Department of Computer Science
UNIVERSITY OF COLORADO BOULDER

Design and Analysis of Operating Systems CSCI 3753

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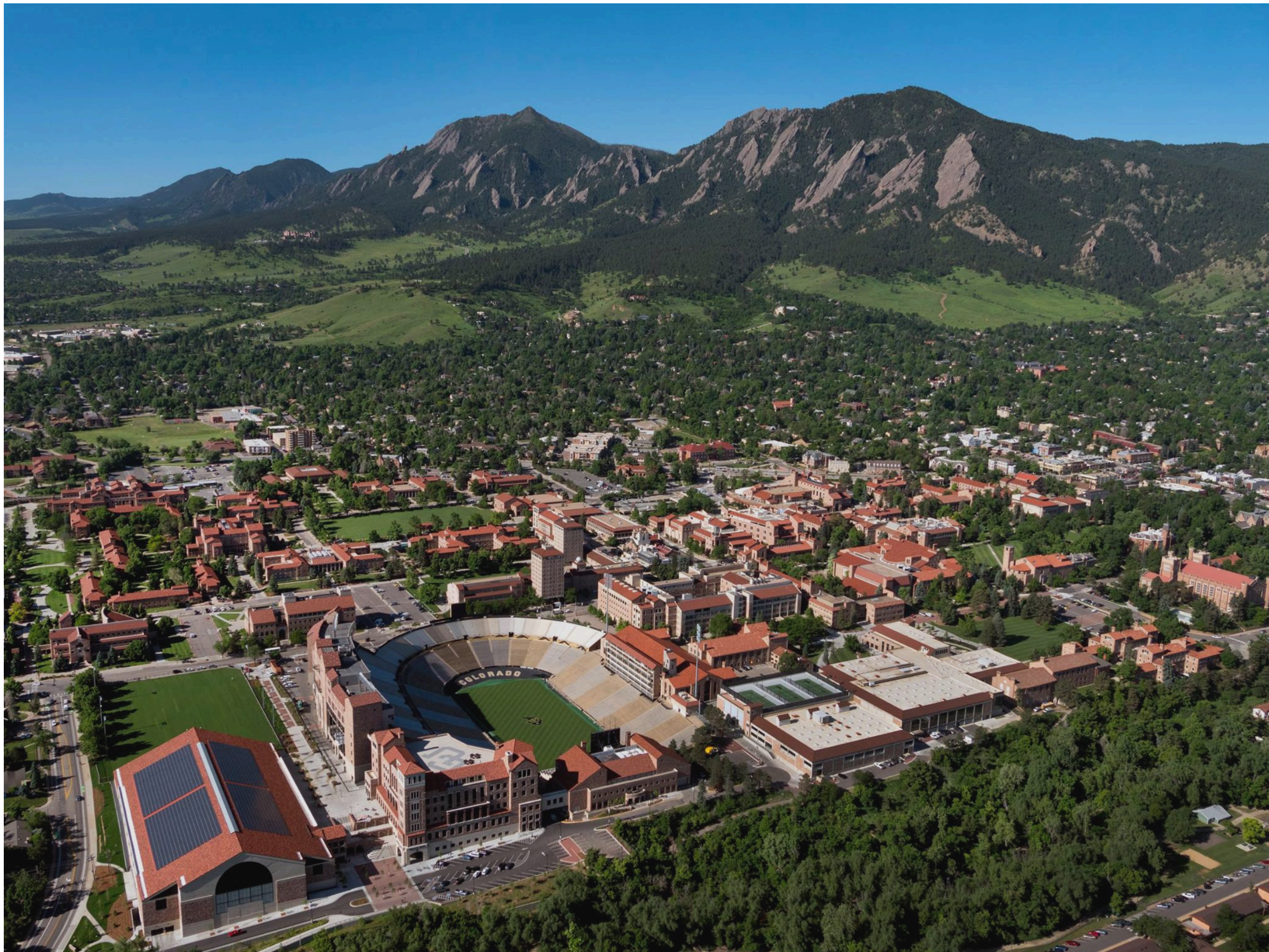
These slides adapted from materials provided by the textbook authors.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Process Scheduling

Diagram of Process State

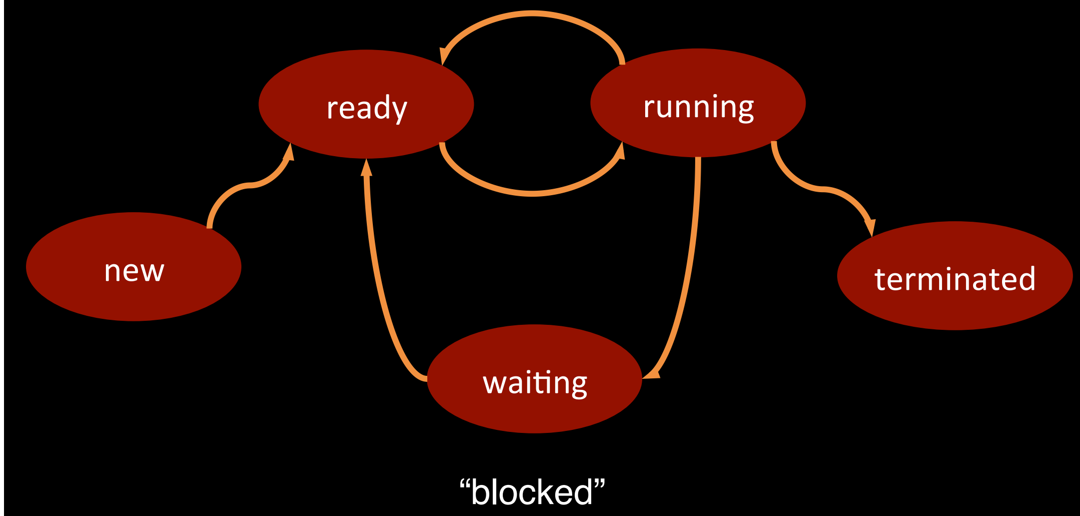
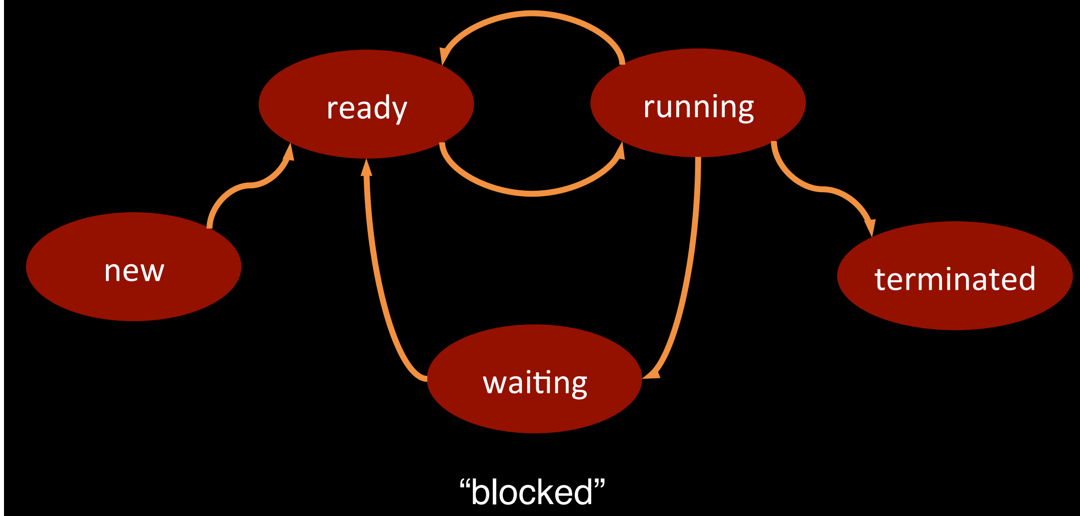


Diagram of Process State

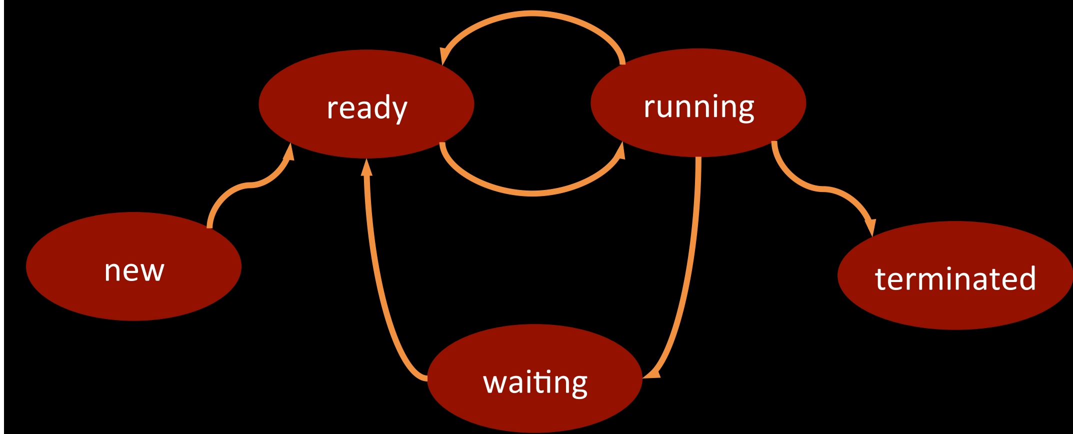


Switching Between Processes

When can a process be switched out :

- blocking on I/O
- voluntarily yielding the CPU, e.g. via other system calls
- being preemptively time sliced, i.e. interrupted
- termination

Diagram of Process State



"blocked"

Switching Between Processes

- The dispatcher gives control of CPU to the process selected by the scheduler, causing context switch:

Policy

Mechanism

  - save old state
  - select next process
  - load new state
  - switch to user mode, jumping to the proper location in the user process to restart that process

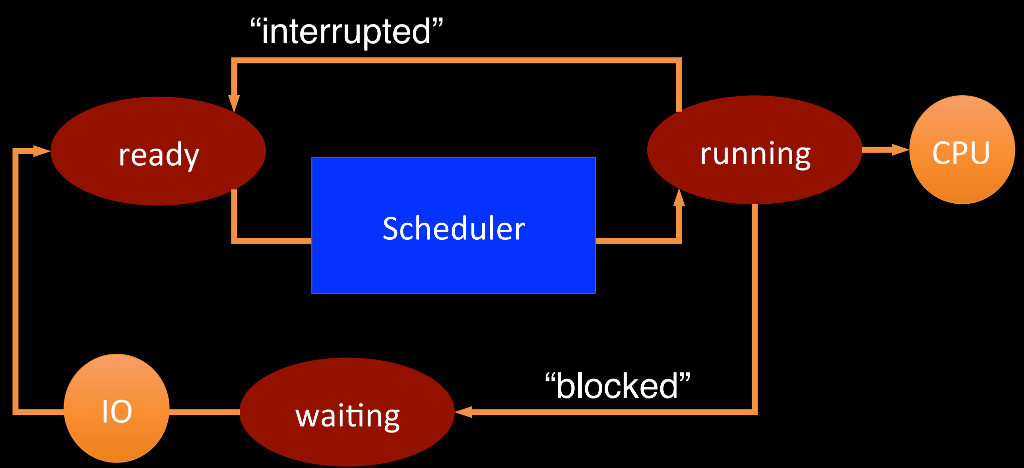
- Separate
  - *mechanism* of scheduling
  - from *policy* of scheduling

Diagram of Process State

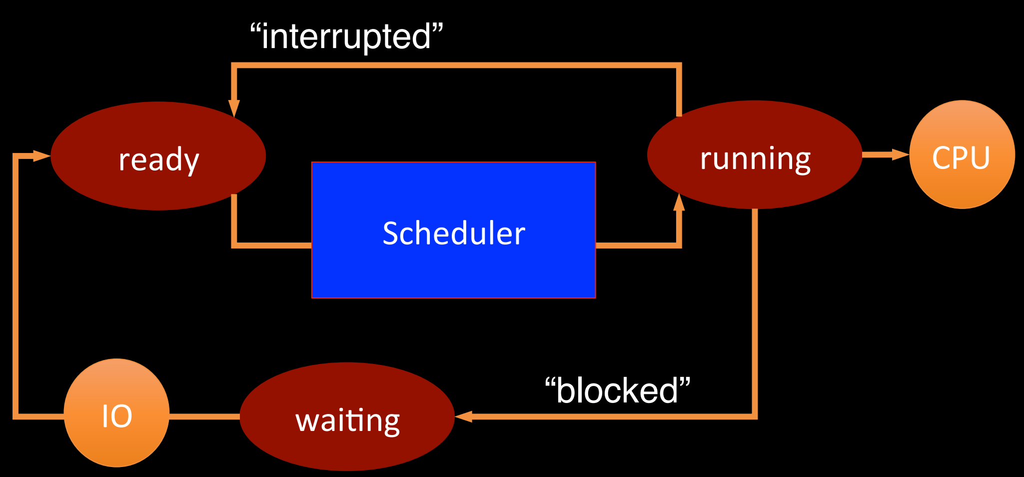
Context Switch Overhead

- Typically take 10 microseconds to copy register state to/from memory
  - on a 1 GHz CPU, that's 10000 wasted cycles per context switch!
- If the time slice is on the order of a context switch, then CPU spends most of its time context switching
  - Typically choose time slice to be large enough so that only 10% of CPU time is spent context switching
  - Most modern systems choose time slices of 10-100 ms

Process Scheduling



Process Scheduling

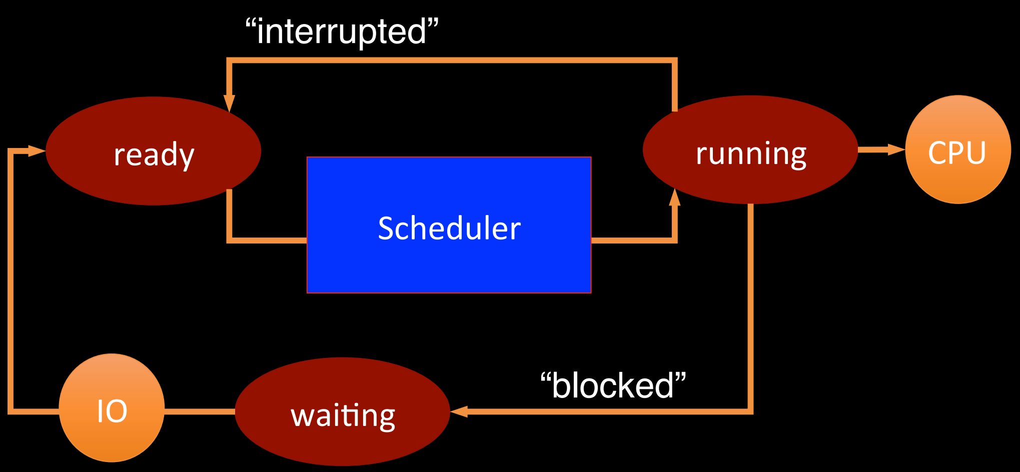


Scheduling

Scheduler's job is to decide the next process (or kernel thread) to run

- From among the set of processes/ kernel threads in the ready queue

Process Scheduling

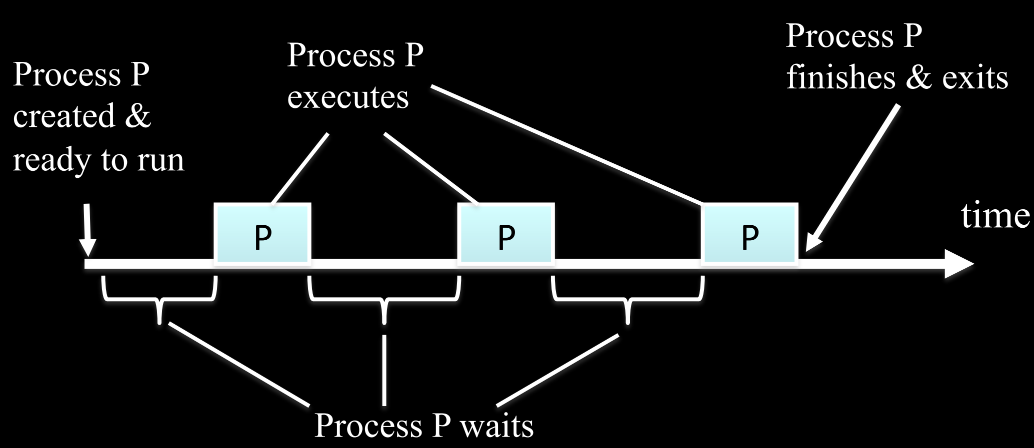


Scheduling Policy

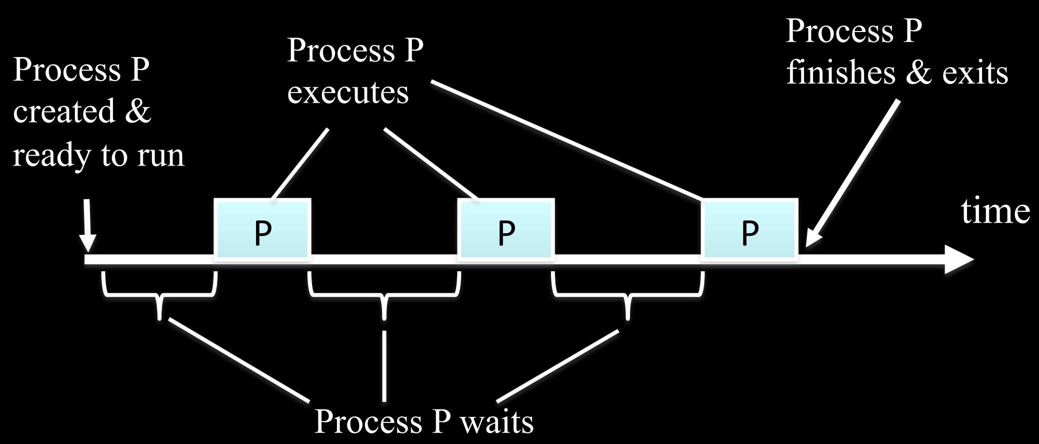
Scheduler implements a *scheduling policy* based on some of the following goals:

- maximize CPU utilization: 40% to 90%
- maximize throughput: # processes completed/second
- maximize fairness
- meet deadlines or delay guarantees
- ensure adherence to priorities
- minimize average or peak turnaround time: from 1st entry to temination
- min avg or peak waiting time: sum of time in ready queue
- min avg or peak response time: time until first response

Scheduling Definitions



Scheduling Definitions



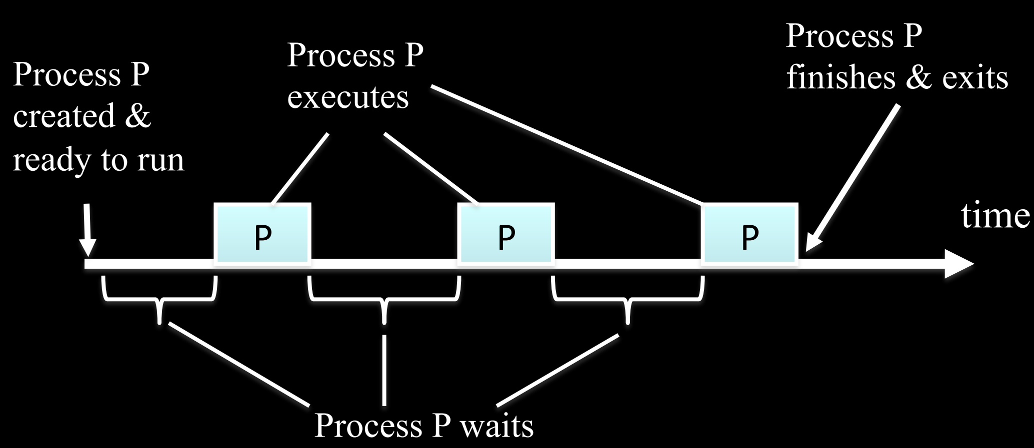
Scheduling Criteria

execution time

$E(P_i)$ = the time on the CPU required to fully execute process i

- Sum up the time slices given to process i
- Also called the "burst time" by textbook

Scheduling Definitions



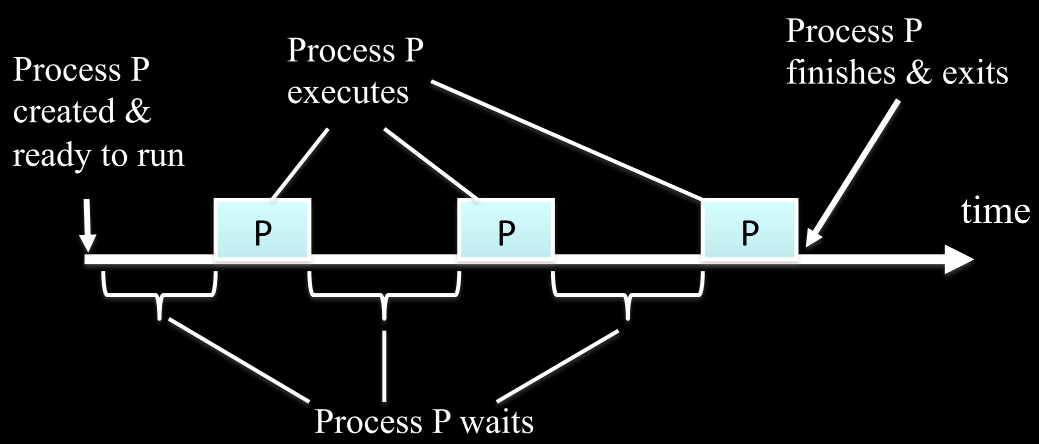
Scheduling Criteria

wait time

$W(P_i)$ = the time process i is in the ready state/ queue waiting but not running

- does NOT include time waiting for IO to complete

Scheduling Definitions



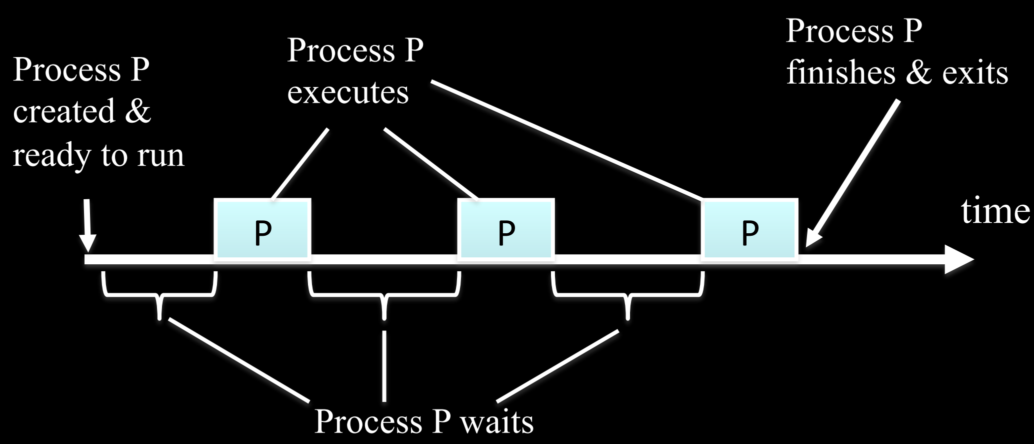
Scheduling Criteria

turnaround time

$T(P_i)$ = the time from 1st entry of process i into the ready queue to its final exit from the system

- does include time waiting and time for IO to complete

Scheduling Definitions



Scheduling Criteria

response time

$R(P_i)$ = the time from 1st entry of process i into the ready queue to its 1st scheduling on the CPU (1st occurrence in running state)

- useful for interactive tasks

Scheduling Analysis

- We analyze various scheduling policies to see how efficiently they perform with respect to metrics
  - wait time, turnaround time, response time, etc.
- Some algorithms will be optimal in certain metrics
- To simplify our analysis, assume:
  - No blocking I/O. Focus only on scheduling processes/tasks that have provided their execution times
  - Processes execute until completion, unless otherwise noted

Scheduling Policy

- How does Scheduler pick the next process to be run?
  - depends on which policy is implemented

- What is the simplest policy you can think of for picking from a group of processes?

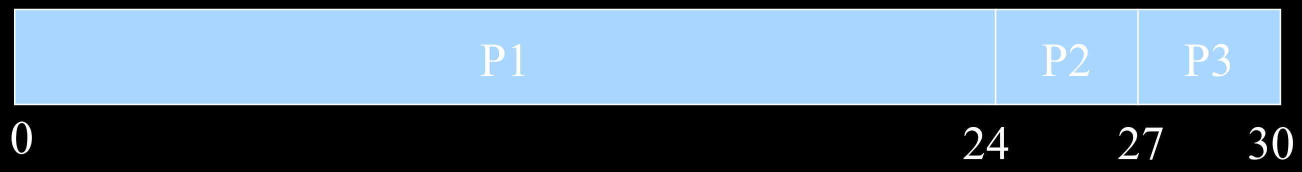
- How about something more complicated?

First Come First Serve (FCFS) Scheduling Policy

- order of arrival dictates order of scheduling
  - Non-preemptive, processes execute until completion

- If processes arrived in order P1, P2, P3 before time 0, then CPU service time is:

Process	CPU Execution Time
P1	24
P2	3
P3	3



FCFS Scheduling

- If processes arrive in reverse order P3, P2, P1 before time 0, then CPU service time is:

Process	CPU Execution Time
P1	24
P2	3
P3	3

Gantt Chart

- The chart we have been using to visualize the sequence of events and time allocated to processes is call a Gantt Chart
- We used this same concept in our first descriptions of scheduling using multi-process and multi-tasking

Process	CPU Execution Time
P1	24
P2	3
P3	3

Gantt Chart

- We used a different format to describe the process times of multi-tasking and multi-programming

- These formats are equivalent

Process	CPU Execution Time
P1	24
P2	3
P3	3

FCFS Scheduling

Process	CPU Execution Time
P1	24
P2	3
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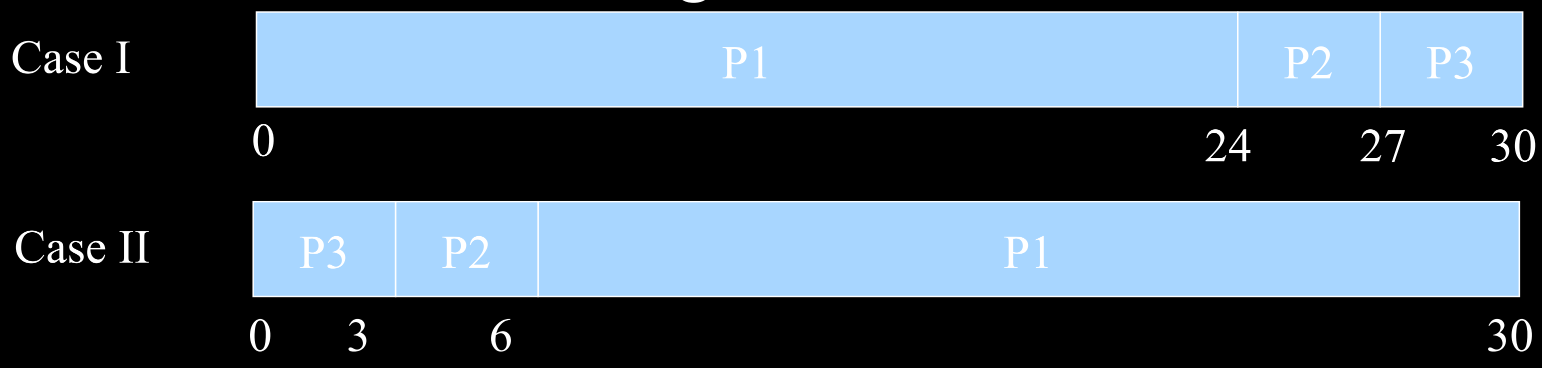


Lets calculate the ***average wait time*** for each of the cases

All processes arrived just before time 0

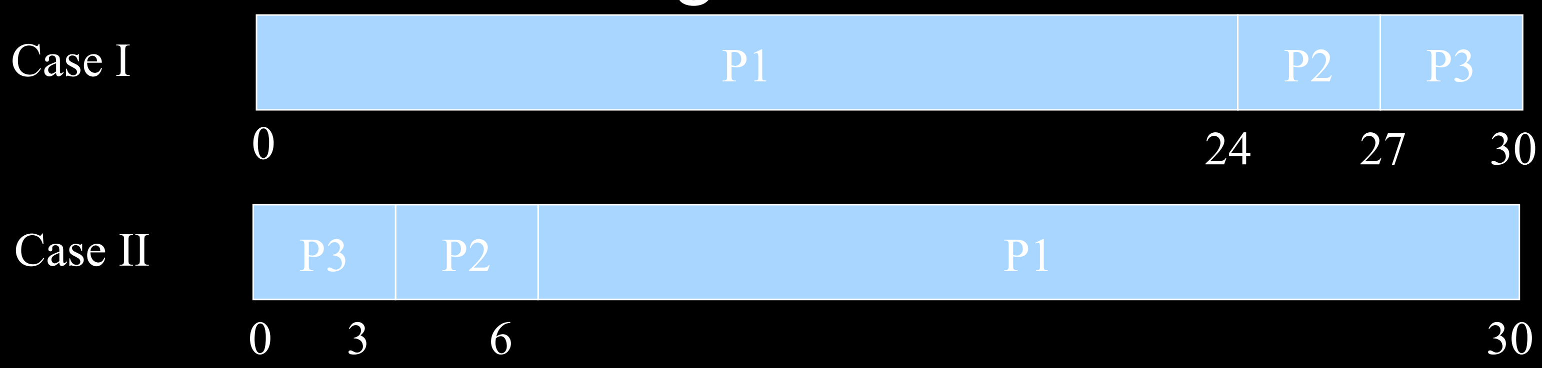
P1 does not wait at all

P2 waits for P1 to complete before being scheduled

P3 waits until P2 has completed

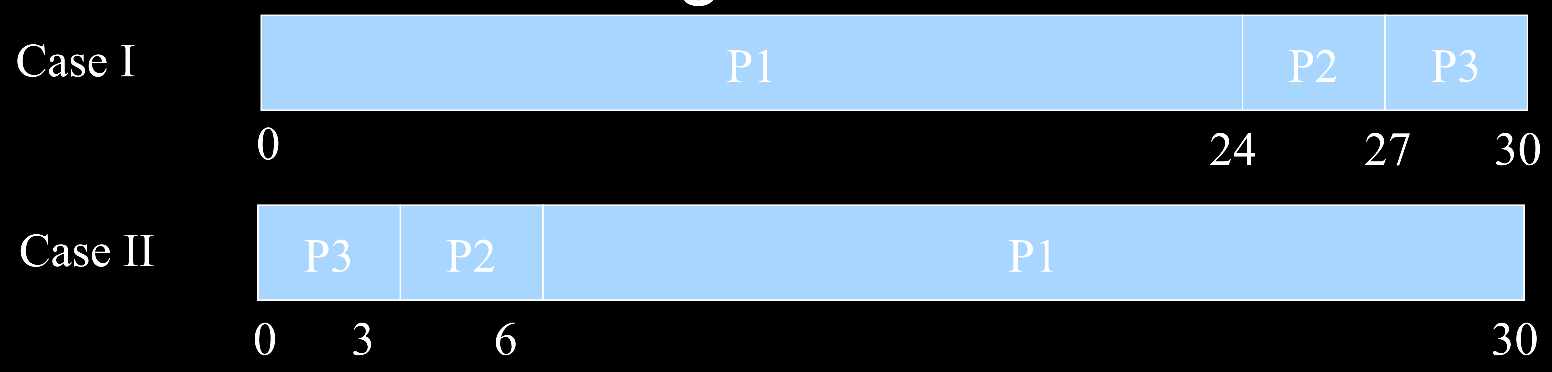
$(0 + 24 + 27)/3 = 17$

FCFS Scheduling



- Case I: average wait time is (0+24+27)/3 = 17 seconds
- Case II: average wait time is (0+3+6)/3 = 3 seconds
- FCFS wait times are generally not minimal - vary a lot if order of arrival changed, which is especially true if the process service times vary a lot (are spread out)

FCFS Scheduling



Lets calculate the ***average turnaround time*** for each of the cases

- Case I: average turnaround time is (24+27+30)/3 = 27 seconds
- Case II: average turnaround time is (3+6+30)/3 = 13 seconds

- A lot of variation in turnaround time too.

FCFS Scheduling

- Just pick the next process in the queue to be run?
  - No other information about the process is required

- Does it meet our goals?
  - maximize CPU utilization: 40% to 90%?
  - maximize throughput: # processes completed/second?
  - minimize average or peak wait, turnaround, or response time?
  - meet deadlines or delay guarantees?
  - maximize fairness?

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