Process Scheduling

ICT 41203 Operating Systems

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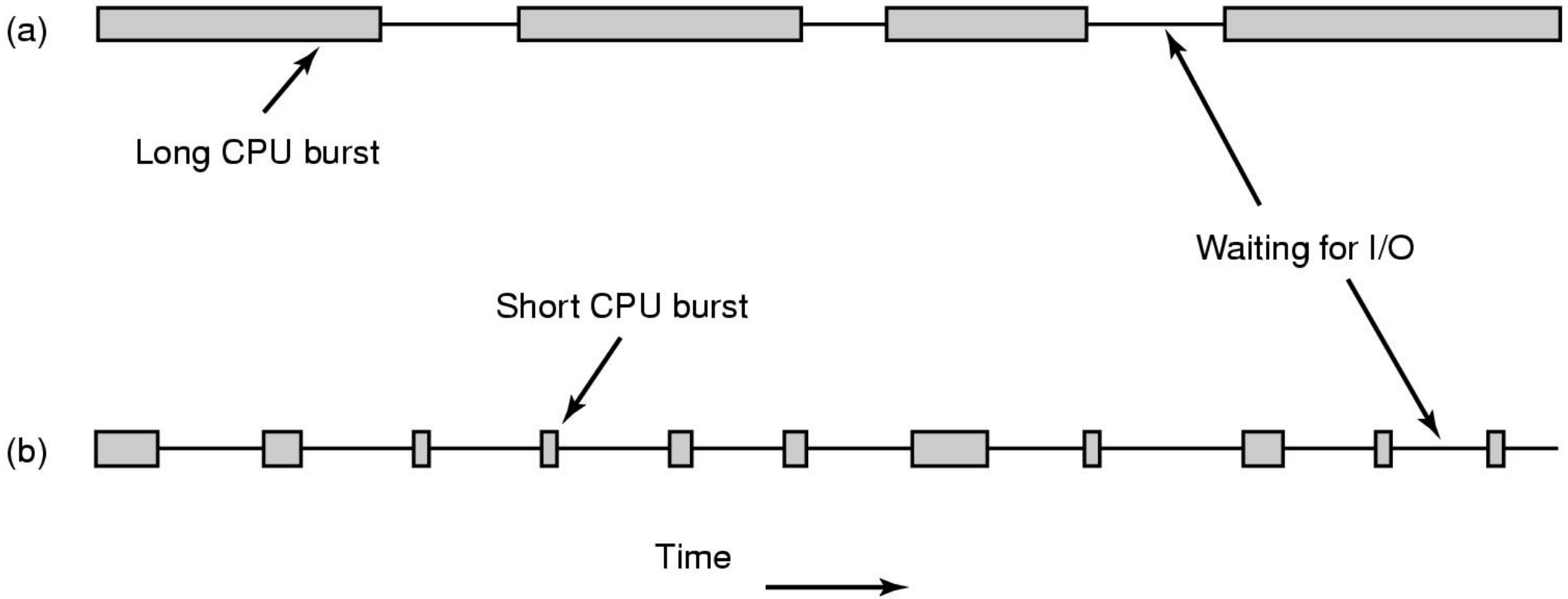
Process Behaviour



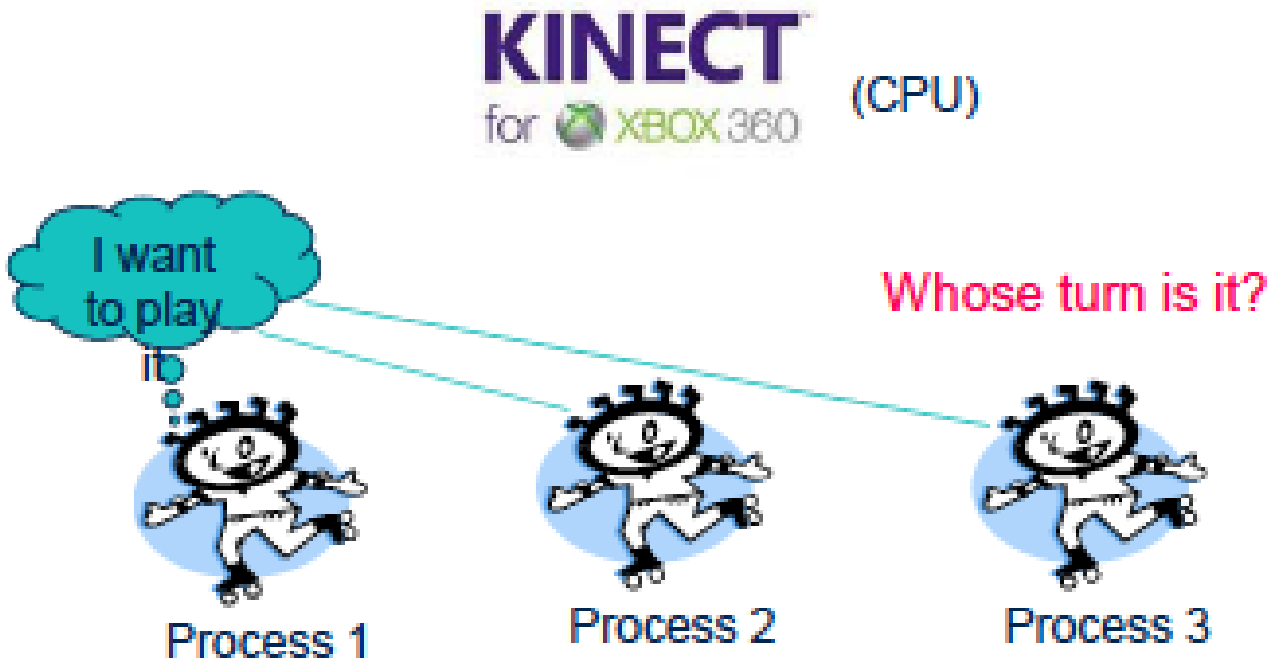
a) **CPU-bound** processes spend most of their time computing

b) **I/O bound** processes spend most of their time waiting for I/O

Multiprogramming

- Increase CPU utilization and job throughput by overlapping I/O and CPU activities
- Previously covered the mechanisms of
  - Context switching, how it happens
  - Process queues and process states
- Now the policies of
  - **which** process (thread) to run, for **how long**, etc. – scheduling

Who gets the CPU?



Scheduling

- Choosing which process to run next, when two or more of them are simultaneously in the ready state
- Deciding which process should occupy the resource (CPU, disk, etc.)
- Done by **scheduler** using the **scheduling algorithm**
- Many of the same issues that apply to process scheduling also apply to thread scheduling, although some are different.
- **Jobs** - schedulable entities (processes, threads)

When to schedule?

- when a new job is created
  - whether to run the parent or the child
- when a job exits
- when a job blocks on I/O,
- when an I/O interrupt occurs
  - from an I/O device that has now completed its work for a waiting job
- if a hardware clock provides periodic interrupts
  - every 1 millisecond (Linux 2.6)

Performance Criteria

- Throughput
  - # of jobs that complete in unit time
- Turnaround time (elapse time)
  - Amount of time to execute a particular process from the time it entered
- Waiting time
  - Amount of time process has been waiting in ready queue
- Meeting deadlines
  - Avoid bad consequences

Scheduling Objectives

- Fair
  - Everyone is happy
- Priority
  - Some are more important
- Efficiency
  - Make best use of equipment
- Encourage good behavior
  - Good boy/girl
- Support heavy load
  - Degrade gracefully
- Adapt to different environment
  - Interactive, real-time, multi-media, etc.

Categories of Scheduling Algorithms

1. Batch
   - Periodic tasks – payroll, bills, interest calculation (at banks)
   - No users impatiently waiting
   - Possible to run for long time periods for each process without switching
2. Interactive
   - For environments with interactive users – personal computing, servers
   - One process cannot be hogging the CPU and denying service to the others
3. Real time
   - Only programs that are intended to further the application at hand
   - Processes may not run for long and usually do their work and block quickly
   - So, it's okay to let them finish

Preemptive vs. Non-preemptive

- Non-preemptive scheduling
  - The running process keeps the CPU until it **voluntarily** gives up the CPU
- Preemptive scheduling
  - The running process can be **interrupted** and must release the CPU

Scheduling Algorithm Goals

All systems

Fairness - giving each process a fair share of the CPU
Policy enforcement - seeing that stated policy is carried out
Balance - keeping all parts of the system busy

Batch systems

Throughput - maximize jobs per hour
Turnaround time - minimize time between submission and termination
CPU utilization - keep the CPU busy all the time

Interactive systems

Response time - respond to requests quickly
Proportionality - meet users' expectations

Real-time systems

Meeting deadlines - avoid losing data
Predictability - avoid quality degradation in multimedia systems

Scheduling Algorithms

- Batch Systems
  - First-Come, First-Served (FCFS)
  - Short Job First (SJF)
- Interactive Systems
  - Round-Robin Scheduling
  - Priority Scheduling
  - Multi-Queue & Multi-Level Feedback
- Real-time Systems
  - Earliest Deadline First Scheduling

First-Come, First-Served (FCFS)

- “Real-world” scheduling of people in lines (e.g., supermarket)
- A single queue of ready jobs
- Jobs are scheduled in order of arrival to ready queue
- Typically non-preemptive (no context switching at market)
- Jobs treated equally, no starvation.
- When the running process blocks, the first process on the queue is run next.
- When a blocked process becomes ready, like a newly arrived job, it is put on the end of the queue, behind all waiting processes.

First-Come, First-Served – Example

Process	Duration	Order	Arrival Time
P1	24	1	0
P2	3	2	0
P3	4	3	0

P1 waiting time: 0
P2 waiting time: 24
P3 waiting time: 27

The average waiting time:
(0+24+27)/3 = 17

First-Come, First-Served – Problems

- Average waiting time can be large
  - If small jobs wait behind long ones (high turnaround time)
  - Non-preemptive
  - You're stuck behind someone with a cart, when you only have two items
- Solution?
  - Express lane (10 items or less)

Shortest Job First (SJF)

- Choose the job with the smallest expected duration first
  - Person with smallest number of items to buy
- Requirement
  - the job duration needs to be known in advance
- Used in Batch Systems
- Optimal for Average Waiting Time if all jobs are available simultaneously

Shortest Job First – Example

Process	Duration	Order	Arrival Time
P1	6	1	0
P2	8	2	0
P3	7	3	0
P4	3	4	0

P4 waiting time: 0
P1 waiting time: 3
P3 waiting time: 9
P2 waiting time: 16

The total time is: 24

The average waiting time (AWT):
(0+3+9+16)/4 = 7

FCFS vs. SJF

Process	Duration	Order	Arrival Time
P1	6	1	0
P2	8	2	0
P3	7	3	0
P4	3	4	0

The total time is the same (why?)

P1 waiting time: 0
P2 waiting time: 6
P3 waiting time: 14
P4 waiting time: 21

The average waiting time (AWT):
(0+6+14+21)/4 = 10.25
(comparing to 7)

Shortest Job First – Problems

- Starvation
  - a job is waiting forever
- All jobs must be available at start
  - Suited for batch systems

Process	Duration	Order	Arrival Time
P1	10	1	0
P2	2	2	2

P1 waiting time: 0
P2 waiting time: 8

The average waiting time (AWT):
(0+8)/2 = 4

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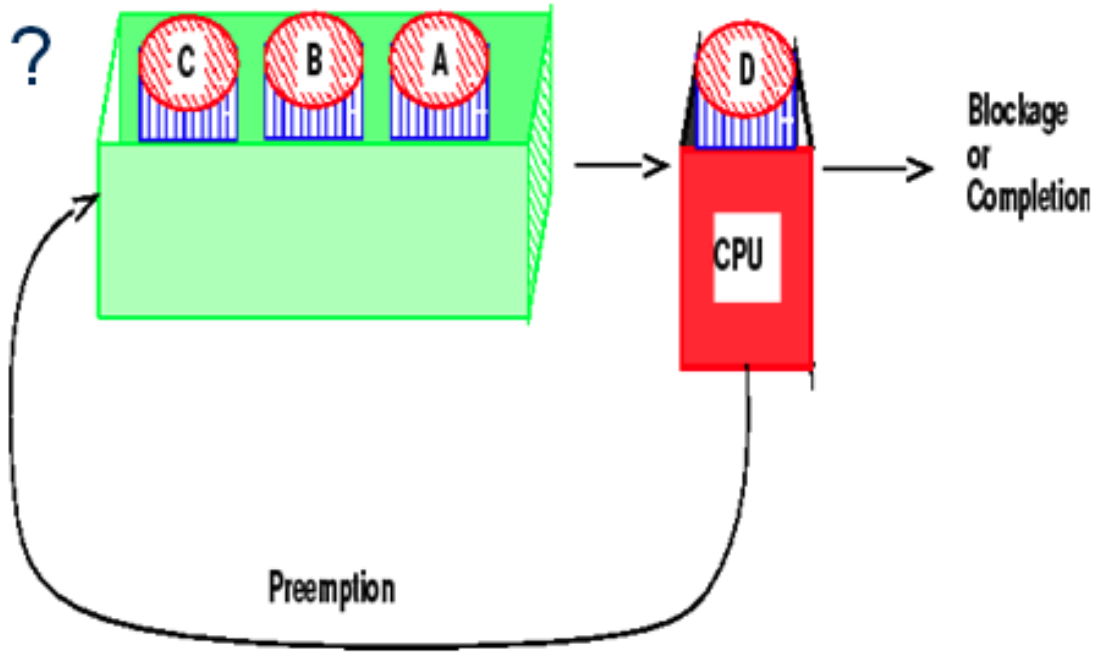
Round-Robin Scheduling

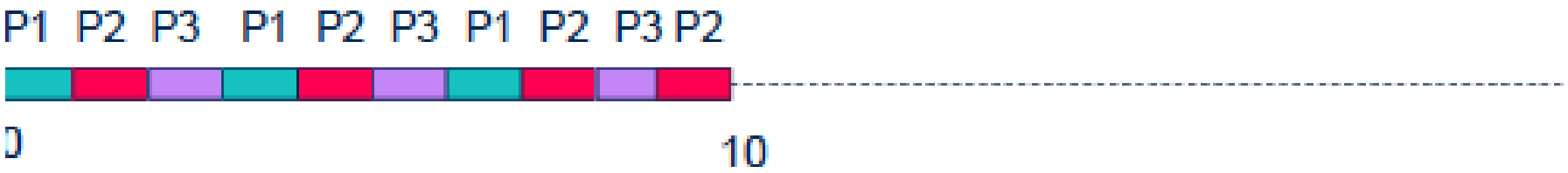
- One of the oldest, simplest, most commonly used scheduling algorithm
- Select process/thread from ready queue in a round-robin fashion (take turns)



Round-Robin Scheduling – Example

Process	Duration	Order	Arrival Time
P1	3	1	0
P2	4	2	0
P3	3	3	0

Suppose time quantum is: 1 unit, P1, P2 & P3 never block



P1 waiting time: 4
P2 waiting time: 6
P3 waiting time: 6

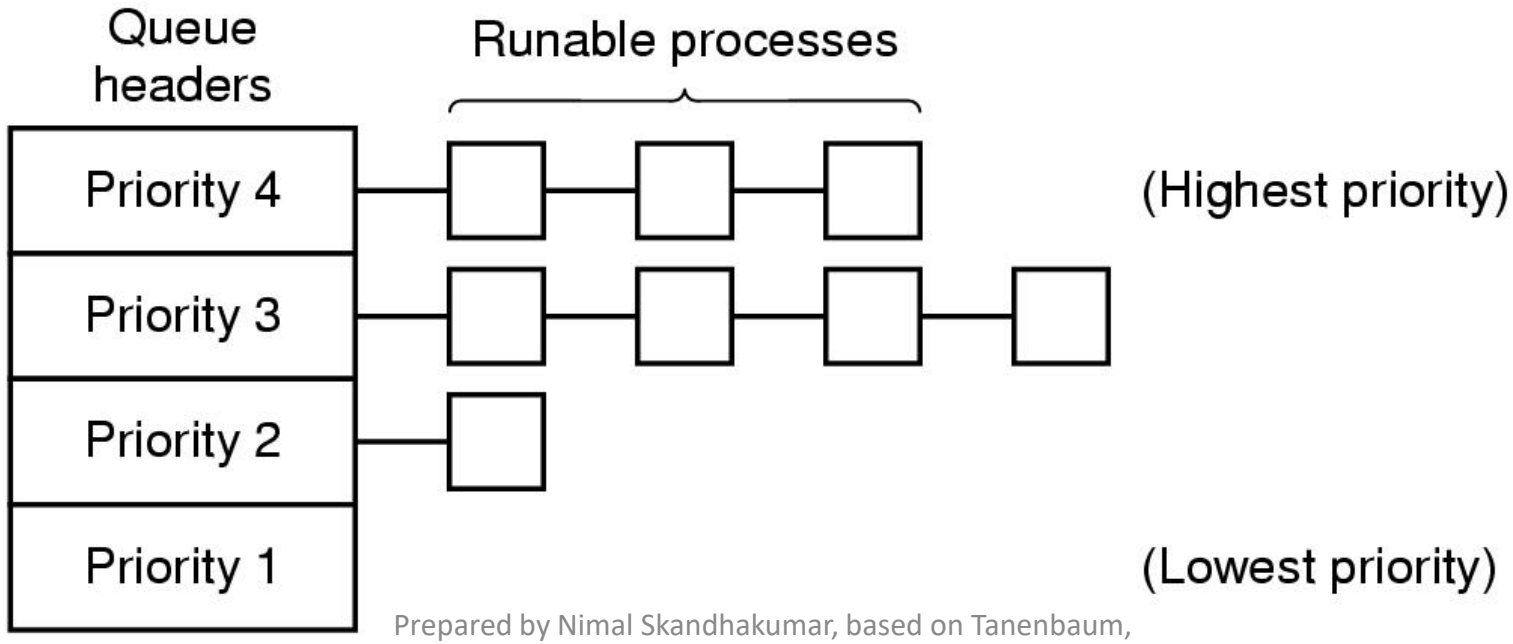
The average waiting time (AWT):
(4+6+6)/3 = 5.33

Round-Robin Scheduling – Problems

- Time slice too large
  - FIFO behavior
  - Poor response to short interactive requests
- Time slice too small
  - Too many context switches (overheads)
  - Inefficient CPU utilization
- A quantum around 20–50 msec is often a reasonable compromise.

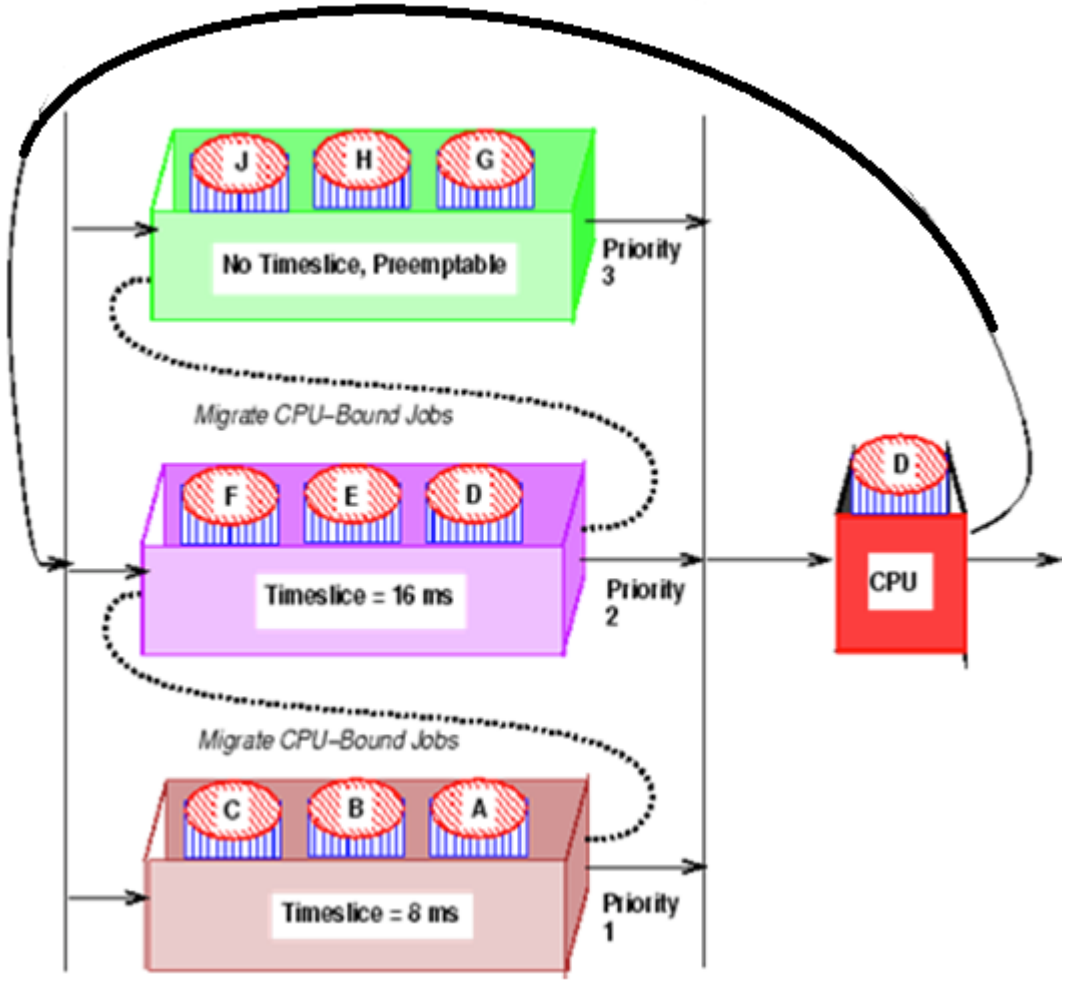
Priority Scheduling

- Not all processes are equally important
- Need to consider external factors
- Email checking less priority than displaying video



Multiple-level feedback queues (MLFQ)

- Scheduling algorithms can be combined
  - Have multiple queues
  - Use a different algorithm among queues
  - Move processes among queues
- Multiple queues representing different job types
  - Interactive, CPU-bound, batch, etc.
  - Queues have priorities
  - Jobs can move among queues based upon execution history



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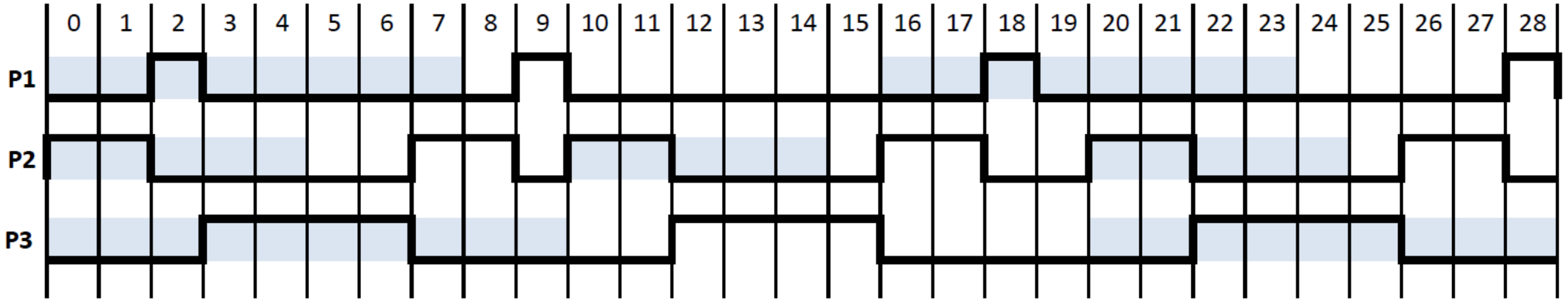
Earliest Deadline First (EDF)

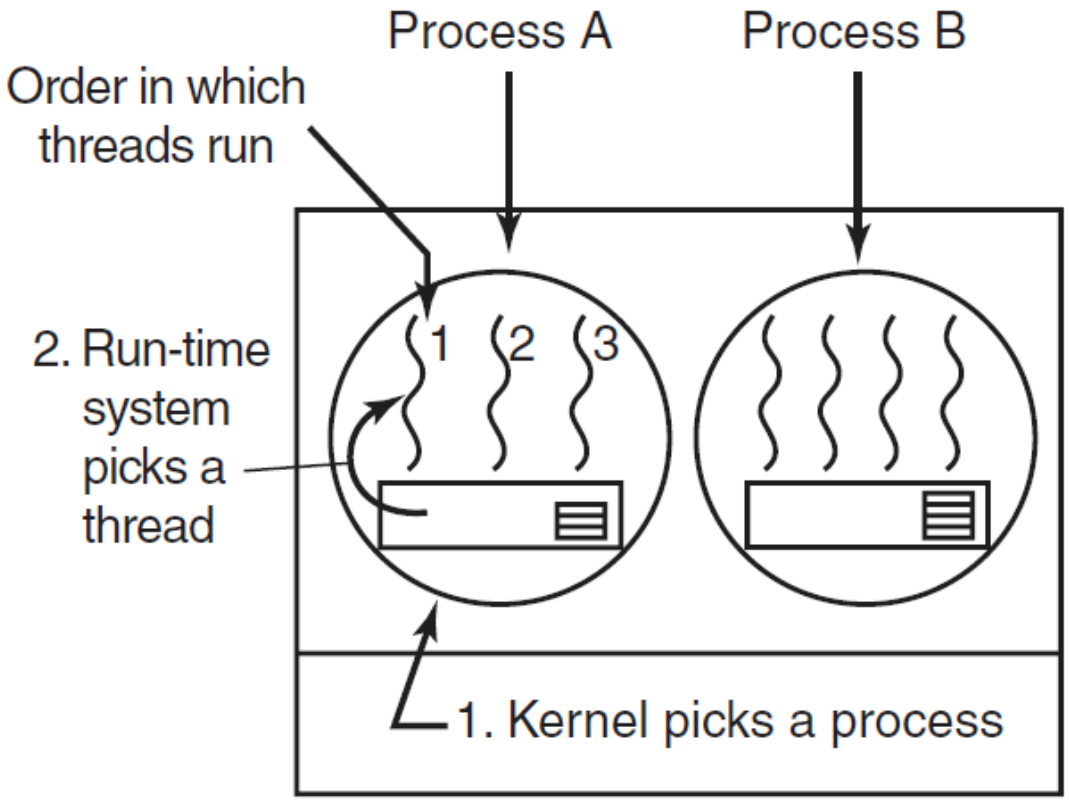
- Each job has an arrival time and a *deadline* to finish
  - Assignments, exams*
- Always pick the job with the earliest deadline to run



Thread Scheduling

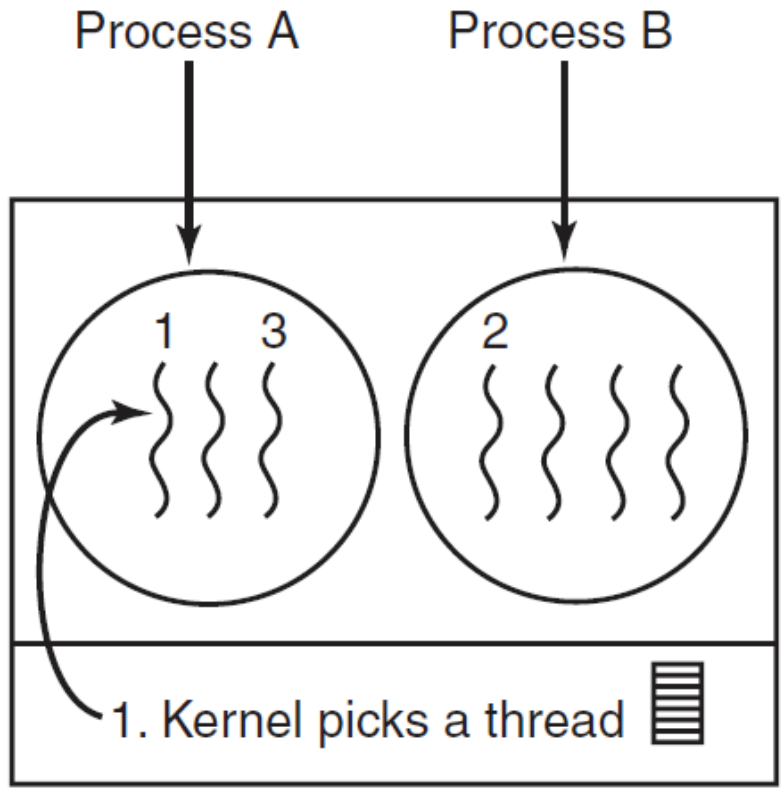
- Two levels of threads
  - User-level threads
  - Kernel-level threads
- User-level threads
  - Kernel picks the process
  - Scheduler inside process picks thread
- Kernel-level threads
  - Kernel picks a particular thread to run
  - Requires a full context switch

Thread Scheduling



Possible: A1, A2, A3, A1, A2, A3
Not possible: A1, B1, A2, B2, A3, B3

(a)



Possible: A1, A2, A3, A1, A2, A3
Also possible: A1, B1, A2, B2, A3, B3

(b)

Scheduling Summary

- Scheduler is the module that gets invoked when a context switch needs to happen
- Scheduling algorithm determines which process runs and where processes are placed on queues
- Scheduling algorithms have many goals
  - Utilization, throughput, wait time, response time, etc.
- Various algorithms to meet these goals
  - FCFS/FIFO, SJF, RR, Priority
- Can combine algorithms
  - Multiple-level feedback queues