CPU SCHEDULING

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CS 537, Spring 2019

ADMINISTRIVIA

- Project 1a is due ~~today!~~ Thursday at 11.59pm
- No office hours from 5pm Tue to noon Thu
- Fill out office hours form? https://goo.gl/forms/5VxrwRawtEFkrjO23

- No more waitlist!
- Project 1b out tomorrow. Schedule updates

AGENDA / LEARNING OUTCOMES

Scheduling

- How does the OS decide what process to run?
- What are some of the metrics to optimize for?

Policies

- How to handle interactive and batch processes?
- What to do when OS doesn't have complete information?

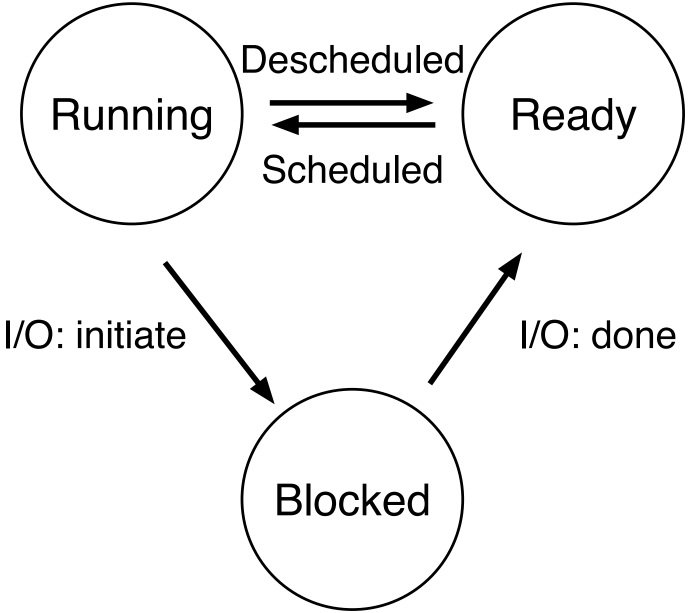
RECAP

RECAP: SCHEDULING MECHANISM

Process: Abstraction to virtualize CPU

Use time-sharing in OS to switch between processes

PROCESS STATE TRANSITIONS



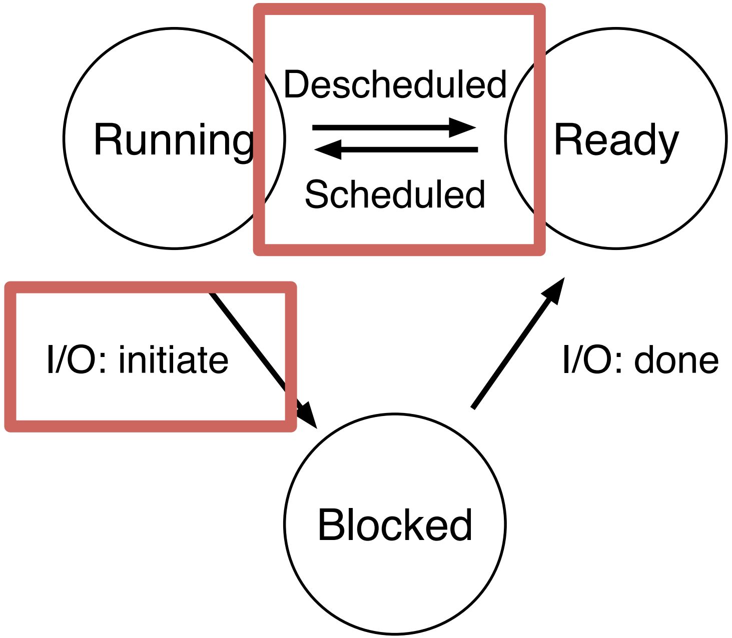
RECAP: SCHEDULING MECHANISM

Limited Direct Execution

Use system calls to run access devices etc. from user mode

Context-switch using interrupts for multi-tasking

Operating System	Hardware	Program
		Process A
	timer interrupt save regs(A) to k-stack(A) move to kernel mode jump to trap handler	
Handle the trap Call switch() routine save kernel regs(A) to proc-struct(A) restore kernel regs(B) from proc-struct(B) switch to k-stack(B) return-from-trap (into B)		
	restore regs(B) from k-stack(B) move to user mode jump to B's IP	
		Process B


Running
Descheduled
Scheduled
Ready
I/O: initiate
I/O: done
Blocked

POLICY ?

VOCABULARY

Workload: set of **jobs** (arrival time, run_time)

Job ~ Current execution of a process

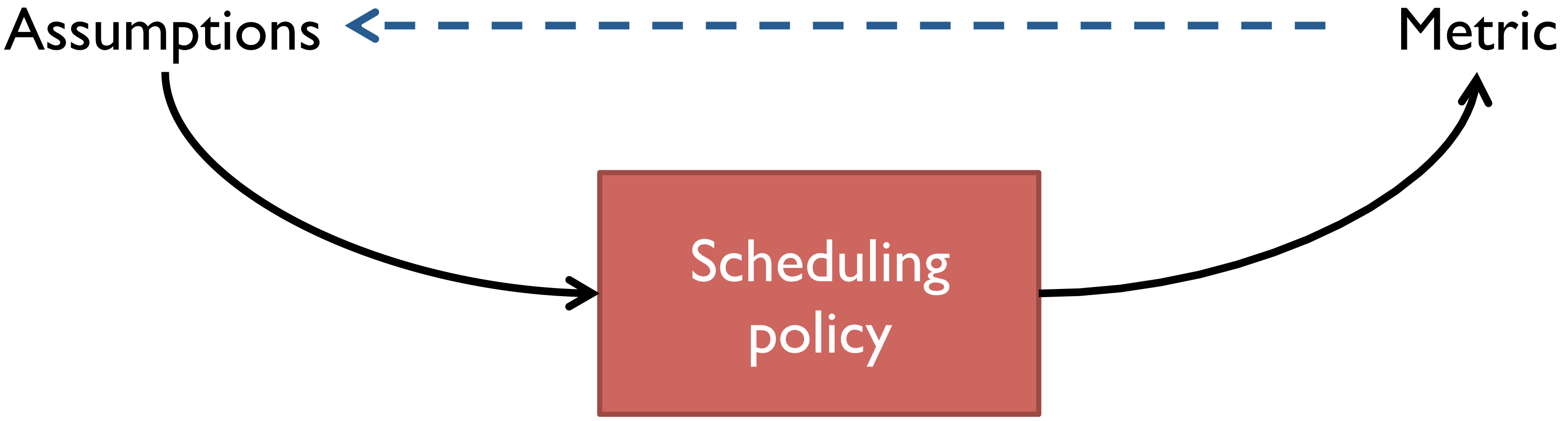
Alternates between CPU and I/O

Moves between ready and blocked queues

Scheduler: Decides which ready job to run

Metric: measurement of scheduling quality

APPROACH



ASSUMPTIONS

1. Each job runs for the same amount of time
2. All jobs arrive at the same time
3. All jobs only use the CPU (no I/O)
4. Run-time of each job is known

METRIC 1: TURNAROUND TIME

Turnaround time = *completion_time - arrival_time*

Example:

Process A arrives at time t = 10, finishes t = 30

Process B arrives at time t = 10, finishes t = 50

Turnaround time

A = 20, B = 40

Average = 30

FIFO / FCFS

FIFO / FCFS

FIFO: First In, First Out

FCFS: First Come, First Served

Job	Arrival(s)	run time (s)
A	~0	10
B	~0	10
C	~0	10

FIFO / FCFS

Job	Arrival(s)	run time (s)
A	~0	10
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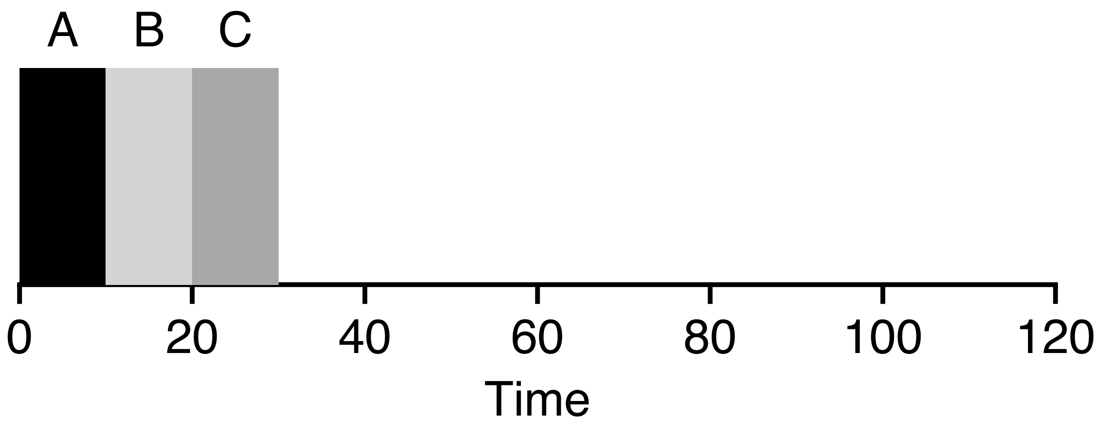

Average Turnaround Time ?

ASSUMPTIONS

1. ~~Each job runs for the same amount of time~~
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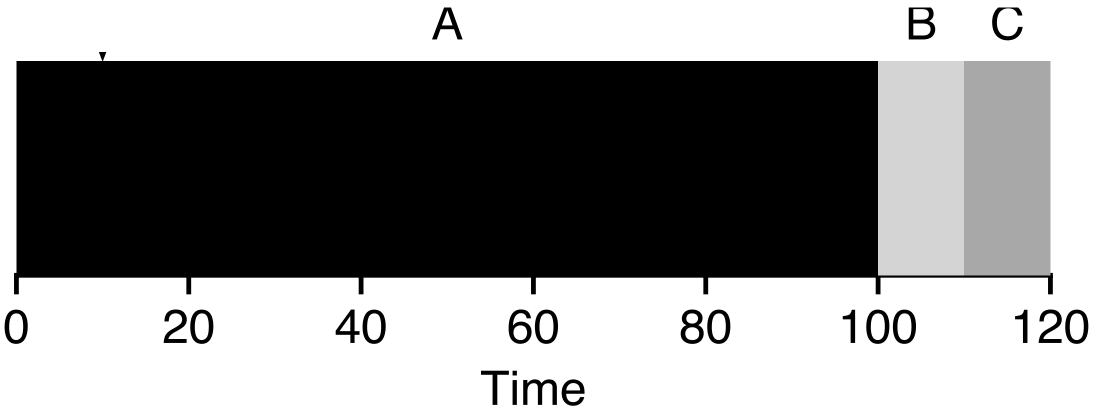
2-MINUTE QUIZ

How will FIFO perform without this assumption ?

What scenarios can lead to bad performance?

BIG FIRST JOB

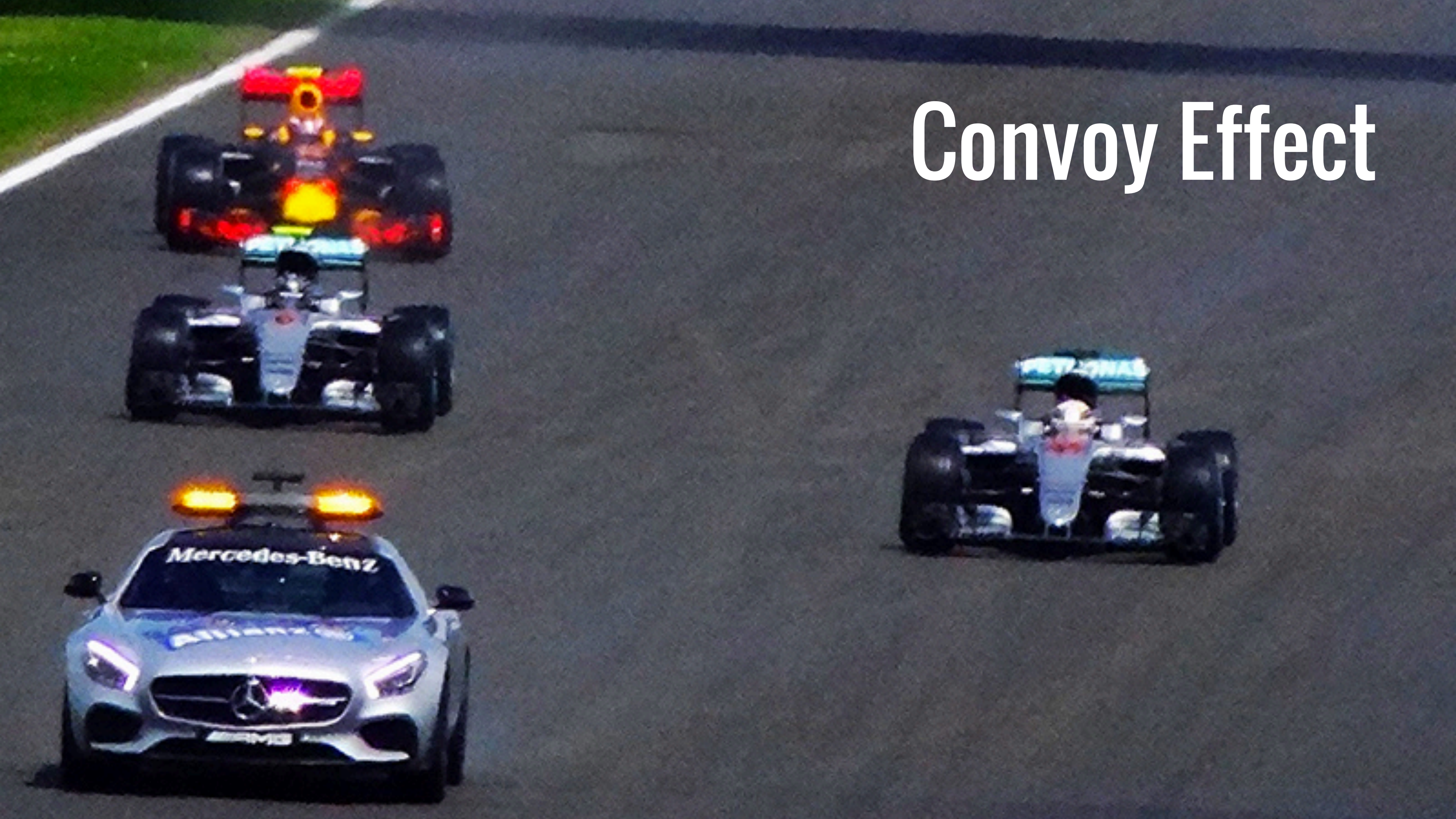
Job	Arrival(s)	run time (s)
A	~0	100
B	~0	10
C	~0	10



Average Turnaround Time

$(100 + 110 + 120)/ 3$
$= 110s$

Convoy Effect



CHALLENGE

Turnaround time suffers when short jobs must wait for long jobs

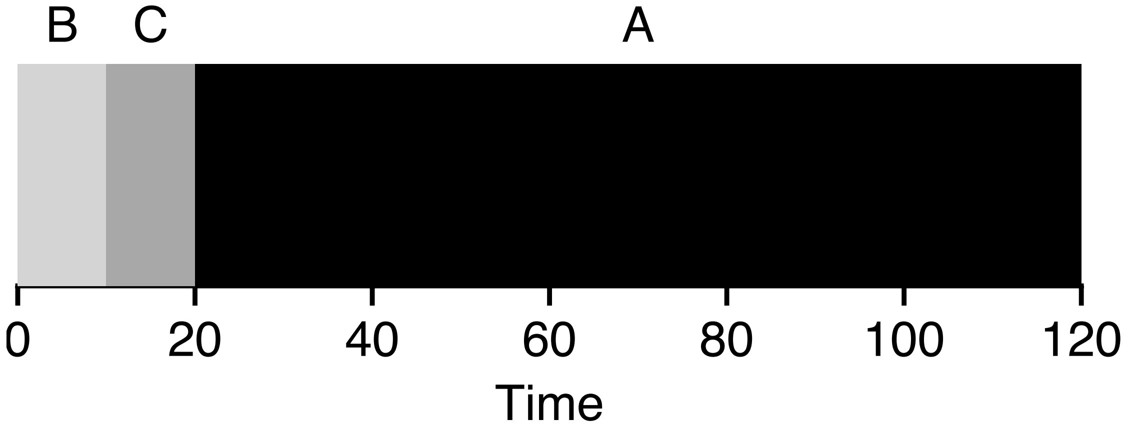
New scheduler:

SJF (Shortest Job First)

Choose job with smallest run_time!

SHORTEST JOB FIRST (SJF)

Job	Arrival(s)	run time (s)
A	~0	100
B	~0	10
C	~0	10



Average Turnaround Time

(10 + 20 + 120)/ 3
= 50s!

FIFO: 110s ?!

ASSUMPTIONS

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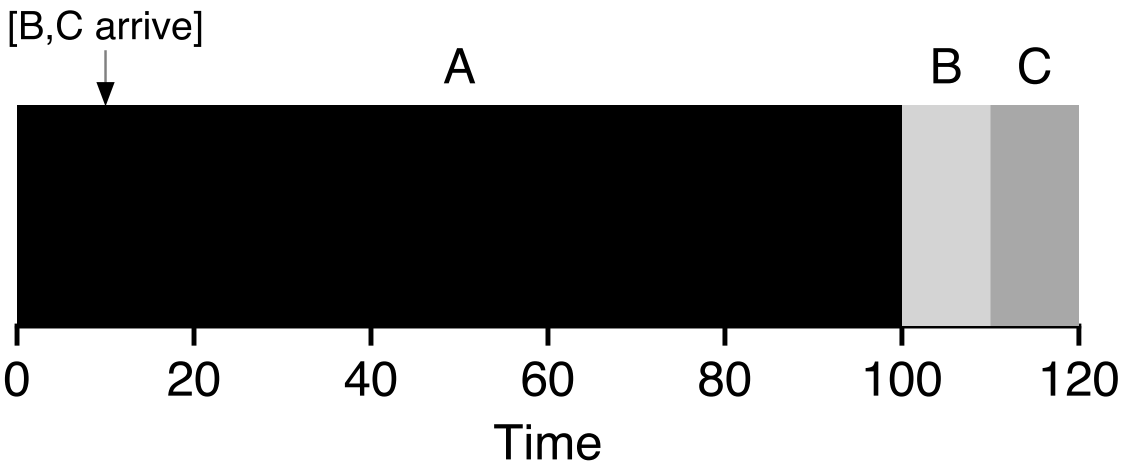
Job	Arrival(s)	run time (s)
A	~0	100
B	10	10
C	10	10

Average Turnaround Time with SJF?

Job	Arrival(s)	run time (s)
A	~0	100
B	10	10
C	10	10



Average Turnaround Time ?

(100 + 110 + 120)/ 3
= 110s

PREEMPTIVE SCHEDULING

Prev schedulers:

FIFO and SJF are non-preemptive

Only schedule new job when previous job voluntarily relinquishes CPU

New scheduler:

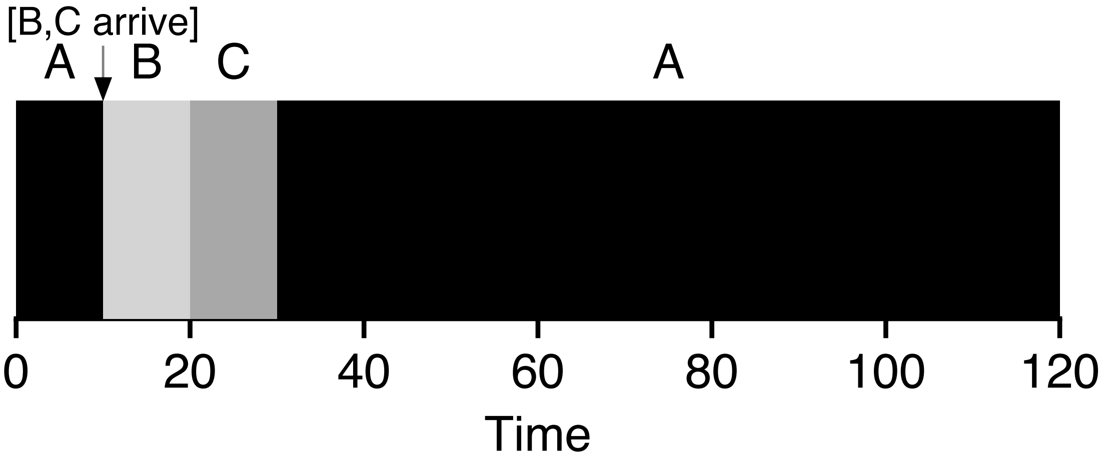
Preemptive: Schedule different job by taking CPU away from running job

STCF (Shortest Time-to-Completion First)

Always run job that will complete the quickest

PREMPTIVE SCTF

Job	Arrival(s)	run time (s)
A	~0	100
B	10	10
C	10	10



Average Turnaround Time

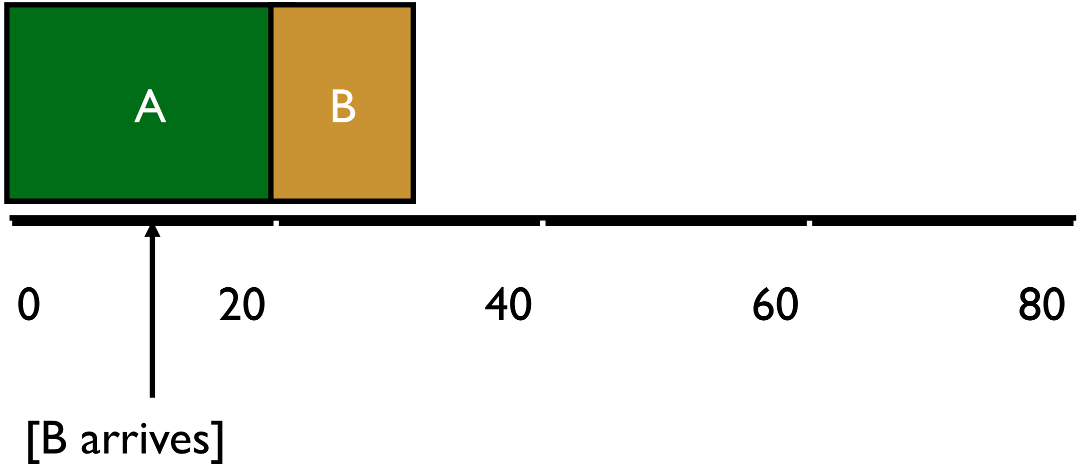
(10 + 20 + 120)/ 3
= 50s

METRIC 2: RESPONSE TIME

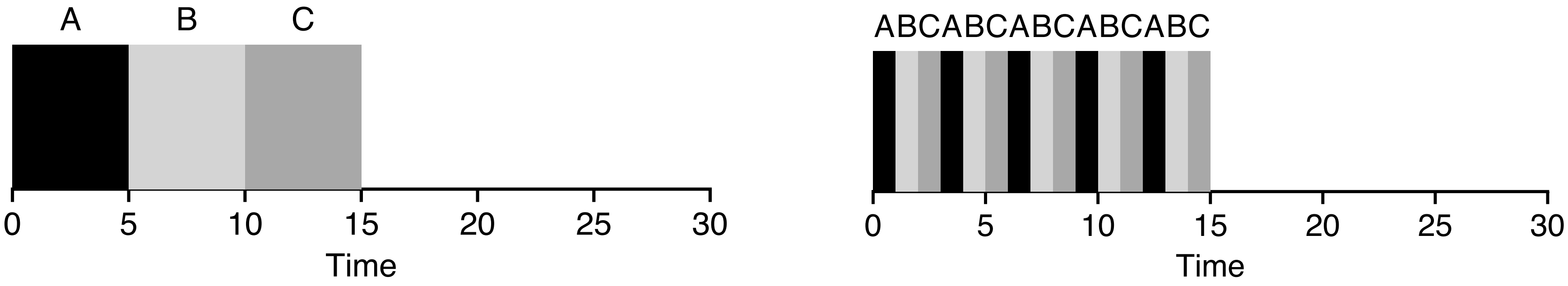
Response time = *first_run_time* - *arrival_time*

B's turnaround: 20s

B's response: 10s



ROUND ROBIN SCHEDULER

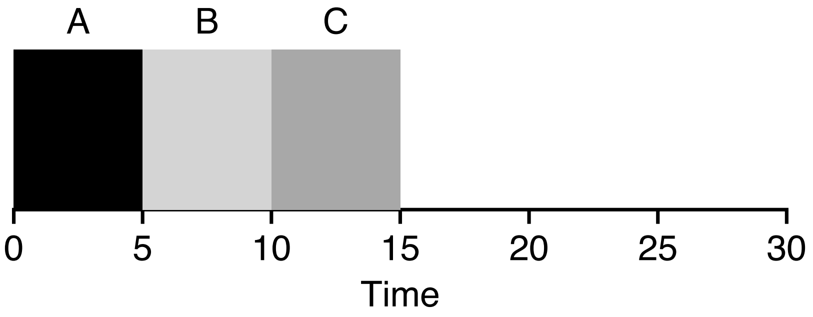


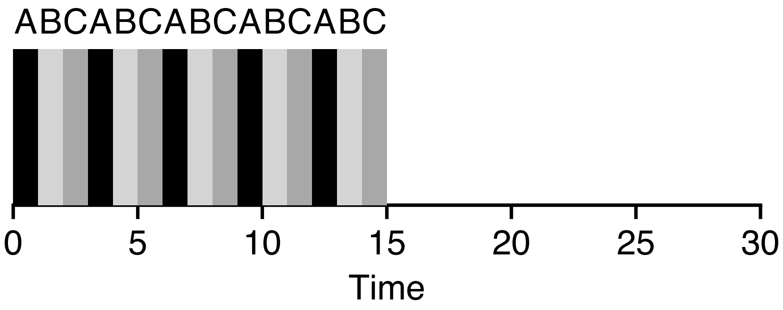
Average Response Time

(0 + 5 + 10)/3 = 5s

(0 + 1 + 2)/3 = 1s

2-MINUTE QUIZ





What is the turnaround time for two cases ?

Is round robin better or worse?

TRADE-OFFS

Round robin increases turnaround time decreases response time

Tuning challenges:

- What is a good time slice for round robin?
- What is the overhead of context switching?

ASSUMPTIONS

1. ~~Each job runs for the same amount of time~~
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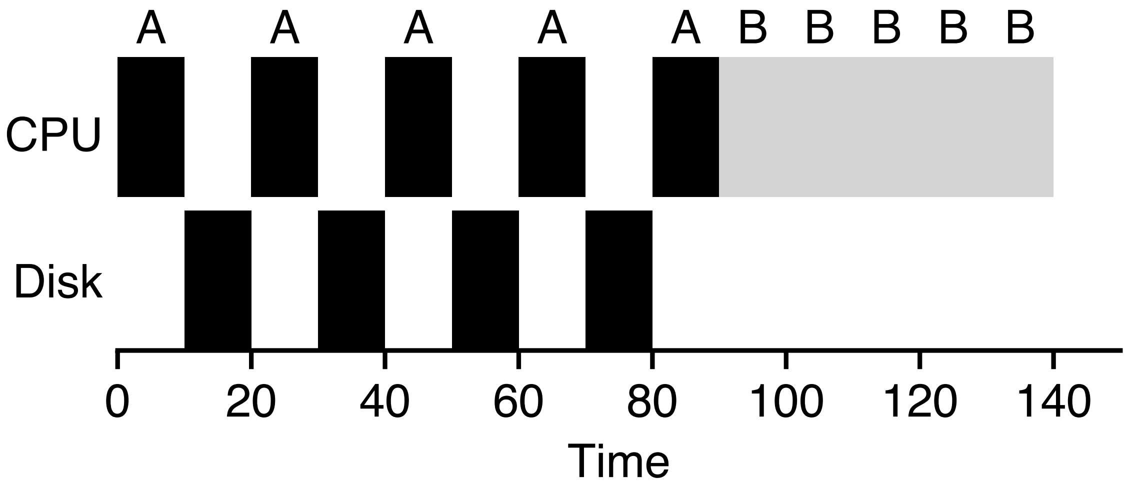
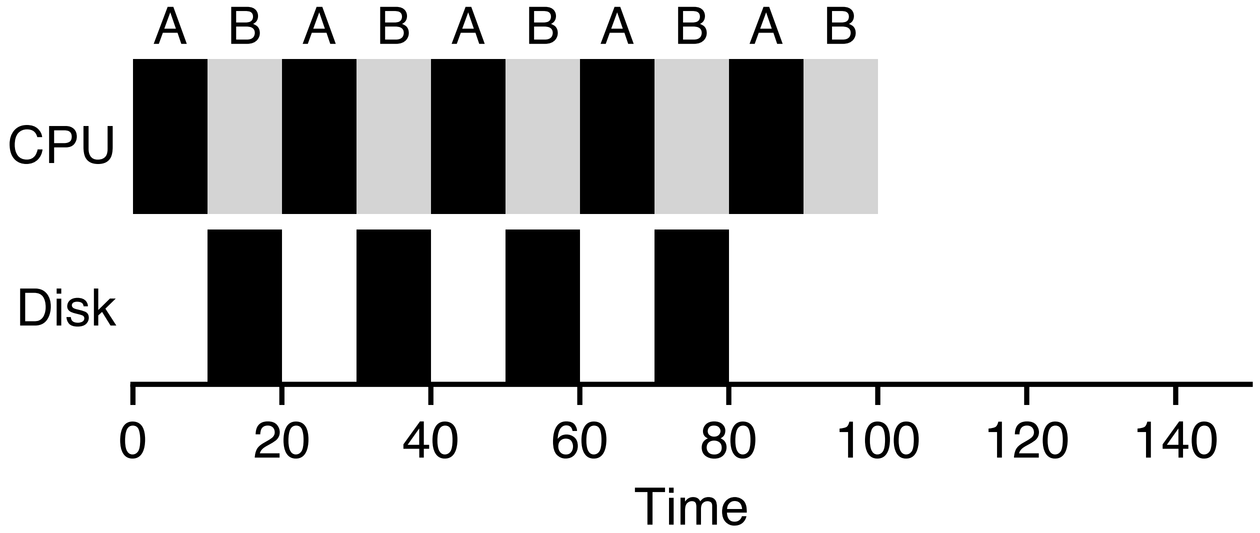
4. Run-time of each job is known

NOT IO AWARE



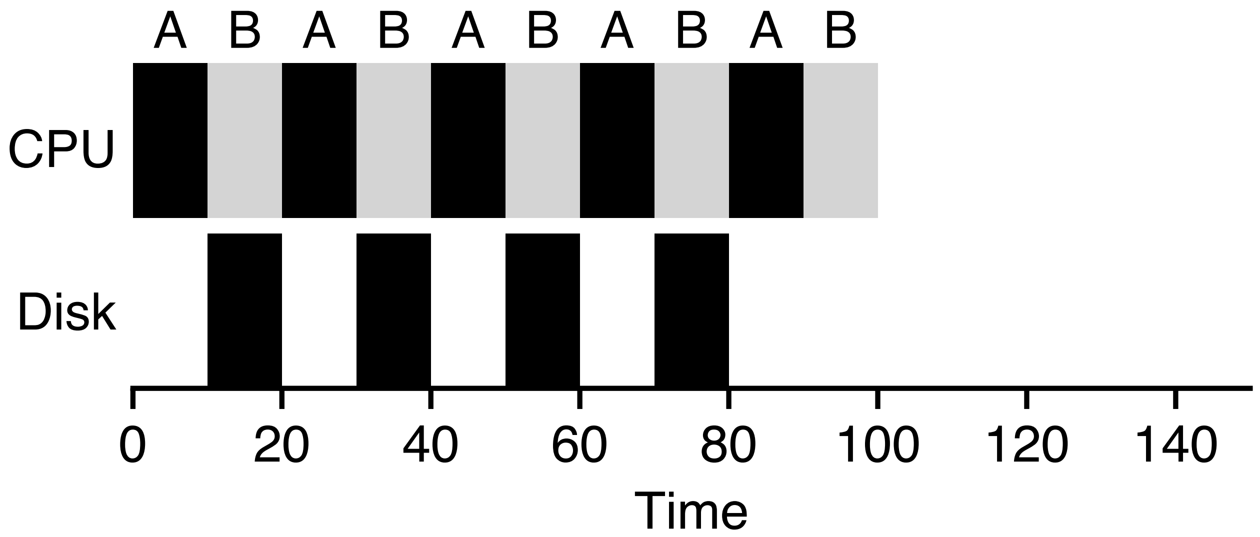
Job holds on to CPU while blocked on disk!

I/O AWARE SCHEDULING



Treat Job A as 3 separate CPU bursts.
When Job A completes I/O, another Job A is ready

I/O AWARE SCHEDULING



Each CPU burst is shorter than Job B

With SCTF,
Job A preempts Job B

Treat Job A as 3 separate CPU bursts.
When Job A completes I/O, another Job A is ready

ASSUMPTIONS

1. ~~Each job runs for the same amount of time~~
2. ~~All jobs arrive at the same time~~
3. ~~All jobs only use the CPU (no I/O)~~
4. ~~Run-time of each job is known~~

MULTI-LEVEL FEEDBACK QUEUE

MLFQ: GENERAL PURPOSE SCHEDULER

Must support two job types with distinct goals

- “interactive” programs care about response time
- “batch” programs care about turnaround time

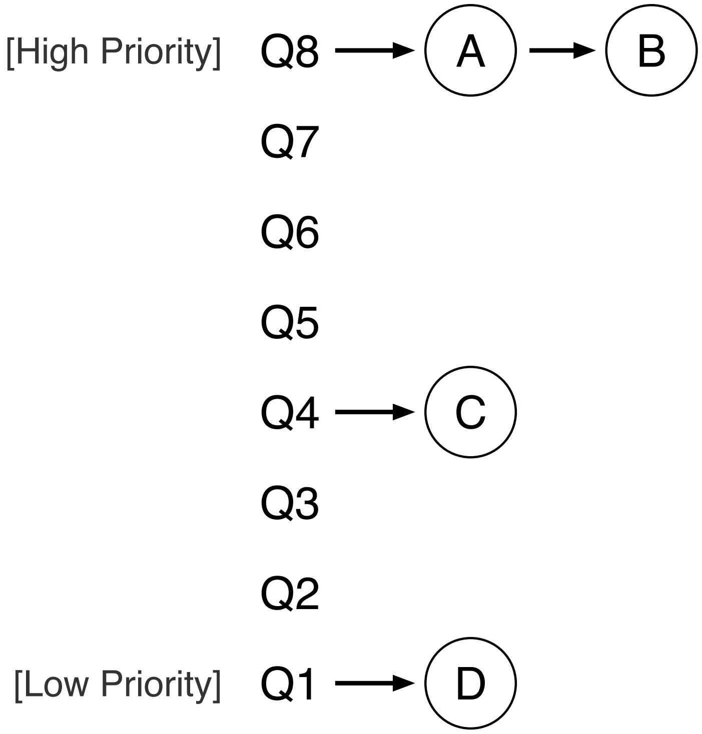
Approach:

Multiple levels of round-robin

Each level has higher priority than lower level

Can preempt them

MLFQ EXAMPLE



"Multi-level" – Each level is a queue!

Rules for MLFQ

Rule 1: If priority(A) > Priority(B)
A runs

Rule 2: If priority(A) == Priority(B),
A & B run in RR

CHALLENGES

How to set priority?

What do we do when a new process arrives?

Does a process stay in one queue or move between queues?

Approach: Use past behavior of process to predict future!

Guess how CPU burst (job) will behave based on past CPU bursts

MORE MLFQ RULES

Rule 1: If priority(A) > Priority(B), A runs

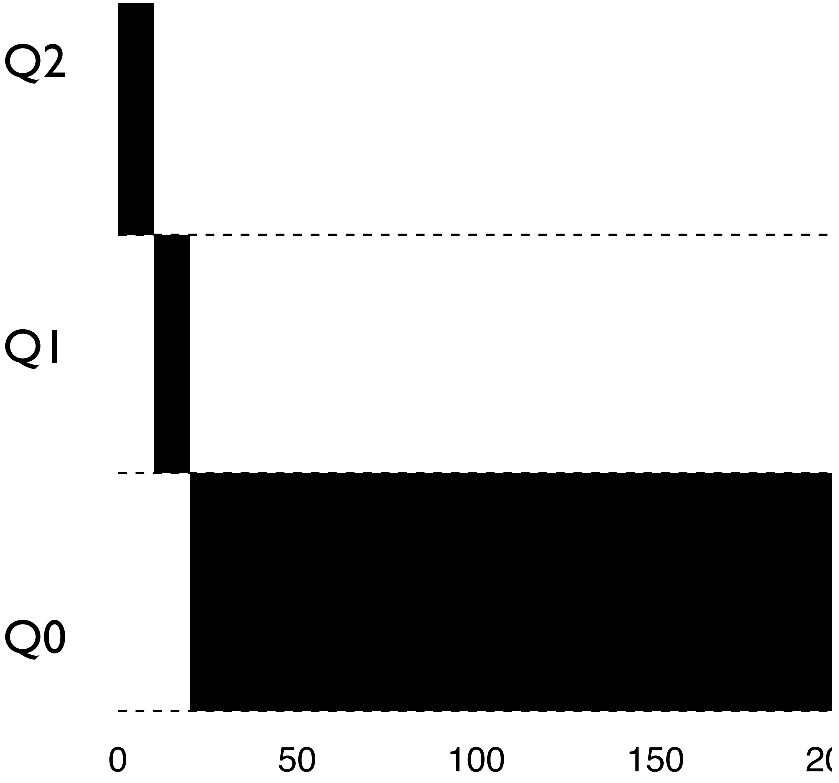
Rule 2: If priority(A) == Priority(B), A & B run in RR

Rule 3: Processes start at top priority

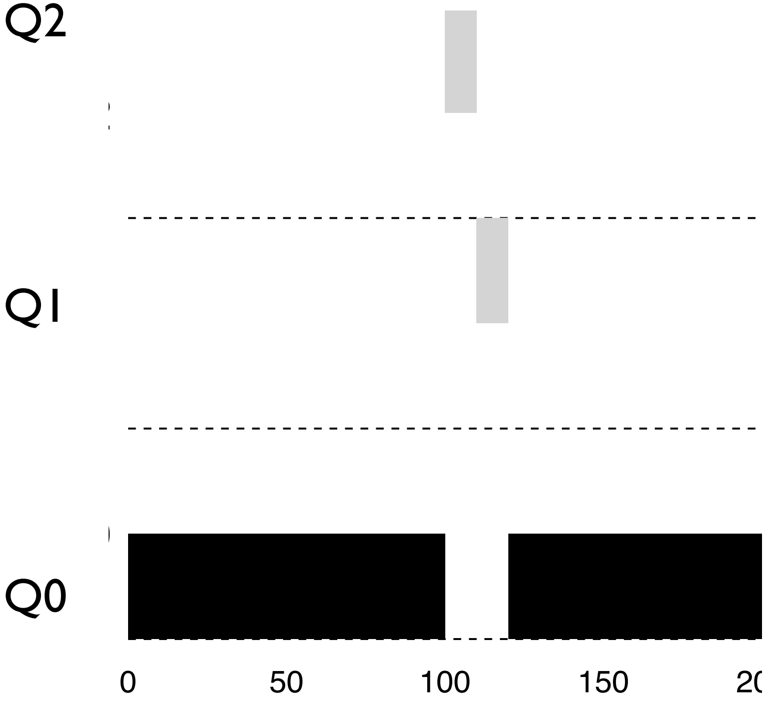
Rule 4: If job uses whole slice, demote process

(longer time slices at lower priorities)

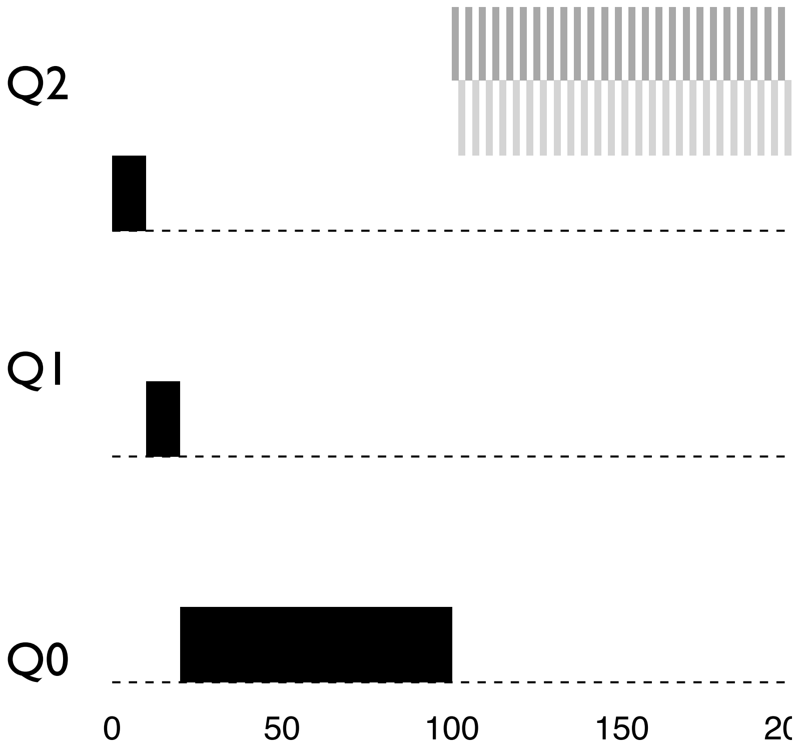
ONE LONG JOB



INTERACTIVE PROCESS JOINS

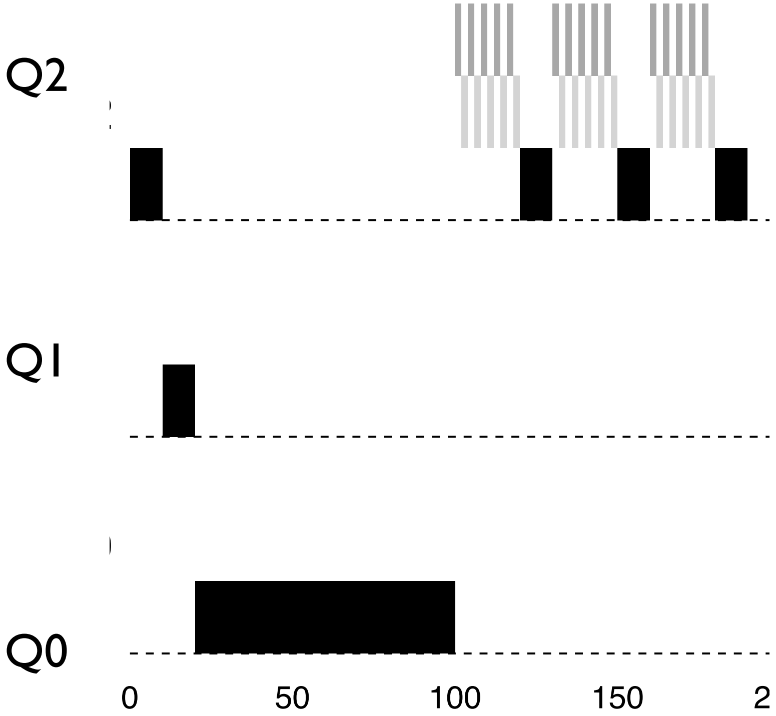


MLFQ PROBLEMS?



What is the problem with this schedule ?

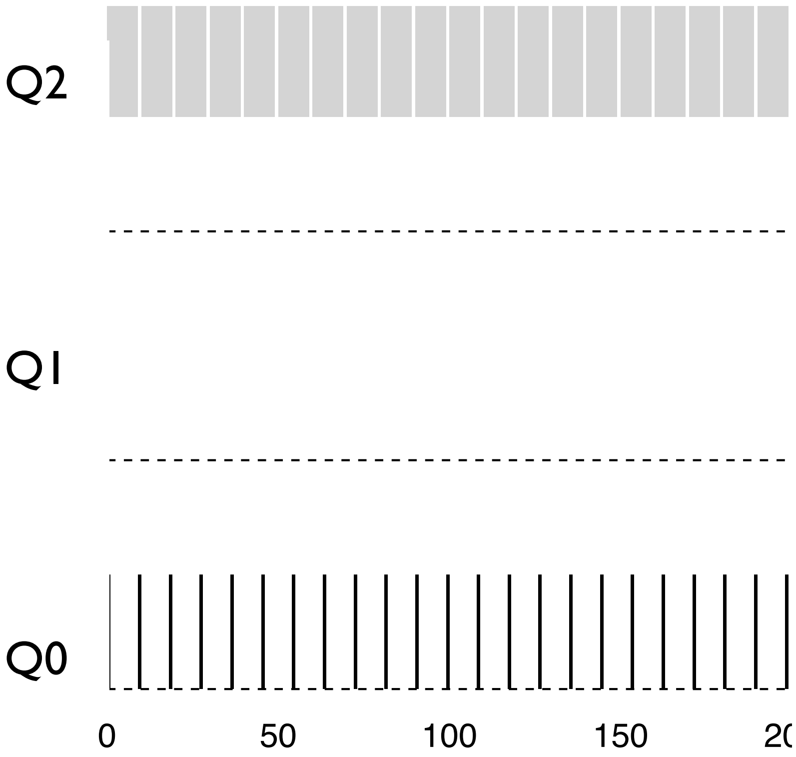
AVOIDING STARVATION



Problem: Low priority job may never get scheduled

Periodically boost priority of all jobs (or all jobs that haven't been scheduled)

GAMING THE SCHEDULER ?



Job could trick scheduler by doing I/O just before time-slice end

Account for total run time at priority
Downgrade when exceed threshold

SUMMARY

Scheduling Policies

Understand workload characteristics like arrival, CPU, I/O

Scope out goals, metrics (turnaround time, response time)

Approach

Trade-offs based on goals, metrics (RR vs. SCTF)

Past behavior is good predictor of future behavior?

NEXT STEPS

Project 1a: Due Jan 31 (Thursday) at 11.59pm

Project 1b: Out on Jan 30th

Thursday class, discussion

- More advanced scheduling policies
- Summary / review of process, CPU scheduling
- xv6 introduction, walk through
- Go through xv6 context switch / syscall?