Amirkabir University of Technology
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# Operating Systems

# Scheduling Algorithms

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Spring 2022

# First-Come, First-Served

# First- Come, First-Served (FCFS) Scheduling

| Process | Burst Time |
|---|---|
| $P_1$ | 24 |
| $P_2$ | 3 |
| $P_3$ | 3 |

- Suppose that the processes arrive in the order: $P_1$ , $P_2$ , $P_3$
- The Gantt Chart for the schedule is:


- Waiting time for $P_1$ = 0; $P_2$ = 24; $P_3$ = 27
- Average waiting time: (0 + 24 + 27)/3 = 17

# FCFS Scheduling (Cont.)

Suppose that the processes arrive in the order:

$$P_2 , P_3 , P_1$$

- The Gantt chart for the schedule is:


- Waiting time for $P_1 = 6; P_2 = 0; P_3 = 3$
- Average waiting time: $(6 + 0 + 3)/3 = 3$
- **Much better than previous case**

# FCFS Scheduling and Convoy effect

- **Short process behind long process.**
  - Consider one CPU-bound and many I/O-bound processes.

- **What is the important side-effect?**

# FCFS Scheduling and Convoy Effect (Cont.)

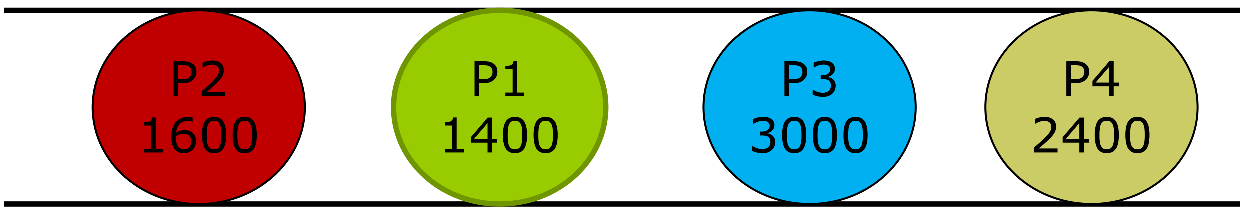
- **Short process behind long process.**
  - Consider one CPU-bound and many I/O-bound processes.

- What is the side-effect?
  - Results in **lower CPU and device utilization** than might be possible if the shorter **processes were allowed to go first.**

# Shortest-Job-First

# 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.




Ready Queue

# Shortest-Job-First (SJF) Scheduling (cont.)

- **SJF is optimal**
  - **Gives minimum average waiting time** for a given set of processes.
- Preemptive version called **shortest-remaining-time-first**
- **The difficulty is knowing the length of the next CPU request**
  - Could ask the user
  - Estimate (we do not cover this in the class and the exams)

# Example of SJF

| <u>Process</u> | <u>Burst Time</u> |
|---|---|
| $P_1$ | 6 |
| $P_2$ | 8 |
| $P_3$ | 7 |
| $P_4$ | 3 |

- SJF scheduling chart

| $P_4$ | $P_1$ | $P_3$ | $P_2$ | |
|---|---|---|---|---|
| 0 | 3 | 9 | 16 | 24 |

- Average waiting time = (3 + 16 + 9 + 0) / 4 = 7

# Round-Robin

# 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:**
  - 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.

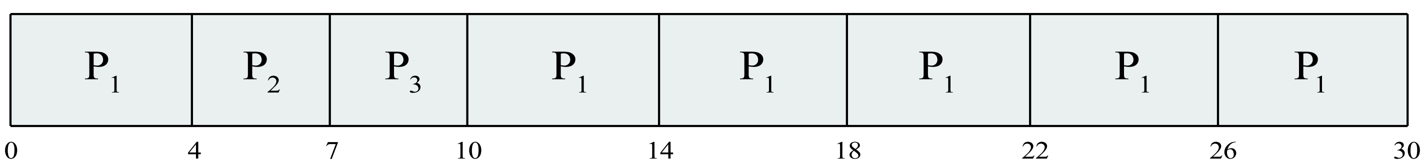
# Round Robin (RR) (cont.)

- 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

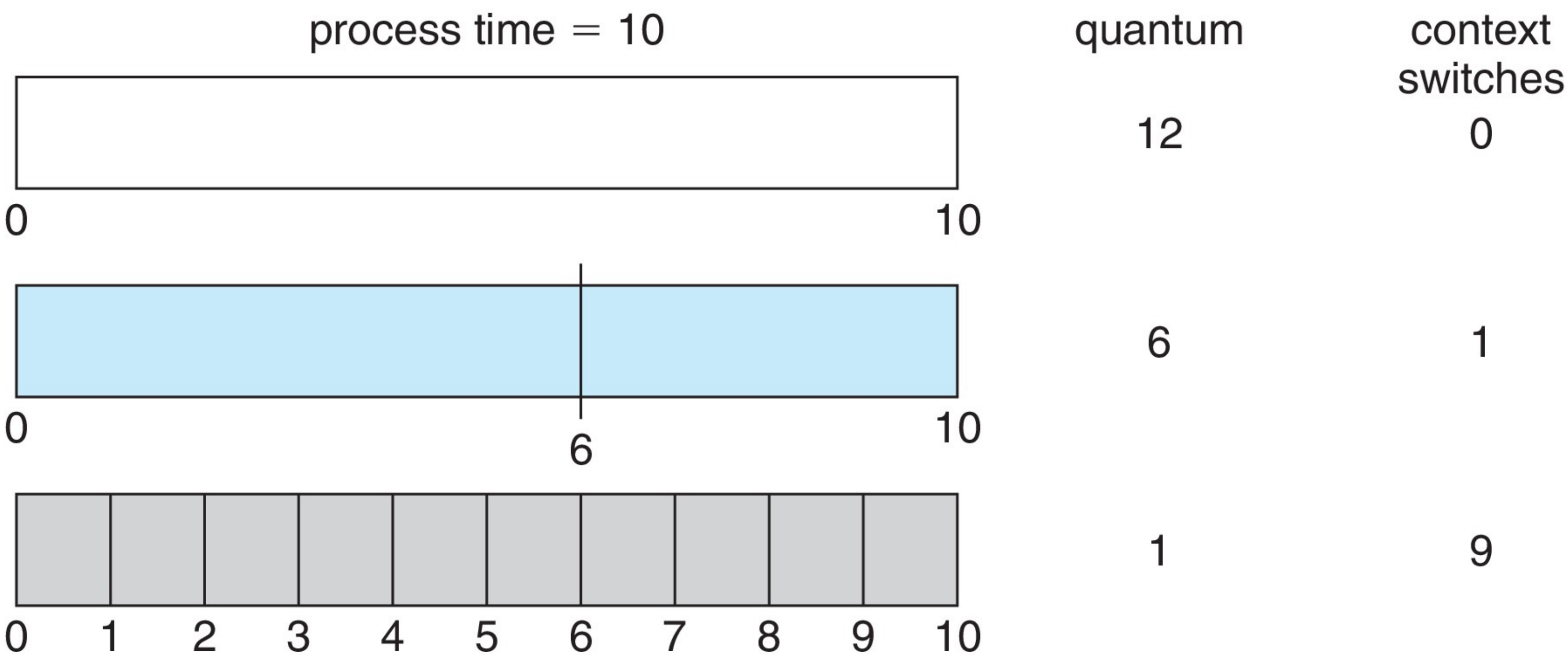
| Process | Burst Time |
|---|---|
| $P_1$ | 24 |
| $P_2$ | 3 |
| $P_3$ | 3 |

- The Gantt chart is:

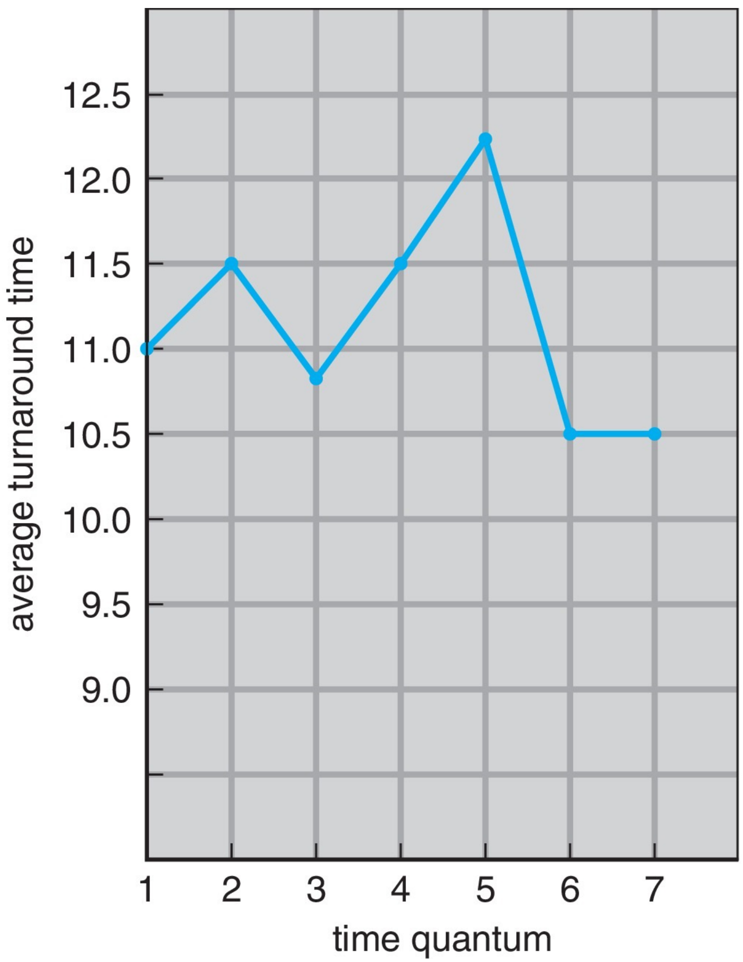



- Typically, higher average turnaround than SJF, but better ***response***
- *q* should be large compared to context switch time
  - **q** usually 10 milliseconds to 100 milliseconds,
  - Context switch < 10 microseconds

# Time Quantum and Context Switch Time



# Turnaround Time Varies With The Time Quantum




| process | time |
|---|---|
| $P_1$ | 6 |
| $P_2$ | 3 |
| $P_3$ | 1 |
| $P_4$ | 7 |

A rule of thump is that 80% of CPU bursts should be shorter than q

# Priority Scheduling

# 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***

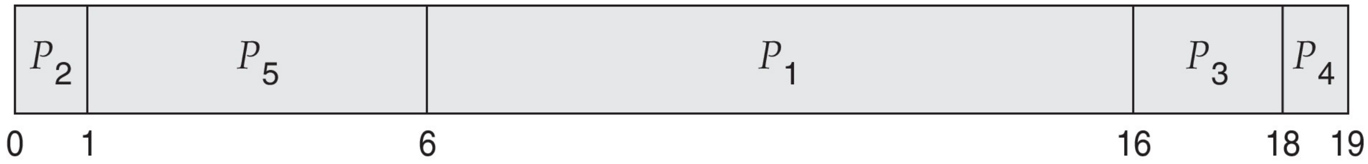
# Priority Scheduling

- **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



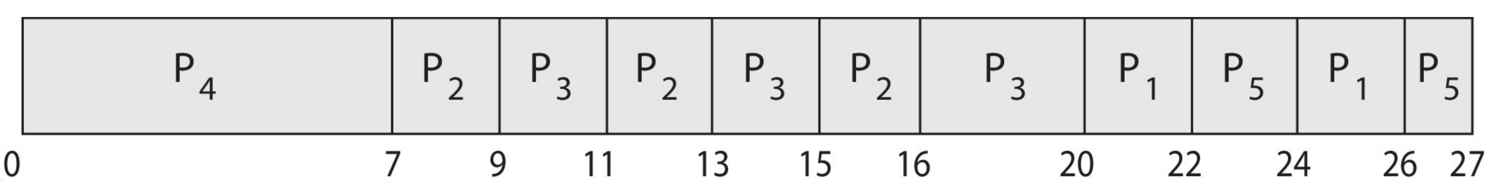

- Average waiting time = 8.2

# Priority Scheduling w/ Round-Robin

| Process | Burst Time | Priority |
|---|---|---|
| $P_1$ | 4 | 3 |
| $P_2$ | 5 | 2 |
| $P_3$ | 8 | 2 |
| $P_4$ | 7 | 1 |
| $P_5$ | 3 | 3 |

- Run the process with the highest priority. Processes with the same priority run round-robin

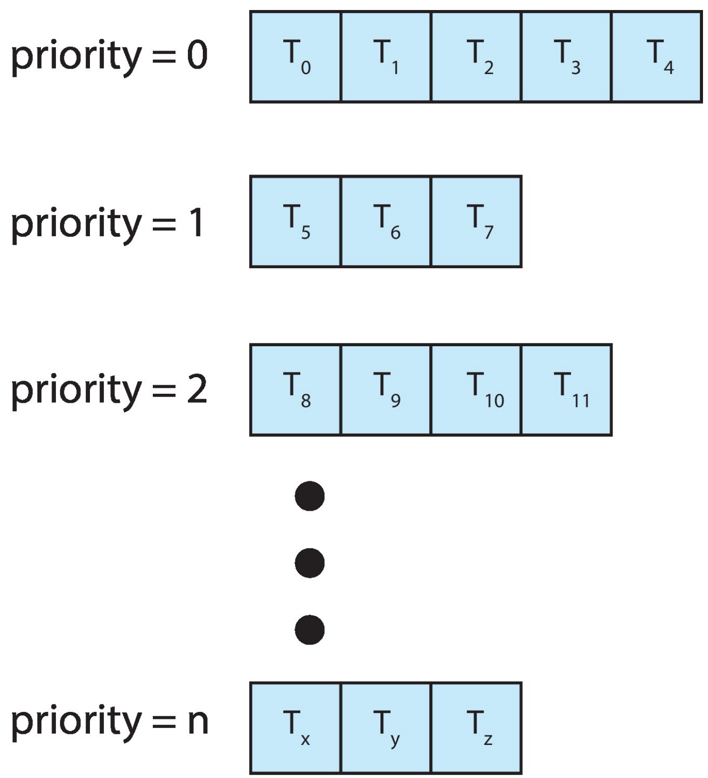
- Gantt Chart with time quantum = 2



# Multilevel Queue Scheduling

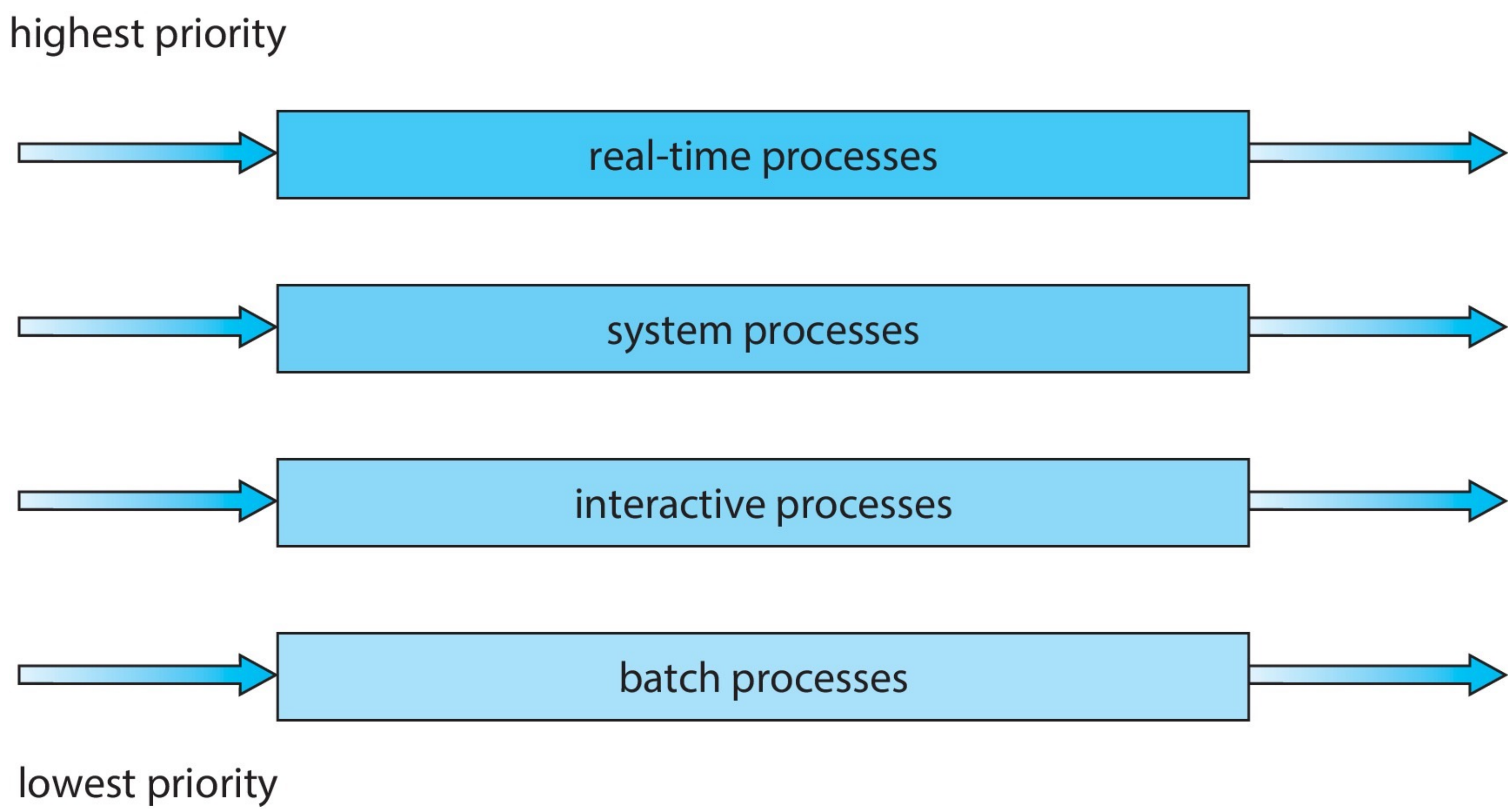
# Multilevel Queue

- With priority scheduling, have separate queues for each priority.
- Schedule the process in the highest-priority queue!



# Multilevel Queue

- Prioritization based upon process type



# Multilevel Feedback Queue

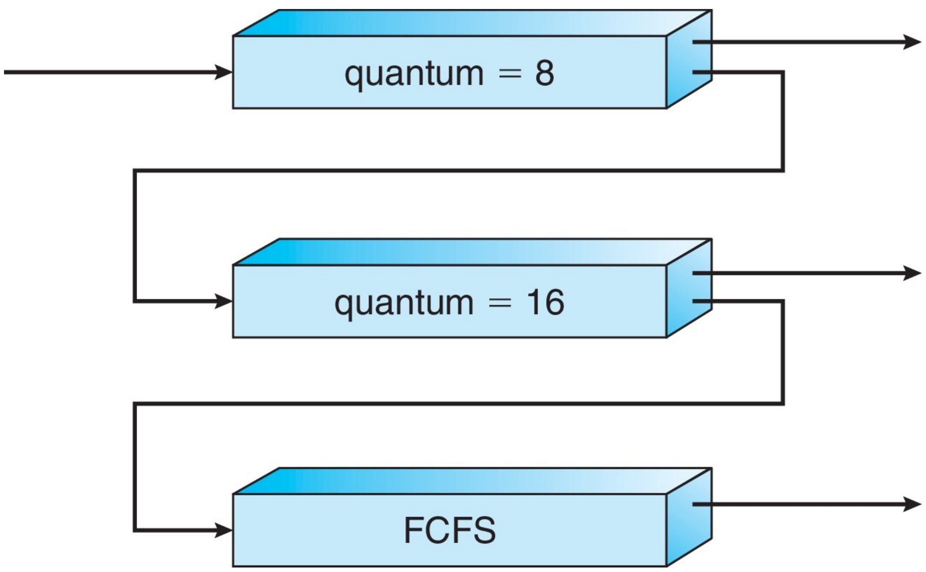
- A process can move between the various queues.

- Multilevel-feedback-queue 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

- **Aging** can be implemented using multilevel feedback queue

# Example of Multilevel Feedback Queue

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



# Example of Multilevel Feedback Queue (cont.)

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