- [x] 1. Last time
- [x] 2. Scheduling intro
- [ ] 3. Scheduling disciplines
    - [x] FIFO
    - [x] SJF
    - [x] RR
    - [x] Incorporating I/O
    - [x] Priority
    - [x] MLFQ
    - [x] Lottery
- [x] 4. Lessons and conclusions

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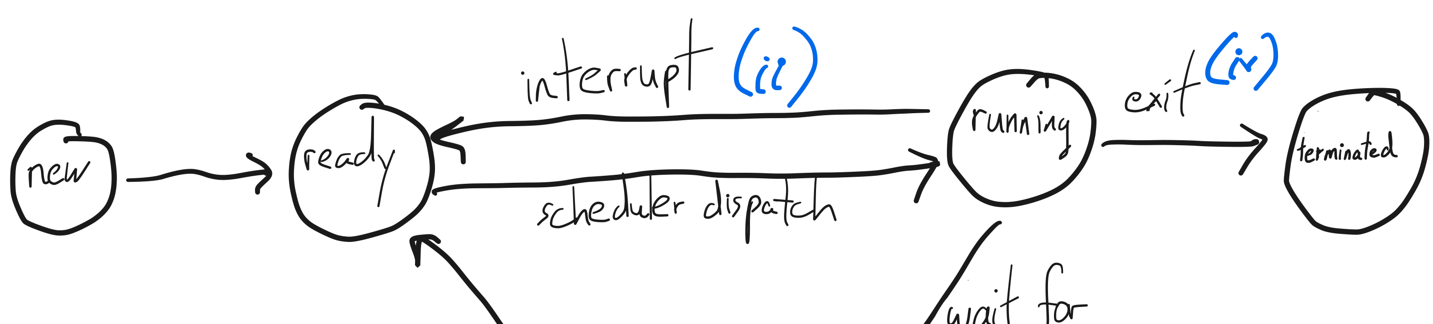
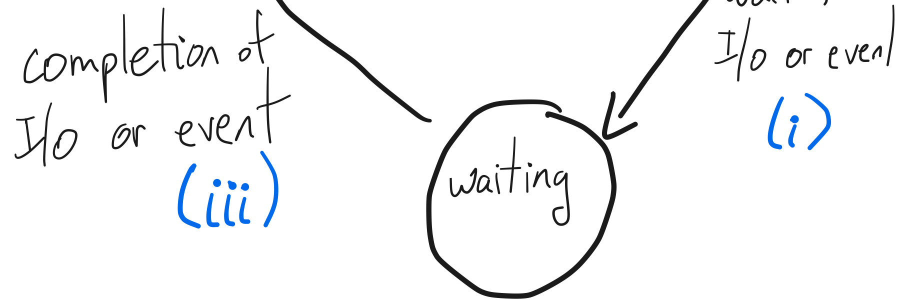
2. Scheduling intro

High-level problem: OS has to decide which process (or thread) to run.

A. When scheduling decisions happen

process state/transitions:





scheduling decisions happen when a process/thread:

(i) Switches from running to waiting
(ii) Switches from running to ready
(iii) Switches from waiting to ready
(iv) Exits

preemptive scheduling vs. non-preemptive scheduling

B. Metrics and criteria

turnaround time: time for each process/thread to complete

waiting/response/output time: time spent waiting for something to happen

system throughput: # completed processes / unit of time

fairness: often conflicts w/ efficiency

C. Context switching has a cost

CPU time in kernel (save and restore registers, switch address spaces)

indirect costs (TLB shootdowns, processor cache, OS caches)

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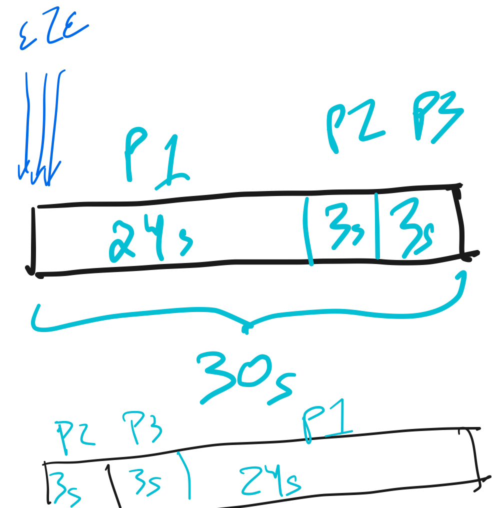
3. Scheduling disciplines

Assume first that process/threads do no I/O. (unrealistic; relax it later)

A. FCFS/FIFO

- run job until done



- ex: P1 needs 24s
  - P2 needs 3s
  - P3 needs 3s

tput? 0.1 tasks or processes per second.

avg tt? (24 + 27 + 30)/3 = 27s

(3+6+30)/3 = 13s

B. SJF + STCF

SJF: choose job w/ shortest upcoming CPU burst

STCF: preemptive version of SJF

example:

process	arrival time	burst time
P1	0	~~7~~ 5
~~P2~~	~~2~~	~~4~~ ~~2~~
~~P3~~	~~4~~	~~1~~
P4	5	4

time: 0 1 2 3 4 5 6 7 8 9 10 11

P1 P1 P2 P2 P3 P2 P2 P4 P4 P4 P4 P1 ...

C. Round robin (RR)

- add a timer
- quantum 10ms - 100ms

... the same length?

what if jobs are

ex: 2 jobs of 50 time units each, quantum is 1.

- avg tt? ~100 tu
- if we did FCFS? 50, 100 → 75 tu

D. Incorporating I/O

motivating example:

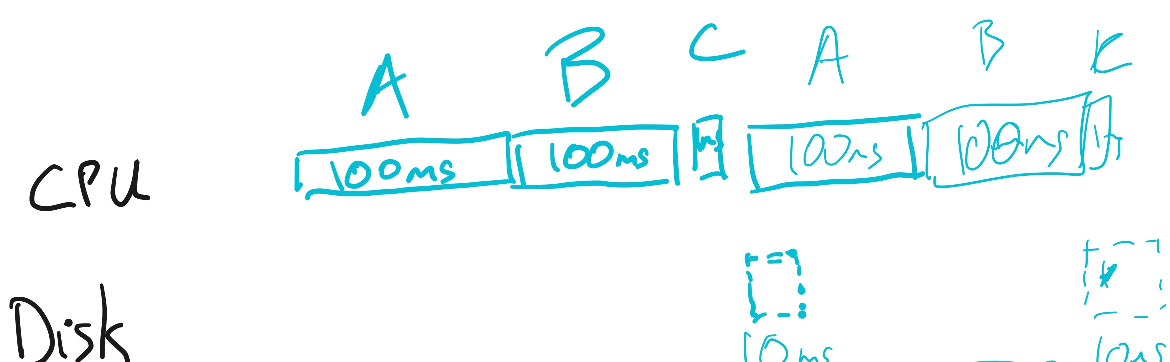
3 jobs

A, B: CPU-bound, run for a week (1 week, 1 week)

C: I/O-bound, loop: 1ms of CPU, 10ms of disk I/O

what happens if we use FIFO?

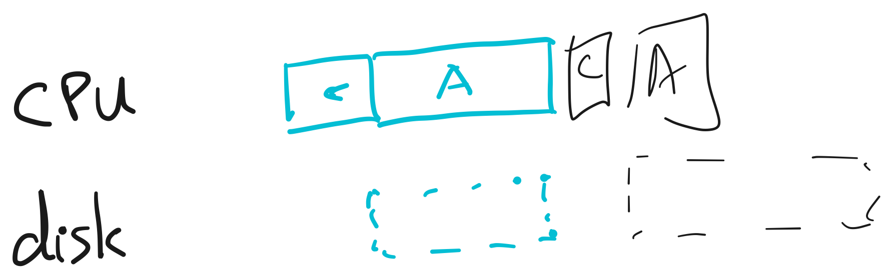
what happens if we use RR w/ 100ms quantum?



Disk utilization = $\frac{10ms}{201ms}$ = 5%

what happens if we use RR w/ 1ms quantum?

what happens if we use STCF?



disk utilization? 90%

context switchs? fewer

EWMA

t_n: length of process's n^{th} CPU burst

τ_{n+1}: estimate for the $n+1^{st}$ burst

$$0 < \alpha \leq 1$$

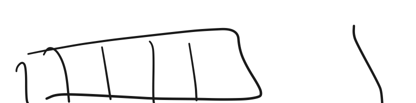
$$\tau_{n+1} \leftarrow \alpha \cdot t_n + (1-\alpha)\tau_n$$

$$= \alpha t_n + (1-\alpha)\alpha t_{n-1} + (1-\alpha)^2 \alpha t_{n-2} + \cdots + (1-\alpha)^n \cdot \alpha t_0$$

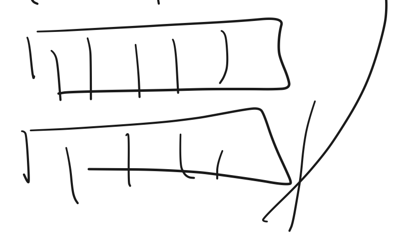
Each older term given exponentially less weight.

E. Priority scheme

prio



F. MLFQ



three ideas:

- multiple queues, with different priority
- RR w/in each queue
- feedback: change prio based on how much/how little process has used the CPU.

G. lottery and stride scheduling

P_i gets t_i tickets

$T = \sum t_i$

prob. of "winning" next quantum is t_i / T.

H. Linux: CFS

~ stride scheduling

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4. Lessons

(i) Know your goals!

(ii) Compare against optimal

(iii) There are different schedulers that interact