Chapter 2: CPU Scheduling

Chapter 6: CPU Scheduling

- Basic Concepts
- Scheduling Criteria
- Scheduling Algorithms

Objectives

▶ To introduce CPU scheduling, which is the basis for multiprogrammed operating systems

▶ To describe various CPU-scheduling algorithms

▶ To discuss evaluation criteria for selecting a CPU-scheduling algorithm for a particular system

▶ To examine the scheduling algorithms of several operating systems

Basic Concepts

- Maximum CPU utilization obtained with multiprogramming

- CPU-I/O Burst Cycle – Process execution consists of a cycle of CPU execution and I/O wait

- CPU burst followed by I/O burst

- CPU burst distribution is of main concern

⋮

load store
add store
read from file

} CPU burst

wait for I/O

} I/O burst

store increment
index
write to file

} CPU burst

wait for I/O

} I/O burst

load store
add store
read from file

} CPU burst

wait for I/O

} I/O burst

⋮

CPU Scheduler

- **Short-term scheduler** selects from among the processes in the ready queue and allocates the CPU to one of them
  - Queue may be ordered in various ways
- 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
- Scheduling under 1 and 4 is non preemptive
- All other scheduling is preemptive
  - Consider access to shared data
  - Consider preemption while in kernel mode
  - Consider interrupts occurring during crucial OS activities

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

- Dispatch latency – the time it takes for the dispatcher to stop one process and start another running

Scheduling Criteria

1. *CPU utilization* – keep the CPU as busy as possible

2. *Throughput* – no. of processes that complete their execution per time unit

3. *Turnaround time* – the amount of time to execute a particular process

4. *Waiting time* – the amount of time a process has been waiting in the ready queue

5. *Response time* – the amount of time it takes from when a request was submitted until the first response is produced, not output (for a time-sharing environment)
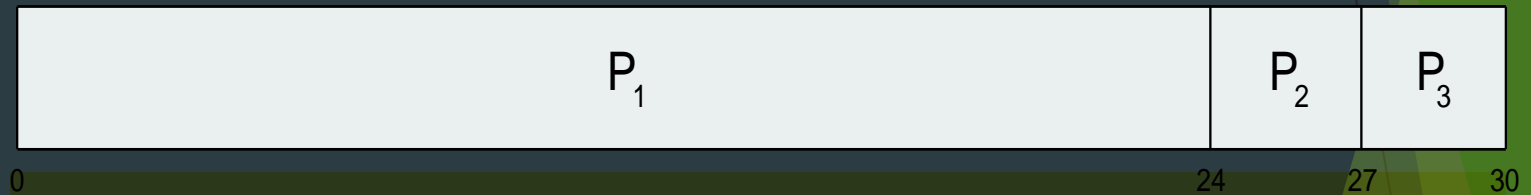
Scheduling Algorithm Optimization Criteria

- Max CPU utilization
- Max throughput
- Min turnaround time
- Min waiting time
- Min response time

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:

P₁	P₂	P₃

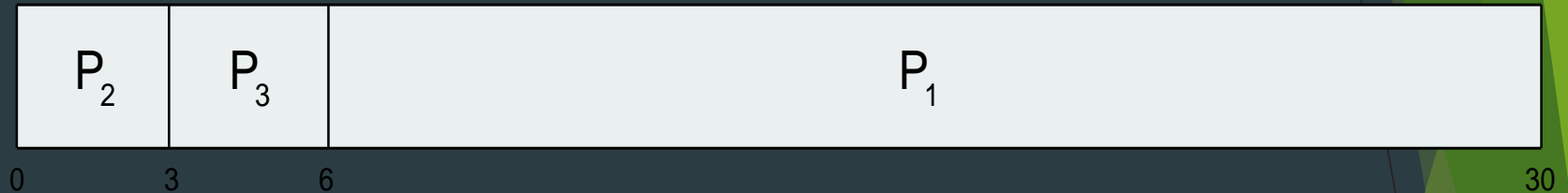0   24   27   30

▶ 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:

P$_2$	P$_3$	P$_1$

0   3   6   30

▶ 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

▶ Convoy effect - short process behind long process

　　▶ Consider one CPU-bound and many I/O-bound processes

Characteristics of FCFS method

▶ It supports non-preemptive and pre-emptive scheduling algorithms.

▶ Jobs are always executed on a first-come, first-serve basis.

▶ It is easy to implement and use.

▶ This method is poor in performance, and the general wait time is quite high.

Advantages of FCFS

- The simplest form of a CPU scheduling algorithm
- Easy to program
- First come first served

Disadvantages of FCFS

- It is a Non-Preemptive CPU scheduling algorithm, so after the process has been allocated to the CPU, it will never release the CPU until it finishes executing.
- The Average Waiting Time is high.
- Short processes that are at the back of the queue have to wait for the long process at the front to finish.
- Not an ideal technique for time-sharing systems.
- Because of its simplicity, FCFS is not very efficient.

Shortest-Job-First (SJF) Scheduling

▶ Associate with each process the length of its next CPU burst

   ▶ Use these lengths to schedule the process in the shortest time

▶ SJF is optimal – gives minimum average waiting time for a given set of processes

   ▶ The difficulty is knowing the length of the next CPU request

   ▶ Could ask the user

Example of SJF

Process	Arrival Time	Burst Time
P_1	0.0	6
P_2	2.0	8
P_3	4.0	7
P_4	5.0	3

▶ SJF scheduling chart

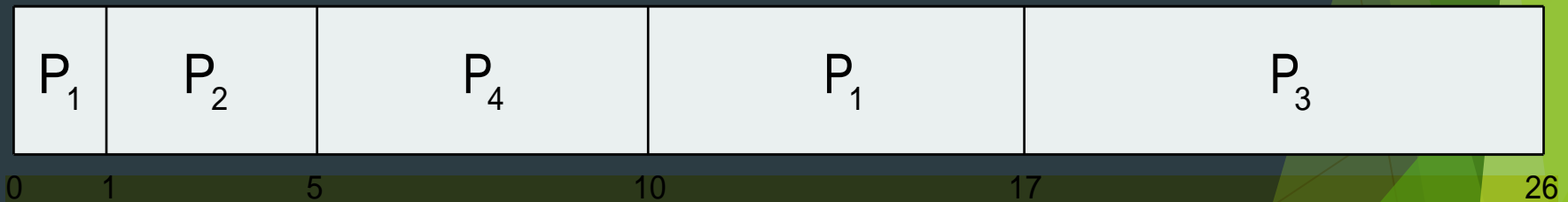| P_4	P_1	P_3	P_2

0   3   9   16   24
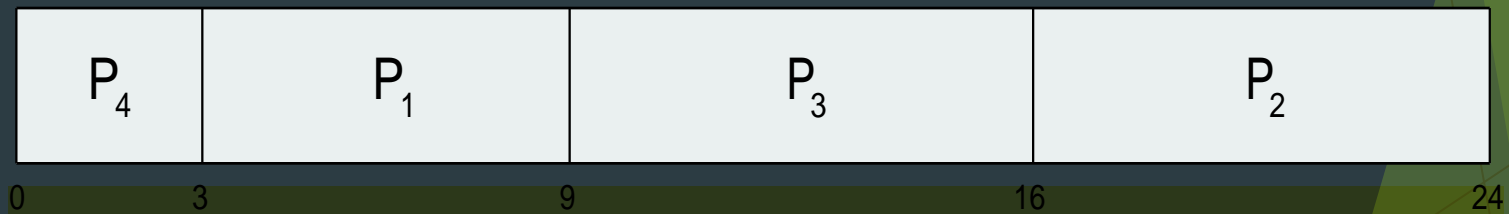
▶ Average waiting time = (3 + 16 + 9 + 0) / 4 = 7

Example of Shortest-remaining-time-first(Preemptive)

▶ Now we add the concepts of varying arrival times and preemption to the analysis

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

▶ *Preemptive* SJF Gantt Chart

P₁	P₂	P₄	P₁	P₃

```
0    1        5              10             17                        26
```

▶ Average waiting time = [(10-1)+(1-1)+(17-2)+(5-3)]/4 = 26/4 = 6.5 msec

sum (compl_wait_time - arrival time - initial_burst_time)

# 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

▶ 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

P_2	P_5	P_1	P_3	P_4

0   1   6   16   18 19
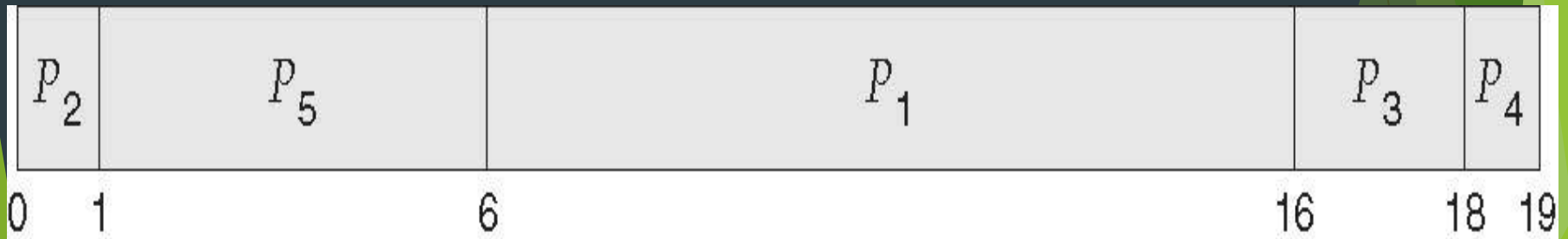
▶ Average waiting time = 8.2 msec

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 $(n-1)q$ 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
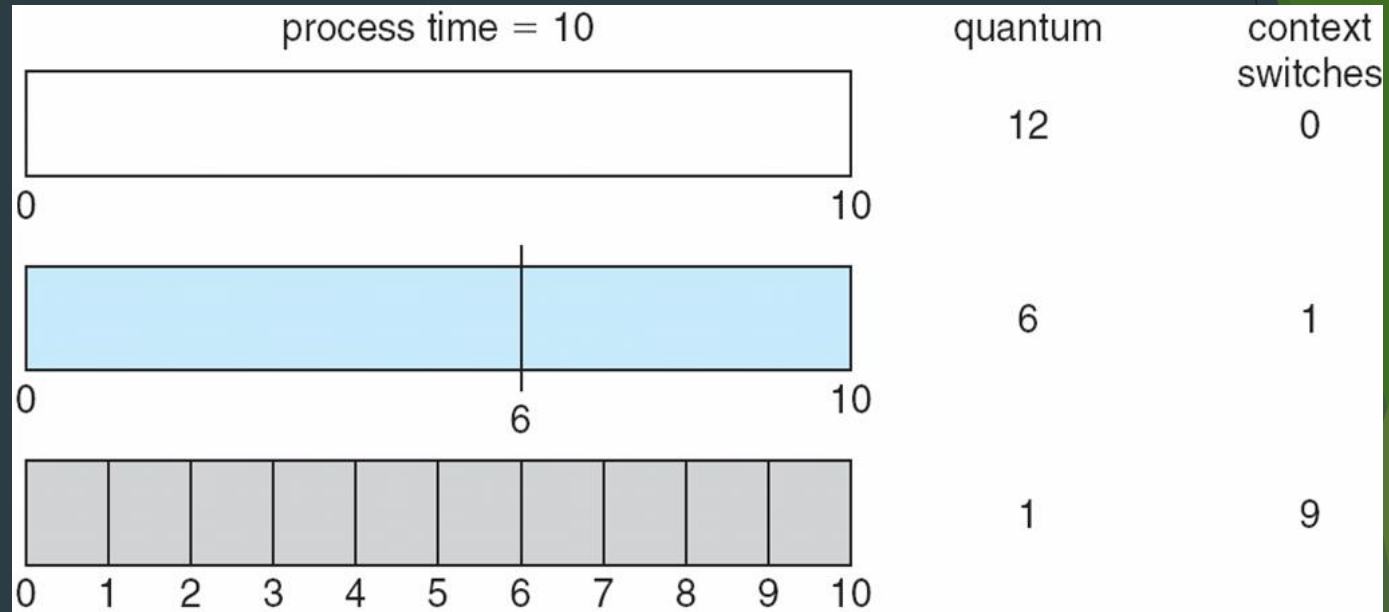
Example of RR with Time slice = 4

Process	Burst Time
P_1	24
P_2	3
P_3	3

▶ The Gantt chart is:

P_1	P_2	P_3	P_1	P_1	P_1	P_1	P_1

0   4   7   10   14   18   22   26   30
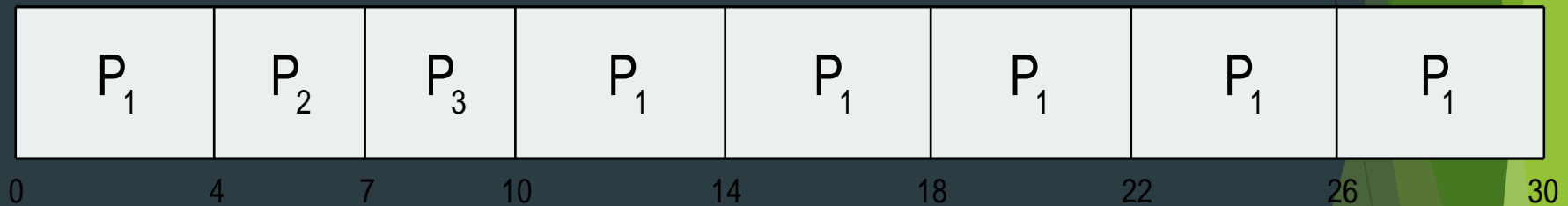
▶ Typically, higher average turnaround than SJF, but better *response*

▶ q should be large compared to context switch time

▶ q usually 10ms to 100ms, context switch < 10 usec

Time Quantum and Context Switch Time

Multilevel Queue

- Ready queue is partitioned into separate queues, eg:
  - foreground (interactive)
  - background (batch)
- Process permanently in a given queue
- Each queue has its own scheduling algorithm:
  - foreground – RR
  - background – FCFS
- Scheduling must be done between the queues:
  - Fixed priority scheduling; (i.e., serve all from foreground then from background). Possibility of starvation.
  - Time slice – each queue gets a certain amount of CPU time which it can schedule amongst its processes; i.e., 80% to foreground in RR
  - 20% to background in FCFS

Multilevel Queue Scheduling