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Operating System

Prof. Sumitra Menaria, Prof. Uma Bhatt,
Assistant Professor Information Technology Department

CHAPTER-2

Processes, Thread & Process Scheduling

Syllabus

Sr.	Topic	Weightage	Teaching Hrs.
2	**PROCESSES, THREAD & PROCESS SCHEDULING:** **Processes:** Definition, Process Relationship, Different states of a Process, Process State transitions, Process Control Block (PCB), Context switching. **Thread:** Definition, Various states, Benefits of threads, Types of threads, Concept of multithreads. **Process Scheduling:** Foundation and Scheduling objectives, Types of Schedulers, Scheduling criteria: CPU utilization, Throughput, Turnaround Time, Waiting Time, Response Time; Scheduling algorithms: Pre-emptive and Non pre-emptive, FCFS, SJF, RR.	20%	9

Process

- **A process is a program in execution.**
- Process is not as same as program code but a lot more than it.
- A process is an 'active' entity as opposed to program which is considered to be a 'passive' entity. Attributes held by process include hardware state, memory, CPU etc.

Main OS Process Related Goals

- Interleave the execution of existing processes to maximize processor utilization
- Provide reasonable response time
- Allocate resources to processes
- Support inter-process communication (and synchronization) and user creation of processes

How are these goals achieved ?

- Schedule and dispatch processes for execution by the processor
- Implement a safe and fair policy for resource allocation to processes
- Respond to requests by user programs
- Construct and maintain tables for each process managed by the operating system

Process Creation

?When is a new process created

- System initialization (Daemons)
- Execution of a process creation system call by a running process
- A user request to create a process
- Initiation of a batch job

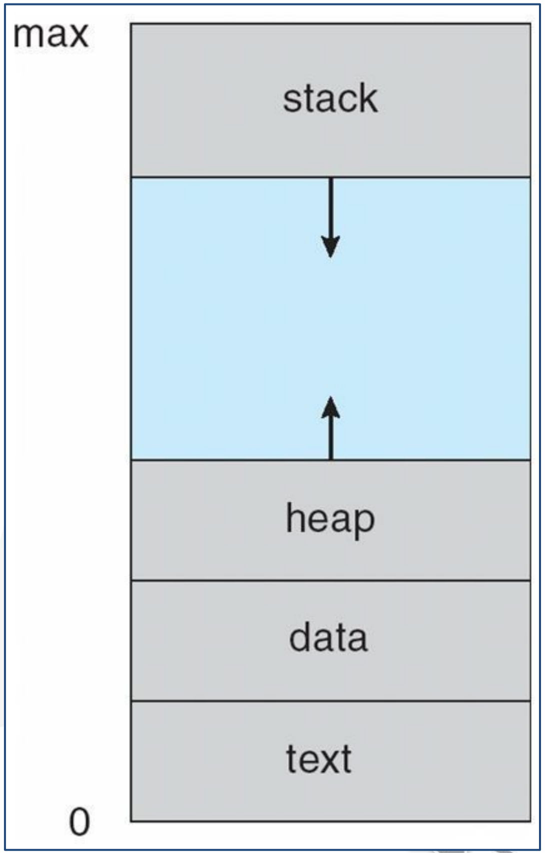
Process Termination

?When does a process terminate

- Normal exit (voluntary)
- Error exit (voluntary)
- Fatal error (involuntary)
- Killed by another process (involuntary)

Contd...

- Programs are executable(.exe) files generally stored in Secondary Memory.
- In order to execute program it must be loaded in main memory.
- When a program is loaded into the memory and it becomes process.
- Then process memory can be divided into four sections – stack, heap, text and data.



Process Stack :Google

Contd..

- The **Text section** is madeup of the compiled program code , read in from non-volatile storage when the program is launched.

- The **Data section** is made up the global and static variables, allocated and initialized prior to executing the main.

- The **Heap Section** is used for the dynamic memory allocation, and is managed via calls to new, delete, malloc, free, etc.

- The **Stack** is used for local variables. Space on the stack is reserved for local variables when they are declared.

Process Vs. Program

Process	Program
A process is program in execution.	**A program is set of instructions.**
A process is an active/ dynamic entity.	A program is a passive/ static entity.
A process has a limited life span. It is created when execution starts and terminated as execution is finished.	A program has a longer life span. It is stored on disk forever.
A process contains various resources like memory address, disk, printer etc... as per requirements.	A program is stored on disk in some file. It does not contain any other resource.
A process contains memory address which is called address space.	A program requires memory space on disk to store all instructions.

Process State

- As a process executes, it changes state.

- The state of a process is defined in part by the current activity of that process. The Process state is an indicator of the nature of the current activity in a Process.

- Processes in the operating system can be in any of the following states:
  - NEW- The process is being created.
  - READY- The process is waiting to be assigned to a processor.
  - RUNNING- Instructions are being executed.
  - WAITING- The process is waiting for some event to occur(such as an I/O completion or reception of a signal).

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Process State & Description

Start

This is the initial state when a process is first started/created.

Ready

The process is waiting to be assigned to a processor. Ready processes are waiting to have the processor allocated to them by the operating system so that they can run.

Process may come into this state after Start state or while running it by but interrupted by the scheduler to assign CPU to some other process.

Contd...

Running

Once the process has been assigned to a processor by the OS scheduler, the process state is set to running and the processor executes its instructions.

Waiting

Process moves into the waiting state if it needs to wait for a resource, such as waiting for user input, or waiting for a file to become available.

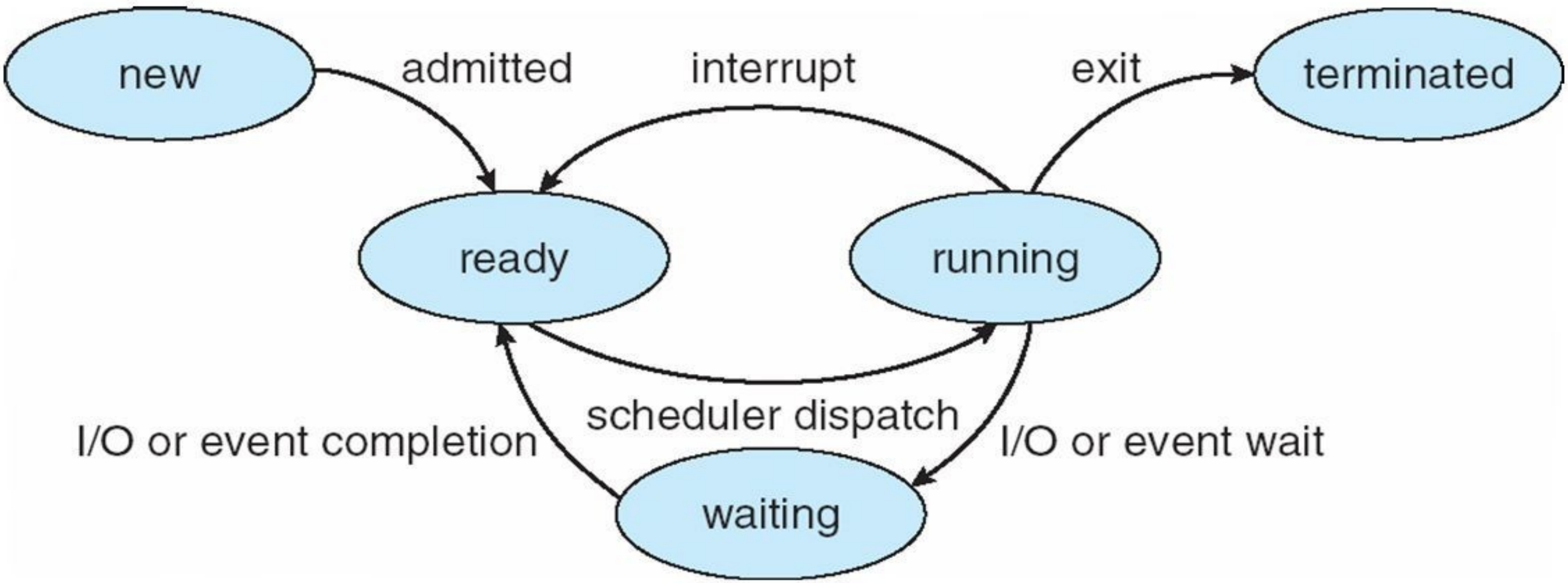
For example the process may be waiting for keyboard input, disk access request, inter-process messages, a timer to go off, or a child process to finish.

Contd..

Terminated or Exit

Once the process finishes its execution, or it is terminated by the operating system, it is moved to the terminated state where it waits to be removed from main memory.

Process State Transitions



Process State[1]

Process Transitions

Ready --> Running

When it is time, the dispatcher selects a new process to run

Running --> Ready

the running process has expired his time slot the running process gets interrupted because a higher priority process is in the ready state

Contd...

Running --> Blocked

When a process requests something for which it must wait
a service that the OS is not ready to perform an access to a resource not yet available initiates I/O and must wait for the result waiting for a process to provide input (IPC).

Blocked --> Ready

When the event for which it was waiting occurs

Process Suspension

- Many OS are built around (Ready, Running, Blocked) states. But there is one more state that may aid in the operation of an OS - suspended state.

- When none of the processes occupying the main memory is in a Ready state, OS swaps one of the blocked processes out onto to the Suspend queue.

- When a Suspended process is ready to run it moves into "Ready, Suspend" queue. Thus we have two more state: **Blocked_Suspend, Ready_Suspend.**

Contd...

- **Blocked_suspend**: The process is in the secondary memory and awaiting an event.

- **Ready_suspend:** The process is in the secondary memory but is available for execution as soon as it is loaded into the main memory.

- Observe on what condition does a state transition take place? What are the possible state transitions?

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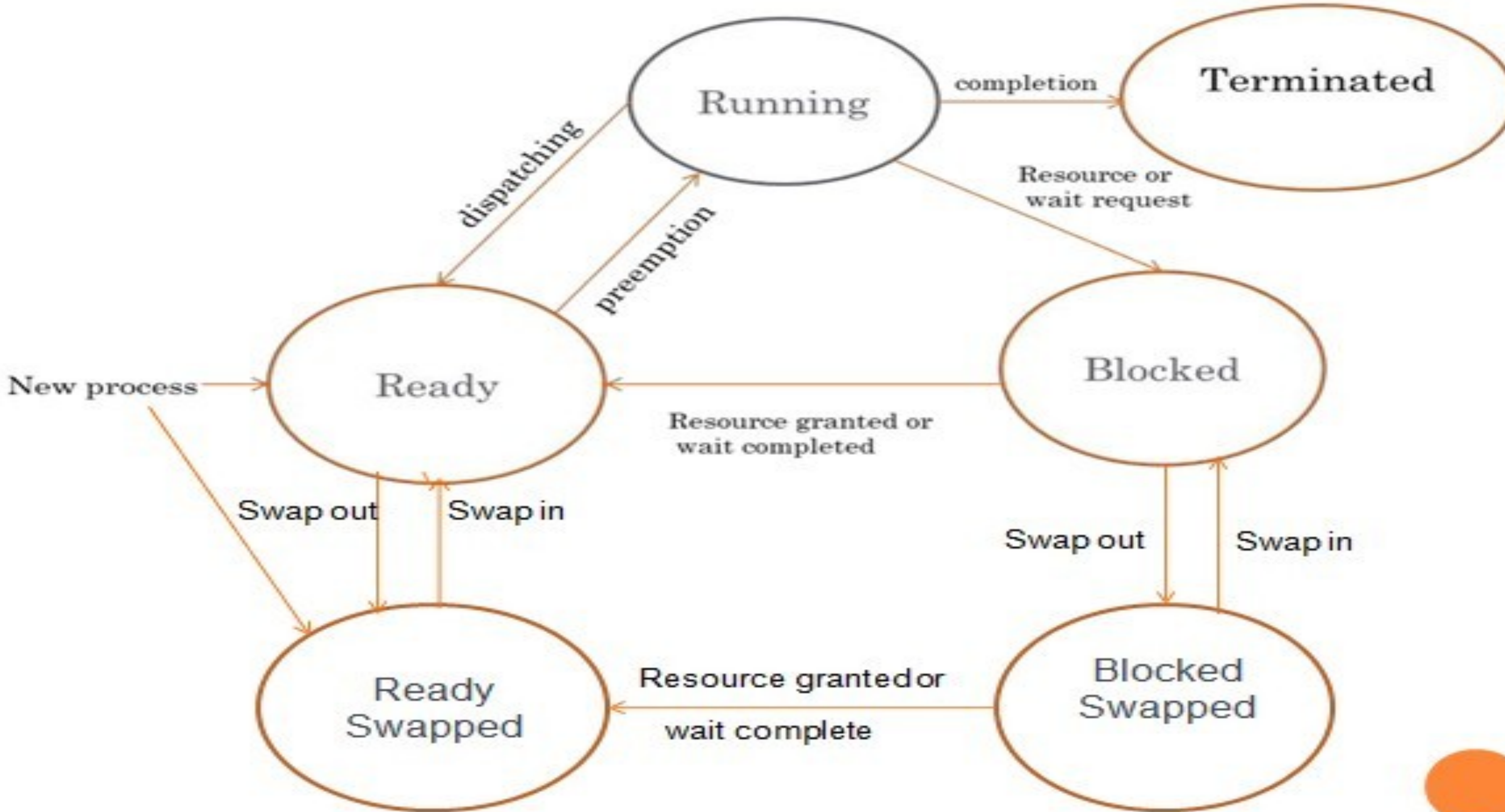


Process Suspension : Google

Process Control Block

- **A Process Control Block is a data structure maintained by the Operating System for every process.**

- The PCB is identified by an integer process ID (PID).

- A PCB keeps all the information needed to keep track of a process

Process Control Block :Google

Contd...

1	**Process State** : The current state of the process i.e., whether it is ready, running, waiting, or whatever.
2	**Process privileges** : This is required to allow/disallow access to system resources.
3	**Process ID** : Unique identification for each of the process in the operating system.
4	**Pointer :** A pointer to parent process.

Table : 2.1 Process States Attributes

Contd...

5	**Program Counter** : Program Counter is a pointer to the address of the next instruction to be executed for this process.
6	**CPU registers** : Various CPU registers where process need to be stored for execution for running state.
7	**CPU Scheduling Information** : Process priority and other scheduling information which is required to schedule the process.
8	**Memory management information** :information of page table, memory limits, Segment table depending on memory used by the OS
9	**Accounting information** :This includes the amount of CPU used for process execution, time limits, execution ID etc.
10	**IO status information** : list of I/O devices allocated to the process.

Table : 2.2 Process States Attributes

Contd...

The PCB is maintained for a process throughout its lifetime, and is deleted once the process terminates.

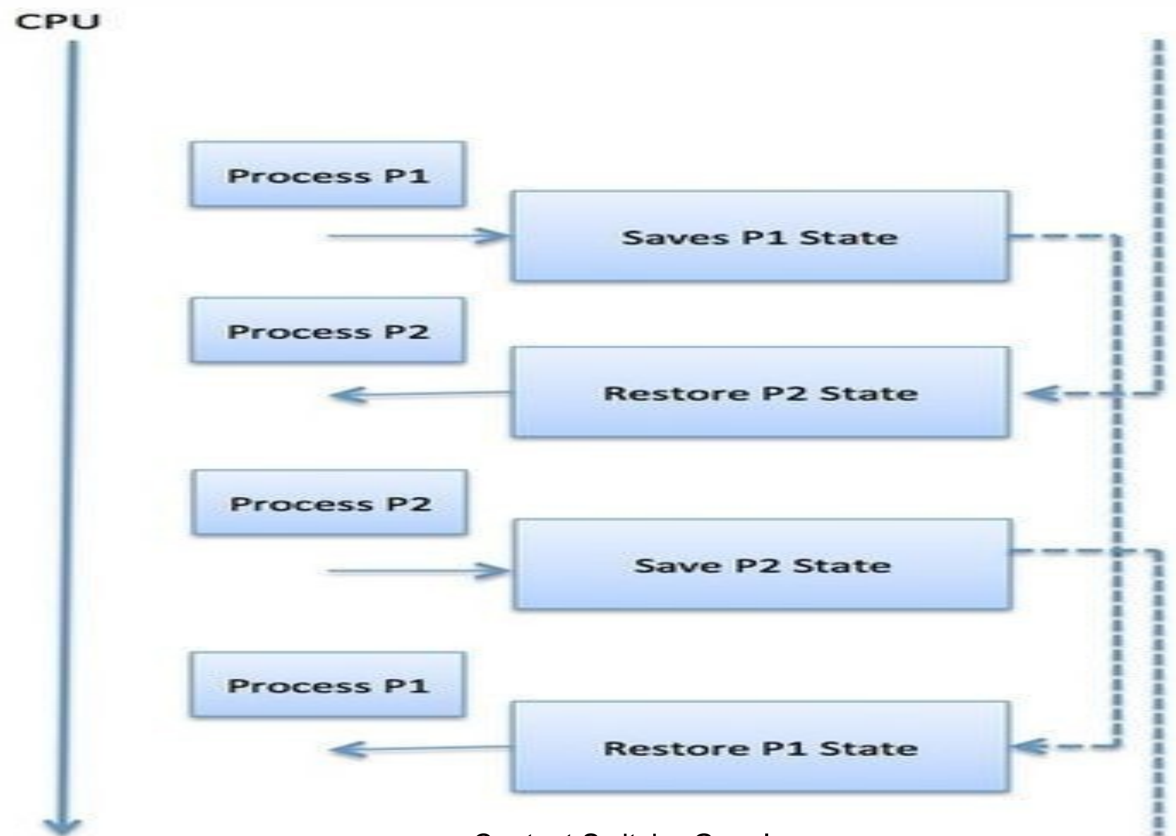
Context Switching

- Switching the CPU to another process requires saving the state of the old process and loading the saved state for the new process. This task is known as a Context Switch.

- A context switch is a procedure that a computer's CPU (central processing unit) follows to **change from one task (or process) to another** while ensuring that the tasks do not conflict.

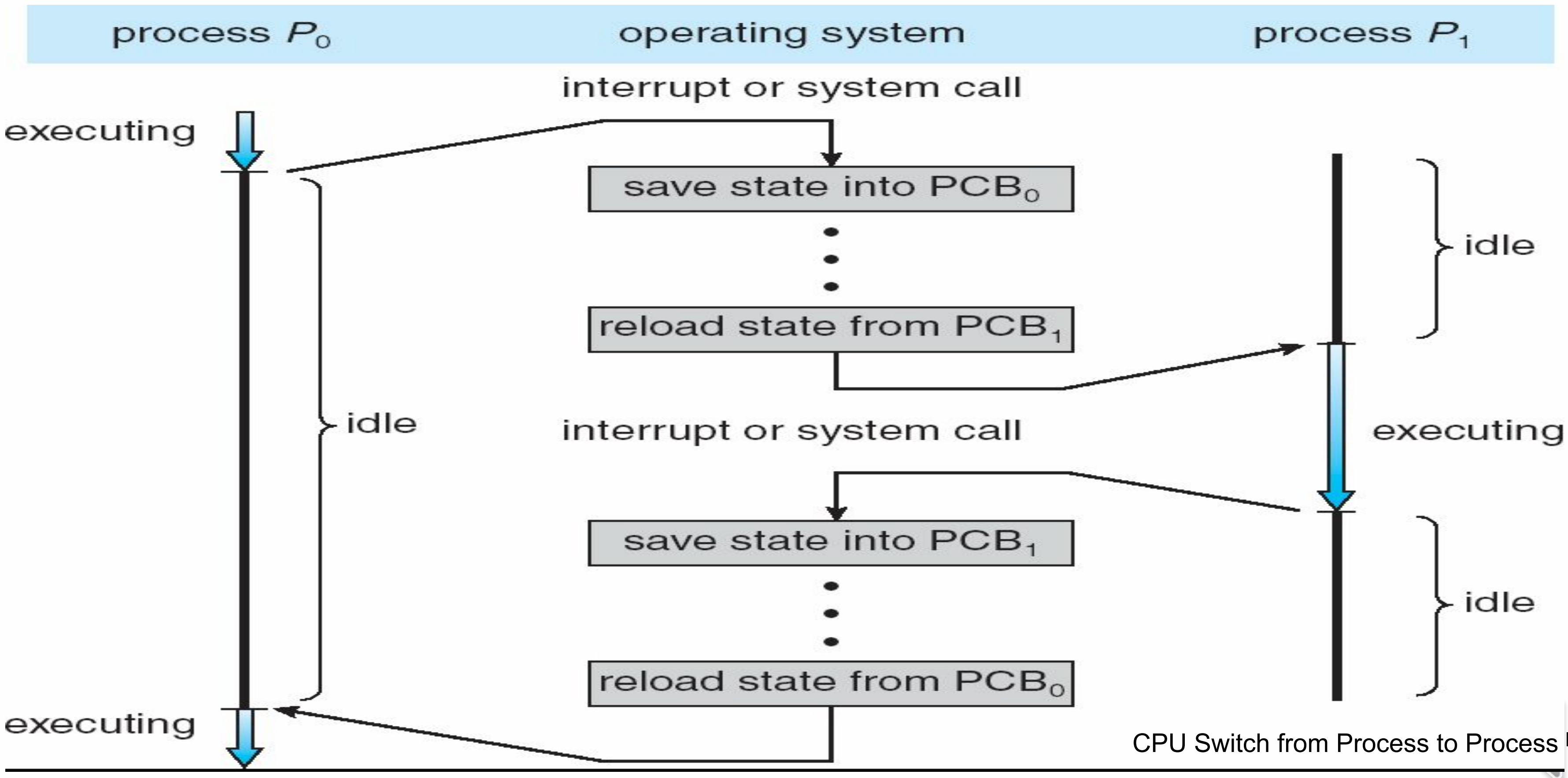
- Effective context switching is critical if a computer is to provide user-friendly **multitasking.**

Example



Context Switch : Google

Example



CPU Switch from Process to Process [1]

Contd...

- A context switch is the mechanism to **store and restore the state** or context of a CPU in Process Control block so that a **process execution can be resumed** from the same point at a later time.

- Using this technique, a context switcher enables multiple **processes to share a single** CPU. Context switching is an essential part of a multitasking operating system features.

Contd...

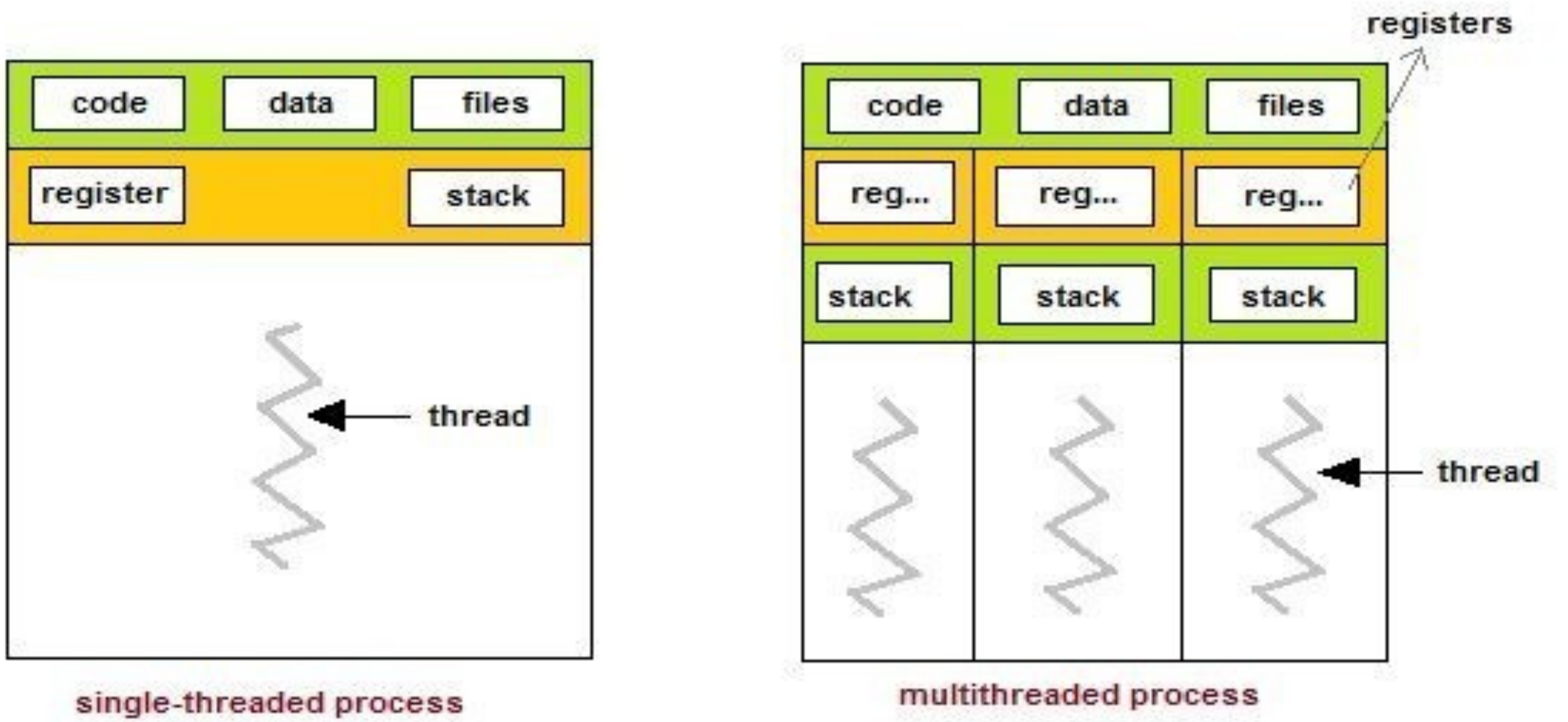
Context switch time is **pure overhead**, because the **system does no useful work while switching.**

Context Switching has become such a performance **bottleneck** that programmers are using new structures(threads) to avoid it whenever and wherever possible.

Thread

- A thread is a single sequence stream within a process.
- They are sometimes called lightweight processes.
- In a process, threads allow multiple executions of streams.
- **Thread** is an execution unit which consists of its own program counter, a stack, and a set of registers.
- As each thread has its own independent resource for process execution, multiple processes can be executed parallel by increasing number of threads.
- Each thread belongs to exactly one process and **no thread can exist outside a process.**

Threads



Single and Multithreaded Processes [1]

Advantages of Thread

- Threads **minimize** the **context switching** time.
- Use of threads provides **concurrency** within a process.
- Efficient communication.
- It is **more economical** to create and context switch threads.
- Threads allow utilization of multiprocessor architectures to a greater scale and efficiency.

Process Vs. Thread

Process	Thread
Process is heavy weight or resource intensive.	Thread is light weight, taking lesser resources than a process.
Process switching needs interaction with operating system.	Thread switching does not need to interact with operating system.
In multiple processing environments, each process executes the same code but has its own memory and file resources.	All threads can share same set of open files, child processes.
If one process is blocked, then no other process can execute until the first process is unblocked.	While one thread is blocked and waiting, a second thread in the same task can run.
Multiple processes without using threads use more resources.	Multiple threaded processes use fewer resources.
In multiple processes each process operates independently of the others.	One thread can read, write or change another thread's data.

Types of Thread

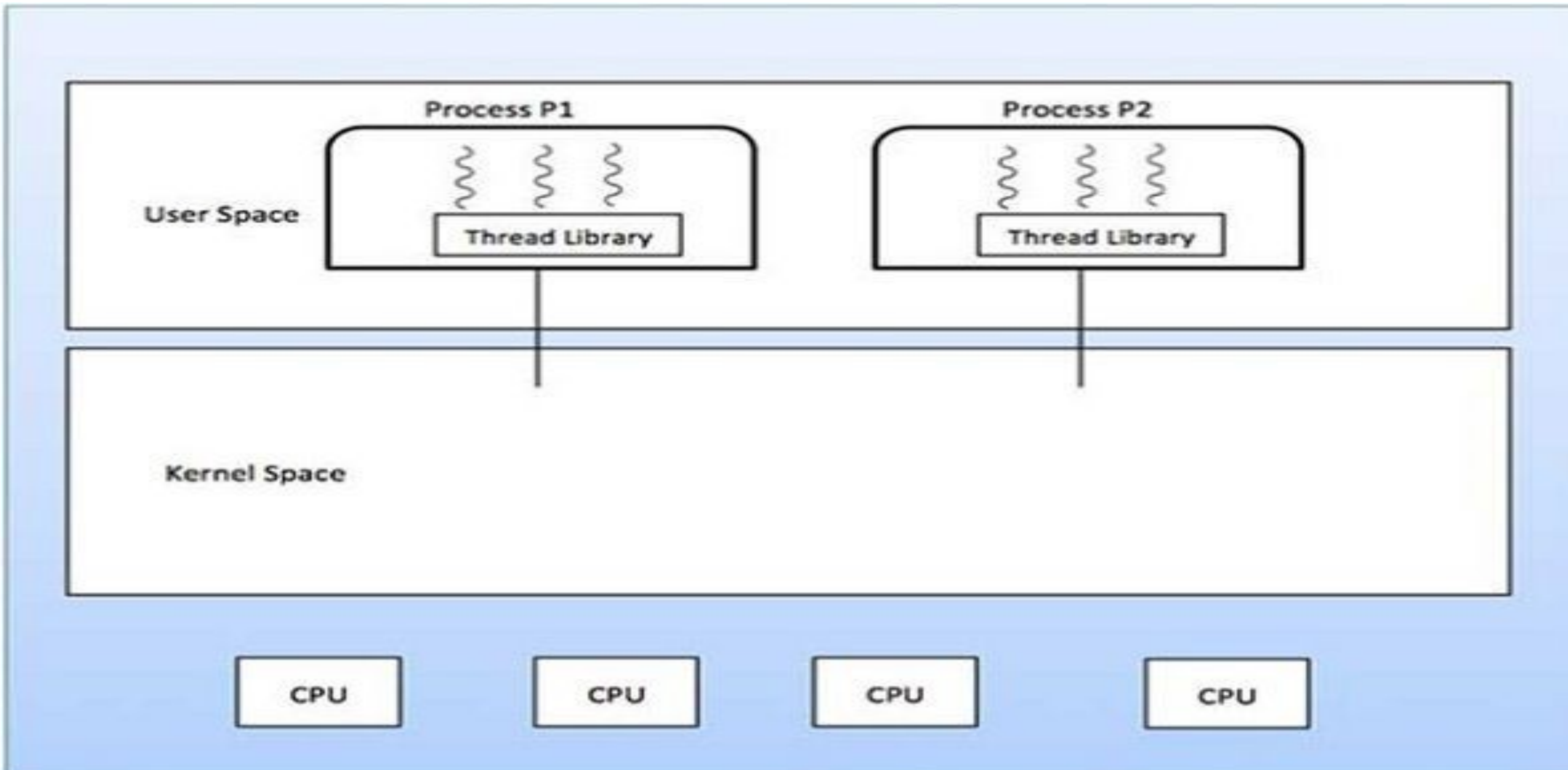
- **User Level Threads** – User managed threads.

- **Kernel Level Threads** – Operating System managed threads acting on kernel, an operating system core.

User Level Thread

- In this case, the thread management **kernel is not aware** of the existence of threads.
- The **thread library contains code** for creating and destroying threads, for passing message and data between threads, for scheduling thread execution and for saving and restoring thread contexts.
- The application starts with a single thread.

Contd...



User Level Thread :Google

Advantages and Disadvantages

Advantages

- Thread switching does not require Kernel mode
- privileges. User level thread can run on any operating
- system.
- Scheduling can be application specific in the user level thread. User level threads are fast to create and manage.

Disadvantages

- Multithreaded application cannot take advantage of multiprocessing

Kernel Level Thread

- In this case, thread **management** is done by the **Kernel**.
- There is no thread management code in the application area.
- Kernel threads are **supported directly by the operating system**.
- The Kernel performs thread creation, scheduling and management in Kernel space.

Advantages

- Kernel can **simultaneously schedule multiple threads** from the same process on multiple processes.
- If one thread in a process is blocked, the Kernel can schedule another thread of the same process.

Disadvantages

- Kernel threads are generally **slower** to create and manage than the user threads.

- Transfer of control from one thread to another within the same process **requires a mode switch to the Kernel.**

Multithreading

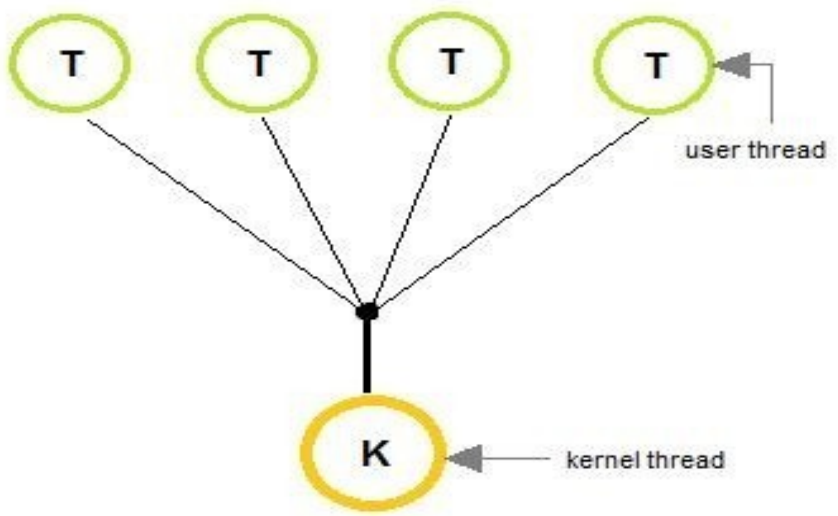
- Ability of operating system to execute multiple threads.

- Some operating system provide a **combined** user level thread and Kernel level thread facility.

- Multithreading Models
  1. Many to One Model
  2. One to One Model
  3. Many to Many Model

Many to one Model

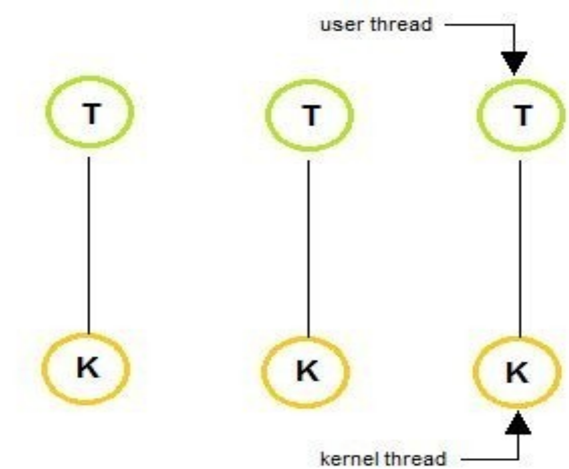
- In the **many to one model**, many user-level threads are all mapped onto a single kernel thread.
- Thread management is handled by the thread library in user space, which is efficient in nature



Many to One Model [1]

One to One Model

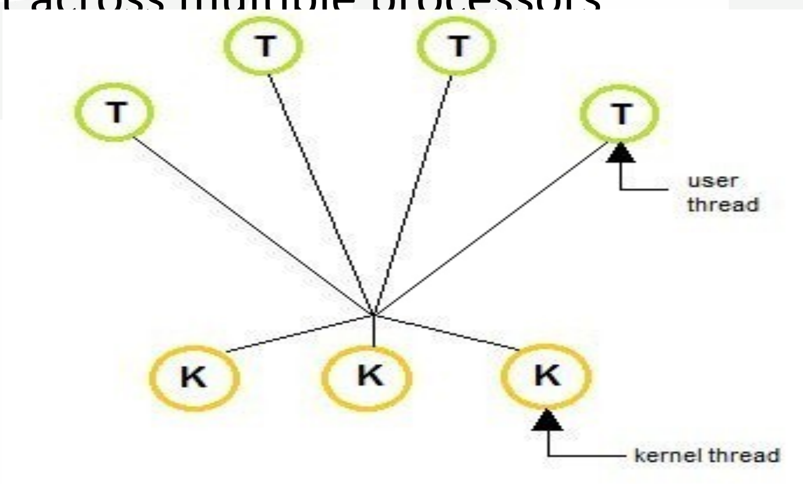
- The one to one model creates a separate kernel thread to handle each and every user thread.
- Most implementations of this model place a limit on how many threads can be created.
- Linux and Windows from 95 to XP implement the one-to-one model for threads



One to One Model [1]

Many to Many Model

- The many to many model multiplexes any number of user threads onto an equal or smaller number of kernel threads, combining the best features of the one-to-one and many-to-one models.
- Users can create any number of the threads.
- Blocking the kernel system calls does not block the entire process.
- Processes can be split across multiple processors



Many to Many Model[1]

Benefits of Multithreading

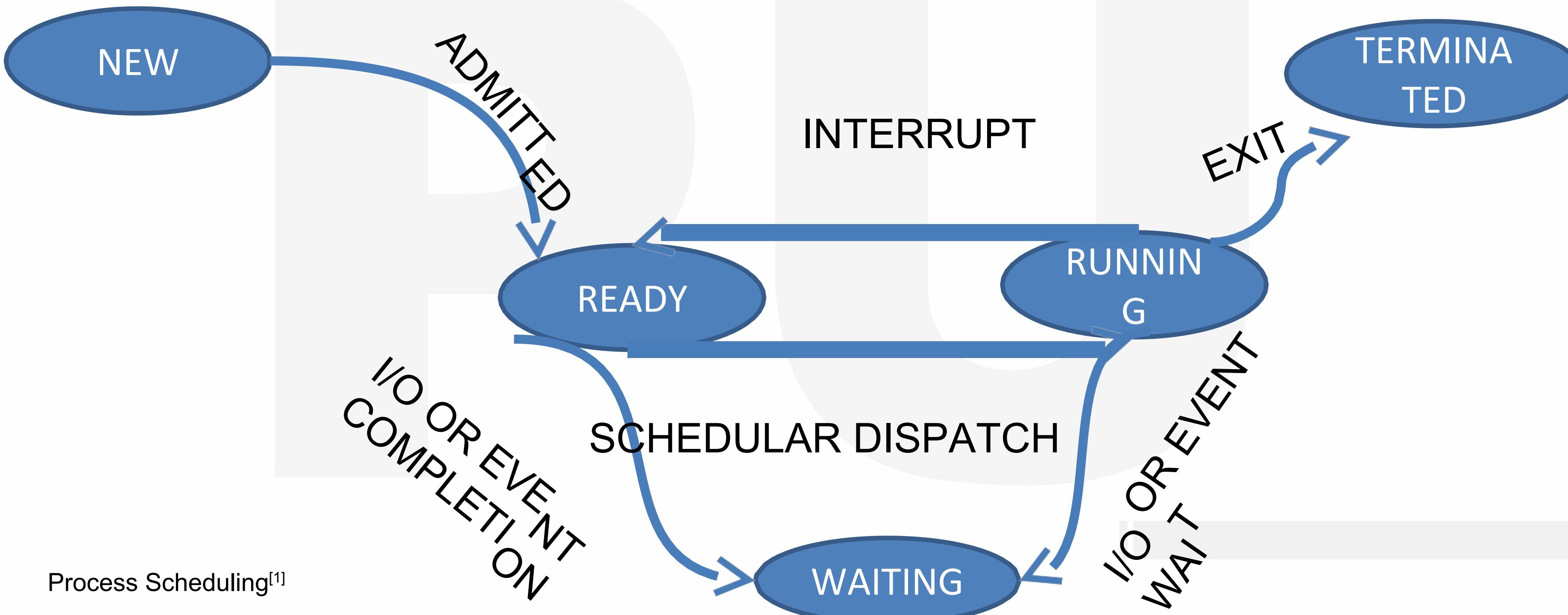
- Responsiveness
- Resource sharing, hence allowing better utilization of resources.
- Economy: Creating and managing threads becomes easier.
- Scalability: One thread runs on one CPU. In Multithreaded processes, threads can be distributed over a series of processors to scale.
- Context Switching is smooth. Context switching refers to the procedure followed by CPU to change from one task to another.

User Level Thread Vs. Kernel Level Thread

User-Level Threads	Kernel-Level Thread
User-level threads are faster to create and manage.	Kernel-level threads are slower to create and manage.
Implementation is by a thread library at the user level.	Operating system supports creation of Kernel threads.
User-level thread is generic and can run on any operating system.	Kernel-level thread is specific to the operating system.
Multi-threaded applications cannot take advantage of multiprocessing.	Kernel routines themselves can be multithreaded.

What is process scheduling?

- The act of determining which process is in the ready state, and should be moved to the running state is known as Process Scheduling”



Process Scheduling[1]

Why process scheduling?

Bill desk

CPU

Although another desk is available people are waiting for their turn

Bill desk for senior citizens

CPU

Billing desk is empty, and can handle other tasks

Why process scheduling?

The prime aim of the process scheduling system is:

1. to <u>keep the CPU busy</u> all the time
2. to deliver minimum response time for all programs

Bill desk

Bill desk(priority to senior citizens)

About process scheduling

1. The scheduler must apply appropriate rules for swapping processes IN and OUT of CPU

2. Process scheduling is a process which **allows one process to use the CPU while the execution of another process is on hold(in** waiting state) due to unavailability of any resource like I/O etc, thereby making full use of CPU

.

3. The aim of CPU scheduling is to make the system **efficient, fast and fair.**

Types of Scheduling

- **Scheduling can be of two types:**

Non Pre-emptive Scheduling: When the currently executing process gives up the CPU voluntarily.

Pre-emptive Scheduling: When the operating system decides to favour another process, pre-empting the currently executing process.

Non Pre-emptive Scheduling

Billing Desk

Non Pre-emptive Scheduling

All jobs in ready queue has to wait till Job in execution completes its task.

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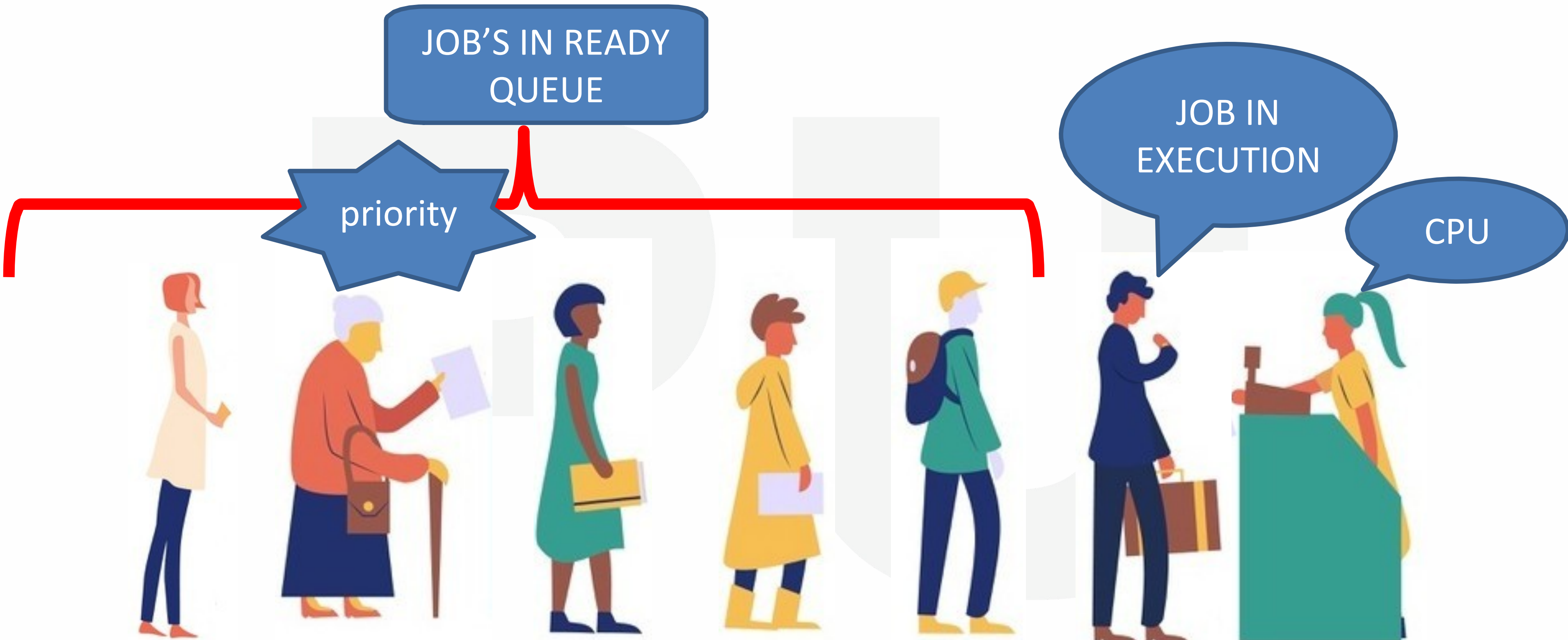
Pre-emptive Scheduling

Pre-emptive Scheduling

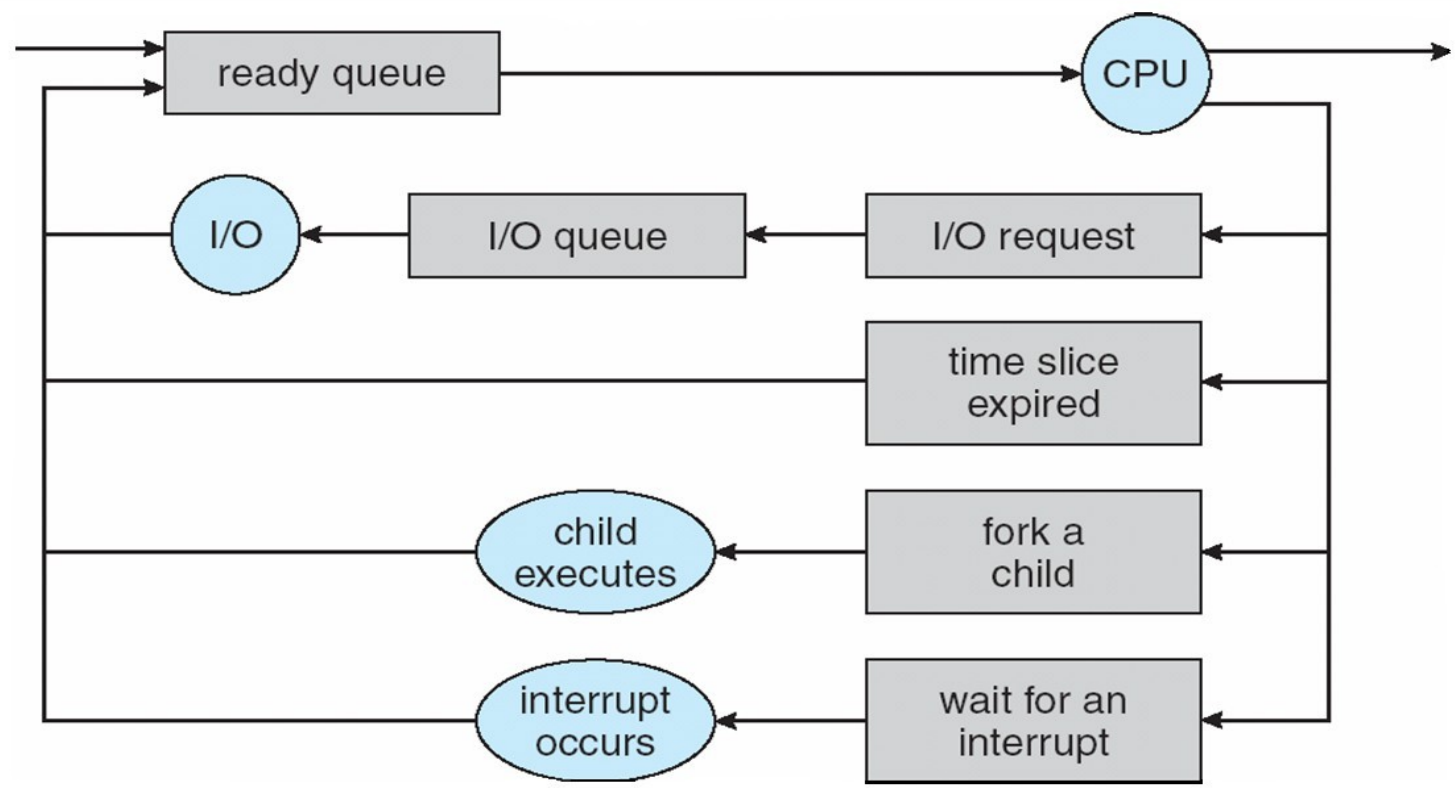


operating system decides to favour another process, pre-empting the currently executing process

Scheduling Queues

1. All processes, upon entering into the system, are stored in the **Job Queue**.
2. Processes in the Ready state are placed in the **Ready Queue**.
3. Processes waiting for a device to become available are placed in **Device Queues**. There are unique device queues available for each I/O device.
4. A new process is initially put in the **Ready queue**. It waits in the ready queue until it is selected for execution(or dispatched).

Scheduling Queues



Scheduling Queues [1]

Scheduling Queues

Once the process is assignedto the CPU and is executing, one of the following several events can occur:

1.The process could issue an I/O request, and then be placed in the **I/O queue**.

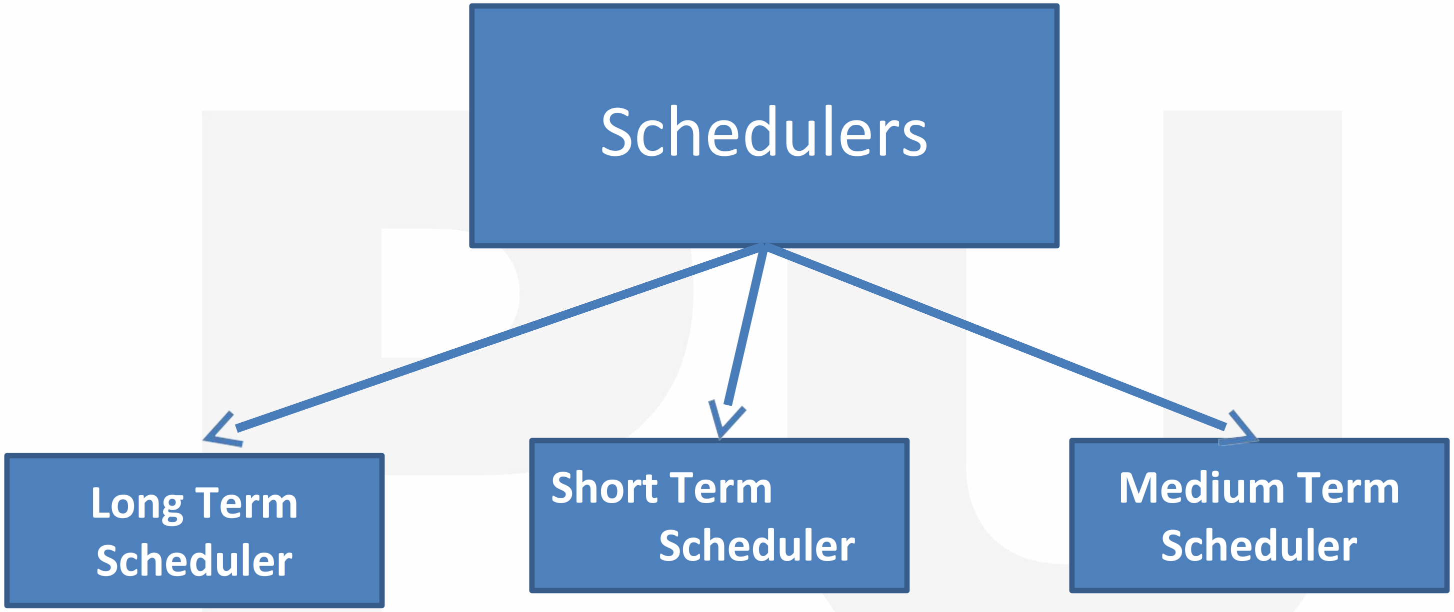
2.The process could create a new sub process and wait for its termination.

3.The process could be removed forcibly from the CPU, as a result of an interrupt, and be put back in the ready queue.

In the first two cases, the process eventually switches from the waiting state to the ready state, and is then put back in the ready queue.

A process continues this cycle until it terminates, at which time it is removed from all queues and has its PCB and resources deallocated.

Types of Schedulers



Long Term Scheduler

- Long term **scheduler runs less frequently**.
- Long Term Schedulers decide which program must get **into the job queue.**
- From the job queue, the Job Processor, selects processes and loads them into the memory for execution.
- Primary aim of the Job Scheduler is to maintain a **good degree of Multiprogramming**

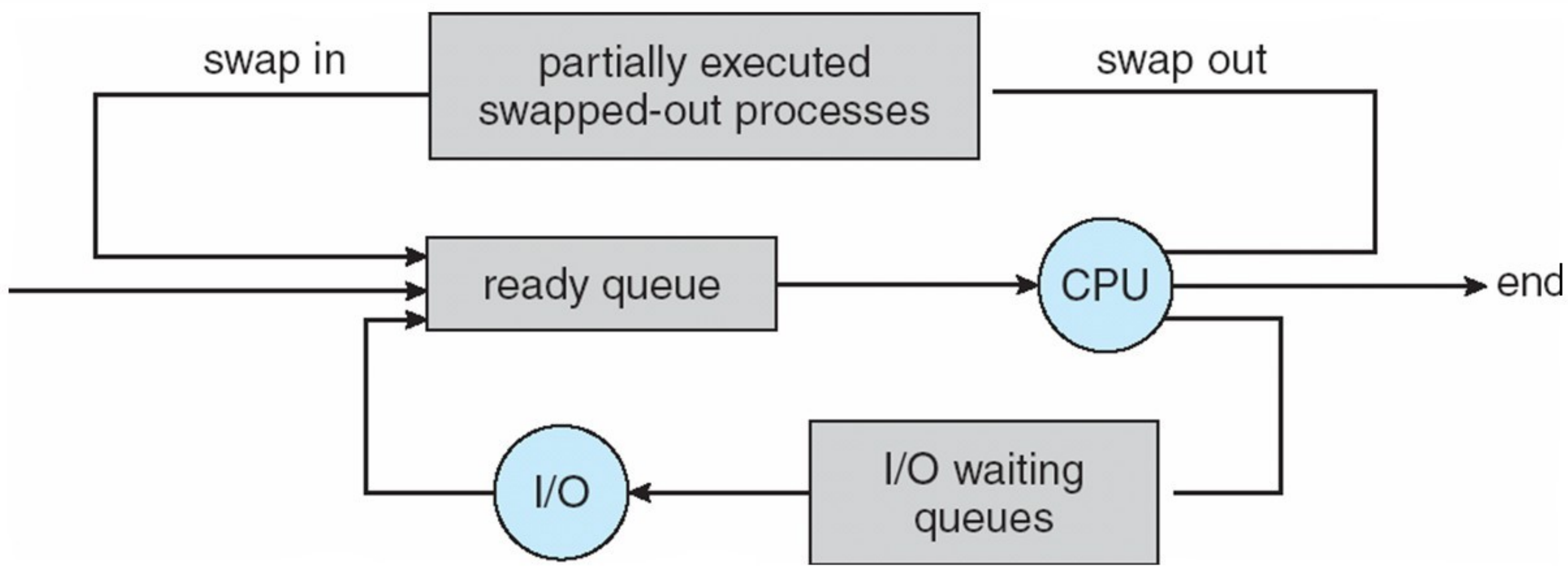
Short Term Scheduler

- This is also known as CPU Scheduler and **runs very frequently.**
- The primary aim of this scheduler is to enhance CPU performance and increase process **execution rate.**

Medium Term Scheduler

- During extra load, this scheduler **picks out big processes** from the ready queue for some time, to **allow smaller processes** to execute, thereby reducing the number of processes in the ready queue.
- At some later time, the process can be reintroduced into memory and its execution can be continued where it left off. This scheme is called swapping

Medium Term Scheduler



Medium Term Scheduler [1]

Scheduling Criteria

1. CPU utilization

- To make out the **best use of CPU** and not to waste any CPU cycle, CPU would be working most of **the time(Ideally 100%** of the time).
- Considering a real system, CPU usage should range from **40% (lightly loaded) to 90% (heavily loaded.)**

2. Throughput

- It is the **total number of processes completed per unit time** or rather say total **amount of work** done in a unit of time.
- This may range from 10/second to 1/hour depending on the specific processes.

Scheduling Criteria

3. **Turnaround time**

   It is the amount of time taken to **execute a particular process**, i.e. The interval from time of **submission** of the process to the time of **completion** of the process(Wall clock time).

4. **Waiting time**

   The sum of the periods **spent waiting in the ready queue** amount of time a process has been waiting in the ready queue to acquire get control on the CPU.

Scheduling Criteria

5. Load average

- It is the **average number of processes** residing in the **ready queue** waiting for their turn to get into the CPU.

6. Response time

- Amount of time it takes from when a **request was submitted until the first response** is produced.

Operation on Process

1. **Process Creation:**

   The process which creates other process, is termed the **parent** of the other process, while the created sub-process is termed its **child**.

   Each process is given an integer identifier, termed as process identifier, or PID.

   The parent PID (PPID) is also stored for each process.

2. **Process Termination:**

   By making the exit(system call), processes may request their own termination.

CPU Scheduling

- CPU scheduling is a process which allows one process to use the CPU while the execution of another process is on hold(in waiting state) due to unavailability of any resource like I/O etc, thereby making full use of CPU.

- The aim of CPU scheduling is to make the system efficient, fast and fair.

- Whenever the CPU becomes idle, the operating system must select one of the processes in the **ready queue** to be executed.

- The selection process is carried out by the short-term scheduler (or CPU scheduler). The scheduler selects from among the processes in memory that are ready to execute, and allocates the CPU to one of them.

Scheduling Algorithms

- **To decide which process to execute first and which process to execute last to achieve maximum CPU utilization, computer scientists have defined some algorithms, they are:**
    - First Come First Serve(FCFS) Scheduling
    - Shortest-Job-First(SJF) Scheduling
    - Priority Scheduling
    - Round Robin(RR) Scheduling
    - Multilevel Queue Scheduling
    - Multilevel Feedback Queue Scheduling

First Come First Serve(FCFS) Schedulin

- In the "First come first serve" scheduling algorithm, as the name suggests, the process which arrives first, gets executed first, or we can say that the process which requests the CPU first, gets the CPU allocated first.
- First Come First Serve, is just like FIFO(First in First out) Queue data structure, where the data element which is added to the queue first, is the one who leaves the queue first.
- This is used in Batch Systems.

First Come First Serve(FCFS)

- It's easy to understand and implement programmatically, using a Queue data structure, where a new process enters through the tail of the queue, and the scheduler selects process from the head of the queue.

- A perfect real life example of FCFS scheduling is buying tickets at ticket counter.

First Come First Serve(FCFS) Schedulin

Calculating Average Waiting Time

- **For every scheduling algorithm, Average waiting time is a crucial parameter to judge it's performance.**

- **AWT or Average waiting time is the average of the waiting times of the processes in the queue, waiting for the scheduler to pick them for execution.**

Lower the Average Waiting Time, better the scheduling algorithm

FCFS:

- **Consider the processes P1, P2, P3, P4 given in the below table, arrives for execution in the same order, with Arrival Time 0, and given Burst Time.**

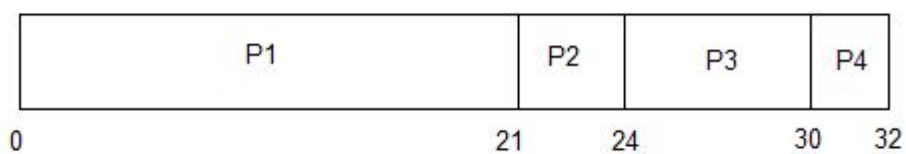
PROCESS	BURST TIME
P1	21
P2	3
P3	6
P4	2

FCFS:

- The average waiting time will be = (0+21+24+30)/4

=18.75 ms

PROCESS	BURST TIME
P1	21
P2	3
P3	6
P4	2



GANTT chart for above process

FCFS:

PROCESS	ARRIVAL TIME	BURST TIME	COMPLETION TIME	TAT (CT-AT)	WT (TAT-BT)	RESPONSE TIME
P1	0	21	21	21	0	0
P2	0	3	24	24	21	21
P3	0	6	30	30	24	24
P4	0	2	32	32	30	30

FCFS:

- Consider the processes P1, P2, P3, P4 given in the below table, arrives for execution in the same order, with different Arrival Time, and given Burst Time.

PROCESS	ARRIVAL TIME	BURST TIME
P1	0	2
P2	1	2
P3	5	3
P4	6	4

FCFS:

PROCESS	ARRIVAL TIME	BURST TIME	COMPLETION TIME	TAT (CT-AT)	WT (TAT-BT)	RESPONSE TIME
P1	0	2	2	2	0	0
P2	1	2	4	3	1	21
P3	5	3	8	3	0	24
P4	6	4	12	6	2	30

Problems in FCFS

- It is Non Pre-emptive algorithm, which means the process priority doesn't matter.
- Not optimal Average Waiting Time.
- Resources utilization in parallel is not possible, which leads to Convoy Effect, and hence poor resource(CPU, I/O etc) utilization.

Convoy Effect: Convoy Effect is a situation where many processes, who need to use a resource for short time are blocked by one process holding that resource for a long time.

- This essentially leads to poor utilization of resources and hence poor performance.

- ***The average waiting time will be 18.75 ms***
  - **For the above given processes, first P1 will be provided with the CPU resources,**
  - **Hence, waiting time for P1 will be 0**
  - **P1 requires 21 ms for completion, hence waiting time for P2 will be 21 ms**
  - **Similarly, waiting time for process P3 will be execution time of P1 + execution time for P2, which will be (21 + 3) ms = 24 ms.**
  - **For process P4 it will be the sum of execution times of P1, P2 and P3.**
  - **In which order if processes comes then average waiting time will be lesser?**

Shortest Job First(SJF)

- Shortest Job First scheduling works on the process with the shortest burst time or duration first.
- It is of two types:
  - Non Pre-emptive
  - Pre-emptive
- To successfully implement it, the burst time/duration time of the processes should be known to the processor in advance, which is practically not feasible all the time.
- This scheduling algorithm is optimal if all the jobs/processes are available at the same time. (either Arrival time is 0 for all, or Arrival time is same for all)

Non Pre-emptive SJF

- Consider the below processes available in the ready queuefor execution, with arrival time as 0 for all and given burst times.

- Based on FCFS what's Avg. waiting time = 18.75ms

PROCESS	BURST TIME
P1	21
P2	3
P3	6
P4	2

In Shortest Job First Scheduling, the shortest Process is executed first.

Hence the GANTT chart will be following :

P4	P2	P3	P1
0 – 2	2 – 5	5 – 11	11 – 32

Now, the average waiting time will be = (0 + 2 + 5 + 11)/4 = 4.5 ms

Problems with Non pre-emptive SJF:

- **If the arrival time for processes are different, which means all the processes are not available in the ready queue at time 0, and some jobs arrive after some time, in such situation, sometimes process with short burst time have to wait for the current process's execution to finish, because in Non Pre-emptive SJF, on arrival of a process with short duration, the existing job/process's execution is not halted/stopped to execute the short job first.**
- This leads to the problem of Starvation, where a shorter process has to wait for a long time until the current longer process gets executed.

Pre-emptive SJF

- In Preemptive Shortest Job First Scheduling, jobs are put into ready queue as they arrive, but as a process with short burst time arrives, the existing process is preempted or removed from execution, and the shorter job is executed first.

PROCESS	BURST TIME	ARRIVAL TIME
P1	21	0
P2	3	1
P3	6	2
P4	2	3

P_1	P2	P4	P_3	P_1
0–1	1–4	4–6	6–12	12–32

Avg. waiting Time $= \dfrac{\left[\{(0-0)+(12-1)\}+\{(1-1)\}+\{(6-2)\}+\{(4-3)\}\right]}{4}$

$= 4$ ms

Priority Scheduling

- **Priority is assigned for each process.**
- **Process with highest priority is executed first and so on.**
- **Processes with same priority are executed in FCFS manner.**
- **Priority can be decided based on memory requirements, time requirements or any other resource requirement.**
- **Pre-emptive:** Preempt the CPU if the priority of newly arrived process is higher than the priority of the currently running process.
- **Nonpreemptive:** It will simply put the new process at the head of the ready queue.

PROCESS	BURST TIME	PRIORITY
P1	21	2
P2	3	1
P3	6	4
P4	2	3

The GANTT chart for following processes based on Priority scheduling will be,

P2	P1	P4	P3
0 – 3	3 – 24	24 – 26	26 – 32

The average waiting time will be, (0 + 3 + 24 + 26)/4 = 13.25 ms

- **Problem:**
  - **Indefinite Blocking/Starvation ◊ In heavily loaded systems with High-priority processes some low priority processes are blocked because of high number of high-priority processes, so low priority process will be waiting indefinitely.**

- **Solution:**
  - **Aging◊ Gradually increase the priority of processes that wait in the system for a long time.**

Round Robin Schedulin

- Each process gets a small unit of CPU time (time quantum q), usually 10-100 milliseconds. After this time has elapsed, the process is preempted and added to the end of the ready queue.
- Context switching is used to save states of preempted processes.
- If there are *n* processes in the ready queue and the time quantum is *q*, then each process gets 1/*n* of the CPU time in chunks of at most *q* time units at once. No process waits more than (*n*-1)*q* time units.
- Timer interrupts every quantum to schedule next process

Time Quantum (q) = 5

PROCESS	BURST TIME
P1	21
P2	3
P3	6
P4	2

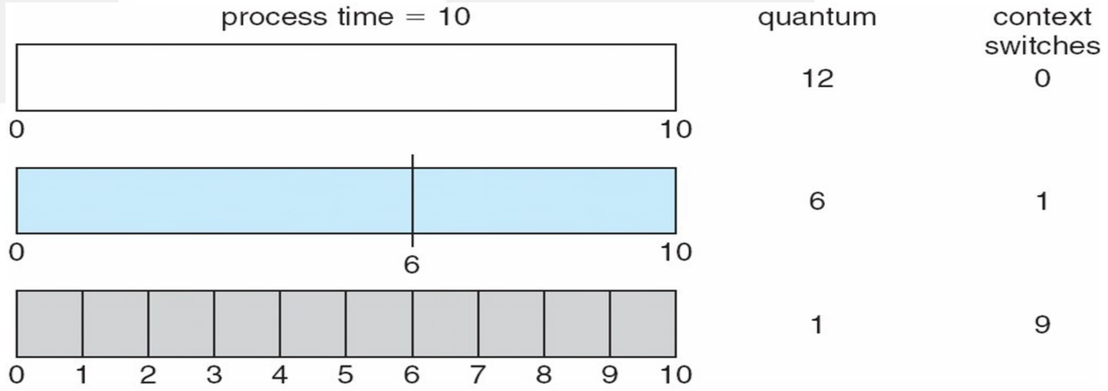
The GANTT chart for round robin scheduling will be,

P1	P2	P3	P4	P1	P3	P1	P1	P1

0 5 8 13 15 20 21 26 31 32

The average waiting time will be, 11 ms.

- Performance
  - *q* large ⇒ FIFO
  - *q* small ⇒ *q* must be large with respect to context switch, otherwise overhead is too high
- q should be large compared to context switch time
- q usually 10ms to 100ms, context switch < 10 µsec



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Arrival Time:       Time at which the process arrives in the ready queue.
Completion Time:    Time at which process completes its execution.
Burst Time:         Time required by a process for CPU execution.
Turn Around Time:   Time Difference between completion time and arrival time.
     Turn Around Time = Completion Time - Arrival Time

Waiting Time(W.T): Time Difference between turn around time and burst time.
     Waiting Time = Turn Around Time - Burst Time
```

Response Time = Start Time of Process – Arrival Time

Consider the following processes with arrival time and burst time. Calculate average turnaround time, average waiting time and average response time using round robin with time quantum 3?

Process id	Arrival time	Burst time
P1	5	5
P2	4	6
P3	3	7
P4	1	9
P5	2	2
P6	6	3

CPU IDEAL	P4	P5	P3	P2	P4	P1	P6	P3	P2	P4	P1	P3

Time: 0 1 4 6 9 12 15 18 21 24 27 30 32 33

Process id	Arrival time	Burst time	Completion time	Turnaround time	Waiting time	Response time
P1	5	5	32	27	22	10
P2	4	6	27	23	17	5
P3	3	7	33	30	23	3
P4	1	9	30	29	20	0
P5	2	2	6	4	2	2
P6	6	3	21	15	12	12

Average turnaround time=(27+23+30+29+4+15)6=21.33

Average waiting time=(22+17+23+20+2+12)6=16

Average response time=(10+5+3+0+2+12)6=5.33

Multilevel Queue

- A multi-level queue scheduling algorithm partitions the ready queue into several separate queues.
  - foreground (interactive)
  - background (batch)
- The processes are permanently assigned to one queue, generally based on some property of the process, such as memory size, process priority, or process type.
- Each queue has its own scheduling algorithm.
  - foreground – RR
  - background – FCFS
- In addition, there must be scheduling among the queues, which is commonly implemented as fixed-priority pre-emptive scheduling.

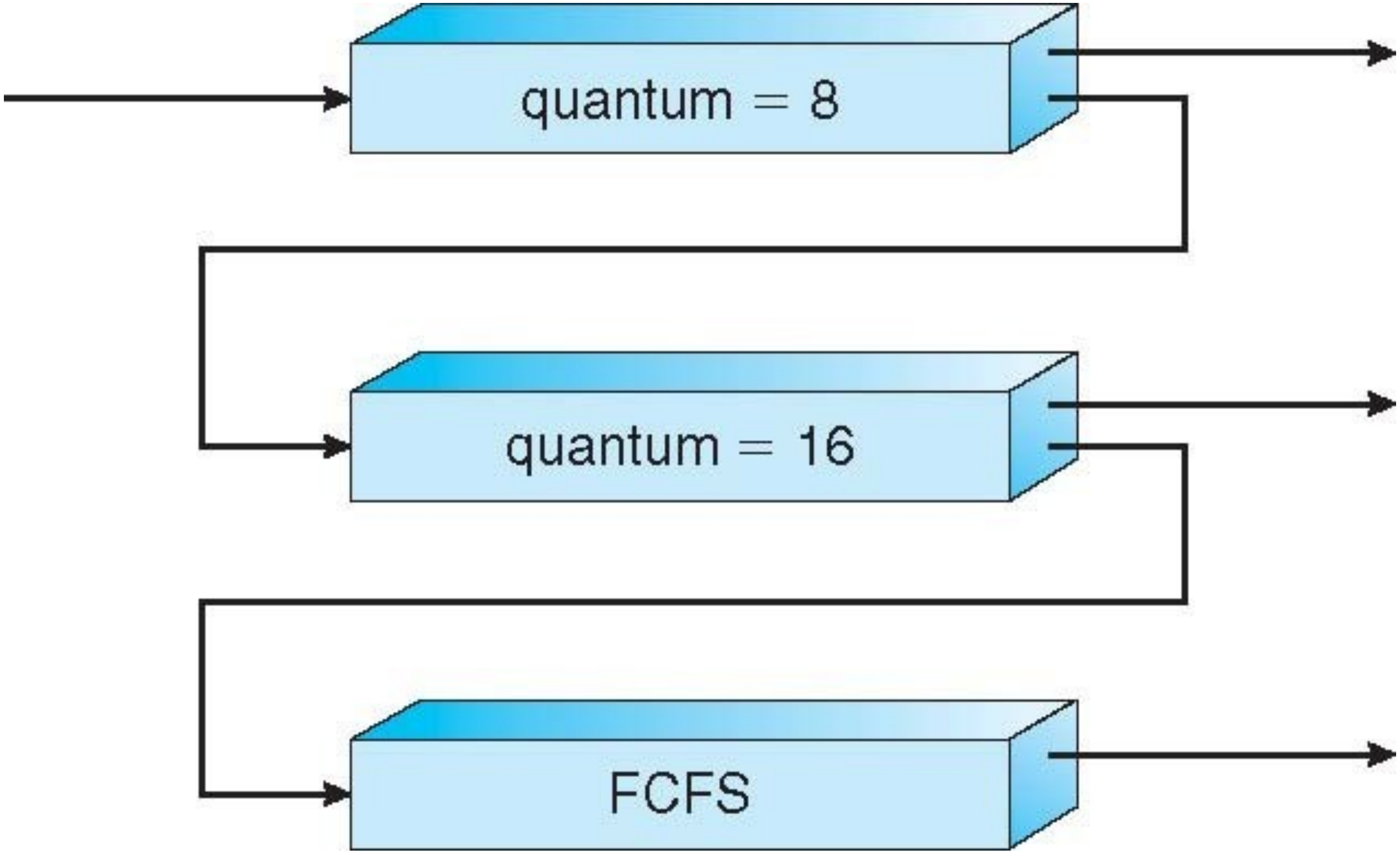
- Each queue has absolute priority over lower-priority queues. No process in the batch queue, for example, could run unless the queues for system processes, interactive processes, and interactive editing processes were all empty.

- If an interactive editing process entered the ready queue while a batch process was running, the batch process will be pre-empted.

Multilevel Feedback Queue

- This Scheduling is like Multilevel Queue(MLQ) Scheduling but in this process can move between the queues. Multilevel Feedback Queue Scheduling (MLFQ) keep analysing the behaviour (time of execution) of processes and according to which it changes its priority.
- Multilevel-feedback-queue scheduler defined by the following parameters:
    - number of queues
    - scheduling algorithms for each queue
    - method used to determine when to upgrade a process
    - method used to determine when to demote a process
    - method used to determine which queue a process will enter when that process needs service

Multilevel Feedback Q



- Three queues:
  - Q_0 – RR with time quantum 8 milliseconds
  - Q_1 – RR time quantum 16 milliseconds
  - Q_2 – FCFS

- Scheduling
  - A new job enters queue Q_0 which is served FCFS
    - When it gains CPU, job receives 8 milliseconds
    - If it does not finish in 8 milliseconds, job is moved to queue Q_1
  - At Q_1 job is again served FCFS and receives 16 additional milliseconds
    - If it still does not complete, it is preempted and moved to queue Q_2

References

1Silberschatz, A., Galvin, P. B., & Gagne, G. (2005). Operating system concepts. Hoboken, NJ: J. Wiley & Sons.

2 Stallings, W. (2018). Operating systems: Internals and design principles. Prentice-Hall

3 Tanenbaum, A. (2014). Modern operating systems. Harlow: Pearson.

4Nutt, G. J. (2004). Operating systems: A modern perspective. Boston: Pearson/ Addison Wesley.

5Bower T. Operating System Structure. K–State Polytechnic. http://faculty.salina.k-state.edu/tim/ossg/Introduction/struct.html

6Bower T. Basic Operating System Concepts. K–State Polytechnic. http://faculty.salina.k-state.edu/tim/ossg/Introduction/OSrole.html

7Operating System Generations. Tutorialspoint. https://www.tutorialspoint.com/operating-system-generations

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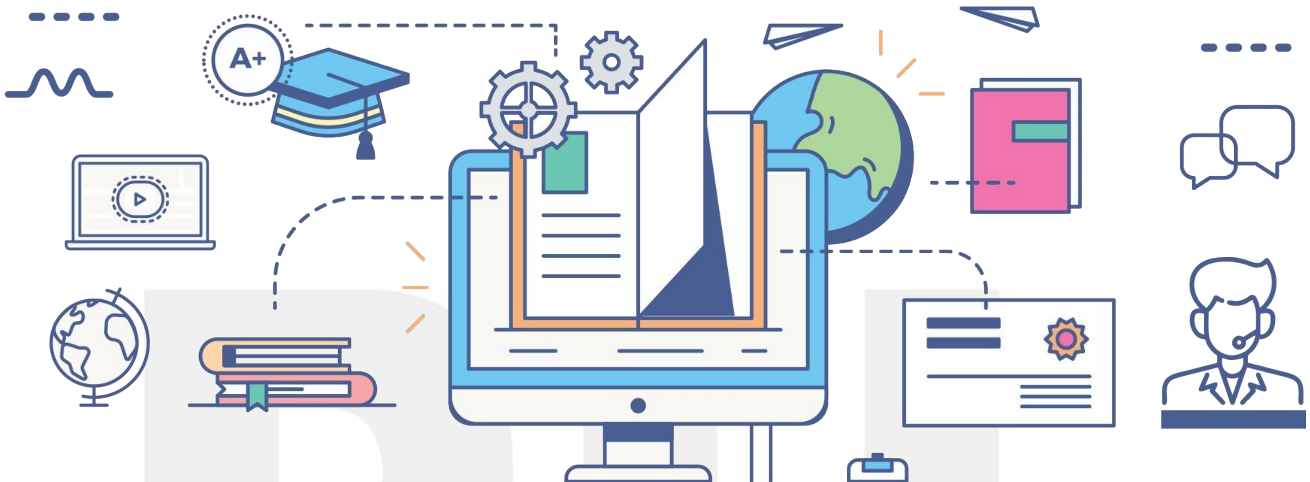
DIGITAL LEARNING CONTENT



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