OPERATING SYSTEMS

What is a process and process table? What are different states of process?

Ans: A process is an instance of program in execution. For example a Web Browser is a process, a shell (or command prompt) is a process. The operating system is responsible for managing all the processes that are running on a computer and allocated each process a certain amount of time to use the processor. In addition, the operating system also allocates various other resources that processes will need such as computer memory or disks. To keep track of the state of all the processes, the operating system maintains a table known as the process table. Inside this table, every process is listed along with the resources the processes is using and the current state of the process.
Processes can be in one of three states: running, ready, or waiting. The running state means that the process has all the resources it need for execution and it has been given permission by the operating system to use the processor. Only one process can be in the running state at any given time. The remaining processes are either in a waiting state (i.e., waiting for some external event to occur such as user input or a disk access) or a ready state (i.e., waiting for permission to use the processor). In a real operating system, the waiting and ready states are implemented as queues which hold the processes in these states.

What is a Thread? What are the differences between process and thread?

Ans: A thread is a single sequence stream within in a process. Because threads have some of the properties of processes, they are sometimes called lightweight processes. Threads are popular way to improve application through parallelism. For example, in a browser, multiple tabs can be different threads. MS word uses multiple threads, one thread to format the text, other thread to process inputs, etc.
A thread has its own program counter (PC), a register set, and a stack space. Threads are not independent of one other like processes as a result threads shares with other threads their code section, data section and OS resources like open files and signals.

What are the benefits of multithreaded programming?

Ans: It makes the system more responsive and enables resource sharing. It leads to the use of multiprocess architectur.It is more economical and preferred.

What are the different scheduling algorithms?

Ans: First-Come First-Served (FCFS) Scheduling, Shortest-Job-Next (SJN) Scheduling, Priority Scheduling, Shortest Remaining Time, Round-Robin (RR) Scheduling, Multiple-Level Queues Scheduling.

What is deadlock?

Ans: Deadlock is a situation when two or more processes wait for each other to finish and none of them ever finish. Consider an example when two trains are coming toward each other on same track and there is only one track, none of the trains can move once they are in front of each other. Similar situation occurs in operating systems when there are two or more processes hold some resources and wait for resources held by other(s).

What are the necessary conditions for deadlock?

Ans: *Mutual Exclusion*: There is a resource that cannot be shared.
Hold and Wait: A process is holding at least one resource and waiting for another resource which is with some other process.
No Preemption: The operating system is not allowed to take a resource back from a process until process gives it back.
Circular Wait: A set of processes are waiting for each other in circular form.

What is Virtual Memory? How is it implemented?

Ans: Virtual memory creates an illusion that each user has one or more contiguous address spaces, each beginning at address zero. The sizes of such virtual address spaces is generally very high.
The idea of virtual memory is to use disk space to extend the RAM. Running processes don't need to care whether the memory is from RAM or disk. The illusion of such a large amount of memory is created by subdividing the virtual memory into smaller pieces, which can be loaded into physical memory whenever they are needed by a process.

What is Thrashing?

Ans: Thrashing is a situation when the performance of a computer degrades or collapses. Thrashing occurs when a system spends more time processing page faults than executing transactions. While processing page faults is necessary to in order to appreciate the benefits of virtual memory, thrashing has a negative affect on the system. As the page fault rate increases, more transactions need processing from the paging device. The queue at the paging device increases, resulting in increased service time for a page fault.

What is Belady's Anomaly?

Ans: Bélády's anomaly is an anomaly with some page replacement policies where increasing the number of page frames results in an increase in the number of page faults. It occurs with First in First Out page replacement is used.

Operating Systems: It is the interface between the user and the computer hardware.

Types of Operating Systems

1. **Batch OS:** A set of similar jobs are stored in the main memory for execution. A job gets assigned to the CPU, only when the execution of the previous job completes.

2. **Multiprogramming OS:** The main memory consists of jobs waiting for CPU time. The OS selects one of the processes and assigns it to the CPU. Whenever the executing process needs to wait for any other operation (like I/O), the OS selects another process from the job queue and assigns it to the CPU. This way, the CPU is never kept idle and the user gets the flavor of getting multiple tasks done at once.

3. **Multitasking OS:** Multitasking OS combines the benefits of Multiprogramming OS and CPU scheduling to perform quick switches between jobs. The switch is so quick that the user can interact with each program as it runs.

4. **Time-Sharing OS: T**ime-sharing systems require interaction with the user to instruct the OS to perform various tasks. The OS responds with an output. The instructions are usually given through an input device like the keyboard.

5. **Real-Time OS:** Real-Time OS are usually built for dedicated systems to accomplish a specific set of tasks within deadlines.

Threads

A thread is a lightweight process and forms the basic unit of CPU utilization. A process can perform more than one task at the same time by including multiple threads. A thread has its own program counter, register set, and stack. A thread shares resources with other threads of the same process the code section, the data section, files and signals. A new thread, or a child process of a given process, can be introduced by using the fork() system call. A process with n fork() system calls generates $2^n - 1$ child processes. There are two types of threads: Kernel Threads, User Threads.

Differences between User Threads and Kernel Threads

User Level Thread	Kernel Level Thread
User threads are implemented by users.	Kernel threads are implemented by OS.
OS doesn't recognize user level threads.	Kernel threads are recognized by OS.
Implementation of User threads is easy.	Implementation of Kernel thread is complicated.
Context switch time is less.	Context switch time is more.
Context switch requires no hardware support.	Hardware support is needed.
If one user level thread performs blocking operation then entire process will be blocked.	If one kernel thread performs blocking operation then another thread can continue execution.

Process

A process is a program under execution. The value of program counter (PC) indicates the address of the next instruction of the process being executed. Each process is represented by a Process Control Block (PCB).

Process Scheduling: Below are different times with respect to a process:

1. Arrival Time – Time at which the process arrives in the ready queue.
2. Completion Time – Time at which process completes its execution.
3. Burst Time – Time required by a process for CPU execution.
4. Turn Around Time – Time Difference between completion time and arrival time.
5. Waiting Time (WT) – Time Difference between turn around time and burst time.

Why do we need Scheduling?

A typical process involves both I/O time and CPU time. In a uniprogramming system like MS-DOS, time spent waiting for I/O is wasted and CPU is free during this time. In multiprogramming systems, one process can use CPU while another is waiting for I/O. This is possible only with process scheduling.

Objectives of Process Scheduling Algorithm:

- Max CPU utilization (Keep CPU as busy as possible)
- Fair allocation of CPU.
- Max throughput (Number of processes that complete their execution per time unit)
- Min turnaround time (Time taken by a process to finish execution)
- Min waiting time (Time for which a process waits in ready queue)
- Min response time (Time when a process produces first response)

Different Scheduling Algorithms:

1. **First Come First Serve (FCFS) Scheduling:** Simplest scheduling algorithm that schedules according to arrival times of processes.

2. **Shortest Job First (SJF):** Process which have the shortest burst time are scheduled first.

3. **Shortest Remaining Time First (SRTF):** It is preemptive mode of SJF algorithm in which jobs are scheduled according to the shortest remaining time.

4. **Round Robin (RR) Scheduling:** Each process is assigned a fixed time, in cyclic way.

5. **Priority Based Scheduling (Non preemptive):** In this scheduling, processes are scheduled according to their priorities, i.e., highest priority process is schedule first. If priorities of two processes match, then scheduling is according to the arrival time.

6. **Highest Response Ratio Next (HRRN):** In this scheduling, processes with highest response ratio is scheduled. This algorithm avoids starvation. **Response Ratio = (Waiting Time + Burst time) / Burst time**

7. **Multilevel Queue (MLQ) Scheduling:** According to the priority of process, processes are placed in the different queues. Generally high priority process are placed in the top level queue. Only after completion of processes from top level queue, lower level queued processes are scheduled.

8. **Multilevel Feedback Queue (MLFQ) Scheduling:** It allows the process to move in between queues. The idea is to separate processes according to the characteristics of their CPU bursts. If a process uses too much CPU time, it is moved to a lower-priority queue.

Some useful facts about Scheduling Algorithms:

- FCFS can cause long waiting times, especially when the first job takes too much CPU time.
- Both SJF and Shortest Remaining time first algorithms may cause starvation. Consider a situation when a long process is there in the ready queue and shorter processes keep coming.
- If time quantum for Round Robin scheduling is very large, then it behaves same as FCFS scheduling.
- SJF is optimal in terms of average waiting time for a given set of processes. SJF gives minimum average waiting time, but problems with SJF is how to know/predict the time of next job.

The Critical Section Problem

1. **Critical Section –** The portion of the code in the program where shared variables are accessed and/or updated.

2. **Remainder Section –** The remaining portion of the program excluding the Critical Section.

3. **Race around Condition –** The final output of the code depends on the order in which the variables are accessed. This is termed as the race around condition.

A solution for the critical section problem must satisfy the following three conditions:

- **Mutual Exclusion –** If a process Pi is executing in its critical section, then no other process is allowed to enter into the critical section.
- **Progress –** If no process is executing in the critical section, then the decision of a process to enter a critical section cannot be made by any other process that is executing in its remainder section. The selection of the process cannot be postponed indefinitely.
- **Bounded Waiting –** There exists a bound on the number of times other processes can enter into the critical section after a process has made request to access the critical section and before the requested is granted.

Synchronization Tools

A Semaphore is an integer variable that is accessed only through two atomic operations, wait () and signal (). An atomic operation is executed in a single CPU time slice without any pre-emption. Semaphores are of two types:

- **Counting Semaphore –** A counting semaphore is an integer variable whose value can range over an unrestricted domain.

- **Mutex –** These can have only two values, 0 or 1. The operations wait () and signal () operate on these in a similar fashion. Mutex is different than a semaphore as it is a locking mechanism while a semaphore is a signalling mechanism. A binary semaphore can be used as a Mutex but a Mutex can never be used as a semaphore.

Deadlock

A situation where a set of processes are blocked because each process is holding a resource and waiting for another resource acquired by some other process. Deadlock can arise if following four conditions hold simultaneously (Necessary Conditions):

- **Mutual Exclusion –** One or more than one resource are non-sharable (Only one process can use at a time).

- **Hold and Wait –** A process is holding at least one resource and waiting for resources.

- **No Preemption –** A resource cannot be taken from a process unless the process releases the resource.

- **Circular Wait –** A set of processes are waiting for each other in circular form.

Methods for handling deadlock: There are three ways to handle deadlock:-

- **Deadlock prevention or avoidance -** The idea is to not let the system into deadlock state.
- **Deadlock detection and recovery -** Let deadlock occur, then do preemption to handle it once occurred.
- **Ignore the problem all together -** If deadlock is very rare, then let it happen and reboot the system. This is the approach that both Windows and UNIX take.

Banker's Algorithm: This algorithm handles multiple instances of the same resource.

Memory Management:

Single Partition Allocation Schemes – The memory is divided into two parts. One part is kept to be used by the OS and the other is kept to be used by the users.

Multiple Partition Schemes -

- **Fixed Partition –** The memory is divided into fixed size partitions.
- **Variable Partition –** The memory is divided into variable sized partitions.

Variable partition allocation schemes:

- **First Fit –** The arriving process is allotted the first hole of memory in which it fits completely.

- **Best Fit –** The arriving process is allotted the hole of memory in which it fits the best by leaving the minimum memory empty.

- **Worst Fit –** The arriving process is allotted the hole of memory in which it leaves the maximum gap.

NOTE:

- Best fit does not necessarily give the best results for memory allocation.
- The cause of external fragmentation is the condition in Fixed partitioning and Variable partitioning saying that entire process should be allocated in a contiguous memory location.Therefore Paging is used.

Paging: The physical memory is divided into equal sized frames. The main memory is divided into fixed size pages. The size of a physical memory frame is equal to the size of a virtual memory frame.

Segmentation: Segmentation is implemented to give users view of memory. The logical address space is a collection of segments. Segmentation can be implemented with or without the use of paging.

Page Fault: A page fault is a type of interrupt, raised by the hardware when a running program accesses a memory page that is mapped into the virtual address space, but not loaded in physical memory.

Page Replacement Algorithms

1. **First In First Out (FIFO) –** This is the simplest page replacement algorithm. In this algorithm, operating system keeps track of all pages in the memory in a queue, oldest page is in the front of the queue. When a page needs to be replaced page in the front of the queue is selected for removal. For example, consider page reference string 1, 3, 0, 3, 5, 6 and 3 page slots. Initially, all slots are empty, so when 1, 3, 0 came they are allocated to the empty slots —> 3 Page Faults. When 3 comes, it is already in memory so —> 0 Page Faults. Then 5 comes, it is not available in memory so it replaces the oldest page slot i.e 1. —> 1 Page Fault. Finally, 6 comes, it is also not available in memory so it replaces the oldest page slot i.e 3 —> 1 Page Fault.

2. **Optimal Page replacement -** In this algorithm, pages are replaced which are not used for the longest duration of time in the future. Let us consider page

reference string 7 0 1 2 0 3 0 4 2 3 0 3 2 and 4 page slots. Initially, all slots are empty, so when 7 0 1 2 are allocated to the empty slots —> 4 Page faults. 0 is already there so —> 0 Page fault. When 3 came it will take the place of 7 because it is not used for the longest duration of time in the future.—> 1 Page fault. 0 is already there so —> 0 Page fault. 4 will takes place of 1 —> 1 Page Fault. Now for the further page reference string —> 0 Page fault because they are already available in the memory.

3. **Least Recently Used (LRU) -** In this algorithm, the page will be replaced which is least recently used. Let say the page reference string 7 0 1 2 0 3 0 4 2 3 0 3 2 . Initially, we have 4-page slots empty. Initially, all slots are empty, so when 7 0 1 2 are allocated to the empty slots —> 4 Page faults. 0 is already their so —> 0 Page fault. When 3 came it will take the place of 7 because it is least recently used —> 1 Page fault. 0 is already in memory so —> 0 Page fault. 4 will takes place of 1 —> 1 Page Fault. Now for the further page reference string —> 0 Page fault because they are already available in the memory.

File System: A file is a collection of related information that is recorded on secondary storage. Or file is a collection of logically related entities.

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, is managed by the operating system.

- **SINGLE-LEVEL DIRECTORY:** In this a single directory is maintained for all the users.

- **TWO-LEVEL DIRECTORY:** Due to two levels there is a path name for every file to locate that file.

- **TREE-STRUCTURED DIRECTORY:** Directory is maintained in the form of a tree. Searching is efficient and also there is grouping capability.

<u>File Allocation Methods:</u>

- **Continuous Allocation:** A single continuous set of blocks is allocated to a file at the time of file creation.

- **Linked Allocation(Non-contiguous allocation):** Allocation is on an individual block basis. Each block contains a pointer to the next block in the chain.

- **Indexed Allocation:** It addresses many of the problems of contiguous and chained allocation. In this case, the file allocation table contains a separate one-level index for each file.

Disk Scheduling:

Disk scheduling is done by operating systems to schedule I/O requests arriving for disk. Disk scheduling is also known as I/O scheduling.

- **Seek Time:** Seek time is the time taken to locate the disk arm to a specified track where the data is to be read or write.

- **Rotational Latency:** Rotational Latency is the time taken by the desired sector of disk to rotate into a position so that it can access the read/write heads.

- **Transfer Time:** Transfer time is the time to transfer the data. It depends on the rotating speed of the disk and number of bytes to be transferred.

- **Disk Access Time:** Seek Time + Rotational Latency + Transfer Time
- **Disk Response Time:** Response Time is the average of time spent by a request waiting to perform its I/O operation. Average Response time is the response time of the all requests.

Disk Scheduling Algorithms:

1. **FCFS:** FCFS is the simplest of all the Disk Scheduling Algorithms. In FCFS, the requests are addressed in the order they arrive in the disk queue.

2. **SSTF:** In SSTF (Shortest Seek Time First), requests having shortest seek time are executed first. So, the seek time of every request is calculated in advance in a queue and then they are scheduled according to their calculated seek time. As a result, the request near the disk arm will get executed first.

3. **SCAN:** In SCAN algorithm the disk arm moves into a particular direction and services the requests coming in its path and after reaching the end of the disk, it reverses its direction and again services the request arriving in its path. So, this algorithm works like an elevator and hence also known as elevator algorithm.

4. **CSCAN:** In SCAN algorithm, the disk arm again scans the path that has been scanned, after reversing its direction. So, it may be possible that too many

requests are waiting at the other end or there may be zero or few requests pending at the scanned area.

5. **LOOK:** It is similar to the SCAN disk scheduling algorithm except for the difference that the disk arm in spite of going to the end of the disk goes only to the last request to be serviced in front of the head and then reverses its direction from there only. Thus it prevents the extra delay which occurred due to unnecessary traversal to the end of the disk.

6. **CLOOK:** As LOOK is similar to SCAN algorithm, in a similar way, CLOOK is similar to CSCAN disk scheduling algorithm. In CLOOK, the disk arm in spite of going to the end goes only to the last request to be serviced in front of the head and then from there goes to the other end’s last request. Thus, it also prevents the extra delay which occurred due to unnecessary traversal to the end of the disk.