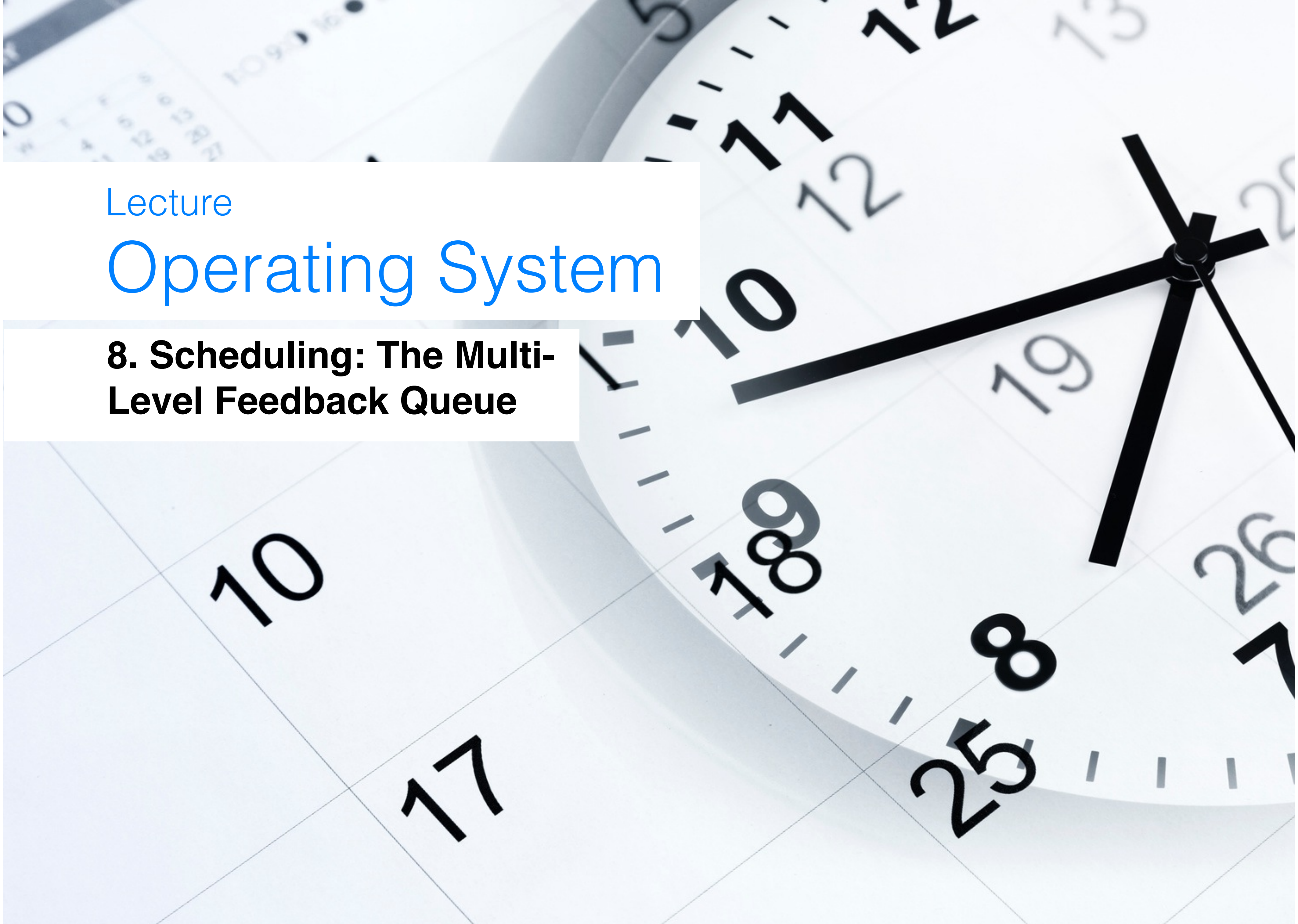


Lecture

Operating System

8. Scheduling: The Multi-Level Feedback Queue

Professor Dr. Michael Mächtel

8. Scheduling: The Multi-Level Feedback Queue

Goal: general-purpose scheduling

Must support two job types with distinct goals:

- **interactive programs care about response time**
- **batch programs care about turnaround time**

Workload 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** (i.e., they perform no I/O).~~
4. ~~The **run-time** of each job is known.~~

History

- Use past behavior of process to predict future behavior
  - Common technique in systems
- Processes alternate between **I/O** and **CPU** work
- Guess how CPU burst (job) will behave based on past CPU bursts (jobs) of this process

Multi-Level Feedback Queue (MLFQ)

- A Scheduler that learns from the past to predict the future.
- Objective:
  - Optimize **turnaround time** ➙ Run shorter jobs first
  - Minimize **response time** without *a priori knowledge of job length*.

MLFQ: Basic Rules

- MLFQ has a number of distinct **queues**.
  - Each queues is assigned a *different priority level*.
- A job that is ready to run is on a single queue.
  - A job **on a higher queue** is chosen to run.
  - Use round-robin scheduling among jobs in the same queue

Rule 1: If Priority(A) > Priority(B), A runs (B doesn't).

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

MLFQ: How to Change Priority

- MLFQ varies the priority of a job based on **its observed behavior**.

Rule 3: When a job enters the system, it is placed at the highest priority

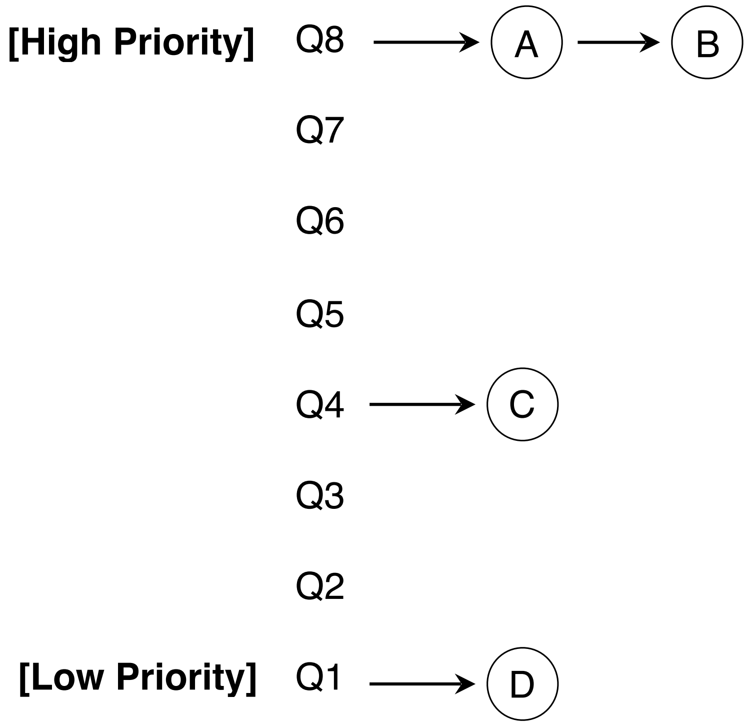
Rule 4a: If a job uses up an entire time slice while running, its priority is reduced (i.e., it moves down on queue).

Rule 4b: If a job gives up the CPU before the time slice is up, it stays at the same priority level

In this manner, MLFQ approximates SJF

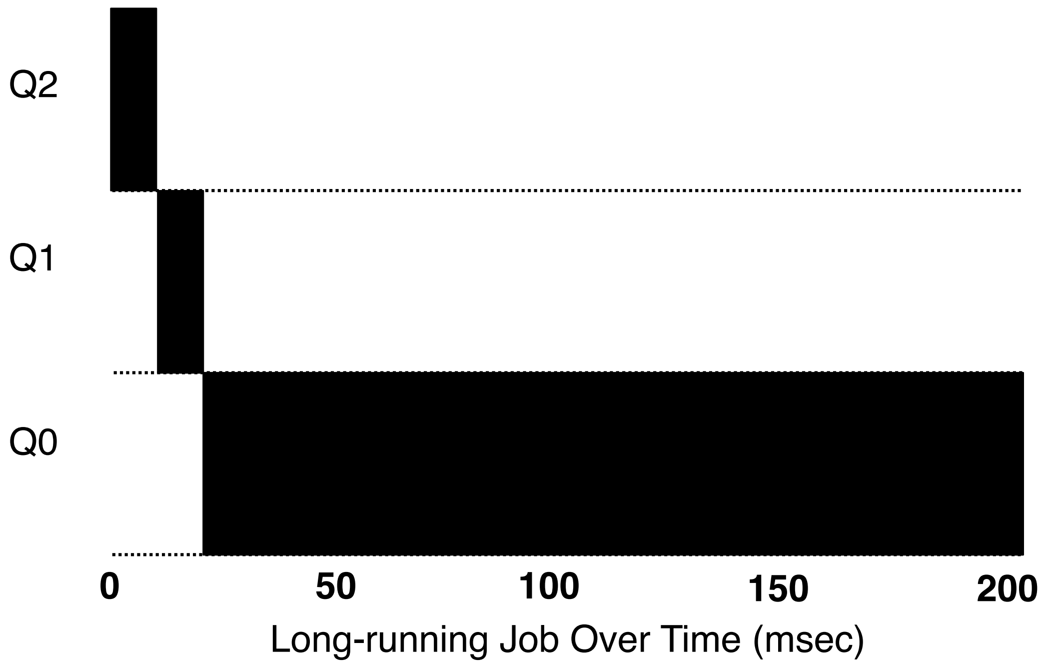
MLFQ: Overview

- A job repeatedly relinquishes the **CPU** while waiting **IOs**
  ➞ Keep its priority *high*
- A job uses the **CPU** intensively for long periods of time
  ➞ *Reduce* its priority.



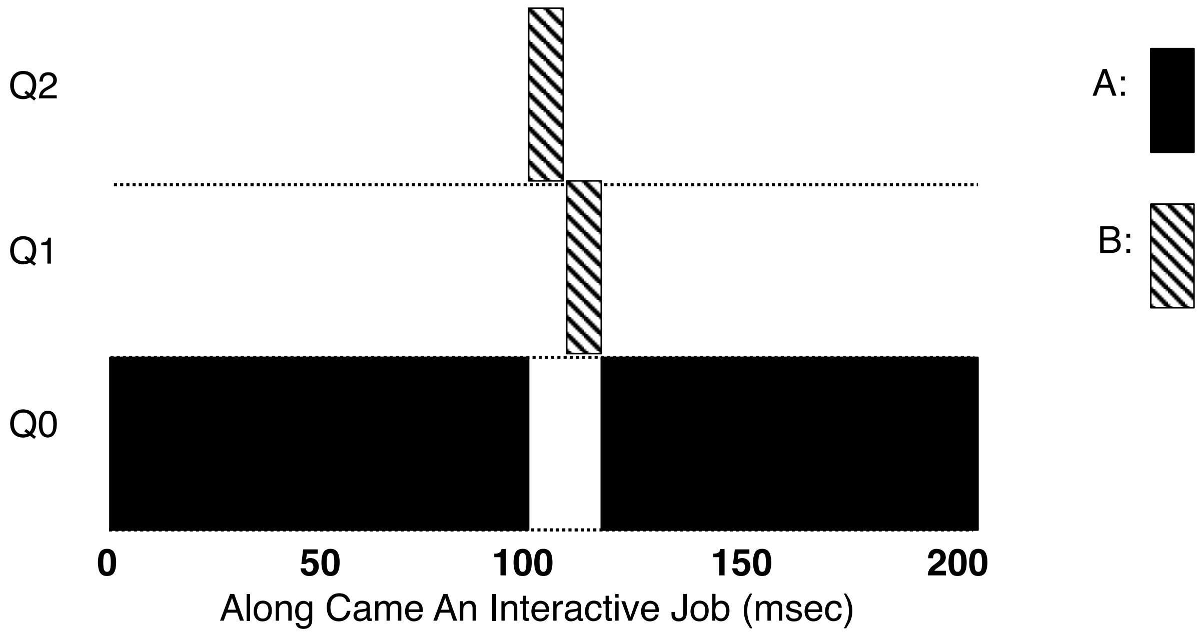
Example 1: A Single Long-Running Job

- A three-queue scheduler with time slice 10ms



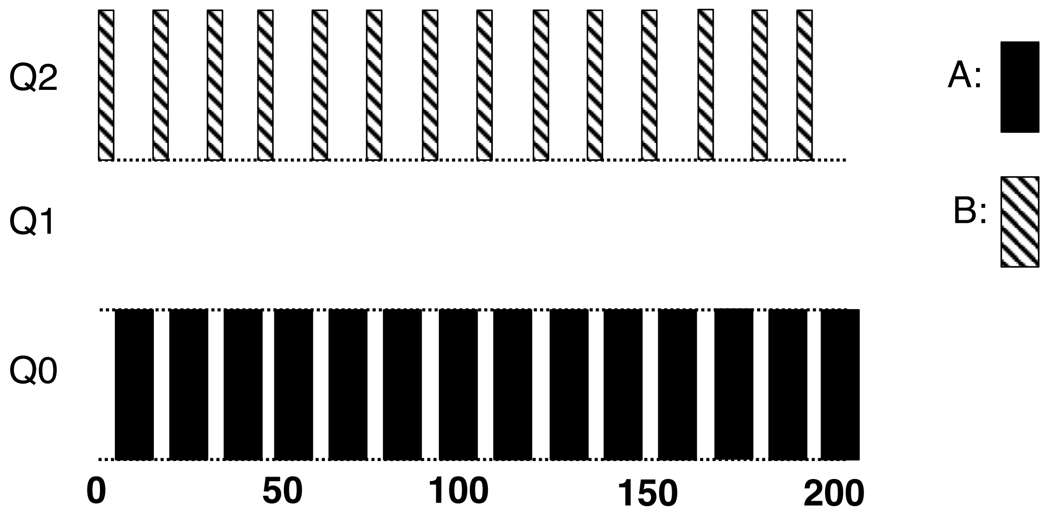
Example 2: Along Came a Short Job

- Assumption:
  - **Job A**: A long-running CPU-intensive job
  - **Job B**: A short-running interactive job (20ms runtime)
  - A has been running for some time, and then B arrives at time T=100.



Example 3: What About I/O?

- Assumption:
  - **Job A**: A long-running **CPU**-intensive job
  - **Job B**: An interactive job that need the CPU only for 1ms before performing an **I/O**

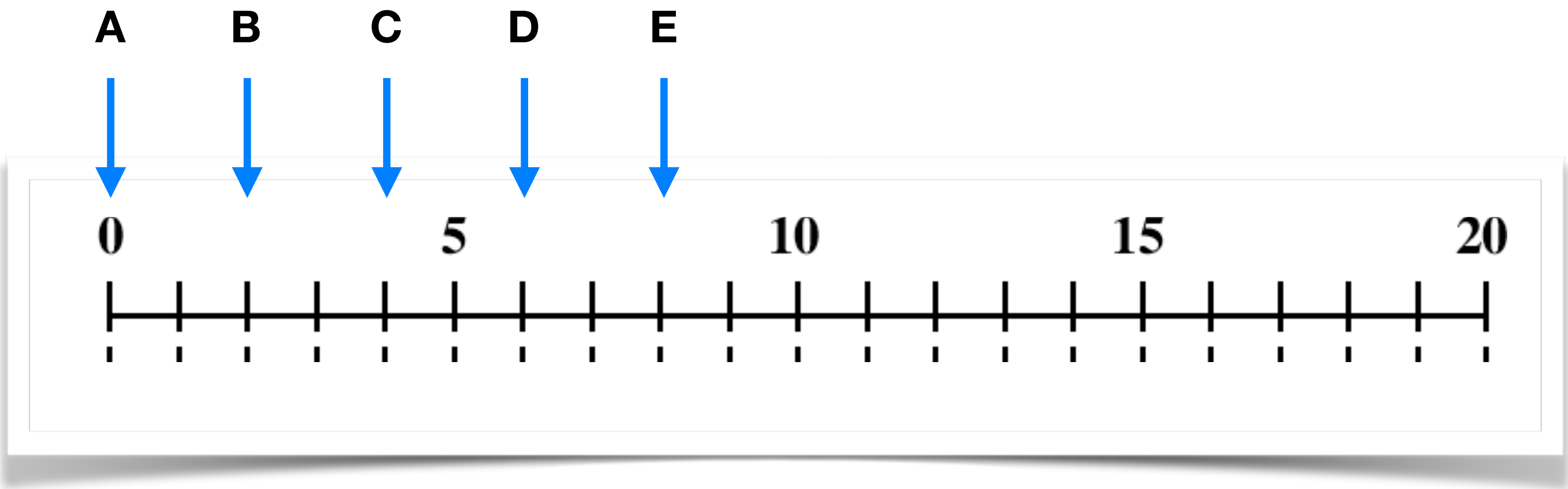


A Mixed I/O-intensive and CPU-intensive Workload (msec)

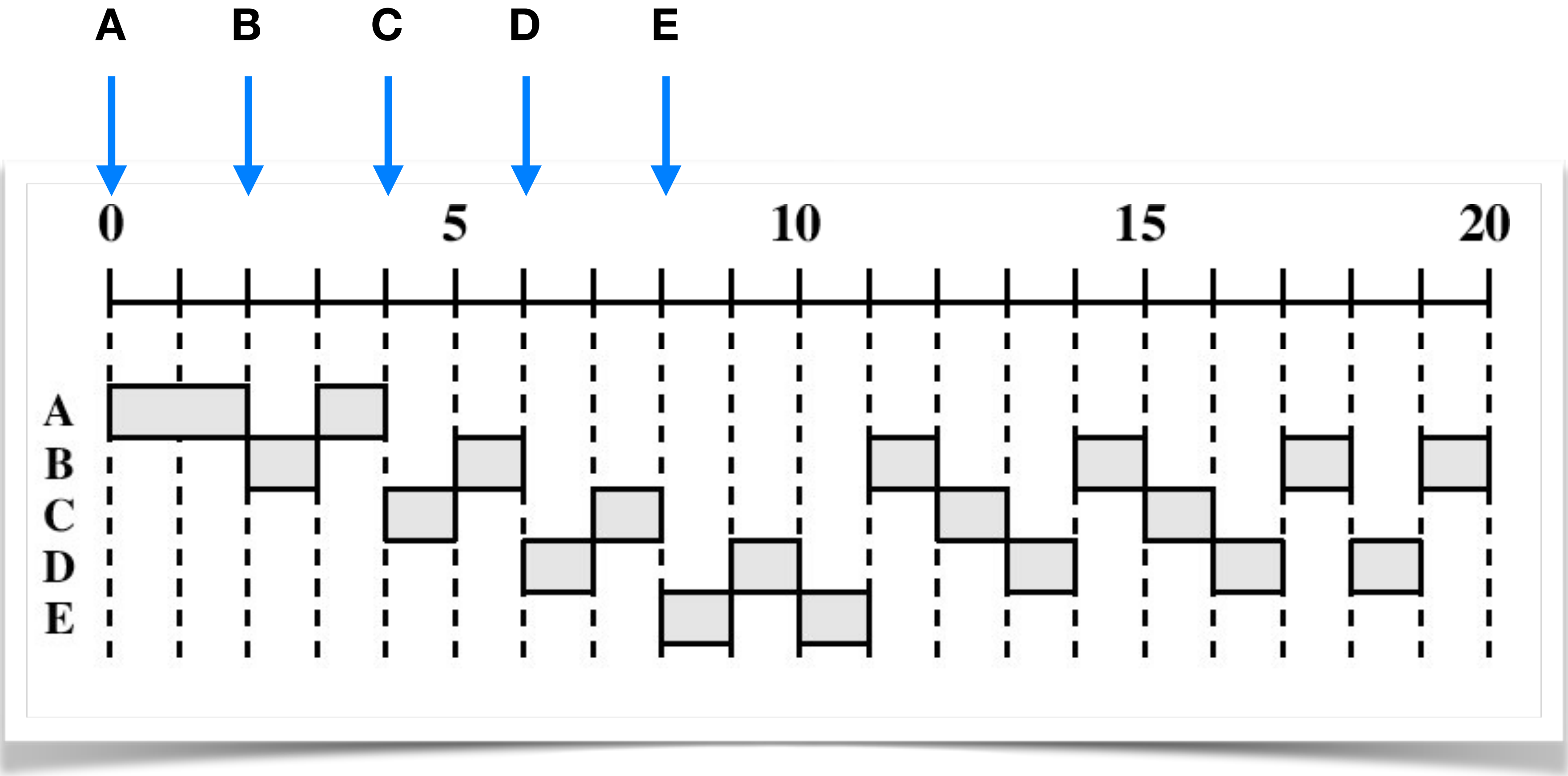
The MLFQ approach keeps an interactive job at the highest priority

Taskset Analysis

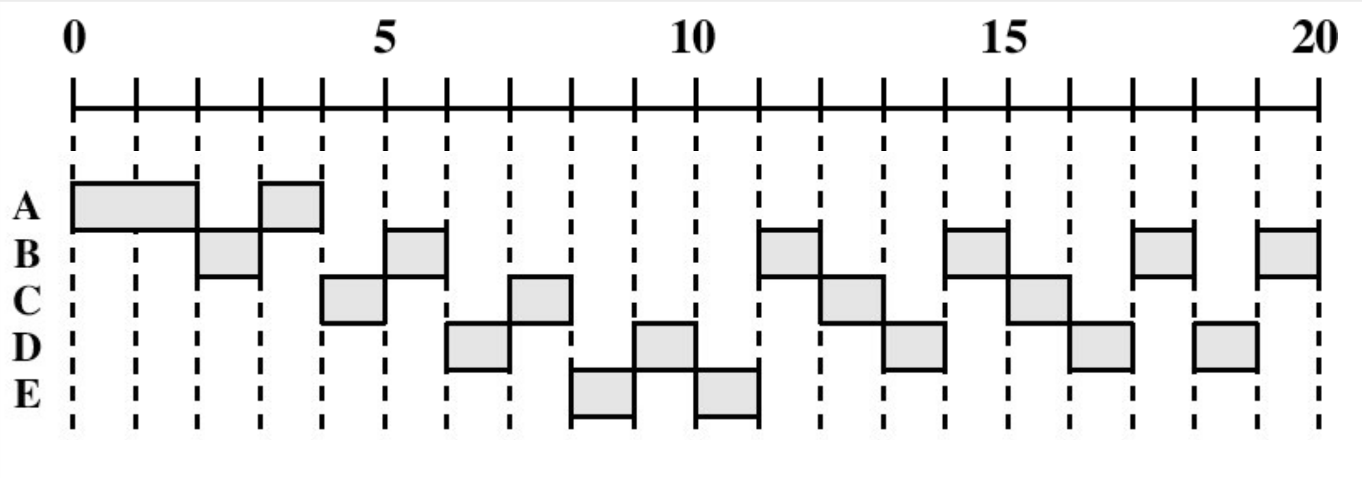
Process	Arrival Time	Service Time
A	0	3
B	2	6
C	4	4
D	6	5
E	8	2



MLFQ Analysis (q=1)



MLFQ Analysis (q=1)



Process	A	B	C	D	E	Mean
Arrival Time	0	2	4	6	8	
Service Time (T_s)	3	6	4	5	2	
Finish Time	4	20	16	19	11	
Turnaround Time (T_r)	4	18	12	13	3	10.00
T_r/T_s	1.33	3.00	3.00	2.60	1.5	2.29

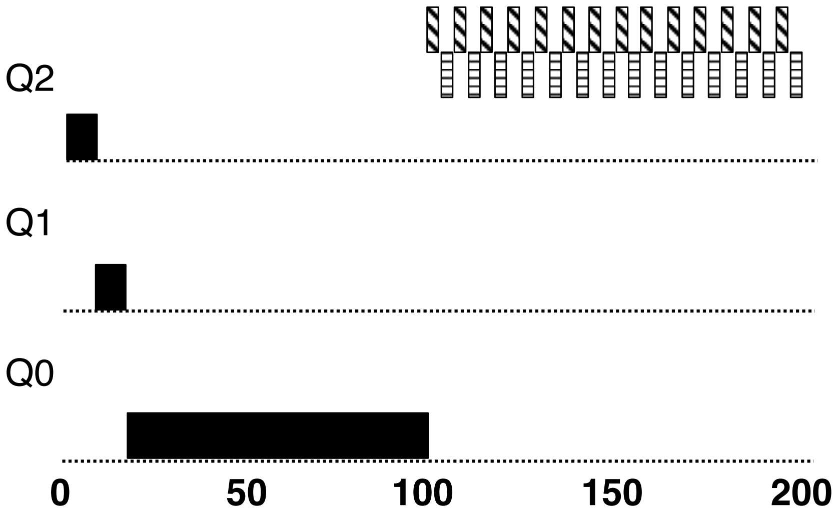
Problems with the Basic MLFQ

- **Starvation**
  - If there are “too many” interactive jobs in the system.
  - Lon-running jobs will never receive any CPU time.
- **Game** the scheduler
  - After running 99% of a time slice, issue an I/O operation.
  - The job gain a higher percentage of CPU time.
- A program may **change its behavior** over time.
  - **CPU** bound process ➝ **I/O** bound process

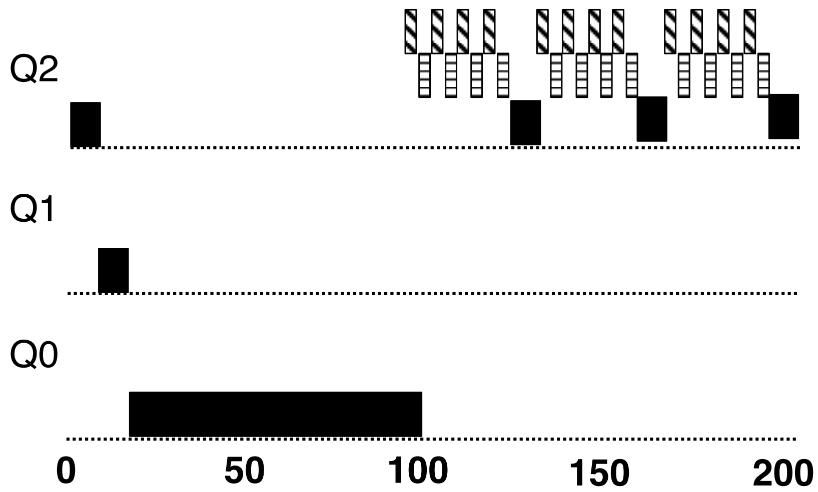
The Priority Boost

- Example:
  - A long-running job(A) with two short-running interactive job(B, C)

A: B: C:



Without Priority Boost



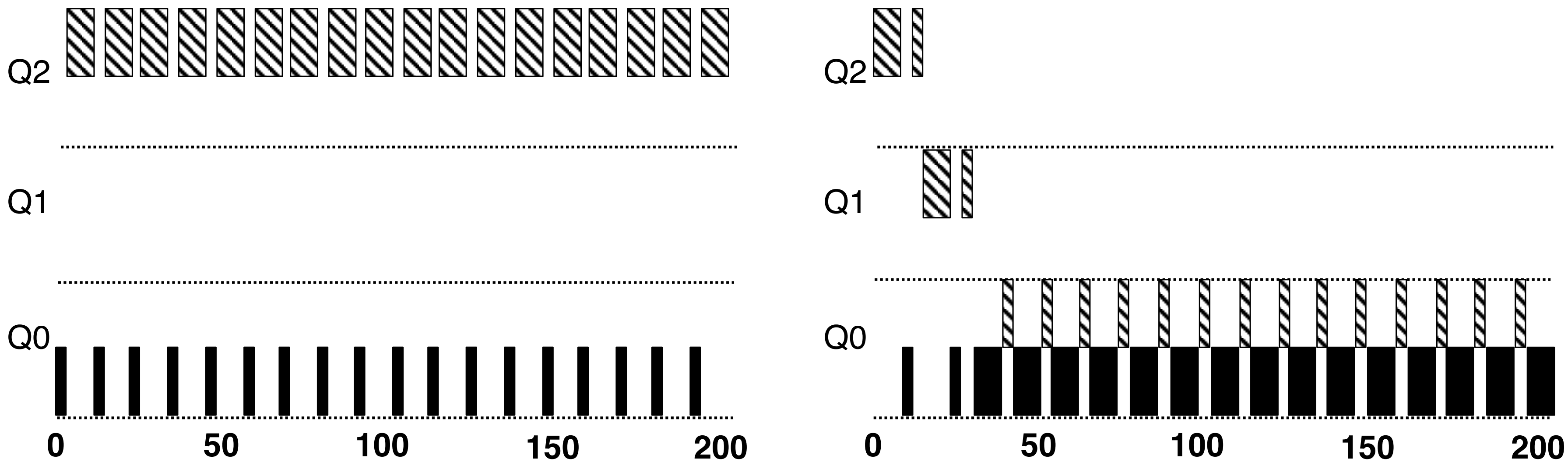
With Priority Boost

> **Rule 5:** After some time period S, move all the jobs in the system to the topmost queue.

Better Accounting

- How to prevent gaming of our scheduler?

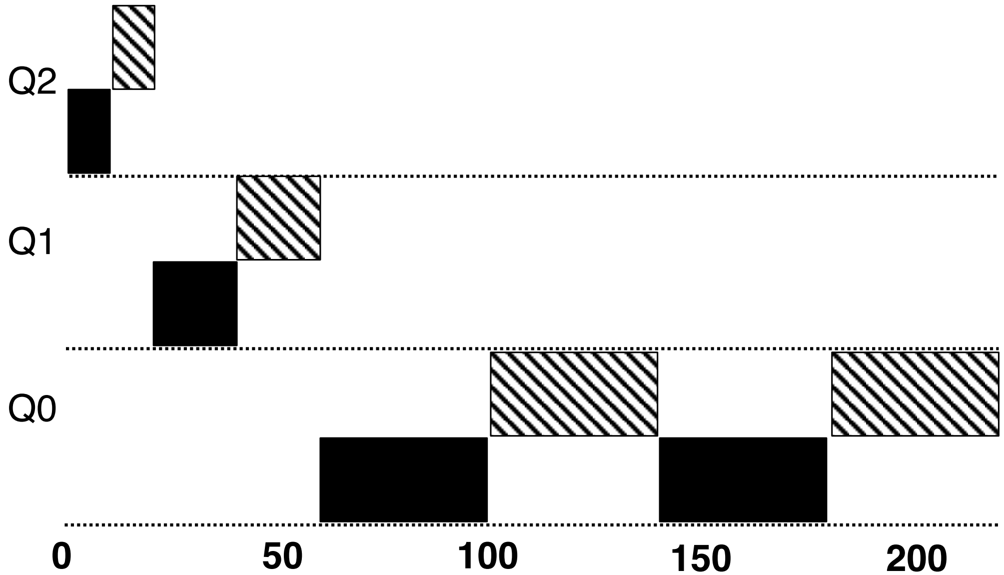
Rule 4 (Rewrite 4a and 4b): Once a job uses up its time allotment at a given level (regardless of how many times it has given up the CPU), its priority is reduced (i.e., it moves down on queue).



Without(Left) and With(Right) Gaming Tolerance

Tuning MLFQ And Other Issues

- The high-priority queues ➙ Short time slices
  - E.g., 10 or fewer milliseconds
- The Low-priority queue ➙ Longer time slices
  - E.g., 100 milliseconds



Example) 10ms for the highest queue, 20ms for the middle, 40ms for the lowest

Lower Priority, Longer Quanta

MLFQ: Summary

Rule 1: If Priority(A) > Priority(B), A runs (B doesn't).

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

Rule 3: When a job enters the system, it is placed at the highest priority

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Thanks

Questions?