3.1/3.2. We test these two parts together for simpler presentation. We make the CPU run one loop in two tests, for 100000000 times and 200000000 times respectively. We can observe that our implementation recorded the total CPU usage correctly. See the test results in Figure 1. Then, we run two processes in one execution. We can see that the total CPU usages were recorded correctly as well. See the results in Figure 2 (since these two processes were executed simultaneously, their test outputs are mixed together. However, even then we could observe that the CPU usages were recorded properly).

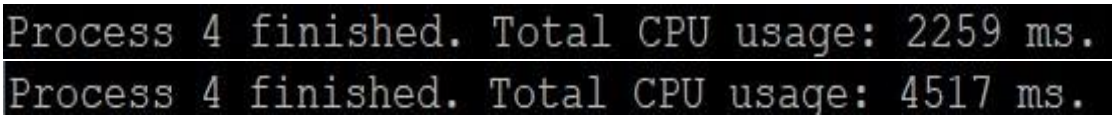

Figure 1

Figure 2

3.3. We resume a starved process (with low priority 1) first, and run a loop in the main process immediately. We can see that the starved process did not start running until the main process was no longer occupying the processor after about 2 seconds. See the test results in Figure 3.

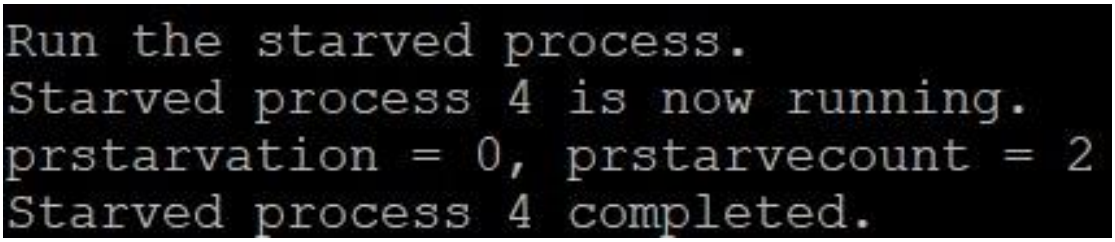

Figure 3

3.4. We resume a process with lower priority than the main process like before, and run a loop for each process. We can see that the mean response time for the lower-priority process is exactly how long the lower-priority process has been waiting. See the test results in Figure 4.

Figure 4

4.5.2A. We run the tests following the requirements of benchmark A. To generate more readable results (preventing them from mixing together), I added different small delays for each process to proceed to output (so they actually have the same clkcounterfine value if we consider that). As predicted, they have similar CPU usages and average response time, and no starvation has occurred. See the test results in Figure 5.

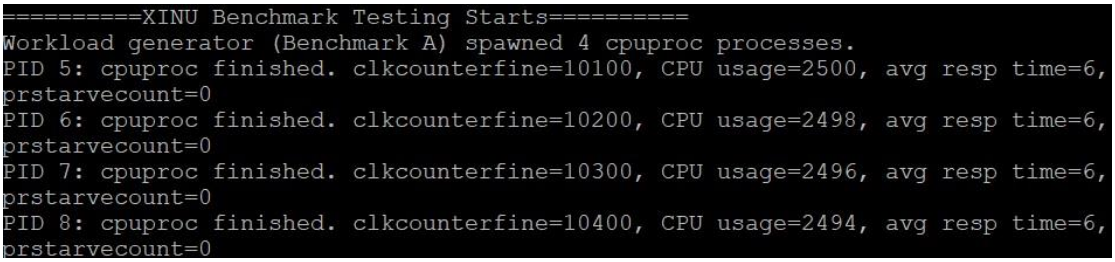

Figure 5

4.5.2B. We run the tests following the requirements of benchmark B. As we can see, they also have similar CPU usages (0) and average response time, and no starvation has occurred. See the test results in Figure 6.

```
==========XINU Benchmark Testing Starts==========
Workload generator (Benchmark B) spawned 4 ioproc processes.
PID 5: ioproc finished. clkcounterfine=10109, CPU usage=0, avg resp time=5034,
 prstarvecount=0
PID 6: ioproc finished. clkcounterfine=10209, CPU usage=0, avg resp time=5035,
 prstarvecount=0
PID 7: ioproc finished. clkcounterfine=10309, CPU usage=0, avg resp time=5035,
 prstarvecount=0
PID 8: ioproc finished. clkcounterfine=10409, CPU usage=0, avg resp time=5036,
 prstarvecount=0
```

Figure 6

4.5.2C. We run the tests following the requirements of benchmark C. As we can see, the CPU usage was mainly occupied by cpuproc as expected. The average response time for cpuproc is short, while the average response time for ioproc is long. This is also expected since ioproc does minimal computations and has comparatively long sleep time. No starvation has occurred either. See the test results in Figure 7.

```
==========XINU Benchmark Testing Starts==========
Workload generator (Benchmark C) spawned 2 cpuproc and 2 ioproc processes.
PID 5: cpuproc finished. clkcounterfine=10100, CPU usage=4994, avg resp time=2
, prstarvecount=0
PID 6: cpuproc finished. clkcounterfine=10200, CPU usage=4991, avg resp time=2
, prstarvecount=0
PID 7: ioproc finished. clkcounterfine=10318, CPU usage=0, avg resp time=5044,
 prstarvecount=0
PID 8: ioproc finished. clkcounterfine=10422, CPU usage=0, avg resp time=5049,
 prstarvecount=0
```

Figure 7

4.5.2D. We run the tests following the requirements of benchmark D. However, the starvation prevention mechanism in 4.4 did not seem to be effective. When it was enabled (Figure 9), we got more starvation counts than disabled (Figure 8). See the test results in Figure 8 and 9 next page.

Bonus. To achieve this goal, we add brief sleeps in between the computations done by rogue, in order to “cheat” the scheduler with an apparent CPU usage lower than actual usage. See the test results in Figure 10.

```
==========XINU Benchmark Testing Starts==========
Workload generator (Bonus) spawned 4 cpuproc and 1 rogue processes.
PID 5: cpuproc finished. clkcounterfine=10102, CPU usage=2003, avg resp time=8, prstarvecount=0
PID 6: cpuproc finished. clkcounterfine=10202, CPU usage=2000, avg resp time=8, prstarvecount=0
PID 7: cpuproc finished. clkcounterfine=10302, CPU usage=1998, avg resp time=8, prstarvecount=0
PID 8: cpuproc finished. clkcounterfine=10400, CPU usage=1994, avg resp time=8, prstarvecount=0
PID 9: rogue finished. clkcounterfine=13060, CPU usage=2391, avg resp time=13, prstarvecount=0
```

Figure 10

```
==========XINU Benchmark Testing Starts==========
Skewed hybrid workload generator: spawned 50 ioproc and 2 cpuproc processes.
PID 5: ioproc finished. clkcounterfine=10109, CPU usage=0, avg resp time=5034, prstarvecount=0
PID 6: ioproc finished. clkcounterfine=10227, CPU usage=0, avg resp time=1237, prstarvecount=0
PID 7: ioproc finished. clkcounterfine=10310, CPU usage=0, avg resp time=5036, prstarvecount=0
PID 8: ioproc finished. clkcounterfine=10410, CPU usage=0, avg resp time=5037, prstarvecount=0
PID 9: ioproc finished. clkcounterfine=10512, CPU usage=0, avg resp time=4954, prstarvecount=0
PID 10: ioproc finished. clkcounterfine=10611, CPU usage=0, avg resp time=5039, prstarvecount=0
PID 11: ioproc finished. clkcounterfine=10713, CPU usage=0, avg resp time=4907, prstarvecount=0
PID 12: ioproc finished. clkcounterfine=10819, CPU usage=0, avg resp time=4350, prstarvecount=0
PID 13: ioproc finished. clkcounterfine=10914, CPU usage=0, avg resp time=4908, prstarvecount=0
PID 14: ioproc finished. clkcounterfine=11037, CPU usage=12, avg resp time=2741, prstarvecount=0
PID 15: ioproc finished. clkcounterfine=11115, CPU usage=0, avg resp time=4765, prstarvecount=0
PID 16: ioproc finished. clkcounterfine=11222, CPU usage=1, avg resp time=2293, prstarvecount=0
PID 17: ioproc finished. clkcounterfine=11316, CPU usage=0, avg resp time=4766, prstarvecount=0
PID 18: ioproc finished. clkcounterfine=11418, CPU usage=0, avg resp time=4421, prstarvecount=0
PID 19: ioproc finished. clkcounterfine=11517, CPU usage=1, avg resp time=4767, prstarvecount=0
PID 20: ioproc finished. clkcounterfine=11621, CPU usage=1, avg resp time=4264, prstarvecount=0
PID 21: ioproc finished. clkcounterfine=11732, CPU usage=14, avg resp time=3637, prstarvecount=0
PID 22: ioproc finished. clkcounterfine=11820, CPU usage=1, avg resp time=4379, prstarvecount=0
PID 23: ioproc finished. clkcounterfine=11946, CPU usage=11, avg resp time=2828, prstarvecount=0
PID 24: ioproc finished. clkcounterfine=12024, CPU usage=5, avg resp time=4317, prstarvecount=0
PID 25: ioproc finished. clkcounterfine=12129, CPU usage=4, avg resp time=3167, prstarvecount=0
PID 26: ioproc finished. clkcounterfine=12222, CPU usage=1, avg resp time=4248, prstarvecount=0
PID 27: ioproc finished. clkcounterfine=12328, CPU usage=1, avg resp time=4146, prstarvecount=0
PID 28: ioproc finished. clkcounterfine=12427, CPU usage=1, avg resp time=2879, prstarvecount=0
PID 29: ioproc finished. clkcounterfine=12531, CPU usage=5, avg resp time=3031, prstarvecount=0
PID 30: ioproc finished. clkcounterfine=12645, CPU usage=4, avg resp time=795, prstarvecount=0
PID 31: ioproc finished. clkcounterfine=12730, CPU usage=0, avg resp time=3051, prstarvecount=0
PID 32: ioproc finished. clkcounterfine=12841, CPU usage=6, avg resp time=2591, prstarvecount=0
PID 33: ioproc finished. clkcounterfine=12926, CPU usage=1, avg resp time=4586, prstarvecount=0
PID 34: ioproc finished. clkcounterfine=13048, CPU usage=6, avg resp time=1143, prstarvecount=0
PID 35: ioproc finished. clkcounterfine=13123, CPU usage=0, avg resp time=5063, prstarvecount=0
PID 36: ioproc finished. clkcounterfine=13248, CPU usage=4, avg resp time=2234, prstarvecount=0
PID 37: ioproc finished. clkcounterfine=13325, CPU usage=1, avg resp time=4249, prstarvecount=0
PID 38: ioproc finished. clkcounterfine=13433, CPU usage=0, avg resp time=1162, prstarvecount=0
PID 39: ioproc finished. clkcounterfine=13535, CPU usage=4, avg resp time=3619, prstarvecount=0
PID 40: ioproc finished. clkcounterfine=13634, CPU usage=7, avg resp time=3999, prstarvecount=0
PID 41: ioproc finished. clkcounterfine=13736, CPU usage=1, avg resp time=4545, prstarvecount=0
PID 42: ioproc finished. clkcounterfine=13840, CPU usage=8, avg resp time=3098, prstarvecount=0
PID 43: ioproc finished. clkcounterfine=13947, CPU usage=5, avg resp time=1241, prstarvecount=0
PID 44: ioproc finished. clkcounterfine=14042, CPU usage=6, avg resp time=3033, prstarvecount=0
PID 45: ioproc finished. clkcounterfine=14145, CPU usage=8, avg resp time=2426, prstarvecount=0
PID 46: ioproc finished. clkcounterfine=14233, CPU usage=0, avg resp time=3791, prstarvecount=0
PID 47: ioproc finished. clkcounterfine=14343, CPU usage=5, avg resp time=2522, prstarvecount=0
PID 48: ioproc finished. clkcounterfine=14439, CPU usage=2, avg resp time=4114, prstarvecount=0
PID 49: ioproc finished. clkcounterfine=14547, CPU usage=4, avg resp time=2566, prstarvecount=0
PID 50: ioproc finished. clkcounterfine=14644, CPU usage=2, avg resp time=1361, prstarvecount=0
PID 51: ioproc finished. clkcounterfine=14749, CPU usage=4, avg resp time=1255, prstarvecount=0
PID 52: ioproc finished. clkcounterfine=14838, CPU usage=1, avg resp time=2977, prstarvecount=0
PID 53: ioproc finished. clkcounterfine=14932, CPU usage=0, avg resp time=5081, prstarvecount=0
PID 54: ioproc finished. clkcounterfine=15034, CPU usage=1, avg resp time=4647, prstarvecount=0
PID 55: cpuproc finished. clkcounterfine=15100, CPU usage=4921, avg resp time=2, prstarvecount=0
PID 56: cpuproc finished. clkcounterfine=15200, CPU usage=4908, avg resp time=2, prstarvecount=0
```

Figure 8

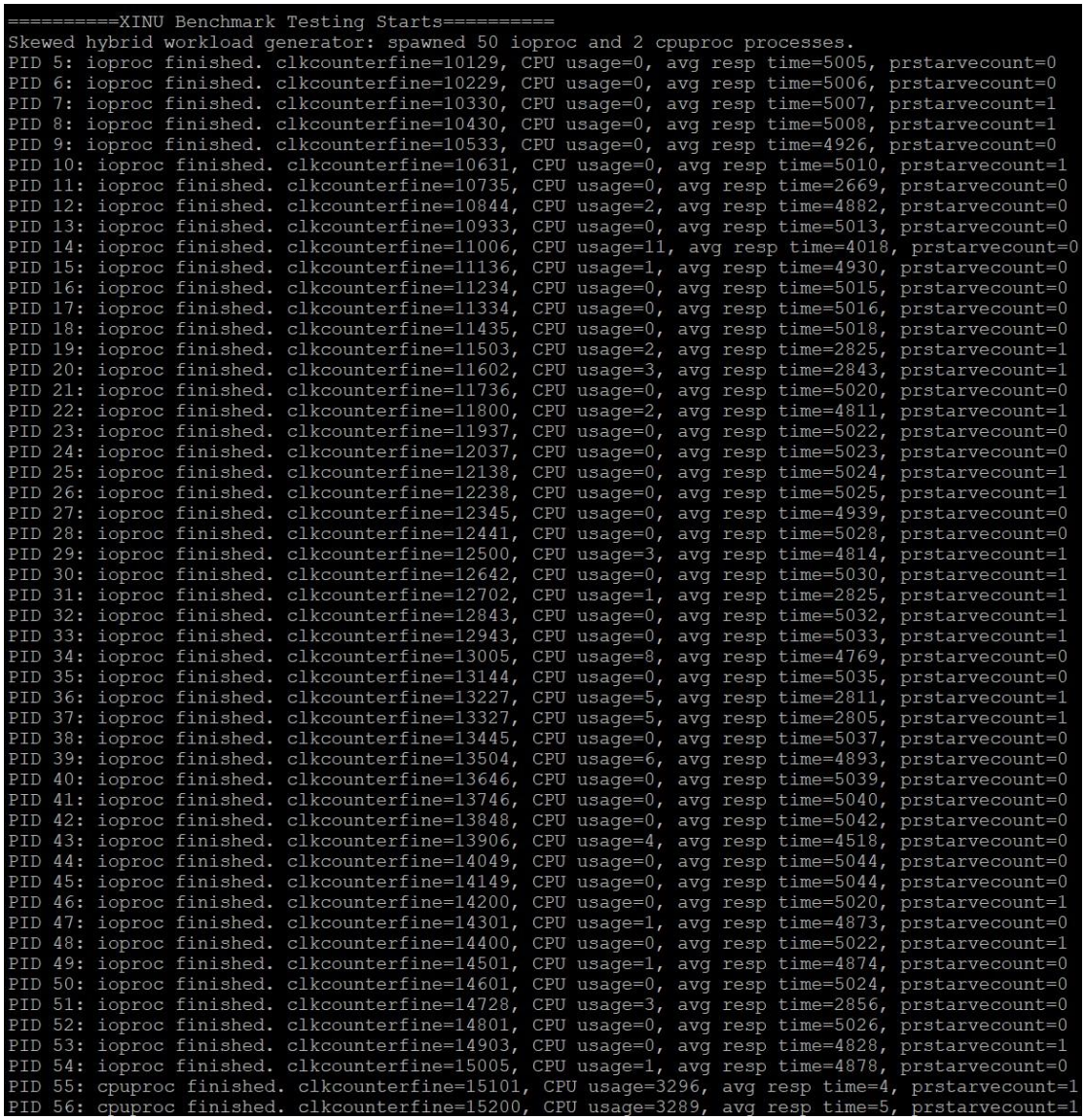
==========XINU Benchmark Testing Starts==========
Skewed hybrid workload generator: spawned 50 ioproc and 2 cpuproc processes.
PID 5: ioproc finished. clkcounterfine=10129, CPU usage=0, avg resp time=5005, prstarvecount=0
PID 6: ioproc finished. clkcounterfine=10229, CPU usage=0, avg resp time=5006, prstarvecount=0
PID 7: ioproc finished. clkcounterfine=10330, CPU usage=0, avg resp time=5007, prstarvecount=1
PID 8: ioproc finished. clkcounterfine=10430, CPU usage=0, avg resp time=5008, prstarvecount=1
PID 9: ioproc finished. clkcounterfine=10533, CPU usage=0, avg resp time=4926, prstarvecount=0
PID 10: ioproc finished. clkcounterfine=10631, CPU usage=0, avg resp time=5010, prstarvecount=1
PID 11: ioproc finished. clkcounterfine=10735, CPU usage=0, avg resp time=2669, prstarvecount=0
PID 12: ioproc finished. clkcounterfine=10844, CPU usage=2, avg resp time=4882, prstarvecount=0
PID 13: ioproc finished. clkcounterfine=10933, CPU usage=0, avg resp time=5013, prstarvecount=0
PID 14: ioproc finished. clkcounterfine=11006, CPU usage=11, avg resp time=4018, prstarvecount=0
PID 15: ioproc finished. clkcounterfine=11136, CPU usage=1, avg resp time=4930, prstarvecount=0
PID 16: ioproc finished. clkcounterfine=11234, CPU usage=0, avg resp time=5015, prstarvecount=0
PID 17: ioproc finished. clkcounterfine=11334, CPU usage=0, avg resp time=5016, prstarvecount=0
PID 18: ioproc finished. clkcounterfine=11435, CPU usage=0, avg resp time=5018, prstarvecount=0
PID 19: ioproc finished. clkcounterfine=11503, CPU usage=2, avg resp time=2825, prstarvecount=1
PID 20: ioproc finished. clkcounterfine=11602, CPU usage=3, avg resp time=2843, prstarvecount=1
PID 21: ioproc finished. clkcounterfine=11736, CPU usage=0, avg resp time=5020, prstarvecount=0
PID 22: ioproc finished. clkcounterfine=11800, CPU usage=2, avg resp time=4811, prstarvecount=1
PID 23: ioproc finished. clkcounterfine=11937, CPU usage=0, avg resp time=5022, prstarvecount=0
PID 24: ioproc finished. clkcounterfine=12037, CPU usage=0, avg resp time=5023, prstarvecount=0
PID 25: ioproc finished. clkcounterfine=12138, CPU usage=0, avg resp time=5024, prstarvecount=1
PID 26: ioproc finished. clkcounterfine=12238, CPU usage=0, avg resp time=5025, prstarvecount=1
PID 27: ioproc finished. clkcounterfine=12345, CPU usage=0, avg resp time=4939, prstarvecount=0
PID 28: ioproc finished. clkcounterfine=12441, CPU usage=0, avg resp time=5028, prstarvecount=0
PID 29: ioproc finished. clkcounterfine=12500, CPU usage=3, avg resp time=4814, prstarvecount=1
PID 30: ioproc finished. clkcounterfine=12642, CPU usage=0, avg resp time=5030, prstarvecount=1
PID 31: ioproc finished. clkcounterfine=12702, CPU usage=1, avg resp time=2825, prstarvecount=1
PID 32: ioproc finished. clkcounterfine=12843, CPU usage=0, avg resp time=5032, prstarvecount=1
PID 33: ioproc finished. clkcounterfine=12943, CPU usage=0, avg resp time=5033, prstarvecount=1
PID 34: ioproc finished. clkcounterfine=13005, CPU usage=8, avg resp time=4769, prstarvecount=0
PID 35: ioproc finished. clkcounterfine=13144, CPU usage=0, avg resp time=5035, prstarvecount=0
PID 36: ioproc finished. clkcounterfine=13227, CPU usage=5, avg resp time=2811, prstarvecount=1
PID 37: ioproc finished. clkcounterfine=13327, CPU usage=5, avg resp time=2805, prstarvecount=1
PID 38: ioproc finished. clkcounterfine=13445, CPU usage=0, avg resp time=5037, prstarvecount=0
PID 39: ioproc finished. clkcounterfine=13504, CPU usage=6, avg resp time=4893, prstarvecount=0
PID 40: ioproc finished. clkcounterfine=13646, CPU usage=0, avg resp time=5039, prstarvecount=0
PID 41: ioproc finished. clkcounterfine=13746, CPU usage=0, avg resp time=5040, prstarvecount=0
PID 42: ioproc finished. clkcounterfine=13848, CPU usage=0, avg resp time=5042, prstarvecount=0
PID 43: ioproc finished. clkcounterfine=13906, CPU usage=4, avg resp time=4518, prstarvecount=0
PID 44: ioproc finished. clkcounterfine=14049, CPU usage=0, avg resp time=5044, prstarvecount=0
PID 45: ioproc finished. clkcounterfine=14149, CPU usage=0, avg resp time=5044, prstarvecount=0
PID 46: ioproc finished. clkcounterfine=14200, CPU usage=0, avg resp time=5020, prstarvecount=1
PID 47: ioproc finished. clkcounterfine=14301, CPU usage=1, avg resp time=4873, prstarvecount=0
PID 48: ioproc finished. clkcounterfine=14400, CPU usage=0, avg resp time=5022, prstarvecount=1
PID 49: ioproc finished. clkcounterfine=14501, CPU usage=1, avg resp time=4874, prstarvecount=0
PID 50: ioproc finished. clkcounterfine=14601, CPU usage=0, avg resp time=5024, prstarvecount=0
PID 51: ioproc finished. clkcounterfine=14728, CPU usage=3, avg resp time=2856, prstarvecount=0
PID 52: ioproc finished. clkcounterfine=14801, CPU usage=0, avg resp time=5026, prstarvecount=0
PID 53: ioproc finished. clkcounterfine=14903, CPU usage=0, avg resp time=4828, prstarvecount=1
PID 54: ioproc finished. clkcounterfine=15005, CPU usage=1, avg resp time=4878, prstarvecount=0
PID 55: cpuproc finished. clkcounterfine=15101, CPU usage=3296, avg resp time=4, prstarvecount=1
PID 56: cpuproc finished. clkcounterfine=15200, CPU usage=3289, avg resp time=5, prstarvecount=1

Figure 9