CS202 (003): Operating Systems
Scheduling

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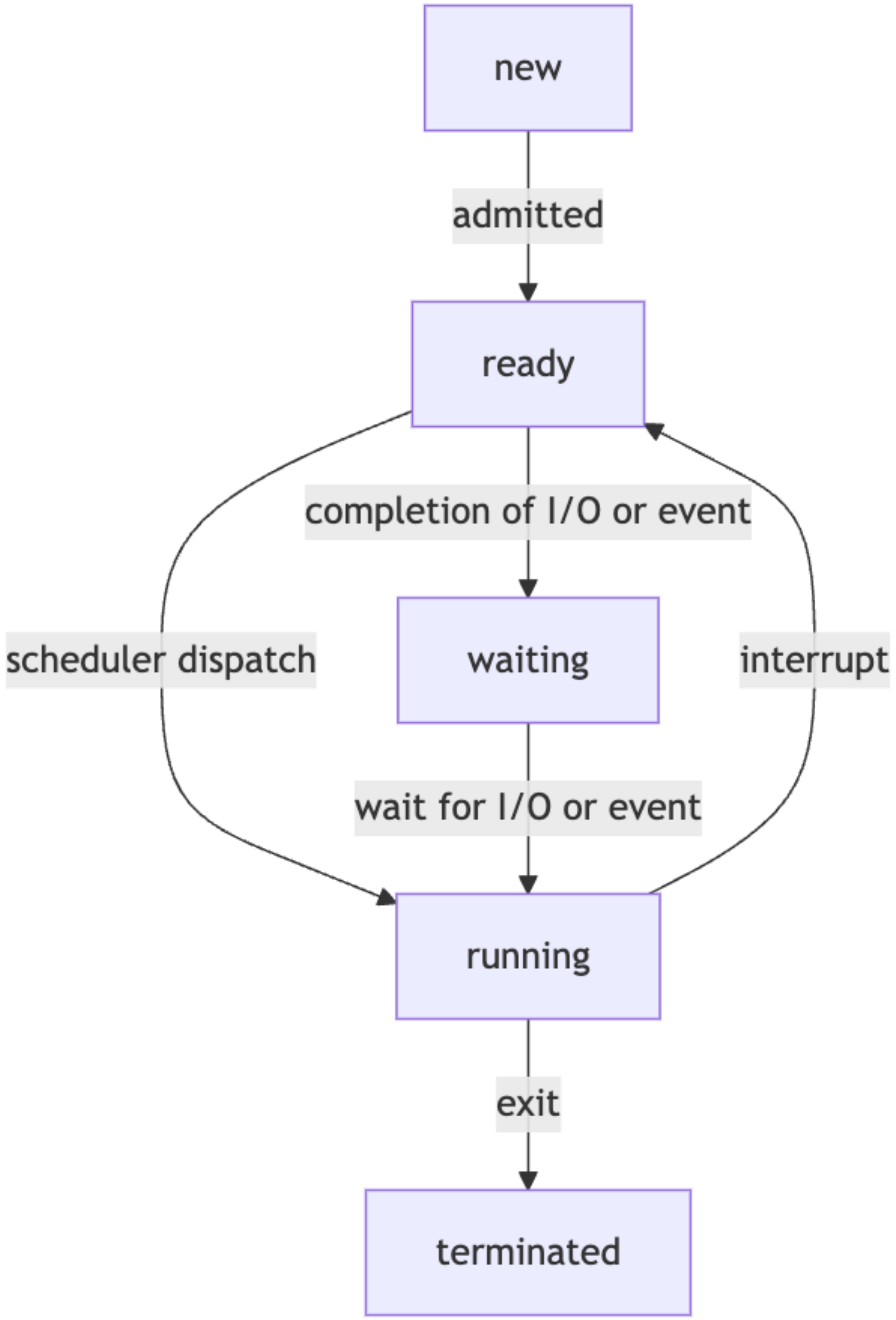
Most of the materials covered in this slide come from the lecture notes of Mike Walfish's CS202

Have you ever wondered how we decide what next process/thread to run?

Operating system has to decide on this!

When scheduling decisions happen



(i) switches from running to waiting state
(ii) switches from running to ready state
(iii) switches from waiting to ready
(iv) exits

Preemptive scheduling

willing to stop one process from running in order to run another

(i), (ii), (iii), (iv)

Non-preemptive scheduling

run each job to completion before considering whether to run a new job

(i), (iv)

What are the metrics and criteria for making decisions?

Turnaround time
Time for each process to complete (from arrival)

Waiting/Response/Output time
Time spent waiting for something to happen

Response time: time between when jobs enters system and starts executing

Output time: time from request to first response

System throughout
# of processes that complete per unit time

Fairness
(different possible definitions)

Free from starvation

All users get equal time on CPU

Highest priority jobs get most of CPU

……

We call …

Stopping one running process temporality and resuming (or starting) another process

Context Switch

Context switching has a **cost**!

CPU time in kernel: save/restore registers, switch address spaces

Indirect cost: TLB shootdown, processor caches, OS caches

More frequent context switches will lead to worse throughput (higher overhead)

Scheduling disciplines (without I/O)

FCFS/FIFO

SJF and STCF

Round-robin (RR)

FCFS/FIFO

Run each job until it's done

Job	Time Needed (s)
P1	24
P2	3
P3	3

Throughput = $\frac{3 \text{ jobs}}{30 \text{ seconds}} = 0.1 \text{ jobs/second}$

Avg Turnaround Time = $\frac{24 + 27 + 30}{3} = 27$

How can we lower avg turnaround time?

Advantages

- simple
- no starvation
- few context switches

Disadvantages

- short jobs get stuck behind long ones!

SJF and STCF

SJF

Schedule the job whose next CPU burst is the shortest

STCF

Preemptive version of SJF: if the new job arrived has a shorter time to completion than the remaining time on the current job, immediately preempt CPU to give to new job

Job	Arrival Time (s)	Burst Time (s)
P1	0	7
P2	2	4
P3	4	1
P4	5	4

Advantages

- Discuss later!

Disadvantages

- Discuss later!

Round Robin

Let's start considering response time
(i.e., we are adding a timer our scheduler)

Preempt CPU from long-running jobs (per time slice/quantum)
=> if a job hasn't finished by the end of a time slice,
put it to the back of the ready queue

Advantages

- Fair allocation of CPU across jobs
- Low average **response time** when job length vary
- Good for output time if small number of jobs

Disadvantages

- RR does not care about turnaround time!

Job	Time Needed (in time unit)
P1	50
P2	50

What is the average turnaround time if we have quantum of 1?

100.5

What happens if we use FIFO?

75

Round Robin

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How do we choose quantum size?

- Want much larger than context switch cost (amortization)
- Majority of bursts should be less than quantum
- If too small -> spend too much time context switching
- If too large -> response time suffers (and reverts to FIFO)

Scheduling disciplines (**with** I/O)

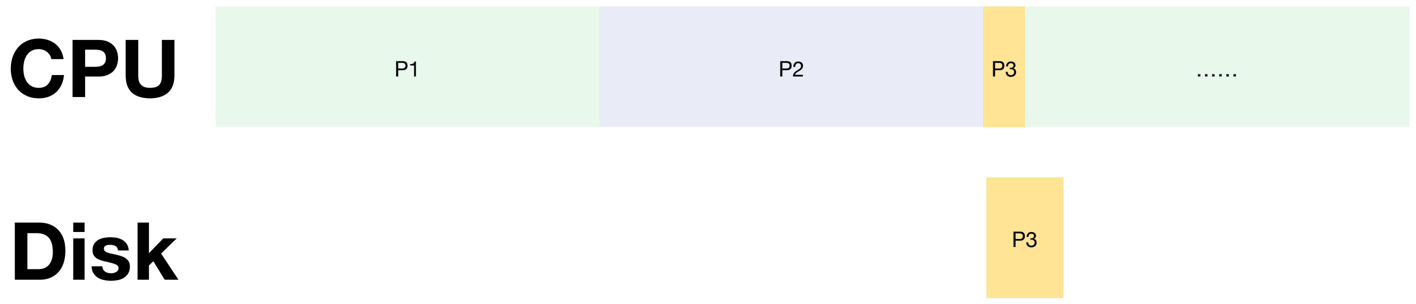
Job	Time Needed
P1	CPU-bound, 1 week
P2	CPU-bound, 1 week
P3	I/O bound, loop: 1ms CPU, 10ms Disk I/O

By itself, P1 or P2 uses 100% of CPU
By itself, P3 uses 90% of Disk

FCFS/FIFO

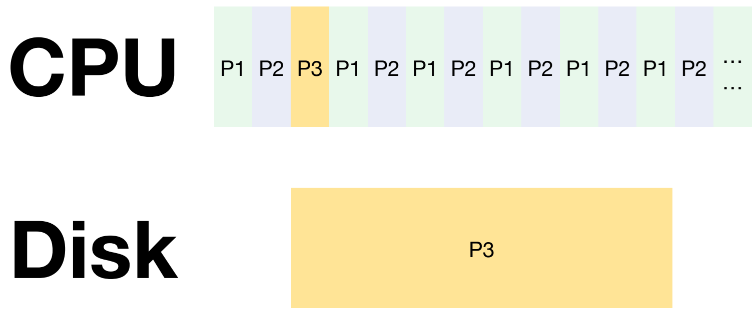
P1+P2 will take 2 weeks

RR (100ms quantum)



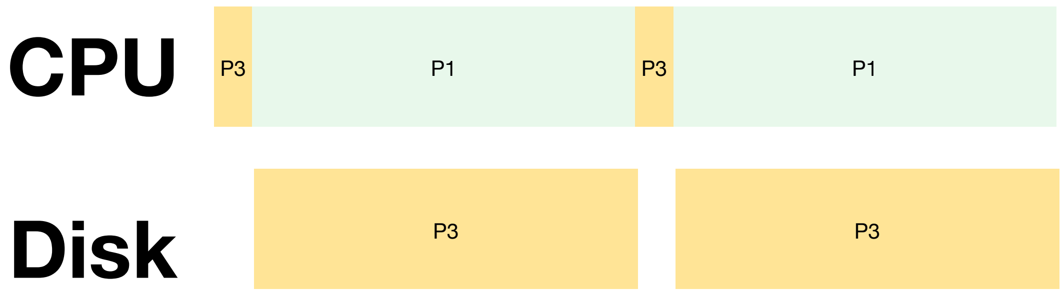
Disk Utilization = $\frac{10\text{ms}}{201\text{ms}} \approx 5\,\%$

RR (1ms quantum)



Disk Utilization = $\frac{10\text{ms}}{11\text{ms}} \approx 91\,\%$

STCF



Good disk utilization

Optimal average turnaround time

Low overhead

SJF and STCF

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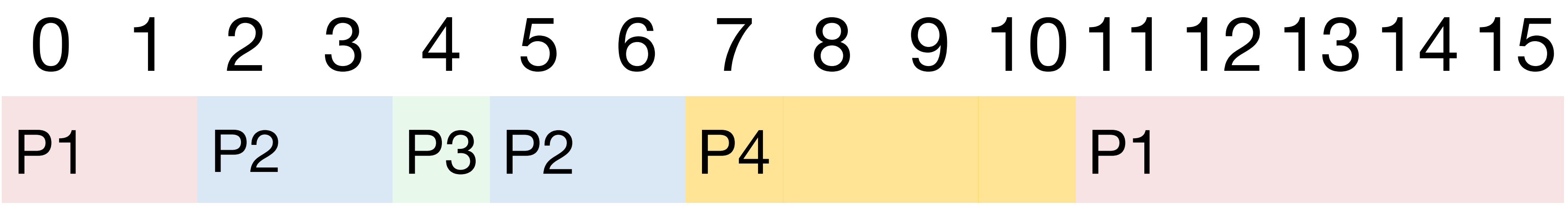

Advantages

- Good disk utilization
- Optimal (minimum) average turnaround time
- Low overhead (no needless preemption)

Disadvantages

- Long-running jobs get starved
- Does not optimize response time
- Requires predicting the future

Predicting CPU burst: EMMA

(exponentially weighted average)

Attempt to estimate future based on the past

t_n :**(time) length of proc's** n**th burst**

τ_{n+1}: **estimate for** $n+1$ **burst**

$\tau_{n+1} = \alpha * t_n + (1-\alpha) * \tau_n$ **where** $0 < \alpha \leq 1$

Favor jobs that have been using CPU the least amount of time

Key idea in scheduling: Priority

Give every process a number, and give the CPU to the process with highest priority (which is either the highest/lowest numbers)

We don’t want to use strict priority (that leads to starvation on low priority tasks)

To reduce starvation, we can increase a process’s priority as it waits

Optimizing turnaround + response time: MLFQ

(multi-level feedback queue)

Multiple queues, each with different priority

RR within each queue

Processes priority changes overtime

Advantages

- Approximate SRTCF (shortest remaining time first)
- It overall gives higher priority that use less CPU time
- Helps reduce average turnaround time and response time for short jobs

Disadvantages

- Cannot donate priority
- Not very flexible
- Not good for real-time and multimedia
- Can be gameable