Operating System Concepts

Lecture 13: CPU Scheduling — Part 2

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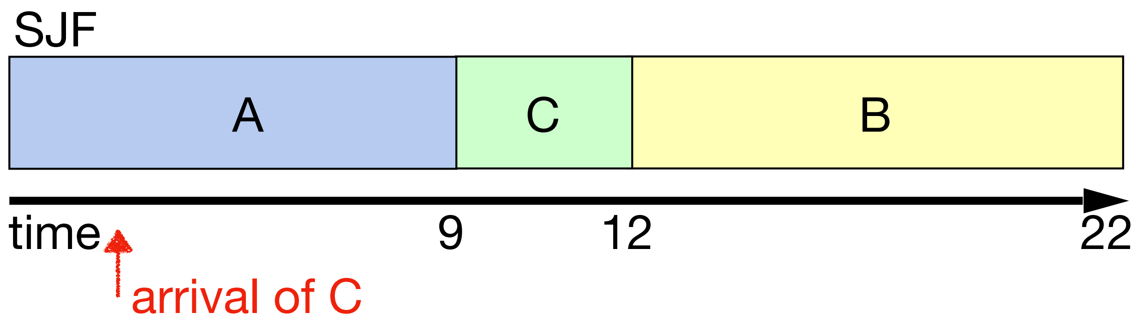
MWF 12:00-12:50 VVC 2 215

Today's class

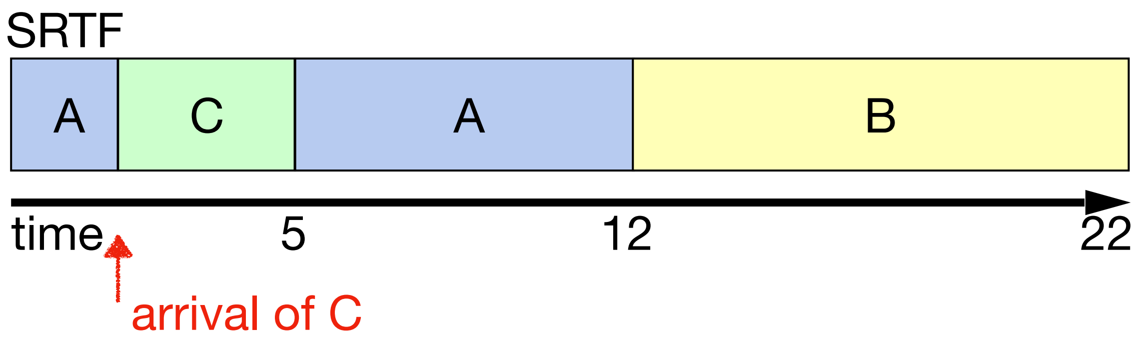
- Scheduling algorithms
  - SJF/SRTF scheduling
  - Priority scheduling
  - MFQ: Multilevel Feedback Queues
  - Proportional-share scheduling (lottery scheduling)
- Multiprocessor scheduling
- Scheduling on real-time systems

Comparing SRTF and SJF

Process	Burst length	Arrival time
A	9	0
B	10	0
C	3	2



Avg. turnaround time:
[9+(12-2)+22]/3=13.6



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- can ask users
  - they user can lie (declare a shorter burst length) to game the system
  - how to encourage truthfulness?
    - terminate execution after the specified burst length has passed

SJF is starvation prone

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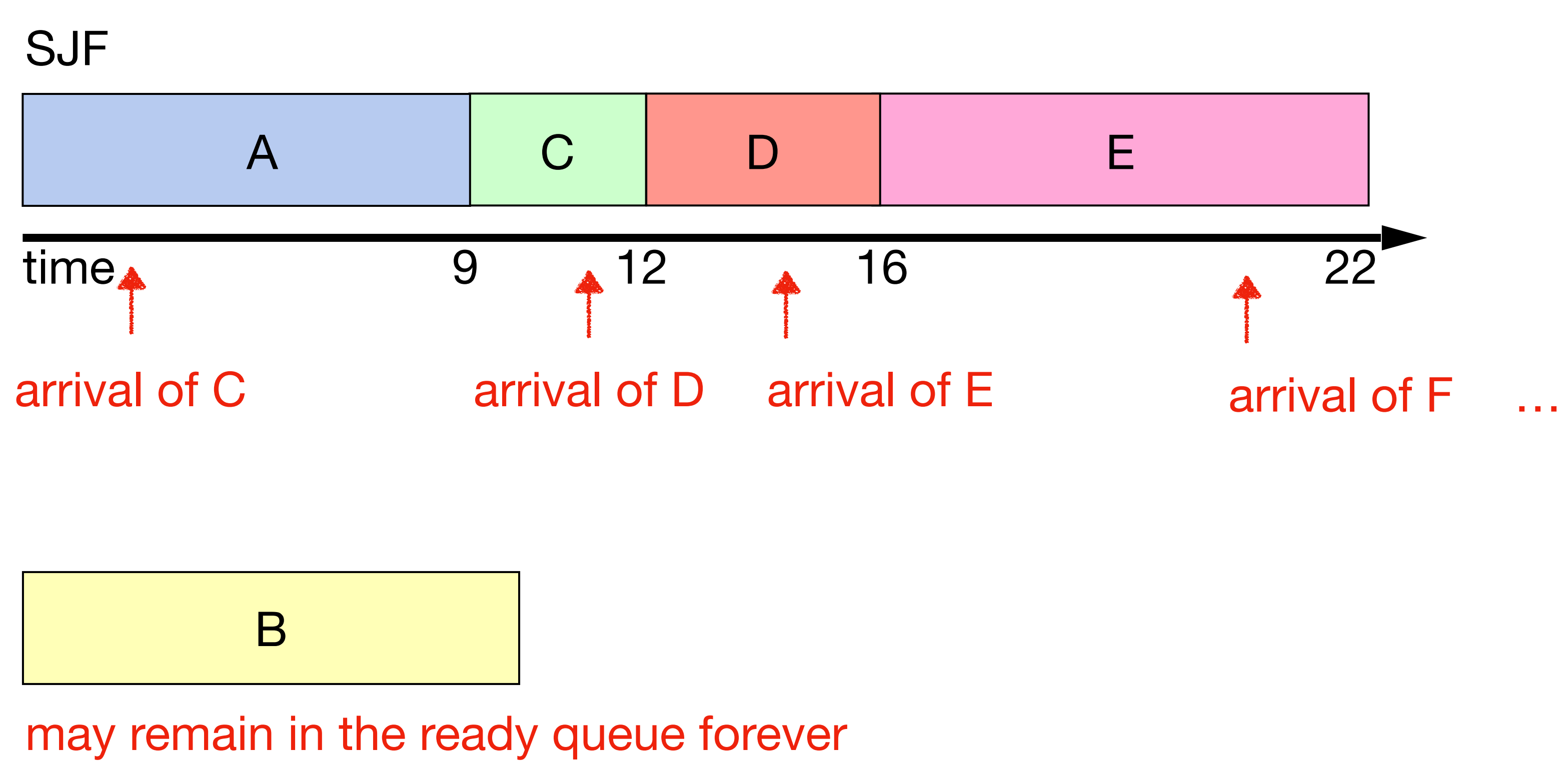
D	4	11
E	6	14



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Is SRJT starvation prone too?

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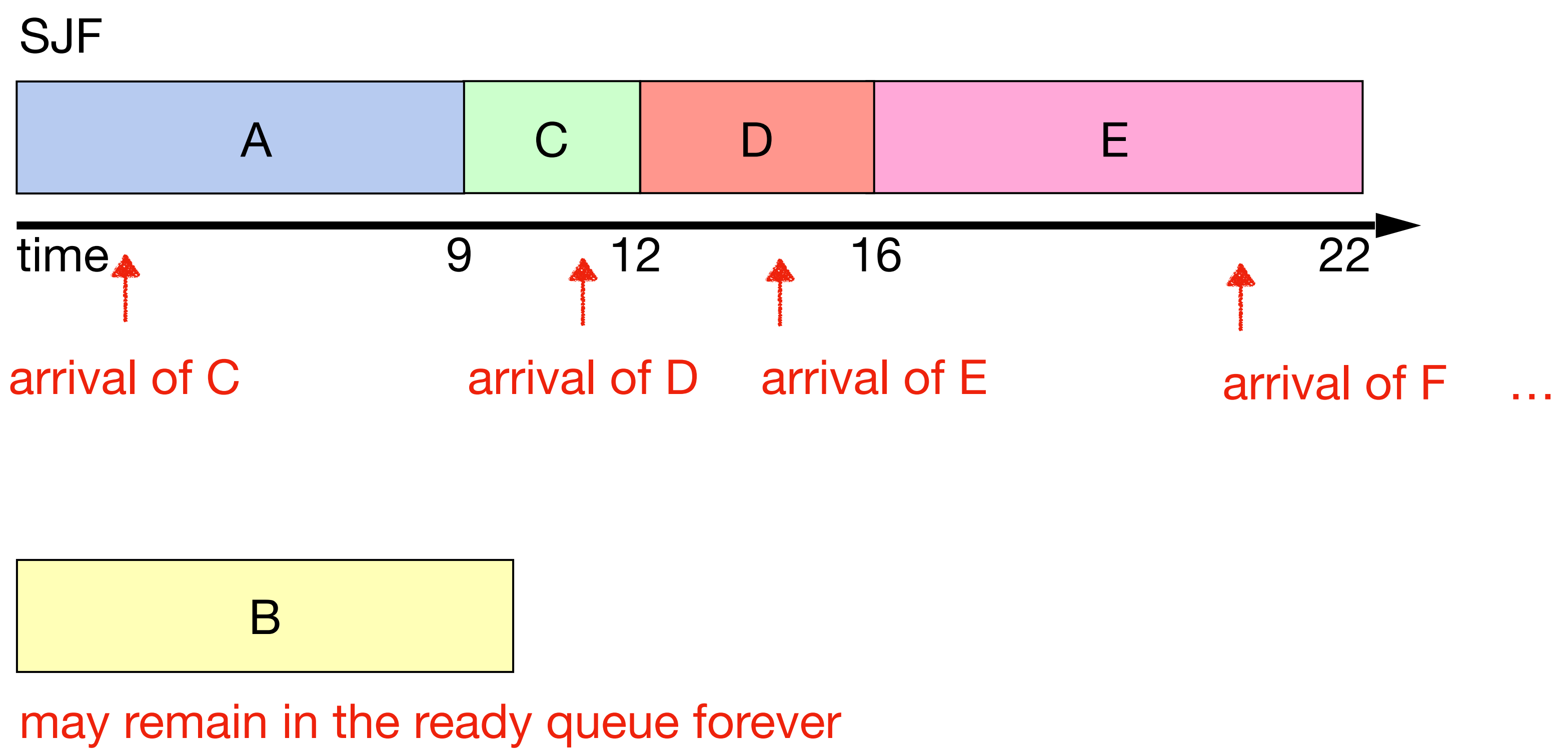

Can we design a policy that is responsive, fair, and starvation free with low overhead?

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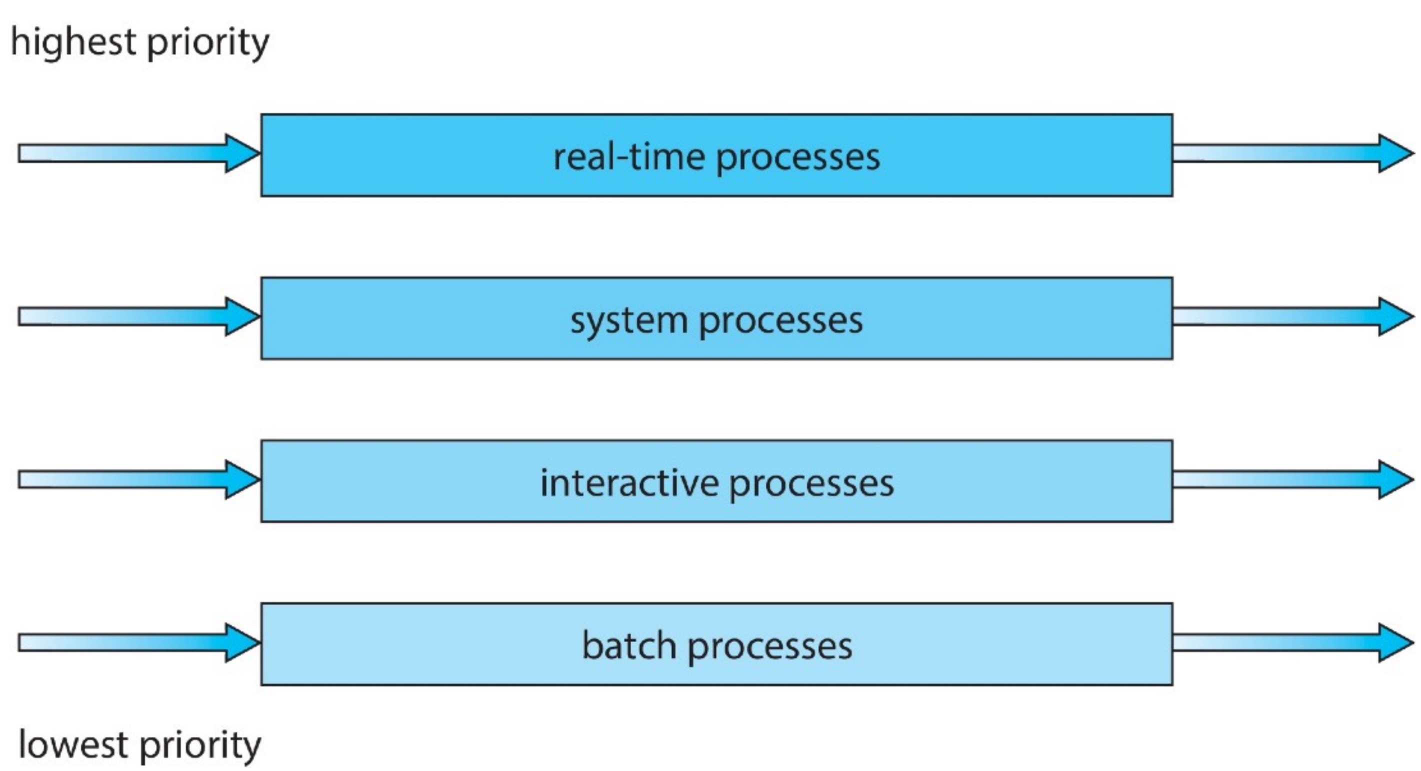
- these solutions could improve fairness but increase response time

How to lower the response time?

- high priority queues have short time slices
- low priority queues have longer time slices



Priority inversion

- where a high priority task is blocked waiting on a low priority task
- the low priority task must run for the high priority task to make progress
- solution: a high priority task temporarily grants a lower priority task its “highest priority” to run on its behalf and release the lock
  - the high priority task then acquires the lock and runs again

MFQ scheduling

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  - use Round Robin scheduling at each priority level, running the jobs in highest priority queue first
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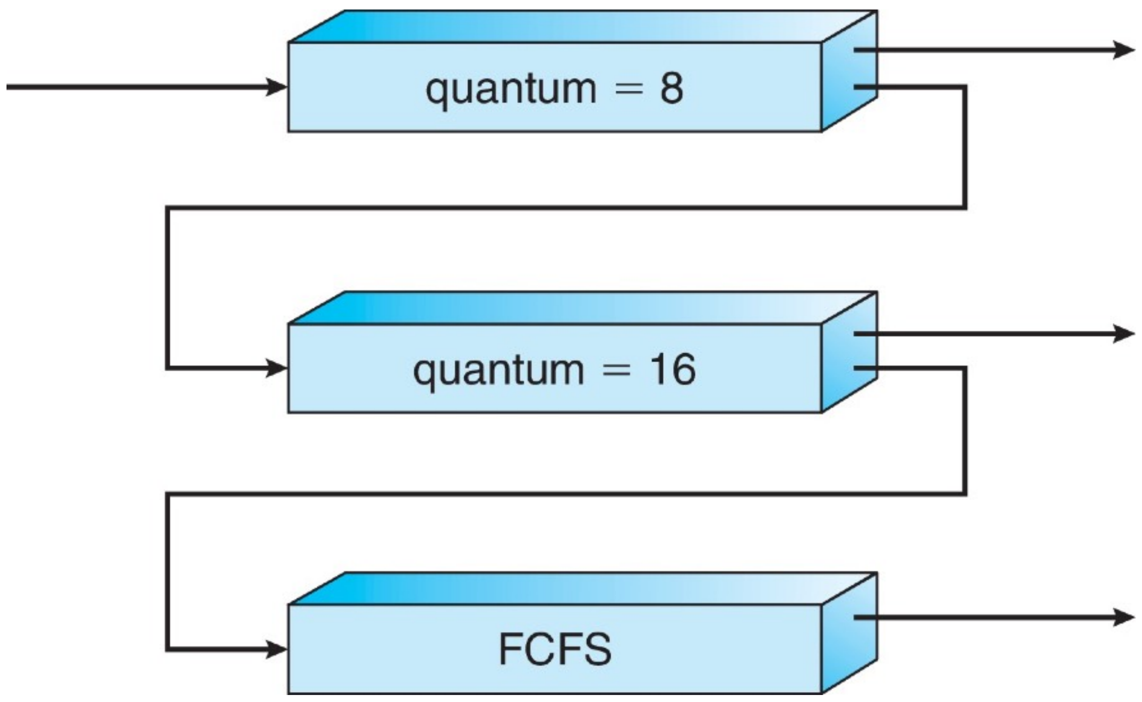

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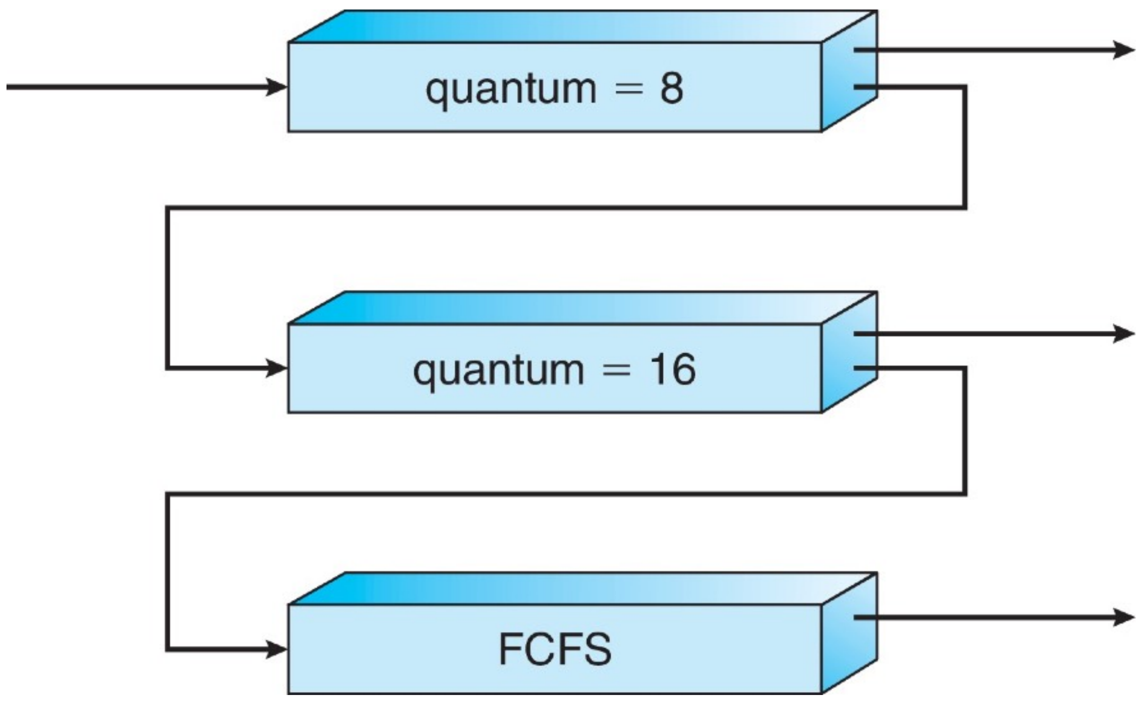
- round robin time slice increases exponentially at lower priorities



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- CPU bound jobs drop in priority and I/O bound jobs stay at a high priority
- by manipulating the assignment of tasks to priority queues, a MFQ scheduler can achieve a balance between responsiveness, low overhead, and fairness

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- possible solutions
  - give each queue a fraction of the CPU time
    - this solution is only fair if there is an even distribution of jobs among queues
  - adjust the priority of jobs if they do not get serviced (UNIX originally did this)
    - this ad hoc solution avoids starvation but average waiting time suffers when the system is overloaded because all the jobs end up with a high priority

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- for priority inversion: donate tickets to process you are waiting on

Lottery scheduling example

short jobs receive **8 tickets**; long jobs receive **2 tickets**

#tickets	#short jobs	#long jobs	%CPU each short job gets	%CPU each long job gets
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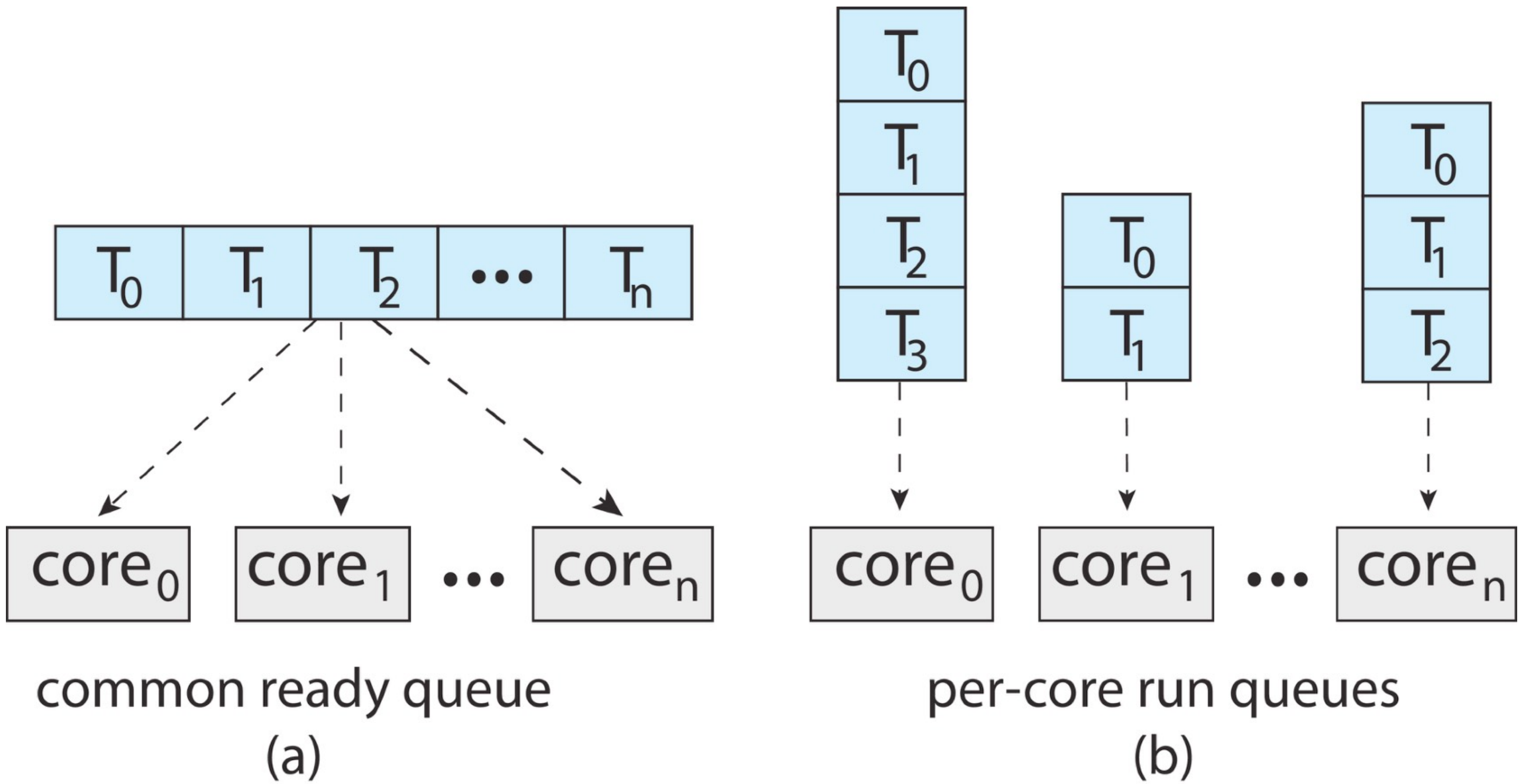
short job removed from queue	10	1	1	80	20	+80%

Scheduling on multicore systems



load balancing may be necessary

Real-time systems

- a real-time system is a system in which task completion by deadline is crucial to its performance
  - soft real-time systems
    - performance degrades if deadlines cannot be met (event latency > time budget)
    - the scheduler is best effort (no guarantee)
  - hard real-time systems
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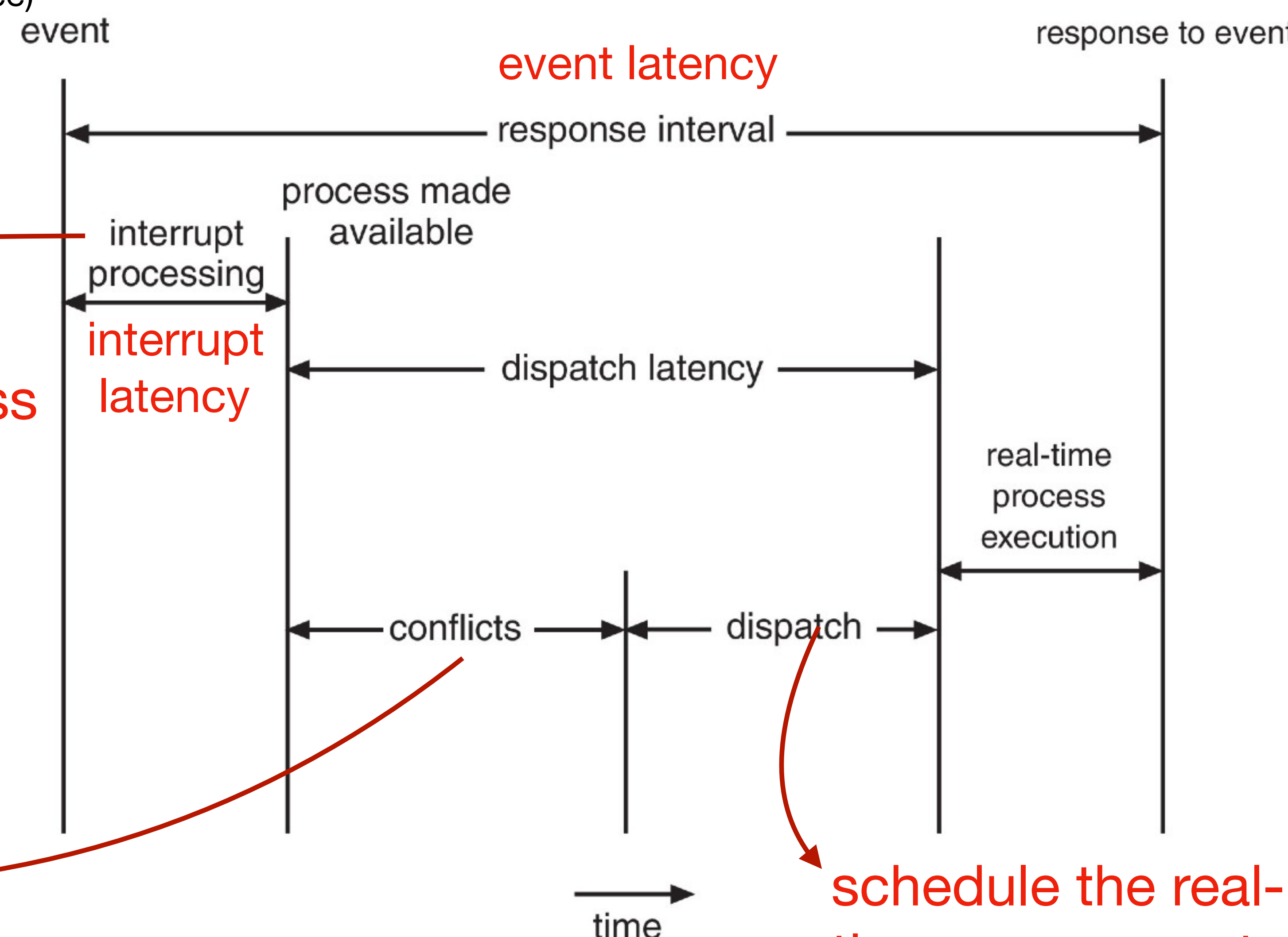


1. saving the state of the current process
2. determining the interrupt type
3. calling the corresponding ISR

1. preemption of any process running on the CPU
2. freeing up resources

schedule the real-time process onto an available CPU

Real-time scheduling

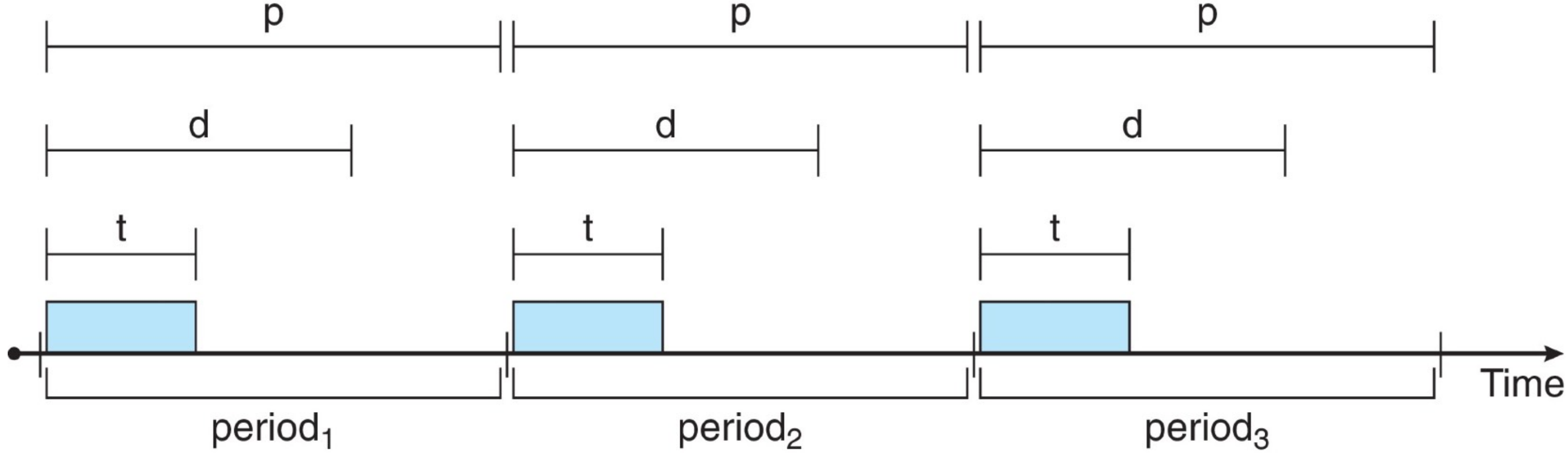
- a preemptive priority-based scheduler is often used in <u>soft real-time systems</u>
  - assigns real-time processes the highest priority
    - e.g., Windows has 32 priority levels, levels 16 to 32 are reserved for real-time processes

Real-time scheduling

- a preemptive priority-based scheduler is often used in soft real-time systems
  - assigns real-time processes the highest priority
    - e.g., Windows has 32 priority levels, levels 16 to 32 are reserved for real-time processes
- **admission control** is necessary in hard real-time systems
  - each task has to announce its deadline to the scheduler when becomes runnable
  - the scheduler admits the task if it can guarantee that it will finish execution by the deadline
  - the scheduler rejects the task if it cannot guarantee that

Assumption: periodic tasks

- a periodic task
  - requires the CPU at constant intervals (period = *p*; rate = *1/p*)
  - has a fixed deadline *d*, by which it must be serviced
  - once acquired the CPU, has a fixed processing time *t*
  - $0 \leq t \leq d \leq p$
  - $\frac{t}{p}$ is the percentage of CPU it needs



Rate-Monotonic scheduling

- a priority is assigned to each task based on the inverse of its period
  - shorter periods = higher priority;
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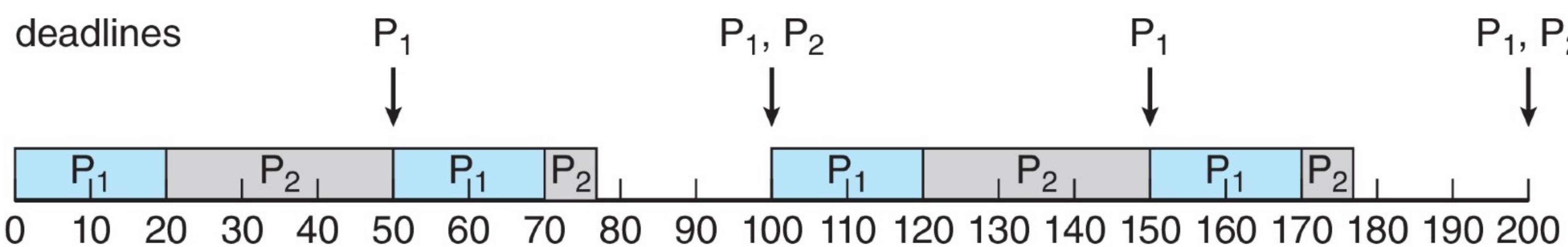

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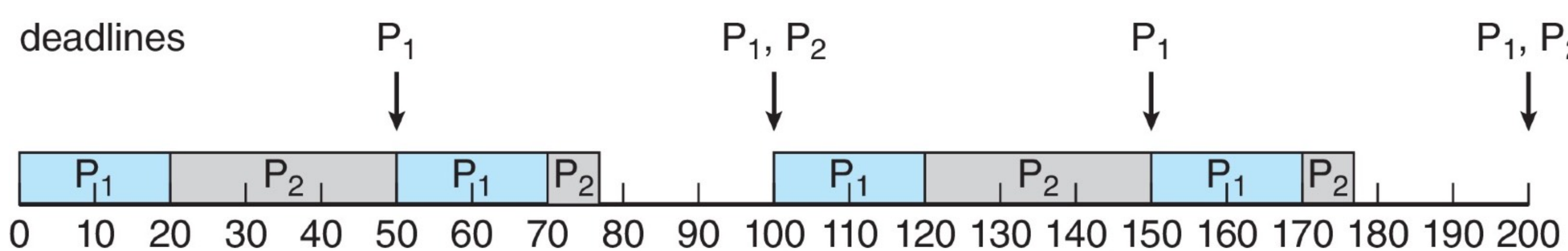
- example: consider two tasks P1 and P2
  - P1: p=50, t=20, d=50
  - P2: p=100, t=35, d=100
  - P1 is assigned a higher priority than P2



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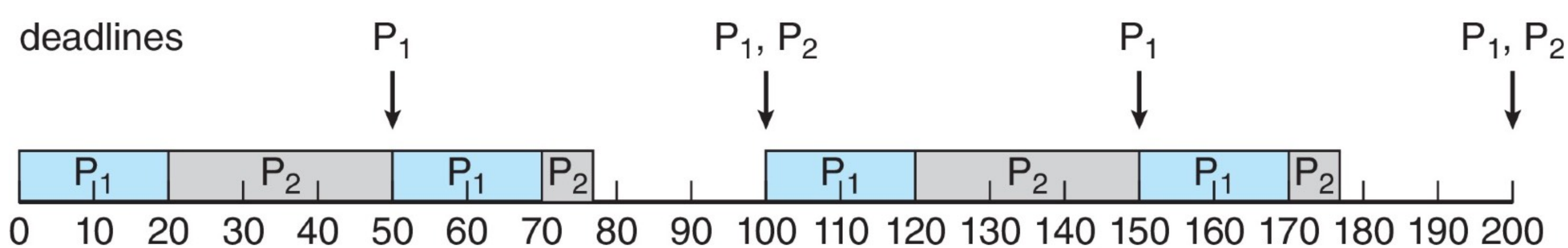
  - P1 is assigned a higher priority than P2
- admission control: reject a submitted task if $\sum_i \frac{t_i}{p_i} > 1$



Earliest-Deadline-First (EDF) scheduling

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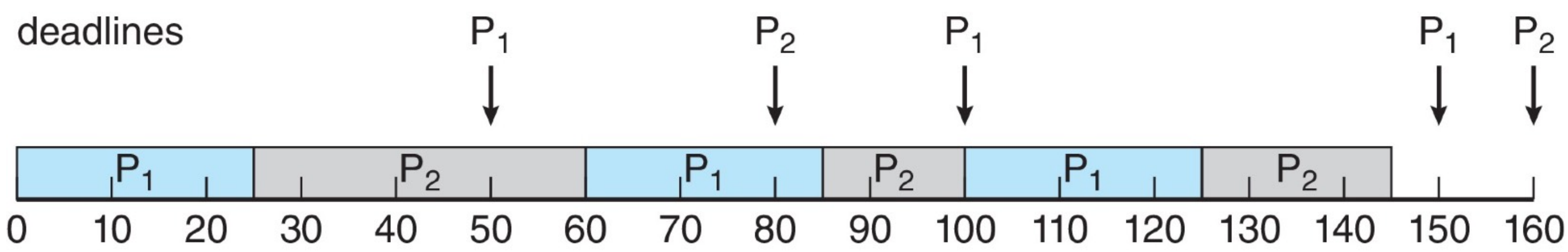
  - the earlier the deadline, the higher the priority
  - does not require tasks to be periodic!



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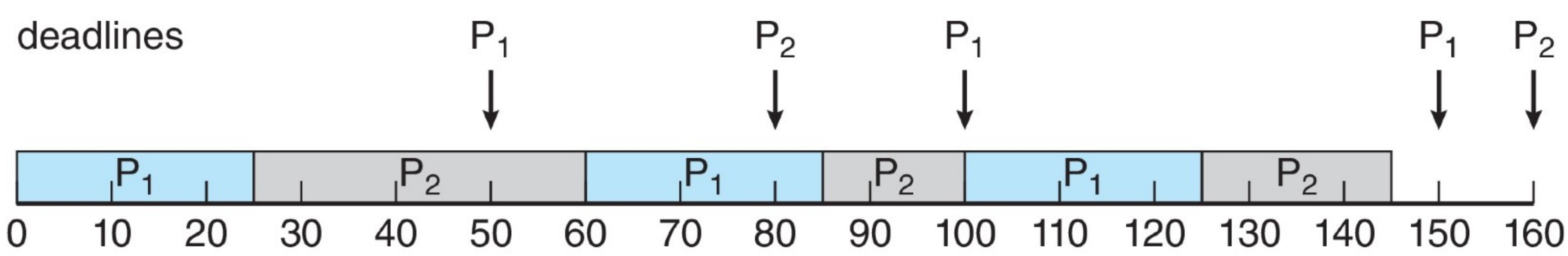
- EDF is theoretically optimal

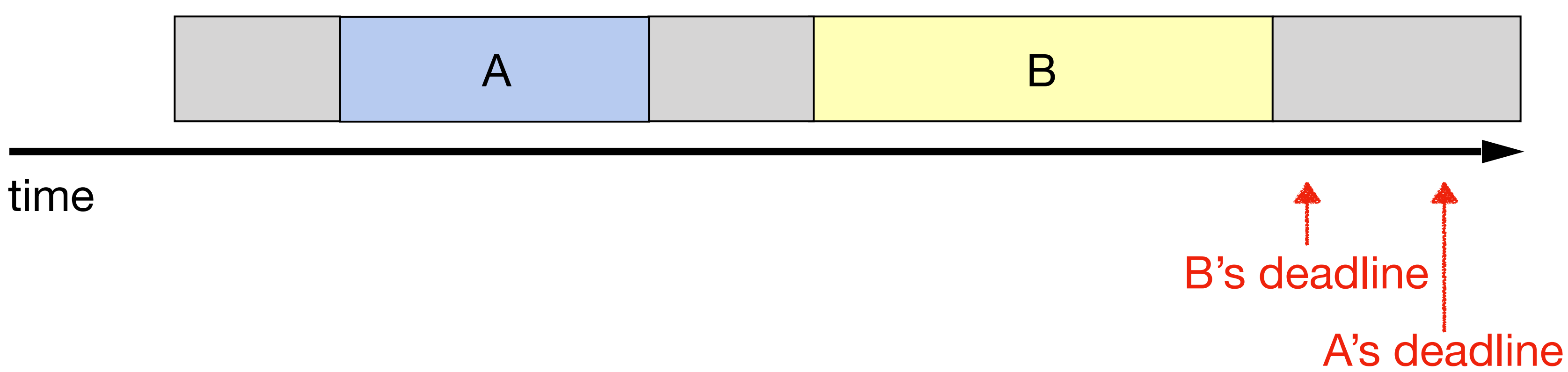


Homework

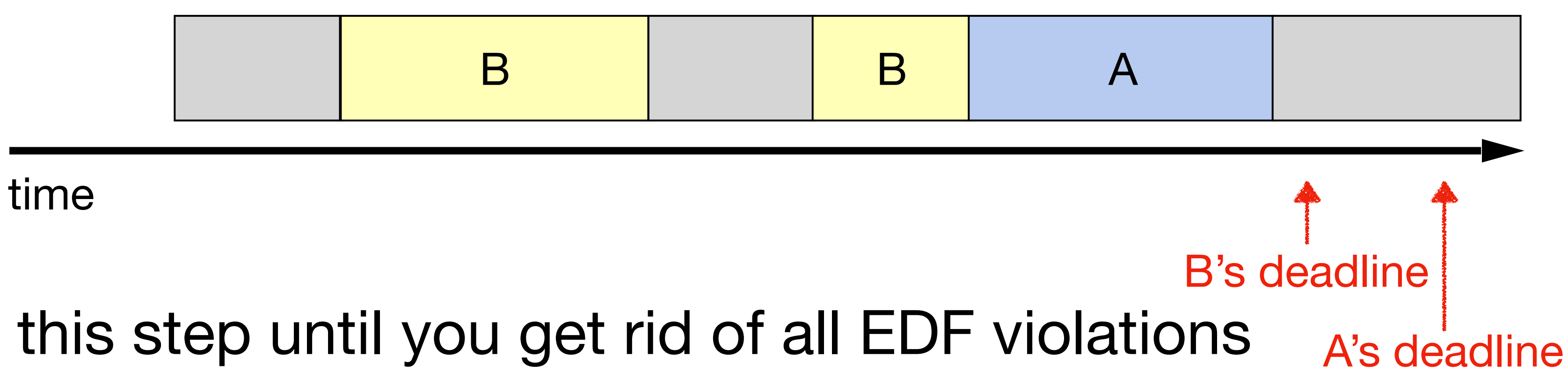
- Prove that when preemption is allowed, the EDF algorithm can produce a feasible schedule of a set S of independent tasks with arbitrary release times and deadlines on a processor if and only if S has a feasible schedule (i.e., a schedule that meets all deadlines)

Proof sketch

- we show that any feasible schedule of *S* can be transformed to an EDF schedule
- suppose the following is a feasible schedule of *S*, but A and B are scheduled in non-EDF order



- this can be transformed into another feasible schedule in EDF order



- repeat this step until you get rid of all EDF violations
- shift the schedule ahead if there is a gap between two tasks