

ECE 344: Operating Systems  
Lecture 14

# Basic Scheduling

1.0.0

Jon Eyolfson  
October 11/12, 2022



This work is licensed under a [Creative Commons Attribution-ShareAlike 4.0 International License](https://creativecommons.org/licenses/by-sa/4.0/)

## There are Preemptible and Non-preemptible Resources

A preemptible resource can be taken away and used for something else  
e.g. a CPU

The resource is shared through scheduling

A non-preemptible resource can not be taken away without acknowledgment  
e.g. disk space

The resource is shared through allocations and deallocations

Note: Parallel and distributed systems may allow you to allocate a CPU

## A Dispatcher and Scheduler Work Together

A dispatcher is a low-level mechanism  
Responsible for context switching

A scheduler is a high-level policy  
Responsible for deciding which processes to run

## The Scheduler Runs Whenever a Process Changes State

First let's consider non-preemptable processes

Once the process starts, it runs until completion

In this case, the scheduler will only make a decision when the process terminates

Preemptive allows the operating system to run the scheduler at will

Check `uname -v`, your kernel should tell you it's preemptable

# Metrics

Minimize waiting time and response time

Don't have a process waiting too long (or too long to start)

Maximize CPU utilization

Don't have the CPU idle

Maximize throughput

Complete as many processes as possible

Fairness

Try to give each process the same percentage of the CPU

## First Come First Served (FCFS)

The most basic form of scheduling

The first process that arrives gets the CPU

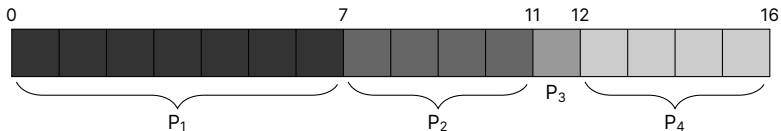
Processes are stored in a FIFO queue in arrival order

## A Gantt Chart Illustrates the Schedule

Consider the following processes:

Process	Arrival Time	Burst Time
P <sub>1</sub>	0	7
P <sub>2</sub>	0	4
P <sub>3</sub>	0	1
P <sub>4</sub>	0	4

Assume, P<sub>1</sub> → P<sub>2</sub> → P<sub>3</sub> → P<sub>4</sub>. For FCFS, our schedule is:



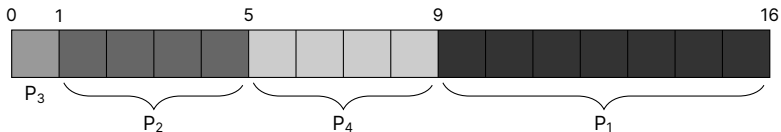
What is the average waiting time?

## What Happens to Our Waiting Time with a Different Arrival Order

Consider the same processes:

Process	Arrival Time	Burst Time
P <sub>1</sub>	0	7
P <sub>2</sub>	0	4
P <sub>3</sub>	0	1
P <sub>4</sub>	0	4

Assume, P<sub>3</sub> → P<sub>2</sub> → P<sub>4</sub> → P<sub>1</sub>. For FCFS, our schedule is:



What is the average waiting time now?



## Shortest Job First (SJF)

A slight tweak to FCFS, we always schedule the job with the shortest burst time first

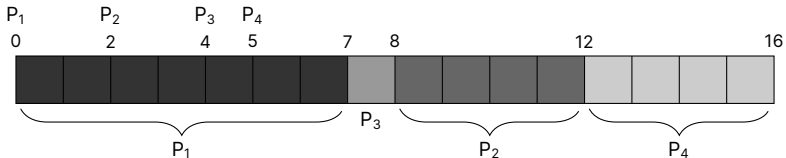
We're still assuming no preemption

## SJF Minimizes the Average Wait Time over FCFS

Consider the same processes with different arrival times:

Process	Arrival Time	Burst Time
P <sub>1</sub>	0	7
P <sub>2</sub>	2	4
P <sub>3</sub>	4	1
P <sub>4</sub>	5	4

For SJF, our schedule is (arrival on top):



$$\text{Average waiting time: } \frac{0+6+3+7}{4} = 4$$

## SJF is Not Practical

It is provably optimal at minimizing average wait time (if no preemption)

You will not know the burst times of each process

You could use the past to predict future executions

You may starve long jobs (they may never execute)

## Shortest Remaining Time First (SRTF)

Changing SJF to run with preemptions requires another tweak

We'll assume that our minimum execution time is one unit

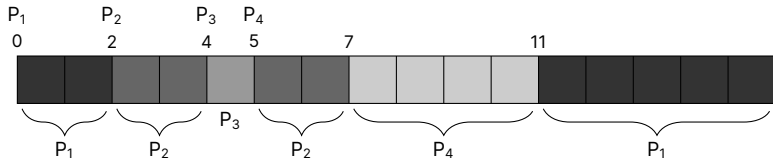
Similar to SJF, this optimizes the average waiting time

## SRTF Reduces the Average Wait Time Compared to SJF

Consider the same processes and arrival times as SJF:

Process	Arrival Time	Burst Time
P <sub>1</sub>	0	7
P <sub>2</sub>	2	4
P <sub>3</sub>	4	1
P <sub>4</sub>	5	4

For SRTF, our schedule is (arrival on top):



$$\text{Average waiting time: } \frac{9+1+0+2}{4} = 3$$

## Round-Robin (RR)

So far we haven't handled fairness (it's a trade off with other metrics)

The operating system divides execution into time slices (or quanta)

An individual time slice is called a quantum

Maintain a FIFO queue of processes similar to FCFS

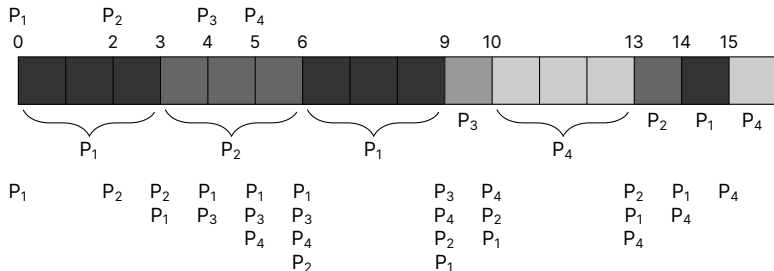
Preempt if still running at end of quantum and re-add to queue

What are practical considerations for determining quantum length?

## RR with a Quantum Length of 3 Units

Process	Arrival Time	Burst Time
P <sub>1</sub>	0	7
P <sub>2</sub>	2	4
P <sub>3</sub>	4	1
P <sub>4</sub>	5	4

For RR, our schedule is (arrival on top, queue on bottom):



## Metrics for RR (3 Unit Quantum Length)

Number of context switches: 7

Average waiting time:  $\frac{8+8+5+7}{4} = 7$

Average response time:  $\frac{0+1+5+5}{4} = 2.75$

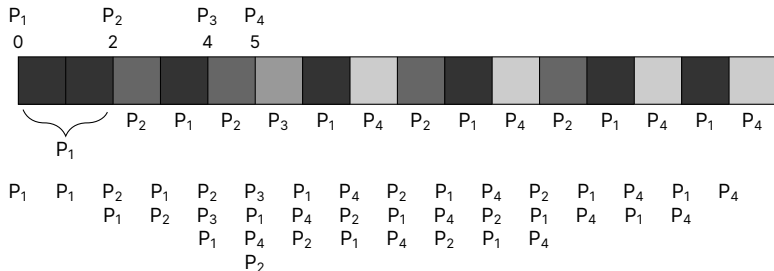
Note: on ties (a new process arrives while one is preempted), favor the new one



## RR with a Quantum Length of 1 Units

Process	Arrival Time	Burst Time
P <sub>1</sub>	0	7
P <sub>2</sub>	2	4
P <sub>3</sub>	4	1
P <sub>4</sub>	5	4

For RR, our schedule is (arrival on top, queue on bottom):



## Metrics for RR (1 Unit Quantum Length)

Number of context switches: 14

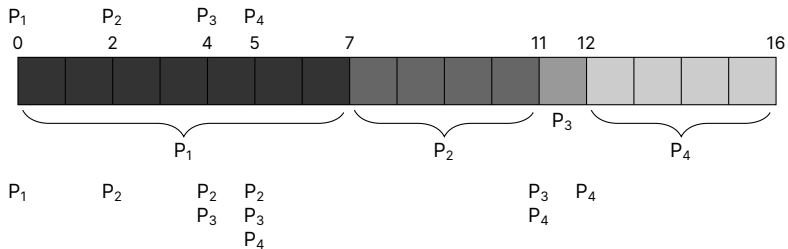
Average waiting time:  $\frac{8+6+1+7}{4} = 5.5$

Average response time:  $\frac{0+0+1+2}{4} = 0.75$

## RR with a Quantum Length of 10 Units

Process	Arrival Time	Burst Time
P <sub>1</sub>	0	7
P <sub>2</sub>	2	4
P <sub>3</sub>	4	1
P <sub>4</sub>	5	4

For RR, our schedule is (arrival on top, queue on bottom):



## Metrics for RR (10 Unit Quantum Length)

Number of context switches: 3

Average waiting time:  $\frac{0+5+7+7}{4} = 4.75$

Average response time:  $\frac{0+5+7+7}{4} = 4.75$

Note: in this case it's the same as FCFS without preemptions

## RR Performance Depends on Quantum Length and Job Length

RR has low response good interactivity

Fair allocation of CPU

Low average waiting time (when job lengths vary)

The performance depends on the quantum length

Too high and it becomes FCFS

Too low and there's too many context switches (overhead)

RR has poor average waiting time when jobs have similar lengths

## Scheduling Involves Trade-Offs

We looked at few different algorithms:

- First Come First Served (FCFS) is the most basic scheduling algorithm
- Shortest Job First (SJF) is a tweak that reduces waiting time
- Shortest Remaining Time First (SRTF) uses SJF ideas with preemptions
- SRTF optimizes lowest waiting time (or turnaround time)
- Round-robin (RR) optimizes fairness and response time