Operating Systems

CPU Scheduling Algorithms

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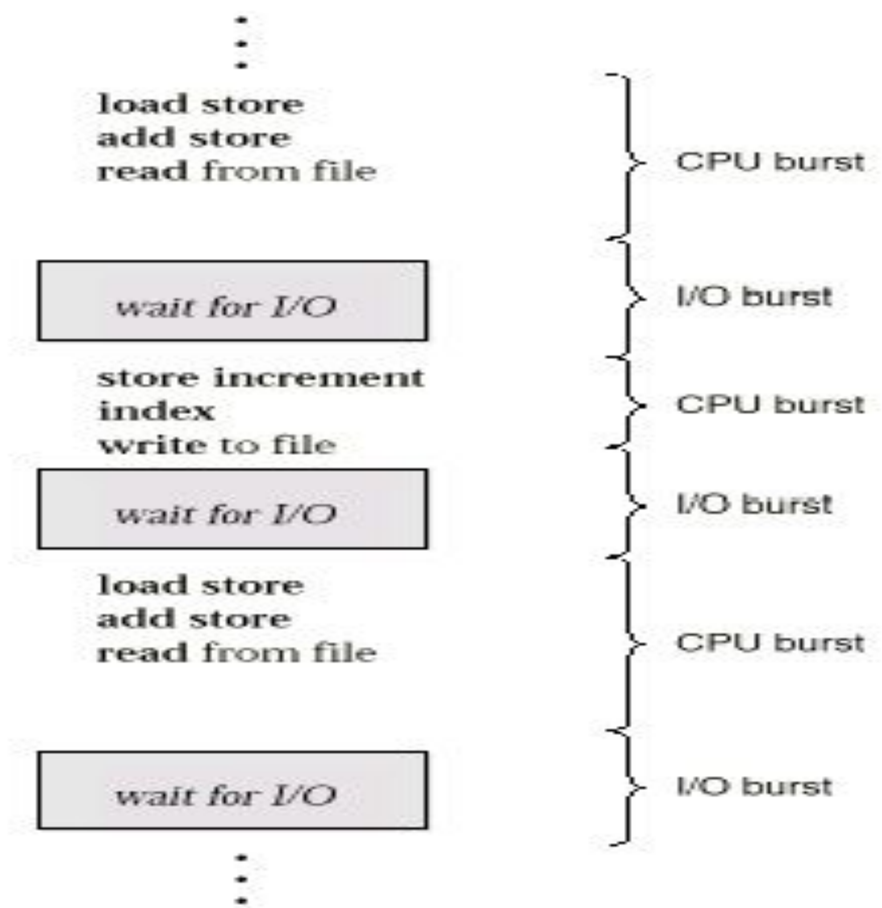
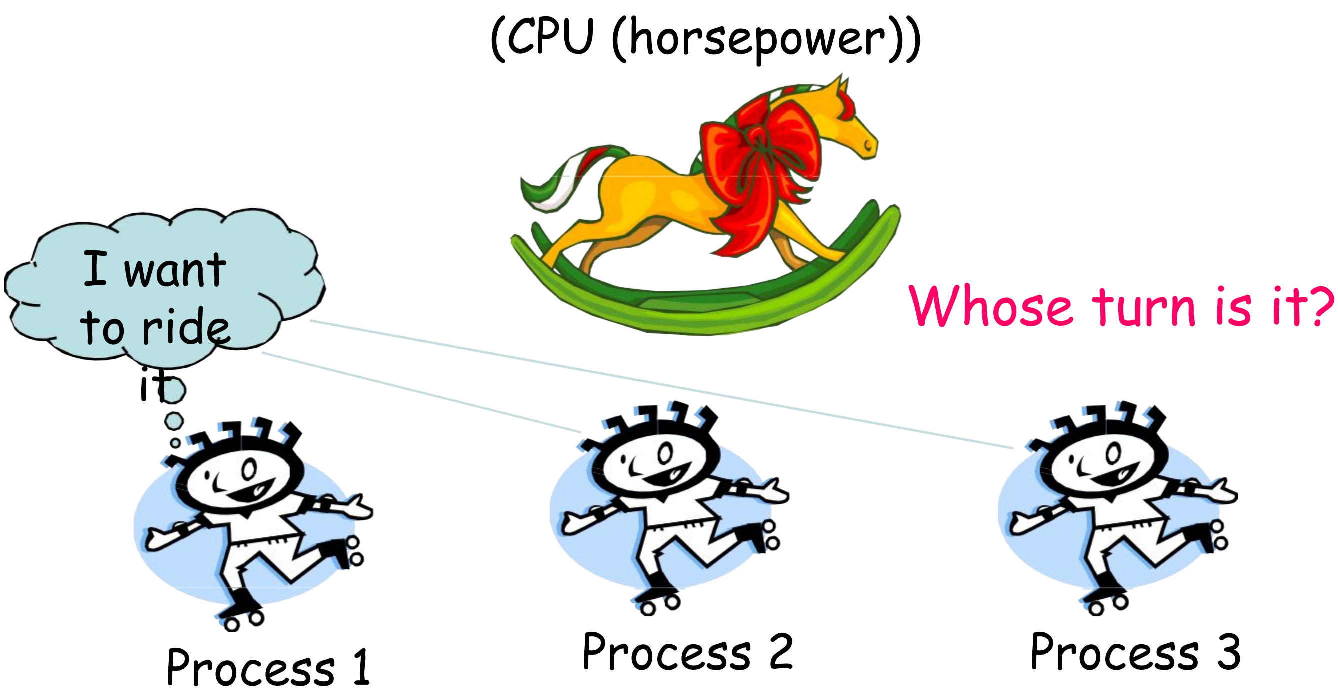
CPU – I/O Burst Cycle

- Process execution consists of a cycle of CPU execution and I/O wait
  - Processes move back & forth between these two states
- A process execution begins with a CPU burst, followed by an I/O burst and then another CPU burst and so on



Scheduling

- Deciding which process/thread should occupy a resource (CPU, disk, etc.)



CPU Scheduler

- When CPU becomes idle
  - OS must select one of the processes from the Ready Queue to be executed.
- **CPU scheduler**
  - is the OS code that implements the CPU scheduling algorithm .
  - selects a process from the processes in memory that are ready to execute (from Ready Queue), and allocates the CPU to one of them.
- CPU scheduling decisions may take place when a process:
  1. Switches from **running to waiting** state
  2. Switches from **running to ready** state (e.g. when time slice of a process expires or an interrupt occurs)
  3. Switches from **waiting to ready** state. (e.g. on completion of I/O)
  4. Terminates

Preemptive vs Non Preemptive Process

Non-preemptive

✔Process runs until voluntarily relinquish CPU

- process blocks on an event (e.g., I/O)
- process terminates
- process periodically calls the yield() system call to give up the CPU

✔Only suitable for domains where processes can be trusted to relinquish the CPU

Preemptive

- The scheduler actively interrupts and reschedules an executing process
- Special device requires for creating interrupt
- Required when applications cannot be trusted to yield
- Incurs some overhead

Scheduling Criteria

- **CPU utilization** – percentage of time the CPU is not idle.
- **Throughput** – completed processes per unit of time
- [the amount of material or items passing through a system or process]

- **Waiting time** – time spent in the ready queue
  - **For Non preemptive Algos = Starting.Time – Arrival.Time**
  - **For Preemptive Algos = Finish.Time – Arrival.Time – Burst.Time**

- **Turnaround time** – amount of time to execute a particular process.
  - **Finish.Time – Arrival.Time**

- **Response time** – response latency

  - amount of time it takes from when a request was submitted until the first response is produced, **not** output (for time-sharing environment)

The Perfect Scheduler

- Max CPU utilization= keep all devices busy
- Max throughput =Maximize jobs/time
- Min turnaround time
- Min waiting time
- Min response time =latency, first response
- Fairness: everyone makes progress, no one starves

Single CPU–Scheduling Algorithms

– First Come First Serve (FCFS)

– Smallest Next CPU Burst
  – Shortest Job First (SJF)
  – Shortest Remaining Time First (SRTF)

– Round Robin

– Priority Scheduling

First Come First Serve

- Simplest CPU scheduling algorithm
- Non preemptive
- The process that requests the CPU first is allocated the CPU first
- Implemented with a FIFO queue.

- **Limitations**
  - FCFS favor long processes as compared to short ones. (Convoy effect)
  - Average waiting time depends on arrival order
  - Average waiting time is often quite long
  - FCFS is non-preemptive, so it is trouble some for time sharing

  systems

Convoy Effect

"A convoy effect happens when a set of processes need to use a resource for a short time, and one process holds the resource for a long time, blocking all of the other processes. Causes poor utilization of the other resources in" the system

FCFS – Example

The process that enters the ready queue first is scheduled first, regardless of the size of its next CPU burst

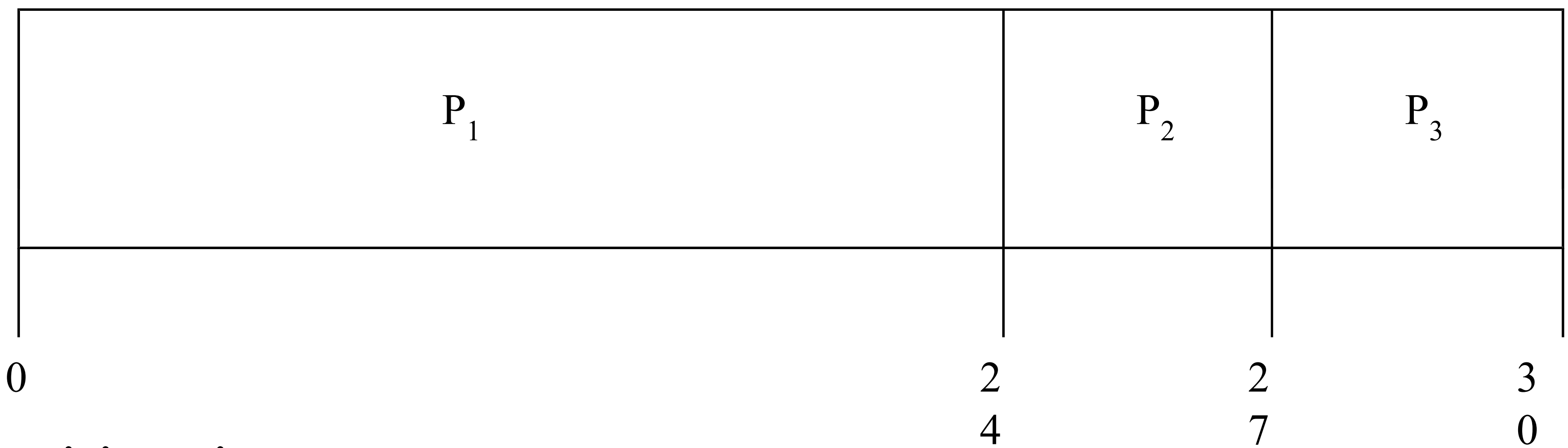
Example:	Process	Burst Time
		24
	P2	3
	P3	3

Suppose that processes arrive into the system in the order: P1, P2 , P3

FCFS – Example

Processes are served in the order: P1, P2, P3

The **Gantt Chart** for the schedule is:



Waiting times P1 = 0; P2 = 24; P3 = 27
Average waiting time: (0+24+27)/3 =

FCFS – Example

Suppose that processes arrive in the order: P2 , P3 , P1 . The Gantt chart for the schedule is:

Waiting time for P1 = 6; P2 = 0; P3 =
Average waiting time: (6 + 0 + 3)/3 = 3

FCFS – Example

- Draw the graph (Gantt chart) and compute average waiting time for the following processes using **FCFS** Scheduling algorithm.

Process	Arrival time	Burst Time
P1	1	16
P2	5	3
P3	6	4
P4	9	2

SJF & SRTF Scheduling…

- When the CPU is available it is assigned to the process that has the smallest next CPU burst.
- If two processes have the same length next CPU bursts, FCFS scheduling is used to break the tie.

Comes in three flavors

- **Shortest Job First (SJF)**
  - It's a non preemptive algorithm.
- **Shortest Remaining Time First (SRTF)**
  - It's a Preemptive algorithm.

SJF Example

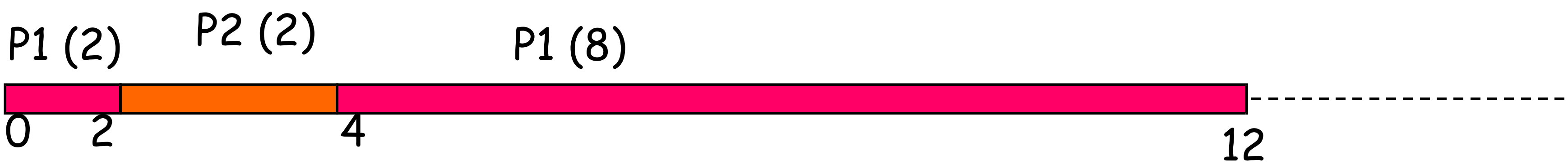
Process	Duration/B.T	Order	Arrival Time
P1	6	1	0
P2	8	2	0
P3	7	3	0
P4	3	4	0

P4 waiting time: 0-0
P1 waiting time: 3-0
P3 waiting time: 9-0
P2 waiting time: 16-0

The total running time is: 28
The average waiting time (AWT):
(0+3+9+16)/4 = 7 time units

SRTF Example

Process	Duration	Order	Arrival Time
P1	10	1	0
P2	2	2	2



P1 waiting time: 12-0-10 =2
P2 waiting time: 4-2-2=0

The average waiting time (AWT):
(0+2)/2 = 1

Now run this using SJF!

SJF & SRTF – Example

Draw the graph (Gantt chart) and compute waiting time and turn around time for the following processes using **SJF** & **SRTF** Scheduling algorithm.

For SJF consider all processes arrive at time 0 in sequence P1, P2, P3, P4.

Process	Arrival Time	Burst Time
P1	0	8
P2	1	4
P3	2	9
P4	3	5

SJF & SRTF – Example

Draw the graph (Gantt chart) and compute waiting time and turn around time for the following processes using **SJF** & **SRTF** Scheduling algorithm.

Process	Arrival Time	Burst Time
P1	0	5
P2	1	2
P3	2	3
P4	3	1

SJF & SRTF – Example

Draw the graph (Gantt chart) and compute waiting time and turn around time for the following processes using **SJF** & **SRTF** Scheduling algorithm.

Process	Arrival Time	Burst Time
P1	0	9
P2	3	6
P3	6	2
P4	9	1

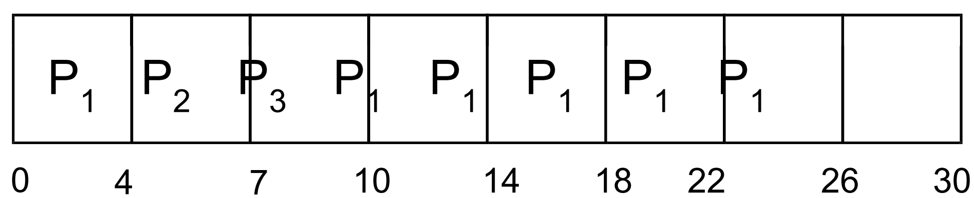
Round Robin (RR)

- 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.
- 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 $\boldsymbol{(n\text{-}1)q}$ time units.
- Timer interrupts every quantum to schedule next process
- **Performance**
  - q large $\Rightarrow$ FIFO
  - q small $\Rightarrow$ q must be large with respect to context switch, otherwise overhead is too high

Example of RR with Time Quantum = 4

Process	Burst Time
P_1	24
P_2	3
P_3	3

- The Gantt chart is:



- Typically, higher average turnaround than SJF, but better ***response***
- q should be large compared to context switch time
- q usually 10ms to 100ms

Priority Scheduling

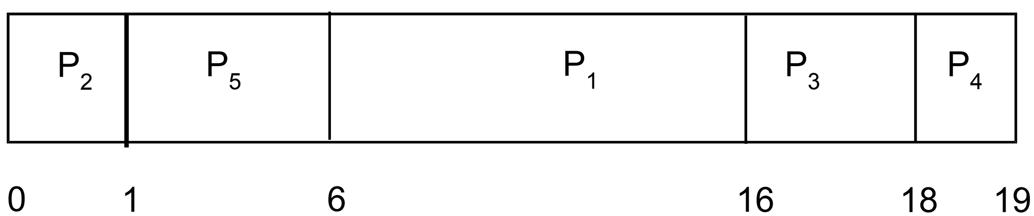
- A priority number (integer) is associated with each process
- The CPU is allocated to the process with the highest priority (smallest integer ≡ highest priority)
  - **Preemptive**
  - **Nonpreemptive**
- SJF is priority scheduling
  - where priority is the inverse of predicted next CPU burst time

  -> Shortest Job, Highest Priority
- Problem ≡ **Starvation** – low priority processes may never execute
- Solution ≡ **Aging** – as time progresses increase the priority of the process

Example of Priority Scheduling

Process	Burst Time	Priority
P_1	10	3
P_2	1	1
P_3	2	4
P_4	1	5
P_5	5	2

- Priority scheduling Gantt Chart



- Non-Preemptive Waiting time= 0+1+6+16+18=41
- Average waiting time = 8.2 msec

Course Materials

@Galvin-5.1-5.3