

CSC 369 Worksheet 5 Solution

August 19, 2020

1. I need to run randomly-generated problems with two jobs and two queues using file `mlfq.py` with I/O turned off, and compute the MLFQ execution trace for each.

Using the command `./mlfq.py -s 1 -m 10 -n 2 -j 2 -M 0`, we have

```
Job List:
Job  0: startTime  0 - runTime  2 - ioFreq  0
Job  1: startTime  0 - runTime  7 - ioFreq  0
```

with

- allotments for queue 1 is 1
- quantum length for queue 1 is 10
- allotments for queue 0 is 1
- quantum length for queue 0 is 10
- no priority boost

,

the execution trace is:

```
1 [time 0] Job begins by job 0
2 [time 0] Job begins by job 1
3 [time 0] Run job 0 at priority 1 [Ticks 9, Allotment 1, Time 1 (of
  2)]
4 [time 1] Run job 0 at priority 1 [Ticks 8, Allotment 1, Time 0 (of
  2)]
5 [time 2] Finished JOB 0
6 [time 2] Run job 1 at priority 1 [Ticks 9, Allotment 1, Time 6 (of
  7)]
```

```

7   [time 3] Run job 1 at priority 1 [Ticks 8, Allotment 1, Time 5 (of
8   7)]
9   [time 4] Run job 1 at priority 1 [Ticks 7, Allotment 1, Time 4 (of
10  7)]
11  [time 5] Run job 1 at priority 1 [Ticks 6, Allotment 1, Time 3 (of
12  7)]
13  [time 6] Run job 1 at priority 1 [Ticks 5, Allotment 1, Time 2 (of
    7)]
    [time 7] Run job 1 at priority 1 [Ticks 4, Allotment 1, Time 1 (of
    7)]
    [time 8] Run job 1 at priority 1 [Ticks 3, Allotment 1, Time 0 (of
    7)]
    [time 9] Finished JOB 1

```

Notes

- Learned that when allotted time is up, the next job starts immediately
(./mlfq.py -s 20 -m 20 -n 2 -j 2 -M 0 -c)

Alloted time is up

Next job runs
immediately

```

[ time 0 ] JOB BEGINS by JOB 0
[ time 0 ] JOB BEGINS by JOB 1
[ time 0 ] Run JOB 0 at PRIORITY 1 [ TICKS 9 ALLOT 1 TIME 17 (of 18) ]
[ time 1 ] Run JOB 0 at PRIORITY 1 [ TICKS 8 ALLOT 1 TIME 16 (of 18) ]
[ time 2 ] Run JOB 0 at PRIORITY 1 [ TICKS 7 ALLOT 1 TIME 15 (of 18) ]
[ time 3 ] Run JOB 0 at PRIORITY 1 [ TICKS 6 ALLOT 1 TIME 14 (of 18) ]
[ time 4 ] Run JOB 0 at PRIORITY 1 [ TICKS 5 ALLOT 1 TIME 13 (of 18) ]
[ time 5 ] Run JOB 0 at PRIORITY 1 [ TICKS 4 ALLOT 1 TIME 12 (of 18) ]
[ time 6 ] Run JOB 0 at PRIORITY 1 [ TICKS 3 ALLOT 1 TIME 11 (of 18) ]
[ time 7 ] Run JOB 0 at PRIORITY 1 [ TICKS 2 ALLOT 1 TIME 10 (of 18) ]
[ time 8 ] Run JOB 0 at PRIORITY 1 [ TICKS 1 ALLOT 1 TIME 9 (of 18) ]
[ time 9 ] Run JOB 0 at PRIORITY 1 [ TICKS 0 ALLOT 1 TIME 8 (of 18) ]
[ time 10 ] Run JOB 1 at PRIORITY 1 [ TICKS 9 ALLOT 1 TIME 14 (of 15) ]
[ time 11 ] Run JOB 1 at PRIORITY 1 [ TICKS 8 ALLOT 1 TIME 13 (of 15) ]
[ time 12 ] Run JOB 1 at PRIORITY 1 [ TICKS 7 ALLOT 1 TIME 12 (of 15) ]
[ time 13 ] Run JOB 1 at PRIORITY 1 [ TICKS 6 ALLOT 1 TIME 11 (of 15) ]
[ time 14 ] Run JOB 1 at PRIORITY 1 [ TICKS 5 ALLOT 1 TIME 10 (of 15) ]
[ time 15 ] Run JOB 1 at PRIORITY 1 [ TICKS 4 ALLOT 1 TIME 9 (of 15) ]
[ time 16 ] Run JOB 1 at PRIORITY 1 [ TICKS 3 ALLOT 1 TIME 8 (of 15) ]

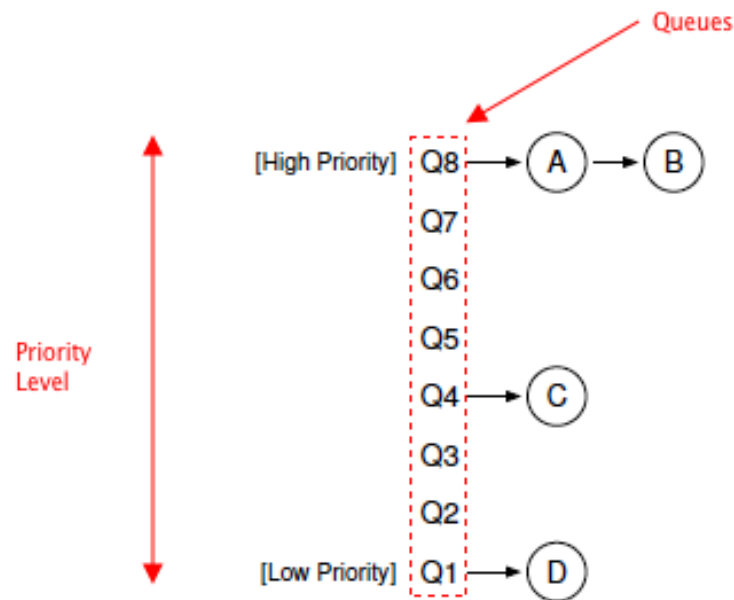
```

- Learned that when all jobs are at the bottom, without priority boost, jobs finishes by round robin
(./mlfq.py -s 20 -m 20 -n 2 -j 2 -M 0 -c)

Round
Robin

```
[ time 20 ] Run JOB 0 at PRIORITY 0 [ TICKS 9 ALLOT 1 TIME 7 (of 18) ]
[ time 21 ] Run JOB 0 at PRIORITY 0 [ TICKS 8 ALLOT 1 TIME 6 (of 18) ]
[ time 22 ] Run JOB 0 at PRIORITY 0 [ TICKS 7 ALLOT 1 TIME 5 (of 18) ]
[ time 23 ] Run JOB 0 at PRIORITY 0 [ TICKS 6 ALLOT 1 TIME 4 (of 18) ]
[ time 24 ] Run JOB 0 at PRIORITY 0 [ TICKS 5 ALLOT 1 TIME 3 (of 18) ]
[ time 25 ] Run JOB 0 at PRIORITY 0 [ TICKS 4 ALLOT 1 TIME 2 (of 18) ]
[ time 26 ] Run JOB 0 at PRIORITY 0 [ TICKS 3 ALLOT 1 TIME 1 (of 18) ]
[ time 27 ] Run JOB 0 at PRIORITY 0 [ TICKS 2 ALLOT 1 TIME 0 (of 18) ]
[ time 28 ] FINISHED JOB 0
[ time 28 ] Run JOB 1 at PRIORITY 0 [ TICKS 9 ALLOT 1 TIME 4 (of 15) ]
[ time 29 ] Run JOB 1 at PRIORITY 0 [ TICKS 8 ALLOT 1 TIME 3 (of 15) ]
[ time 30 ] Run JOB 1 at PRIORITY 0 [ TICKS 7 ALLOT 1 TIME 2 (of 15) ]
[ time 31 ] Run JOB 1 at PRIORITY 0 [ TICKS 6 ALLOT 1 TIME 1 (of 15) ]
[ time 32 ] Run JOB 1 at PRIORITY 0 [ TICKS 5 ALLOT 1 TIME 0 (of 15) ]
[ time 33 ] FINISHED JOB 1
```

- Learned that notification and subsequent job execution happen at the same time.
- The reason why round robin doesn't occur despite $\text{Priority}(A) = \text{Priority}(B)$ is because allotment of queue is 1 (i.e. only one job can be in a queue)
- **allotment** means the amount of something allocated to a person/object (i.e. the size of queue)
- `-m 10` sets the maximum runtime of a job to 10
- `-M 0` turns off I/O in `mlfq.py`
- `-n 2` sets number of queues to 2
- `-j 2` sets number of jobs to 2
- **Multi-level Feedback Queue (MLFQ):**
 - Is one of the most well-known approaches to scheduling
 - Does two things:
 - a) Optimizes turnaround time
 - b) Minimizes response time
 - Uses **priority level** and **Queues** to achieve it's goal
- **MLFQ Basic Rules:**
 - Jobs on same queue \rightarrow Same priority
 - **Rule 1:** If $\text{Priority}(A) > \text{Priority}(B)$, A runs (B doesn't)
 - **Rule 2:** If $\text{Priority}(A) = \text{Priority}(B)$, A & B run in RR

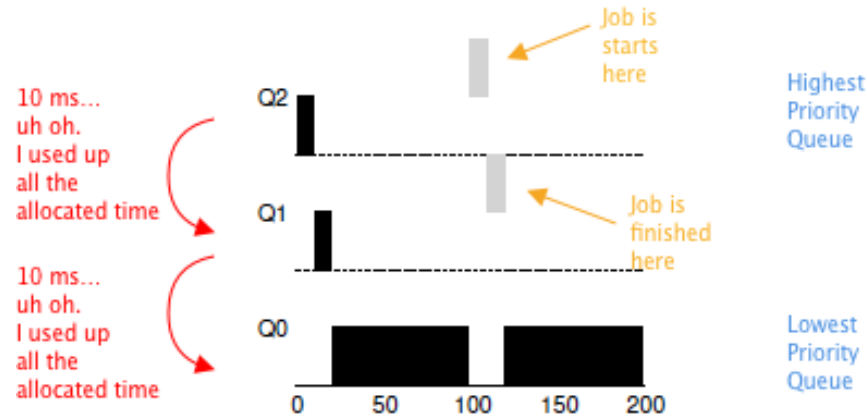


• **Attemp #1: How to Change Priority**

- **Rule 3:** When a job enters the system, it is placed at the highest priority (the topmost queue)
- **Rule 4a:** If a job uses up an entire time slice while running, its' priority is reduced (i.e. it moves down on queue).
- **Rule 4b:** If a job gives up the CPU before the time slice is up, it stays at the same priority level (e.g I/O Operation)
 - * Means that the shifting down of priority level only depends on CPU time

Example (Along Came a Short Job):

- 1) A job A enters system
- 2) Job is placed on highest Queue Q_2
- 3) After time-slice (e.g. 10 ms) in Q_2 , A is placed on lower queue Q_1
- 4) After time-slice in Q_1 , A is placed in lowest priority queue Q_0



- **Attemp #2: The Priority Boost**

- **Rule 5:** After some time period S , move all the jobs in the system to the topmost queue.
- * This is to prevent starvation (i.e. a job never being run)

- **Attempt #3: Better Accounting (Fix of Attempt # 1)**

- Is to prevent programmers from gaming (i.e tricking) the CPU so all programs get a fair share of allotment time
- **Rule 4:** Once a job uses up its time allotment at a given level (regardless of how many times it has given up the CPU), its priority is reduced (it moves down one queue).

2. I need to run the scheduler (mlfq.py) to reproduce each of the examples in the chapter.

- **Example 1: A Single Long-Running Job**

Here, the example has

- 3 queues
- 1 job
- 10ms as quantum length for queue 1
- 10ms as quantum length for queue 2
- 10ms as quantum length for queue 3
- 200ms as run time for job 1
- no priority boost

Combining together we have

```
./mlfq.py -l 0,200,0 -n 3 -j 1 -c
```

- Example 2: Along Came A Short Job

Here, the example has

- 3 queues
- 2 jobs
- 10ms as quantum length for queue 1
- 10ms as quantum length for queue 2
- 10ms as quantum length for queue 3
- 180ms as run time for job 1
- 20ms as run time for job 2
- 0ms as the starting time for job 1
- 100ms as the starting time for job 2
- no I/O operations for job 1
- no I/O operations for job 2
- no priority boost

Combining together we have

```
./mlfq.py -l 0,180,0:100,20,0 -n 3 -j 2 -c
```

- Example 3: What About I/O

Here, the example has

- 3 queues
- 2 jobs
- 10ms as quantum length for queue 1
- 10ms as quantum length for queue 2
- 10ms as quantum length for queue 3
- 0ms as the starting time for job 1
- 185ms as run time for job 1
- no I/O operations for job 1
- 50ms as the starting time for job 2
- 15ms as run time for job 2
- 1ms as the frequency of I/O request (Start immediately)
- 9ms as the I/O time for job 2
- no priority boost
- Uses older rules (Rule 4.a, Rule 4.b)

Combining together we have

```
./mlfq.py -l 0,185,0:50,15,1 -i 9 -n 3 -j 2 -S -c
```

3. I need to answer the question how would `.mlfq.py` be configured to behave just like round-robin scheduler.

The round-robin scheduler occurs when jobs are at bottom most priority with no priority boost and I/O operations (i.e. jobs are at same priority until completion).

So, the configuration is:

```
./mlfq.py -l 0,100,0:0,100,0 -n 1 -j 2 -c
```

4. I need to craft a workload with two jobs and scheduler parameters so that one job takes of the older rules and obtain 99% of the CPU over a particular time interval.

The following configuration allows job 1 to occupy most of CPU time.

```
./mlfq.py -l 0,100,9:0,100,0 -i 1 -n 3 -j 2 -S -c
```

This occurs once job 2 moves down to lower priority

5. Let a system has quantum length of 10ms in its highest queue. Assume no I/O operations are in place.

I need to answer how often job needs to be bosted back to the highest priority level so job gets at least 5% of CPU.

Given 500ms turn around time, the job needs to be boosted every 100ms to get at least 5% CPU time.