# CS314: Lab Report
# Assignment 5 - Minix3 Scheduling and Pseudo-FIFO

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05 February 2023

## 1 Part I - MINIX3 Scheduling

> **Task:** Prepare (at least 4) workload mixes having different characteristics, ranging from all compute-intensive benchmarks to all I/O-intensive benchmarks. Each workload should spawn around 5 processes.
>
> Study how the standard Minix3 scheduler schedules your workloads. Your study should not only encompass the order of the processes, but also the time quanta spent in the CPU by the processes. Record your observations and your inferences.

### 1.1 Workload Mix 1: Completely CPU-Intensive

Let us check how the Minix3 scheduler schedules a fully CPU-intensive workload. In assignment 3, we identified `arithoh.sh` as being CPU-intensive due to the computational nature of the program. So, this workload mix (`workload_mix0.sh`) consists of executing 5 instances of this script. **(Note that observations and inferences are briefly explained after the figures in each subsection.)**

```bash
#!/bin/bash


./arithoh.sh &
./arithoh.sh &
./arithoh.sh &
./arithoh.sh &
./arithoh.sh &
wait
```



Figure 1: Observable Round-Robin behaviour

Figure 2: Observable Round-Robin behaviour near the end of execution

In the above snapshots, we can observe the endpoint IDs (similar to PID) 33883, 33884, 33882, 33885, 33886 repeating in a round-robin fashion. Time quantum of 200 is fully utilized in each burst, cementing the conclusion me made about `arithoh.sh` being CPU-intensive.

## 1.2 Workload Mix 2: Completely I/O-Intensive

Next, let's check how the Minix3 scheduler schedules a fully I/O-intensive workload. In assignment 3, we identified `fstime.sh` as being I/O-intensive due to the read/write/copy nature of the program. So, this workload mix ( `workload_mix1.sh` ) consists of executing 5 instances of this script.

```bash
#!/bin/bash

./fstime.sh &
./fstime.sh &
./fstime.sh &
./fstime.sh &
./fstime.sh &
wait
```



Figure 3: Observable Round-Robin behaviour

Figure 4: Near the end of execution

The five I/O-bound processes run in a round-robin fashion, as expected. From the figures above, we can also observe that they do not use the entire allotted time quantum. hence, `fstime.sh` is conclusively I/O-bound, unlike the previous section.

## 1.3 Workload Mix 3: Completely System Call-Intensive

Now, let us check how the Minix3 scheduler schedules a fully System call-intensive workload. In assignment 3, we identified `syscall.sh` as being System call-intensive due to the nature of the calls made in the program. So, this workload mix ( `workload_mix2.sh` ) consists of executing 5 instances of this script.

```bash
#!/bin/bash


./syscall.sh &
./syscall.sh &
./syscall.sh &
./syscall.sh &
./syscall.sh &
wait
```



Figure 5: Observable Round-Robin behaviour

Figure 6: Near the end of execution

We observe round–robin scheduling yet again, with the time quanta not always being fully used. From this, we conclude that `syscall.sh` is less CPU-intensive than `arithoh.sh`. Since CPU-intensive processes don't need to wait for I/O, they don't relinquish the CPU until the end of their time bursts.

## 1.4 Workload Mix 4: Mix of different workloads

Next, let us check how the Minix3 scheduler schedules a fully System call-intensive workload. This workload mix (`workload_mix3.sh`) consists of the following:

```bash
#!/bin/bash


./arithoh.sh &
./fstime.sh &
./syscall.sh &
./arithoh.sh &
./arithoh.sh &
wait
```



Figure 7: Observable Round–Robin behaviour

Figure 8: Near the end of execution



Figure 9: syscall.sh completes first



Figure 10: fstime.sh finishes next

This workload mix consists of `arithoh.sh`, `fstime.sh` and `syscall.sh`. We observe that the processes occur in a round robin fashion, with syscall finishing first, followed by fstime, with all the arithoh finishing at the end. Also, we can see that fstime was sometimes allotted a time quantum of 500, which is more than the usual 200. Since fstime is I/O-bound, it doesn't usually use up entire time slice. Once the other processes are done, the three arithoh processes run in round robin.

# 2 Part II – Pseudo-FIFO implementation

> **Task:** Modify the user-level scheduler in Minix3 to the following "Pseudo-FIFO" policy: among the user-level processes that are ready to execute, the one that entered the earliest must be scheduled. Study how the workloads you prepared are scheduled under the new scheduler. Compare with the original Minix3 scheduler. Discuss your observations.

The changes made to the source code of Minix3 to obtain the desired Pseudo-FIFO execution of processes are as follows:

- In `minix/servers/sched/schedule.c`, the function `do_noquantum()` had a line that was modified as follows:
  **From:** `rmp->priority += 1;`
  **To:** `rmp->priority -= 1;`
  This allows FIFO to happen by lowering the priority value, preventing the incoming process to pre-emptively get time slices for execution.

- In the same file, the function `balance_queues()` was edited to not increase the priority of processes, preventing overflow of priority queue. The commented out line is as follows:
  `// rmp->priority -= 1;`

## 2.1 Workload Mix 1: Completely CPU-Intensive

**Note that: the code in the scripts for these subsections is the same as respective subsections of the previous sections.** In the below screenshots, we observe that the arithoh processes occur serially/sequentially, in the order of endpoint IDs: 33002 → 33003 → 33005 → 33004 → 33006. This is in contrast to the round robin behaviour from earlier. There is no requirement to wait for I/O due to the compute-intensive nature of these processes. Hence, we have obtained a Pseudo-FIFO scheduling behaviour in Minix3.



```
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33002
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33002
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33002
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33002
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33002
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33002
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 114 Endpoint: 33002
Minix: PID 258 exited
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33003
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33003
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33003
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33003
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33003
_
```

Figure 11: 33002 → 33003

```
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33003
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33003
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33003
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33003
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 0 Endpoint: 33003
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 192 Endpoint: 33003
Minix: PID 259 exited
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33005
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33005
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33005
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33005
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33005
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33005
```

Figure 12: 33003 → 33005

```
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33005
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 131 Endpoint: 33005
Minix: PID 261 exited
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 500 Endpoint: 65570
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 500 Endpoint: 65571
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
_
```

Figure 13: 33005 → 33004

```
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33004
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 194 Endpoint: 33004
Minix: PID 260 exited
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33006
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33006
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33006
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33006
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 33006
```

Figure 14: 33004 → 33006

## 2.2   Workload Mix 2: Completely I/O-Intensive

We observe from the below screenshot that FIFO is not followed with fstime, since it is I/O-bound, and is in the blocked state when it requests for I/O. After the I/O call is over, it goes back to the ready queue, and continues execution when it gets the CPU. Thus, this is effectively like round robin. Hence, this case puts the 'Pseudo' into 'Pseudo-FIFO'.

Thus, CPU-intensive jobs in the current policy will execute in a mostly FIFO policy, while the I/O-bound jobs frequently resort to round robin, by exiting and re-entering the ready state, when they wait for then receive I/O.



```
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65594
Minix: PID 313 created
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65595
Minix: PID 314 created
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65596
Minix: PID 315 created
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65597
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 1 Endpoint: 65560
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 14 Endpoint: 65563
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 19 Endpoint: 65564
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 500 Endpoint: 65560
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 53 Endpoint: 65560
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 11 Endpoint: 65563
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 15 Endpoint: 65564

_
```

Figure 15: 'Pseudo' FIFO



```
Time Quantum: 500, Time Quantum Executed: 88 Endpoint: 65560
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 9 Endpoint: 65563
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 11 Endpoint: 65564
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 500 Endpoint: 65560
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65581
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 478 Endpoint: 65560
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 5 Endpoint: 65563
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 7 Endpoint: 65564
Copy done: 1000004 in 5.4500, score 45871
COUNT:45871:0:KBps
TIME:5.5
Minix: PID 299 exited
        28.40 real        0.46 user        4.23 sys
Minix: PID 297 exited
fstime completed
---
Minix: PID 290 exited
```

Figure 16: Near the end of execution

## 2.3 Workload Mix 3: Completely System Call–Intensive

The execution of this workload script is quite similar to that of the arithoh–based CPU-intensive script. This is because syscall is effectively a CPU-intensive process, albeit not as intensive as arithoh. Note that syscall process uses the full CPU burst a lot of the time, and doesn't end up in the round-robin that I/O processes end up doing. Hence, Pseudo–FIFO behaviour has been observed in the scheduling policy after we made modifications to the source code of Minix3, as mentioned at the beginning of the section.

```
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65607
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 0 Endpoint: 65560
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 3 Endpoint: 65563
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 5 Endpoint: 65564
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65607
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 500 Endpoint: 98341
Minix: PID 325 exited
        9.51 real        2.01 user        4.06 sys
Minix: PID 321 exited
syscall completed
---
Minix: PID 317 exited
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65608
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65608
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65608
```

Figure 17: Observable FIFO

```
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65613
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65613
R.No.:2000100+03/12
Time Quantum: 500, Time Quantum Executed: 1 Endpoint: 65560
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 4 Endpoint: 65563
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 5 Endpoint: 65564
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65613
Minix: PID 331 exited
        20.00 real        2.26 user        4.00 sys
Minix: PID 329 exited
syscall completed
---
Minix: PID 322 exited
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65610
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65610
R.No.:2000100+03/12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65610
```

Figure 18: Continued FIFO

Figure 19: Continued FIFO

## 2.4 Workload Mix 4: Mix of different workloads

We can infer from the following screenshots that even though we do have a pseudo-FIFO mechanism, the processes are being executed in such an order that the CPU takes up the CPU-intensive processes at first, which is a set of `arithoh.sh` processes running at the same time.

This is because the I/O-intensive processes get blocked after requesting for I/O. Of course, we do have `syscall.sh` which is a CPU-intensive process as well, but it is not as intensive as arithoh. This is why after executing the arithoh processes (endpoints 65639,42,43) it moves on to the syscall process with endpoint 65641.



Figure 20: Workload 4

```
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65639
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65639
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65639
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 123 Endpoint: 65639
    Minix: PID 360 exited
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65642
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65642
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65642
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65642
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65642
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65642
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65642
    Roll Numbers: 2000100- 03 & 12
    Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65642
```

Figure 21: Continued

```
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65642
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 65 Endpoint: 65642
Minix: PID 363 exited
     10.50 real       21.18 real      10.45 user       10.65 user       0.05 sys
Minix: PID 355 exited
arithoh completed
      0.03Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
_
```

Figure 22: Continued

```
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65643
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 48 Endpoint: 65643
Minix: PID 364 exited
---
 sys
Minix: PID 358 exited
Minix: PID 350 exited
arithoh completed
---
Minix: PID 353 exited
     31.85 real       10.66 user       0.00 sys
Minix: PID 359 exited
arithoh completed
---
Minix: PID 354 exited
```

Figure 23: Continued
```

```
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65641
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65641
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65641
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65641
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65641
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65641
Roll Numbers: 2000100- 03 & 12
Time Quantum: 200, Time Quantum Executed: 200 Endpoint: 65641
Minix: PID 362 exited
        39.98 real         2.85 user         5.26 sys
Minix: PID 357 exited
syscall completed
---
Minix: PID 352 exited
Roll Numbers: 2000100- 03 & 12
Time Quantum: 500, Time Quantum Executed: 500 Endpoint: 65560
Write done: 1008000 in 1.5667, score 160851
COUNT:160851:0:KBps
TIME:1.6

_
```

Figure 24: Continued FIFO