Systems and Networking I

Applied Computer Science and Artificial Intelligence

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Scheduling Algorithms: An Overview

- First-Come-First-Serve (FCFS)
- Round Robin (RR)
- Shortest-Job-First (SJF)
- Priority Scheduling

LAST TIME

- Multilevel Queue (MQ)
- Multilevel Feedback-Queue (MFQ)

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TODAY

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Note: Jobs cannot switch from queue to queue

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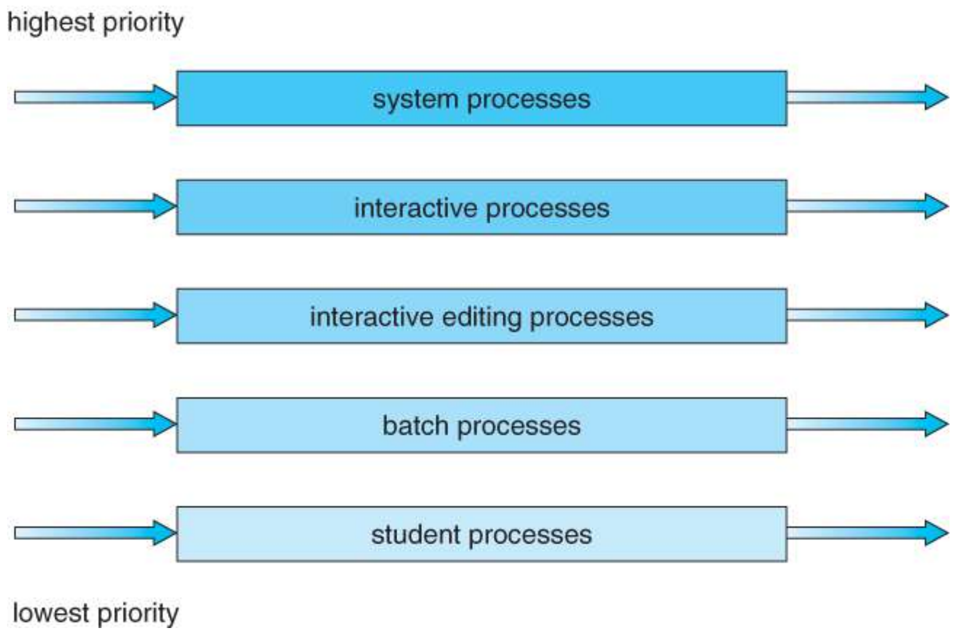

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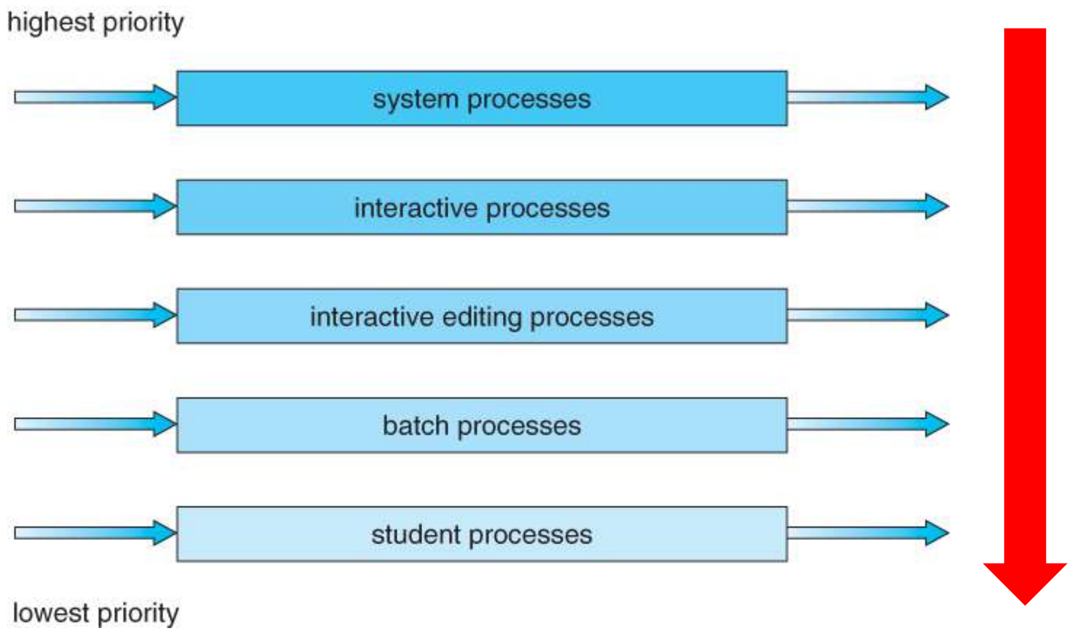

Time slice usually increases (exponentially) as priority gets lower

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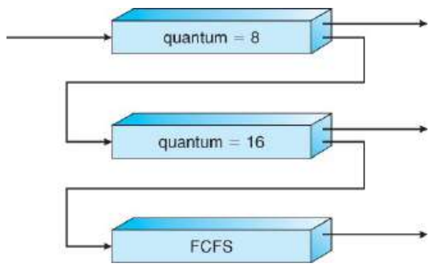
- Moving jobs may be required when:
  - The characteristics of a job change between CPU-intensive and I/O-intensive
  - A job that has waited for a long time can get bumped up into a higher priority queue for a while (to compensate the aging problem)



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- I/O-bound jobs will stay at higher priority levels

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- Some of the (many) parameters which define MLFQ systems include:
  - The number of queues
  - The scheduling algorithm for each queue
  - The methods used to upgrade or demote processes from one queue to another
  - The method used to determine which queue a process enters initially

Multilevel Feedback Queue (MLFQ): Example I

New A B C

Order	Job	CPU burst (time units)
1	A	30
2	B	20
3	C	10

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3 queues

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$$\text{JOB\_ID}_{total\_elapsed\_time}^{job\_exec\_time} = \text{The job JOB\_ID has executed } job\_exec\_time \text{ time units after } total\_elapsed\_time \text{ time units}$$

$$A_7^2 = \text{The job } A \text{ has executed } 2 \text{ time units after } 7 \text{ time units overall}$$

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2	2	
3	4	

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Multilevel Feedback Queue (MLFQ): Example II

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2 queues and C now alternates 1 time unit of CPU with 1 time unit of I/O

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Queue	Time Slice (time units)	Jobs
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2	2	$A^3{}_5$, $B^3{}_8$

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2	2	A^{3}_{5}, B^{3}_{8}, A^{5}_{11}, B^{5}_{14}, …, B^{12}_{32}, A^{14}_{34}, …

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- It explicitly promotes short jobs (i.e., I/O-bound ones) by design
- **Problem:** SJF (and MLFQ) might be unfair (as opposed to RR)

Any increase in fairness by giving long jobs a fraction of the CPU when shorter jobs could be instead selected will increase waiting time

MLFQ: Improving Fairness

- Give each queue a fraction of the CPU time
  - This is fair only if jobs are evenly distributed (i.e., uniformly) across queues

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- Adjust dinamically the priority of jobs as they don't get scheduled
  - This avoids starvation but average waiting time might increase when the system is overloaded (all jobs get to the highest priority queue, eventually)

Advanced Topics: Lottery Scheduling

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As the number of time slices
(i.e., the number of random picks) goes to infinity

Law of Large Numbers

Lottery Scheduling: Policy

- Assign tickets to jobs as follows:
  - Give more tickets to short running jobs
  - Give few tickets to long running jobs

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- To avoid starvation, each job gets at least one ticket
- Degrades gracefully as system load changes
  - Adding/deleting a job affects all the other jobs proportionally

Lottery Scheduling vs. All

Question:

What is the main difference between lottery scheduling and any other algorithgm we have seen so far?

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Answer:

This is the only example of randomized scheduler

(rather than deterministic one)

Lottery Scheduling: Example

#short jobs / #long jobs	% of CPU for each short job	% of CPU for each long job

Lottery Scheduling: Example

short jobs get 10 tickets each | long jobs get 1 ticket each

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#short jobs / #long jobs	% of CPU for each short job	% of CPU for each long job
1/1		

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1/1	~91% (10/11)	

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Lottery Scheduling: Example

short jobs get 10 tickets each | long jobs get 1 ticket each

#short jobs / #long jobs	% of CPU for each short job	% of CPU for each long job
1/1	~91% (10/11)	~9% (1/11)
0/2		

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short jobs get 10 tickets each | long jobs get 1 ticket each

#short jobs / #long jobs	% of CPU for each short job	% of CPU for each long job
1/1	~91% (10/11)	~9% (1/11)
0/2	-	50% (1/2)

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0/2	-	50% (1/2)
2/0	50% (10/20)	-

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#short jobs / #long jobs	% of CPU for each short job	% of CPU for each long job
1/1	~91% (10/11)	~9% (1/11)
0/2	-	50% (1/2)
2/0	50% (10/20)	-
10/1	~9.9% (10/101)	~0.99% (1/101)

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10/1	~9.9% (10/101)	~0.99% (1/101)
1/10	50% (10/20)	5% (1/20)

Lottery Scheduling: CPU Assignment

$$n_{short} = \text{total number of } \textit{short} \text{ jobs}$$
$$n_{long} = \text{total number of } \textit{long} \text{ jobs}$$
$$N = n_{short} + n_{long} = \text{total number of jobs}$$

$$m_{short} = \text{number of tickets assigned to each } \textit{short} \text{ job}$$
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$$M = m_{short} * n_{short} + m_{long} * n_{long} = \text{total number of tickets}$$

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$$M = m_{short} * n_{short} + m_{long} * n_{long} = \text{total number of tickets}$$

$$\boxed{\begin{aligned} \text{CPU}_{short} &= \frac{m_{short}}{M} \\ \text{CPU}_{long} &= \frac{m_{long}}{M} \end{aligned}}$$

Lottery Scheduling: CPU Assignment Probability

$$m_i = \text{number of tickets assigned to job } i$$

$$N = \text{total number of jobs}$$

$$M = \sum_{i=1}^{N} m_i = \text{total number of tickets}$$

$$P(i) = \frac{m_i}{M} = \text{probability of job } i \text{ being scheduled}$$

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