CS 471 Operating Systems

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CPU Scheduling

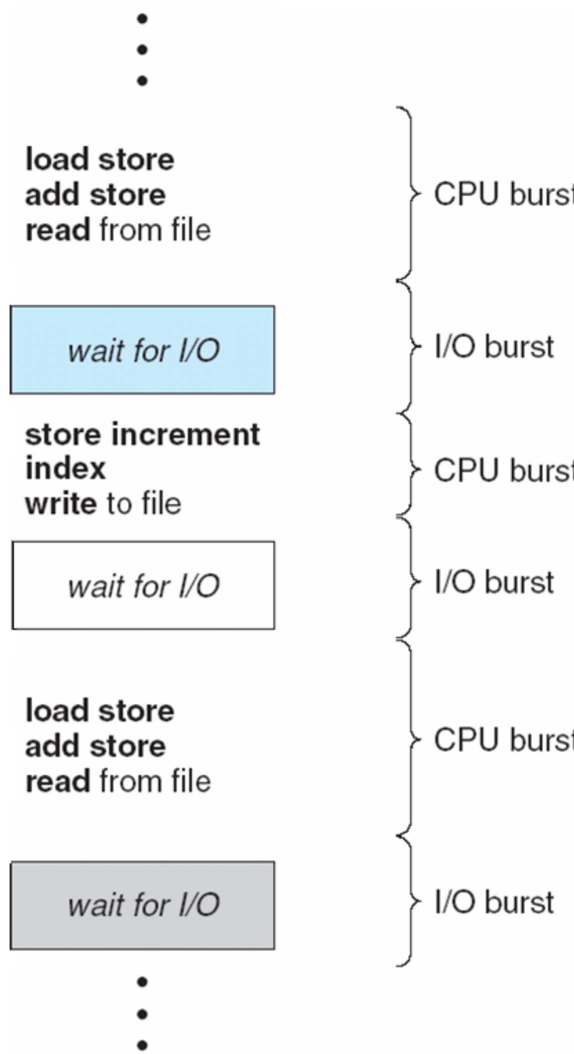
Outline

- Basic Concepts
- Scheduling Criteria
- Scheduling Algorithms
  - First-In-First-Out
  - Shortest-Job-First, Shortest-Remaining-Time-First
  - Priority Scheduling
  - Round Robin
  - Multi-level Queue
  - Multi-level Feedback Queue

Basic Concepts

- During its lifetime, a process goes through a sequence of CPU and I/O bursts
- The CPU scheduler (a.k.a. short-term scheduler) will select one of the processes in the ready queue for execution
- The CPU scheduler algorithm may have tremendous effects on the system performance
  - Interactive systems: Responsiveness
  - Real-time systems: Not missing the deadlines

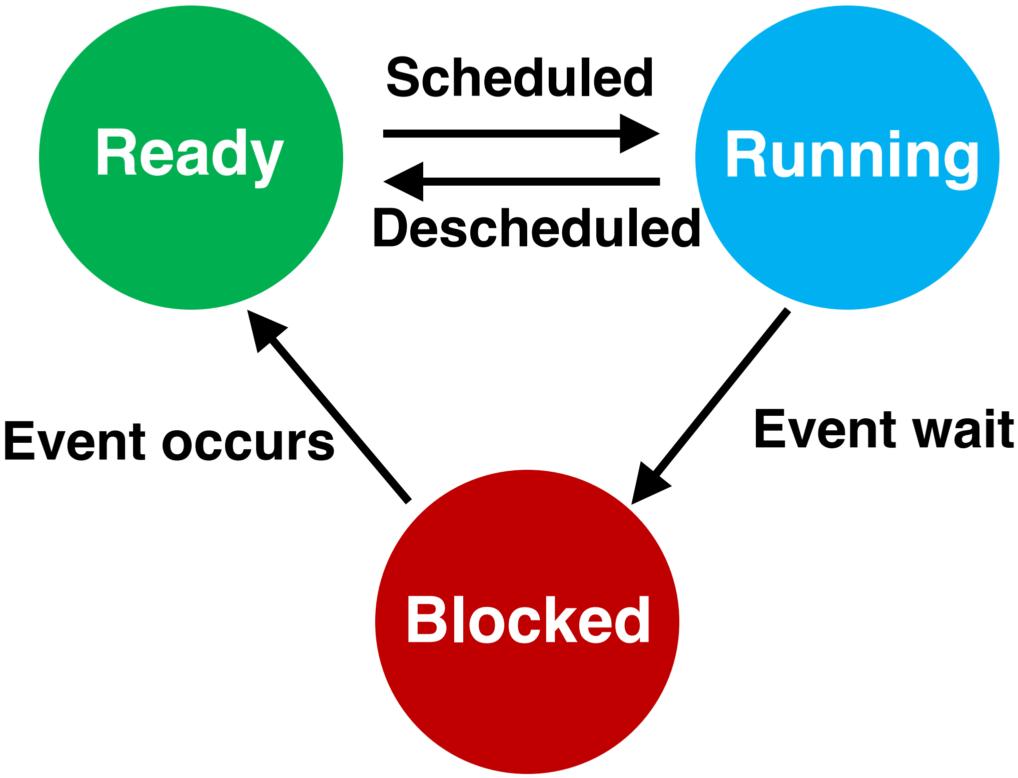
Alternating Sequence of CPU and I/O Bursts



When to Schedule?

- Under the simple process state transition model, CPU scheduler can be potentially invoked at five different points:
  1. When a process switches from the new state to the ready state
  2. When a process switches from the running state to the waiting (or blocked) state
  3. When a process switches from the running state to the ready state
  4. When a process switches from the waiting state to the ready state
  5. When a process terminates

Process State Transitions



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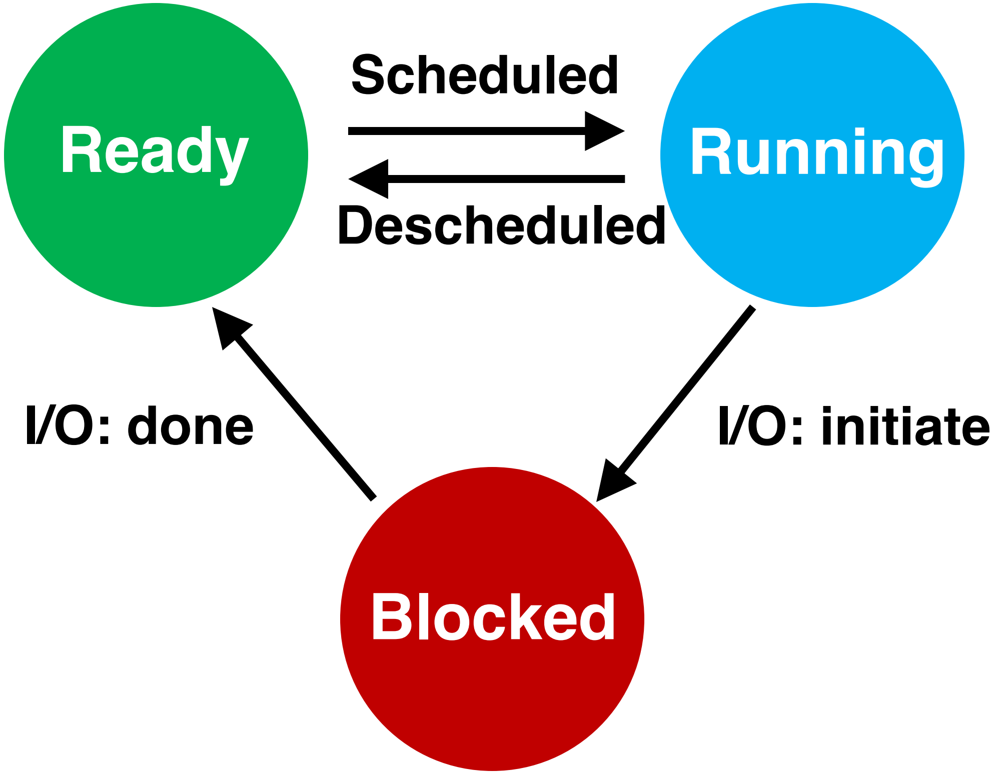

Non-preemptive vs. Preemptive Scheduling

- Under non-preemptive scheduling, each running process keeps the CPU until it completes or it switches to the waiting (blocked) state

- Under preemptive scheduling, a running process may be forced to release the CPU even though it is neither completed nor blocked
  - In time-sharing systems, when the running process reaches the end of its time quantum (slice)
  - In general, whenever there is a change in the ready queue

Non-preemptive vs. Preemptive Scheduling

- Non-preemptive kernels do not allow preemption of a process running in kernel mode
  - Serious drawback for real-time applications

- Preemptive kernels allow preemption even in kernel mode
  - Insert safe preemption points in long-duration system calls
  - Or, use synchronization mechanisms (e.g., "mutex locks") to protect the kernel data structures against race conditions

Dispatcher

- Dispatcher module gives control of the CPU to the process selected by the short-term scheduler; this involves:
  - switching context
  - switching to user mode
  - jumping to the proper location in the user program to restart that program

- Scheduler → Policy: When and how to schedule
- Dispatcher → Mechanism: Actuator following the commands of the scheduler

Scheduling Metrics

- To compare the performance of scheduling algorithms
  - CPU utilization – percentage of time CPU is busy executing jobs
  - Throughput – # 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 the complete output
  - Meeting the deadlines (real-time systems)

Optimization Goals

- To **maximize**:
  - Maximize the CPU utilization
  - Maximize the throughput
- To **minimize**:
  - Minimize the (average) turnaround time
  - Minimize the (average) waiting time
  - Minimize the (average) response time

Waiting Time

- Waiting time definition

$$T_{waiting} = T_{start} - T_{arrival}$$

- Average waiting time = Sum($T_{waiting}$)/ #processes

- **For now, we assume**
  - –Average waiting time is the performance measure
  - –Only one CPU burst (e.g., in milliseconds or ms) per process
  - –Only CPU, No I/O
  - –All processes arrive at the same time
  - –Once started, each process runs to completion

First-In-First-Out (FIFO)

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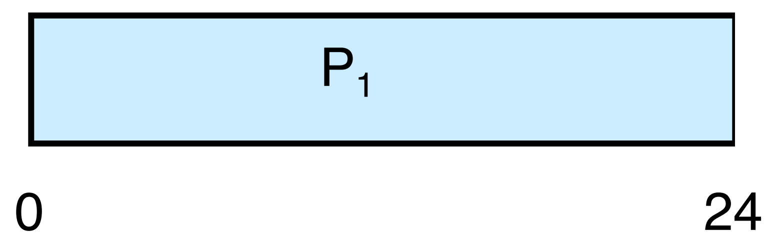
Process	Burst Time
P_1	24

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



First-In-First-Out (FIFO)

Process	Burst Time
P_1	24
P_2	3

- Suppose that the processes arrive in order: P_1 , P_2 , P_3
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Process	Burst Time
P_1	24
P_2	3
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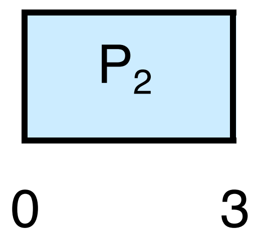
- Suppose that the processes arrive in order: P_1 , P_2 , P_3
  The Gantt Chart for the schedule:

- Waiting time for P_1 = 0; P_2 = 24; P_3 = 27
- Average waiting time: 17

FIFO (cont.)

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



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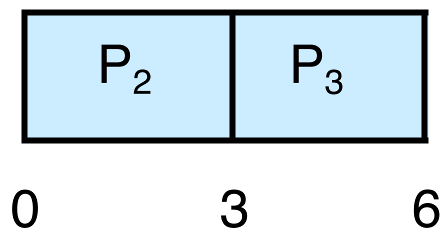

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- The Gantt chart for the schedule:

- Waiting time for $P_1 = 6$; $P_2 = 0$; $P_3 = 3$
- Average waiting time: (6 + 0 + 3)/3 = 3

FIFO (cont.)

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

- Waiting time for $P_1 = 6;$ $P_2 = 0;$ $P_3 = 3$
- Average waiting time: $(6 + 0 + 3)/3 = 3$
- Problems:
  – **Convoy effect** (short processes behind long processes)
  – Non-preemptive: Not suitable for time-sharing systems

Shortest-Job-First (SJF)

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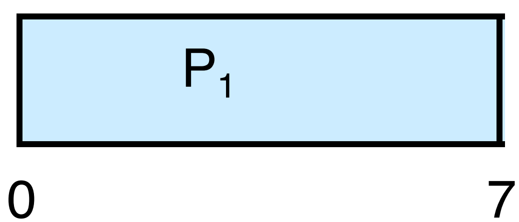
- Associate with each process the length of its next CPU burst
- The CPU is assigned to the process with the smallest (next) CPU burst (run_time)

- Two schemes:
  - Non-preemptive
  - Preemptive: Also known as the **Shortest-Remaining-Time-First (SRTF)**

Example for Non-Preemptive SJF

Process	Arrival Time	Burst Time
P_1	0.0	7
P_2	2.0	4
P_3	4.0	1
P_4	5.0	4

- SJF (non-preemptive)



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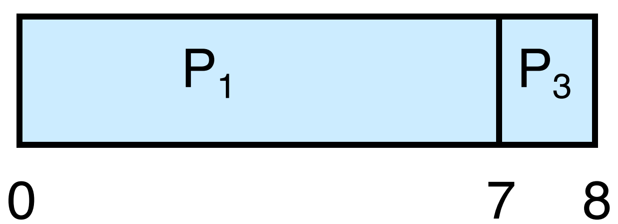

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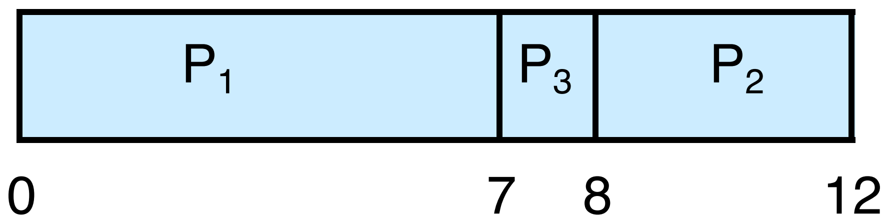

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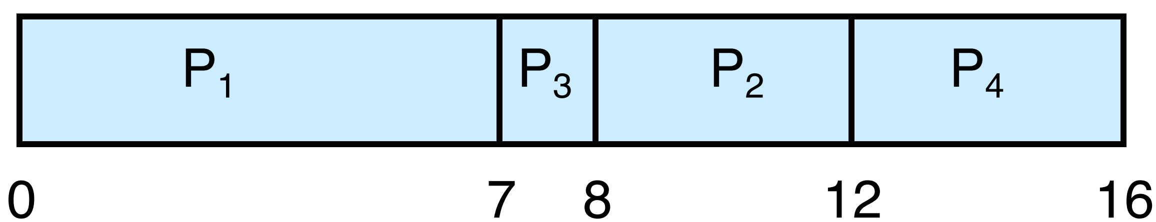

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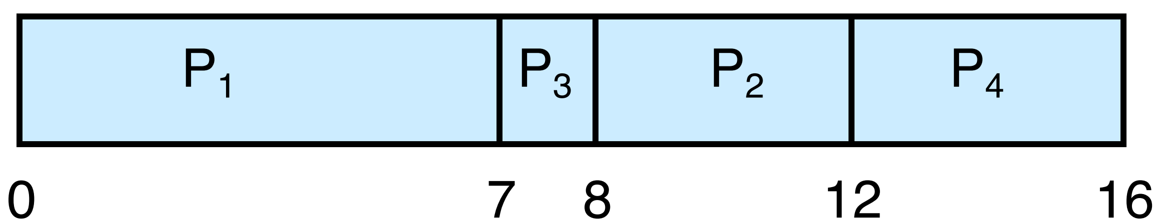


- Average waiting time = (0 + 6 + 3 + 7)/4 = 4

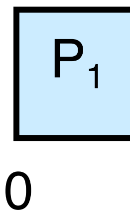
Example for Preemptive SJF (SRTF)

Process	Arrival Time	Burst Time	**Left Time**
P_1	0.0	7	

Example for Preemptive SJF (SRTF)

Process	Arrival Time	Burst Time	**Left Time**
P_1	0.0	7	5
P_2	2.0	4	

- SJF (preemptive)



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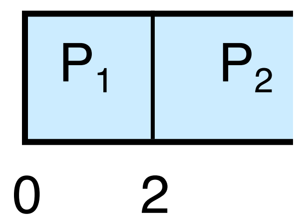

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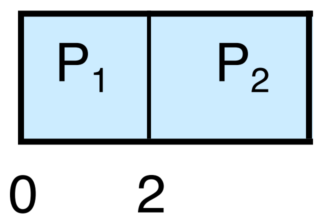

Example for Preemptive SJF (SRTF)

Process	Arrival Time	Burst Time	**Left Time**
P_1	0.0	7	5
P_2	2.0	4	**2**
P_3	4.0	1	1

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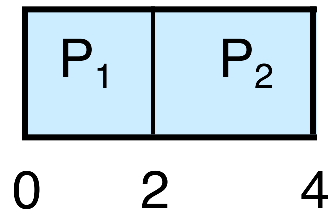

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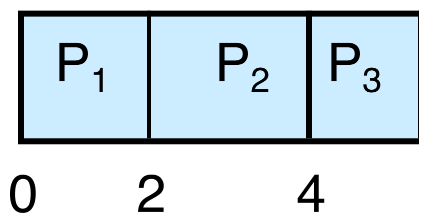

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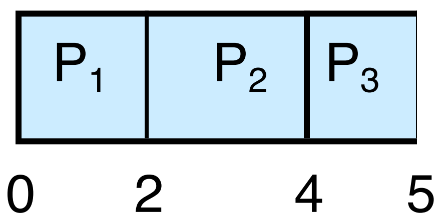

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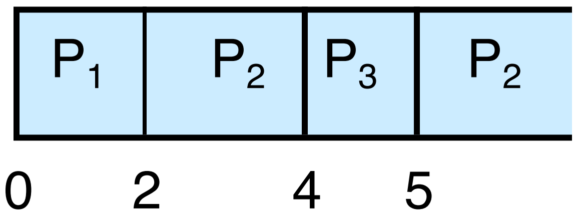

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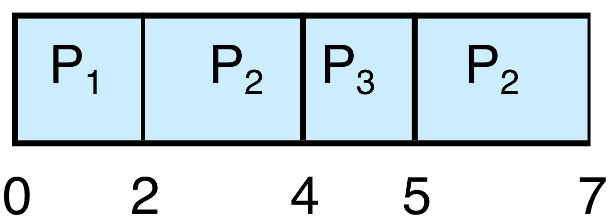

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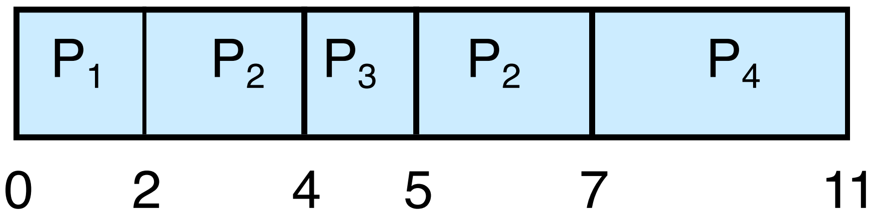

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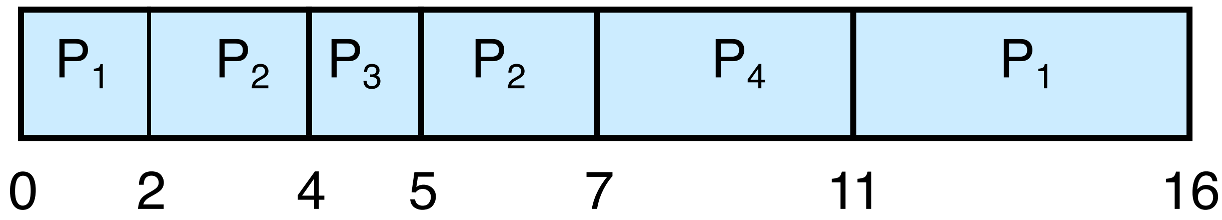

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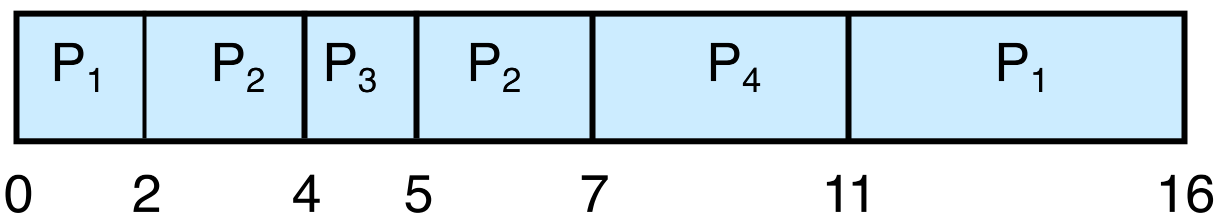

- Average waiting time = (9 + 1 + 0 + 2)/4 = 3