- Preemptive Multi-Tasking
- Cooperative Multi-Tasking

Multitasking

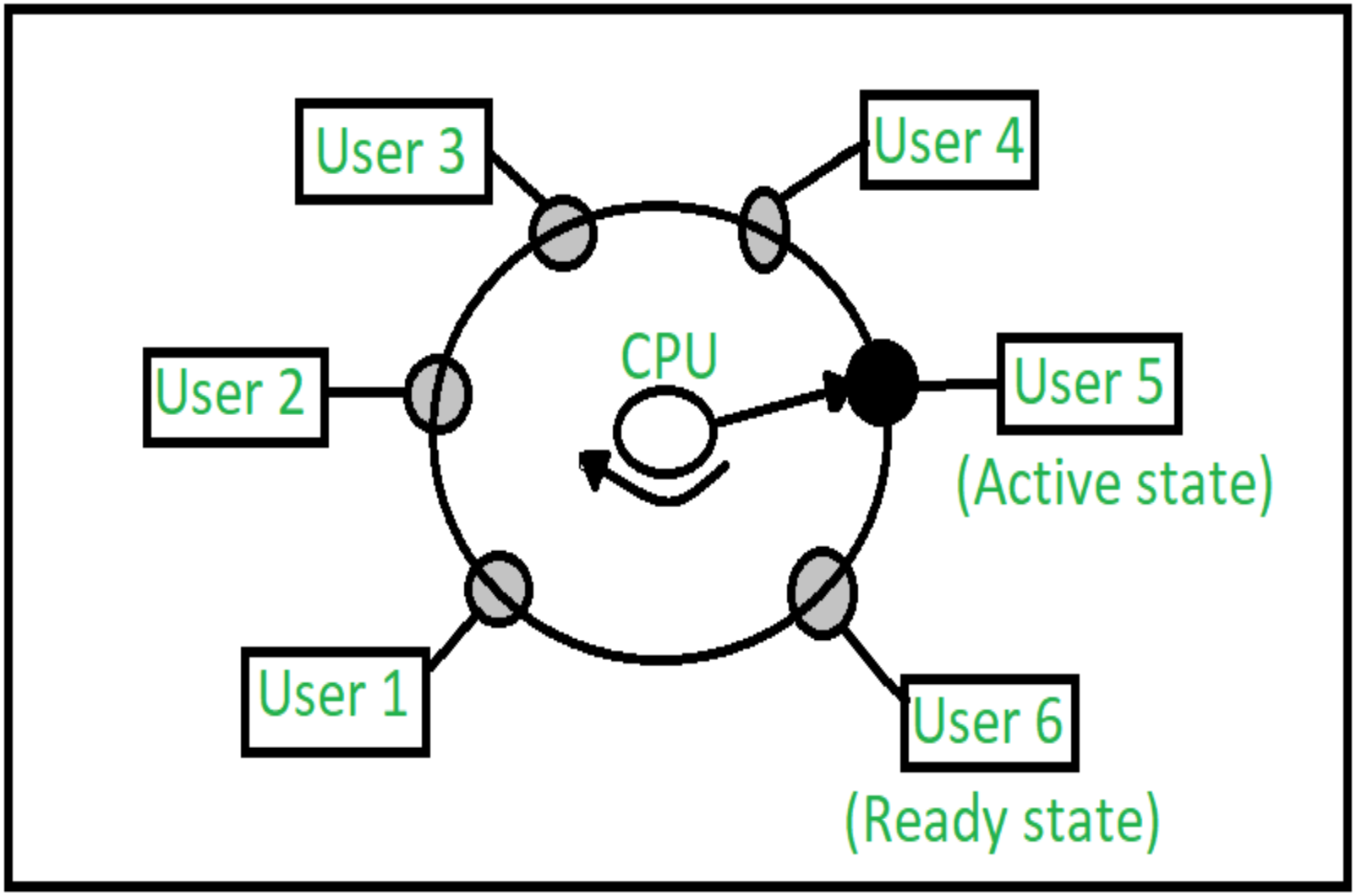


Multi-Tasking Operating System

- **Advantages of Multi-Tasking Operating System**
  - Multiple Programs can be executed simultaneously in Multi-Tasking Operating System.
  - It comes with proper memory management.
- **Disadvantages of Multi-Tasking Operating System**
  - The system gets heated in case of heavy programs multiple times.

5. Time-Sharing Operating Systems

- Each task is given some time to execute so that all the tasks work smoothly.
- Each user gets the time of the CPU as they use a single system. These systems are also known as Multitasking Systems.
- The task can be from a single user or different users also. The time that each task gets to execute is called quantum. After this time interval is over OS switches over to the next task.


User 3
User 4
CPU
User 2
User 5
(Active state)
User 1
User 6
(Ready state)

Advantages of Time-Sharing OS

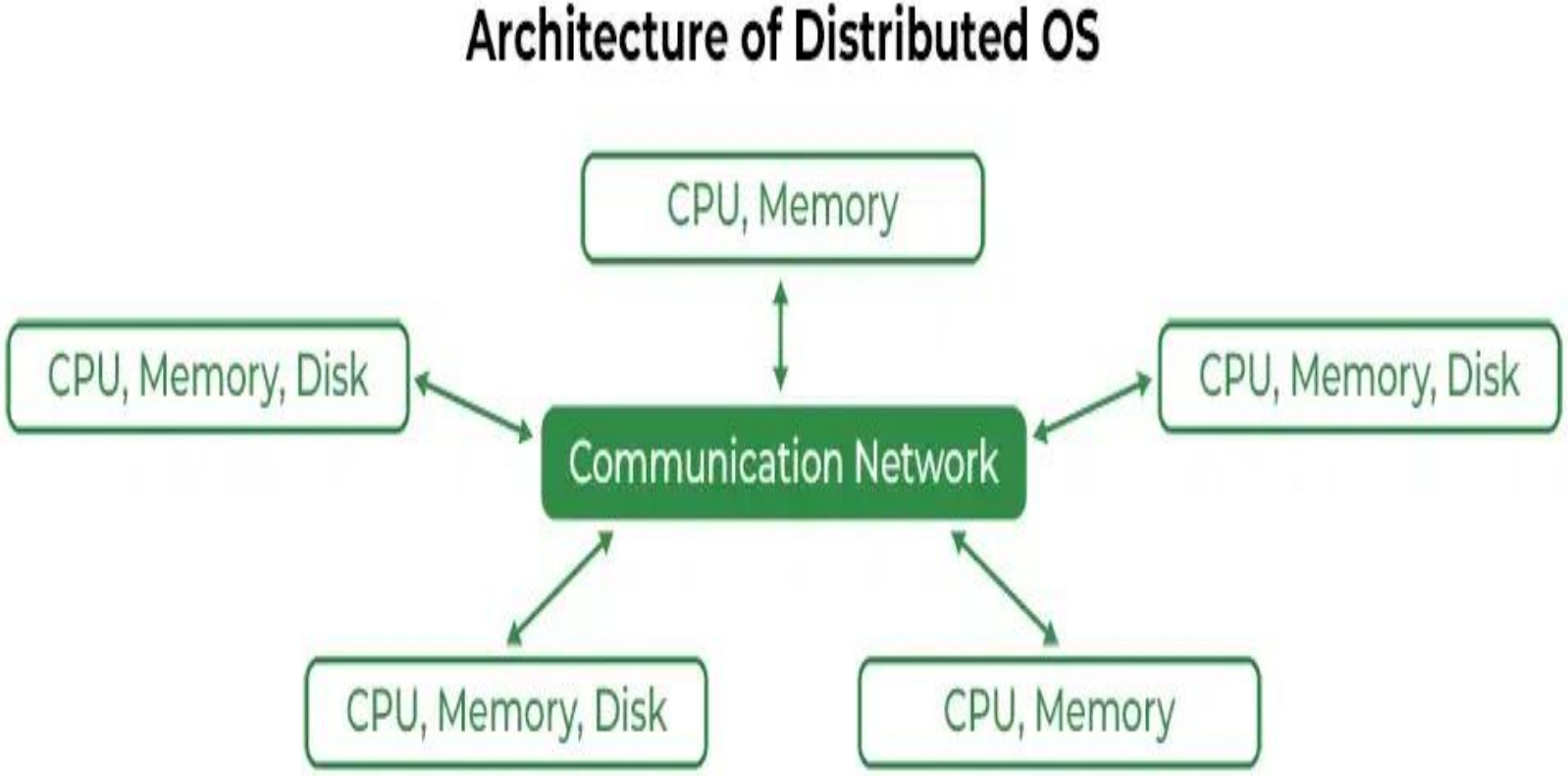
- Each task gets an equal opportunity.
- Fewer chances of duplication of software.
- CPU idle time can be reduced.
- Resource Sharing: Time-sharing systems allow multiple users to share hardware resources such as the CPU, memory, and peripherals, reducing the cost of hardware and increasing efficiency.
- Improved Productivity: Time-sharing allows users to work concurrently, thereby reducing the waiting time for their turn to use the computer. This increased productivity translates to more work getting done in less time.
- Improved User Experience: Time-sharing provides an interactive environment that allows users to communicate with the computer in real time, providing a better user experience than batch processing.

Disadvantages of Time-Sharing OS

- Reliability problem.
- One must have to take care of the security and integrity of user programs and data.
- Data communication problem.
- High Overhead: Time-sharing systems have a higher overhead than other operating systems due to the need for scheduling, context switching, and other overheads that come with supporting multiple users.
- Complexity: Time-sharing systems are complex and require advanced software to manage multiple users simultaneously. This complexity increases the chance of bugs and errors.
- Security Risks: With multiple users sharing resources, the risk of security breaches increases. Time-sharing systems require careful management of user access, authentication, and authorization to ensure the security of data and software.

6. Distributed Operating System

- These types of operating system is a recent advancement in the world of computer technology and are being widely accepted all over the world and, that too, at a great pace.
- Various autonomous interconnected computers communicate with each other using a shared communication network.
- Independent systems possess their own memory unit and CPU. These are referred to as loosely coupled systems or distributed systems. These systems' processors differ in size and function.
- The major benefit of working with these types of the operating system is that it is always possible that one user can access the files or software which are not actually present on his system but some other system connected within this network i.e., remote access is enabled within the devices connected in that network.



Distributed OS

Advantages of Distributed Operating System

- Failure of one will not affect the other network communication, as all systems are independent of each other.
- Electronic mail increases the data exchange speed.
- Since resources are being shared, computation is highly fast and durable.
- Load on host computer reduces.
- These systems are easily scalable as many systems can be easily added to the network.
- Delay in data processing reduces.

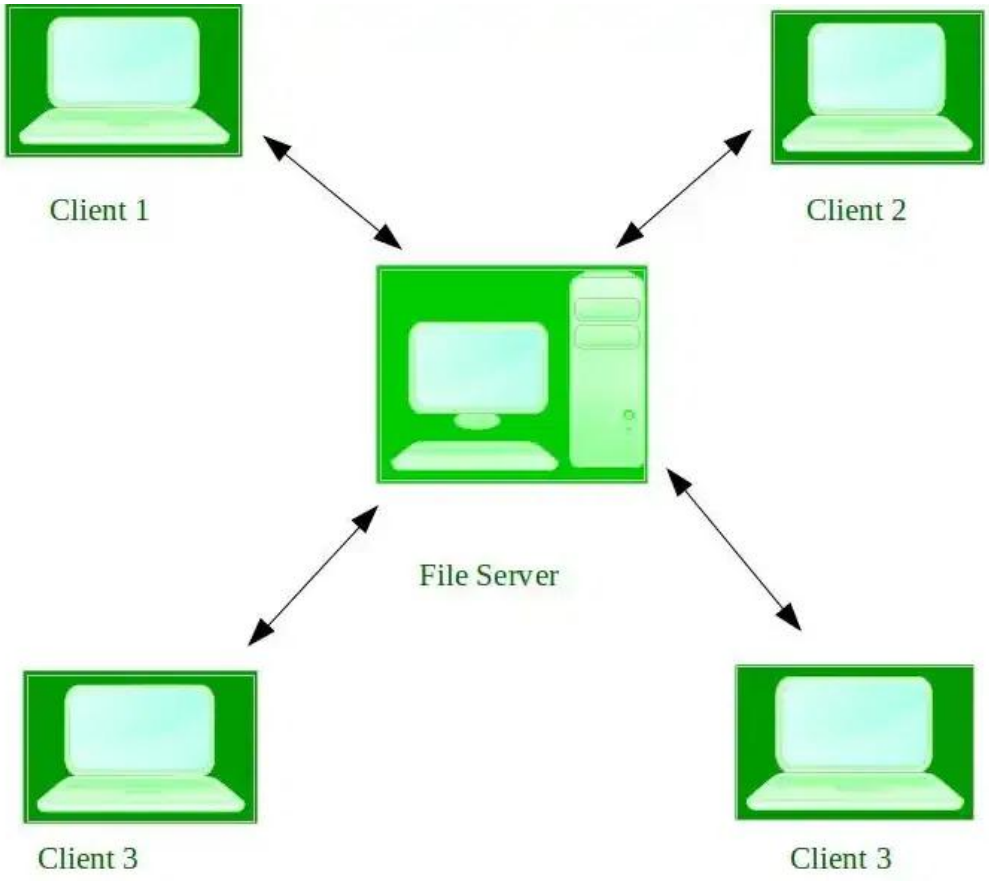
Disadvantages of Distributed Operating System

- Failure of the main network will stop the entire communication.
- To establish distributed systems the language is used not well-defined yet.
- These types of systems are not readily available as they are very expensive. Not only that the underlying software is highly complex and not understood well yet.

7. Network Operating System

- These systems run on a server and provide the capability to manage data, users, groups, security, applications, and other networking functions.
- These types of operating systems allow shared access to files, printers, security, applications, and other networking functions over a small private network.
- One more important aspect of Network Operating Systems is that all the users are well aware of the underlying configuration, of all other users within the network, their individual connections, etc. and that's why these computers are popularly known as tightly coupled systems.

Examples of Network Operating Systems are Microsoft Windows Server 2003, Microsoft Windows Server 2008, UNIX, Linux, Mac OS X, Novell NetWare, BSD, etc.



- **Advantages of Network Operating System**
  - Highly stable centralized servers.
  - Security concerns are handled through servers.
  - New technologies and hardware up-gradation are easily integrated into the system.
  - Server access is possible remotely from different locations and types of systems.
- **Disadvantages of Network Operating System**
  - Servers are costly.
  - User has to depend on a central location for most operations.
  - Maintenance and updates are required regularly.

8. Real-Time Operating System

- These types of OSs serve real-time systems. The time interval required to process and respond to inputs is very small. This time interval is called **response time**.
- **Real-time systems** are used when there are time requirements that are very strict like missile systems, air traffic control systems, robots, etc.

Types of Real-Time Operating Systems

- **Hard Real-Time Systems:**
  Hard Real-Time OSs are meant for applications where time constraints are very strict and even the shortest possible delay is not acceptable. These systems are built for saving life like automatic parachutes or airbags which are required to be readily available in case of an accident. Virtual memory is rarely found in these systems.
- **Soft Real-Time Systems:**
  These OSs are for applications where time-constraint is less strict.

Real-Time Operating System

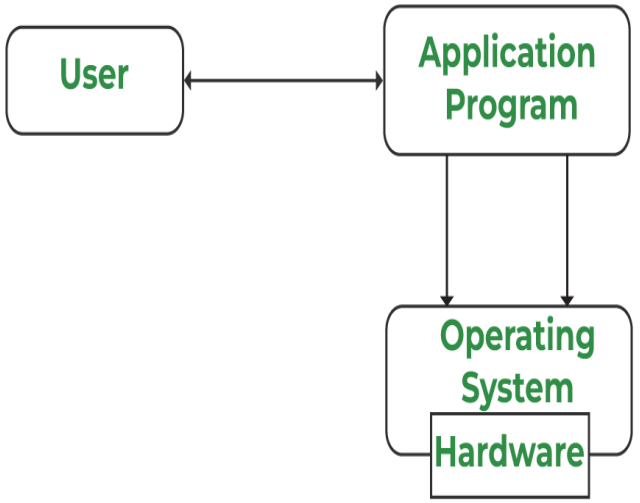
- **Examples of Real-Time Operating Systems are** Scientific experiments, medical imaging systems, industrial control systems, weapon systems, robots, air traffic control systems, etc.

Single user System

- A single user can access the computer at a particular time.
- The single-user operating system allows permission to access your personal computer at a time by a single user, but sometimes it can support multiple profiles.
- It can also be used in official work and other environments as well.

Single user

- **Advantages:**
  - This OS occupies less space in memory.
  - Easy to maintain.
  - Less chance of damage.
  - This is a single-user interface it allows only one user's tasks to execute in a given time.
  - In this operating system only one user work at a time, so there will be no interruption of others.



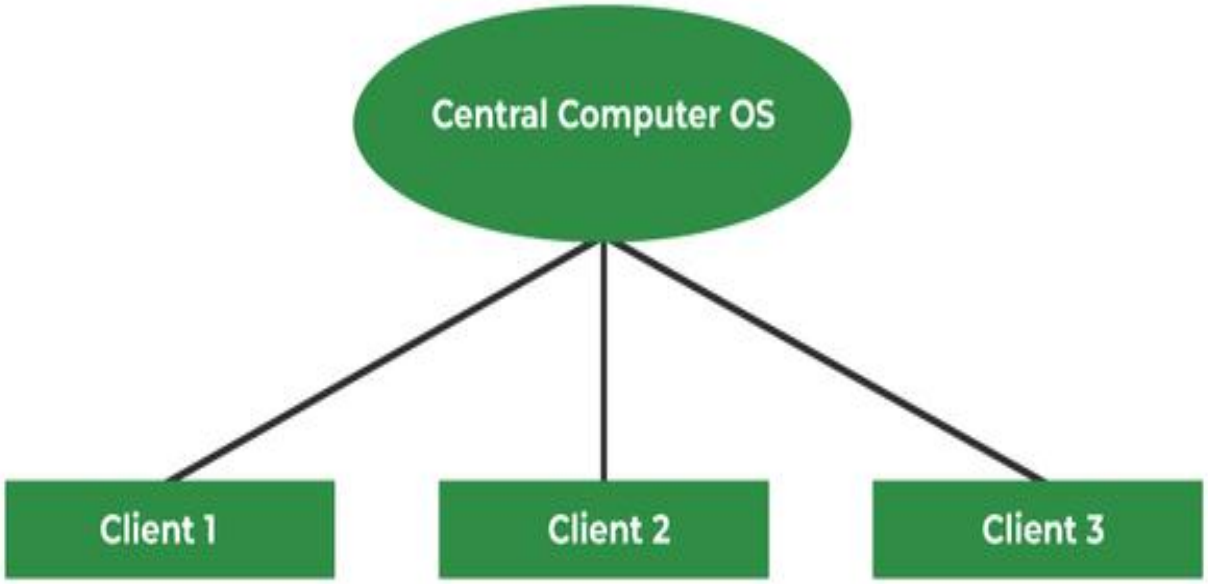
Single-user operating system

Single user System

- **Disadvantages:**
  - It can perform only a single task.
  - The main drawback is, the OS remains idle for most of the time and is not utilized to its maximum.
  - Tasks take longer to complete.
  - It has a high response time.

Multiuser Systems

- In a multiuser operating system, multiple numbers of users can access different resources of a computer at the same time.
- The access is provided using a network that consists of various personal computers attached to a mainframe computer system.
- A multi-user operating system allows the permission of multiple users for accessing a single machine at a time.
- The various personal computers can send and receive information to the mainframe computer system. Thus, the mainframe computer acts as the server and other personal computers act as clients for that server.



Multi-user Operating system

Components of the multi-user operating system

1. Memory: Consists of main memory (RAM). Main memory is determined as an important part of the operating system because it specifies how many programs may be executed simultaneously. The system can correct data that is present in the main memory, therefore every program that is executed must be copied from physical storage.
The types of physical storage:

- **Hard disk:** Hard disk can hold a huge amount of data and also determines how many programs can be run at a single time.
- **Floppy disk:** It is more inexpensive, but it is potable
- **Optical disks:** They use a laser to read and write data. They can hold large data and portable
- **Tapes:** They are expensive but they can hold a huge amount of data.

Components of the multi-user operating system

2. Kernel: This component is embedded in the computer system's main memory and may interact directly with the system's hardware. The multi-user operating system uses the kernel component at a low level, it is written in a low-level language.

3. Processor: The core of the computer is called the central processing unit (CPU).

4. Device handler: The device handler's primary goal is to provide all requests from the whole device request queue. The device handler operates in continuous cycle mode, first discarding the I/O request block from the queue side. The concept that is behind the handler is a queue where we follow the first in first out (FIFO) principle.

Components of the multi-user operating system

5. Spooler: Simultaneously peripheral output on line. The spooler runs all computer processes and outputs the results at the same time.

6. User interface: Create a simple environment for all users for using the computer system. It is the point of communication between users and hardware (or) software. The main frame is one of the systems which works on the concepts of multi-user programming concept. It is widely used in banks, to store bank account and transaction details. This mainframe helps in various ways: security and scalability.

Types of Multi-user Operating Systems

- The multi-user operating systems is of the following types:
- Distributed System
- Time sliced system
- Multiprocessor system

Distributed system

- The distributed operating system also known as distributed computing is a collection of multiple computers located on different computers. Communicate and coordinate their actions by passing messages to one another from any system.
- These all systems emulate a single coherent system to the end user. The end user will communicate with them with the help of the network. This system is divided in a way that multiple requests can be handled and in turn, the individual request can be satisfied eventually.
- **Examples:** Electronic banking, Mobile apps.

Time-sliced system

- It is the system where each user talk is allocated to a short span of CPU time. A small time duration is allotted to every task.
- CPU time is divided into small time slices, and one time is assigned to each other. The decision to run the next piece of the job is decided by the schedule. This schedule executes the run instructions that need to be executed. The user can take turns and thus the operating system will handle the user's request among the users who are connected. This feature is not applicable in the single-user operating system. They use the mainframe system concurrently
- **Example:** Mainframe, a partial exam of the time-sliced system.

Multi-processor system

- It involves multiple processors at a time. Enhance the overall performance. If one processor fails other continues working.
- **Example:** Spreadsheets, Music player

- **Features:** The multi-user operating system has the following features:
  - **Resource sharing:** This maps to time slicing, multiple peripherals such as printers can be shared different files or data.
  - Time-sharing
  - Background sharing
  - **Invisibility:** Many functions of multi-user operating systems are invisible to the user.

Advantages of Multiuser System

- It helps in the sharing of data and information among different users.
- It also helps in the sharing of hardware resources such as printers.
- It avoids disruption if any one computer fails it does not affect any other computer present on that network.
- Users can share their work with other users.
- The multi-user operating system is very helpful in economic improvement.
- Backing up data can be done in the multi-user operating system.
- The services of the multi-user operating systems are very stable and systematic.

Disadvantages of Multiuser System

- It requires expensive hardware to set up a mainframe computer
- When multiple users log on or work on the same system it reduces the overall performance of the system.
- Information is shared with the public so privacy becomes a concern here.

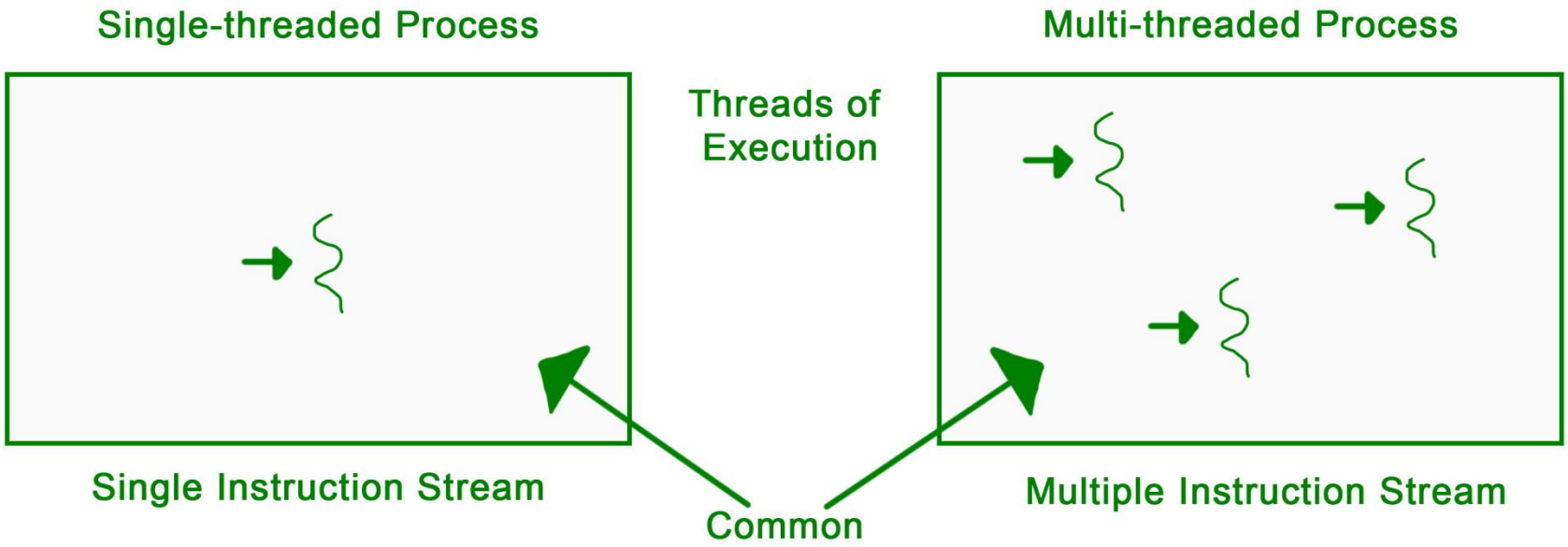
Multithreading in Operating System

- A **thread** is a path which is followed during a program's execution. Majority of programs written now a days run as a single thread.
- For example a program is not capable of reading keystrokes while making drawings. These tasks cannot be executed by the program at the same time. This problem can be solved through multitasking so that two or more tasks can be executed simultaneously.
- Multitasking is of two types:
  - Processor based and
  - thread based.
- Processor based multitasking is totally managed by the OS, however multitasking through multithreading can be controlled by the programmer to some extent. The concept of **multi-threading** needs proper understanding of these two terms – **a process and a thread**.

- A process is a program being executed.
- A process can be further divided into independent units known as threads.
- A thread is like a small light-weight process within a process.

Or

- We can say a collection of threads is what is known as a process.



Single Thread and Multi Thread Process

Lifecycle of a thread

There are various stages in the lifecycle of a thread. Following are the stages a thread goes through in its whole life.

- **New:** The lifecycle of a born thread (new thread) starts in this state. It remains in this state till a program starts.
- **Runnable**: A thread becomes runnable after it starts. It is considered to be executing the task given to it.
- **Waiting**: While waiting for another thread to perform a task, the currently running thread goes into the waiting state and then transitions back again after receiving a signal from the other thread.
- **Timed Waiting:** A runnable thread enters into this state for a specific time interval and then transitions back when the time interval expires or the event the thread was waiting for occurs.
- **Terminated (Dead)**: A thread enters into this state after completing its task.

Types of execution in OS

There are two types of execution:

- **Concurrent Execution:** This occurs when a processor is successful in switching resources between threads in a multithreaded process on a single processor.
- **Parallel Execution:** This occurs when every thread in the process runs on a separate processor at the same time and in the same multithreaded process

Operating System Structure

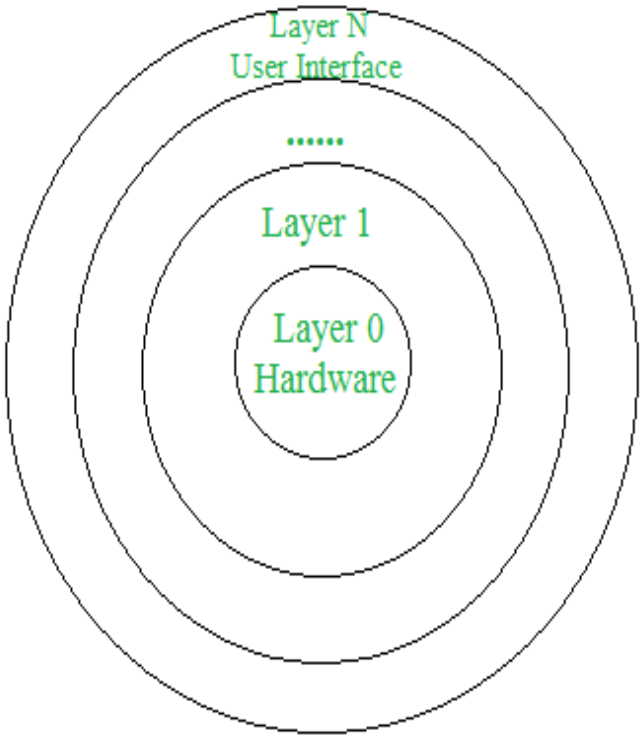
- **Layered structure**
  - An OS can be broken into pieces and retain much more control over the system. In this structure, the OS is broken into a number of layers (levels).
  - The bottom layer (layer 0) is the hardware, and the topmost layer (layer N) is the user interface. These layers are so designed that each layer uses the functions of the lower-level layers. This simplifies the debugging process, if lower-level layers are debugged and an error occurs during debugging, then the error must be on that layer only, as the lower-level layers have already been debugged.

Layered Structure

- The main disadvantage of this structure is that at each layer, the data needs to be modified and passed on which adds overhead to the system.
- UNIX is an example of this structure.

Layered Structure

- **Advantages of Layered structure**
  - Layering makes it easier to enhance the operating system, as the implementation of a layer can be changed easily without affecting the other layers.
  - It is very easy to perform debugging and system verification.



Layered Structure

- **Disadvantages of Layered structure**
  - In this structure, the application's performance is degraded as compared to simple structure.
  - It requires careful planning for designing the layers, as the higher layers use the functionalities of only the lower layers.

System Components

- An Operating system is an interface between users and the hardware of a computer system.
- It is a system software that is viewed as an organized collection of software consisting of procedures and functions, providing an environment for the execution of programs.
- The operating system manages resources of system software and computer hardware resources.
- It allows computing resources to be used in an efficient way. Programs interact with computer hardware with the help of operating system.
- A user can interact with the operating system by making system calls or using OS commands.

Important Components of the Operating System

- Process management
- Files management
- Command Interpreter
- System calls
- Signals
- Network management
- Security management
- I/O device management
- Secondary storage management
- Main memory management

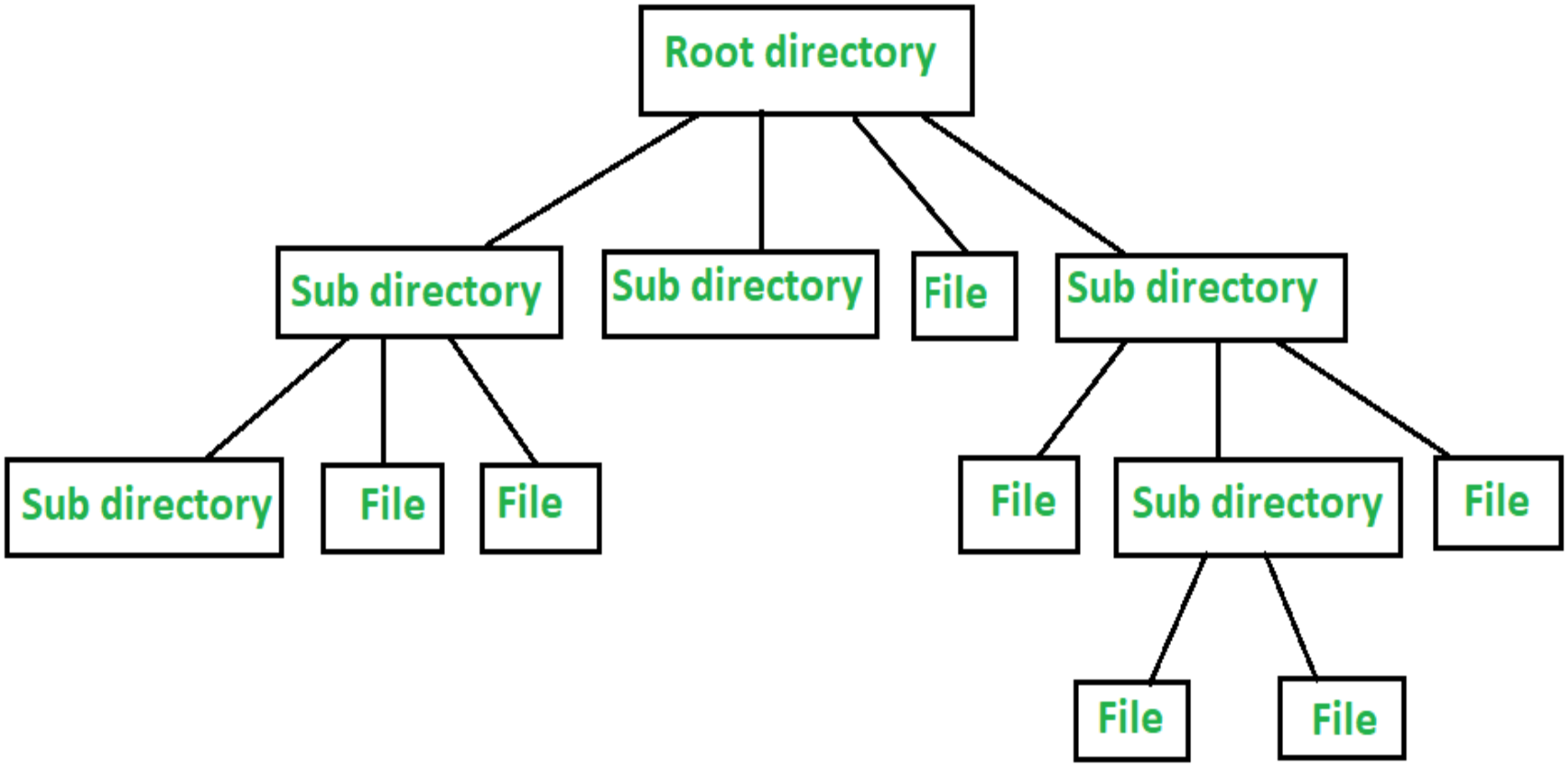
Process Management

- A process is a program in execution. It consists of the followings:
- Executable program
- Program's data
- Stack and stack pointer
- Program counter and other CPU registers
- Details of opened files
- A process can be suspended temporarily and the execution of another process can be taken up. A suspended process can be restarted later. Before suspending a process, its details are saved in a table called the process table so that it can be executed later on. An operating system supports two system calls to manage processes Create and Kill –
- Create a system call used to create a new process.
- Kill system call used to delete an existing process.
- A process can create a number of child processes. Processes can communicate among themselves either using shared memory or by message-passing techniques. Two processes running on two different computers can communicate by sending messages over a network.

Files Management

- Files are used for long-term storage. Files are used for both input and output. Every operating system provides a file management service. This file management service can also be treated as an abstraction as it hides the information about the disks from the user. The operating system also provides a system call for file management. The system call for file management includes –
- File creation
- File deletion
- Read and Write operations

- Files are stored in a directory. System calls provide to put a file in a directory or to remove a file from a directory. Files in the system are protected to maintain the privacy of the user.
- Diagram shows the Hierarchical File Structure directory.



Command Interpreter

- There are several ways for users to interface with the operating system. One of the approaches to user interaction with the operating system is through commands. Command interpreter provides a **command-line interface**. It allows the user to enter a command on the command line prompt (cmd). The command interpreter accepts and executes the commands entered by a user. For example, a shell is a command interpreter under UNIX. The commands to be executed are implemented in two ways:
  - The command interpreter itself contains code to be executed.
  - The command is implemented through a system file. The necessary system file is loaded into memory and executed.

System Calls

- System calls provide an interface to the services made by an operating system. The user interacts with the operating system programs through System calls. These calls are normally made available as library functions in high-level languages such as C, Java, Python etc. It provides a level of abstraction as the user is not aware of the implementation or execution of the call made. Details of the operating system is hidden from the user.

- Different hardware and software services can be availed through system calls.

- System calls are available for the following operations:
  - Process Management
  - Memory Management
  - File Operations
  - Input / Output Operations

Signals

Signals are used in the operating systems to notify a process that a particular event has occurred. Signals are the software or hardware interrupts that suspend the current execution of the task. Signals are also used for inter-process communication. A signal follows the following pattern :

- A signal is generated by the occurrence of a particular event it can be the clicking of the mouse, the execution of the program successfully or an error notifying, etc.
- A generated signal is delivered to a process for further execution.

- Once delivered, the signal must be handled.
- A signal can be synchronous and asynchronous which is handled by a default handler or by the user-defined handler.
- The signal causes temporarily suspends the current task it was processing, saves its registers on the stack, and starts running a special signal handling procedure, where the signal is assigned to it.

Network Management

- Network management is a fundamental concept of computer networks.
- Network Management Systems is a software application that provides network administrators with information on components in their networks.
- It ensures the quality of service and availability of network resources.
- It also examines the operations of a network, reconstructs its network configuration, modifies it for improving performance of tasks.

Security Management

- The security mechanisms in an operating system ensure that authorized programs have access to resources, and unauthorized programs have no access to restricted resources.
- Security management refers to the various processes where the user changes the file, memory, CPU, and other hardware resources that should have authorization from the operating system.

I/O Device Management

- The I/O device management component is an I/O manager that hides the details of hardware devices and manages the main memory for devices using cache and spooling. This component provides a buffer cache and general device driver code that allows the system to manage the main memory and the hardware devices connected to it. It also provides and manages custom drivers for particular hardware devices.

- The purpose of the I/O system is to hide the details of hardware devices from the application programmer. An I/O device management component allows highly efficient resource utilization while minimizing errors and making programming easy on the entire range of devices available in their systems.

Secondary Storage Management

- The secondary storage area is any space, where data is stored permanently and the user can retrieve it easily. Your computer's hard drive is the primary location for your files and programs.
- Other spaces, such as CD-ROM/DVD drives, flash memory cards, and networked devices, also provide secondary storage for data on the computer.
- The computer's main memory (RAM) is a volatile storage device in which all programs reside, it provides only temporary storage space for performing tasks.
- Secondary storage refers to the media devices other than RAM (e.g. CDs, DVDs, or hard disks) that provide additional space for permanent storing of data and software programs which is also called non-volatile storage.

Main memory management

- Main memory is a flexible and volatile type of storage device.
- It is a large sequence of bytes and addresses used to store volatile data.
- Main memory is also called Random Access Memory (RAM), which is the fastest computer storage available on PCs.
- It is costly and low in terms of storage as compared to secondary storage devices. Whenever computer programs are executed, it is temporarily stored in the main memory for execution.
- The user can permanently store the data or program in the secondary storage device.

Operating System Services

- **Services of Operating System**
- Program execution
- Input Output Operations
- Communication between Process
- File Management
- Memory Management
- Process Management
- Security and Privacy
- Resource Management
- User Interface
- Networking
- Error handling
- Time Management

1. Program Execution

- It is the Operating System that manages how a program is going to be executed.
- It loads the program into the memory after which it is executed.
- The order in which they are executed depends on the CPU Scheduling Algorithms.
- A few are FCFS, SJF, etc. When the program is in execution, the Operating System also handles deadlock i.e. no two processes come for execution at the same time.
- The Operating System is responsible for the smooth execution of both user and system programs.
- The Operating System utilizes various resources available for the efficient running of all types of functionalities.

2. **Input Output Operations**

- Operating System manages the input-output operations and establishes communication between the user and device drivers.
- Device drivers are software that is associated with hardware that is being managed by the OS so that the sync between the devices works properly.
- It also provides access to input-output devices to a program when needed.

3. Communication between Processes

- The Operating system manages the communication between processes. Communication between processes includes data transfer among them.
- If the processes are not on the same computer but connected through a computer network, then also their communication is managed by the Operating System itself.

4. **File Management**

- The operating system helps in managing files also.
- If a program needs access to a file, it is the operating system that grants access.
- These permissions include read-only, read-write, etc.
- It also provides a platform for the user to create, and delete files.
- The Operating System is responsible for making decisions regarding the storage of all types of data or files, i.e, floppy disk/hard disk/pen drive, etc.
- The Operating System decides how the data should be manipulated and stored.

5. **Memory Management**

- Let’s understand memory management by OS in simple way. Imagine a cricket team with limited number of player .
- The team manager (OS) decide whether the upcoming player will be in playing 11, playing 15 or will not be included in team, based on his performance.
- In the same way, OS first check whether the upcoming program fulfill all requirement to get memory space or not ,if all things good, it checks how much memory space will be sufficient for program and then load the program into memory at certain location.
- And thus, it prevents program from using unnecessary memory.

6. **Process Management**

- Let’s understand the process management in unique way. Imagine, our kitchen stove as the (CPU) where all cooking(execution) is really happen and chef as the (OS) who uses kitchen-stove(CPU) to cook different dishes(program).
- The chef(OS) has to cook different dishes(programs) so he ensure that any particular dish(program) does not take long time(unnecessary time) and all dishes(programs) gets a chance to cooked(execution) .
- The chef(OS) basically scheduled time for all dishes(programs) to run kitchen(all the system) smoothly and thus cooked(execute) all the different dishes(programs) efficiently.

7. Security and Privacy

- **Security :** OS keep our computer safe from an unauthorized user by adding security layer to it. Basically, Security is nothing but just a layer of protection which protect computer from bad guys like viruses and hackers. OS provide us defenses like firewalls and anti-virus software and ensure good safety of computer and personal information.
- **Privacy :** OS give us facility to keep our essential information hidden like having a lock on our door, where only you can enter and other are not allowed . Basically , it respect our secrets and provide us facility to keep it safe.

8. **Resource Management**

- System resources are shared between various processes.
- It is the Operating system that manages resource sharing.
- It also manages the CPU time among processes using CPU Scheduling Algorithms.
- It also helps in the memory management of the system. It also controls input-output devices.
- The OS also ensures the proper use of all the resources available by deciding which resource to be used by whom.

9. **User Interface**

- User interface is essential and all operating systems provide it. Users either interface with the operating system through the command-line interface or graphical user interface or GUI. The command interpreter executes the next user-specified command.
- A GUI offers the user a mouse-based window and menu system as an interface.

10. **Networking**

- This service enables communication between devices on a network, such as connecting to the internet, sending and receiving data packets, and managing network connections.

11. Error Handling

- The Operating System also handles the error occurring in the CPU, in Input-Output devices, etc.
- It also ensures that an error does not occur frequently and fixes the errors.
- It also prevents the process from coming to a deadlock.
- It also looks for any type of error or bugs that can occur while any task.
- The well-secured OS sometimes also acts as a countermeasure for preventing any sort of breach of the Computer System from any external source and probably handling them.

12. Time Management

- Imagine traffic light as (OS), which indicates all the cars(programs) whether it should be stop(red)=>(simple queue), start(yellow)=>(ready queue),move(green)=>(under execution) and this light (control) changes after a certain interval of time at each side of the road(computer system) so that the cars(program) from all side of road move smoothly without traffic.