Introduction to Operating Systems

CPSC/ECE 3220 Summer 2018

Lecture Notes
OSPP Chapter 7 – Part A

(adapted by Mark Smotherman from Tom Anderson's slides on OSPP web site)

Main Points

- Scheduling policy: what to do next, when there are multiple threads ready to run
  - Or multiple packets to send, or web requests to serve, or …
- Definitions
  - Response time, throughput, predictability
- Uniprocessor policies
  - FIFO, Round Robin (RR), optimal
  - Multilevel feedback (MFQ) as approx. of optimal

Example

- You manage a web site that suddenly becomes wildly popular. Do you?
  - Buy more hardware?
  - Implement a different scheduling policy?
  - Turn away some users? Which ones?
- How much worse will performance get if the web site becomes even more popular?

Definitions

- Task/Job
  - User request: e.g., mouse click, web request, shell command, …
- Latency/response time
  - How long does a task take to complete?
- Throughput
  - How many tasks can be done per unit of time?
- Overhead
  - How much extra work is done by the scheduler?
- Fairness
  - How equal is the performance received by different users?
- Predictability
  - How consistent is the performance over time?

More Definitions

- Workload
  - Set of tasks for system to perform
- Preemptive scheduler
  - If we can take resources away from a running task
- Work-conserving
  - Resource is used whenever there is a task to run
  - For non-preemptive schedulers, work-conserving is not always better
- Scheduling algorithm
  - Takes a workload as input
  - Decides which tasks to do first
  - Performance metric (throughput, latency) as output
  - Only preemptive, work-conserving schedulers to be considered

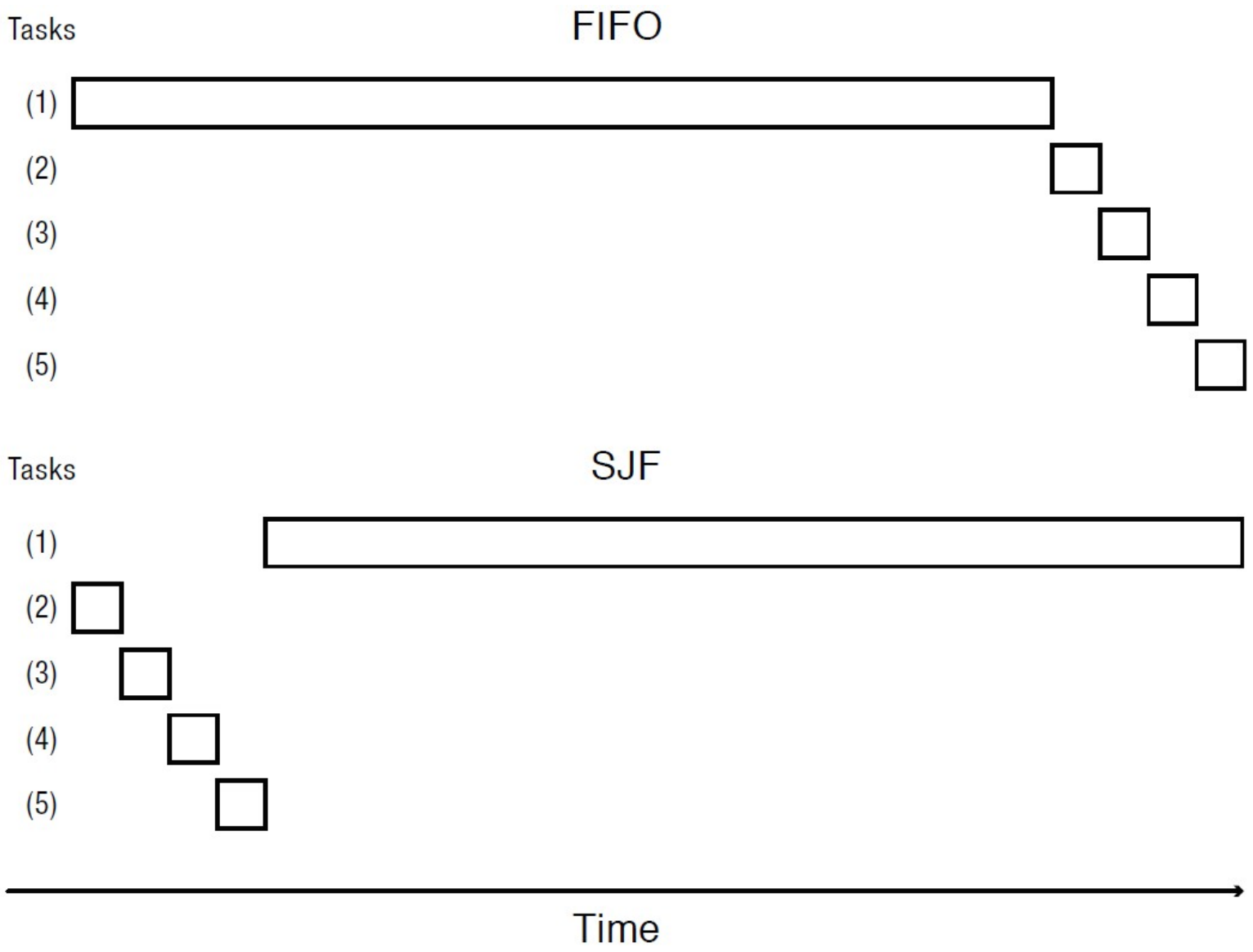
First In First Out (FIFO)

- Schedule tasks in the order they arrive
  - Continue running them until they complete or give up the processor
- Example: memcached
  - Facebook cache of friend lists, …
- On what workloads is FIFO particularly bad?

Shortest Job First (SJF) Premeptive

- Always do the task that has the shortest remaining amount of work to do
  - Often called Shortest Remaining Time First (SRTF) or Shortest Remaining Time Next (SRTN)
- Suppose we have five tasks arrive one right after each other, but the first one is much longer than the others
  - Which completes first in FIFO? Next?
  - Which completes first in SJF(preemptive)? Next?

FIFO vs. SJF(preemptive)



Question

- Claim: SJF(preemptive) is optimal for average response time
  - Why?

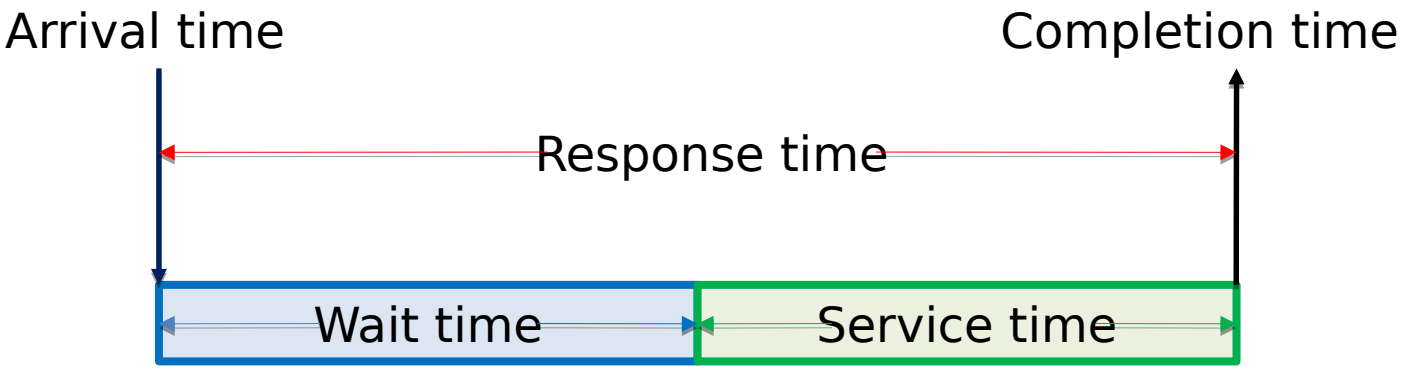
- Does SJF(preemptive) have any downsides?

Question

- Is FIFO ever optimal?

- Pessimal?

Relationships Among 5 “Time” Values



Wait time (if any) precedes service time in FIFO

Wait time and service time can be intermixed in other policies

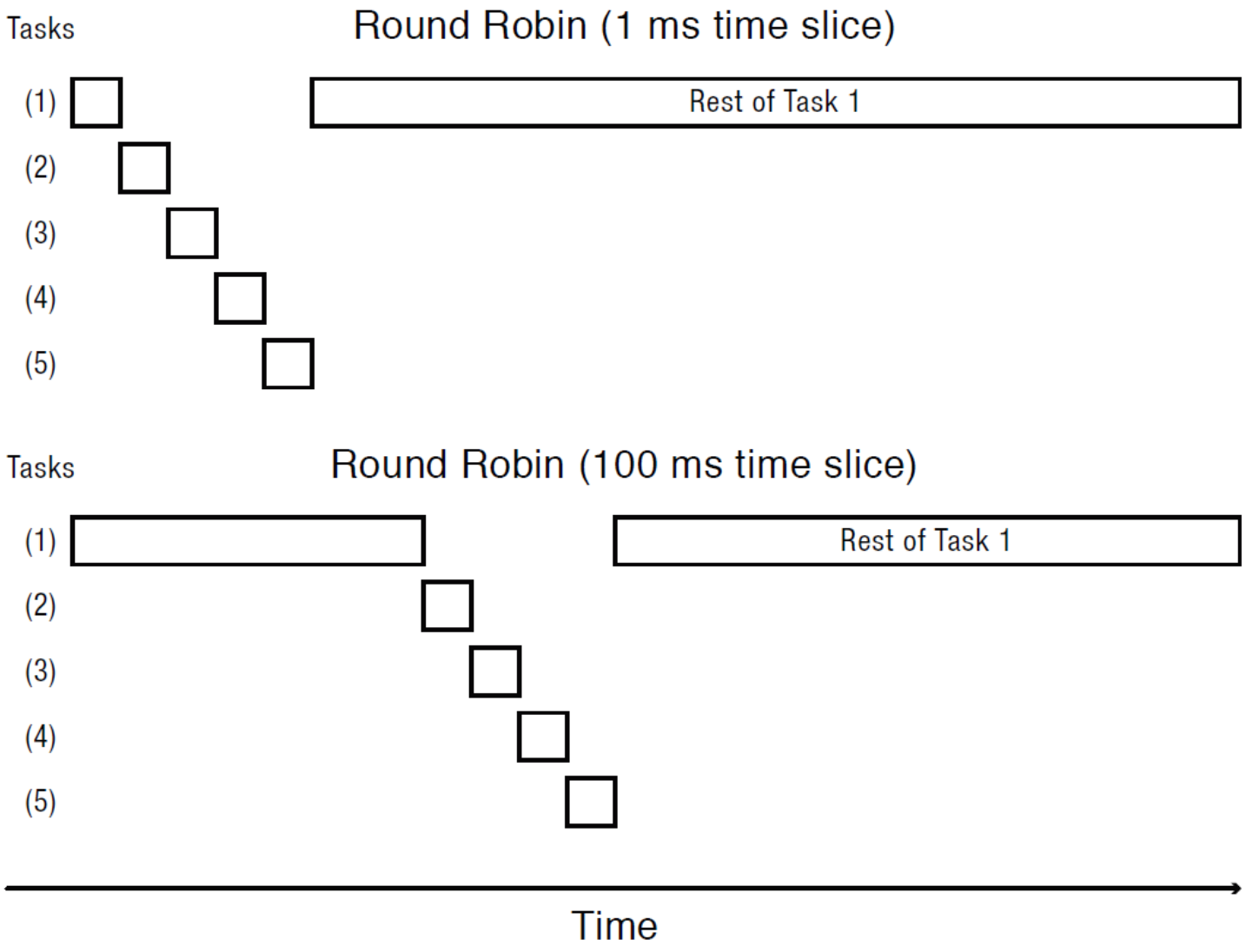
Range of Classic Policies

- Policies that do not use service times:
  - FIFO – easiest to implement
  - RR
  - MFQ
- Future knowledge policies – decisions made based on knowledge of service times:
  - SJF(non-preemptive)
  - SJF(preemptive) – minimum avg. response time
  - Approximate SJF(preemptive) by predicting service times
    - E.g., based on running average of CPU burst lengths, file sizes

Round Robin

- Each task gets resource for a fixed period of time = time quantum (or time slice)
  - If task doesn’t complete, it goes back in line
- Need to pick a time quantum
  - What if time quantum is too long?
    - Infinite?
  - What if time quantum is too short?
    - One instruction?
  - Rule of thumb: 80%+ of tasks finish in one quantum

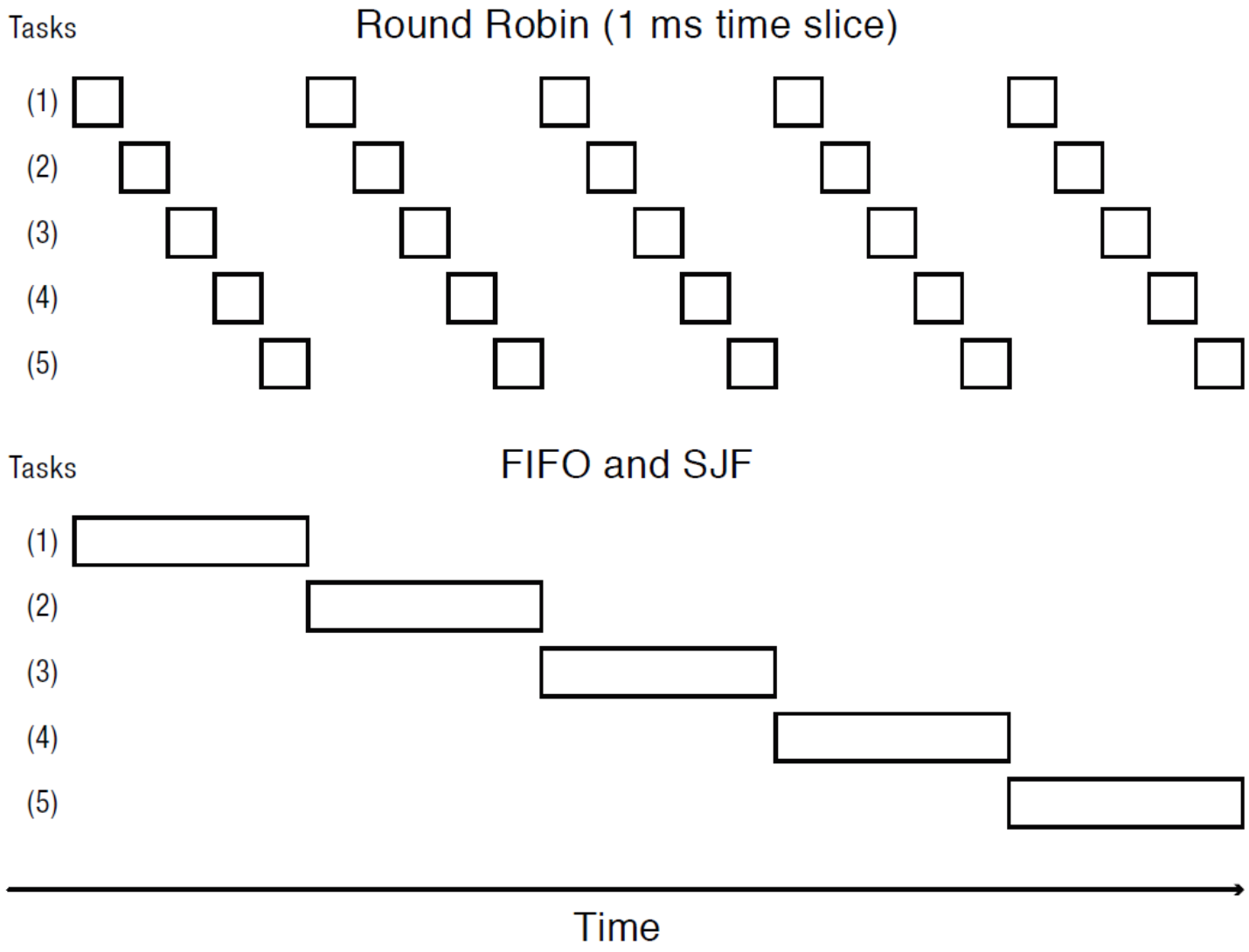
Round Robin


Tasks
Round Robin (1 ms time slice)
(1)
Rest of Task 1
(2)
(3)
(4)
(5)
Tasks
Round Robin (100 ms time slice)
(1)
Rest of Task 1
(2)
(3)
(4)
(5)
Time

Round Robin vs. FIFO

- Assuming zero-cost time slice, is Round Robin always better than FIFO?

Round Robin vs. FIFO



Round Robin = Fairness?

- Is Round Robin always fair?

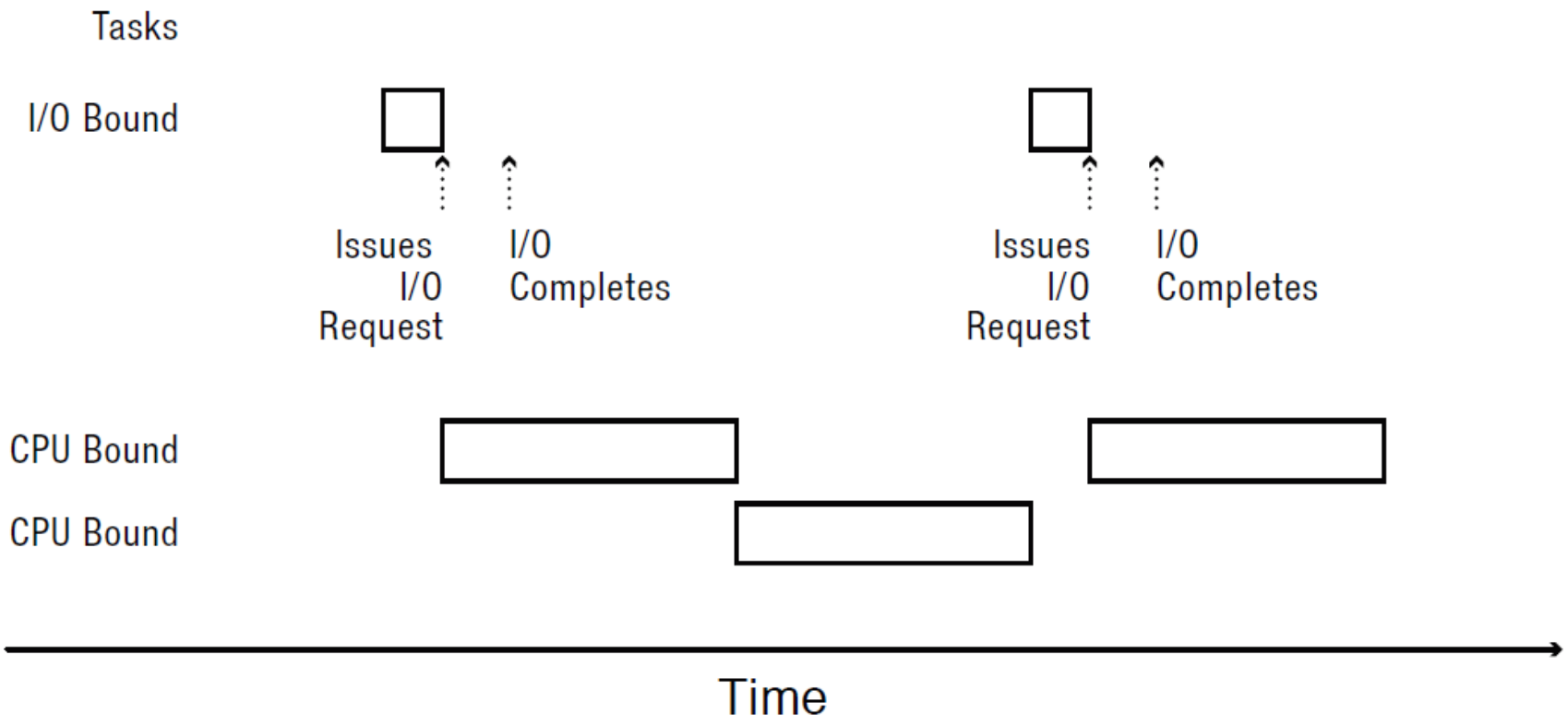
- What is fair?
  - FIFO?
  - Equal share of the CPU?
  - What if some tasks don’t need their full share?
  - Minimize worst case divergence?
    - Time task would take if no one else was running
    - Time task takes under scheduling algorithm

Policy vs. Mechanism

- Policy = decision-making rule
  - "what to do"
- Mechanism = hardware or software that is used to implement a policy
  - "how to do it"

- What are mechanisms for Round Robin?

Mixed Workload



Max-Min Fairness

- How do we balance a mixture of repeating tasks:
  - Some I/O bound, need only a little CPU
  - Some compute bound, can use as much CPU as they are assigned
- One approach: maximize the minimum allocation given to a task
  - If any task needs less than an equal share, schedule the smallest of these first
  - Split the remaining time using max-min
  - If all remaining tasks need at least equal share, split evenly

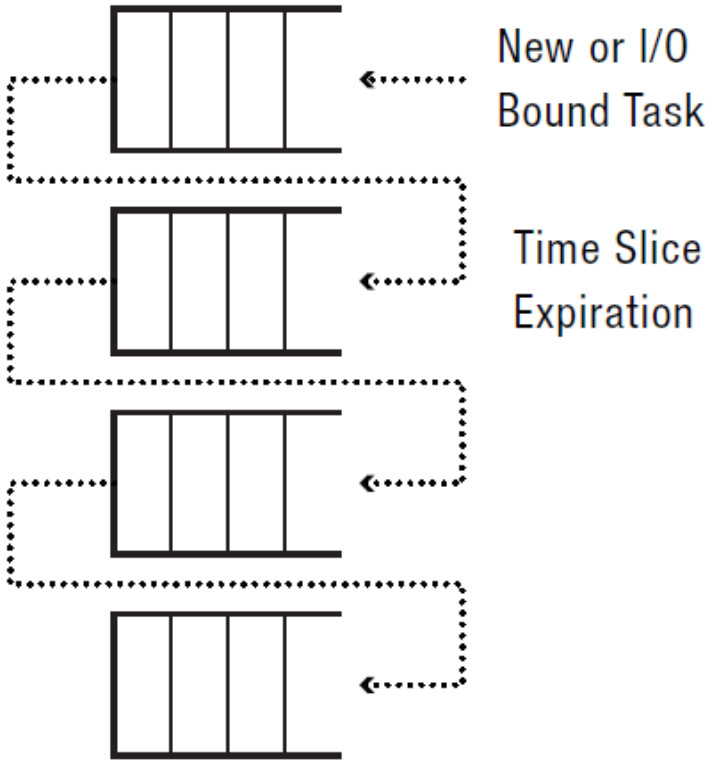
Multi-level Feedback Queue (MFQ)

- Set of Round Robin queues
  - Each queue has a separate priority
- High priority queues have short time slices
  - Low priority queues have long time slices
- Scheduler picks first thread in highest priority queue
- Tasks start in highest priority queue
  - If time slice expires, task drops one level

MFQ

Priority	Time Slice (ms)
1	10
2	20
3	40
4	80

Round Robin Queues



Uniprocessor Summary (1)

- FIFO is simple and minimizes overhead
- If tasks are variable in size, then FIFO can have very poor average response time
- If tasks are equal in size, FIFO is optimal in terms of average response time
- Considering only the processor, SJF(preemptive) is optimal in terms of average response time
- SJF(preemptive) is pessimal in terms of variance in response time

Uniprocessor Summary (2)

- If tasks are variable in size, Round Robin approximates SJF
- If tasks are equal in size, Round Robin will have very poor average response time
- Tasks that intermix processor and I/O benefit from SJF(preemptive) and can do poorly under Round Robin

Uniprocessor Summary (3)

- Max-Min fairness can improve response time for I/O-bound tasks
- Round Robin and Max-Min fairness both avoid starvation

Simulation Comparisons

```
fcfs results:
 1-th 10-percentile avg. wait is     19.800  |*****************
 2-th 10-percentile avg. wait is     21.796  |*******************
 3-th 10-percentile avg. wait is     19.908  |*****************
 4-th 10-percentile avg. wait is     18.432  |****************
 5-th 10-percentile avg. wait is     19.444  |*****************
 6-th 10-percentile avg. wait is     19.618  |*****************
 7-th 10-percentile avg. wait is     19.984  |*****************
 8-th 10-percentile avg. wait is     21.264  |*******************
 9-th 10-percentile avg. wait is     21.188  |*******************
10-th 10-percentile avg. wait is     18.490  |****************
                                             +--------------------
                                              scaled to max value
                                              overall avg.

19.992
rr results:
 1-th 10-percentile avg. wait is      4.932  |**
 2-th 10-percentile avg. wait is      5.164  |**
 3-th 10-percentile avg. wait is      5.142  |**
 4-th 10-percentile avg. wait is      9.858  |***
 5-th 10-percentile avg. wait is      9.696  |***
 6-th 10-percentile avg. wait is     15.340  |*****
 7-th 10-percentile avg. wait is     19.858  |*******
 8-th 10-percentile avg. wait is     26.128  |*********
 9-th 10-percentile avg. wait is     35.976  |************
10-th 10-percentile avg. wait is     61.794  |********************
                                             +--------------------
                                              scaled to max value
                                              overall avg.

19.389
```

```
mlfq results:
 1-th 10-percentile avg. wait is      2.690  |*
 2-th 10-percentile avg. wait is      2.808  |*
 3-th 10-percentile avg. wait is      3.262  |*
 4-th 10-percentile avg. wait is      7.084  |***
 5-th 10-percentile avg. wait is      6.562  |**
 6-th 10-percentile avg. wait is      6.566  |**
 7-th 10-percentile avg. wait is     24.858  |*******
 8-th 10-percentile avg. wait is     33.758  |**********
 9-th 10-percentile avg. wait is     34.030  |**********
10-th 10-percentile avg. wait is     68.922  |********************
                                             +--------------------
                                              scaled to max value
                                              overall avg.

19.054
srtn results:
 1-th 10-percentile avg. wait is      0.058  |
 2-th 10-percentile avg. wait is      0.170  |
 3-th 10-percentile avg. wait is      0.470  |
 4-th 10-percentile avg. wait is      0.874  |
 5-th 10-percentile avg. wait is      1.234  |*
 6-th 10-percentile avg. wait is      2.286  |*
 7-th 10-percentile avg. wait is      4.222  |**
 8-th 10-percentile avg. wait is      7.232  |***
 9-th 10-percentile avg. wait is     14.148  |******
10-th 10-percentile avg. wait is     47.980  |********************
                                             +--------------------
                                              scaled to max value
                                              overall avg.

7.867
```