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

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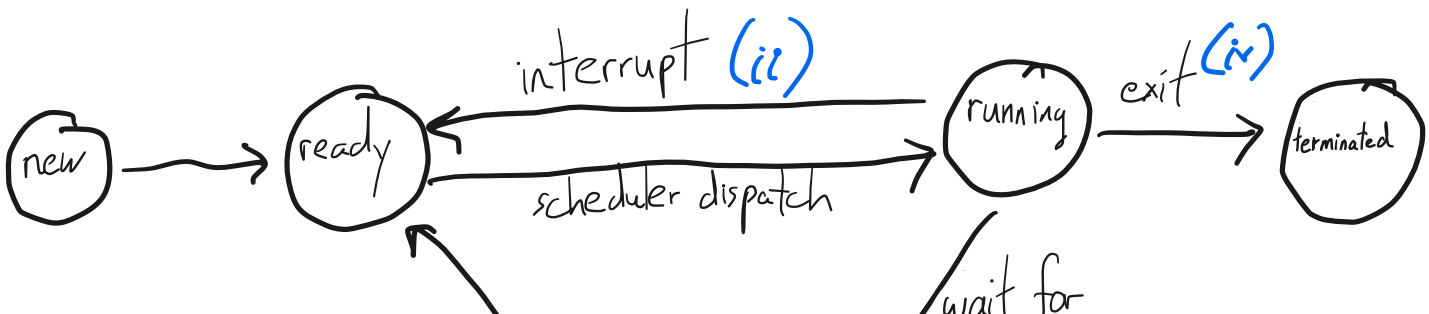
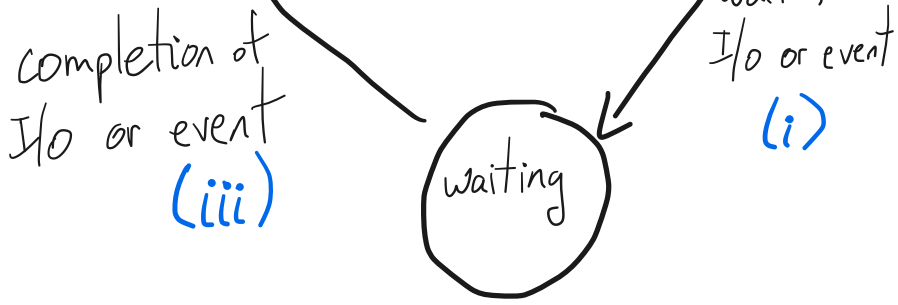
2. Scheduling intro

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

$\frac{3 \text{ process}}{(24+3+3)=30s} = \frac{3 \text{ processes}}{= 0.1 \text{ proc/sec.}}$

tput? 0.1 processes/sec.

avg tt? $\frac{24 (P1) + 27 (P2) + 30 (P3)}{3} = 27s.$

B. SJF + STCF

P3: 3 sec, P2 = 6 sec, P1 = 30, 39/3 = 13

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

... the same length?

what if jobs are

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

- avg tt? 99.5 quanta
- if we did FCFS? 75 quanta.

D. Incorporating I/O

motivating example:

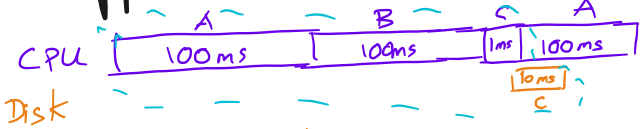
3 jobs

A, B: CPU-bound, run for a 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?



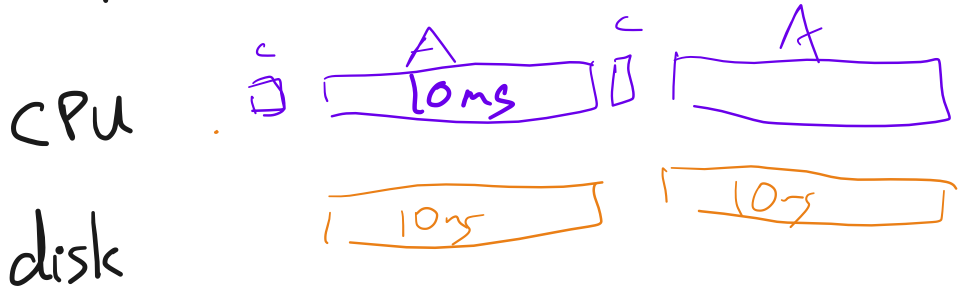
disk utilization ≈ 5%

b/c $\frac{10ms}{201ms} \approx \frac{10ms}{200ms} = 5\%$

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

(exercise)

what happens if we use STCF?



disk utilization? ≈ 90%.

context switches?

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

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