IOWA STATE UNIVERSITY
Department of Electrical and Computer Engineering

Lecture 10: Scheduling II

Agenda

- Recap
- Scheduling II
  - Scheduling Algorithms (cont')

Recap

- Scheduling Concept
  - Process scheduling
    - When to run a different process?
      - New process is created
      - Process terminates
      - A process blocks on I/O etc.
      - interrupt occurs
    - Which one to run?
      - Depends on system characteristics/requirements
        - Various scheduling algorithms

Recap

- Scheduling Concept
  - Process behavior
    - CPU-bound (compute-bound)
    - I/O-bound
  - Non-preemptive V.S. preemptive scheduling
    - Non-preemptive
    - Preemptive
  - General goals of scheduling
    - Fairness
    - Policy enforcement
    - Balance
  - Specific goals for batch, interactive, real-time systems

Recap

- Scheduling Algorithms
  - First-Come, First-Served (FCFS)
    - based on the arrival order of processes

Process	Burst Time
P_1	24
P_2	3
P_3	3

    - Assume the processes arrive in the order: P_1 , P_2 , P_3
    - The **Gantt Chart** for the schedule is:

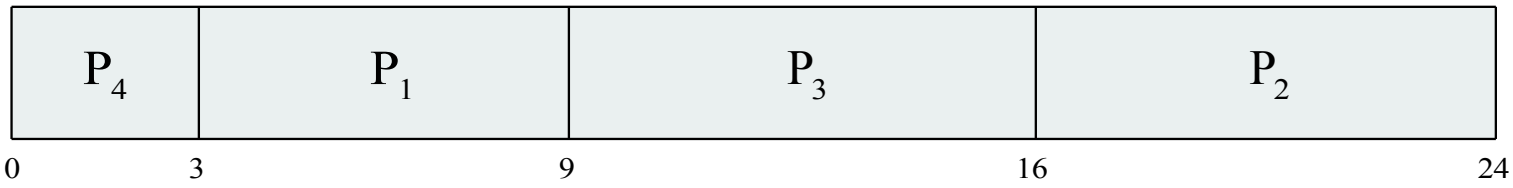
    - Waiting time for P_1 = 0; P_2 = 24; P_3 = 27
    - Average waiting time: (0 + 24 + 27)/3 = 17

Recap

- Scheduling Algorithms
  - Shortest-Job-First (SJF)
    - based on (predicted) CPU burst time

Process	Burst Time
P_1	6
P_2	8
P_3	7
P_4	3

    - Assume all processes are ready at time 0
    - Gantt Chart:



    - Average waiting time = (3 + 16 + 9 + 0) / 4 = 7
    - Turnaround time: P1 = 9; P2 = 24; P3 = 16; P4 = 3

Agenda

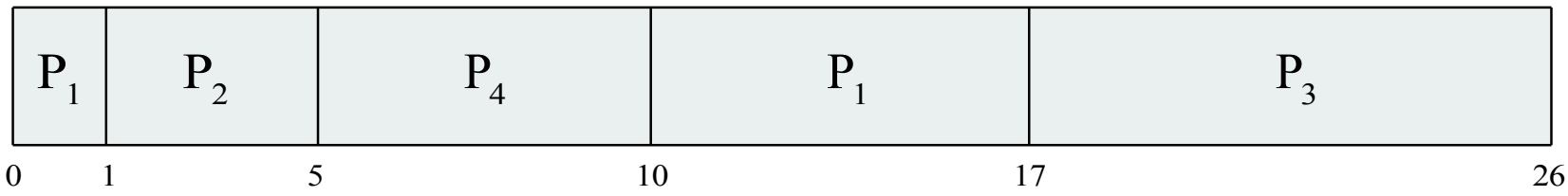
- Recap
- Scheduling II
  - Scheduling Algorithms (cont')

Scheduling Algorithms

- Shortest Remaining Time Next
  - Preemptive; varying arrival time

Process	*Arrival* Time	Burst Time
P_1	0	8
P_2	1	4
P_3	2	9
P_4	3	5

  - Gantt Chart:



Scheduling Algorithms

- Shortest Remaining Time Next
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P_1	0	8
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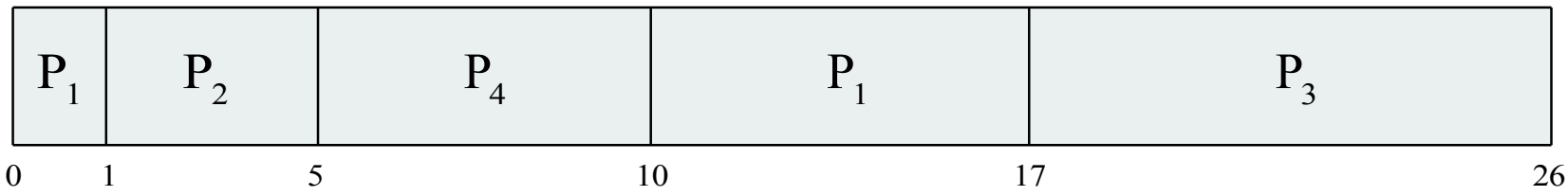

  - Average waiting time = ?

Scheduling Algorithms

- Shortest Remaining Time Next
  - Preemptive; varying arrival time

Process	*Arrival* Time	Burst Time
P_1	0	8
P_2	1	4
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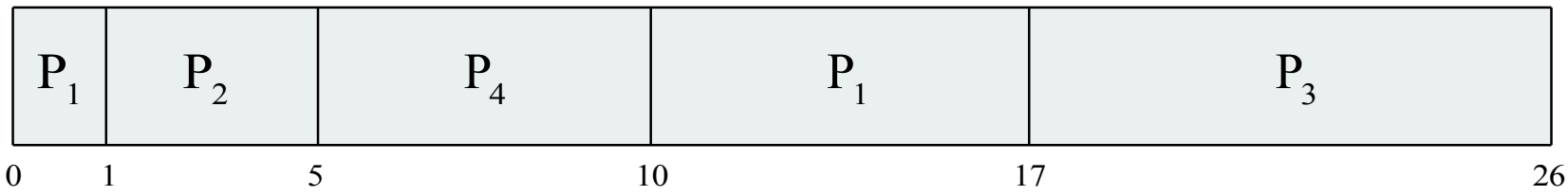
  - Gantt Chart:



  - Average waiting time = 6.5

Scheduling Algorithms

- Round Robin (RR)
  - Each process is assigned a time interval (quantum) during which it is allowed to run

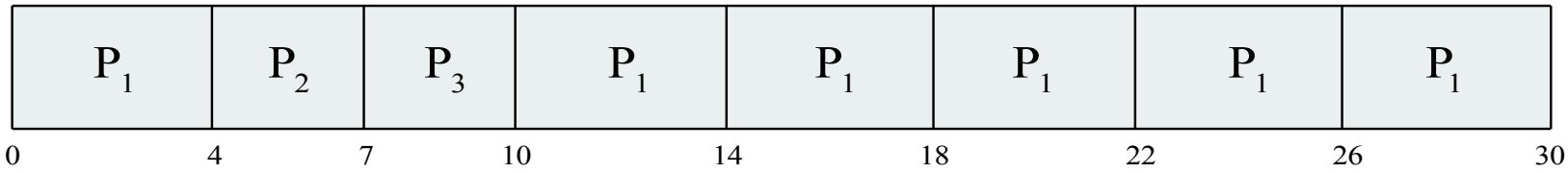
  - Left: The list of runnable processes.
  - Right: The list of runnable processes after B uses up its quantum

Scheduling Algorithms

- Round Robin (RR)
  - Each process is assigned a time interval (quantum) during which it is allowed to run

Process	Burst Time
P_1	24
P_2	3
P_3	3

  - Assume quantum q = 4. The Gantt chart is:



  - q should be large compared to context switch time
    - E.g., q usually 10ms to 100ms, context switch < 10 usec

Scheduling Algorithms

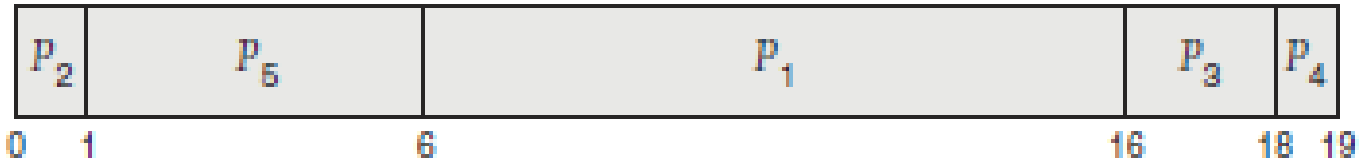
- Priority Scheduling
  - A priority number is associated with each process
  - schedule the process with the highest priority
    - Preemptive
    - Non-preemptive
  - SJF is priority scheduling where priority is based on the predicted next CPU burst time

Scheduling Algorithms

- Priority Scheduling
  - E.g.,

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

  - Assume non-preemptive, all processes are ready at time 0
  - Gantt Chart:



Scheduling Algorithms

- Priority Scheduling
  - E.g.,

Process	Burst Time	Priority
P_1	10	3
P_2	1	1
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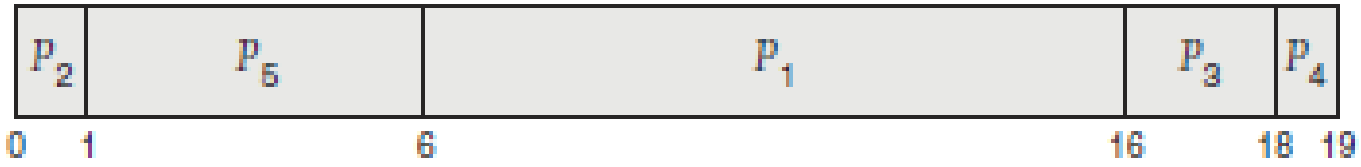
  - Assume non-preemptive, all processes are ready at time 0
  - Gantt Chart:



  - Average waiting time = ?

Scheduling Algorithms

- Priority Scheduling
  - E.g.,

Process	Burst Time	Priority
P_1	10	3
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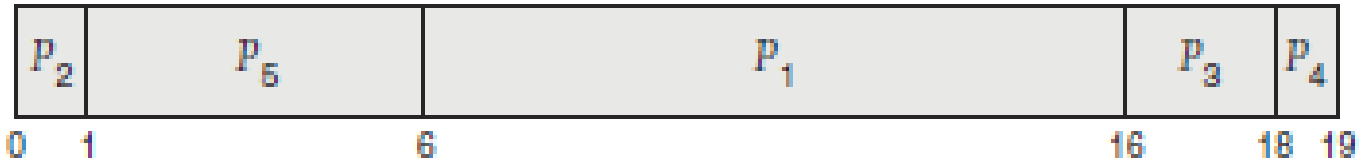
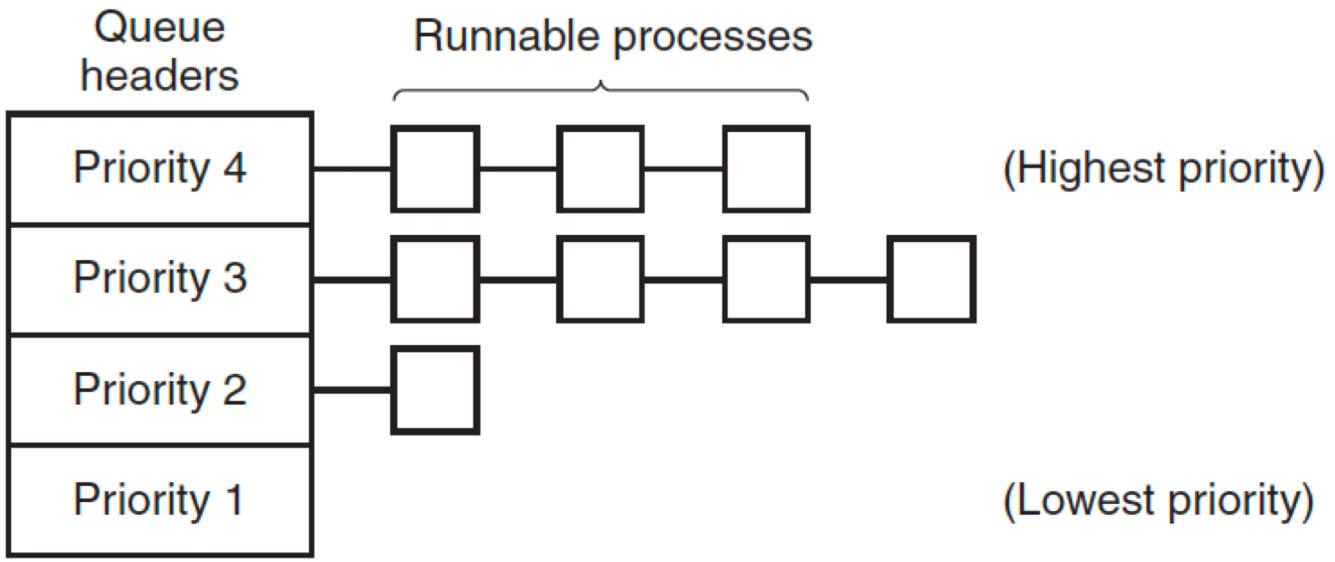
  - Assume non-preemptive, all processes are ready at time 0
  - Gantt Chart:



  - Average waiting time = (1+6+16+18)/5 = 8.2

Scheduling Algorithms

- Priority Scheduling
  - E.g., four priority classes
    - Always schedule process from high priority class
    - Round-Robin within each class



Scheduling Algorithms

- Summary
  - First-Come, First-Served (FCFS)
  - Shortest-Job-First (SJF)
  - Shortest Remaining Time Next
  - Round Robin (RR)
  - Priority Scheduling

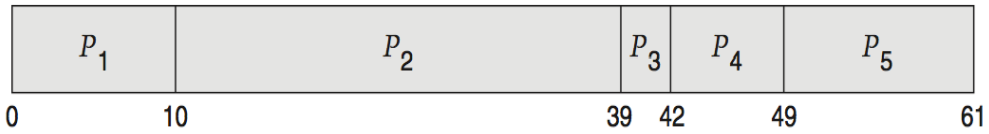
Scheduling Algorithms

- Algorithm Comparison
  - Consider 5 processes arriving in the order of P1-P5; all are ready at time 0
  - Draw Gantt Chart for each algorithm and calculate average waiting time
    - FCFS:
    - SJF (Non-preemptive):
    - RR (quantum = 10):

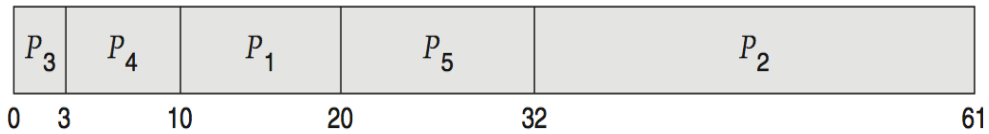
Process	Burst Time
P_1	10
P_2	29
P_3	3
P_4	7
P_5	12

Scheduling Algorithms

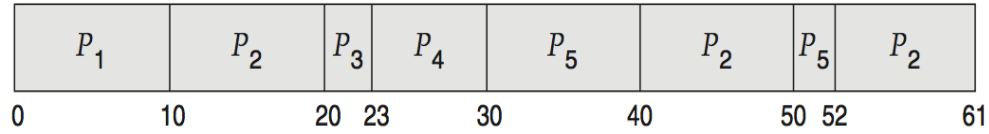
- Algorithm Comparison
  - Consider 5 processes arriving in the order of P1-P5; all are ready at time 0
  - Draw Gantt Chart for each algorithm and calculate average waiting time
    - FCFS: 28



    - SJF (Non-preemptive): 13



    - RR (quantum = 10): 23



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Agenda

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- ~~Scheduling II~~
  - ~~Scheduling Algorithms (cont')~~

Questions?

*acknowledgement: slides include content from "Modern Operating Systems" by A. Tanenbaum, "Operating Systems Concepts" by A. Silberschatz etc., "Operating Systems: Three Easy Pieces" by R. Arpaci-Dusseau etc., and anonymous pictures from internet.