

# 1 Abstract

The Linux Scheduler has been the Completely Fair Scheduler (CFS) for a while now, but is it the most efficient scheduler? That is up for debate. This report will address the pros and cons of each scheduling scheme as well as comparing it to a completely different scheduler. We will show that the Brain Fuck Scheduler (BFS) is far more efficient for everyday personal computing tasks, and much more suited to what Linux home distrobutions should build default with. We will also show that the default scheduling scheme of the CFS is far better than the other real time schemes.

# 2 Introduction

A scheduler is a vital part of any modern operating system. It decides how to efficiently utilize the CPU. This is important in the resource manager view of an operating system, that the OS is only supposed to manage resources. There are three schedulers that I will test, the Completely Fair Scheduler(CFS), also known as `SCHED_OTHER`, the First in First Out(FIFO) scheduler, also known as `SCHED_FIFO`, and the Round Robin(RR) Scheduler, also known as `SCHED_RR`.

Every test was preformed on a Macbook Pro running Ubuntu 12.04 through VMWare Fusion. The VM has 2Gb of RAM, 2 Cores of the Processor, and has hardware virtualization turned on (Intel VT-x). This provided very uniform data that rarely deviated more than a few percentage points.

# 3 Method

The testing code will test three different kinds of programs, CPU bound processes, I/O bound processes, and a mixed combination of these two. The CPU bound process repededly

calculates the product of two prime numbers, then performs a factoring algorithm to find the two prime numbers once again. I did this since this is a common process that a computer might do in real life to, for instance, crack a RSA key. It is also entirely CPU bound. Each individual process has no I/O when measuring total execution time. This code was made using algorithms I found online [1][2]. The I/O bound process will read a line at a time from `/dev/urandom` and write that line to `/dev/null`. This is going to have a comparable effect to reading and writing to any file, a common application in everyday code. The mixed processes combine these two tasks, performing both in an interweaved fashion. This is more representative of your everyday tasks that you run on a computer. Each of these three types of processes are designed so as to use comparable amounts of time on the CPU. Each uses about 0.58 seconds of time where that process is running on the CPU. This way comparing data will be much easier.

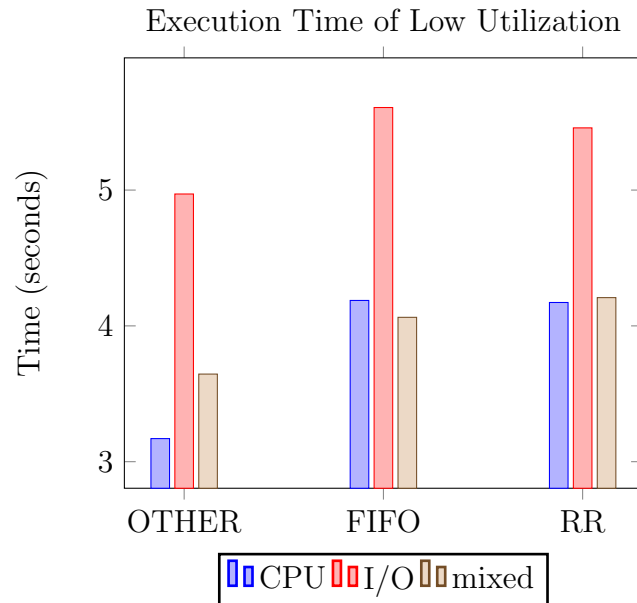
The main code is `pa3.c`. This must be run as root like so: `sudo .`

`pa3 <number of processes> <scheduling scheme> <process type> <test type>`. The number of processes can be any integer. For my tests I consider 10 to be low, 50 to be medium, and 250 to be high. The scheduling scheme can be either `SCHED_OTHER`, `SCHED_FIFO`, or `SCHED_RR`. The process type can be either `cpu`, `io`, or `mixed`. The test type is the desired outcome of the test. In order to get more accurate data, I decided to split up the tests. The test type can be either `extime`, `restime`, or `turntime`. `extime` is the time it takes to execute every process. This is the total time from before the parent process forks each child, to after the parent process has waited for every child. `restime` is the response time of the scheduler. This is the time from when the parent begins to fork each child, until after each individual child has had a chance to begin. `turntime` is the Turnaround time of each process. This is the time from when the process starts to the time when the process ends. All of these parameters are things that a good scheduler would want to minimize.

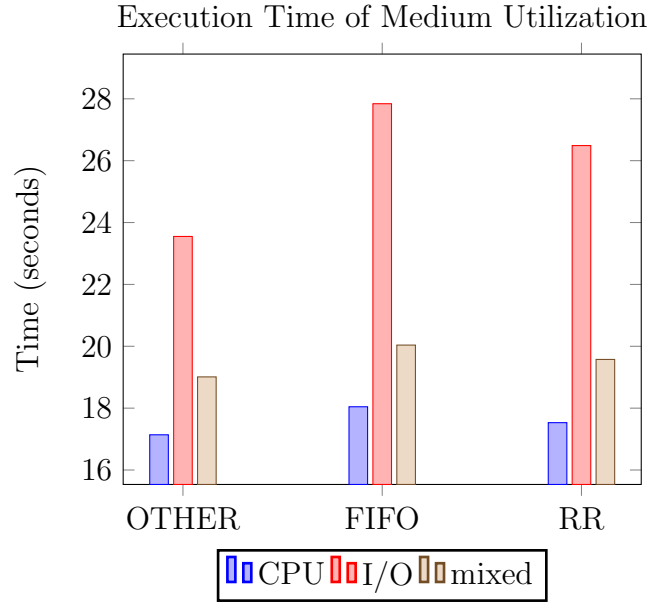
Running the code as listed above will give you a value, or a collection of values, but it is not designed to be run as a standalone test. The shell scripts included will be a much easier and more efficient test. The three shell scripts each run the three tests that can be run, and each returns the results in an easily formatted way. Each shell script will spit out to `stdout` a table in LaTeX formatting that can be easily copied and pasted anywhere it is needed. LaTeX is the standard for most academic articles, and is very easy to generate from a shell script. These scripts will test each level of utilization, each scheduling scheme, and each process type, 10 times, then average out these values. All of this data can be seen in Appendix A. The only alteration to the code that was spit out by the scripts was a few line breaks so as to fit everything on multiple pages.

## 4 Results

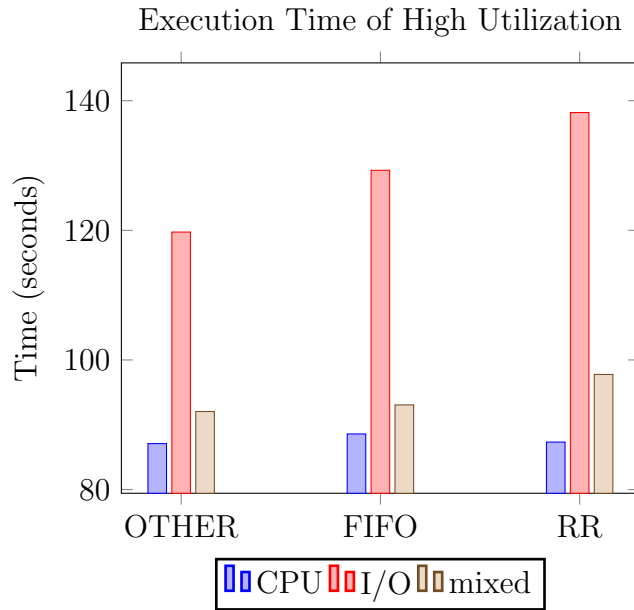
The results from the scripted tests can be fully examined in Appendix A. The averaged values will be explored in this section. This is the Execution time of the processes using Low Utilizations(10 processes):



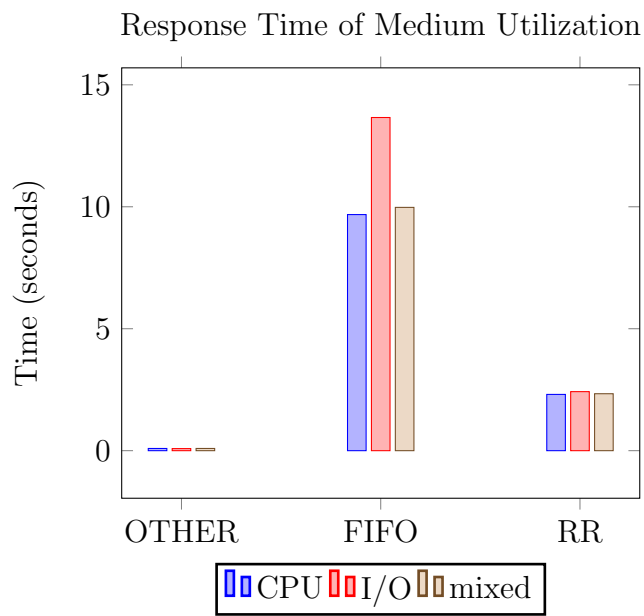
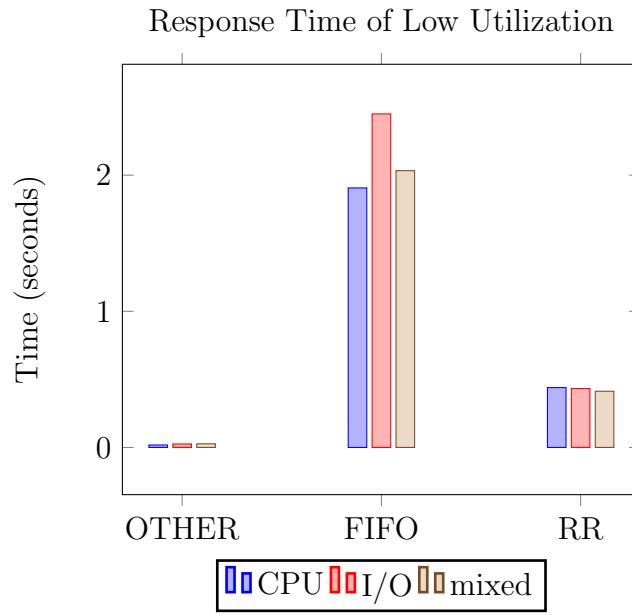
As you can see, the CFS scheduler's default behavior is far more efficient than the other real-time policies in the long run. For a CPU based process, SCHED\_OTHER is by far the fastest. FIFO and RR are relatively equivalent.

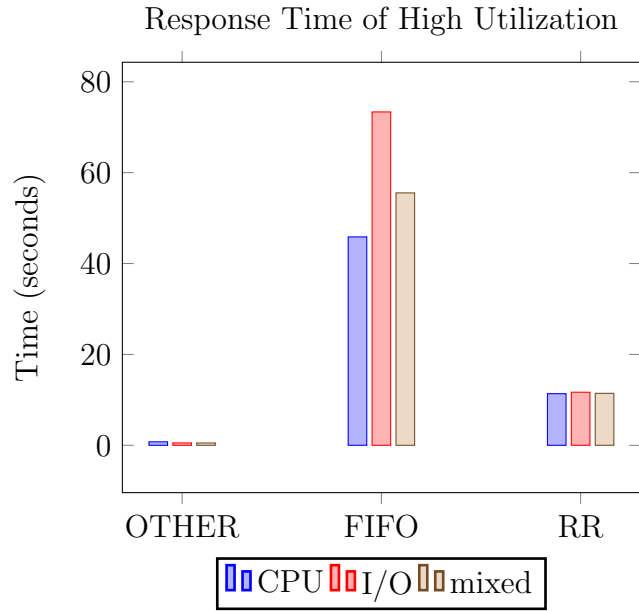


At medium utilization, the benefit of SCHED\_OTHER begins to taper off, and is not so apparent. For mixed processes, the performance is comparable.

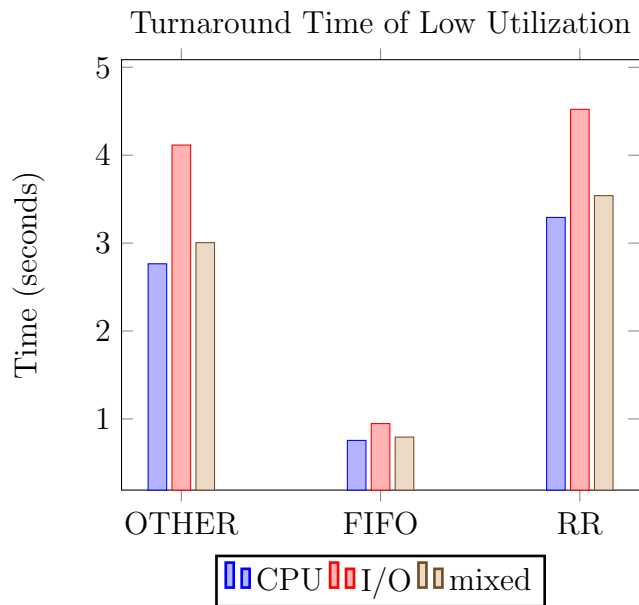


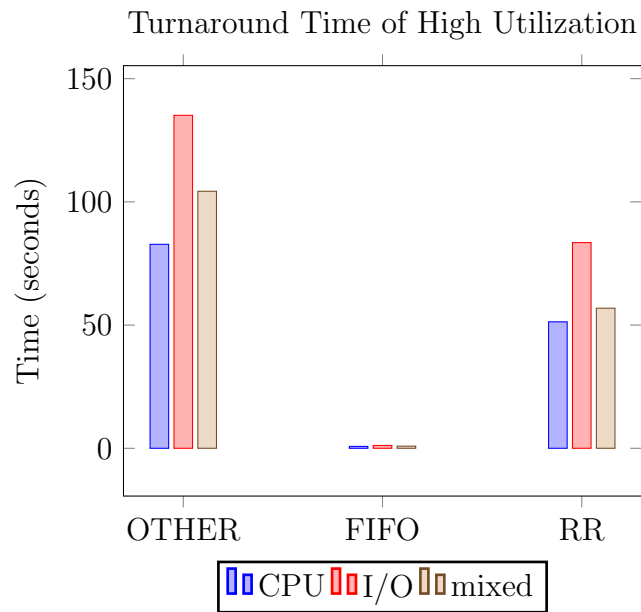
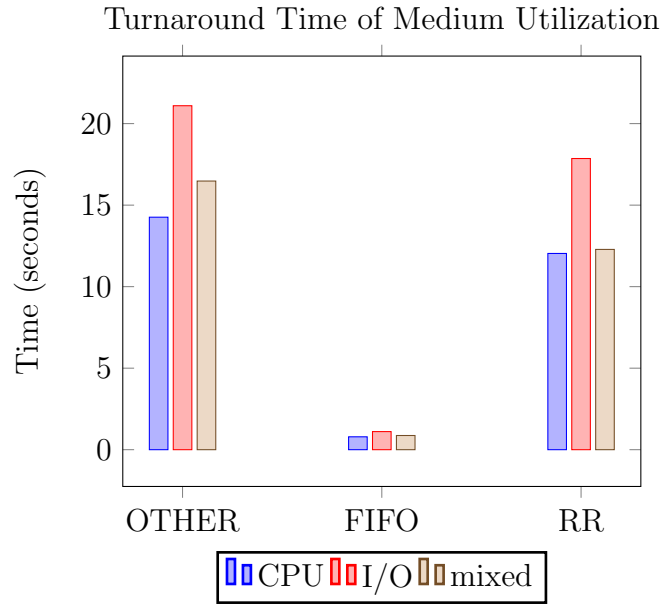
Once again the performance for mixed and cpu bound processes are comparable. An I/O bound program, however, is far faster on SCHED\_OTHER. This is because the process of blocking it, and then moving to the next process becomes much more apparent at high amounts of processes.





The Response time is relatively the same regardless of utilization. SCHED\_OTHER is by far the fastest, but SCHED\_FIFO is by far the slowest. This is what makes sense intuitively, since FIFO will wait until a process is done before beginning on the next one.

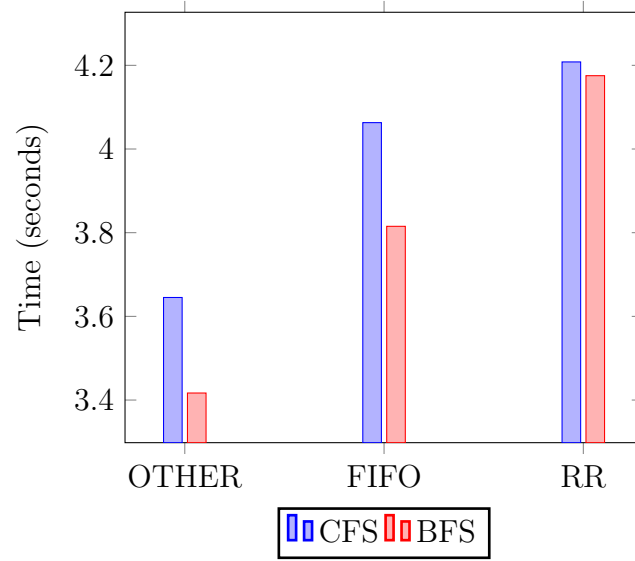




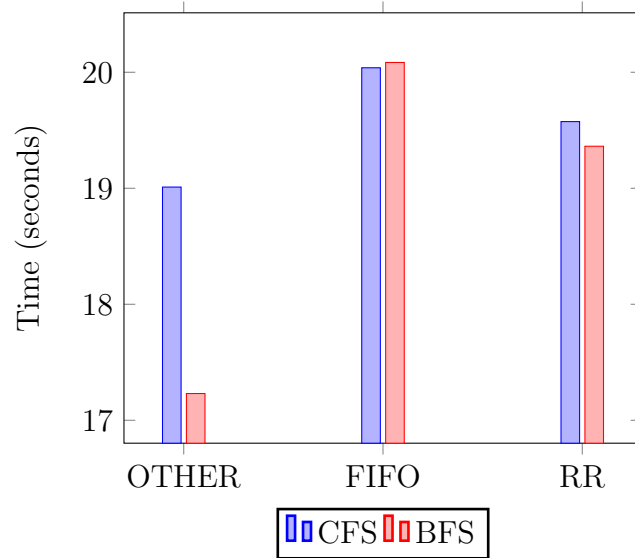
As the amount of processes increases, the turnaround time of FIFO and RR become relatively better to SCHED\_OTHER, which maintains the worst turnaround time.

We can also compare this data to the BFS:

Execution Time of mixed process at Low Utilization

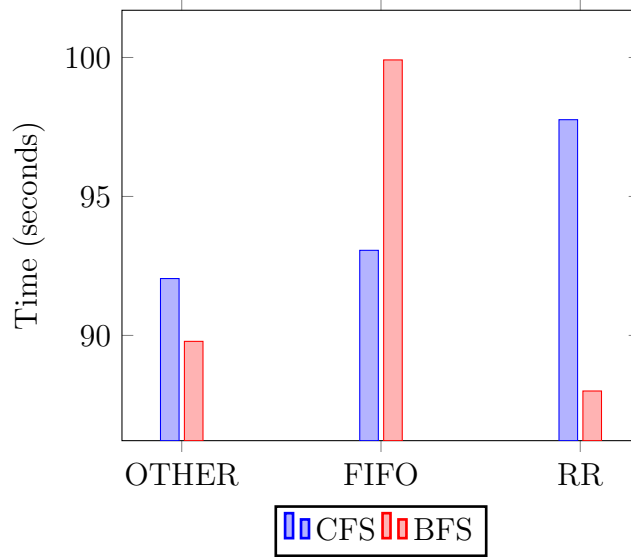


Execution Time of mixed process at Medium Utilization





Execution Time of mixed process at High Utilization



These results are slightly misleading, since I skewed the plots so that they don't start at 0. This makes the differences much more pronounced. Nevertheless, for almost every category, the BFS is much better. This is because it is far simpler, and less overhead is spent in the code of the scheduler itself. For typical programs (mixed), and the default scheduler (OTHER), we can see that the BFS is much more efficient. One thing I noticed, however, is that when I ran the simulations on my CFS scheduler, I could move my mouse around, and maybe open a window. When the BFS scheduler was used, the computer froze to a standstill until the script had finished. I have no idea why this is, but it was very noticeable.

## 5 Analysis

The results begin to paint a picture of what we should use and when. If we are looking to get many things done very quickly, we would be best served by using SCHED\_OTHER. If, however, we want to get one thing done, very quickly, the best scheduler would seem to be FIFO. It all depends on our priorities.

## 6 Conclusion

## 7 References

[1] - [http://en.wikipedia.org/wiki/Fast\\_inverse\\_square\\_root](http://en.wikipedia.org/wiki/Fast_inverse_square_root)

[2] - <http://www.geeksforgeeks.org/print-all-prime-factors-of-a-given-number/>

## 8 Appendix A - Raw Data

### 8.1 Execution Time of CFS

| Schedule    | Utilization | Type  | Trial | Execution Time |
|-------------|-------------|-------|-------|----------------|
| SCHED_OTHER | Low         | cpu   | 1     | 3.113322       |
|             |             |       | 2     | 3.085774       |
|             |             |       | 3     | 3.076218       |
|             |             |       | 4     | 3.060629       |
|             |             |       | 5     | 3.167129       |
|             |             |       | 6     | 3.052559       |
|             |             |       | 7     | 3.073442       |
|             |             |       | 8     | 3.378702       |
|             |             |       | 9     | 3.284676       |
|             |             |       | 10    | 3.409316       |
|             |             |       | avg   | 3.170176       |
| SCHED_OTHER | Low         | io    | 1     | 4.858287       |
|             |             |       | 2     | 5.200969       |
|             |             |       | 3     | 5.428231       |
|             |             |       | 4     | 4.881179       |
|             |             |       | 5     | 4.905814       |
|             |             |       | 6     | 4.968016       |
|             |             |       | 7     | 4.945884       |
|             |             |       | 8     | 4.644300       |
|             |             |       | 9     | 5.012675       |
|             |             |       | 10    | 4.865288       |
|             |             |       | avg   | 4.971064       |
| SCHED_OTHER | Low         | mixed | 1     | 3.585013       |
|             |             |       | 2     | 3.668794       |
|             |             |       | 3     | 3.689240       |
|             |             |       | 4     | 3.600797       |
|             |             |       | 5     | 3.628582       |
|             |             |       | 6     | 3.654732       |
|             |             |       | 7     | 3.635530       |
|             |             |       | 8     | 3.649710       |
|             |             |       | 9     | 3.655495       |
|             |             |       | 10    | 3.683408       |
|             |             |       | avg   | 3.645130       |

| Schedule    | Utilization | Type  | Trial | Execution Time |
|-------------|-------------|-------|-------|----------------|
| SCHED_OTHER | Medium      | cpu   | 1     | 16.546016      |
|             |             |       | 2     | 16.723781      |
|             |             |       | 3     | 16.827731      |
|             |             |       | 4     | 16.770428      |
|             |             |       | 5     | 17.079005      |
|             |             |       | 6     | 17.568007      |
|             |             |       | 7     | 17.338567      |
|             |             |       | 8     | 17.359850      |
|             |             |       | 9     | 17.489747      |
|             |             |       | 10    | 17.679774      |
|             |             |       | avg   | 17.138290      |
| SCHED_OTHER | Medium      | io    | 1     | 23.229726      |
|             |             |       | 2     | 23.032418      |
|             |             |       | 3     | 23.035275      |
|             |             |       | 4     | 24.173956      |
|             |             |       | 5     | 23.249260      |
|             |             |       | 6     | 23.627208      |
|             |             |       | 7     | 23.411219      |
|             |             |       | 8     | 23.826516      |
|             |             |       | 9     | 24.132010      |
|             |             |       | 10    | 23.787340      |
|             |             |       | avg   | 23.550492      |
| SCHED_OTHER | Medium      | mixed | 1     | 17.923470      |
|             |             |       | 2     | 18.240552      |
|             |             |       | 3     | 17.608088      |
|             |             |       | 4     | 18.732967      |
|             |             |       | 5     | 18.818474      |
|             |             |       | 6     | 18.518211      |
|             |             |       | 7     | 18.774386      |
|             |             |       | 8     | 21.456718      |
|             |             |       | 9     | 19.925959      |
|             |             |       | 10    | 20.103890      |
|             |             |       | avg   | 19.010271      |

| Schedule    | Utilization | Type  | Trial | Execution Time |
|-------------|-------------|-------|-------|----------------|
| SCHED_OTHER | High        | cpu   | 1     | 87.915865      |
|             |             |       | 2     | 86.416415      |
|             |             |       | 3     | 83.287822      |
|             |             |       | 4     | 83.467525      |
|             |             |       | 5     | 88.670789      |
|             |             |       | 6     | 90.876241      |
|             |             |       | 7     | 91.918730      |
|             |             |       | 8     | 84.765072      |
|             |             |       | 9     | 86.627548      |
|             |             |       | 10    | 86.983002      |
|             |             |       | avg   | 87.092900      |
| SCHED_OTHER | High        | io    | 1     | 121.480541     |
|             |             |       | 2     | 121.367239     |
|             |             |       | 3     | 119.486197     |
|             |             |       | 4     | 119.011534     |
|             |             |       | 5     | 118.936303     |
|             |             |       | 6     | 119.131862     |
|             |             |       | 7     | 118.061361     |
|             |             |       | 8     | 121.140718     |
|             |             |       | 9     | 118.960390     |
|             |             |       | 10    | 119.760408     |
|             |             |       | avg   | 119.733655     |
| SCHED_OTHER | High        | mixed | 1     | 93.420030      |
|             |             |       | 2     | 91.236862      |
|             |             |       | 3     | 91.372184      |
|             |             |       | 4     | 91.478747      |
|             |             |       | 5     | 91.419111      |
|             |             |       | 6     | 92.016583      |
|             |             |       | 7     | 90.145052      |
|             |             |       | 8     | 93.487565      |
|             |             |       | 9     | 94.055634      |
|             |             |       | 10    | 91.831055      |
|             |             |       | avg   | 92.046282      |

| Schedule   | Utilization | Type  | Trial | Execution Time |
|------------|-------------|-------|-------|----------------|
| SCHED_FIFO | Low         | cpu   | 1     | 4.767669       |
|            |             |       | 2     | 4.232951       |
|            |             |       | 3     | 4.217194       |
|            |             |       | 4     | 4.217439       |
|            |             |       | 5     | 4.230748       |
|            |             |       | 6     | 4.330329       |
|            |             |       | 7     | 3.834218       |
|            |             |       | 8     | 4.058068       |
|            |             |       | 9     | 3.966241       |
|            |             |       | 10    | 4.018254       |
|            |             |       | avg   | 4.187311       |
| SCHED_FIFO | Low         | io    | 1     | 5.741159       |
|            |             |       | 2     | 5.877660       |
|            |             |       | 3     | 5.609448       |
|            |             |       | 4     | 5.110795       |
|            |             |       | 5     | 5.605161       |
|            |             |       | 6     | 5.701053       |
|            |             |       | 7     | 5.698759       |
|            |             |       | 8     | 5.266880       |
|            |             |       | 9     | 5.538235       |
|            |             |       | 10    | 5.928820       |
|            |             |       | avg   | 5.607797       |
| SCHED_FIFO | Low         | mixed | 1     | 3.956731       |
|            |             |       | 2     | 4.341535       |
|            |             |       | 3     | 4.126415       |
|            |             |       | 4     | 4.356061       |
|            |             |       | 5     | 3.914087       |
|            |             |       | 6     | 4.065533       |
|            |             |       | 7     | 4.023859       |
|            |             |       | 8     | 4.067056       |
|            |             |       | 9     | 3.961594       |
|            |             |       | 10    | 3.817489       |
|            |             |       | avg   | 4.063036       |

| Schedule   | Utilization | Type  | Trial | Execution Time |
|------------|-------------|-------|-------|----------------|
| SCHED_FIFO | Medium      | cpu   | 1     | 17.507954      |
|            |             |       | 2     | 18.265287      |
|            |             |       | 3     | 17.984095      |
|            |             |       | 4     | 18.353659      |
|            |             |       | 5     | 17.427843      |
|            |             |       | 6     | 17.686919      |
|            |             |       | 7     | 18.021866      |
|            |             |       | 8     | 18.969621      |
|            |             |       | 9     | 17.487940      |
|            |             |       | 10    | 18.741169      |
|            |             |       | avg   | 18.044635      |
| SCHED_FIFO | Medium      | io    | 1     | 28.380893      |
|            |             |       | 2     | 28.056699      |
|            |             |       | 3     | 27.722469      |
|            |             |       | 4     | 27.918015      |
|            |             |       | 5     | 27.557618      |
|            |             |       | 6     | 27.956404      |
|            |             |       | 7     | 28.168144      |
|            |             |       | 8     | 27.764034      |
|            |             |       | 9     | 27.210386      |
|            |             |       | 10    | 27.678325      |
|            |             |       | avg   | 27.841298      |
| SCHED_FIFO | Medium      | mixed | 1     | 19.873724      |
|            |             |       | 2     | 20.103292      |
|            |             |       | 3     | 20.331504      |
|            |             |       | 4     | 19.724655      |
|            |             |       | 5     | 19.790082      |
|            |             |       | 6     | 20.189537      |
|            |             |       | 7     | 20.268001      |
|            |             |       | 8     | 20.216373      |
|            |             |       | 9     | 19.964954      |
|            |             |       | 10    | 19.924743      |
|            |             |       | avg   | 20.038686      |

| Schedule   | Utilization | Type  | Trial | Execution Time |
|------------|-------------|-------|-------|----------------|
| SCHED_FIFO | High        | cpu   | 1     | 89.850884      |
|            |             |       | 2     | 89.744659      |
|            |             |       | 3     | 89.961705      |
|            |             |       | 4     | 89.349951      |
|            |             |       | 5     | 89.692762      |
|            |             |       | 6     | 90.594082      |
|            |             |       | 7     | 87.831015      |
|            |             |       | 8     | 87.147024      |
|            |             |       | 9     | 86.709310      |
|            |             |       | 10    | 84.953540      |
|            |             |       | avg   | 88.583493      |
| SCHED_FIFO | High        | io    | 1     | 126.372693     |
|            |             |       | 2     | 127.417443     |
|            |             |       | 3     | 128.292543     |
|            |             |       | 4     | 129.334590     |
|            |             |       | 5     | 129.293336     |
|            |             |       | 6     | 128.910176     |
|            |             |       | 7     | 130.221451     |
|            |             |       | 8     | 129.878459     |
|            |             |       | 9     | 131.673224     |
|            |             |       | 10    | 131.214761     |
|            |             |       | avg   | 129.260867     |
| SCHED_FIFO | High        | mixed | 1     | 92.218250      |
|            |             |       | 2     | 93.045968      |
|            |             |       | 3     | 91.826259      |
|            |             |       | 4     | 93.013395      |
|            |             |       | 5     | 92.342805      |
|            |             |       | 6     | 93.398109      |
|            |             |       | 7     | 93.194504      |
|            |             |       | 8     | 94.171661      |
|            |             |       | 9     | 93.371145      |
|            |             |       | 10    | 94.035168      |
|            |             |       | avg   | 93.061726      |



| Schedule | Utilization | Type  | Trial | Execution Time |
|----------|-------------|-------|-------|----------------|
| SCHED_RR | Low         | cpu   | 1     | 4.823887       |
|          |             |       | 2     | 4.144268       |
|          |             |       | 3     | 4.347092       |
|          |             |       | 4     | 4.156300       |
|          |             |       | 5     | 4.160639       |
|          |             |       | 6     | 4.033034       |
|          |             |       | 7     | 4.056237       |
|          |             |       | 8     | 4.008037       |
|          |             |       | 9     | 4.011384       |
|          |             |       | 10    | 3.982087       |
|          |             |       | avg   | 4.172296       |
| SCHED_RR | Low         | io    | 1     | 5.198447       |
|          |             |       | 2     | 6.489720       |
|          |             |       | 3     | 5.499373       |
|          |             |       | 4     | 5.340822       |
|          |             |       | 5     | 5.851695       |
|          |             |       | 6     | 5.234775       |
|          |             |       | 7     | 4.992583       |
|          |             |       | 8     | 5.726227       |
|          |             |       | 9     | 5.142166       |
|          |             |       | 10    | 5.103642       |
|          |             |       | avg   | 5.457945       |
| SCHED_RR | Low         | mixed | 1     | 4.328107       |
|          |             |       | 2     | 4.499245       |
|          |             |       | 3     | 4.350500       |
|          |             |       | 4     | 4.801048       |
|          |             |       | 5     | 3.876172       |
|          |             |       | 6     | 3.925147       |
|          |             |       | 7     | 4.316064       |
|          |             |       | 8     | 3.875015       |
|          |             |       | 9     | 4.164466       |
|          |             |       | 10    | 3.945480       |
|          |             |       | avg   | 4.208124       |

| Schedule | Utilization | Type  | Trial | Execution Time |
|----------|-------------|-------|-------|----------------|
| SCHED_RR | Medium      | cpu   | 1     | 16.857580      |
|          |             |       | 2     | 17.342540      |
|          |             |       | 3     | 18.258574      |
|          |             |       | 4     | 16.647446      |
|          |             |       | 5     | 18.546699      |
|          |             |       | 6     | 17.116629      |
|          |             |       | 7     | 17.041275      |
|          |             |       | 8     | 18.089882      |
|          |             |       | 9     | 17.098960      |
|          |             |       | 10    | 18.305961      |
|          |             |       | avg   | 17.530554      |
| SCHED_RR | Medium      | io    | 1     | 26.414129      |
|          |             |       | 2     | 26.476345      |
|          |             |       | 3     | 26.401803      |
|          |             |       | 4     | 27.046376      |
|          |             |       | 5     | 26.531291      |
|          |             |       | 6     | 26.114130      |
|          |             |       | 7     | 26.550292      |
|          |             |       | 8     | 26.431817      |
|          |             |       | 9     | 26.748029      |
|          |             |       | 10    | 26.171264      |
|          |             |       | avg   | 26.488547      |
| SCHED_RR | Medium      | mixed | 1     | 18.661498      |
|          |             |       | 2     | 19.635452      |
|          |             |       | 3     | 19.520348      |
|          |             |       | 4     | 19.894632      |
|          |             |       | 5     | 20.114134      |
|          |             |       | 6     | 19.728331      |
|          |             |       | 7     | 19.951527      |
|          |             |       | 8     | 19.040728      |
|          |             |       | 9     | 18.179519      |
|          |             |       | 10    | 21.020220      |
|          |             |       | avg   | 19.574638      |

| Schedule | Utilization | Type  | Trial | Execution Time |
|----------|-------------|-------|-------|----------------|
| SCHED_RR | High        | cpu   | 1     | 85.113127      |
|          |             |       | 2     | 86.124189      |
|          |             |       | 3     | 86.252366      |
|          |             |       | 4     | 86.529106      |
|          |             |       | 5     | 86.564893      |
|          |             |       | 6     | 87.501662      |
|          |             |       | 7     | 87.151608      |
|          |             |       | 8     | 88.686935      |
|          |             |       | 9     | 89.373674      |
|          |             |       | 10    | 90.036917      |
|          |             |       | avg   | 87.333447      |
| SCHED_RR | High        | io    | 1     | 139.077522     |
|          |             |       | 2     | 139.556447     |
|          |             |       | 3     | 138.275238     |
|          |             |       | 4     | 138.918804     |
|          |             |       | 5     | 139.911959     |
|          |             |       | 6     | 141.536998     |
|          |             |       | 7     | 138.044715     |
|          |             |       | 8     | 135.848934     |
|          |             |       | 9     | 135.838639     |
|          |             |       | 10    | 134.731781     |
|          |             |       | avg   | 138.174103     |
| SCHED_RR | High        | mixed | 1     | 97.897644      |
|          |             |       | 2     | 96.327284      |
|          |             |       | 3     | 96.395055      |
|          |             |       | 4     | 97.117333      |
|          |             |       | 5     | 97.192371      |
|          |             |       | 6     | 98.868089      |
|          |             |       | 7     | 98.874825      |
|          |             |       | 8     | 99.085297      |
|          |             |       | 9     | 98.512640      |
|          |             |       | 10    | 97.348903      |
|          |             |       | avg   | 97.761944      |

## 8.2 Response Time of CFS

| Schedule    | Utilization | Type  | Trial | Response Time |
|-------------|-------------|-------|-------|---------------|
| SCHED_OTHER | Low         | cpu   | 1     | .029775       |
|             |             |       | 2     | .020091       |
|             |             |       | 3     | .012965       |
|             |             |       | 4     | .023557       |
|             |             |       | 5     | .011803       |
|             |             |       | 6     | .017302       |
|             |             |       | 7     | .010763       |
|             |             |       | 8     | .012556       |
|             |             |       | 9     | .018300       |
|             |             |       | 10    | .022464       |
|             |             |       | avg   | .017957       |
| SCHED_OTHER | Low         | io    | 1     | .025224       |
|             |             |       | 2     | .027931       |
|             |             |       | 3     | .022903       |
|             |             |       | 4     | .018454       |
|             |             |       | 5     | .016182       |
|             |             |       | 6     | .027825       |
|             |             |       | 7     | .025980       |
|             |             |       | 8     | .035748       |
|             |             |       | 9     | .035660       |
|             |             |       | 10    | .019295       |
|             |             |       | avg   | .025520       |
| SCHED_OTHER | Low         | mixed | 1     | .018082       |
|             |             |       | 2     | .035731       |
|             |             |       | 3     | .035565       |
|             |             |       | 4     | .019533       |
|             |             |       | 5     | .021661       |
|             |             |       | 6     | .023291       |
|             |             |       | 7     | .037184       |
|             |             |       | 8     | .025106       |
|             |             |       | 9     | .026795       |
|             |             |       | 10    | .021998       |
|             |             |       | avg   | .026495       |

| Schedule    | Utilization | Type  | Trial | Response Time |
|-------------|-------------|-------|-------|---------------|
| SCHED_OTHER | Medium      | cpu   | 1     | .096281       |
|             |             |       | 2     | .110186       |
|             |             |       | 3     | .087933       |
|             |             |       | 4     | .089371       |
|             |             |       | 5     | .070637       |
|             |             |       | 6     | .089415       |
|             |             |       | 7     | .071433       |
|             |             |       | 8     | .103204       |
|             |             |       | 9     | .106489       |
|             |             |       | 10    | .084033       |
|             |             |       | avg   | .090898       |
| SCHED_OTHER | Medium      | io    | 1     | .084871       |
|             |             |       | 2     | .103185       |
|             |             |       | 3     | .086338       |
|             |             |       | 4     | .073281       |
|             |             |       | 5     | .058578       |
|             |             |       | 6     | .066008       |
|             |             |       | 7     | .089326       |
|             |             |       | 8     | .107627       |
|             |             |       | 9     | .082960       |
|             |             |       | 10    | .107375       |
|             |             |       | avg   | .085955       |
| SCHED_OTHER | Medium      | mixed | 1     | .108302       |
|             |             |       | 2     | .128181       |
|             |             |       | 3     | .088555       |
|             |             |       | 4     | .096712       |
|             |             |       | 5     | .094228       |
|             |             |       | 6     | .068670       |
|             |             |       | 7     | .081678       |
|             |             |       | 8     | .108873       |
|             |             |       | 9     | .081419       |
|             |             |       | 10    | .054916       |
|             |             |       | avg   | .091153       |

| Schedule    | Utilization | Type  | Trial | Response Time |
|-------------|-------------|-------|-------|---------------|
| SCHED_OTHER | High        | cpu   | 1     | 2.493044      |
|             |             |       | 2     | .487741       |
|             |             |       | 3     | .567370       |
|             |             |       | 4     | .598412       |
|             |             |       | 5     | .485264       |
|             |             |       | 6     | .667362       |
|             |             |       | 7     | .596231       |
|             |             |       | 8     | .601163       |
|             |             |       | 9     | .623526       |
|             |             |       | 10    | .490976       |
|             |             |       | avg   | .761109       |
| SCHED_OTHER | High        | io    | 1     | .591600       |
|             |             |       | 2     | .511346       |
|             |             |       | 3     | .518590       |
|             |             |       | 4     | .528305       |
|             |             |       | 5     | .589642       |
|             |             |       | 6     | .460307       |
|             |             |       | 7     | .460874       |
|             |             |       | 8     | .449338       |
|             |             |       | 9     | .418420       |
|             |             |       | 10    | .683177       |
|             |             |       | avg   | .521160       |
| SCHED_OTHER | High        | mixed | 1     | .531096       |
|             |             |       | 2     | .504026       |
|             |             |       | 3     | .508656       |
|             |             |       | 4     | .501507       |
|             |             |       | 5     | .481601       |
|             |             |       | 6     | .558121       |
|             |             |       | 7     | .597610       |
|             |             |       | 8     | .488798       |
|             |             |       | 9     | .478473       |
|             |             |       | 10    | .424585       |
|             |             |       | avg   | .507447       |

| Schedule   | Utilization | Type  | Trial | Response Time |
|------------|-------------|-------|-------|---------------|
| SCHED_FIFO | Low         | cpu   | 1     | 1.788079      |
|            |             |       | 2     | 2.339941      |
|            |             |       | 3     | 1.856832      |
|            |             |       | 4     | 1.859701      |
|            |             |       | 5     | 1.803476      |
|            |             |       | 6     | 1.902196      |
|            |             |       | 7     | 1.829024      |
|            |             |       | 8     | 1.931661      |
|            |             |       | 9     | 1.843469      |
|            |             |       | 10    | 1.907786      |
|            |             |       | avg   | 1.906217      |
| SCHED_FIFO | Low         | io    | 1     | 2.553619      |
|            |             |       | 2     | 2.701657      |
|            |             |       | 3     | 2.406873      |
|            |             |       | 4     | 2.394868      |
|            |             |       | 5     | 2.326282      |
|            |             |       | 6     | 2.609726      |
|            |             |       | 7     | 2.530085      |
|            |             |       | 8     | 2.133407      |
|            |             |       | 9     | 2.549455      |
|            |             |       | 10    | 2.291884      |
|            |             |       | avg   | 2.449786      |
| SCHED_FIFO | Low         | mixed | 1     | 2.403184      |
|            |             |       | 2     | 2.177544      |
|            |             |       | 3     | 1.780954      |
|            |             |       | 4     | 1.729888      |
|            |             |       | 5     | 1.672752      |
|            |             |       | 6     | 2.448211      |
|            |             |       | 7     | 2.345417      |
|            |             |       | 8     | 1.935650      |
|            |             |       | 9     | 1.815883      |
|            |             |       | 10    | 2.020718      |
|            |             |       | avg   | 2.033020      |

| Schedule   | Utilization | Type  | Trial | Response Time |
|------------|-------------|-------|-------|---------------|
| SCHED_FIFO | Medium      | cpu   | 1     | 8.613151      |
|            |             |       | 2     | 9.160897      |
|            |             |       | 3     | 10.484417     |
|            |             |       | 4     | 8.984179      |
|            |             |       | 5     | 9.169944      |
|            |             |       | 6     | 9.057966      |
|            |             |       | 7     | 10.102713     |
|            |             |       | 8     | 10.870018     |
|            |             |       | 9     | 9.769173      |
|            |             |       | 10    | 10.589246     |
|            |             |       | avg   | 9.680170      |
| SCHED_FIFO | Medium      | io    | 1     | 13.748009     |
|            |             |       | 2     | 13.928651     |
|            |             |       | 3     | 13.806987     |
|            |             |       | 4     | 14.222799     |
|            |             |       | 5     | 13.299201     |
|            |             |       | 6     | 13.532180     |
|            |             |       | 7     | 13.262725     |
|            |             |       | 8     | 13.562708     |
|            |             |       | 9     | 13.671614     |
|            |             |       | 10    | 13.564571     |
|            |             |       | avg   | 13.659945     |
| SCHED_FIFO | Medium      | mixed | 1     | 9.592414      |
|            |             |       | 2     | 9.938778      |
|            |             |       | 3     | 10.002375     |
|            |             |       | 4     | 9.617395      |
|            |             |       | 5     | 9.828413      |
|            |             |       | 6     | 10.279999     |
|            |             |       | 7     | 9.671231      |
|            |             |       | 8     | 10.031096     |
|            |             |       | 9     | 10.348455     |
|            |             |       | 10    | 10.441911     |
|            |             |       | avg   | 9.975207      |



| Schedule   | Utilization | Type  | Trial | Response Time |
|------------|-------------|-------|-------|---------------|
| SCHED_FIFO | High        | cpu   | 1     | 45.517253     |
|            |             |       | 2     | 45.354153     |
|            |             |       | 3     | 46.363413     |
|            |             |       | 4     | 46.307296     |
|            |             |       | 5     | 46.163106     |
|            |             |       | 6     | 44.983417     |
|            |             |       | 7     | 45.472608     |
|            |             |       | 8     | 45.936692     |
|            |             |       | 9     | 46.284498     |
|            |             |       | 10    | 46.247824     |
|            |             |       | avg   | 45.863026     |
| SCHED_FIFO | High        | io    | 1     | 70.812604     |
|            |             |       | 2     | 70.728756     |
|            |             |       | 3     | 71.161349     |
|            |             |       | 4     | 72.767261     |
|            |             |       | 5     | 73.285520     |
|            |             |       | 6     | 74.607732     |
|            |             |       | 7     | 73.902446     |
|            |             |       | 8     | 75.820110     |
|            |             |       | 9     | 75.868966     |
|            |             |       | 10    | 74.709167     |
|            |             |       | avg   | 73.366391     |
| SCHED_FIFO | High        | mixed | 1     | 56.389336     |
|            |             |       | 2     | 56.805692     |
|            |             |       | 3     | 55.967300     |
|            |             |       | 4     | 74.243835     |
|            |             |       | 5     | 57.075412     |
|            |             |       | 6     | 51.209485     |
|            |             |       | 7     | 50.081463     |
|            |             |       | 8     | 51.864769     |
|            |             |       | 9     | 50.586947     |
|            |             |       | 10    | 51.266033     |
|            |             |       | avg   | 55.549027     |

| Schedule | Utilization | Type  | Trial | Response Time |
|----------|-------------|-------|-------|---------------|
| SCHED_RR | Low         | cpu   | 1     | .447936       |
|          |             |       | 2     | .448944       |
|          |             |       | 3     | .448219       |
|          |             |       | 4     | .448722       |
|          |             |       | 5     | .451383       |
|          |             |       | 6     | .449617       |
|          |             |       | 7     | .450575       |
|          |             |       | 8     | .388915       |
|          |             |       | 9     | .441489       |
|          |             |       | 10    | .420055       |
|          |             |       | avg   | .439585       |
| SCHED_RR | Low         | io    | 1     | .450547       |
|          |             |       | 2     | .449053       |
|          |             |       | 3     | .441349       |
|          |             |       | 4     | .449703       |
|          |             |       | 5     | .448740       |
|          |             |       | 6     | .434772       |
|          |             |       | 7     | .449258       |
|          |             |       | 8     | .383733       |
|          |             |       | 9     | .451032       |
|          |             |       | 10    | .367309       |
|          |             |       | avg   | .432550       |
| SCHED_RR | Low         | mixed | 1     | .493480       |
|          |             |       | 2     | .447926       |
|          |             |       | 3     | .434324       |
|          |             |       | 4     | .418243       |
|          |             |       | 5     | .413773       |
|          |             |       | 6     | .384451       |
|          |             |       | 7     | .382458       |
|          |             |       | 8     | .396684       |
|          |             |       | 9     | .380458       |
|          |             |       | 10    | .375885       |
|          |             |       | avg   | .412768       |

| Schedule | Utilization | Type  | Trial | Response Time |
|----------|-------------|-------|-------|---------------|
| SCHED_RR | Medium      | cpu   | 1     | 2.326943      |
|          |             |       | 2     | 2.176469      |
|          |             |       | 3     | 2.302464      |
|          |             |       | 4     | 2.359505      |
|          |             |       | 5     | 2.245194      |
|          |             |       | 6     | 2.145829      |
|          |             |       | 7     | 2.345610      |
|          |             |       | 8     | 2.358036      |
|          |             |       | 9     | 2.357245      |
|          |             |       | 10    | 2.452947      |
|          |             |       | avg   | 2.307024      |
| SCHED_RR | Medium      | io    | 1     | 2.564563      |
|          |             |       | 2     | 2.308179      |
|          |             |       | 3     | 2.308199      |
|          |             |       | 4     | 2.665195      |
|          |             |       | 5     | 2.292393      |
|          |             |       | 6     | 2.254763      |
|          |             |       | 7     | 2.253465      |
|          |             |       | 8     | 2.275580      |
|          |             |       | 9     | 2.258530      |
|          |             |       | 10    | 3.026400      |
|          |             |       | avg   | 2.420727      |
| SCHED_RR | Medium      | mixed | 1     | 2.377238      |
|          |             |       | 2     | 2.294038      |
|          |             |       | 3     | 2.451860      |
|          |             |       | 4     | 2.231386      |
|          |             |       | 5     | 2.409059      |
|          |             |       | 6     | 2.398041      |
|          |             |       | 7     | 2.355530      |
|          |             |       | 8     | 2.211466      |
|          |             |       | 9     | 2.411408      |
|          |             |       | 10    | 2.211740      |
|          |             |       | avg   | 2.335176      |

| Schedule | Utilization | Type  | Trial | Response Time |
|----------|-------------|-------|-------|---------------|
| SCHED_RR | High        | cpu   | 1     | 11.082622     |
|          |             |       | 2     | 11.063431     |
|          |             |       | 3     | 11.827796     |
|          |             |       | 4     | 11.499834     |
|          |             |       | 5     | 11.217948     |
|          |             |       | 6     | 11.356375     |
|          |             |       | 7     | 11.504727     |
|          |             |       | 8     | 11.309596     |
|          |             |       | 9     | 11.357104     |
|          |             |       | 10    | 11.362759     |
|          |             |       | avg   | 11.358219     |
| SCHED_RR | High        | io    | 1     | 11.615277     |
|          |             |       | 2     | 11.562313     |
|          |             |       | 3     | 10.917932     |
|          |             |       | 4     | 11.875607     |
|          |             |       | 5     | 11.687035     |
|          |             |       | 6     | 12.915274     |
|          |             |       | 7     | 11.539156     |
|          |             |       | 8     | 11.556079     |
|          |             |       | 9     | 11.434712     |
|          |             |       | 10    | 11.719167     |
|          |             |       | avg   | 11.682255     |
| SCHED_RR | High        | mixed | 1     | 11.480303     |
|          |             |       | 2     | 11.245461     |
|          |             |       | 3     | 11.322383     |
|          |             |       | 4     | 11.409192     |
|          |             |       | 5     | 11.552720     |
|          |             |       | 6     | 11.349232     |
|          |             |       | 7     | 11.545749     |
|          |             |       | 8     | 11.496801     |
|          |             |       | 9     | 11.596514     |
|          |             |       | 10    | 11.393969     |
|          |             |       | avg   | 11.439232     |

### 8.3 Turnaround Time of CFS

| Schedule    | Utilization | Type  | Trial | Turnaround Time |
|-------------|-------------|-------|-------|-----------------|
| SCHED_OTHER | Low         | cpu   | 1     | 2.683808        |
|             |             |       | 2     | 2.845356        |
|             |             |       | 3     | 2.682009        |
|             |             |       | 4     | 2.828021        |
|             |             |       | 5     | 2.814909        |
|             |             |       | 6     | 2.722009        |
|             |             |       | 7     | 2.693313        |
|             |             |       | 8     | 2.655308        |
|             |             |       | 9     | 2.734307        |
|             |             |       | 10    | 2.987498        |
|             |             |       | avg   | 2.764654        |
| SCHED_OTHER | Low         | io    | 1     | 4.259679        |
|             |             |       | 2     | 4.171792        |
|             |             |       | 3     | 4.097003        |
|             |             |       | 4     | 4.002966        |
|             |             |       | 5     | 4.009730        |
|             |             |       | 6     | 4.336636        |
|             |             |       | 7     | 3.947332        |
|             |             |       | 8     | 4.158953        |
|             |             |       | 9     | 3.975034        |
|             |             |       | 10    | 4.193978        |
|             |             |       | avg   | 4.115310        |
| SCHED_OTHER | Low         | mixed | 1     | 3.031443        |
|             |             |       | 2     | 2.914330        |
|             |             |       | 3     | 2.905814        |
|             |             |       | 4     | 3.050252        |
|             |             |       | 5     | 2.994757        |
|             |             |       | 6     | 2.941995        |
|             |             |       | 7     | 3.003292        |
|             |             |       | 8     | 3.097569        |
|             |             |       | 9     | 3.036036        |
|             |             |       | 10    | 3.072483        |
|             |             |       | avg   | 3.004797        |

| Schedule    | Utilization | Type  | Trial | Turnaround Time |
|-------------|-------------|-------|-------|-----------------|
| SCHED_OTHER | Medium      | cpu   | 1     | 14.689355       |
|             |             |       | 2     | 14.708221       |
|             |             |       | 3     | 13.962657       |
|             |             |       | 4     | 13.963776       |
|             |             |       | 5     | 13.574216       |
|             |             |       | 6     | 14.055479       |
|             |             |       | 7     | 14.111121       |
|             |             |       | 8     | 13.976513       |
|             |             |       | 9     | 15.394558       |
|             |             |       | 10    | 14.164990       |
|             |             |       | avg   | 14.260089       |
| SCHED_OTHER | Medium      | io    | 1     | 21.581018       |
|             |             |       | 2     | 21.219423       |
|             |             |       | 3     | 21.166271       |
|             |             |       | 4     | 20.292891       |
|             |             |       | 5     | 20.568618       |
|             |             |       | 6     | 21.253086       |
|             |             |       | 7     | 21.404320       |
|             |             |       | 8     | 21.287798       |
|             |             |       | 9     | 21.154360       |
|             |             |       | 10    | 21.042521       |
|             |             |       | avg   | 21.097031       |
| SCHED_OTHER | Medium      | mixed | 1     | 16.355885       |
|             |             |       | 2     | 16.928453       |
|             |             |       | 3     | 17.744174       |
|             |             |       | 4     | 15.589540       |
|             |             |       | 5     | 15.708228       |
|             |             |       | 6     | 16.656403       |
|             |             |       | 7     | 16.008487       |
|             |             |       | 8     | 17.355543       |
|             |             |       | 9     | 16.342353       |
|             |             |       | 10    | 16.084520       |
|             |             |       | avg   | 16.477359       |

| Schedule    | Utilization | Type  | Trial | Turnaround Time |
|-------------|-------------|-------|-------|-----------------|
| SCHED_OTHER | High        | cpu   | 1     | 74.440989       |
|             |             |       | 2     | 77.096329       |
|             |             |       | 3     | 77.597706       |
|             |             |       | 4     | 80.943882       |
|             |             |       | 5     | 77.195917       |
|             |             |       | 6     | 78.004809       |
|             |             |       | 7     | 84.718553       |
|             |             |       | 8     | 91.611381       |
|             |             |       | 9     | 90.321768       |
|             |             |       | 10    | 95.813024       |
|             |             |       | avg   | 82.774436       |
| SCHED_OTHER | High        | io    | 1     | 138.650437      |
|             |             |       | 2     | 134.465075      |
|             |             |       | 3     | 138.252449      |
|             |             |       | 4     | 144.518427      |
|             |             |       | 5     | 143.772998      |
|             |             |       | 6     | 140.871598      |
|             |             |       | 7     | 128.915328      |
|             |             |       | 8     | 124.283309      |
|             |             |       | 9     | 128.156826      |
|             |             |       | 10    | 129.348439      |
|             |             |       | avg   | 135.123488      |
| SCHED_OTHER | High        | mixed | 1     | 98.930642       |
|             |             |       | 2     | 100.290346      |
|             |             |       | 3     | 97.213620       |
|             |             |       | 4     | 107.413937      |
|             |             |       | 5     | 106.990227      |
|             |             |       | 6     | 106.750659      |
|             |             |       | 7     | 106.587639      |
|             |             |       | 8     | 104.429753      |
|             |             |       | 9     | 107.608186      |
|             |             |       | 10    | 106.846614      |
|             |             |       | avg   | 104.306162      |

| Schedule   | Utilization | Type  | Trial | Turnaround Time |
|------------|-------------|-------|-------|-----------------|
| SCHED_FIFO | Low         | cpu   | 1     | .755385         |
|            |             |       | 2     | .754999         |
|            |             |       | 3     | .760403         |
|            |             |       | 4     | .799779         |
|            |             |       | 5     | .663137         |
|            |             |       | 6     | .729554         |
|            |             |       | 7     | .781372         |
|            |             |       | 8     | .771091         |
|            |             |       | 9     | .815302         |
|            |             |       | 10    | .653374         |
|            |             |       | avg   | .748440         |
| SCHED_FIFO | Low         | io    | 1     | 1.049659        |
|            |             |       | 2     | .824301         |
|            |             |       | 3     | .928255         |
|            |             |       | 4     | 1.111109        |
|            |             |       | 5     | .913183         |
|            |             |       | 6     | 1.029675        |
|            |             |       | 7     | .849404         |
|            |             |       | 8     | .996157         |
|            |             |       | 9     | .788037         |
|            |             |       | 10    | .980059         |
|            |             |       | avg   | .946984         |
| SCHED_FIFO | Low         | mixed | 1     | .712128         |
|            |             |       | 2     | .767637         |
|            |             |       | 3     | .860447         |
|            |             |       | 4     | .821943         |
|            |             |       | 5     | .671969         |
|            |             |       | 6     | .827172         |
|            |             |       | 7     | .815762         |
|            |             |       | 8     | .839716         |
|            |             |       | 9     | .858463         |
|            |             |       | 10    | .755406         |
|            |             |       | avg   | .793064         |



| Schedule   | Utilization | Type  | Trial | Turnaround Time |
|------------|-------------|-------|-------|-----------------|
| SCHED_FIFO | Medium      | cpu   | 1     | .774496         |
|            |             |       | 2     | .776368         |
|            |             |       | 3     | .826651         |
|            |             |       | 4     | .764645         |
|            |             |       | 5     | .793908         |
|            |             |       | 6     | .805739         |
|            |             |       | 7     | .785515         |
|            |             |       | 8     | .768447         |
|            |             |       | 9     | .794304         |
|            |             |       | 10    | .812700         |
|            |             |       | avg   | .790277         |
| SCHED_FIFO | Medium      | io    | 1     | 1.095736        |
|            |             |       | 2     | 1.105379        |
|            |             |       | 3     | 1.117092        |
|            |             |       | 4     | 1.097927        |
|            |             |       | 5     | 1.111461        |
|            |             |       | 6     | 1.096562        |
|            |             |       | 7     | 1.106568        |
|            |             |       | 8     | 1.115655        |
|            |             |       | 9     | 1.121483        |
|            |             |       | 10    | 1.131976        |
|            |             |       | avg   | 1.109984        |
| SCHED_FIFO | Medium      | mixed | 1     | .840144         |
|            |             |       | 2     | .887506         |
|            |             |       | 3     | .867735         |
|            |             |       | 4     | .880707         |
|            |             |       | 5     | .893843         |
|            |             |       | 6     | .856566         |
|            |             |       | 7     | .863410         |
|            |             |       | 8     | .839795         |
|            |             |       | 9     | .899442         |
|            |             |       | 10    | .870925         |
|            |             |       | avg   | .870007         |

| Schedule   | Utilization | Type  | Trial | Turnaround Time |
|------------|-------------|-------|-------|-----------------|
| SCHED_FIFO | High        | cpu   | 1     | .805434         |
|            |             |       | 2     | .807148         |
|            |             |       | 3     | .743464         |
|            |             |       | 4     | .711729         |
|            |             |       | 5     | .724211         |
|            |             |       | 6     | .750403         |
|            |             |       | 7     | .778896         |
|            |             |       | 8     | .778270         |
|            |             |       | 9     | .803921         |
|            |             |       | 10    | .754711         |
|            |             |       | avg   | .765819         |
| SCHED_FIFO | High        | io    | 1     | 1.149876        |
|            |             |       | 2     | 1.138526        |
|            |             |       | 3     | 1.148598        |
|            |             |       | 4     | 1.149755        |
|            |             |       | 5     | 1.138787        |
|            |             |       | 6     | 1.150127        |
|            |             |       | 7     | 1.169862        |
|            |             |       | 8     | 1.154688        |
|            |             |       | 9     | 1.155832        |
|            |             |       | 10    | 1.143194        |
|            |             |       | avg   | 1.149925        |
| SCHED_FIFO | High        | mixed | 1     | .832460         |
|            |             |       | 2     | .841731         |
|            |             |       | 3     | .835322         |
|            |             |       | 4     | .830543         |
|            |             |       | 5     | .847208         |
|            |             |       | 6     | .877371         |
|            |             |       | 7     | .873527         |
|            |             |       | 8     | .903167         |
|            |             |       | 9     | .918748         |
|            |             |       | 10    | .907841         |
|            |             |       | avg   | .866792         |

| Schedule | Utilization | Type  | Trial | Turnaround Time |
|----------|-------------|-------|-------|-----------------|
| SCHED_RR | Low         | cpu   | 1     | 3.958025        |
|          |             |       | 2     | 3.429795        |
|          |             |       | 3     | 3.484253        |
|          |             |       | 4     | 2.892537        |
|          |             |       | 5     | 2.747446        |
|          |             |       | 6     | 2.756412        |
|          |             |       | 7     | 3.198352        |
|          |             |       | 8     | 4.601408        |
|          |             |       | 9     | 2.673358        |
|          |             |       | 10    | 3.177458        |
|          |             |       | avg   | 3.291904        |
| SCHED_RR | Low         | io    | 1     | 3.925899        |
|          |             |       | 2     | 4.962669        |
|          |             |       | 3     | 4.455024        |
|          |             |       | 4     | 3.948698        |
|          |             |       | 5     | 4.751469        |
|          |             |       | 6     | 5.239481        |
|          |             |       | 7     | 4.136852        |
|          |             |       | 8     | 4.822852        |
|          |             |       | 9     | 3.891441        |
|          |             |       | 10    | 5.080505        |
|          |             |       | avg   | 4.521489        |
| SCHED_RR | Low         | mixed | 1     | 4.715432        |
|          |             |       | 2     | 3.564962        |
|          |             |       | 3     | 3.625617        |
|          |             |       | 4     | 3.353560        |
|          |             |       | 5     | 2.840617        |
|          |             |       | 6     | 2.708833        |
|          |             |       | 7     | 3.268703        |
|          |             |       | 8     | 4.318927        |
|          |             |       | 9     | 3.605347        |
|          |             |       | 10    | 3.397312        |
|          |             |       | avg   | 3.539931        |

| Schedule | Utilization | Type  | Trial | Turnaround Time |
|----------|-------------|-------|-------|-----------------|
| SCHED_RR | Medium      | cpu   | 1     | 11.462400       |
|          |             |       | 2     | 11.734749       |
|          |             |       | 3     | 12.011819       |
|          |             |       | 4     | 12.772976       |
|          |             |       | 5     | 12.162775       |
|          |             |       | 6     | 11.767298       |
|          |             |       | 7     | 12.224796       |
|          |             |       | 8     | 12.333258       |
|          |             |       | 9     | 11.858432       |
|          |             |       | 10    | 12.034425       |
|          |             |       | avg   | 12.036293       |
| SCHED_RR | Medium      | io    | 1     | 19.608245       |
|          |             |       | 2     | 17.914993       |
|          |             |       | 3     | 17.439505       |
|          |             |       | 4     | 17.106413       |
|          |             |       | 5     | 18.251606       |
|          |             |       | 6     | 17.584194       |
|          |             |       | 7     | 17.620449       |
|          |             |       | 8     | 16.879894       |
|          |             |       | 9     | 17.812836       |
|          |             |       | 10    | 18.375035       |
|          |             |       | avg   | 17.859317       |
| SCHED_RR | Medium      | mixed | 1     | 12.159948       |
|          |             |       | 2     | 13.158809       |
|          |             |       | 3     | 11.601103       |
|          |             |       | 4     | 12.943573       |
|          |             |       | 5     | 12.350547       |
|          |             |       | 6     | 12.408756       |
|          |             |       | 7     | 11.417541       |
|          |             |       | 8     | 12.087923       |
|          |             |       | 9     | 12.352870       |
|          |             |       | 10    | 12.356233       |
|          |             |       | avg   | 12.283730       |

| Schedule | Utilization | Type  | Trial | Turnaround Time |
|----------|-------------|-------|-------|-----------------|
| SCHED_RR | High        | cpu   | 1     | 50.495704       |
|          |             |       | 2     | 50.720685       |
|          |             |       | 3     | 49.952416       |
|          |             |       | 4     | 49.832446       |
|          |             |       | 5     | 50.255277       |
|          |             |       | 6     | 49.785087       |
|          |             |       | 7     | 50.594825       |
|          |             |       | 8     | 50.501449       |
|          |             |       | 9     | 52.983516       |
|          |             |       | 10    | 58.054662       |
|          |             |       | avg   | 51.317607       |
| SCHED_RR | High        | io    | 1     | 87.252550       |
|          |             |       | 2     | 81.615423       |
|          |             |       | 3     | 83.300093       |
|          |             |       | 4     | 83.825166       |
|          |             |       | 5     | 85.502920       |
|          |             |       | 6     | 83.471720       |
|          |             |       | 7     | 81.217935       |
|          |             |       | 8     | 82.323837       |
|          |             |       | 9     | 82.956598       |
|          |             |       | 10    | 83.187958       |
|          |             |       | avg   | 83.465420       |
| SCHED_RR | High        | mixed | 1     | 57.912147       |
|          |             |       | 2     | 56.021378       |
|          |             |       | 3     | 56.234628       |
|          |             |       | 4     | 56.355909       |
|          |             |       | 5     | 57.286122       |
|          |             |       | 6     | 56.541501       |
|          |             |       | 7     | 56.492660       |
|          |             |       | 8     | 55.772067       |
|          |             |       | 9     | 57.732711       |
|          |             |       | 10    | 58.141057       |
|          |             |       | avg   | 56.849018       |

## 8.4 Execution Time of BFS

| Schedule    | Utilization | Type  | Trial | Execution Time |
|-------------|-------------|-------|-------|----------------|
| SCHED_OTHER | Low         | cpu   | 1     | 3.050476       |
|             |             |       | 2     | 3.105130       |
|             |             |       | 3     | 3.078327       |
|             |             |       | 4     | 3.111985       |
|             |             |       | 5     | 3.128143       |
|             |             |       | 6     | 3.072700       |
|             |             |       | 7     | 3.107441       |
|             |             |       | 8     | 3.127176       |
|             |             |       | 9     | 3.106832       |
|             |             |       | 10    | 3.114357       |
|             |             |       | avg   | 3.100256       |
| SCHED_OTHER | Low         | io    | 1     | 3.161187       |
|             |             |       | 2     | 3.276934       |
|             |             |       | 3     | 3.276495       |
|             |             |       | 4     | 3.244901       |
|             |             |       | 5     | 3.236139       |
|             |             |       | 6     | 3.419036       |
|             |             |       | 7     | 3.299788       |
|             |             |       | 8     | 3.315823       |
|             |             |       | 9     | 3.453758       |
|             |             |       | 10    | 3.222414       |
|             |             |       | avg   | 3.290647       |
| SCHED_OTHER | Low         | mixed | 1     | 3.541285       |
|             |             |       | 2     | 3.428980       |
|             |             |       | 3     | 3.375245       |
|             |             |       | 4     | 3.481335       |
|             |             |       | 5     | 3.417114       |
|             |             |       | 6     | 3.373077       |
|             |             |       | 7     | 3.560955       |
|             |             |       | 8     | 3.301487       |
|             |             |       | 9     | 3.403257       |
|             |             |       | 10    | 3.285314       |
|             |             |       | avg   | 3.416804       |

| Schedule    | Utilization | Type  | Trial | Execution Time |
|-------------|-------------|-------|-------|----------------|
| SCHED_OTHER | Medium      | cpu   | 1     | 15.854477      |
|             |             |       | 2     | 15.775794      |
|             |             |       | 3     | 16.113107      |
|             |             |       | 4     | 16.058427      |
|             |             |       | 5     | 15.878714      |
|             |             |       | 6     | 15.972906      |
|             |             |       | 7     | 15.832716      |
|             |             |       | 8     | 15.961680      |
|             |             |       | 9     | 15.678609      |
|             |             |       | 10    | 15.545405      |
|             |             |       | avg   | 15.867183      |
| SCHED_OTHER | Medium      | io    | 1     | 17.012918      |
|             |             |       | 2     | 16.836760      |
|             |             |       | 3     | 17.089329      |
|             |             |       | 4     | 16.745066      |
|             |             |       | 5     | 16.586207      |
|             |             |       | 6     | 16.539349      |
|             |             |       | 7     | 16.790100      |
|             |             |       | 8     | 16.909341      |
|             |             |       | 9     | 16.703020      |
|             |             |       | 10    | 16.975618      |
|             |             |       | avg   | 16.818770      |
| SCHED_OTHER | Medium      | mixed | 1     | 17.014851      |
|             |             |       | 2     | 16.993121      |
|             |             |       | 3     | 17.196389      |
|             |             |       | 4     | 17.469941      |
|             |             |       | 5     | 17.101072      |
|             |             |       | 6     | 17.552146      |
|             |             |       | 7     | 16.945087      |
|             |             |       | 8     | 17.633391      |
|             |             |       | 9     | 16.845377      |
|             |             |       | 10    | 17.552058      |
|             |             |       | avg   | 17.230343      |

| Schedule    | Utilization | Type  | Trial | Execution Time |
|-------------|-------------|-------|-------|----------------|
| SCHED_OTHER | High        | cpu   | 1     | 81.506915      |
|             |             |       | 2     | 81.078191      |
|             |             |       | 3     | 81.831499      |
|             |             |       | 4     | 81.617476      |
|             |             |       | 5     | 81.191212      |
|             |             |       | 6     | 82.032392      |
|             |             |       | 7     | 82.423082      |
|             |             |       | 8     | 81.816409      |
|             |             |       | 9     | 81.994060      |
|             |             |       | 10    | 82.027391      |
|             |             |       | avg   | 81.751862      |
| SCHED_OTHER | High        | io    | 1     | 87.236685      |
|             |             |       | 2     | 87.129539      |
|             |             |       | 3     | 87.374060      |
|             |             |       | 4     | 87.170068      |
|             |             |       | 5     | 88.693243      |
|             |             |       | 6     | 88.014258      |
|             |             |       | 7     | 88.741125      |
|             |             |       | 8     | 90.818835      |
|             |             |       | 9     | 87.281841      |
|             |             |       | 10    | 91.109499      |
|             |             |       | avg   | 88.356915      |
| SCHED_OTHER | High        | mixed | 1     | 87.804176      |
|             |             |       | 2     | 90.809356      |
|             |             |       | 3     | 90.282483      |
|             |             |       | 4     | 89.473266      |
|             |             |       | 5     | 88.344753      |
|             |             |       | 6     | 91.236950      |
|             |             |       | 7     | 89.821557      |
|             |             |       | 8     | 90.263133      |
|             |             |       | 9     | 90.136362      |
|             |             |       | 10    | 89.690332      |
|             |             |       | avg   | 89.786236      |



| Schedule   | Utilization | Type  | Trial | Execution Time |
|------------|-------------|-------|-------|----------------|
| SCHED_FIFO | Low         | cpu   | 1     | 3.603275       |
|            |             |       | 2     | 3.630984       |
|            |             |       | 3     | 3.328510       |
|            |             |       | 4     | 3.239451       |
|            |             |       | 5     | 3.319335       |
|            |             |       | 6     | 3.645505       |
|            |             |       | 7     | 3.565032       |
|            |             |       | 8     | 3.699188       |
|            |             |       | 9     | 3.547206       |
|            |             |       | 10    | 3.498191       |
|            |             |       | avg   | 3.507667       |
| SCHED_FIFO | Low         | io    | 1     | 3.855346       |
|            |             |       | 2     | 3.549734       |
|            |             |       | 3     | 3.627153       |
|            |             |       | 4     | 4.265454       |
|            |             |       | 5     | 3.287910       |
|            |             |       | 6     | 3.496590       |
|            |             |       | 7     | 3.488063       |
|            |             |       | 8     | 3.627615       |
|            |             |       | 9     | 3.575925       |
|            |             |       | 10    | 3.454624       |
|            |             |       | avg   | 3.622841       |
| SCHED_FIFO | Low         | mixed | 1     | 4.010396       |
|            |             |       | 2     | 3.776258       |
|            |             |       | 3     | 3.809140       |
|            |             |       | 4     | 3.682535       |
|            |             |       | 5     | 3.825809       |
|            |             |       | 6     | 3.794203       |
|            |             |       | 7     | 3.991235       |
|            |             |       | 8     | 3.783310       |
|            |             |       | 9     | 3.666232       |
|            |             |       | 10    | 3.813138       |
|            |             |       | avg   | 3.815225       |

| Schedule   | Utilization | Type  | Trial | Execution Time |
|------------|-------------|-------|-------|----------------|
| SCHED_FIFO | Medium      | cpu   | 1     | 16.099366      |
|            |             |       | 2     | 16.560516      |
|            |             |       | 3     | 17.403689      |
|            |             |       | 4     | 17.275705      |
|            |             |       | 5     | 17.252448      |
|            |             |       | 6     | 17.453940      |
|            |             |       | 7     | 17.315604      |
|            |             |       | 8     | 17.208000      |
|            |             |       | 9     | 17.230861      |
|            |             |       | 10    | 17.827863      |
|            |             |       | avg   | 17.162799      |
| SCHED_FIFO | Medium      | io    | 1     | 18.511190      |
|            |             |       | 2     | 18.600525      |
|            |             |       | 3     | 17.960715      |
|            |             |       | 4     | 18.218530      |
|            |             |       | 5     | 19.705208      |
|            |             |       | 6     | 18.967103      |
|            |             |       | 7     | 20.284493      |
|            |             |       | 8     | 19.574449      |
|            |             |       | 9     | 19.029583      |
|            |             |       | 10    | 19.326024      |
|            |             |       | avg   | 19.017782      |
| SCHED_FIFO | Medium      | mixed | 1     | 18.318534      |
|            |             |       | 2     | 20.533580      |
|            |             |       | 3     | 19.587665      |
|            |             |       | 4     | 20.397149      |
|            |             |       | 5     | 19.140760      |
|            |             |       | 6     | 20.275054      |
|            |             |       | 7     | 21.039787      |
|            |             |       | 8     | 19.772468      |
|            |             |       | 9     | 19.912595      |
|            |             |       | 10    | 21.865973      |
|            |             |       | avg   | 20.084356      |

| Schedule   | Utilization | Type  | Trial | Execution Time |
|------------|-------------|-------|-------|----------------|
| SCHED_FIFO | High        | cpu   | 1     | 90.071385      |
|            |             |       | 2     | 83.504283      |
|            |             |       | 3     | 81.979106      |
|            |             |       | 4     | 89.597640      |
|            |             |       | 5     | 86.297950      |
|            |             |       | 6     | 85.765636      |
|            |             |       | 7     | 86.016167      |
|            |             |       | 8     | 91.791243      |
|            |             |       | 9     | 91.438396      |
|            |             |       | 10    | 90.323764      |
|            |             |       | avg   | 87.678557      |
| SCHED_FIFO | High        | io    | 1     | 92.470460      |
|            |             |       | 2     | 92.916520      |
|            |             |       | 3     | 94.023782      |
|            |             |       | 4     | 97.198504      |
|            |             |       | 5     | 99.477202      |
|            |             |       | 6     | 100.750224     |
|            |             |       | 7     | 98.028396      |
|            |             |       | 8     | 98.231702      |
|            |             |       | 9     | 95.970876      |
|            |             |       | 10    | 97.929062      |
|            |             |       | avg   | 96.699672      |
| SCHED_FIFO | High        | mixed | 1     | 95.383766      |
|            |             |       | 2     | 97.113729      |
|            |             |       | 3     | 98.592690      |
|            |             |       | 4     | 97.826817      |
|            |             |       | 5     | 101.060273     |
|            |             |       | 6     | 98.028809      |
|            |             |       | 7     | 102.005094     |
|            |             |       | 8     | 107.865629     |
|            |             |       | 9     | 102.945106     |
|            |             |       | 10    | 98.300617      |
|            |             |       | avg   | 99.912253      |

| Schedule | Utilization | Type  | Trial | Execution Time |
|----------|-------------|-------|-------|----------------|
| SCHED_RR | Low         | cpu   | 1     | 3.875441       |
|          |             |       | 2     | 3.456891       |
|          |             |       | 3     | 3.716245       |
|          |             |       | 4     | 3.632656       |
|          |             |       | 5     | 4.092471       |
|          |             |       | 6     | 3.589672       |
|          |             |       | 7     | 3.718323       |
|          |             |       | 8     | 4.163718       |
|          |             |       | 9     | 3.367274       |
|          |             |       | 10    | 3.466300       |
|          |             |       | avg   | 3.707899       |
| SCHED_RR | Low         | io    | 1     | 4.363085       |
|          |             |       | 2     | 3.845227       |
|          |             |       | 3     | 3.849536       |
|          |             |       | 4     | 3.926205       |
|          |             |       | 5     | 4.651334       |
|          |             |       | 6     | 3.840403       |
|          |             |       | 7     | 3.772023       |
|          |             |       | 8     | 3.743614       |
|          |             |       | 9     | 3.817757       |
|          |             |       | 10    | 4.012979       |
|          |             |       | avg   | 3.982216       |
| SCHED_RR | Low         | mixed | 1     | 4.482845       |
|          |             |       | 2     | 3.816849       |
|          |             |       | 3     | 3.759525       |
|          |             |       | 4     | 3.789929       |
|          |             |       | 5     | 4.787760       |
|          |             |       | 6     | 3.872292       |
|          |             |       | 7     | 4.217242       |
|          |             |       | 8     | 4.237890       |
|          |             |       | 9     | 4.368774       |
|          |             |       | 10    | 4.419292       |
|          |             |       | avg   | 4.175239       |

| Schedule | Utilization | Type  | Trial | Execution Time |
|----------|-------------|-------|-------|----------------|
| SCHED_RR | Medium      | cpu   | 1     | 17.863797      |
|          |             |       | 2     | 18.405668      |
|          |             |       | 3     | 17.942015      |
|          |             |       | 4     | 18.098654      |
|          |             |       | 5     | 18.205578      |
|          |             |       | 6     | 18.036021      |
|          |             |       | 7     | 17.373177      |
|          |             |       | 8     | 17.408317      |
|          |             |       | 9     | 18.033012      |
|          |             |       | 10    | 18.178475      |
|          |             |       | avg   | 17.954471      |
| SCHED_RR | Medium      | io    | 1     | 19.890356      |
|          |             |       | 2     | 19.251160      |
|          |             |       | 3     | 19.313216      |
|          |             |       | 4     | 19.431954      |
|          |             |       | 5     | 20.594353      |
|          |             |       | 6     | 18.939111      |
|          |             |       | 7     | 19.515339      |
|          |             |       | 8     | 19.725853      |
|          |             |       | 9     | 19.108904      |
|          |             |       | 10    | 21.803579      |
|          |             |       | avg   | 19.757382      |
| SCHED_RR | Medium      | mixed | 1     | 19.751690      |
|          |             |       | 2     | 19.820719      |
|          |             |       | 3     | 19.630981      |
|          |             |       | 4     | 19.106144      |
|          |             |       | 5     | 19.783981      |
|          |             |       | 6     | 19.119501      |
|          |             |       | 7     | 18.734108      |
|          |             |       | 8     | 19.155539      |
|          |             |       | 9     | 19.770186      |
|          |             |       | 10    | 18.749857      |
|          |             |       | avg   | 19.362270      |

| Schedule | Utilization | Type  | Trial | Execution Time |
|----------|-------------|-------|-------|----------------|
| SCHED_RR | High        | cpu   | 1     | 87.506789      |
|          |             |       | 2     | 87.421710      |
|          |             |       | 3     | 87.176070      |
|          |             |       | 4     | 86.753762      |
|          |             |       | 5     | 86.289147      |
|          |             |       | 6     | 86.712578      |
|          |             |       | 7     | 88.071883      |
|          |             |       | 8     | 88.145742      |
|          |             |       | 9     | 87.507202      |
|          |             |       | 10    | 86.917228      |
|          |             |       | avg   | 87.250211      |
| SCHED_RR | High        | io    | 1     | 92.310844      |
|          |             |       | 2     | 96.490035      |
|          |             |       | 3     | 96.744996      |
|          |             |       | 4     | 98.010646      |
|          |             |       | 5     | 93.521493      |
|          |             |       | 6     | 101.165408     |
|          |             |       | 7     | 96.391161      |
|          |             |       | 8     | 96.584936      |
|          |             |       | 9     | 98.482611      |
|          |             |       | 10    | 100.098232     |
|          |             |       | avg   | 96.980036      |
| SCHED_RR | High        | mixed | 1     | 86.986053      |
|          |             |       | 2     | 85.614611      |
|          |             |       | 3     | 86.193241      |
|          |             |       | 4     | 87.799907      |
|          |             |       | 5     | 87.891323      |
|          |             |       | 6     | 86.403160      |
|          |             |       | 7     | 89.352697      |
|          |             |       | 8     | 88.573268      |
|          |             |       | 9     | 90.956802      |
|          |             |       | 10    | 90.227689      |
|          |             |       | avg   | 87.999875      |

## 9 Appendix B - Description of Files

pa3.c - This is the test code that will evaluate the performance of the various scheduling mechanisms. Usage will be printed if the function is called with incorrect parameters, or you can read this document for usage.

pa3.pdf - This is the thing you are reading right now.

pa3.tex - This is the code that generated this report.

extime.sh - The script that will test the execution time of all schedulers.

restime.sh - The script that will test response time.

turntime.sh - the script that will test turnaround time.

Makefile - this will compile the c code. The entire process is as follows: make, then run a script, then read stdout.