



Information Technology Institute

Operating System Fundamentals

Chapter Five

CPU SCHEDULING

Table of Content

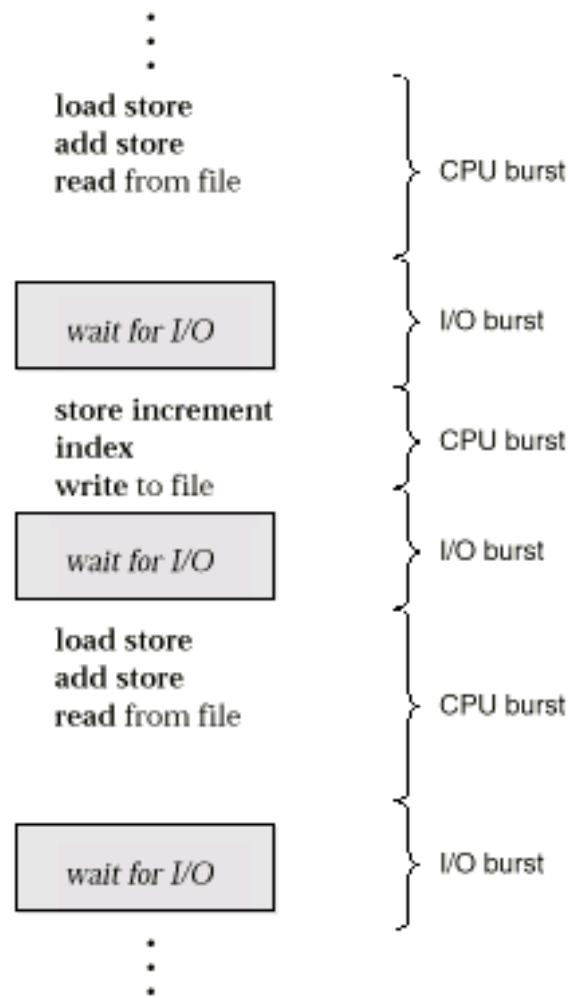
- Basic Concepts
- Scheduling Criteria
- Scheduling Algorithms

BASIC CONCEPTS

Basic Concepts

- Maximum CPU utilization obtained with multitasking
- CPU–I/O Burst Cycle
 - Process execution consists of a cycle of CPU execution and I/O wait.

Alternating Sequence of CPU And I/O Bursts



CPU Scheduler

- Selects from among the processes in memory that are ready to run, 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.
 3. Switches from waiting to ready.
 4. Terminates.

CPU Scheduler

Cont'd

- **Preemptive**
 - Process release the CPU before it finish execution
 - Example: Modern OS: Unix, Linux, Windows7
- **Non-preemptive**
 - Process release CPU when:
 - Running → Waiting
 - Running → Terminated
 - Example: MS Windows 3.1

Dispatcher

- Gives control of the CPU to the process selected by the short-term scheduler:
 - switching context
 - switching to suitable mode (User or Monitor)
 - jumping to the proper location in the user program to restart that program
- Dispatch latency
 - time taken by dispatcher to stop one process and start another running.

SCHEDULING CRITERIA

Scheduling Criteria

- CPU utilization
 - Keep the CPU as busy as possible
- Throughput
 - Number of processes that complete their execution per time unit
- Turnaround time
 - Amount of time to execute a particular process
- Waiting time
 - Amount of time a process has been waiting in the ready queue
- Response time
 - Amount of time it takes from when a request was submitted until the first response is produced, **not** output (for time-sharing environment)

Optimization Criteria

- Maximize
 - CPU Utilization
 - Throughput
- Minimize
 - Turnaround time
 - Waiting time
 - Response time
- Considerations
 - Minimize maximum response time
 - Minimize the variance of response times

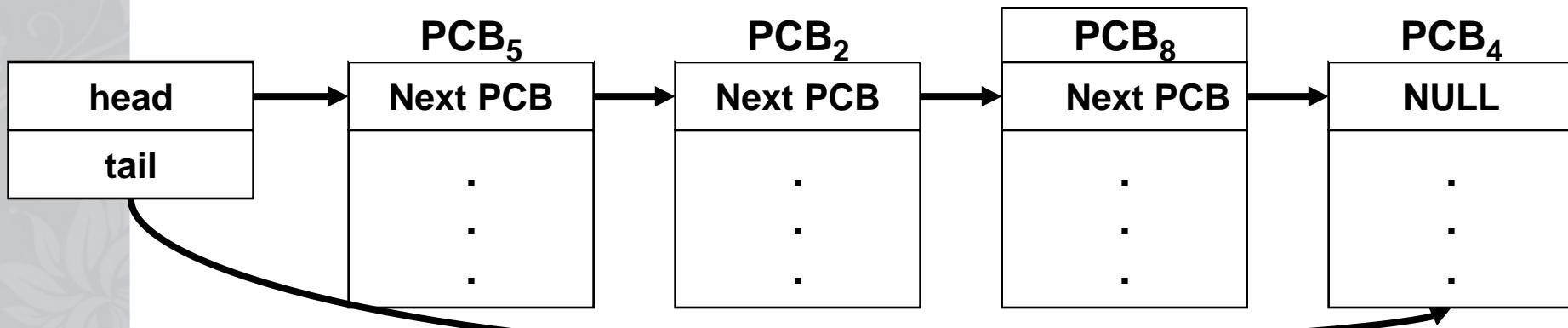
SCHEDULING ALGORITHMS

Scheduling Algorithms

- First-Come First Served
- Shortest-Job First
- Priority
- Round-Robin

First-Come, First-Served (FCFS) Scheduling

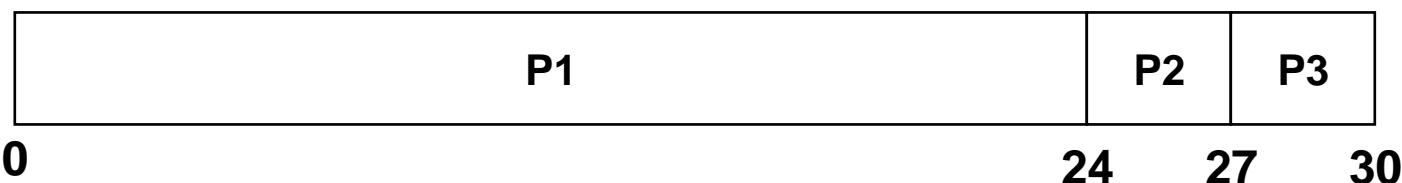
- Easily implemented
- Ready queue is FIFO
- P_n ready $\rightarrow P_n$ PCB is linked to tail of queue
- Process at head of ready queue \rightarrow CPU
- Average waiting time is long!



Example 1

Process	Burst Time
P1	24
P2	3
P3	3

- Suppose that the processes arrive in the order:
 $P1, P2, P3$ The Gantt Chart for the schedule is:

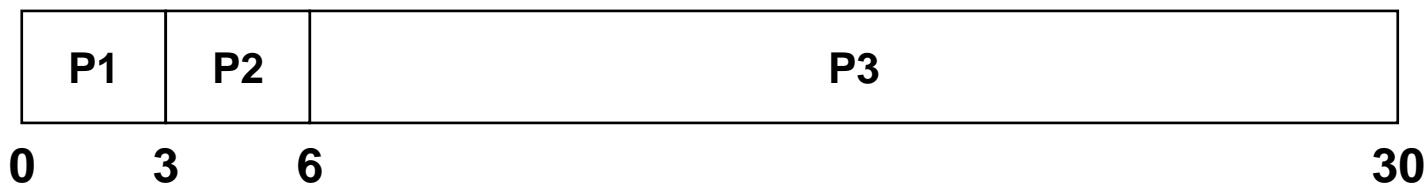


- Waiting time for $P1 = 0$; $P2 = 24$; $P3 = 27$
- Average waiting time: $(0 + 24 + 27)/3 = 17$

Example 2

Process	Burst Time
P1	3
P2	3
P3	24

- Suppose that the processes arrive in the order:
 $P1, P2, P3$ The Gantt Chart for the schedule is:



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

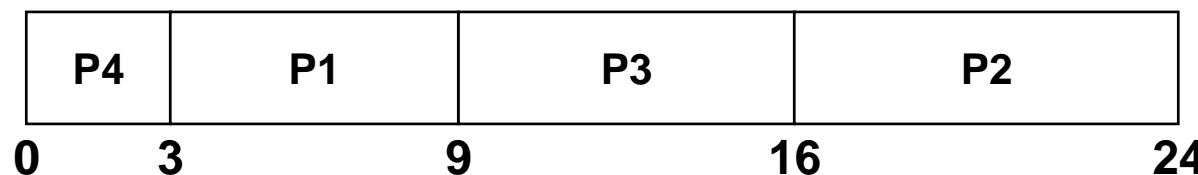
Shortest-Job-First (SJF) Scheduling

- Associate with each process the length of its next CPU burst. Use these lengths to schedule the process with the shortest time.
- Two schemes:
 - **Non-preemptive** – once CPU given to the process it cannot be preempted until completes its CPU burst.
 - **Preemptive** – if a new process arrives with CPU burst length less than remaining time of current executing process, preempt. This scheme is known as the Shortest-Remaining-Time-First (SRTF).
- **SJF is optimal**
 - Gives minimum average waiting time for a given set of processes.

Example 1

Process	Burst Time
P_1	6
P_2	8
P_3	7
P_4	3

- Suppose that all processes arrive at the same time: The Gantt Chart for the schedule is:

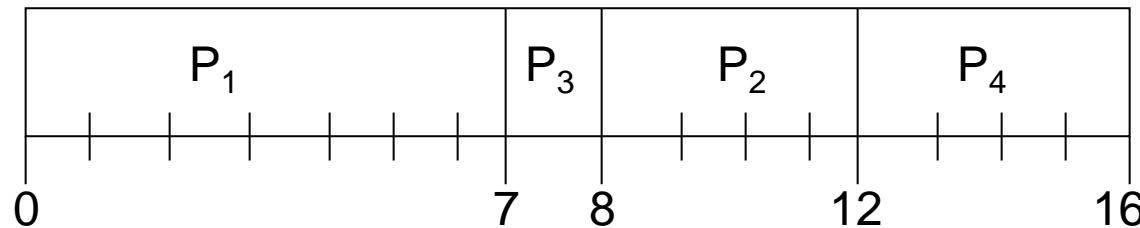


- Waiting time for $P_1 = 3$; $P_2 = 16$; $P_3 = 9$; $P_4 = 0$
- Average waiting time: $(3 + 16 + 9 + 0)/4 = 7$

Example of Non-Preemptive SJF

Process	Arrival Time	Burst Time
P1	0.0	7
P2	2.0	4
P3	4.0	1
P4	5.0	4

- SJF (non-preemptive)

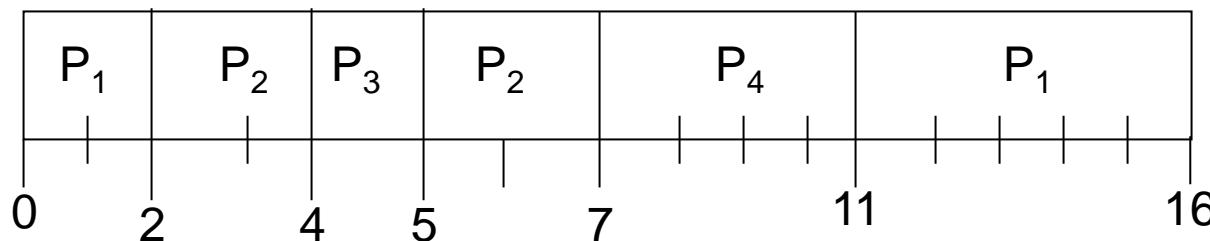


- Average waiting time = $(0 + 6 + 3 + 7)/4 = 4$

Example of Preemptive SJF

Process	Arrival Time	Burst Time
P1	0.0	7
P2	2.0	4
P3	4.0	1
P4	5.0	4

- SJF (preemptive)



- Average waiting time = $(9 + 1 + 0 + 2)/4 = 3$

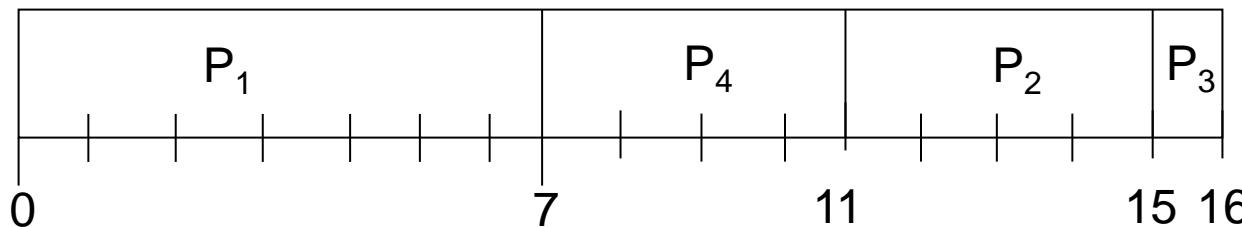
Priority Scheduling

- Priority number (integer) is associated with each process
- The CPU is allocated to the process with the highest priority (smallest integer \equiv highest priority).
 - Preemptive
 - Non-preemptive
- SJF is a priority scheduling where priority is the predicted next CPU burst time.
 - Problem \equiv **Starvation** – low priority processes may never execute.
 - Solution \equiv **Aging** – as time progresses increase the priority of the process.

Example of Non-Preemptive Priority

Process	Arrival Time	Burst Time	Priority
P1	0.0	7	3
P2	2.0	4	2
P3	4.0	1	4
P4	5.0	4	1

- Priority (Non-Preemptive)

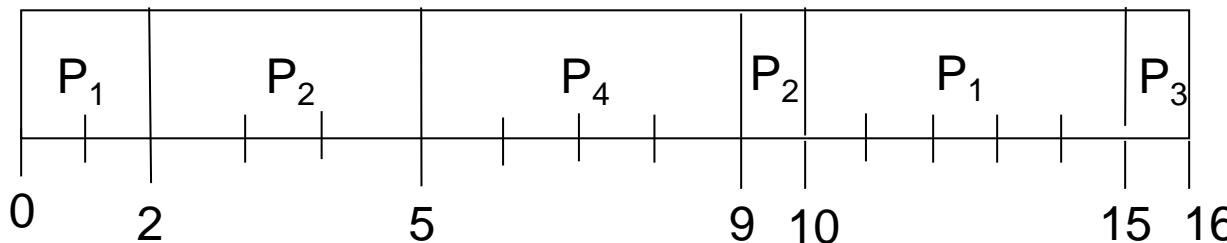


- Average waiting time = $(0 + 9 + 11 + 2)/4 = 22/4$

Example of Preemptive Priority

Process	Arrival Time	Burst Time	Priority
P1	0.0	7	3
P2	2.0	4	2
P3	4.0	1	4
P4	5.0	4	1

- Priority (Preemptive)



- Average waiting time = $(8 + 4 + 11 + 0)/4 = 23/4$

Round Robin (RR)

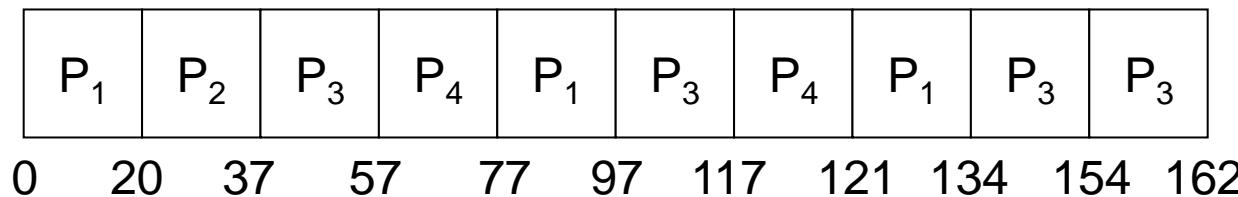
- Each process gets a small unit of CPU time (*time quantum*), usually 10-100 milliseconds. After this time has elapsed, the process is preempted and added to the end of the ready queue.
- If there are n processes in the ready queue and the time quantum is q , then each process gets $1/n$ of the CPU time in chunks of at most q time units at once. No process waits more than $(n-1)q$ time units.
- Performance
 - q large FIFO
 - q small q must be large with respect to context switch, otherwise overhead is too high.

Example of RR, Time Quantum = 20

Process Burst Time

P1	53
P2	17
P3	68
P4	24

- The Gantt chart is:



*Note: higher average turnaround than SJF, but better response.

