

Lecture 4

CPU Scheduling

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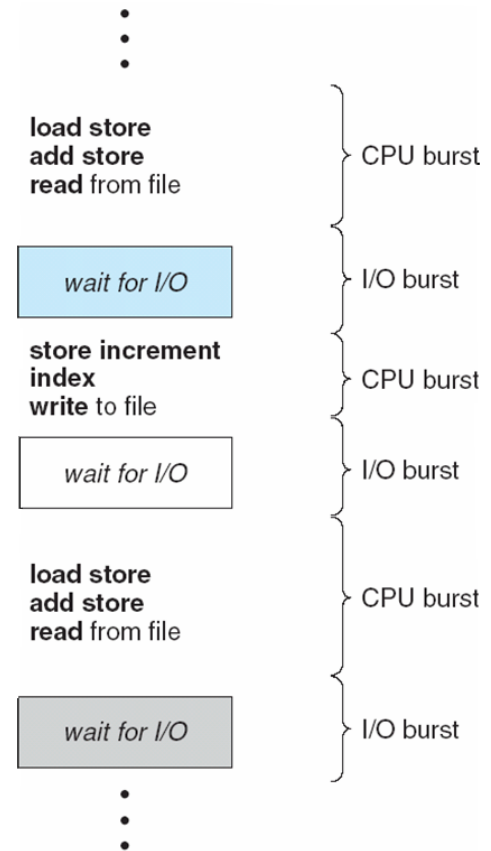
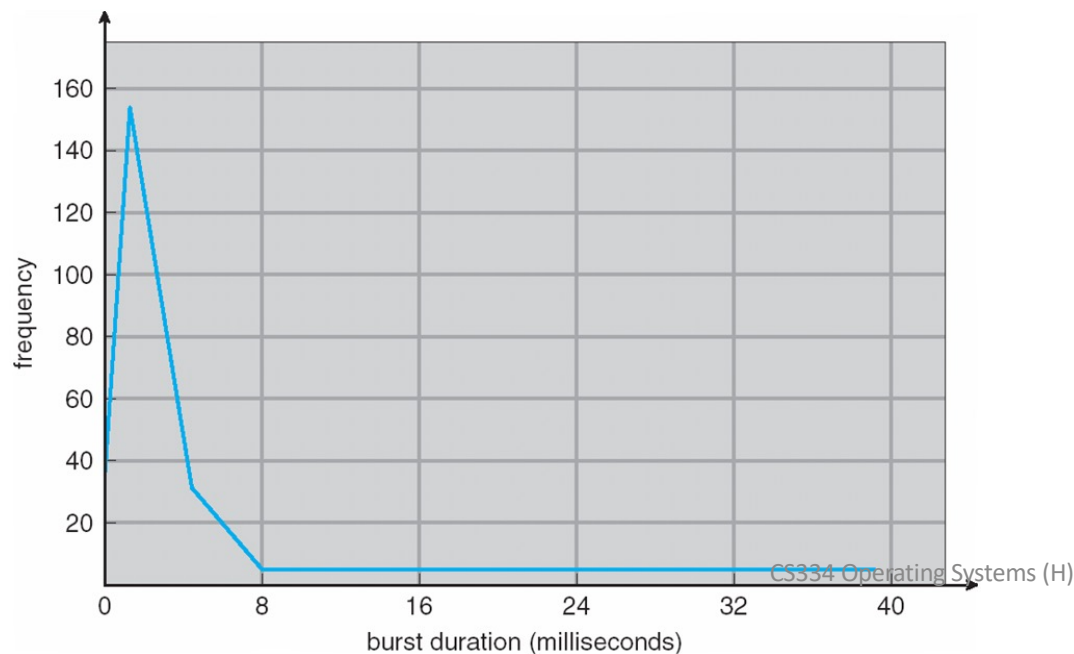
CPU Scheduling

- Scheduling is important when multiple processes wish to run on a single CPU
 - CPU scheduler decides which process to run next
- Two types of processes
 - CPU bound and I/O bound

CPU-bound Process	I/O-bound process
Spends most of its running time on the CPU, i.e., user-time > sys-time	Spends most of its running time on I/O, i.e., sys-time > user-time
<u>Examples</u> - AI course assignments.	<u>Examples</u> - /bin/l s, networking programs.

CPU Burst

- Process execution consists of a *cycle* of CPU execution and I/O wait
- **CPU burst** distribution



CPU Scheduler

- CPU scheduler selects one of the processes that are ready to execute and allocates the CPU to it
- CPU scheduling decisions may take place when a process:
 - 1. Switches from running to waiting state
 - 2. Switches from running to ready state
 - 3. Switches from waiting to ready
 - 4. Terminates
- A scheduling algorithm takes place **only** under circumstances 1 and 4 is **non-preemptive**
- All other scheduling algorithms are **preemptive**

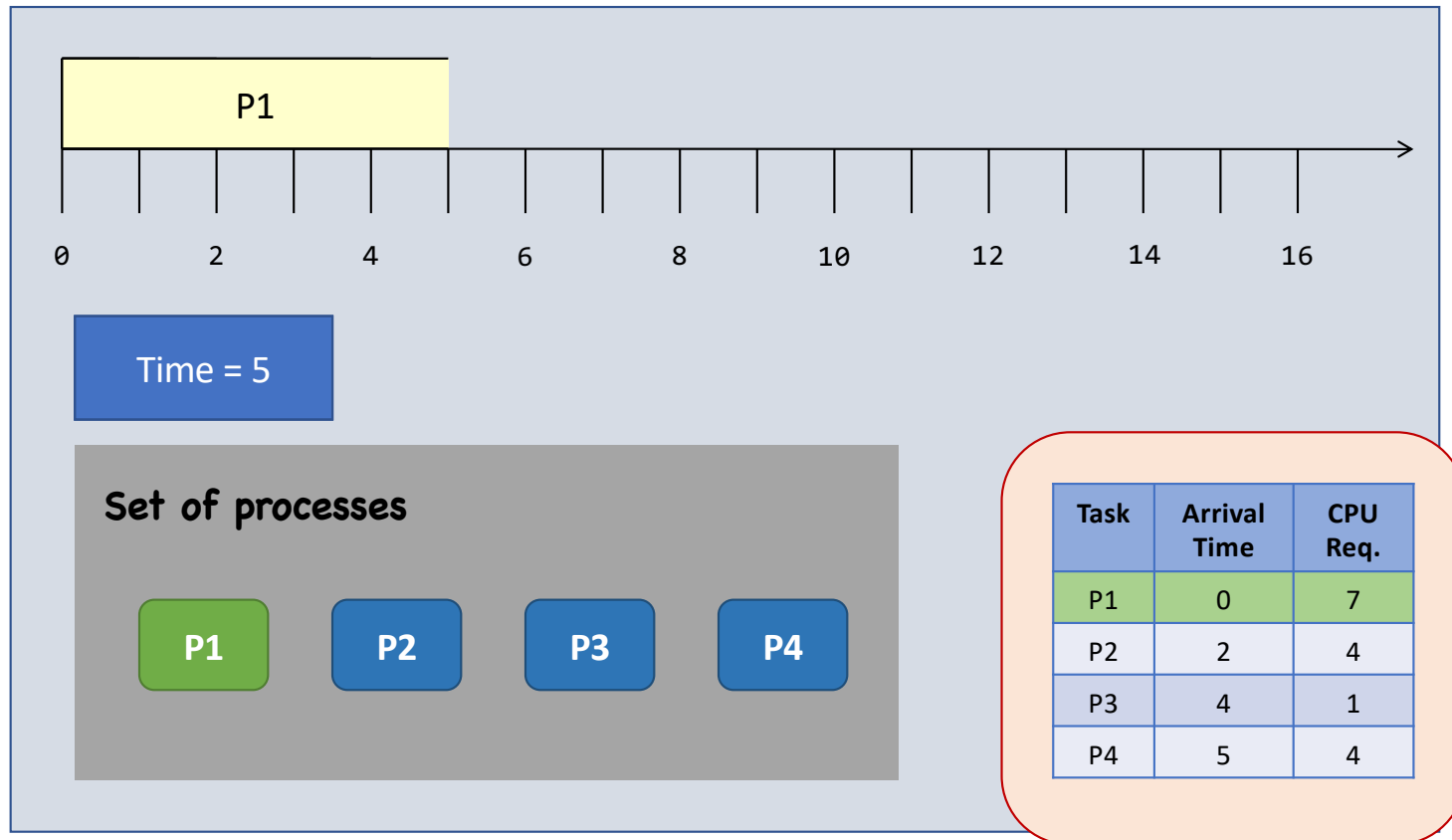
Scheduling Algorithm Optimization Criteria

- Given a set of processes, with
 - **Arrival time:** the time they arrive in the CPU ready queue (from waiting state or from new state)
 - **CPU requirement:** their expected CPU burst time
- Minimize average turnaround time
 - **Turnaround time:** The time between the arrival of the task and the time it is blocked or terminated.
- Minimize average waiting time
 - **Waiting time:** The accumulated time that a task has waited in the ready queue.
- Reduce the number of context switches

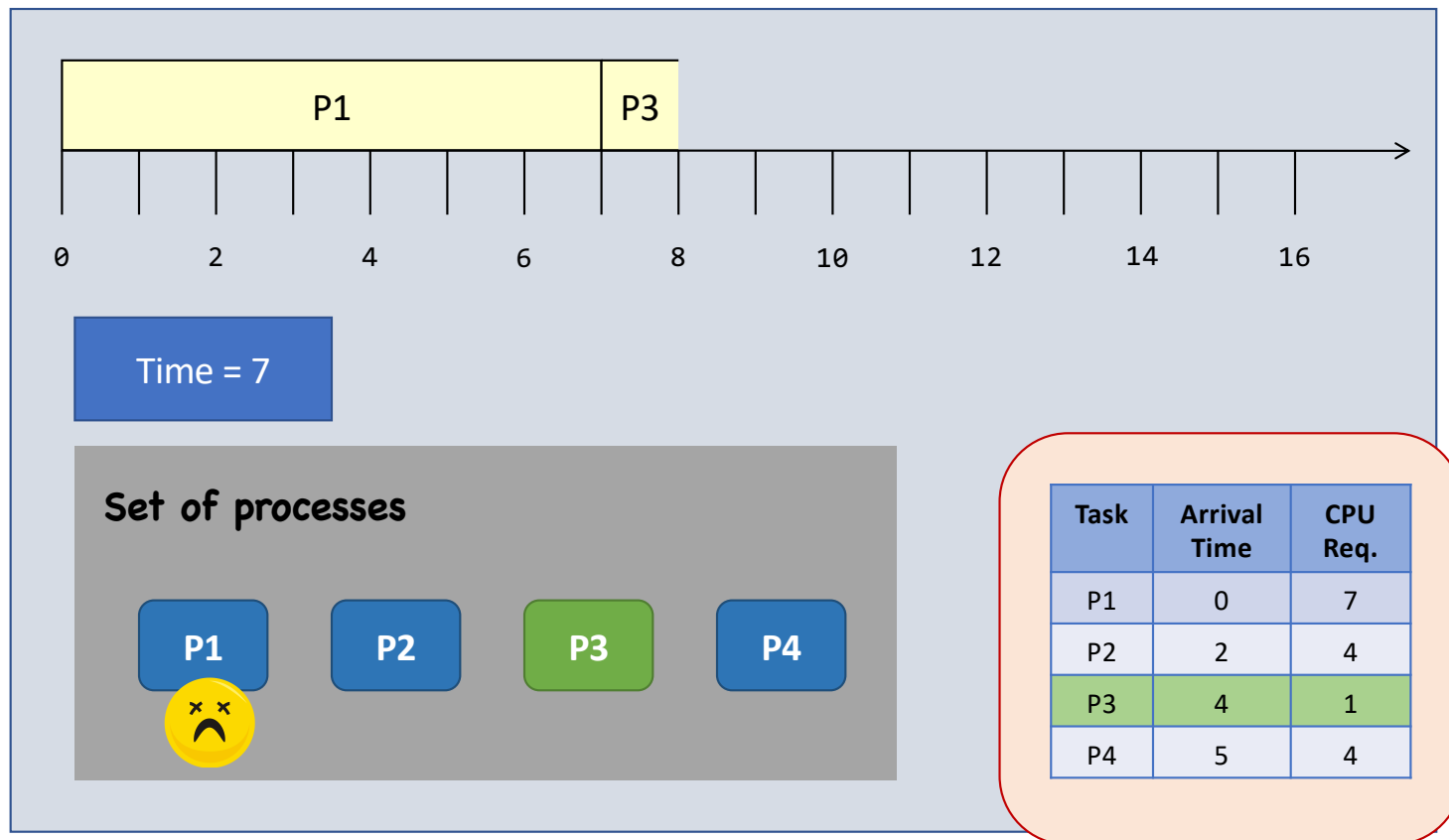
Different Algorithms

- Shortest-job-first (SJF)
- Round-robin (RR)
- Priority scheduling
- Multiple queue priority scheduler

Non-preemptive SJF

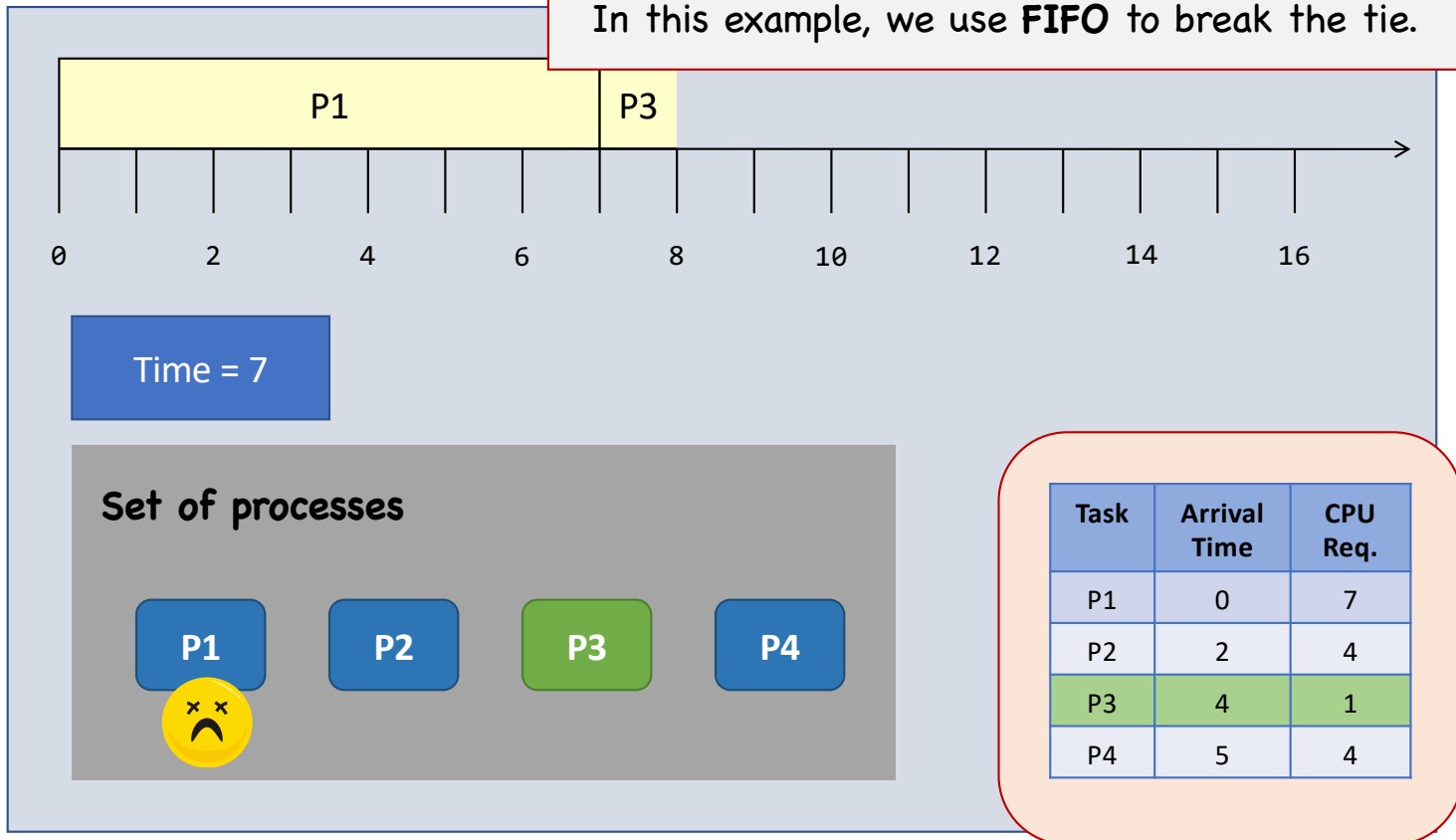


Non-preemptive SJF

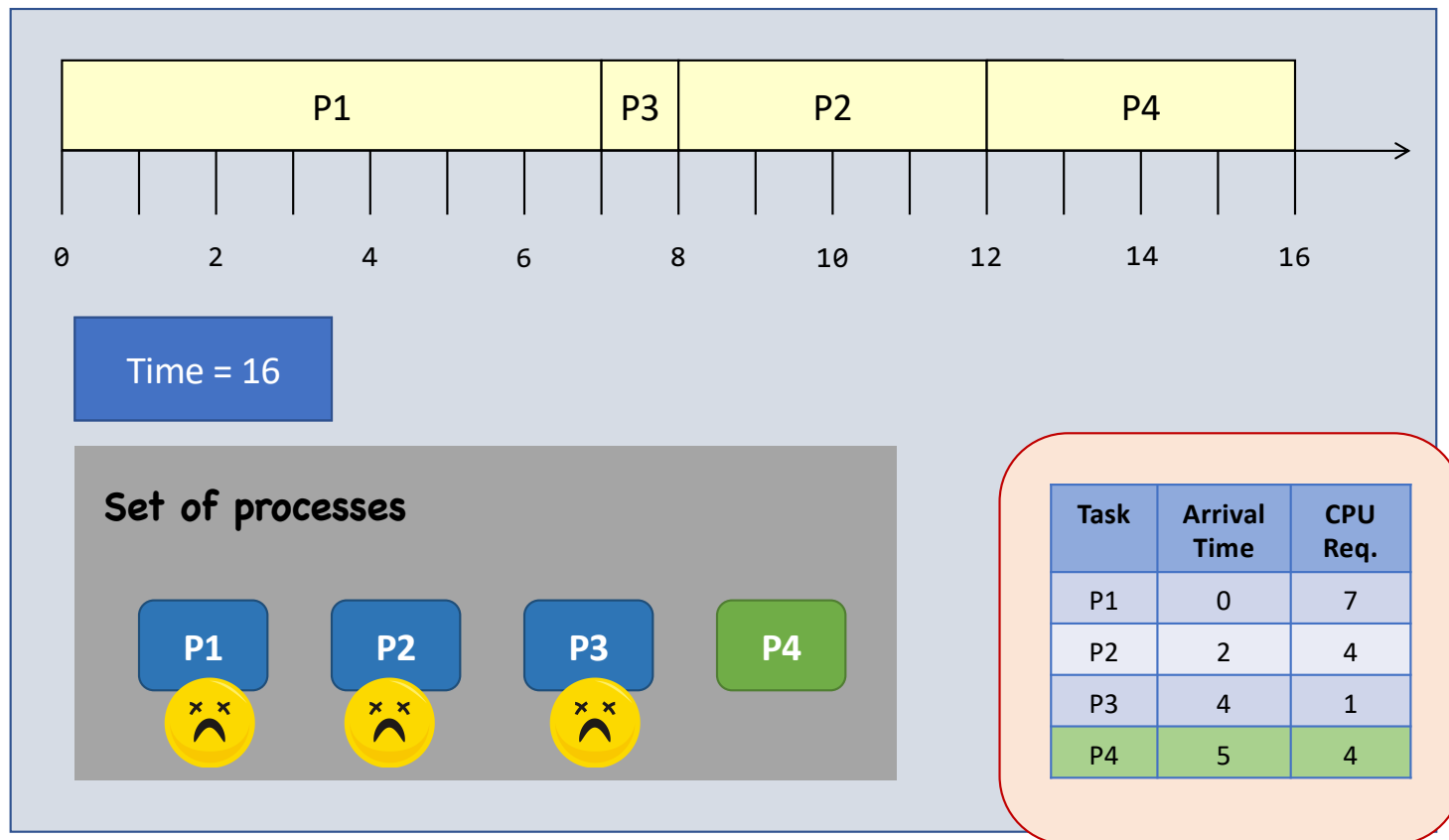


Non-preemptive SJF

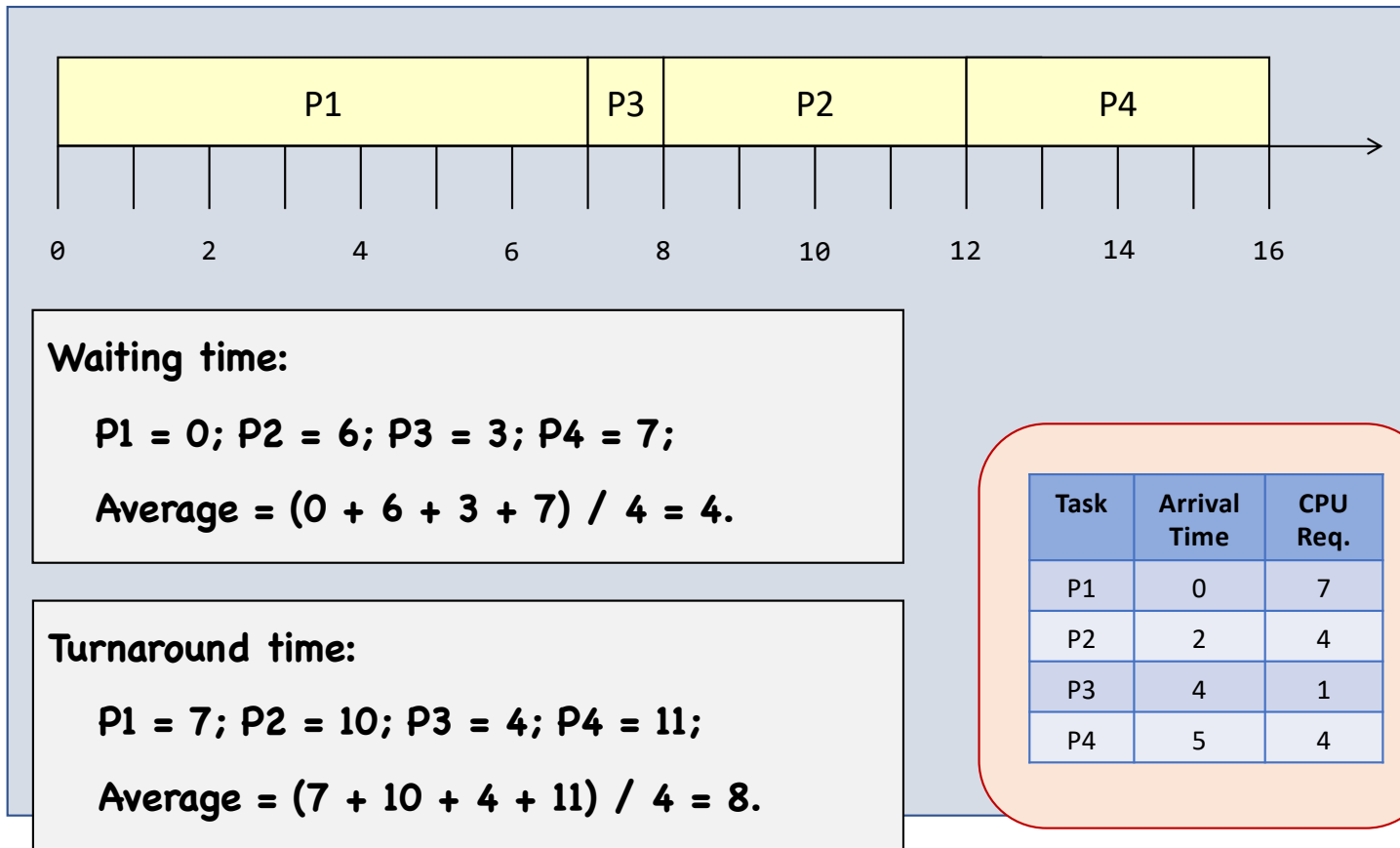
In this example, we use **FIFO** to break the tie.



Non-preemptive SJF



Non-preemptive SJF



Preemptive SJF

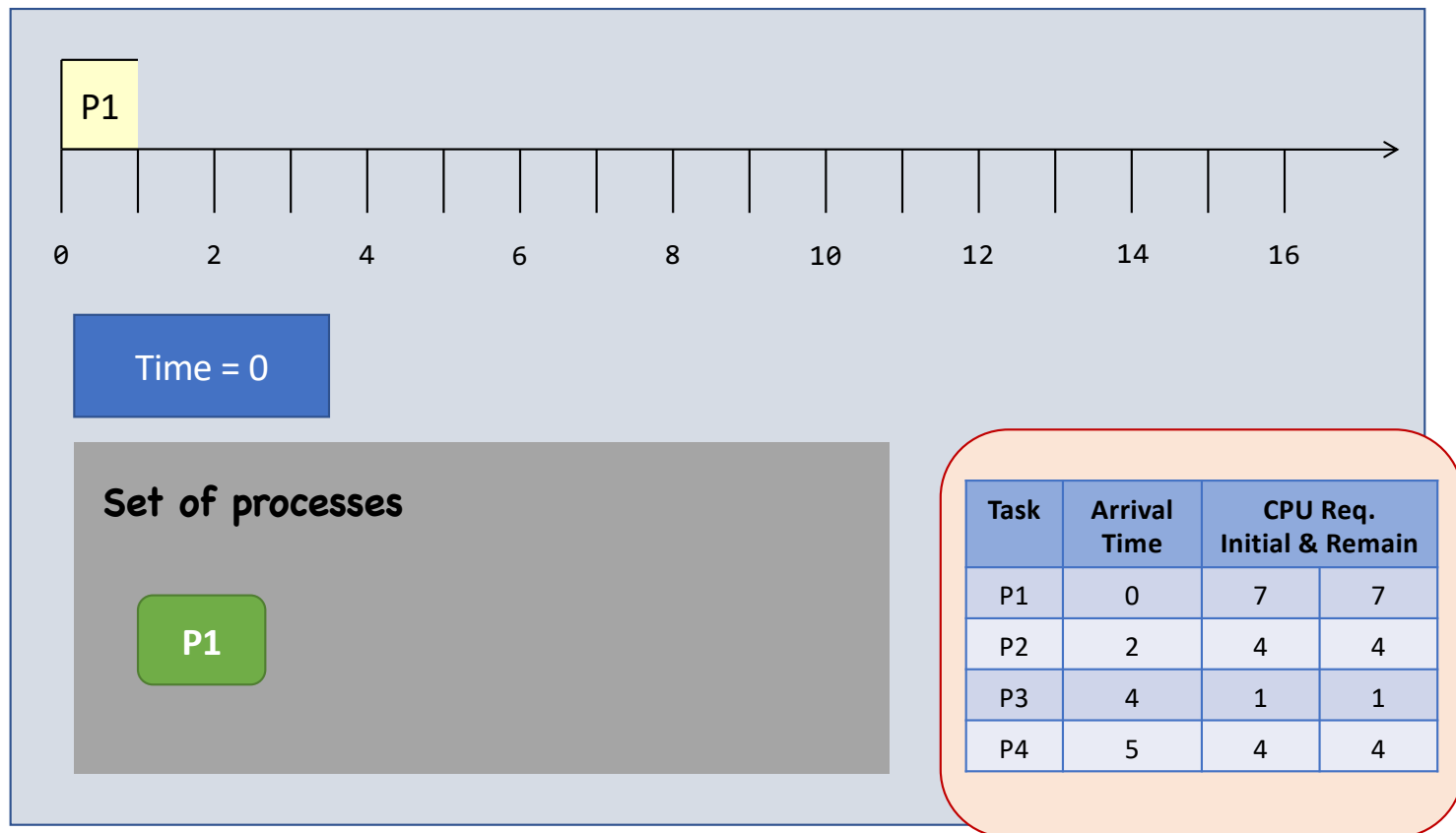


Whenever a new process arrives in the ready queue (either from waiting or from new state), the scheduler steps in and selects the next task based on **their remaining CPU requirements**.

Task	Arrival Time	CPU Req.	
		Initial	Remain
P1	0	7	7
P2	2	4	4
P3	4	1	1
P4	5	4	4

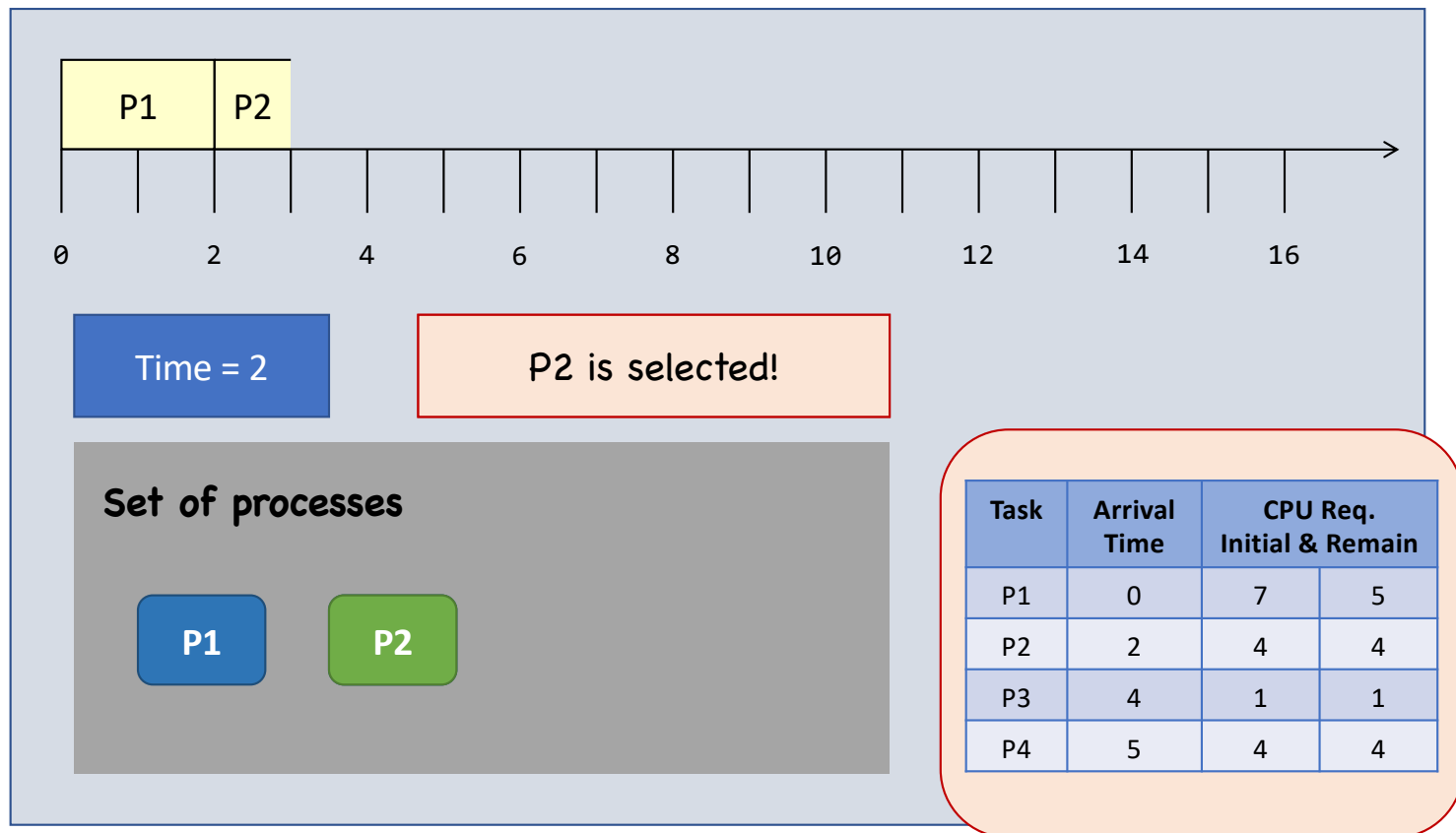
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Preemptive SJF



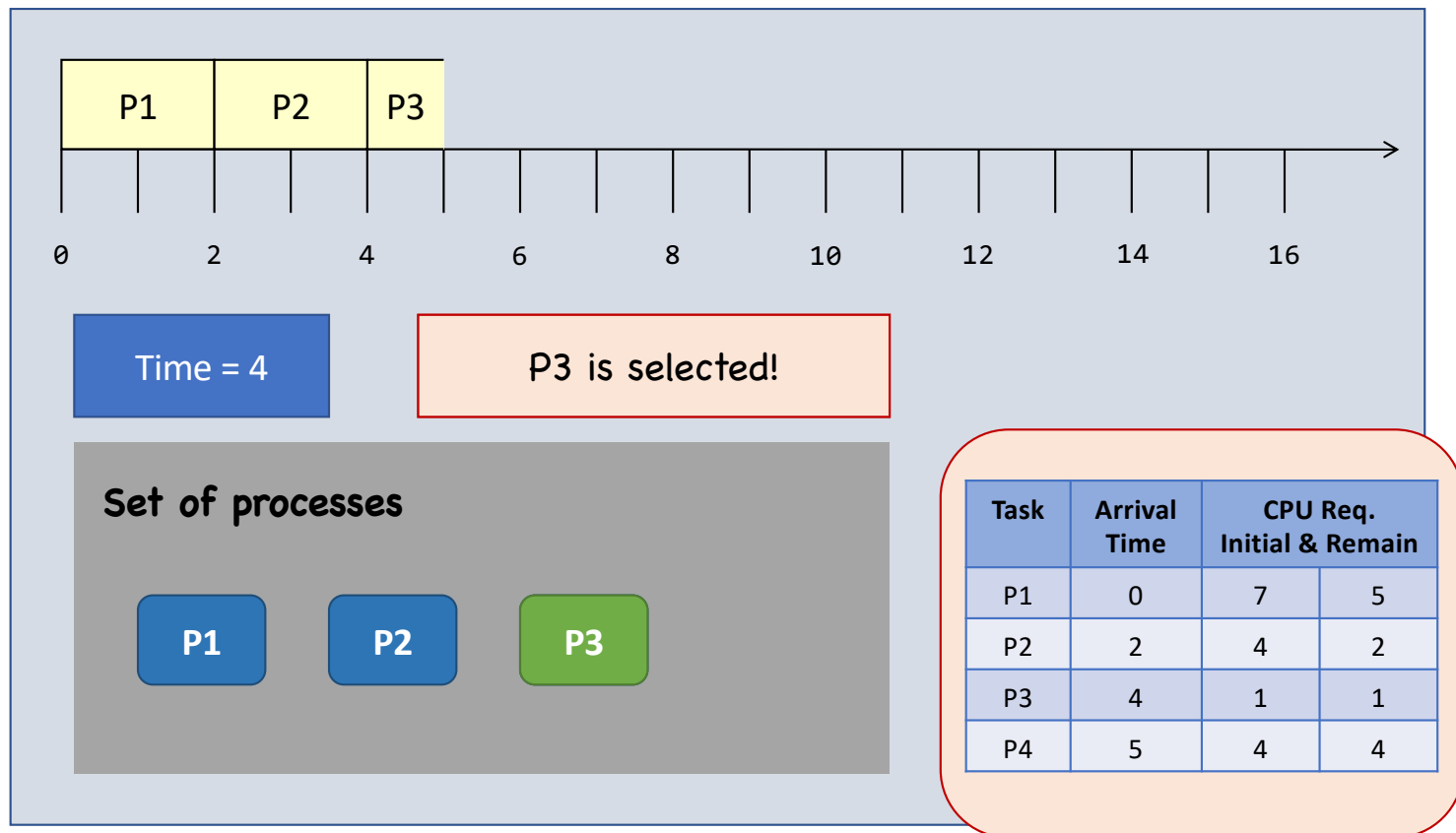
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Preemptive SJF



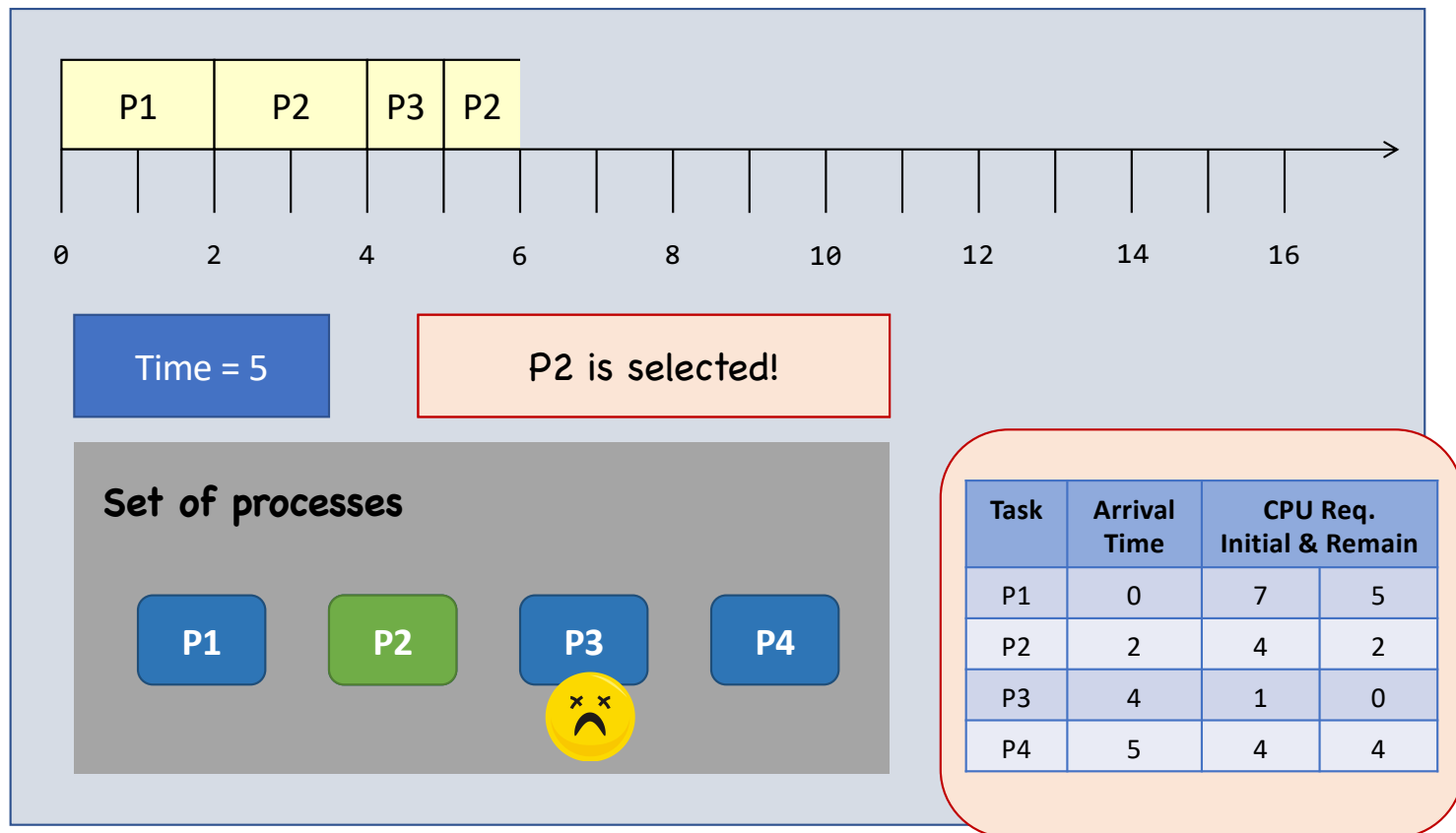
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Preemptive SJF



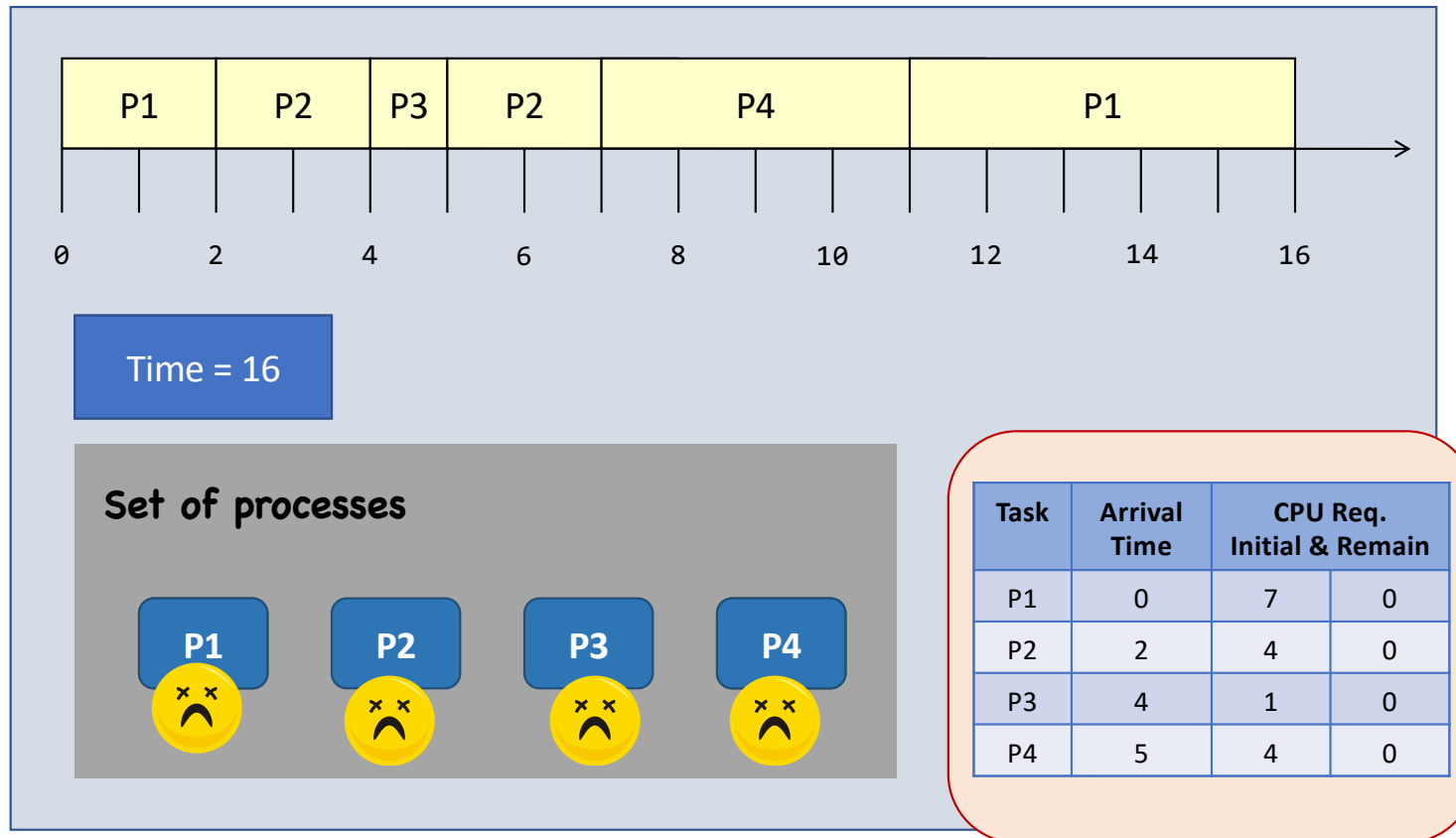
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Preemptive SJF

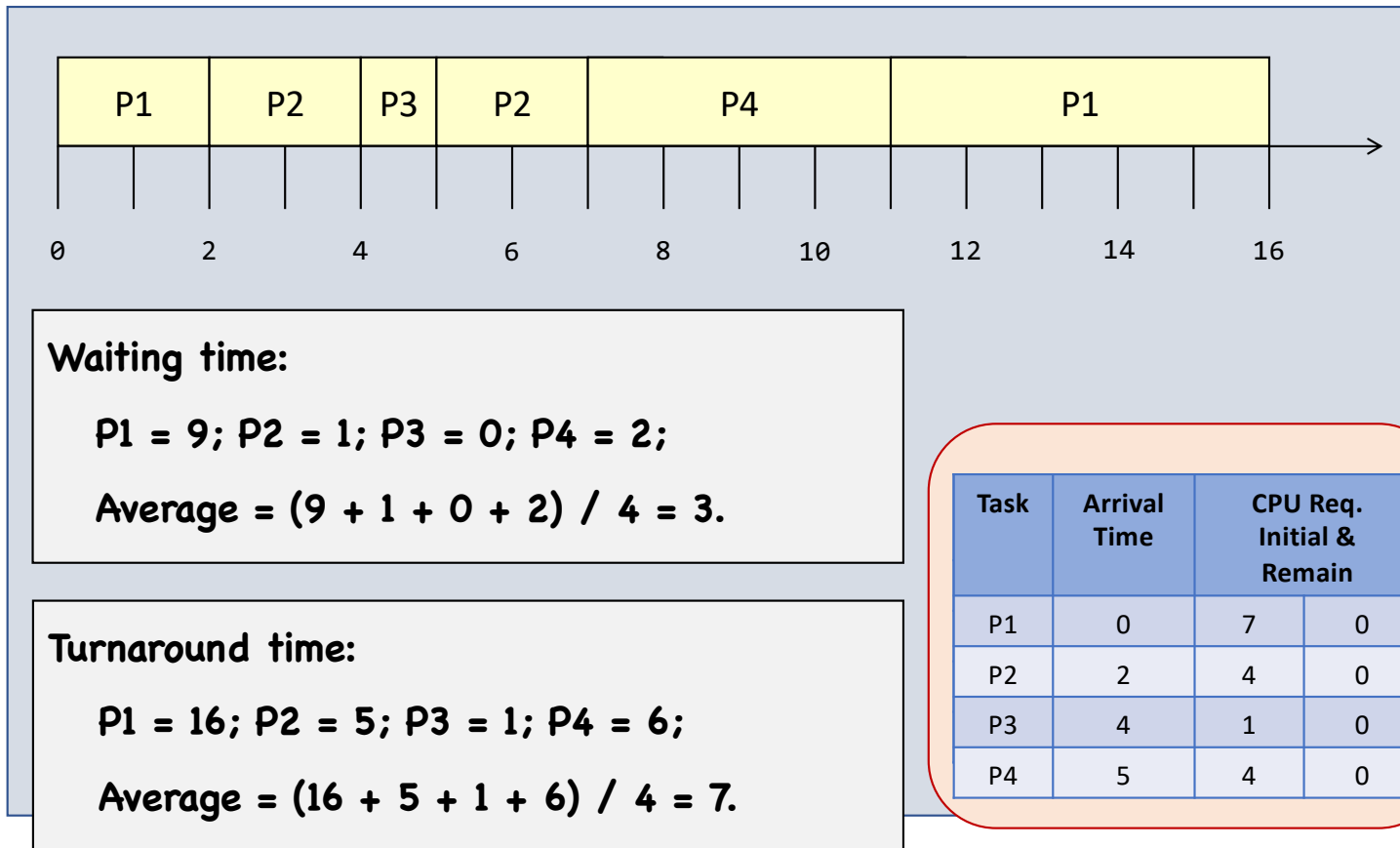


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Preemptive SJF




Preemptive SJF



SJF: Preemptive or Not?

	Non-preemptive SJF	Preemptive SJF
Average waiting time	4	3 (smallest)
Average turnaround time	8	7 (smallest)
# of context switching	3	5 (largest)

The waiting time and the turnaround time decrease at the expense of the increased number of context switches.



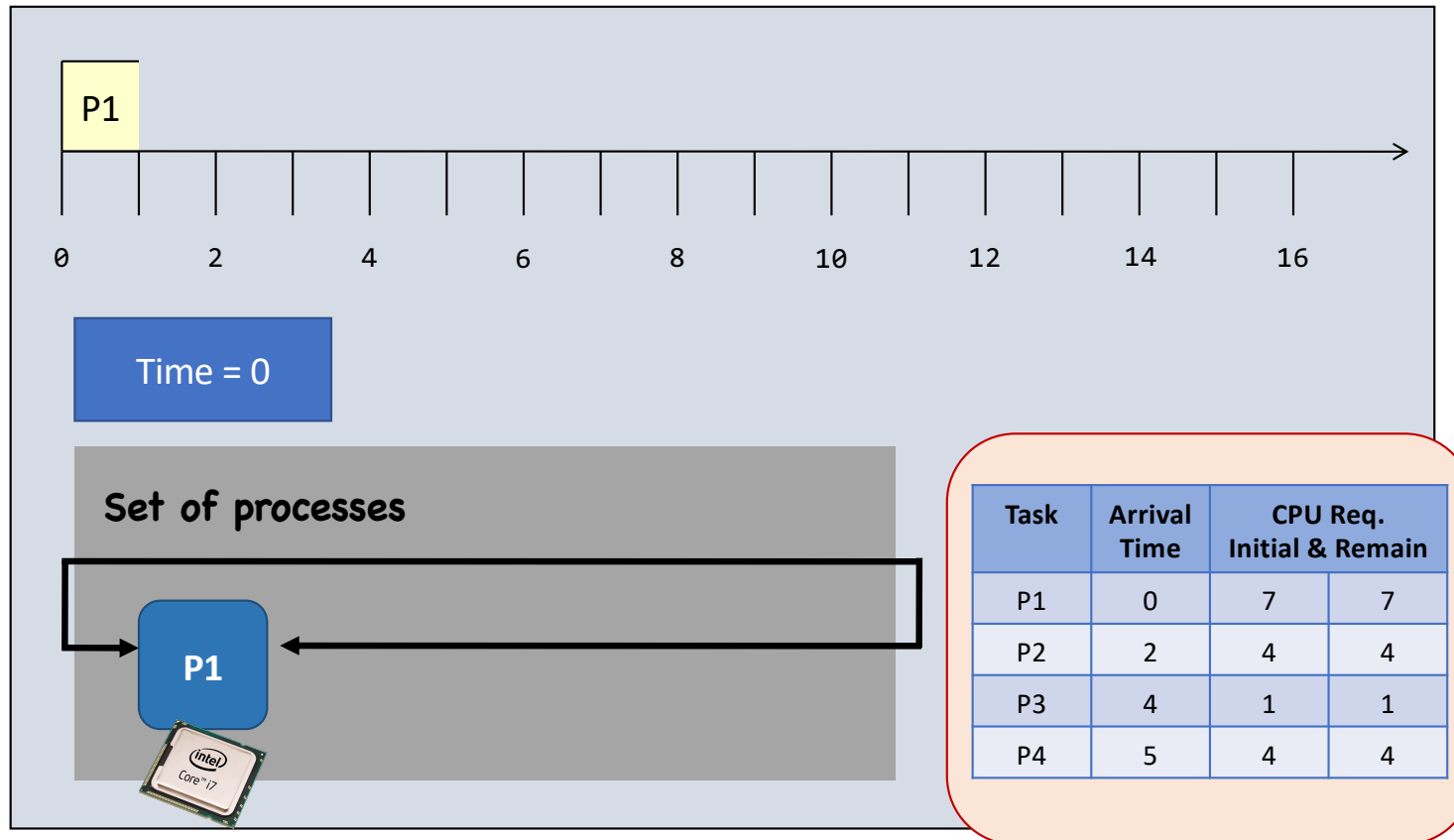
Task	Arrival Time	CPU Req.
P1	0	7
P2	2	4
P3	4	1
P4	5	4

Round Robin (RR)

- Round-Robin (RR) scheduling is preemptive.
 - Every process is given a **quantum** (the amount of time allowed to execute).
 - Whenever the quantum of a process is used up (i.e., 0), the process is preempted, placed at the end of the queue, with its quantum re-charged
 - Then, the scheduler steps in and it chooses the next process which has a non-zero quantum to run.
 - Processes are therefore running one-by-one as a circular queue
- New processes are added to the tail of the ready queue
 - New process's arrival won't trigger a new selection decision

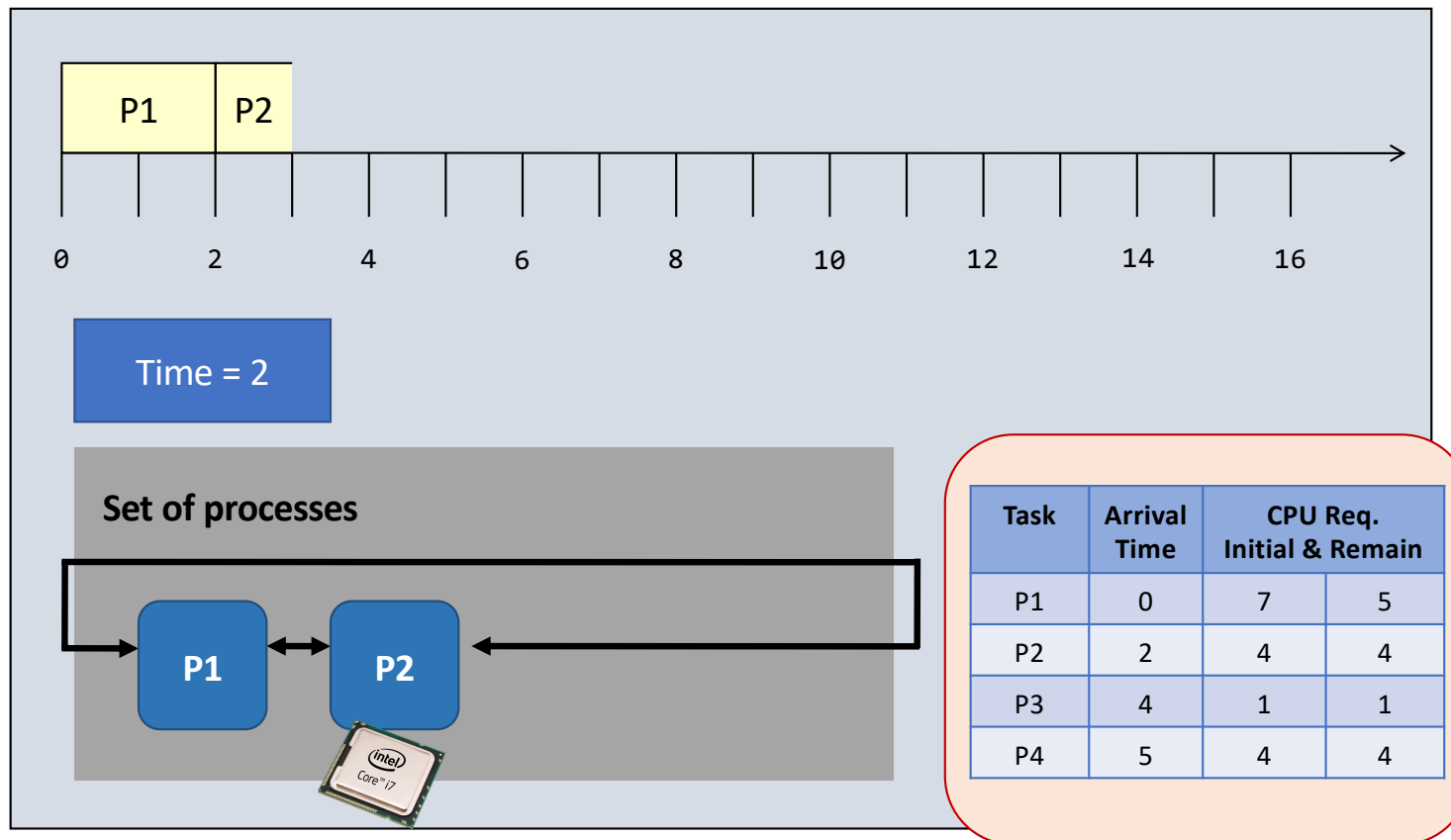
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Round Robin (Quantum = 2)



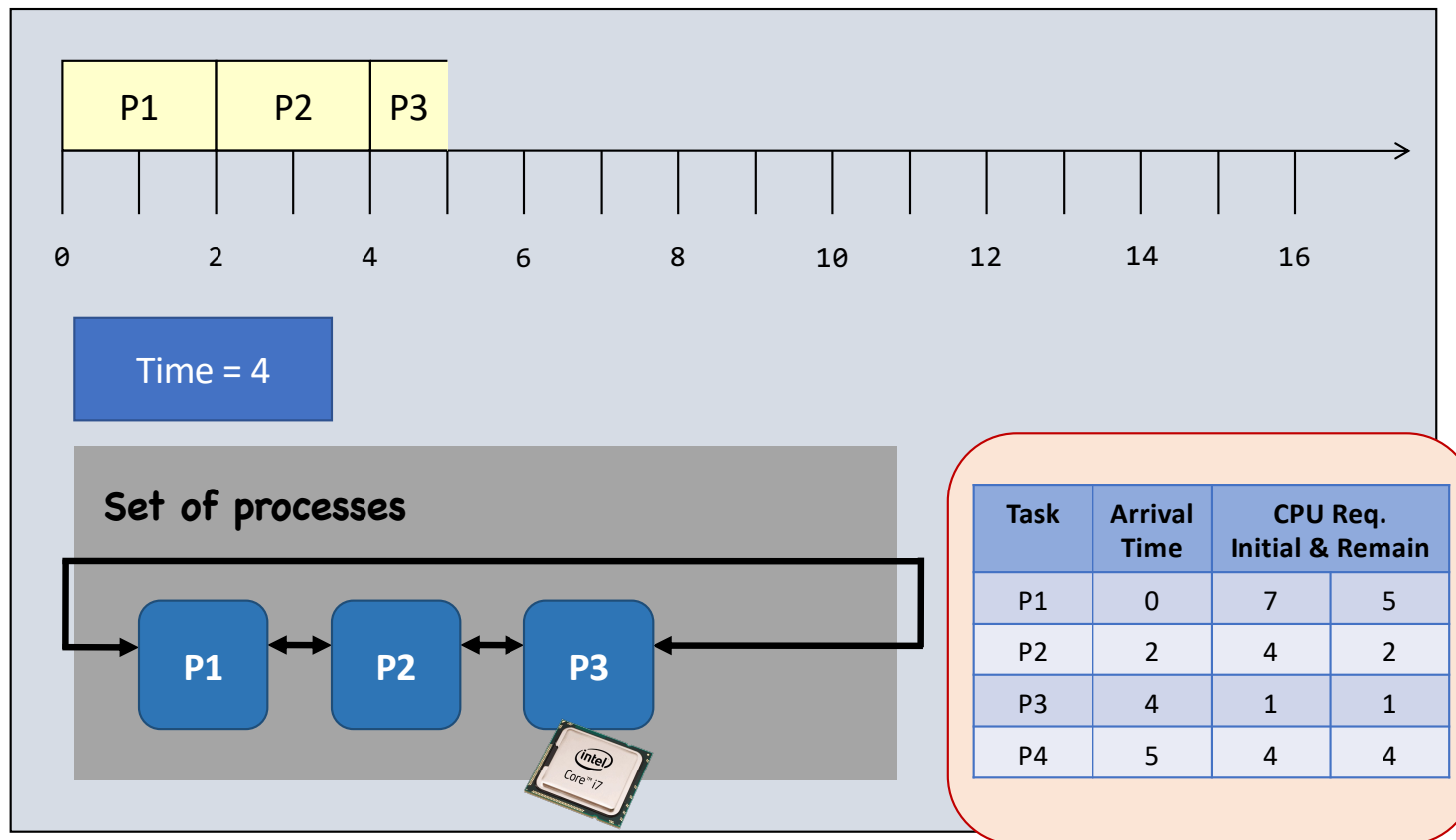
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Round Robin (Quantum = 2)



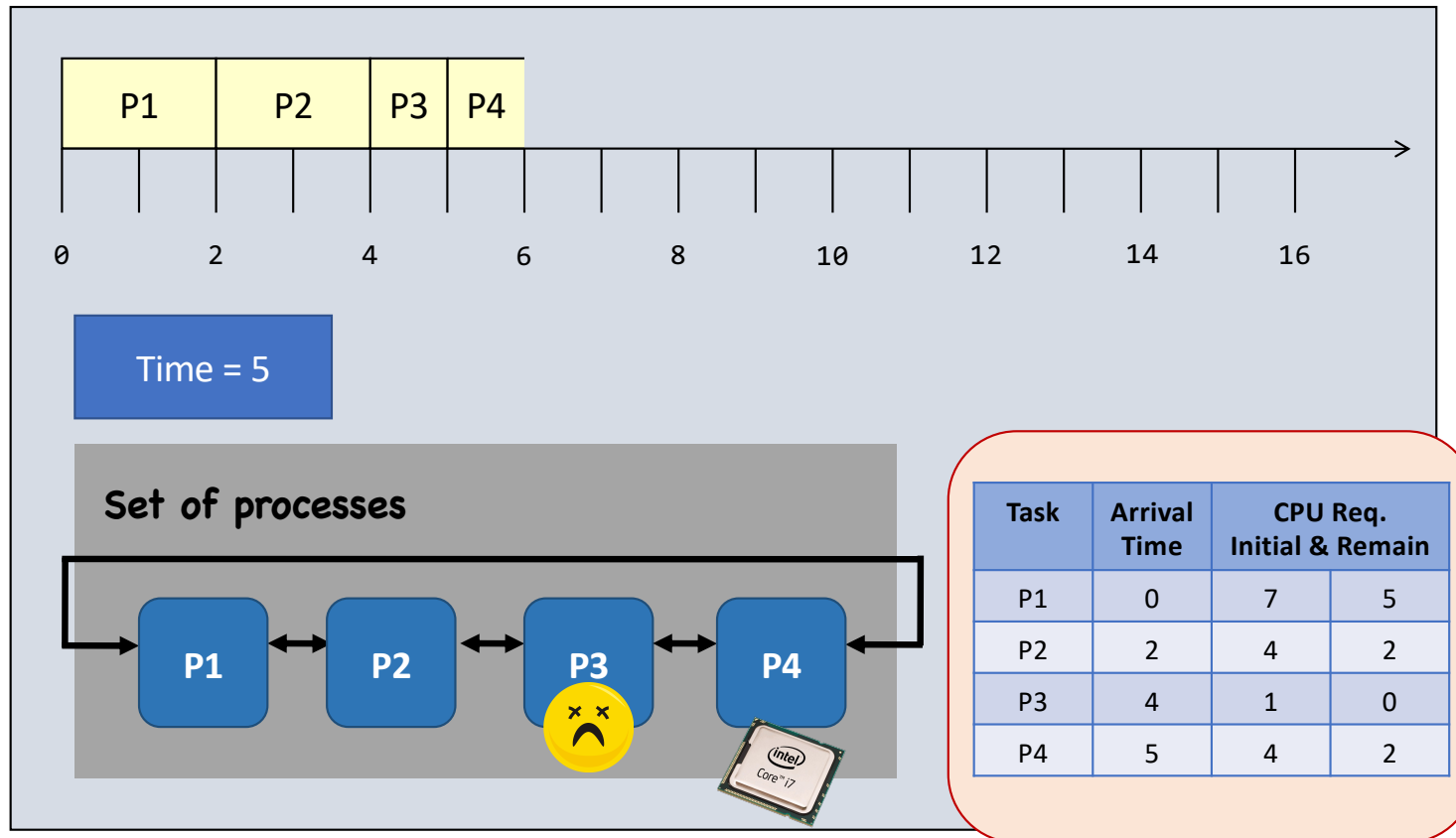
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Round Robin (Quantum = 2)



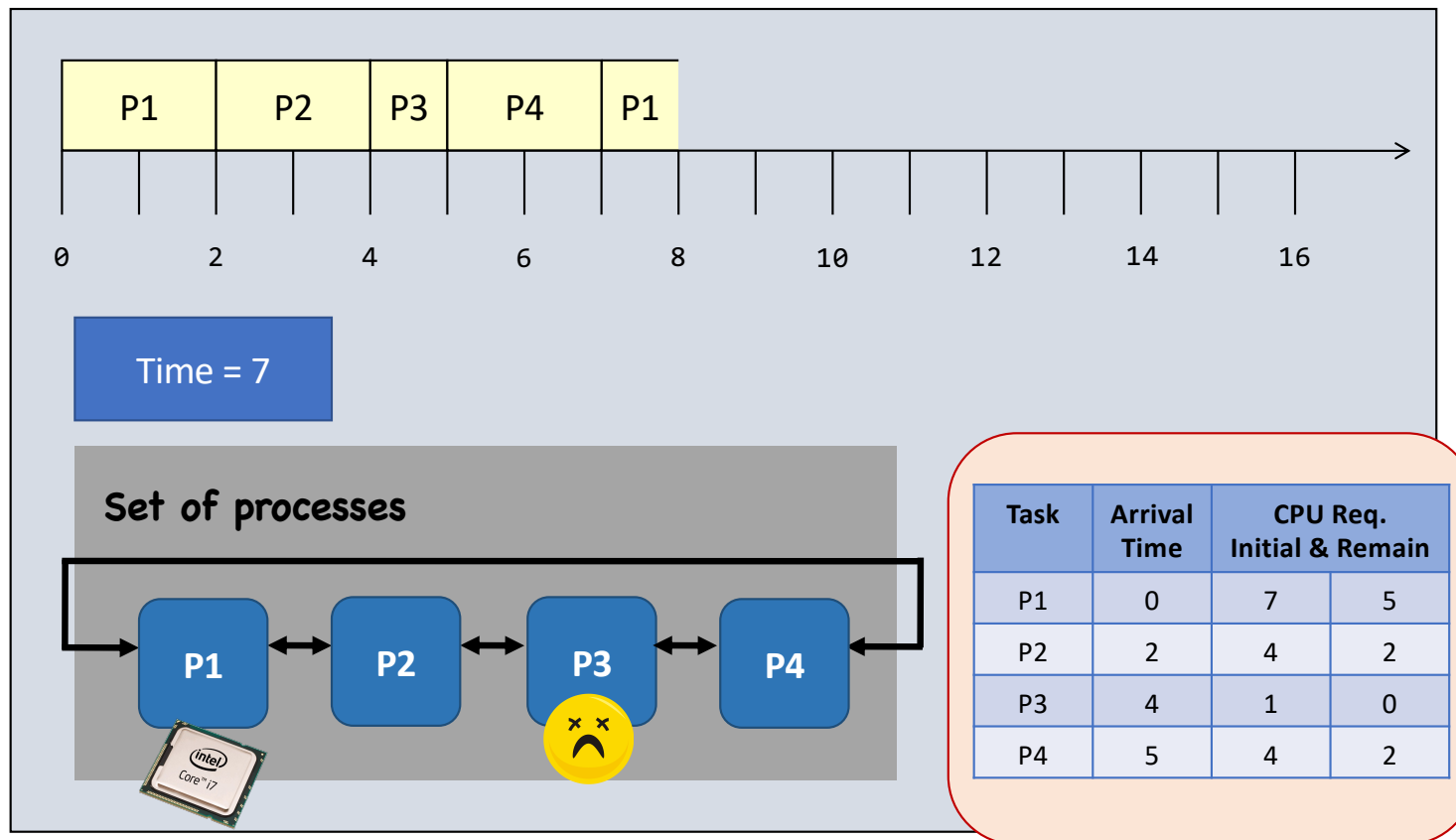
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Round Robin (Quantum = 2)



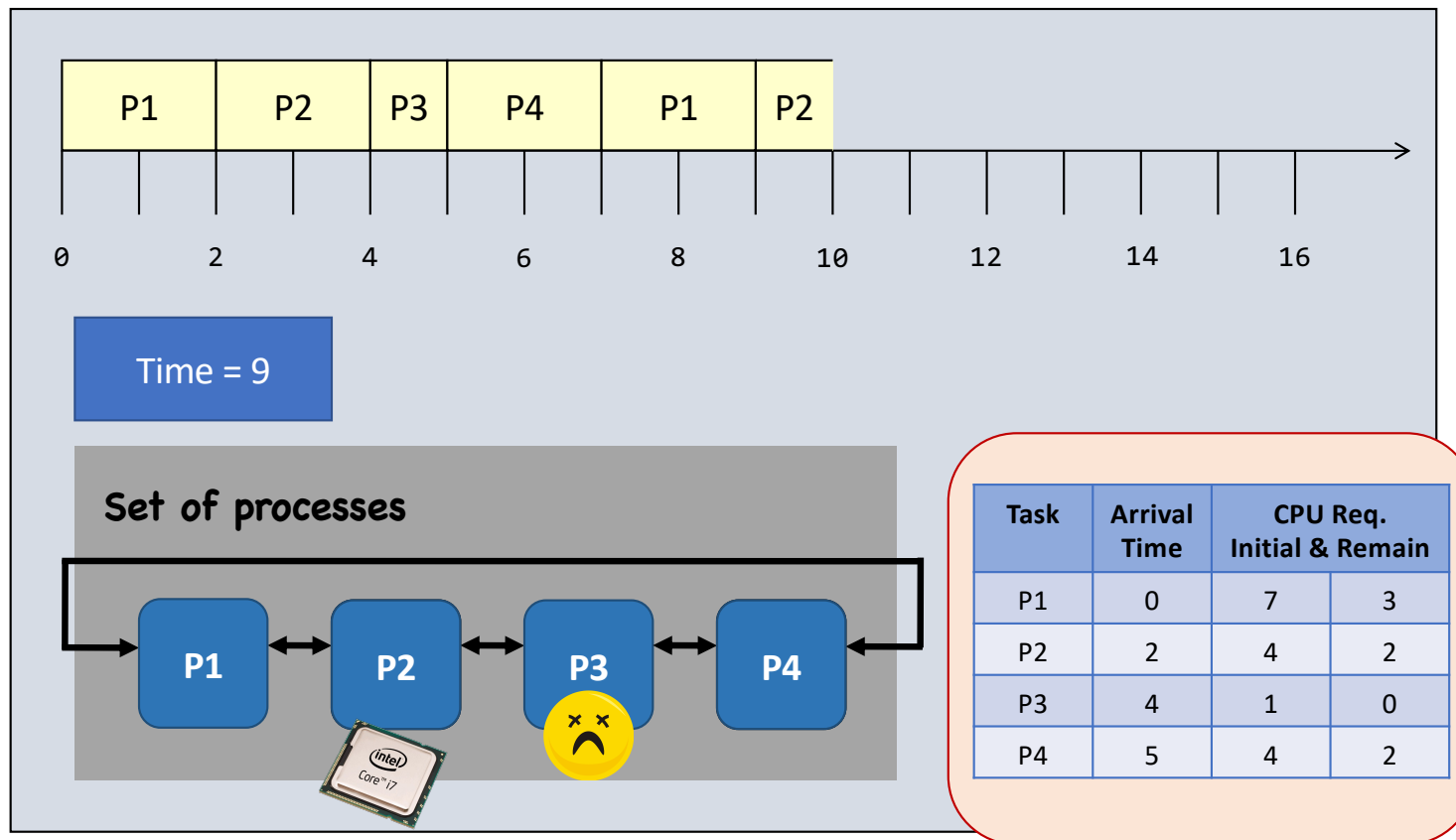
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Round Robin (Quantum = 2)



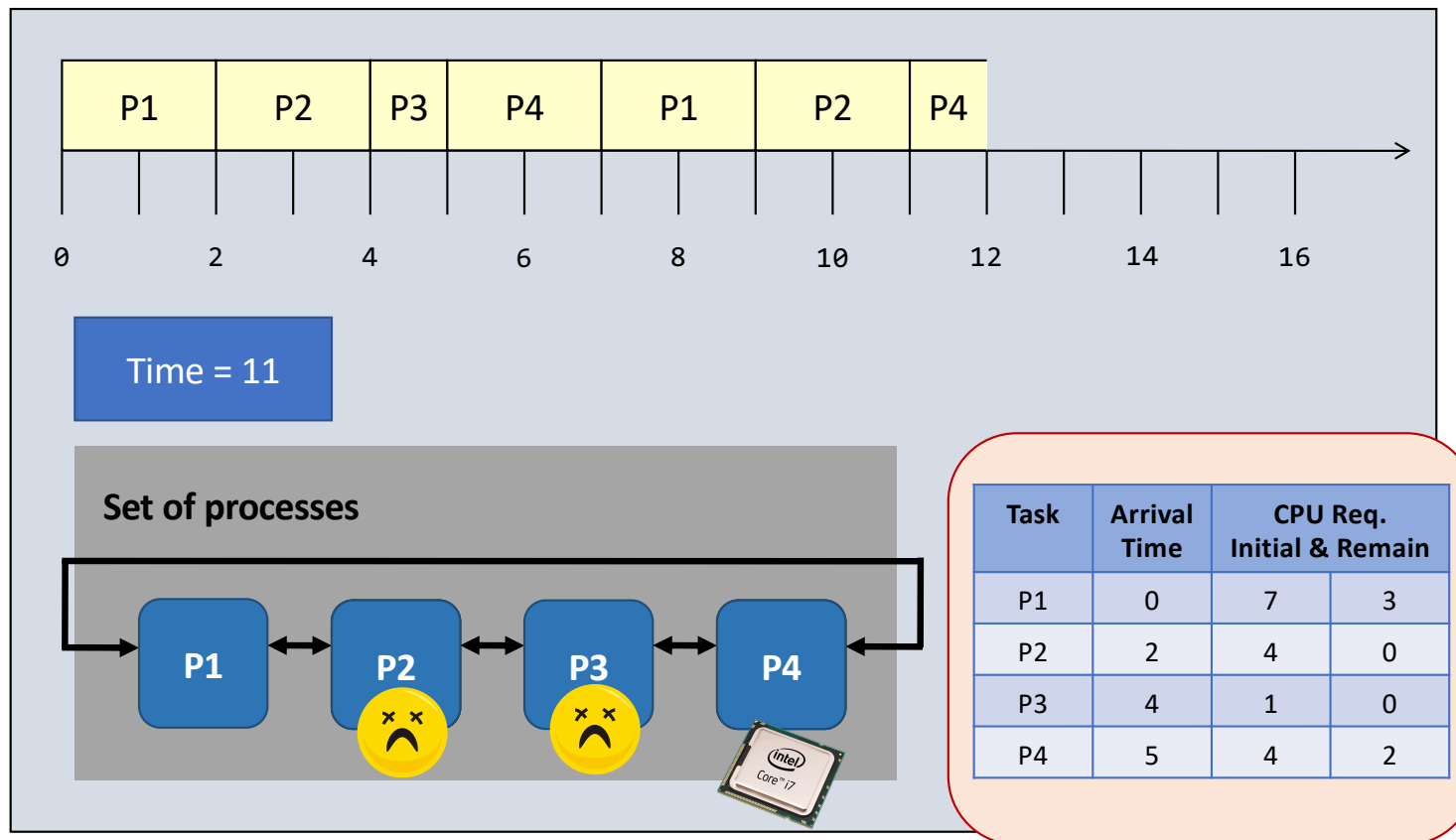
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Round Robin (Quantum = 2)



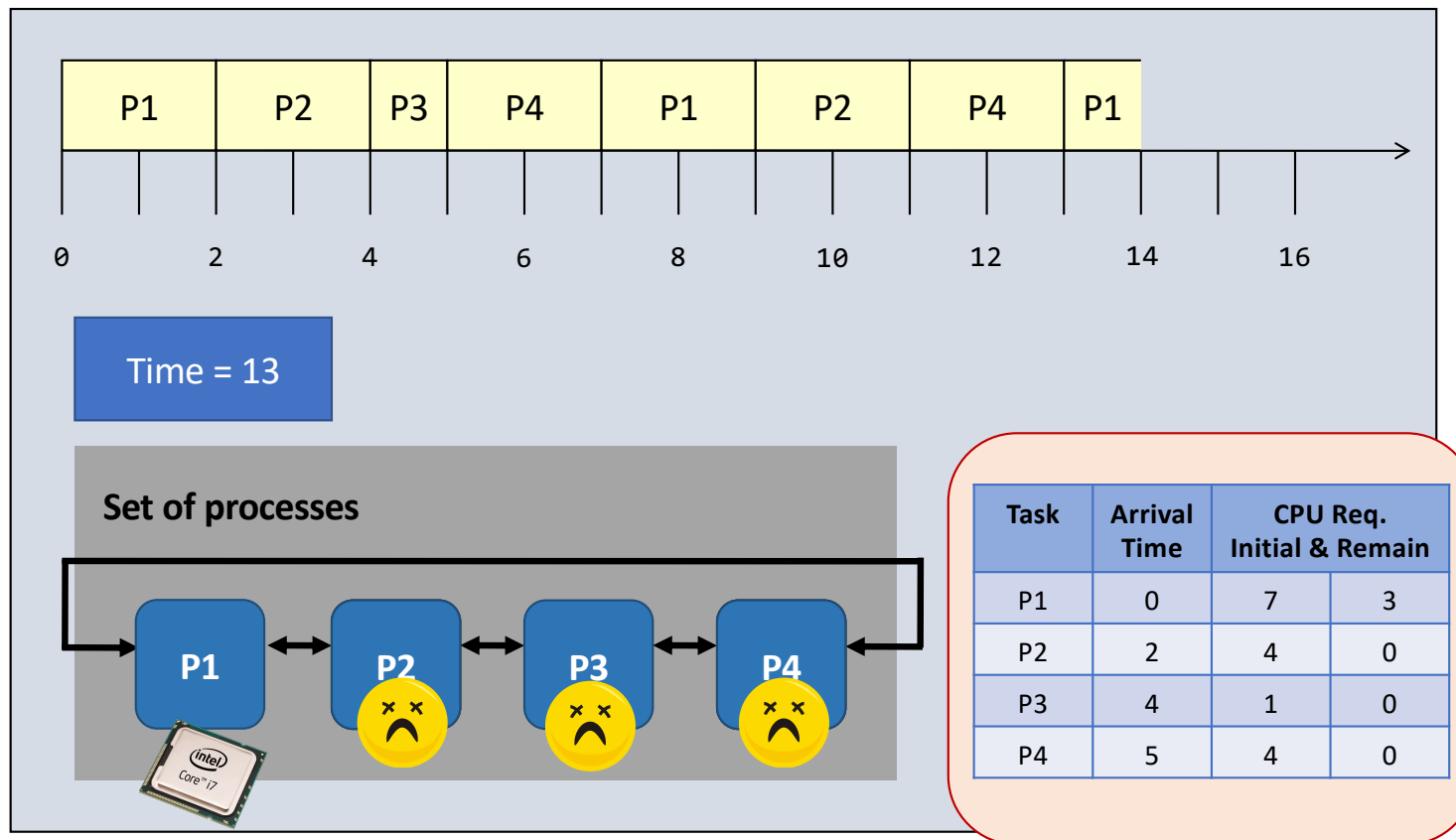
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Round Robin (Quantum = 2)



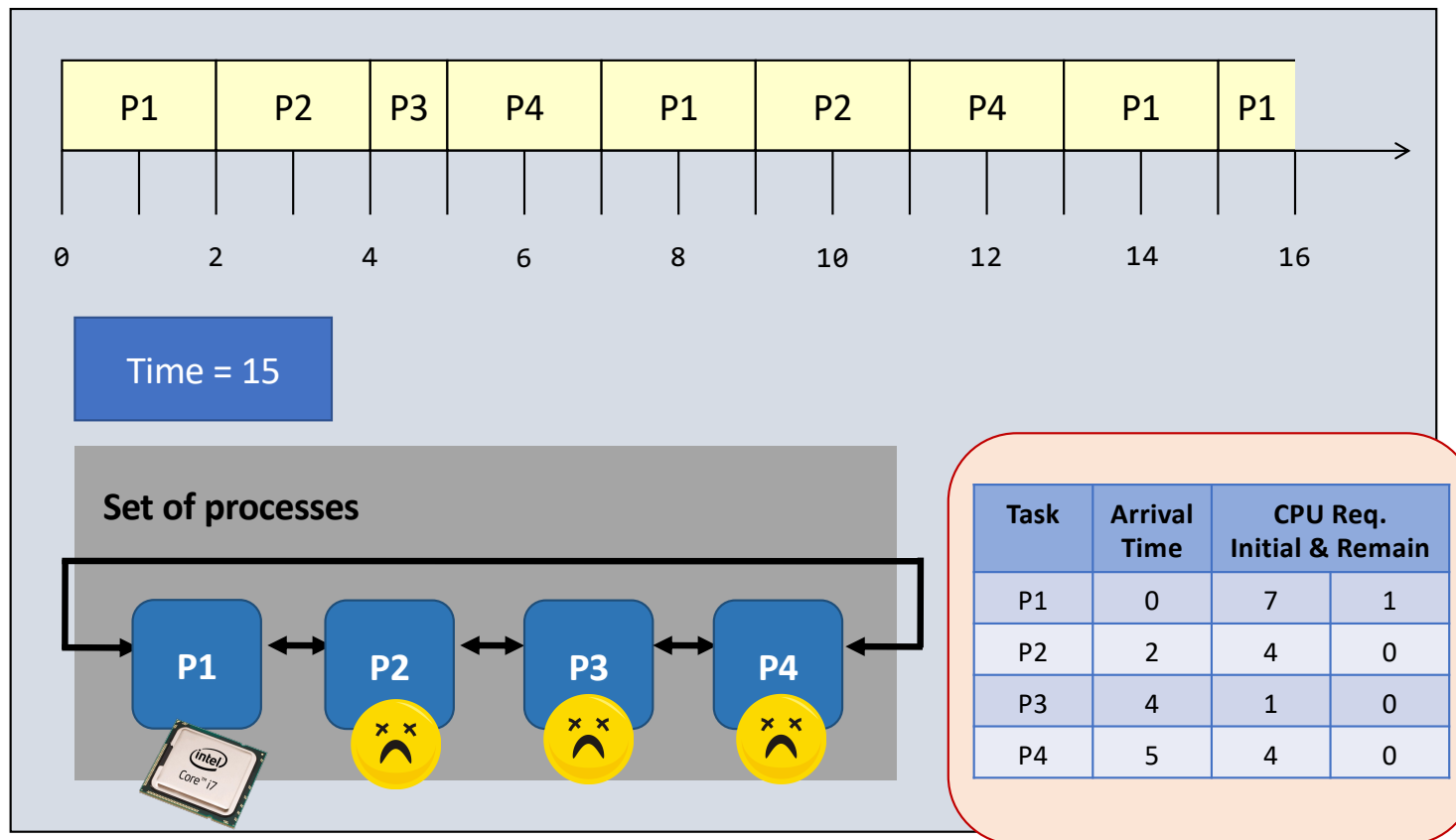
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Round Robin (Quantum = 2)

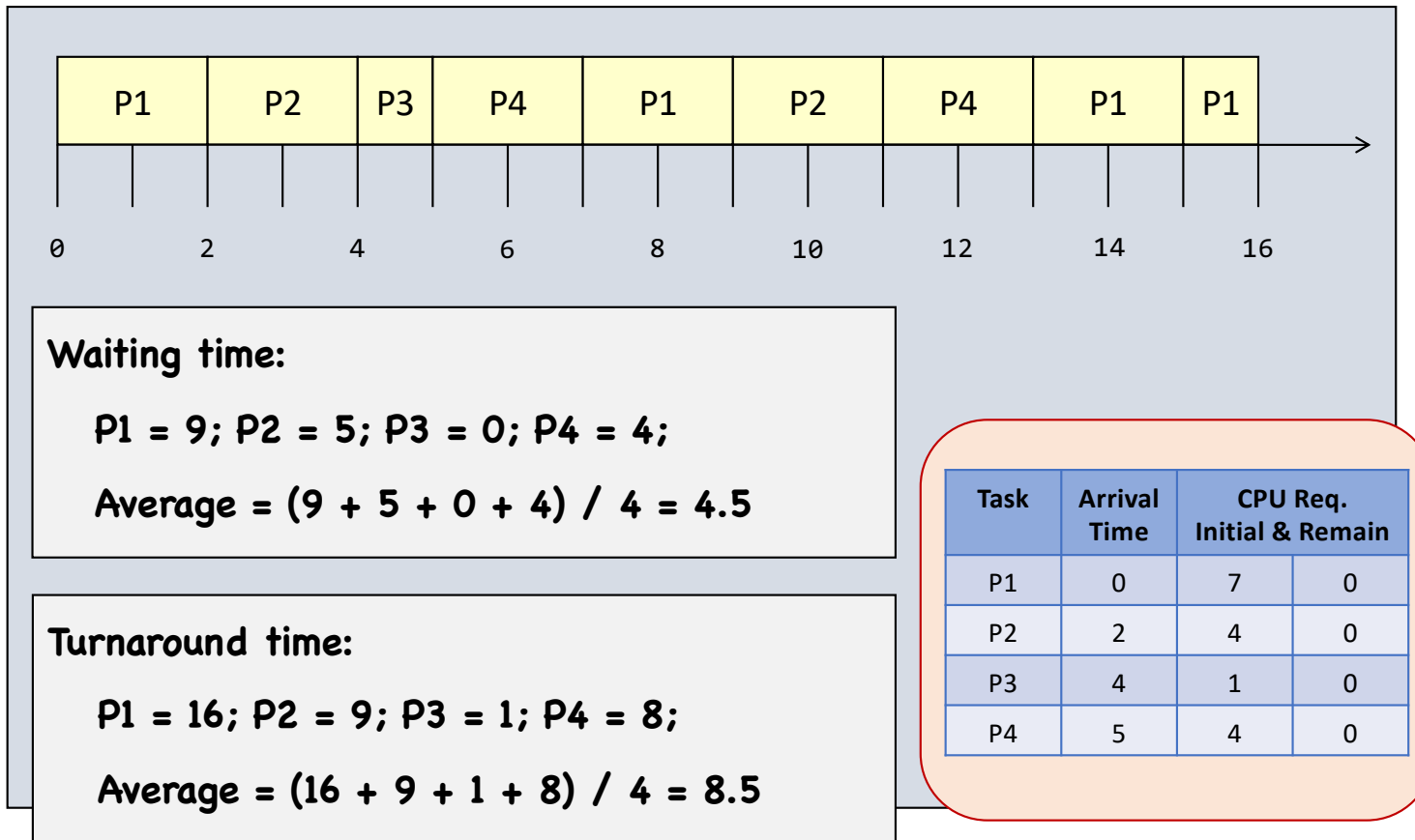


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Round Robin (Quantum = 2)



Round Robin (Quantum = 2)



RR v.s. SJF

	Non-preemptive SJF	Preemptive SJF	RR
Average waiting time	4	3	4.5 (largest)
Average turnaround time	8	7	8.5 (largest)
# of context switching	3	5	8 (largest)



So, the RR algorithm gets all the bad! Why do we still need it?

The responsiveness of the processes is great under the RR algorithm. E.g., you won't feel a job is "frozen" because every job gets the CPU from time to time!

Priority Scheduling

- A priority number (integer) is associated with each process
- The CPU is allocated to the process with the highest priority (smallest integer \equiv highest priority)
 - Nonpreemptive: newly arrived process simply put into the queue
 - Preemptive: if the priority of the newly arrived process is higher than priority of the currently running process---preempt the CPU
- Static priority and dynamic priority
 - static priority: fixed priority throughout its lifetime
 - dynamic priority: priority changes over time
- SJF is a priority scheduling where priority is the next CPU burst time

Priority Scheduling (Cont'd)

- Problem \equiv **Starvation** – low priority processes may never execute
 - Rumors has it that when they shut down the IBM 7094 at MIT in 1973, they found a low priority process that had been submitted in 1967 and had not yet been run.
- Solution \equiv **Aging** – as time progresses increase the priority of the process
 - Example: priority range from 127 (low) to 0 (high)
 - Increase priority of a waiting process by 1 every 15 minutes
 - 32 hours to reach priority 0 from 127

Linux Scheduling

- Before Linux kernel version 2.5, traditional UNIX scheduling, not adequately support SMP
- Linux kernel version 2.5, O(1) scheduler
 - Constant scheduling time regardless number of tasks
 - Better support for SMP
 - Poor response time for interactive processes
- After Linux kernel version 2.6.23, CFS-completely fair scheduler
 - Default scheduler now

Completely Fair Scheduler

- Scheduling class
 - Standard Linux kernel implements two scheduling classes
 - (1) Default scheduling class: CFS
 - (2) Real-time scheduling class
- Varying length scheduling quantum
 - Traditional UNIX scheduling uses 90ms fixed scheduling quantum
 - CFS assigns a proportion of CPU processing time to each task
- Nice value
 - -20 to +19, default nice is 0
 - Lower nice value indicates a higher relative priority
 - Higher value is “being nice”
 - Task with lower nice value receives higher proportion of CPU time

Completely Fair Scheduler (Cont'd)

- Virtual run time
 - Each task has a per-task variable **vruntime**
 - Decay factor
 - Lower priority has higher rate of decay
 - $\text{nice} = 0$ virtual run time is identical to actual physical run time
 - A task with $\text{nice} > 0$ runs for 200 milliseconds, its **vruntime** will be higher than 200 milliseconds
 - A task with $\text{nice} < 0$ runs for 200 milliseconds, its **vruntime** will be lower than 200 milliseconds
- Lower virtual run time, higher priority
 - To decide which task to run next, scheduler chooses the task that has the smallest **vruntime** value
 - Higher priority can preempt lower priority

Completely Fair Scheduler (Cont'd)

- Example: Two tasks have the same nice value
- One task is I/O bound and the other is CPU bound
- **vruntime** of I/O bound will be shorter than **vruntime** of CPU bound
- I/O bound task will eventually have higher priority and preempt CPU-bound tasks whenever it is ready to run

Thank you!

