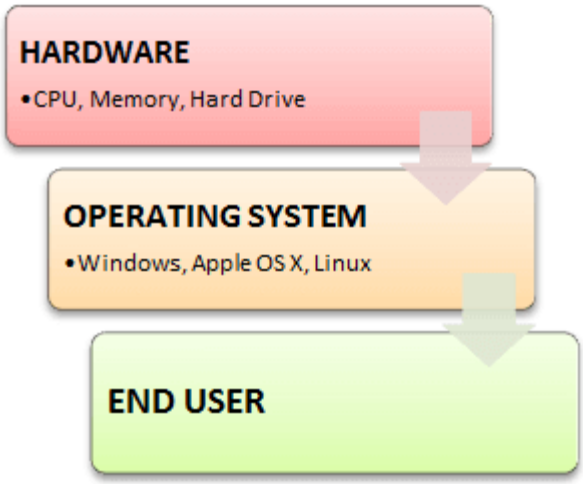
جامعة الفرات الاوسط التقنية
الكلية التقنية الإدارية- كوفة
قسم تكنولوجيا المعلومات
د.عمار وسام الطاهر

Operating system

Lecture 1,2

What is an Operating System?

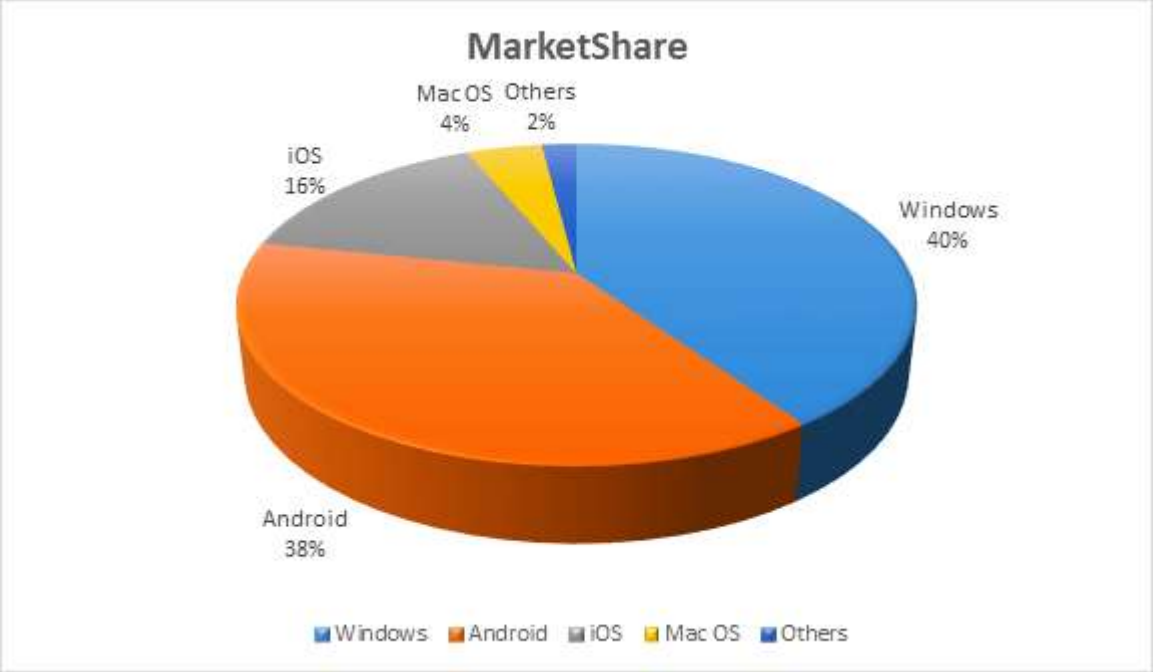
An **Operating System (OS)** is a software that acts as an interface between computer hardware components and the user. Every computer system must have at least one operating system to run other programs. Applications like Browsers, MS Office, Notepad Games, etc., need some environment to run and perform its tasks.
The OS helps you to communicate with the computer without knowing how to speak the computer's language. It is not possible for the user to use any computer or mobile device without having an operating system.



History Of OS

- Operating systems were first developed in the late 1950s to manage tape storage
- The General Motors Research Lab implemented the first OS in the early 1950s for their IBM 701
- In the mid-1960s, operating systems started to use disks
- In the late 1960s, the first version of the Unix OS was developed
- The first OS built by Microsoft was DOS. It was built in 1981 by purchasing the 86-DOS software from a Seattle company
- The present-day popular OS Windows first came to existence in 1985 when a GUI was created and paired with MS-DOS.

Examples of Operating System with Market Share



Market Share of Operating Systems

Types of Operating System (OS)

Following are the popular types of OS (Operating System):

- Batch Operating System
- Multitasking/Time Sharing OS
- Multiprocessing OS
- Real Time OS
- Distributed OS
- Network OS
- Mobile OS

Batch Operating System

Some computer processes are very lengthy and time-consuming. To speed the same process, a job with a similar type of needs are batched together and run as a group.

The user of a batch operating system never directly interacts with the computer. In this type of OS, every user prepares his or her job on an offline device like a punch card and submit it to the computer operator.

Multi-Tasking/Time-sharing Operating systems

Time-sharing operating system enables people located at a different terminal(shell) to use a single computer system at the same time. The processor time (CPU) which is shared among multiple users is termed as time sharing.

Real time OS

A real time operating system time interval to process and respond to inputs is very small. Examples: Military Software Systems, Space Software Systems are the Real time OS example.

Distributed Operating System

Distributed systems use many processors located in different machines to provide very fast computation to its users.

Network Operating System

Network Operating System runs on a server. It provides the capability to serve to manage data, user, groups, security, application, and other networking functions.

Mobile OS

Mobile operating systems are those OS which is especially that are designed to power smartphones, tablets, and wearables devices.

Some most famous mobile operating systems are Android and iOS, but others include BlackBerry, Web, and watchOS.

What is Open Source Operating System?

To understand it, first, you should know **what is Open source?**
Open source refers to the computer software or applications where the owners or copyright holders allow the users or third party to see, use and provide the right to modify the source code of the product.

An **Open-source Operating System** is the Operating System in which source code is visible publically and editable. The generally known Operating Systems like **Microsoft's Windows, Apple's iOS and Mac OS, are closed Operating system.**
Closed Operating Systems are built with numerous codes and complex programming and that is called source code. This source code is kept secret by the respective companies (owners) and inaccessible to third parties. By doing so, they ensure the safety and secure the Operating System and computer from any threats.

Functions of Operating System

Some typical operating system functions may include managing memory, files, processes, I/O system & devices, security, etc.

Below are the main functions of Operating System:

Functions of Operating System

In an operating system software performs each of the function:

1. **Process management**:- Process management helps OS to create and delete processes. It also provides mechanisms for synchronization and communication among processes.

2. **Memory management:-** Memory management module performs the task of allocation and de-allocation of memory space to programs in need of this resources.

3. **File management**:- It manages all the file-related activities such as organization storage, retrieval, naming, sharing, and protection of files.

4. **Device Management**: Device management keeps tracks of all devices. This module also responsible for this task is known as the I/O controller. It also performs the task of allocation and de-allocation of the devices.

5. **I/O System Management:** One of the main objects of any OS is to hide the peculiarities of that hardware devices from the user.

6. **Secondary-Storage Management**: Systems have several levels of storage which includes primary storage, secondary storage, and cache storage. Instructions and data must be stored in primary storage or cache so that a running program can reference it.

7. **Security**:- Security module protects the data and information of a computer system against malware threat and authorized access.

8. **Command interpretation**: This module is interpreting commands given by the and acting system resources to process that commands.

9. **Networking:** A distributed system is a group of processors which do not share memory, hardware devices, or a clock. The processors communicate with one another through the network.

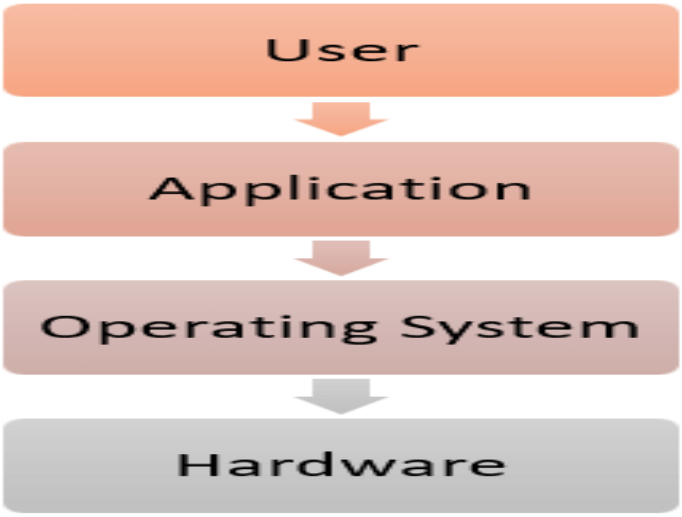
10. **Job accounting**: Keeping track of time & resource used by various job and users.

11. **Communication management**: Coordination and assignment of compilers, interpreters, and another software resource of the various users of the computer systems.

Features of Operating System (OS)

Here is a list important features of OS:

- Protected and supervisor mode
- Allows disk access and file systems Device drivers Networking Security
- Program Execution
- Memory management Virtual Memory Multitasking
- Handling I/O operations
- Manipulation of the file system
- Error Detection and handling
- Resource allocation
- Information and Resource Protection



Advantage of using Operating System

- Allows you to hide details of hardware by creating an abstraction
- Easy to use with a GUI
- Offers an environment in which a user may execute programs/applications
- The operating system must make sure that the computer system convenient to use
- Operating System acts as an intermediary among applications and the hardware components
- It provides the computer system resources with easy to use format
- Acts as an intermediator between all hardware's and software's of the system

Disadvantages of using Operating System

- If any issue occurs in OS, you may lose all the contents which have been stored in your system
- Operating system's software is quite expensive for small size organization which adds burden on them. Example Windows
- It is never entirely secure as a threat can occur at any time

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Operating System Services

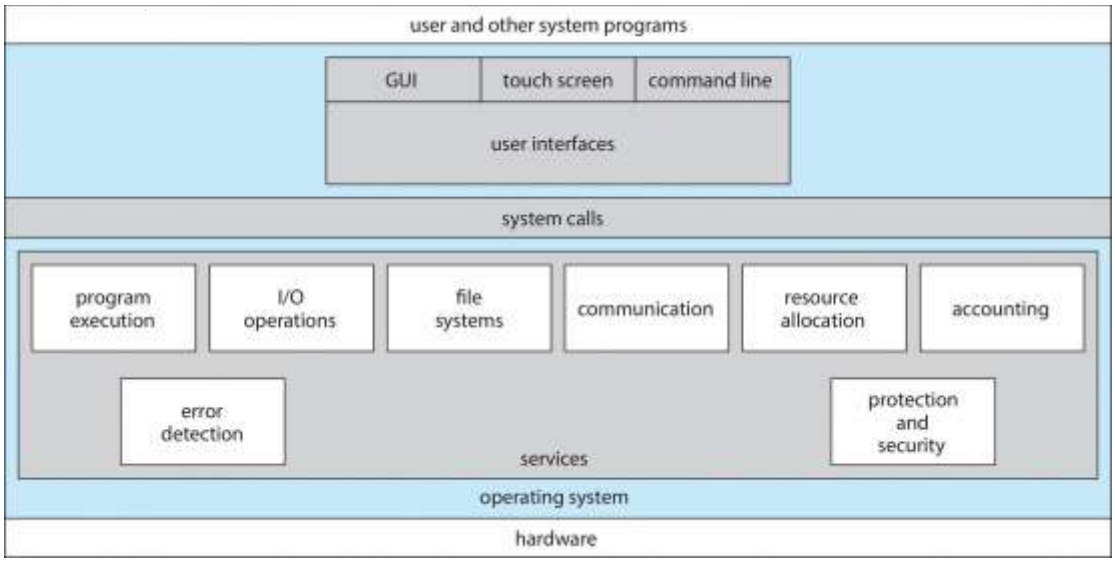
- Operating systems provide an environment for execution of programs and services to programs and users
- One set of operating-system services provides functions that are helpful to the user:
- **User interface** - Almost all operating systems have a user interface (**UI**).
- Varies between **Command-Line (CLI)**, **Graphical User Interface (GUI)**, **touch-screen, Batch**
- **Program execution** - The system must be able to load a program into memory and to run that program, terminate execution, either normally or abnormally (indicating error).
- **I/O operations** - A running program may require I/O, which may involve a file or an I/O device; OS must provide interface to I/O subsystems.
- **File-system manipulation** - The file system is of particular interest.

Programs need to read and write files and directories, create and delete them, search them, list file Information, permission management.

- **Communications** – Processes may exchange information, on the same computer or between computers over a network
- Communications may be via shared memory or through message passing (packets moved by the OS)
- **Error detection** – OS needs to be constantly aware of possible errors
- May occur in the CPU and memory hardware, in I/O devices, in user program
- For each type of error, OS should take the appropriate action to ensure correct and consistent computing
- Debugging facilities can greatly enhance the user's and programmer's abilities to efficiently use the system

- **Resource allocation -** When multiple users or multiple jobs running concurrently, resources must be allocated to each of them
- Many types of resources - CPU cycles, main memory, file storage,I/O devices.
- **Logging -** To keep track of which users use how much and what kinds of computer resources
- **Protection and security -** The owners of information stored in a multi user or networked computer system may want to control use of that information, concurrent processes should not interfere with each other
- **Protection** involves ensuring that all access to system resources is controlled
- **Security** of the system from outsiders requires user authentication, extends to defending external I/O devices from invalid access attempts

A View of Operating System Services

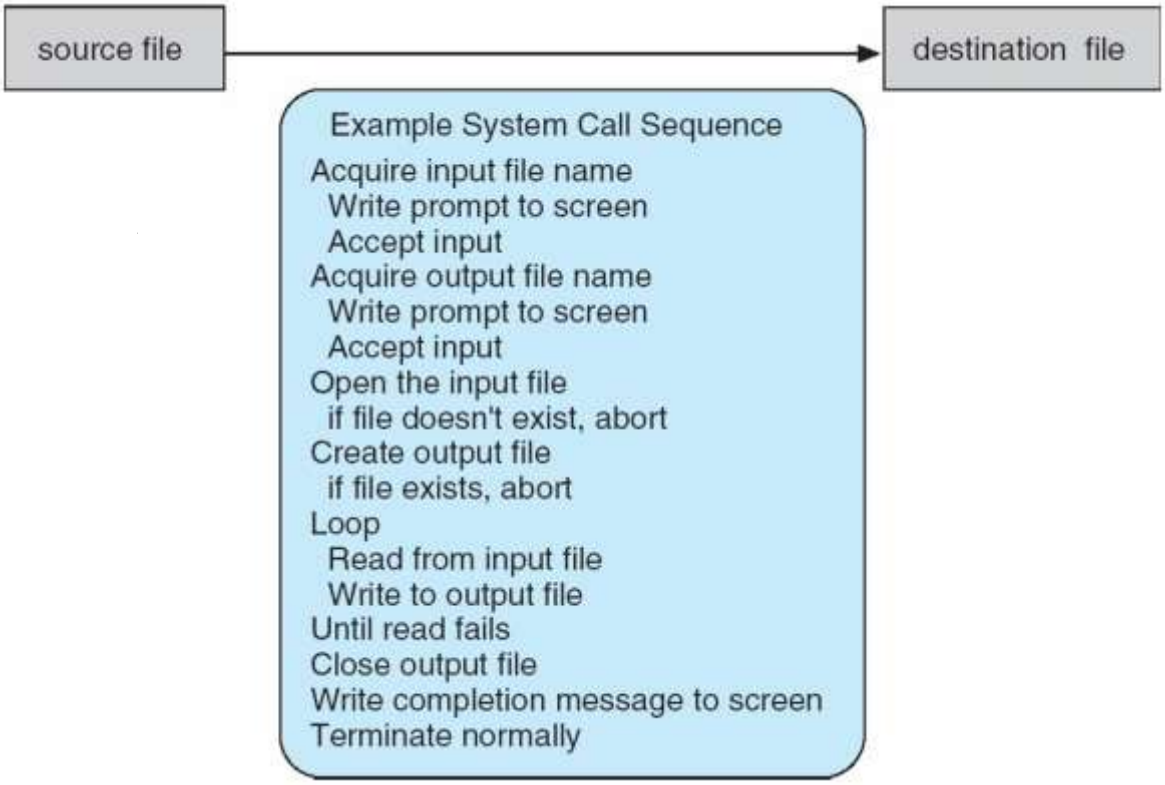


System Calls

- Programming interface to the services provided by the OS
- Typically written in a high-level language (C or C++)
- Mostly accessed by programs via a high-level **Application Programming Interface** (**API**) rather than direct system call use

Example of System Calls

- System call sequence to copy the contents of one file to another file

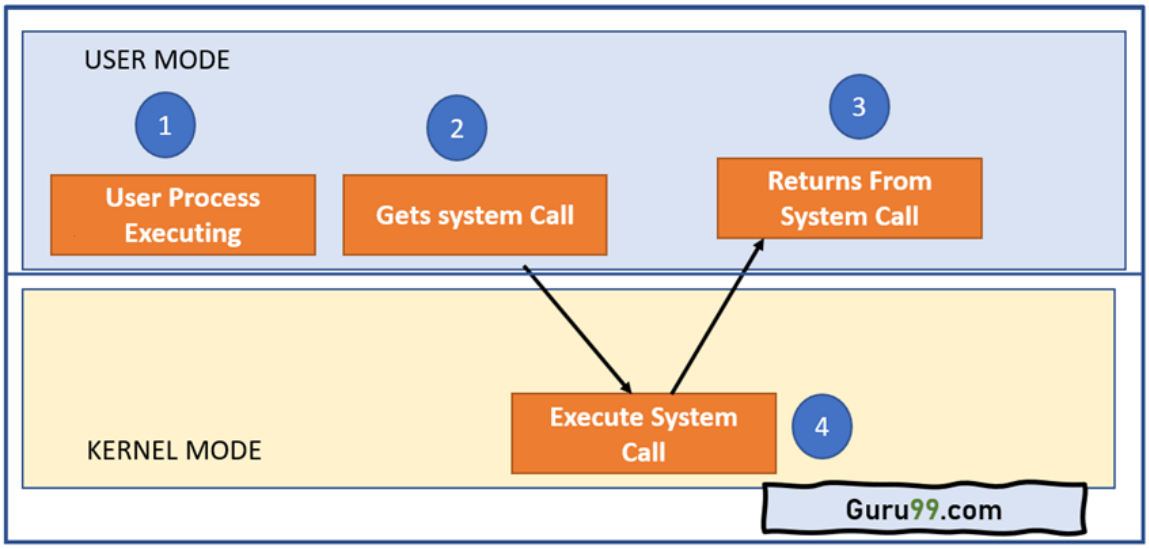


What is System Call in Operating System?

A **system call** is a mechanism that provides the interface between a process and the operating system. It is a programmatic method in which a computer program requests a service from the kernel of the OS.

System call offers the services of the operating system to the user programs via API (Application Programming Interface).

Here are the steps for System Call in OS:



Architecture of the System Call

As you can see in the above-given System Call example diagram.

Step 1) The processes executed in the user mode till the time a system call interrupts it.

Step 2) After that, the system call is executed in the kernel-mode on a priority basis.

Step 3) Once system call execution is over, control returns to the user mode.,

Step 4) The execution of user processes resumed in Kernel mode.

Types of System calls

Here are the five types of System Calls in OS:

- Process Control
- File Management
- Device Management
- Information Maintenance
- Communications

Process Control

This system calls perform the task of process creation, process termination, etc.

Functions:

- End and Abort
- Load and Execute
- Create Process and Terminate Process
- Wait and Signal Event
- Allocate and free memory

File Management

File management system calls handle file manipulation jobs like creating a file, reading, and writing, etc.

Functions:

- Create a file
- Delete file
- Open and close file
- Read, write, and reposition
- Get and set file attributes

Device Management

Device management does the job of device manipulation like reading from device buffers, writing into device buffers, etc.

Functions:

- Request and release device
- Logically attach/ detach devices
- Get and Set device attributes

Information Maintenance

It handles information and its transfer between the OS and the user program.

Functions:

- Get or set time and date

Communication:

These types of system calls are specially used for interprocess communications.

Functions:

- Create, delete communications connections

- Send, receive message
- Help OS to transfer status information
- Attach or detach remote devices

Operating System Design and Implementation

There are basically two types of goals while designing an operating system. These are −

User Goals

The operating system should be convenient, easy to use, reliable, safe and fast according to the users.

System Goals

The operating system should be easy to design, implement and maintain. These are specifications required by those who create, maintain and operate the operating system. But there is not specific method to achieve these goals as well.

Operating System Mechanisms and Policies

There is no specific way to design an operating system as it is a highly creative task. However, there are general software principles that are applicable to all operating systems.

A subtle difference between mechanism and policy is that mechanism shows how to do something and policy shows what to do. Policies may change over time and this would lead to changes in mechanism. So, it is better to have a general mechanism that would require few changes even when a policy change occurs.

Operating System Implementation

The operating system needs to be implemented after it is designed. Earlier they were written in assembly language but now higher level languages are used. The first system not written in assembly language was the Master Control Program (MCP) for Burroughs Computers.

- Early OSes in assembly language
- Then system programming languages like Algol, PL/1
- Now C, C++
- Actually usually a mix of languages
- Lowest levels in assembly
- Main body in C
- Systems programs in C, C++, scripting languages like PERL,Python, shell scripts

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Operating system Process Management

A Program does nothing unless its instructions are executed by a CPU. A program in execution is called a process. In order to accomplish its task, process needs the computer resources.

There may exist more than one process in the system which may require the same resource at the same time. Therefore, the operating system has to manage all the processes and the resources in a convenient and efficient way.

Attributes of a process

The Attributes of the process are used by the Operating System to create the process control block (PCB) for each of them. This is also called context of the process. Attributes which are stored in the PCB are described below.

1. Process ID

When a process is created, a unique id is assigned to the process which is used for unique identification of the process in the system.

2. Program counter

A program counter stores the address of the last instruction of the process on which the process was suspended. The CPU uses this address when the execution of this process is resumed.

3. Process State

The Process, from its creation to the completion, goes through various states which are new, ready, running and waiting. .....later in detail.

4. Priority

Every process has its own priority. The process with the highest priority among the processes gets the CPU first. This is also stored on the process control block.

5. General Purpose Registers

Every process has its own set of registers which are used to hold the data which is generated during the execution of the process.

6. List of open files

During the Execution, Every process uses some files which need to be present in the main memory. OS also maintains a list of open files in the PCB.

7. List of open devices

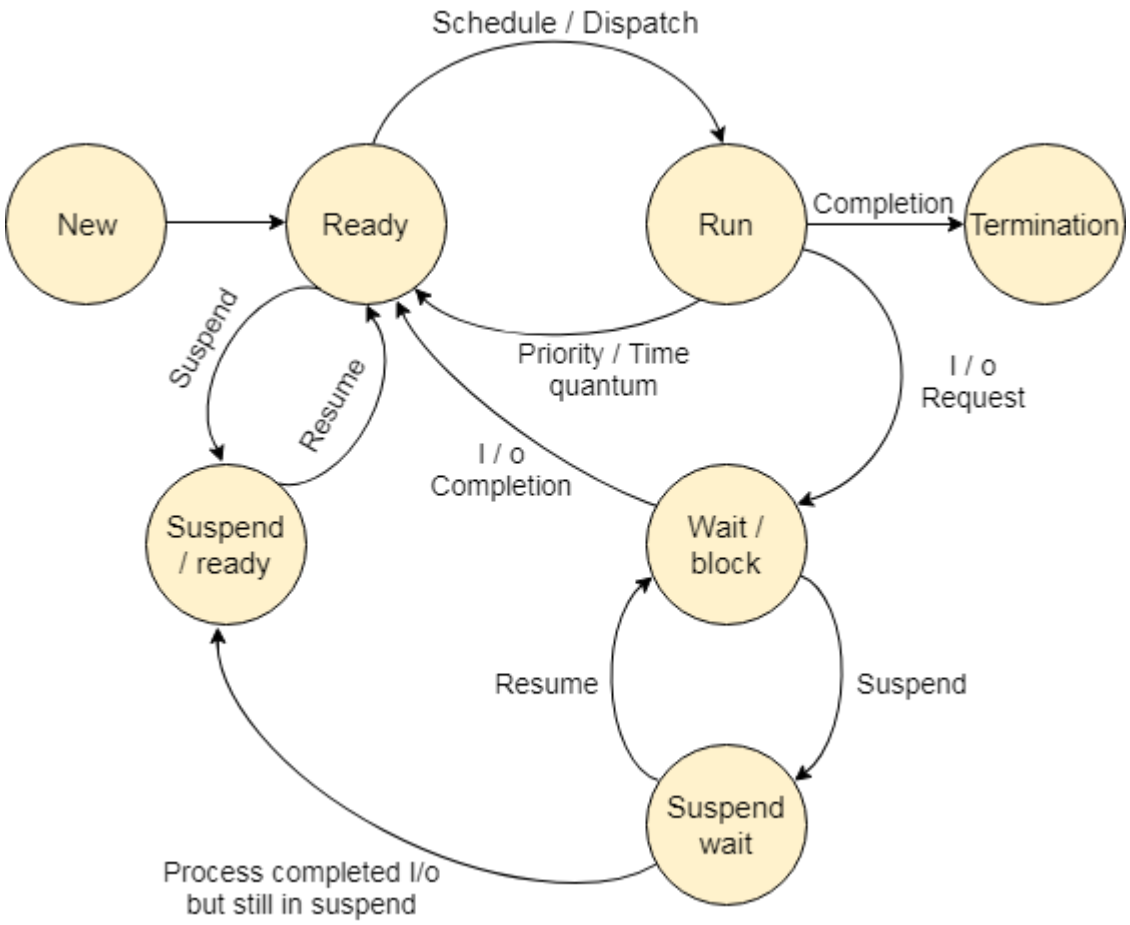
OS also maintain the list of all open devices which are used during the execution of the process.

Process ID
Program Counter
Process State
Priority
General Purpose Registers
List of Open Files
List of Open Devices

Process Attributes

Process States

State Diagram



The process, from its creation to completion, passes through various states. The minimum number of states is five.

1. New

A program which is going to be picked up by the OS into the main memory is called a new process.

2. Ready

Whenever a process is created, it directly enters in the ready state, in which, it waits for the CPU to be assigned. The OS picks the new processes from the secondary memory and put all of them in the main memory.

The processes which are ready for the execution and reside in the main memory are called ready state processes.

3. Running

One of the processes from the ready state will be chosen by the OS depending upon the scheduling algorithm. Hence, if we have only one CPU in our system, the number of running processes for a particular time will always be one. If we have n processors in the system then we can have n processes running together .

4. Block or wait

From the Running state, a process can make the transition to the block or wait state depending upon the scheduling algorithm or behavior of the process.

When a process waits for a certain resource to be assigned or for the input from the user then the OS move this process to the block or wait state and assigns the CPU to the other processes.

5. Completion or termination

When a process finishes its execution, it comes in the termination state. All the context of the process (Process Control Block) will also be deleted the process will be terminated by the Operating system.

6. Suspend ready

A process in the ready state, which is moved to secondary memory from the main memory due to lack of the resources (mainly primary memory) is called in the suspend ready state.

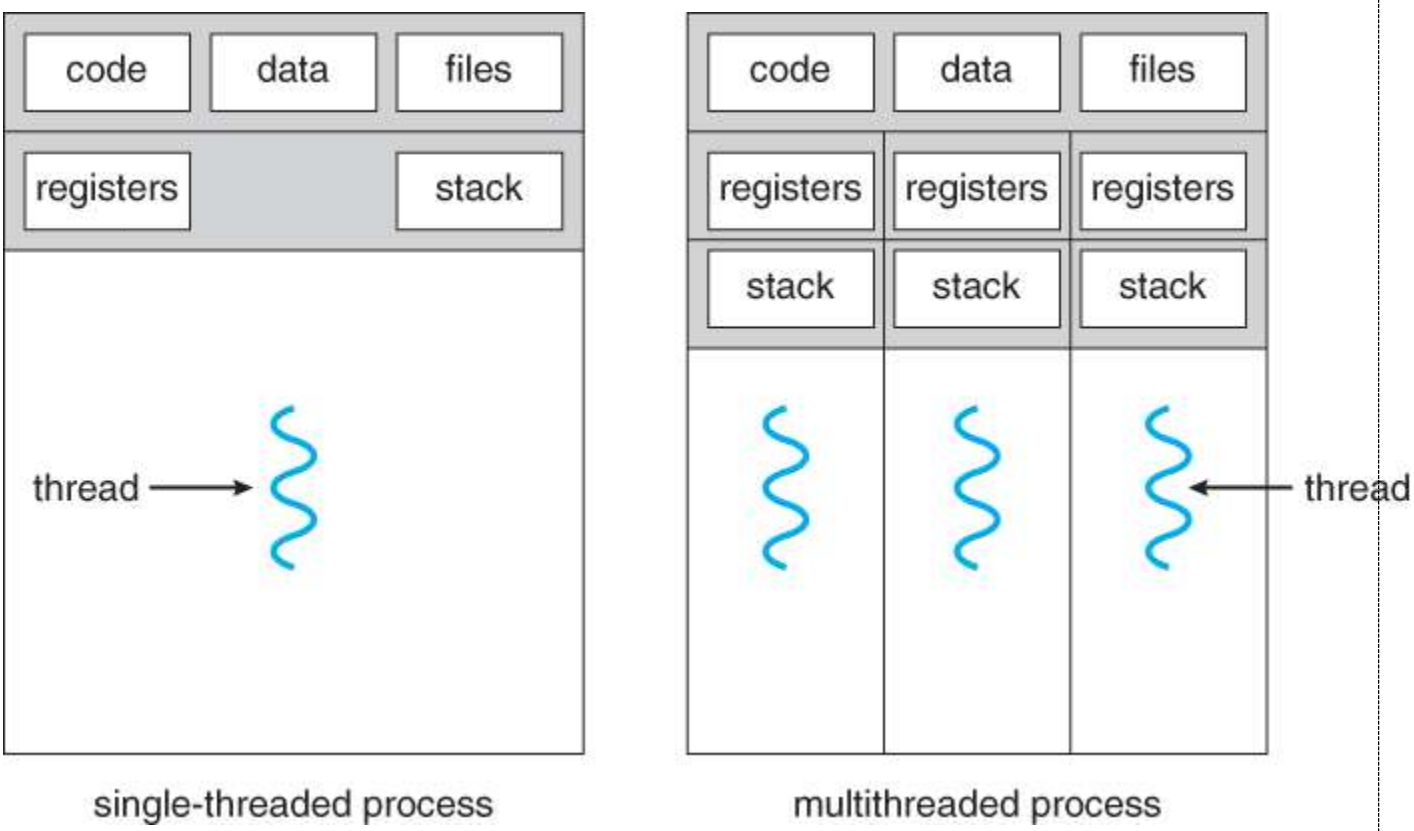
If the main memory is full and a higher priority process comes for the execution then the OS have to make the room for the process in the main memory by throwing the lower priority process out into the secondary memory. The suspend ready processes remain in the secondary memory until the main memory gets available.

7. Suspend wait

Instead of removing the process from the ready queue, it's better to remove the blocked process which is waiting for some resources in the main memory. Since it is already waiting for some resource to get available hence it is better if it waits in the secondary memory and make room for the higher priority process. These processes complete their execution once the main memory gets available and their wait is finished.

Thread (computing)

In computer science, a **thread** of execution is the smallest sequence of programmed instructions that can be managed independently by a scheduler, which is typically a part of the operating system.The implementation of threads and processes differs between operating systems, but in most cases a thread is a component of a process. The multiple threads of a given process may be executed concurrently ,sharing resources such as memory, while different processes do not share these resources. In particular, the threads of a process share its executable code and the values of its dynamically allocated variables and non-thread-local global variables at any given time



- Single-threaded and multithreaded processes

Multicore Programming

Figure 4 - Concurrent execution on a single-core system.

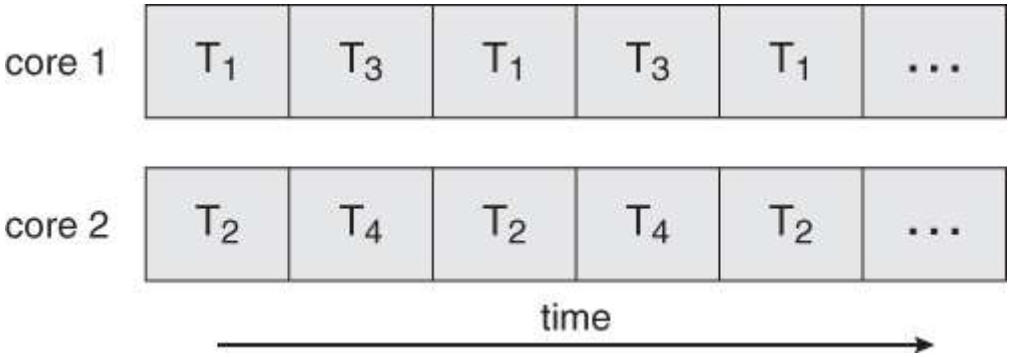


Figure 5- Parallel execution on a multicore system

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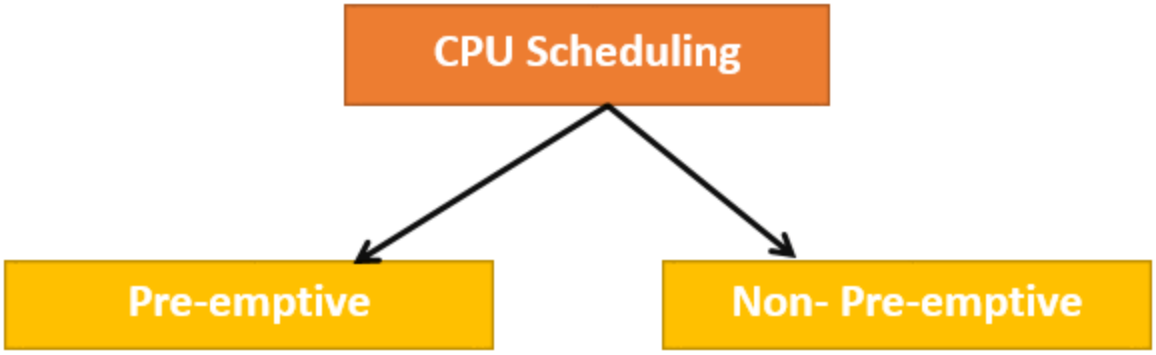
CPU Scheduling Algorithms in Operating Systems

What is CPU Scheduling?

CPU Scheduling is a process of determining which process will own CPU for execution while another process is on hold.

Types of CPU Scheduling

Here are two kinds of Scheduling methods:



Preemptive Scheduling

In Preemptive Scheduling, the tasks are mostly assigned with their priorities. Sometimes it is important to run a task with a higher priority before another lower priority task, even if the lower priority task is still running. The lower priority task holds for some time and resumes when the higher priority task finishes its execution.

Non-Preemptive Scheduling

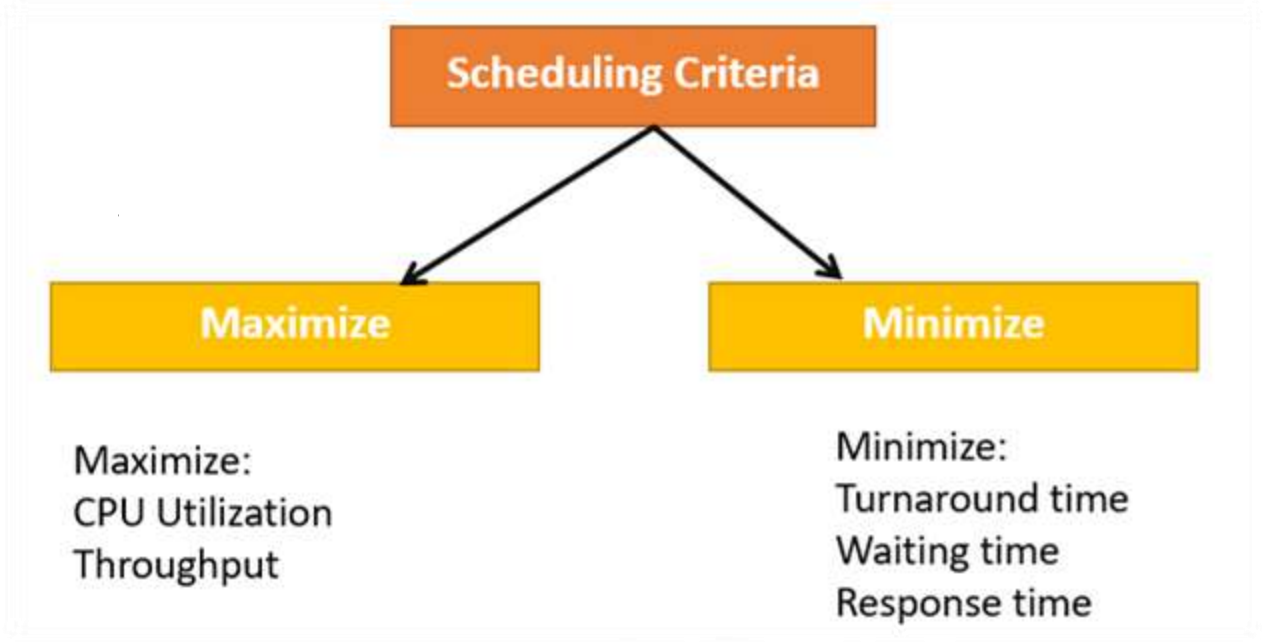
In this type of scheduling method, the CPU has been allocated to a specific process. The process that keeps the CPU busy will release the CPU either by switching context or terminating.

Important CPU scheduling Terminologies

- **Burst Time/Execution Time:** It is a time required by the process to complete execution. It is also called running time.
- **Arrival Time:** when a process enters in a ready state
- **Finish Time:** when process complete and exit from a system
- **Multiprogramming:** A number of programs which can be present in memory at the same time.
- **Jobs:** It is a type of program without any kind of user interaction.
- **User:** It is a kind of program having user interaction.
- **Process:** It is the reference that is used for both job and user.
- **CPU/IO burst cycle:** Characterizes process execution, which alternates between CPU and I/O activity. CPU times are usually shorter than the time of I/O.

CPU Scheduling Criteria

A CPU scheduling algorithm tries to maximize and minimize the following:



Maximize:

CPU utilization: CPU utilization is the main task in which the operating system needs to make sure that CPU remains as busy as possible. It can range from 0 to 100 percent.

Throughput: The number of processes that finish their execution per unit time is known Throughput.

Minimize:

Waiting time: Waiting time is an amount that specific process needs to wait in the ready queue.

Response time: It is an amount to time in which the request was submitted until the first response is produced.

Turnaround Time: Turnaround time is an amount of time to execute a specific process. It is the calculation of the total time spent waiting to get into the memory, waiting in the queue and, executing on the CPU.

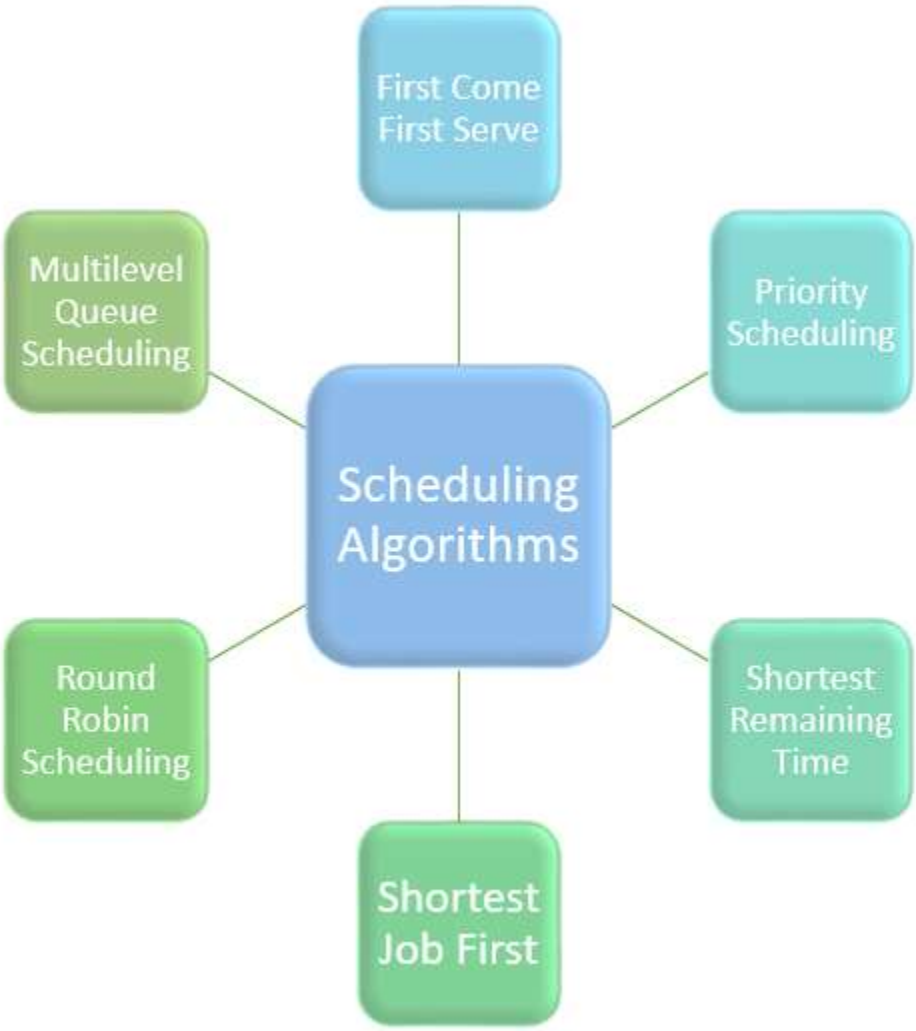
What is Dispatcher?

It is a module that provides control of the CPU to the process. The Dispatcher should be fast so that it can run on every context switch. Dispatch latency is the amount of time needed by the CPU scheduler to stop one process and start another.

Types of CPU scheduling Algorithm

There are mainly six types of process scheduling algorithms

1. First Come First Serve (FCFS)
2. Shortest-Job-First (SJF) Scheduling
3. Shortest Remaining Time
4. Priority Scheduling
5. Round Robin Scheduling
6. Multilevel Queue Scheduling



Scheduling Algorithms

First Come First Serve

First Come First Serve FCFS. It is the easiest and most simple CPU scheduling algorithm. In this type of algorithm, the process which requests the CPU gets the CPU allocation first. This scheduling method can be managed with a FIFO queue.

As the process enters the ready queue, its PCB (Process Control Block) is linked with the tail of the queue. So, when CPU becomes free, it should be assigned to the process at the beginning of the queue.

Shortest Remaining Time

The full form of SRT is Shortest remaining time.. In this method, the process will be allocated to the task, which is closest to its completion. This method prevents a newer ready state process from holding the completion of an older process.

Priority Based Scheduling

Priority scheduling is a method of scheduling processes based on priority. In this method, the scheduler selects the tasks to work as per the priority.

Priority scheduling also helps OS to involve priority assignments. The processes with higher priority should be carried out first, Priority can be decided based on memory requirements, time requirements, etc.

Round-Robin Scheduling

Round robin is the oldest, simplest scheduling algorithm. The name of this algorithm comes from the round-robin principle, where each person gets an equal share of something in turn. It is mostly used for scheduling algorithms in multitasking. This algorithm method helps for starvation free execution of processes.

Shortest Job First

SJF is a full form of (Shortest job first) is a scheduling algorithm in which the process with the shortest execution time should be selected for execution next. This scheduling method can be preemptive or non-preemptive. It significantly reduces the average waiting time for other processes awaiting execution.

Multiple-Level Queues Scheduling

This algorithm separates the ready queue into various separate queues. In this method, processes are assigned to a queue based on a specific property of the process, like the process priority, size of the memory, etc.

The Purpose of a Scheduling algorithm

Here are the reasons for using a scheduling algorithm:

- The CPU uses scheduling to improve its efficiency.
- It helps you to allocate resources among competing processes.
- The maximum utilization of CPU can be obtained with multi-programming.
- The processes which are to be executed are in ready queue.

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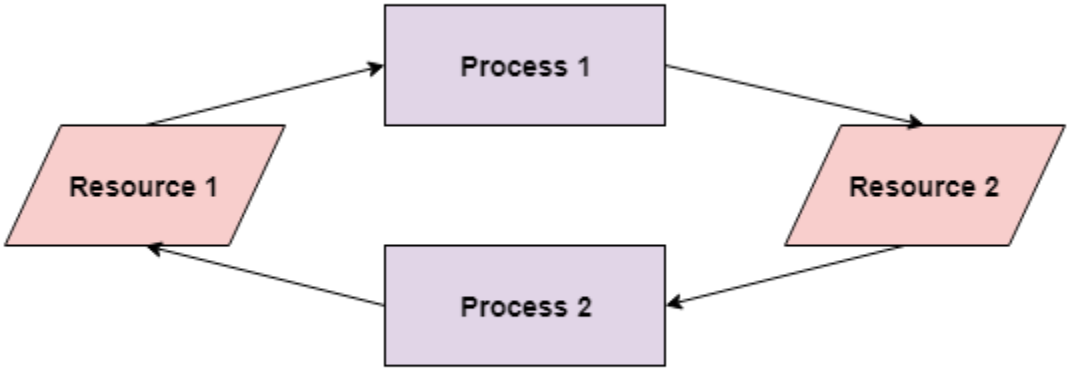
Process Deadlocks in Operating System

A deadlock happens in operating system when two or more processes need some resource to complete their execution that is held by the other process.



Deadlock in Operating System

In the above diagram, the process 1 has resource 1 and needs to acquire resource 2. Similarly process 2 has resource 2 and needs to acquire resource 1. Process 1 and process 2 are in deadlock as each of them needs the other's resource to complete their execution but neither of them is willing to relinquish their resources.

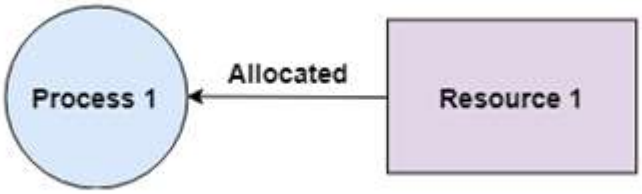
Coffman Conditions

A deadlock occurs if the four Coffman conditions hold true. But these conditions are not mutually exclusive.

The Coffman conditions are given as follows −

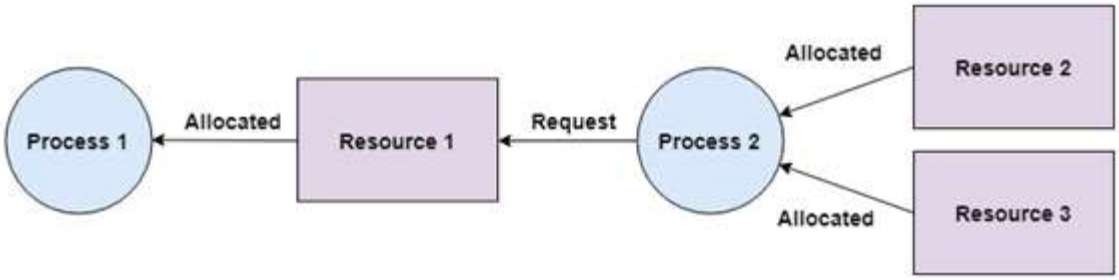
- **Mutual Exclusion**

  There should be a resource that can only be held by one process at a time. In the diagram below, there is a single instance of Resource 1 and it is held by Process 1 only.



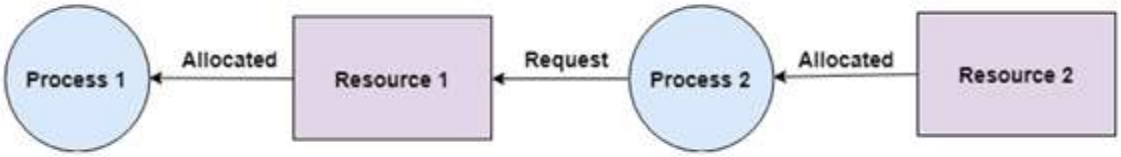
- **Hold and Wait**

  A process can hold multiple resources and still request more resources from other processes which are holding them. In the diagram given below, Process 2 holds Resource 2 and Resource 3 and is requesting the Resource 1 which is held by Process 1.



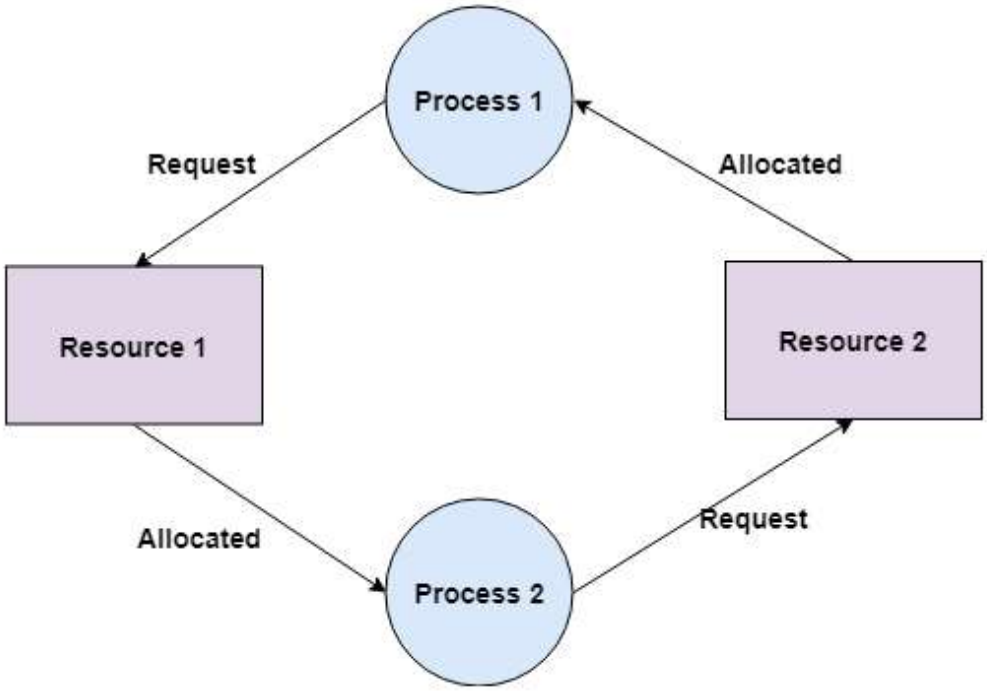
- **No Preemption**

  A resource cannot be preempted from a process by force. A process can only release a resource voluntarily. In the diagram below, Process 2 cannot preempt Resource 1 from Process 1. It will only be released when Process 1 relinquishes it voluntarily after its execution is complete.



- **Circular Wait**

  A process is waiting for the resource held by the second process, which is waiting for the resource held by the third process and so on, till the last process is waiting for a resource held by the first process. This forms a circular chain. For example: Process 1 is allocated Resource2 and it is requesting Resource 1. Similarly, Process 2 is allocated Resource 1 and it is requesting Resource 2. This forms a circular wait loop.



Deadlock Detection

A deadlock can be detected by a resource scheduler as it keeps track of all the resources that are allocated to different processes. After a deadlock is detected, it can be resolved using the following methods −

- All the processes that are involved in the deadlock are terminated. This is not a good approach as all the progress made by the processes is destroyed.
- Resources can be preempted from some processes and given to others till the deadlock is resolved.

Deadlock Prevention

It is very important to prevent a deadlock before it can occur. So, the system checks each transaction before it is executed to make sure it does not lead to deadlock. If there is even a slight chance that a transaction may lead to deadlock in the future, it is never allowed to execute.

Deadlock Avoidance

It is better to avoid a deadlock rather than take measures after the deadlock has occurred. The wait for graph can be used for deadlock avoidance. This is however only useful for smaller databases as it can get quite complex in larger databases.

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Deadlock recovery performs when a deadlock is detected.

When deadlock detected, then our system stops working, and after the recovery of the deadlock, our system start working again.

Therefore, after the detection of deadlock, a method/way must require to recover that deadlock to run the system again. The method/way is called as deadlock recovery.

Here are various ways of deadlock recovery that we will discuss :

- Deadlock recovery through preemption
- Deadlock recovery through rollback
- Deadlock recovery through killing processes

Let's discuss about all the above three ways of deadlock recovery one by one.

Deadlock Recovery through Preemption

The ability to take a resource away from a process, have another process use it, and then give it back without the process noticing. It is highly dependent on the nature of the resource.

Deadlock recovery through preemption is too difficult or sometime impossible.

Deadlock Recovery through RollBack

In this case of deadlock recovery through rollback, whenever a deadlock is detected, it is easy to see which resources are needed.

To do the recovery of deadlock, a process that owns a needed resource is rolled back to a point in time before it acquired some other resource just by starting one of its earlier checkpoints.

Deadlock Recovery through Killing Processes

This method of deadlock recovery through killing processes is the simplest way of deadlock recovery.

Sometime it is best to kill a process that can be return from the beginning with no ill effects.

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Operating System - Memory Management

Memory management is the functionality of an operating system which handles or manages primary memory and moves processes back and forth between main memory and disk during execution. Memory management keeps track of each and every memory location, regardless of either it is allocated to some process or it is free. It checks how much memory is to be allocated to processes. It decides which process will get memory at what time. It tracks whenever some memory gets freed or unallocated and correspondingly it updates the status.

Process Address Space

The process address space is the set of logical addresses that a process references in its code. For example, when 32-bit addressing is in use, addresses can range from 0 to 0x7fffffff; that is, 2^31 possible numbers, for a total theoretical size of 2 gigabytes.

The operating system takes care of mapping the logical addresses to physical addresses at the time of memory allocation to the program. There are three types of addresses used in a program before and after memory is allocated −

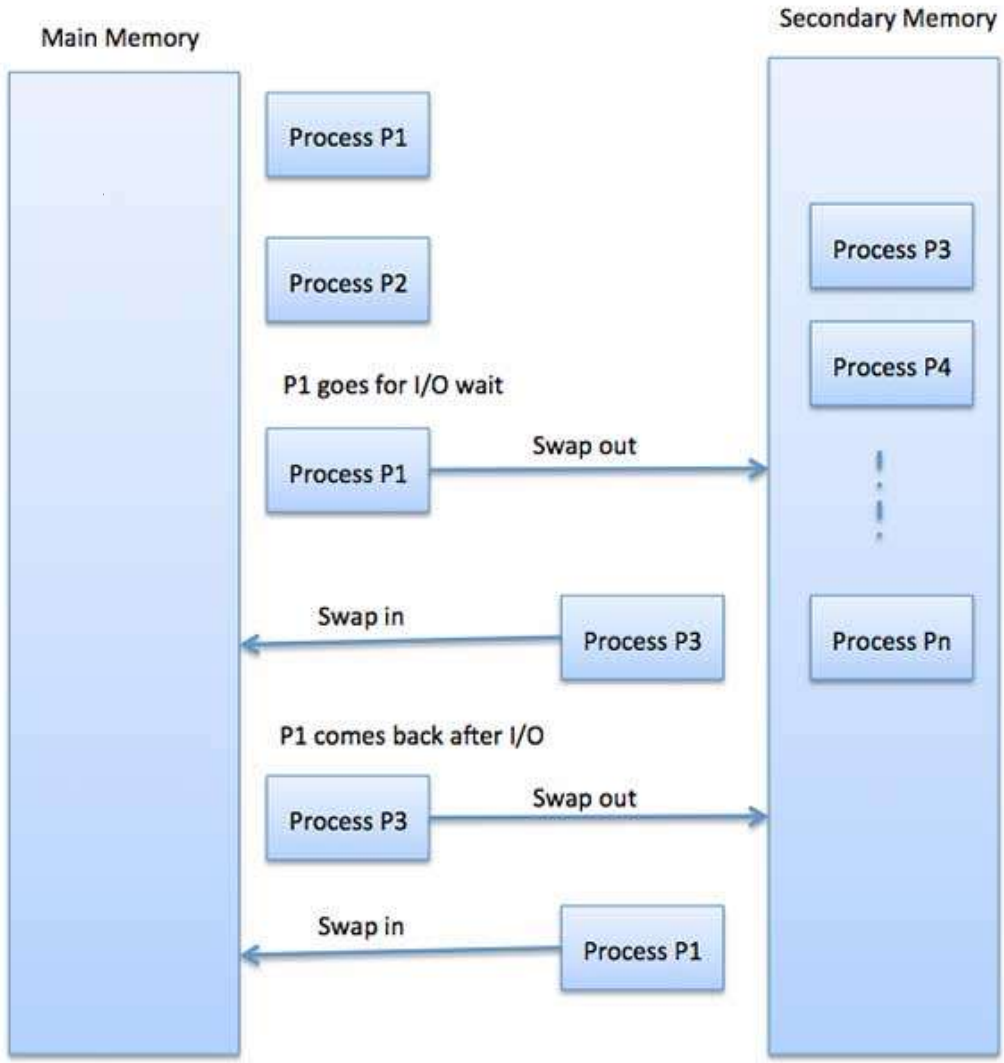
S.N.	Memory Addresses & Description
1	**Symbolic addresses** The addresses used in a source code. The variable names, constants, and instruction labels are the basic elements of the symbolic address space.

2	**Relative addresses** At the time of compilation, a compiler converts symbolic addresses into relative addresses.
3	**Physical addresses** The loader generates these addresses at the time when a program is loaded into main memory.

Swapping

Swapping is a mechanism in which a process can be swapped temporarily out of main memory (or move) to secondary storage (disk) and make that memory available to other processes. At some later time, the system swaps back the process from the secondary storage to main memory.

Though performance is usually affected by swapping process but it helps in running multiple and big processes in parallel and that's the reason **Swapping is also known as a technique for memory compaction**.



The total time taken by swapping process includes the time it takes to move the entire process to a secondary disk and then to copy the process back to memory, as well as the time the process takes to regain main memory.

Let us assume that the user process is of size 2048KB and on a standard hard disk where swapping will take place has a data transfer rate around 1 MB per second. The actual transfer of the 1000K process to or from memory will take

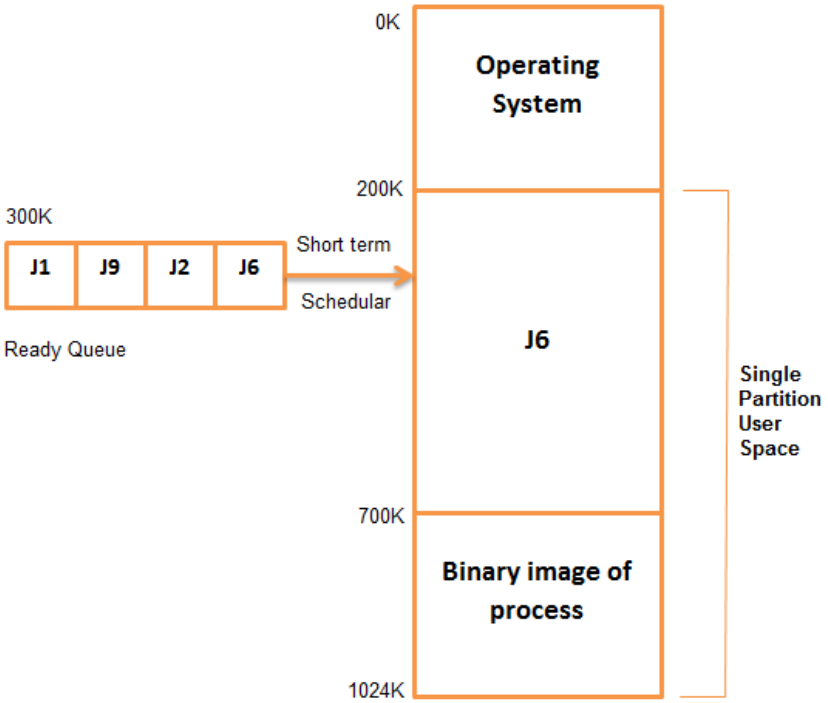
```
2048KB / 1024KB per second
= 2 seconds
= 2000 milliseconds
```

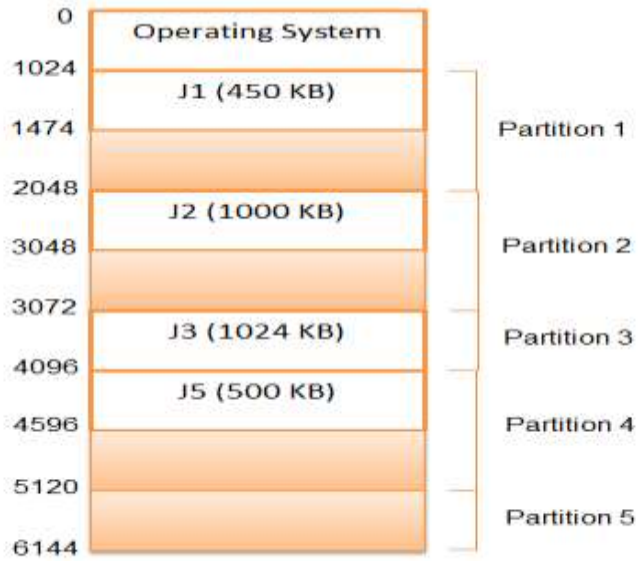
Memory Allocation

Main memory usually has two partitions −

- **Low Memory** − Operating system resides in this memory.
- **High Memory** − User processes are held in high memory.

Operating system uses the following memory allocation mechanism.

S.N.	Memory Allocation & Description
1	**Single-partition allocation** In this type of allocation, relocation-register scheme is used to protect user processes from each other, and from changing operating-system code and data.  Fig: Memory Allocation for Single Partitioned

2	**Multiple-partition allocation** In this type of allocation, main memory is divided into a number of fixed-sized partitions where each partition should contain only one process. When a partition is free, a process is selected from the input queue and is loaded into the free partition. When the process terminates, the partition becomes available for another process.  **Fig: Memory Allocation for Multiple Partitioned**

Fragmentation

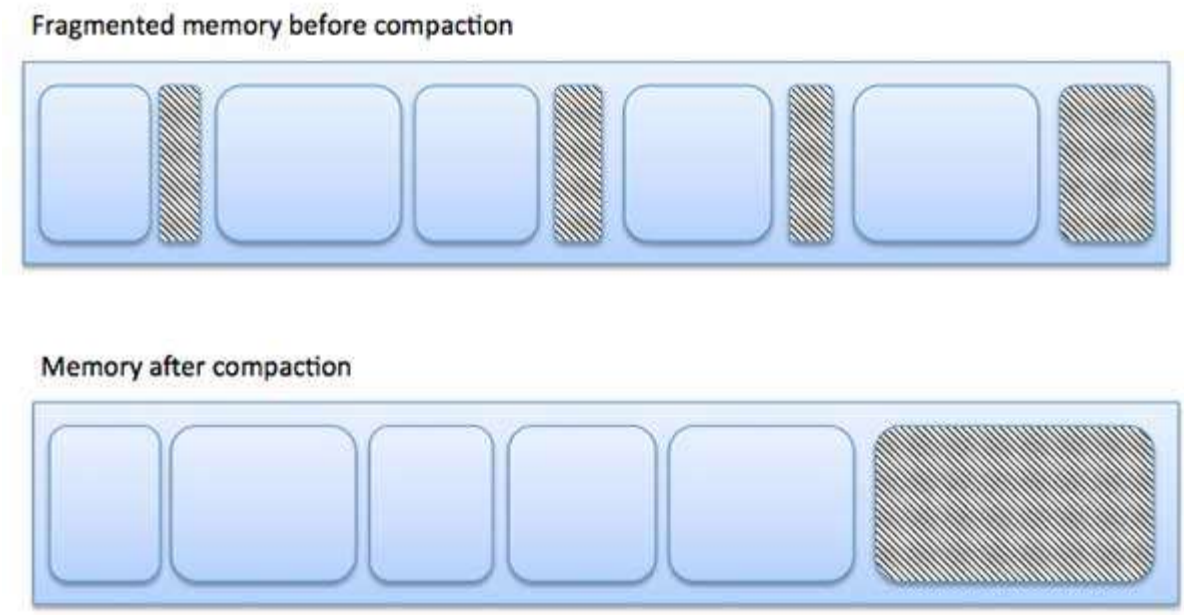
As processes are loaded and removed from memory, the free memory space is broken into little pieces. It happens after sometimes that processes cannot be allocated to memory blocks considering their small size and memory blocks remains unused. This problem is known as Fragmentation.

Fragmentation is of two types −

S.N.	Fragmentation & Description
1	**External fragmentation** Total memory space is enough to satisfy a request or to reside a process in it, but it is not contiguous, so it cannot be used.

2	**Internal fragmentation** Memory block assigned to process is bigger. Some portion of memory is left unused, as it cannot be used by another process.

The following diagram shows how fragmentation can cause waste of memory and a compaction technique can be used to create more free memory out of fragmented memory −



External fragmentation can be reduced by compaction or shuffle memory contents to place all free memory together in one large block. To make compaction feasible, relocation should be dynamic.

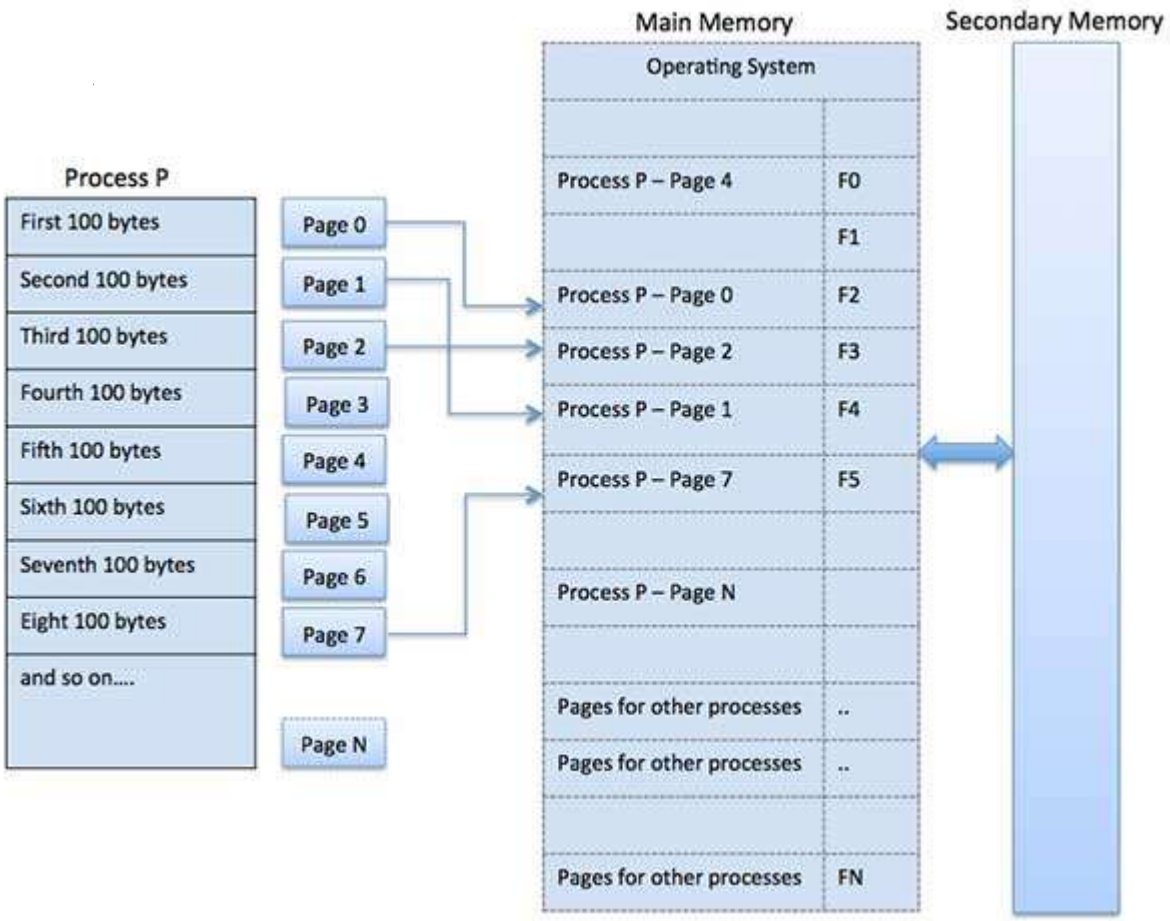
The internal fragmentation can be reduced by effectively assigning the smallest partition but large enough for the process.

Paging

A computer can address more memory than the amount physically installed on the system. This extra memory is actually called virtual memory and it is a section of a hard that's set up to emulate the computer's RAM. Paging technique plays an important role in implementing virtual memory.

Paging is a memory management technique in which process address space is broken into blocks of the same size called **pages** (size is power of 2, between 512 bytes and 8192 bytes). The size of the process is measured in the number of pages.

Similarly, main memory is divided into small fixed-sized blocks of (physical) memory called **frames** and the size of a frame is kept the same as that of a page to have optimum utilization of the main memory and to avoid external fragmentation.



Advantages and Disadvantages of Paging

Here is a list of advantages and disadvantages of paging −

- Paging reduces external fragmentation, but still suffer from internal fragmentation.
- Paging is simple to implement and assumed as an efficient memory management technique.
- Due to equal size of the pages and frames, swapping becomes very easy.
- Page table requires extra memory space, so may not be good for a system having small RAM.

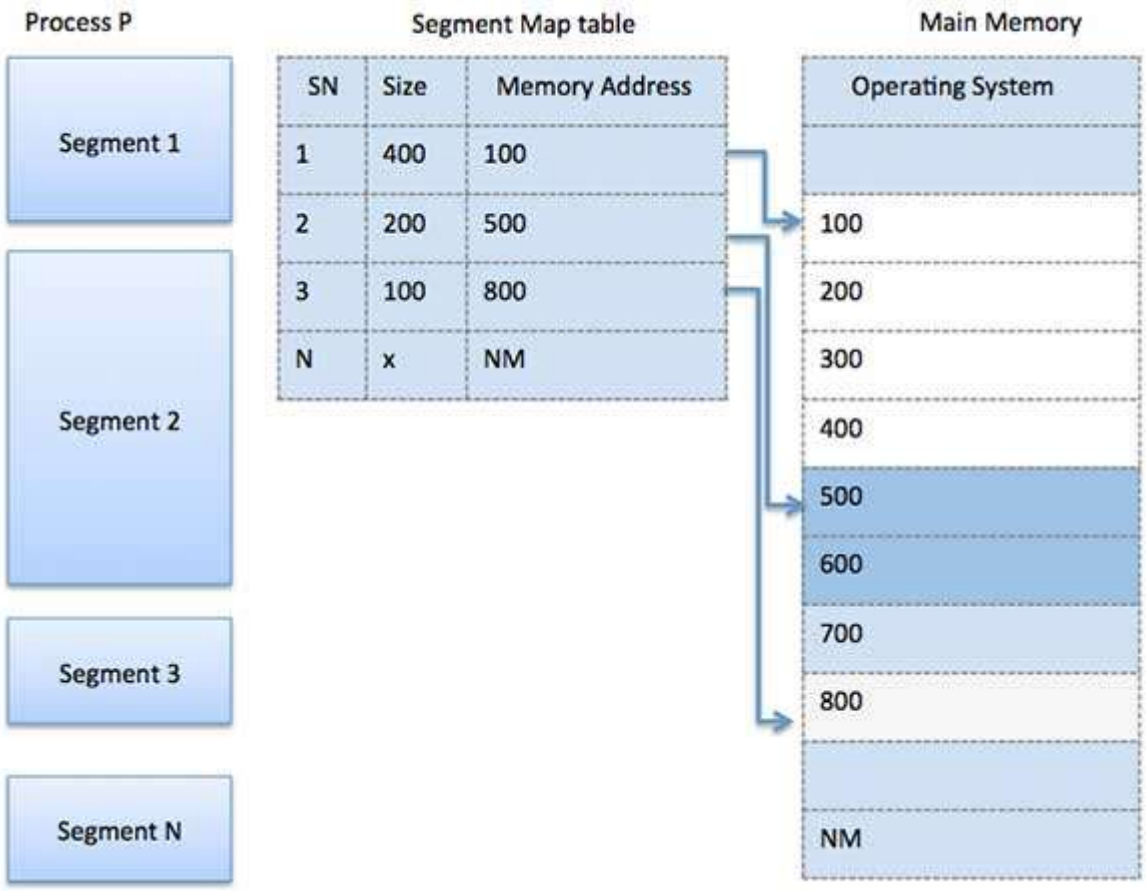
Segmentation

Segmentation is a memory management technique in which each job is divided into several segments of different sizes, one for each module that contains pieces that perform related functions. Each segment is actually a different logical address space of the program.

When a process is to be executed, its corresponding segmentation are loaded into non-contiguous memory though every segment is loaded into a contiguous block of available memory.

Segmentation memory management works very similar to paging but here segments are of variable-length where as in paging pages are of fixed size.

A program segment contains the program's main function, utility functions, data structures, and so on. The operating system maintains a **segment map table** for every process and a list of free memory blocks along with segment numbers, their size and corresponding memory locations in main memory. For each segment, the table stores the starting address of the segment and the length of the segment. A reference to a memory location includes a value that identifies a segment and an offset.



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Virtual Memory

Virtual Memory is a storage scheme that provides user an illusion of having a very big main memory. This is done by treating a part of secondary memory as the main memory.

In this scheme, User can load the bigger size processes than the available main memory by having the illusion that the memory is available to load the process.

Instead of loading one big process in the main memory, the Operating System loads the different parts of more than one process in the main memory.

By doing this, the degree of multiprogramming will be increased and therefore, the CPU utilization will also be increased.

How Virtual Memory Works?

In modern word, virtual memory has become quite common these days. In this scheme, whenever some pages needs to be loaded in the main memory for the execution and the memory is not available for those many pages, then in that case, instead of stopping the pages from entering in the main memory, the OS search for the RAM area that are least used in the recent times or that are not referenced and copy that into the secondary memory to make the space for the new pages in the main memory.

Since all this procedure happens automatically, therefore it makes the computer feel like it is having the unlimited RAM.

Demand Paging

Demand Paging is a popular method of virtual memory management. In demand paging, the pages of a process which are least used, get stored in the secondary memory,

A page is copied to the main memory when its demand is made or page fault occurs. There are various page replacement algorithms which are used to determine the pages which will be replaced.

Advantages of Virtual Memory

1. The degree of Multiprogramming will be increased.
2. User can run large application with less real RAM.
3. There is no need to buy more memory RAMs.

Disadvantages of Virtual Memory

1. The system becomes slower since swapping takes time.
2. It takes more time in switching between applications.
3. The user will have the lesser hard disk space for its use.

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File Systems in Operating System

A file is a collection of related information that is recorded on secondary storage.

The name of the file is divided into two parts as shown below:

- name
- extension, separated by a period

FILE DIRECTORIES:

Collection of files is a file directory. The directory contains information about the files, including attributes, location and ownership. Much of this information, especially that is concerned with storage,

Information contained in a device directory are:

- Name
- Type
- Address
- Current length
- Maximum length
- Date last accessed
- Date last updated
- Owner id
- Protection information

Operation performed on directory are:

- Search for a file
- Create a file
- Delete a file
- List a directory
- Rename a file
- Traverse the file system

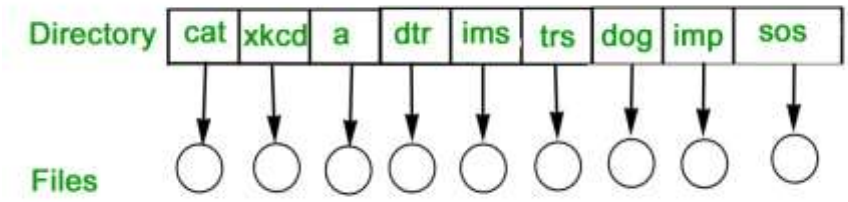
Advantages of maintaining directories are:

- **Efficiency:** A file can be located more quickly.
- **Naming:** It becomes convenient for users as two users can have same name for different files or may have different name for same file.
- **Grouping:** Logical grouping of files can be done by properties e.g. all java programs, all games etc.

SINGLE-LEVEL DIRECTORY

In this a single directory is maintained for all the users.

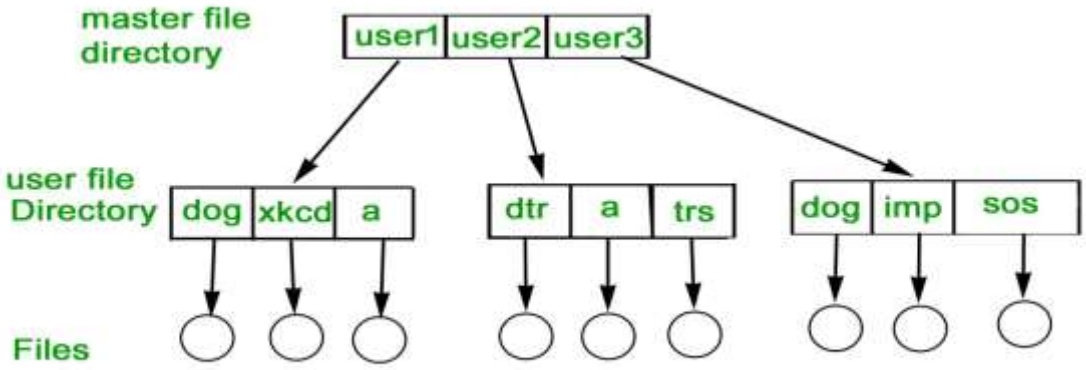
- **Naming problem:** Users cannot have same name for two files.
- **Grouping problem:** Users cannot group files according to their need.



TWO-LEVEL DIRECTORY

In this separate directories for each user is maintained.

- Path name:Due to two levels there is a path name for every file to locate that file.
- Now,we can have same file name for different user.
- Searching is efficient in this method.



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Protection in File System

In computer systems, alot of user's information is stored, the objective of the operating system is to keep safe the data of the user from the improper access to the system. Protection can be provided in number of ways. For a single laptop system, we might provide protection by locking the computer in a desk drawer or file cabinet. For multi-user systems, different mechanisms are used for the protection.

Types of Access :
The files which have direct access of the any user have the need of protection. The files which are not accessible to other users doesn't require any kind of protection. The mechanism of the protection provide the facility of the controlled access by just limiting the types of access to the file. Access can be given or not given to any user depends on several factors, one of which is the type of access required. Several different types of operations can be controlled:

- **Read –**
  Reading from a file.
- **Write –**
  Writing or rewriting the file.
- **Execute –**
  Loading the file and after loading the execution process starts.
- **Append –**
  Writing the new information to the already existing file, editing must be end at the end of the existing file.
- **Delete –**
  Deleting the file which is of no use and using its space for the another data.
- **List –**
  List the name and attributes of the file.

Operations like renaming, editing the existing file, copying; these can also be controlled. There are many protection mechanism. each of them mechanism have different advantages and disadvantages and must be appropriate for the intended application.

Access Control :
The general way of protection is to associate *identity-dependent access* with all the files and directories an list called access-control list (ACL) which specify the names of the users and the types of access associate with each of the user. The main problem with the access list is their **length.** If we want to allow everyone to read a file, we must list all the users with the read access. **This technique has two undesirable consequences:** Constructing such a list may be tedious and unrewarding task, especially if we do not know in advance the list of the users in the system.

Previously, the entry of the any directory is of the fixed size but now it changes to the variable size which results in the complicates space management. These problems can be resolved by use of a condensed version of the access list. To condense the length of the access-control list, many systems recognize three classification of users in connection with each file:

- **Owner –**
  Owner is the user who has created the file.
- **Group –**
  A group is a set of members who has similar needs and they are sharing the same file.
- **Universe –**
  In the system, all other users are under the category called universe.

Other Protection Approaches:
The access to any system is also controlled by the **password**. If the use of password are random and it is changed often, this may be result in limit the effective access to a file. The use of **passwords has a few disadvantages:**

- The number of passwords are very large so it is difficult to remember the large passwords.
- If one password is used for all the files, then once it is discovered, all files are accessible;

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Storage Structure in Operating Systems

Basically we want the programs and data to reside in main memory permanently.
This arrangement is usually not possible for the following two reasons:

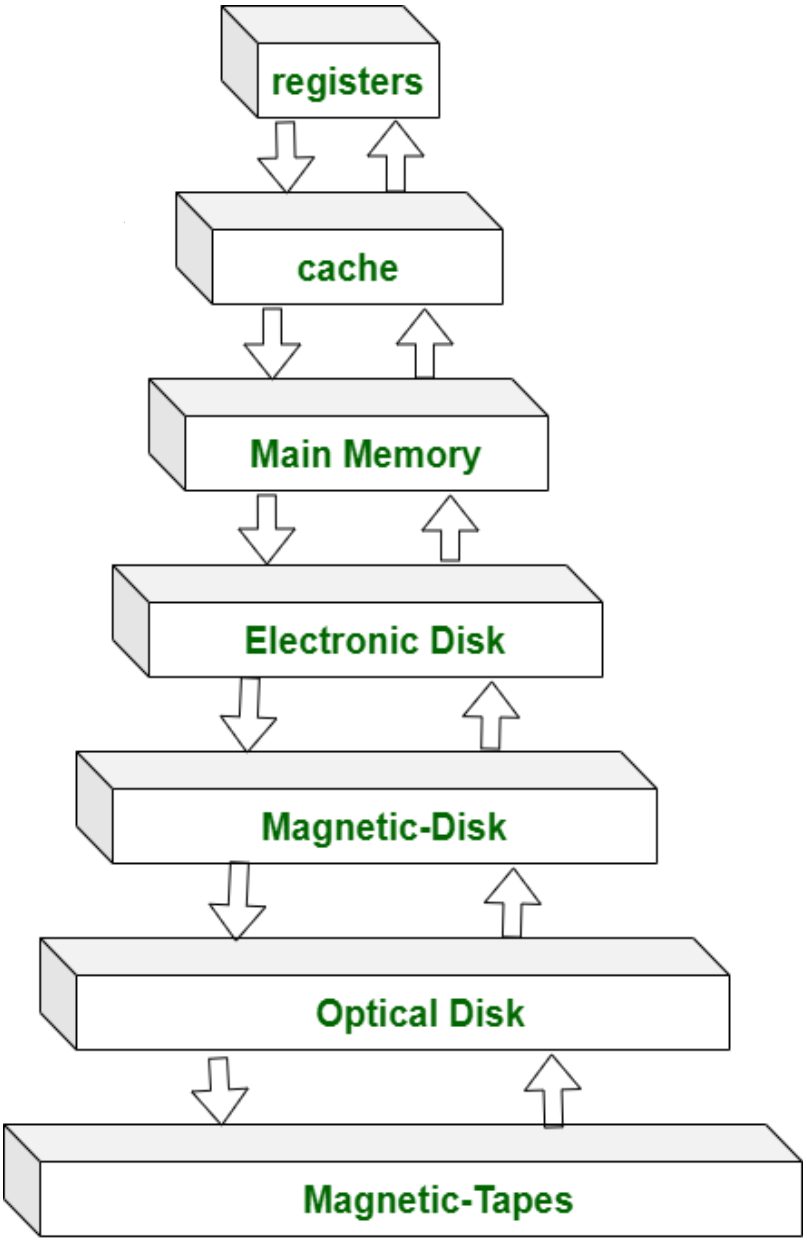
1. Main memory is usually too small to store all needed programs and data permanently.
2. Main memory is a volatile storage device that loses its contents when power is turned off or otherwise lost.

There are two types of storage devices:-

- **Volatile Storage Device –**
  It loses its contents when the power of the device is removed.
- **Non-Volatile Storage device –**
  It does not loses its contents when the power is removed. It holds all the data when the power is removed.

Secondary Storage is used as an extension of main memory. Secondary storage devices can hold the data permanently.
Storage devices consists of Registers, Cache, Main-Memory, Electronic-Disk, Magnetic-Disk, Optical-Disk, Magnetic-Tapes. Each storage system provides the basic system of storing a datum and of holding the datum until it is retrieved at a later time. All the storage devices differ in speed, cost, size and volatility. The most common Secondary-storage device is a Magnetic-disk, which provides storage for both programs and data.

In this fig Hierarchy of storage is shown –



Storage Device Hierarchy

In this hierarchy all the storage devices are arranged according to speed and cost. The higher levels are expensive, but they are fast. As we move down the hierarchy, the cost per bit generally decreases,

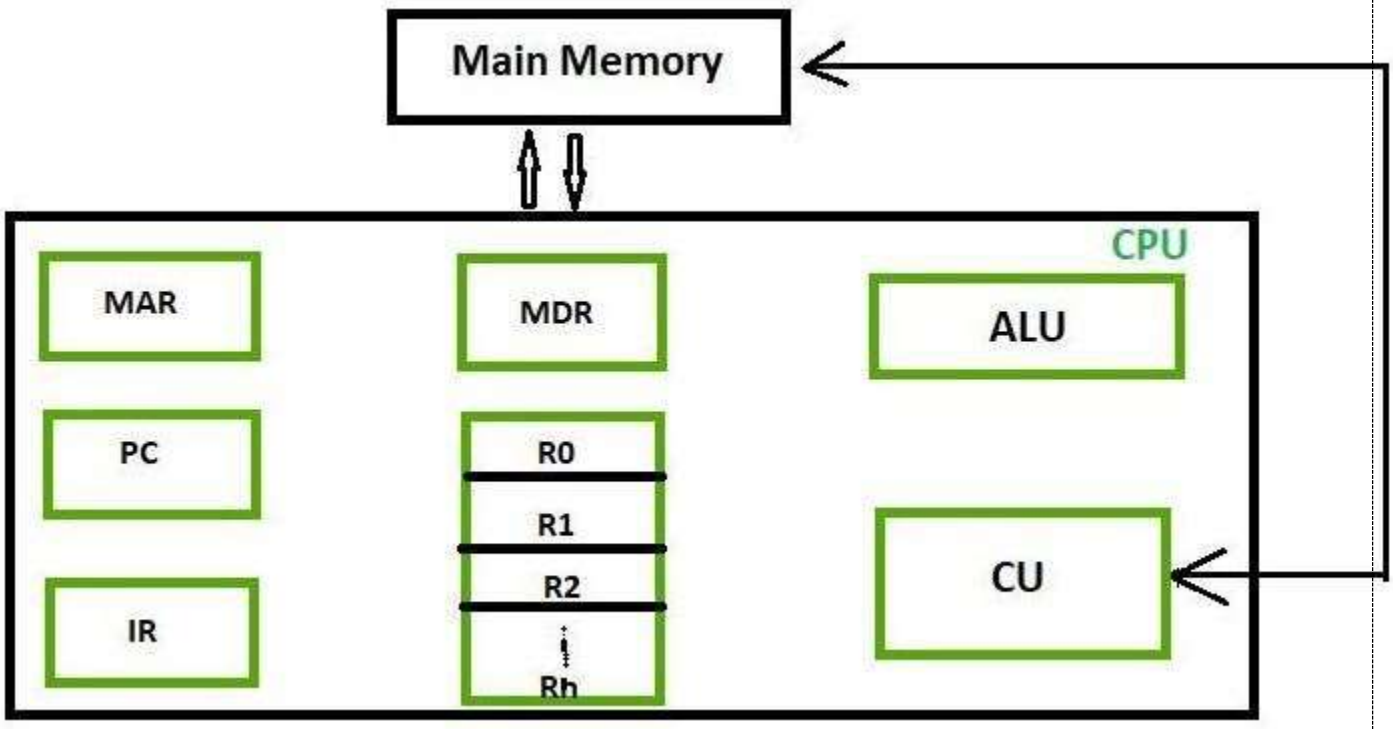
An Electronic disk can be either designed to be either Volatile or Non-Volatile. During normal operation, the electronic disk stores data in a large DRAM array, which is Volatile. But many electronic disk devices contain a hidden magnetic hard disk and a

battery for backup power. If external power is interrupted, the electronic disk controller copies the data from RAM to the magnetic disk. When external power is restored, the controller copies the data back into the RAM.

Different Classes of CPU Registers

the Registers are very fast computer memory which are used to execute programs and operations efficiently. This does by giving access to commonly used values, i.e., the values which are in the point of operation/execution at that time. So, for this purpose, there are several different classes of CPU registers which works in coordination with the computer memory to run operations efficiently.

The purpose of having register is fast retrieval of data for processing by CPU. Though accessing instructions from RAM is comparatively faster with hard drive, it still isn't enough for CPU. For even better processing, there are memories in CPU which can get data from RAM which are about to be executed. After registers we have cache memory, which are faster but less faster than registers.



These are classified as given below.

These are the different registers which are operating for a specific purpose.

- **Accumulator:**
  This is the most frequently used register used to store data taken from memory. It is in different numbers in different microprocessors.

- **Memory Address Registers (MAR):**
  It holds the address of the location to be accessed from memory.

- **Memory Data Registers (MDR):**
  It contains data to be written into or to be read out from the addressed location.

- **General Purpose Registers:**
  These are numbered as R0, R1, R2….Rn-1, and used to store temporary data during any ongoing operation. Its content can be accessed by assembly programming. Modern CPU architectures tends to use more GPR

- **Program Counter (PC):**
  Program Counter (PC) is used to keep the track of execution of the program. It contains the memory address of the next instruction to be fetched. PC points to the address of the next instruction to be fetched from the main memory when the previous instruction has been successfully completed. Program Counter (PC) also functions to count the number of instructions.

- **Instruction Register (IR):**
  The IR holds the instruction which is just about to be executed. The instruction from PC is fetched and stored in IR. As soon as the instruction in placed in IR, the CPU starts executing the instruction and the PC points to the next instruction to be executed.

- **Condition code register (CCR) :**
  Condition code registers contain different flags that indicate the status of any operation.for instance lets suppose an operation caused creation of a negative result or zero, then these flags are set high accordingly.

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System Protection in Operating System

Protection refers to a mechanism which controls the access of programs, processes, or users to the resources defined by a computer system. We can take protection as a helper to multi programming operating system, so that many users might safely share a common logical name space such as directory or files.

Hardware Protection and Type of Hardware Protection

we know that a computer system contains the hardware like processor, monitor, RAM and many more, and one thing that the operating system ensures that these devices can not directly accessible by the user.

Basically, hardware protection is divided into 3 categories: CPU protection, Memory Protection, and I/O protection. These are explained as following below.

1. **CPU Protection:**
   CPU protection is referred to as we can not give CPU to a process forever, it should be for some limited time otherwise other processes will not get

the chance to execute the process. So for that, a timer is used to get over from this situation. which is basically give a certain amount of time a process and after the timer execution a signal will be sent to the process to leave the CPU. hence process will not hold CPU for more time.

2. **Memory Protection:**
   In memory protection, we are talking about that situation when two or more processes are in memory and one process may access the other process memory. and to prevent this situation we are using two registers as:

1. Bare register
2. Limit register

So basically Bare register store the starting address of program and limit register store the size of the process, so when a process wants to access the memory then it is checked that it can access or can not access the memory.

3. I/O Protection:
So when we're ensuring the I/O protection then some cases will never have occurred in the system as:
1. Termination I/O of other process
2. View I/O of other process
3. Giving priority to a particular process I/O