COEN 241 Cloud Computing

HW1 Report

Yujie Zhu

W1607481

Table of Contents:

Detailed Configuration:

Qemu Configuration:

- 2 Cpu Cores, 2G Memory
- 4 Cpu Cores, 2G Memory
- 2 Cpu Cores, 4G Memory

Docker Configuration:

- 2 Cpu Cores, 2G Memory
- 4 Cpu Cores, 2G Memory
- 2 Cpu Cores, 4G Memory

Other non-specified configurations are set as default

This configuration is to set 2 Cores, 2G memory as a default benchmark and test how doubling CPU/memory can impact performance.

Enabling Qemu vm:

Host OS: macOS Monterey 12.2.1

Platform: Apple Silicon M1 Pro

Qemu was install by brew:

```
brew install qemu
```

Qemu version: 6.2.0_1

Create disk for Qemu:

```
/opt/homebrew/bin/qemu0img create ubuntu.img 10G -f qcow2
```

Check shell archetecture:

```
arch

>arm64
```

Download ubuntu iso file: ubuntu-20.04.4-live-server-arm64.iso

Run Qemu with ISO file in cdrom to install Ubuntu:

```
-device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic

/opt/homebrew/bin/qemu-system-aarch64 \

-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2048 -smp 2 \

-drive file=/opt/homebrew/Cellar/qemu/6.2.0_1/share/qemu/edk2-
aarch64-code.fd,if=pflash,format=raw,readonly=on \

-drive if=none,file=ubuntu.img,format=qcow2,id=hd0 \

-device virtio-blk-device,drive=hd0,serial="dummyserial" \

-device virtio-net-device,netdev=net0 \

-netdev user,id=net0 \

-vga none -device ramfb \

-cdrom ubuntu-20.04.4-live-server-arm64.iso \
```

```
    -device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic
```

Finish installing Ubuntu from CLI and shutdown.

Run Qemu with 2 Cores, 2G memory:

```
    /opt/homebrew/bin/qemu-system-aarch64 \
    -accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2048 -smp 2 \
    -drive file=/opt/homebrew/Cellar/qemu/6.2.0_1/share/qemu/edk2-aarch64-code.fd,if=pflash,format=raw,readonly=on \
    -drive if=none,file=ubuntu.img,format=qcow2,id=hd0 \
    -device virtio-blk-device,drive=hd0,serial="dummyserial" \
    -device virtio-net-device,netdev=net0 \
    -netdev user,id=net0 \
    -vga none -device ramfb \
    -device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic
```

Run Qemu with 4 Cores, 2G memory:

```
    /opt/homebrew/bin/qemu-system-aarch64 \
    -accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2048 -smp 4 \
    -drive file=/opt/homebrew/Cellar/qemu/6.2.0_1/share/qemu/edk2-aarch64-code.fd,if=pflash,format=raw,readonly=on \
    -drive if=none,file=ubuntu.img,format=qcow2,id=hd0 \
    -device virtio-blk-device,drive=hd0,serial="dummyserial" \
    -device virtio-net-device,netdev=net0 \
    -netdev user,id=net0 \
    -vga none -device ramfb \
    -device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic
```

Run Qemu with 2 Cores, 4G memory:

```
/opt/homebrew/bin/qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 4096 -smp 2 \
-drive file=/opt/homebrew/Cellar/qemu/6.2.0_1/share/qemu/edk2-aarch64-code.fd,if=pflash,format=raw,readonly=on \
-drive if=none,file=ubuntu.img,format=qcow2,id=hd0 \
-device virtio-blk-device,drive=hd0,serial="dummyserial" \
-device virtio-net-device,netdev=net0 \
-netdev user,id=net0 \
-vga none -device ramfb \
-device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic
```

Enabling Docker container:

Host OS: macOS Monterey 12.2.1

Platform: Apple Silicon M1 Pro

Docker native is not available on Apple Silicon platform, so docker is enabled by using docker desktop

Install docker desktop:

```
brew install --cask docker
```

Start docker daemon:

```
open /Applications/Docker.app
```

Download and run sysbench:

```
docker run --rm -it --cpus="2" --memory=2048m --entrypoint /bin/sh zyclonite/sysbench
```

Create test file in docker:

```
touch cpu-test.sh
```

```
touch io-test.sh
```

Paste in test automation scripts using vi

Commit current docker process into my own image:

```
docker commit <container ID> my_sysbench
```

Run docker with 2 Cores, 2G memory:

```
docker run --rm -it --cpus="2" --memory=2048m --entrypoint /bin/sh my_sysbench
```

Run docker with 4 Cores, 2G memory:

```
docker run --rm -it --cpus="4" --memory=2048m --entrypoint /bin/sh my_sysbench
```

Run docker with 2 Cores, 4G memory:

```
docker run --rm -it --cpus="2" --memory=4096m --entrypoint /bin/sh my_sysbench
```

Other docker operations that are useful:

Check running docker containers:

```
docker ps
```

Check local docker images:

```
docker images
```

Commit a container to a images:

```
docker commit <container ID> <images_name>
```

Clean up:

```
docker system prune
```

Proof of Experiment:

Please see appendix (at the end of this report) for screenshots of this experiment.

Measurement methodology:

Experiments for both techonologies (Qemu and Docker) are conducted in the same approach:

Frist, the environment is started with 2 CPU cores and 2G memory. Both tests (cpu-test.sh and io-test.sh) are conducted 5 times each and record the data. These data are used as a benchmark.

Secondly, the enviroment is shutdown and restarted with 4 CPU cores and 2G memory. Both tests (cpu-test.sh and io-test.sh) are conducted 5 times each and record the data. These data will be compared to the benchmark data to see how doubling CPU cores will impact test results.

Finally, the enviroment is shutdown and restarted with 2 CPU cores and 4G memory. Both tests (cpu-test.sh and io-test.sh) are conducted 5 times each and record the data. These data will be compared to the benchmark data to see how doubling memory will impact test results.

For io test:

Overally there are 60 test conducted:

- Qemu (2 CPU cores, 2G memory)
  - 5 cpu tests, 5 io tests
- Qemu (4 CPU cores, 2G memory)
  - 5 cpu tests, 5 io tests

- Qemu (2 CPU cores, 4G memory)
  - 5 cpu tests, 5 io tests
- Docker (2 CPU cores, 2G memory)
  - 5 cpu tests, 5 io tests
- Docker (4 CPU cores, 2G memory)
  - 5 cpu tests, 5 io tests
- Docker (2 CPU cores, 4G memory)
  - 5 cpu tests, 5 io tests

Shell Script:

Shell scripts are also included in the same folder of this report as seperate files.

Shell scripts are design to run tests automatically, they should be running inside virtual enviroment. That is to say, qemu/docker container should be started first, then run these scripts on a shell inside qemu/docker.

cpu-test.sh

```
#!/bin/sh
sysbench --test=cpu --cpu-max-prime=200000 --time=30 run
```

io-test.sh

```
#!/bin/sh
sysbench --num-threads=16 --test=fileio --file-total-size=3G --file-test-mode=rndrw prepare
sysbench --num-threads=16 --test=fileio --file-total-size=3G --file-test-mode=rndrw --time=30 run
sysbench --num-threads=16 --test=fileio --file-total-size=3G --file-test-mode=rndrw cleanup
sudo sh -c "/usr/bin/echo 3 > /proc/sys/vm/drop_caches"
```

Before running these scripts for testing, we need to change their permission for them to be executable:

```
sudo chmod 777 io-test.sh
sudo chmod 777 cpu-test.sh
```

Data Collection:

CPU test:

Max prime number is set to 200000, so that it's not too small that the test finishes in seconds and not to big that never stops, time is set to 30 to insure the test runs long enough and won't run forever. Since time is set to exactly 30s, events per second data will be used to compare CPU performance. Also, kernel-level utilization and user-level utilization are recorded. They are calculated by kernel-level CPU utilization during test minus kernel-level CPU utilization while idle and user-level CPU utilization during test minus user-level CPU utilization while idle, respectively. In other words:

kernel-level utilization = (kernel-level CPU utilization during test) - (kernel-level CPU utilization while idle)

user-level utilization = (user-level CPU utilization during test) - (user-level CPU utilization while idle)

Data collected: events per second, kernel-level CPU utilization, user-level CPU utilization

IO test:

Total file size is set to 3G, so that it's not too small that the test finishes in seconds and not to big that eats up all vm spaces, time is set to 30 to insure the test runs long enough.

Dick utilization is collected from host OS using activity monitor.

For latency, an average latency is taken for it's value.

For throughput, both read (MB/s) and write(MB/s) are recoded.

Data collected: read (MB/s), write(MB/s), latency, disk utilization

Data Presentation and Analysis:

CPU test												
	events per second				kernel-level CPU utilization				user-level CPU utilization			
	avg	max	min	std	avg	max	min	std	avg	max	min	std
Qemu (2CPU, 2G)	189.5	190.6	188.01	0.942	17.07%	18.27%	15.15%	0.013	8.96%	20.61%	3.07%	0.082
Qemu (4CPU, 2G)	190.3	191.4	189.45	0.741	15.28%	17.54%	13.52%	0.017	2.82%	5.76%	0.73%	0.019
Qemu (2CPU, 4G)	191	192.18	188.85	1.37	17.75%	19.95%	15.87%	0.015	9.37%	18.93%	5.44%	0.055
Docker (2CPU, 2G)	171.8	173.9	169.6	1.788	18.01%	20.00%	15.05%	0.018	5.06%	7.75%	1.43%	0.025
Docker (4CPU, 2G)	172.6	174.72	171.23	1.386	16.82%	18.74%	13.79%	0.02	3.78%	6.64%	0.89%	0.024
Docker (2CPU, 4G)	172.1	172.91	170.03	1.184	16.05%	17.83%	14.60%	0.012	2.95%	5.72%	1.34%	0.016

As we can tell from the above CPU test results table, events per second is almost consistent within one technology, no matter how many CPUs or memory are allocated. One possible explanation could be that this cpu test is a single thread process so it won't utilized multi-core advantage. Also this test might be a CPU-bound process, so more memory won't help execution because it has very limited I/O. This can also be proven by looking at kernel

vs user CPU utilization. We can tell that for every technology and configuration, kernel takes much more percentage of CPU than userspace.That is to say, this CPU test is a mostly CPU-bound process. Therefore, more cores or more memory won't help with performance in this case.

Also, Docker has lower events per second than Qemu VM. This is unusual because Docker is a OS virtualization and should be faster than QEMU, which is a system virtualization. On probable explanation is that we are using Docker Desktop here instead of native Docker beaucse native Docker is not available on Apple Silicon machines. Docker Desktop may have added another layer, and could slow down the execution speed of Docker containers here.

IO test

	read (MB/s)				write(MB/s)				latency			
	avg	max	min	std	avg	max	min	std	avg	max	min	std
Qemu (2CPU, 2G)	317.786	353.37	253.84	38.56	211.856	235.58	169.22	25.71	0.21	0.26	0.19	0.03
Qemu (4CPU, 2G)	211.372	214.9	208.78	2.9	140.912	143.27	139.18	1.93	0.31	0.31	0.31	0
Qemu (2CPU, 4G)	409.074	427.83	380.53	21.21	272.716	285.22	253.69	14.14	0.16	0.17	0.15	0.01
Docker (2CPU, 2G)	164.108	172.04	159.09	5.26	109.134	115.35	106.06	3.8	0.396	0.41	0.38	0.02
Docker (4CPU, 2G)	158.412	161.1	153.46	2.92	105.604	107.4	102.3	1.95	0.414	0.43	0.41	0.01
Docker (2CPU, 4G)	199.482	202.31	196.92	1.94	132.99	134.88	131.28	1.3	0.328	0.33	0.32	0

IO test continued								
	Disk Utilization							
	Reads in / sec				Writes out / sec			
	avg	max	min	std	avg	max	min	std
Qemu (2CPU, 2G)	1631	4283	3	2187.061	13372	16331	9380	2674.376
Qemu (4CPU, 2G)	52.6	75	40	15.994	10368.4	10638	10099	214.092
Qemu (2CPU, 4G)	71	312	2	134.976	17433.4	18390	15709	1084.069
Docker (2CPU, 2G)	283.2	347	148	79.156	7891	8189	7211	389.952
Docker (4CPU, 2G)	3647.6	3910	3165	332.871	7270.8	7706	6864	376.374
Docker (2CPU, 4G)	199	254	59	82.043	9552.6	9815	8783	441.989

From IO test table, we are able to see that, for both technologies, doubling CPU does not improve io performance and can cause negative impact. This could be an overhead caused by multi-core utilization. On the other hand, doubling memory helps increase read, write and latency a lot. This is predictable that more memory dramatically reduces the time for CPU to read data (from memory vs from disk) and will improve io performance a lot.

However, overall IO performance for Docker is still worse than QEMU and this could be caused by overhead of Docker Desktop. Also, Docker generally has less disk utilization than QEMU.

Git Repository Information:

Git HTTPS: https://github.com/ugzhu/COEN241.git

Git SSH: git@github.com:ugzhu/COEN241.git

Github CLI: gh repo clone ugzhu/COEN241

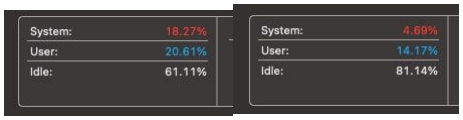
Collaborator invited: sean.choi@scu.edu

Appendix

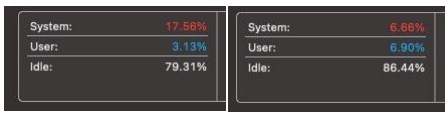
Proof of Experiment:

CPU test:

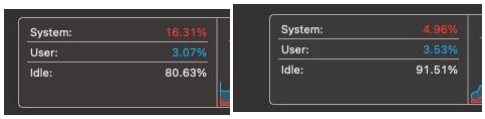
QEMU (2 Cores, 2G)




```
CPU speed:
    events per second:   190.60

General statistics:
    total time:                          30.0041s
    total number of events:              5719

Latency (ms):
         min:                                    5.14
         avg:                                    5.25
         max:                                   10.44
         95th percentile:                        5.37
         sum:                                29998.62

Threads fairness:
    events (avg/stddev):           5719.0000/0.00
    execution time (avg/stddev):   29.9986/0.00
```

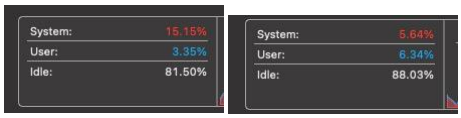



```
CPU speed:
    events per second:   188.01

General statistics:
    total time:                          30.0032s
    total number of events:              5641

Latency (ms):
         min:                                    5.15
         avg:                                    5.32
         max:                                   10.73
         95th percentile:                        5.47
         sum:                                29997.79

Threads fairness:
    events (avg/stddev):           5641.0000/0.00
    execution time (avg/stddev):   29.9978/0.00
```



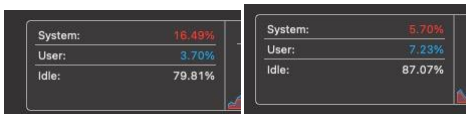
```
CPU speed:
    events per second:   189.60

General statistics:
    total time:                          30.0051s
    total number of events:              5689

Latency (ms):
         min:                                    5.15
         avg:                                    5.27
         max:                                   10.21
         95th percentile:                        5.47
         sum:                                29998.93

Threads fairness:
    events (avg/stddev):           5689.0000/0.00
    execution time (avg/stddev):   29.9989/0.00
```


```
CPU speed:
    events per second:   189.46

General statistics:
    total time:                          30.0053s
    total number of events:              5685

Latency (ms):
         min:                                    5.12
         avg:                                    5.28
         max:                                   10.23
         95th percentile:                        5.47
         sum:                                29999.34

Threads fairness:
    events (avg/stddev):           5685.0000/0.00
    execution time (avg/stddev):   29.9993/0.00
```



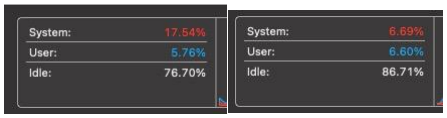

```
CPU speed:
    events per second:   189.83

General statistics:
    total time:                          30.0051s
    total number of events:              5696

Latency (ms):
         min:                                    5.11
         avg:                                    5.27
         max:                                   11.55
         95th percentile:                        5.47
         sum:                                29999.85

Threads fairness:
    events (avg/stddev):           5696.0000/0.00
    execution time (avg/stddev):   29.9999/0.00
```

QEMU (4 Cores, 2G)

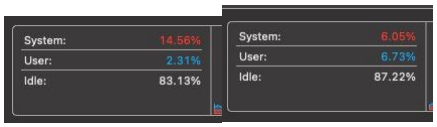


```
CPU speed:
    events per second:   191.04

General statistics:
    total time:                          30.0032s
    total number of events:              5732

Latency (ms):
         min:                                    4.99
         avg:                                    5.23
         max:                                    9.47
         95th percentile:                        5.47
         sum:                                29997.91

Threads fairness:
    events (avg/stddev):           5732.0000/0.00
    execution time (avg/stddev):   29.9979/0.00
```

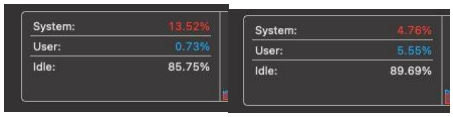

```
CPU speed:
    events per second:   190.33

General statistics:
    total time:                          30.0047s
    total number of events:              5711

Latency (ms):
         min:                                    5.15
         avg:                                    5.25
         max:                                   10.37
         95th percentile:                        5.37
         sum:                                30000.17

Threads fairness:
    events (avg/stddev):           5711.0000/0.00
    execution time (avg/stddev):   30.0002/0.00
```




```
CPU speed:
    events per second:   189.45

General statistics:
    total time:                          30.0029s
    total number of events:              5684

Latency (ms):
         min:                                    5.14
         avg:                                    5.28
         max:                                   10.40
         95th percentile:                        5.47
         sum:                                29997.26

Threads fairness:
    events (avg/stddev):           5684.0000/0.00
    execution time (avg/stddev):   29.9973/0.00
```

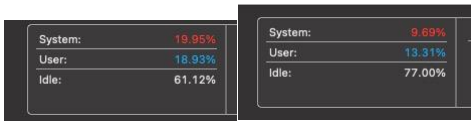



```
CPU speed:
    events per second:   189.78

General statistics:
    total time:                          30.0022s
    total number of events:              5694

Latency (ms):
         min:                                    5.15
         avg:                                    5.27
         max:                                   10.35
         95th percentile:                        5.47
         sum:                                29996.70

Threads fairness:
    events (avg/stddev):           5694.0000/0.00
    execution time (avg/stddev):   29.9967/0.00
```

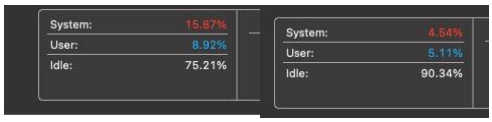



```
CPU speed:
    events per second:   190.32

General statistics:
    total time:                          30.0014s
    total number of events:              5710

Latency (ms):
         min:                                    5.14
         avg:                                    5.25
         max:                                   13.09
         95th percentile:                        5.37
         sum:                                29995.79

Threads fairness:
    events (avg/stddev):           5710.0000/0.00
    execution time (avg/stddev):   29.9958/0.00
```

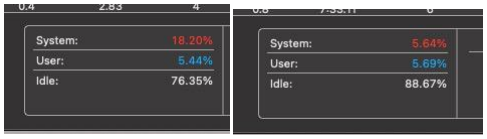
QEMU (2 Cores, 4G)



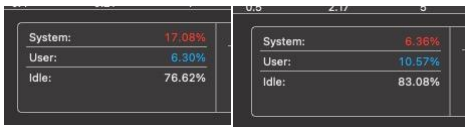

```
CPU speed:
    events per second:   192.03

General statistics:
    total time:                          30.0048s
    total number of events:              5762

Latency (ms):
         min:                                    5.14
         avg:                                    5.21
         max:                                    8.21
         95th percentile:                        5.28
         sum:                                30001.88

Threads fairness:
    events (avg/stddev):           5762.0000/0.00
    execution time (avg/stddev):   30.0019/0.00
```



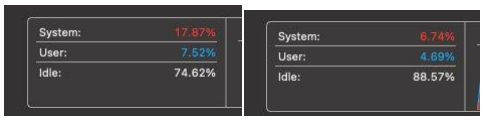

```
CPU speed:
    events per second:   192.18

General statistics:
    total time:                          30.0029s
    total number of events:              5766

Latency (ms):
         min:                                    5.14
         avg:                                    5.20
         max:                                    8.70
         95th percentile:                        5.28
         sum:                                29999.96

Threads fairness:
    events (avg/stddev):           5766.0000/0.00
    execution time (avg/stddev):   30.0000/0.00
```



```
CPU speed:
    events per second:   191.40

General statistics:
    total time:                          30.0046s
    total number of events:              5743

Latency (ms):
         min:                                    5.15
         avg:                                    5.22
         max:                                   10.25
         95th percentile:                        5.37
         sum:                                30000.43

Threads fairness:
    events (avg/stddev):           5743.0000/0.00
    execution time (avg/stddev):   30.0004/0.00
```



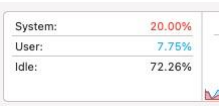

```
CPU speed:
    events per second:   188.85

General statistics:
    total time:                          30.0013s
    total number of events:              5666

Latency (ms):
         min:                                    5.15
         avg:                                    5.29
         max:                                   10.02
         95th percentile:                        5.47
         sum:                                29994.75

Threads fairness:
    events (avg/stddev):           5666.0000/0.00
    execution time (avg/stddev):   29.9948/0.00
```




```
CPU speed:
    events per second:   190.48

General statistics:
    total time:                          30.0031s
    total number of events:              5715

Latency (ms):
         min:                                    5.15
         avg:                                    5.25
         max:                                   10.22
         95th percentile:                        5.37
         sum:                                29996.64

Threads fairness:
    events (avg/stddev):           5715.0000/0.00
    execution time (avg/stddev):   29.9966/0.00
```

Docker (2 Cores, 2G)

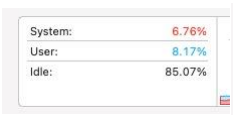

```
CPU speed:
    events per second:   172.33

General statistics:
    total time:                          30.0051s
    total number of events:              5171

Latency (ms):
         min:                                    5.68
         avg:                                    5.80
         max:                                   26.15
         95th percentile:                        5.99
         sum:                                30000.15

Threads fairness:
    events (avg/stddev):           5171.0000/0.00
    execution time (avg/stddev):   30.0001/0.00
```




```
CPU speed:
    events per second:   173.90

General statistics:
    total time:                          30.0047s
    total number of events:              5218

Latency (ms):
         min:                                    5.68
         avg:                                    5.75
         max:                                   13.65
         95th percentile:                        5.88
         sum:                                30000.32

Threads fairness:
    events (avg/stddev):           5218.0000/0.00
    execution time (avg/stddev):   30.0003/0.00
```


```
CPU speed:
    events per second:   169.60

General statistics:
    total time:                          30.0045s
    total number of events:              5089

Latency (ms):
         min:                                    5.68
         avg:                                    5.89
         max:                                   20.49
         95th percentile:                        6.21
         sum:                                29999.36

Threads fairness:
    events (avg/stddev):           5089.0000/0.00
    execution time (avg/stddev):   29.9994/0.00
```


```
CPU speed:
    events per second:   170.34

General statistics:
    total time:                          30.0036s
    total number of events:              5111

Latency (ms):
         min:                                    5.68
         avg:                                    5.87
         max:                                   23.67
         95th percentile:                        6.21
         sum:                                29997.89

Threads fairness:
    events (avg/stddev):           5111.0000/0.00
    execution time (avg/stddev):   29.9979/0.00
```



```
CPU speed:
    events per second:   172.86

General statistics:
    total time:                          30.0002s
    total number of events:              5186

Latency (ms):
         min:                                    5.68
         avg:                                    5.78
         max:                                   14.04
         95th percentile:                        6.09
         sum:                                29995.57

Threads fairness:
    events (avg/stddev):           5186.0000/0.00
    execution time (avg/stddev):   29.9956/0.00
```

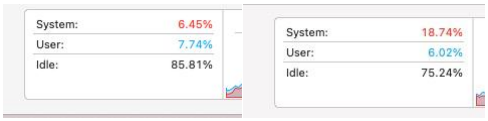
Docker (4 Cores, 2G)


```
CPU speed:
    events per second:   171.48

General statistics:
    total time:                          30.0018s
    total number of events:              5145

Latency (ms):
         min:                                    5.68
         avg:                                    5.83
         max:                                   15.13
         95th percentile:                        6.09
         sum:                                29996.02

Threads fairness:
    events (avg/stddev):           5145.0000/0.00
    execution time (avg/stddev):   29.9960/0.00
```


```
CPU speed:
    events per second:   172.74

General statistics:
    total time:                          30.0046s
    total number of events:              5183

Latency (ms):
         min:                                    5.68
         avg:                                    5.79
         max:                                   19.42
         95th percentile:                        5.99
         sum:                                29999.12

Threads fairness:
    events (avg/stddev):           5183.0000/0.00
    execution time (avg/stddev):   29.9991/0.00
```

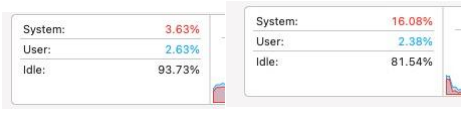
```
CPU speed:
    events per second:   172.80

General statistics:
    total time:                          30.0044s
    total number of events:              5185

Latency (ms):
         min:                                    5.68
         avg:                                    5.79
         max:                                   19.56
         95th percentile:                        5.99
         sum:                                29999.55

Threads fairness:
    events (avg/stddev):           5185.0000/0.00
    execution time (avg/stddev):   29.9996/0.00
```


```
CPU speed:
    events per second:   174.72

General statistics:
    total time:                          30.0013s
    total number of events:              5242

Latency (ms):
         min:                                    5.67
         avg:                                    5.72
         max:                                   16.40
         95th percentile:                        5.77
         sum:                                29997.85

Threads fairness:
    events (avg/stddev):           5242.0000/0.00
    execution time (avg/stddev):   29.9978/0.00
```




```
CPU speed:
    events per second:   171.23

General statistics:
    total time:                          30.0049s
    total number of events:              5138

Latency (ms):
         min:                                    5.68
         avg:                                    5.84
         max:                                   16.85
         95th percentile:                        6.09
         sum:                                29999.08

Threads fairness:
    events (avg/stddev):           5138.0000/0.00
    execution time (avg/stddev):   29.9991/0.00
```

Docker (2 Cores, 4G)

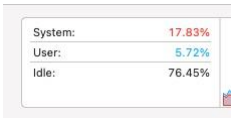


```
CPU speed:
    events per second:   172.47

General statistics:
    total time:                          30.0035s
    total number of events:              5175

Latency (ms):
         min:                                    5.68
         avg:                                    5.80
         max:                                   14.00
         95th percentile:                        5.99
         sum:                                29998.19

Threads fairness:
    events (avg/stddev):           5175.0000/0.00
    execution time (avg/stddev):   29.9982/0.00
```


```
CPU speed:
    events per second:   172.82

General statistics:
    total time:                          30.0014s
    total number of events:              5185

Latency (ms):
         min:                                    5.68
         avg:                                    5.79
         max:                                   16.47
         95th percentile:                        5.99
         sum:                                29996.18

Threads fairness:
    events (avg/stddev):           5185.0000/0.00
    execution time (avg/stddev):   29.9962/0.00
```


```
CPU speed:
    events per second:   172.91

General statistics:
    total time:                          30.0042s
    total number of events:              5188

Latency (ms):
         min:                                    5.68
         avg:                                    5.78
         max:                                   14.01
         95th percentile:                        5.99
         sum:                                30000.07

Threads fairness:
    events (avg/stddev):           5188.0000/0.00
    execution time (avg/stddev):   30.0001/0.00
```


```
CPU speed:
    events per second:   172.19

General statistics:
    total time:                          30.0003s
    total number of events:              5166

Latency (ms):
         min:                                    5.68
         avg:                                    5.81
         max:                                   14.72
         95th percentile:                        6.09
         sum:                                29995.18

Threads fairness:
    events (avg/stddev):           5166.0000/0.00
    execution time (avg/stddev):   29.9952/0.00
```




```
CPU speed:
    events per second:   170.03

General statistics:
    total time:                          30.0057s
    total number of events:              5102

Latency (ms):
         min:                                    5.69
         avg:                                    5.88
         max:                                   22.41
         95th percentile:                        6.21
         sum:                                29999.22

Threads fairness:
    events (avg/stddev):           5102.0000/0.00
    execution time (avg/stddev):   29.9992/0.00
```

IO test:

QEMU (2 Cores, 2G)


```
File operations:
    reads/s:                      16246.00
    writes/s:                     10830.39
    fsyncs/s:                     34723.78

Throughput:
    read, MiB/s:                  253.84
    written, MiB/s:               169.22

General statistics:
    total time:                          30.0294s
    total number of events:              1853802

Latency (ms):
         min:                                    0.00
         avg:                                    0.26
         max:                                   79.86
         95th percentile:                        0.74
         sum:                                  478631.45

Threads fairness:
    events (avg/stddev):           115862.6250/545.94
    execution time (avg/stddev):   29.9145/0.00
```


```
File operations:
    reads/s:                      20532.76
    writes/s:                     13688.23
    fsyncs/s:                     43867.97

Throughput:
    read, MiB/s:                  320.82
    written, MiB/s:               213.88

General statistics:
    total time:                          30.0250s
    total number of events:              2342607

Latency (ms):
         min:                                    0.00
         avg:                                    0.20
         max:                                   42.43
         95th percentile:                        0.62
         sum:                                  478456.73

Threads fairness:
    events (avg/stddev):           146412.9375/663.23
    execution time (avg/stddev):   29.9035/0.01
```


```
File operations:
    reads/s:                      21883.18
    writes/s:                     14588.62
    fsyncs/s:                     46747.88

Throughput:
    read, MiB/s:                  341.92
    written, MiB/s:               227.95

General statistics:
    total time:                          30.0144s
    total number of events:              2495788

Latency (ms):
         min:                                    0.00
         avg:                                    0.19
         max:                                   19.48
         95th percentile:                        0.60
         sum:                                  478135.90

Threads fairness:
    events (avg/stddev):           155986.7500/638.98
    execution time (avg/stddev):   29.8835/0.01
```

```
File operations:
    reads/s:                      22615.42
    writes/s:                     15076.88
    fsyncs/s:                     48312.98

Throughput:
    read, MiB/s:                  353.37
    written, MiB/s:               235.58

General statistics:
    total time:                          30.0118s
    total number of events:              2579169

Latency (ms):
         min:                                    0.00
         avg:                                    0.19
         max:                                   18.09
         95th percentile:                        0.58
         sum:                               478106.06

Threads fairness:
    events (avg/stddev):           161198.0625/564.00
    execution time (avg/stddev):   29.8816/0.00
```


```
File operations:
    reads/s:                      20414.46
    writes/s:                     13609.53
    fsyncs/s:                     43616.91

Throughput:
    read, MiB/s:                  318.98
    written, MiB/s:               212.65

General statistics:
    total time:                          30.0166s
    total number of events:              2328503

Latency (ms):
         min:                                    0.00
         avg:                                    0.21
         max:                                   17.38
         95th percentile:                        0.63
         sum:                               478304.02

Threads fairness:
    events (avg/stddev):           145531.4375/586.90
    execution time (avg/stddev):   29.8940/0.00
```

QEMU (4 Cores, 2G)


```
File operations:
    reads/s:                      13703.78
    writes/s:                     9135.63
    fsyncs/s:                     29299.79

Throughput:
    read, MiB/s:                  214.12
    written, MiB/s:               142.74

General statistics:
    total time:                          30.0267s
    total number of events:              1563538

Latency (ms):
         min:                                    0.00
         avg:                                    0.31
         max:                                   18.47
         95th percentile:                        0.83
         sum:                               478992.80

Threads fairness:
    events (avg/stddev):           97721.1250/438.80
    execution time (avg/stddev):   29.9371/0.01
```

```
File operations:
    reads/s:                      13753.85
    writes/s:                     9169.01
    fsyncs/s:                     29405.21

Throughput:
    read, MiB/s:                  214.90
    written, MiB/s:               143.27

General statistics:
    total time:                          30.0265s
    total number of events:              1569196

Latency (ms):
         min:                                    0.00
         avg:                                    0.31
         max:                                   19.91
         95th percentile:                        0.81
         sum:                                 478949.42

Threads fairness:
    events (avg/stddev):          98074.7500/362.37
    execution time (avg/stddev):  29.9343/0.01
```


```
File operations:
    reads/s:                      13398.00
    writes/s:                     8931.78
    fsyncs/s:                     28646.79

Throughput:
    read, MiB/s:                  209.34
    written, MiB/s:               139.56

General statistics:
    total time:                          30.0268s
    total number of events:              1528634

Latency (ms):
         min:                                    0.00
         avg:                                    0.31
         max:                                   21.49
         95th percentile:                        0.84
         sum:                                 478990.47

Threads fairness:
    events (avg/stddev):          95539.6250/456.14
    execution time (avg/stddev):  29.9369/0.00
```


```
File operations:
    reads/s:                      13422.17
    writes/s:                     8947.83
    fsyncs/s:                     28699.15

Throughput:
    read, MiB/s:                  209.72
    written, MiB/s:               139.81

General statistics:
    total time:                          30.0220s
    total number of events:              1531168

Latency (ms):
         min:                                    0.00
         avg:                                    0.31
         max:                                   35.59
         95th percentile:                        0.84
         sum:                                 479006.63

Threads fairness:
    events (avg/stddev):          95698.0000/386.21
    execution time (avg/stddev):  29.9379/0.00
```

```
File operations:
    reads/s:                      13361.78
    writes/s:                     8907.58
    fsyncs/s:                     28569.44

Throughput:
    read, MiB/s:                  208.78
    written, MiB/s:               139.18

General statistics:
    total time:                          30.0320s
    total number of events:              1524758

Latency (ms):
         min:                                    0.00
         avg:                                    0.31
         max:                                   20.12
         95th percentile:                        0.84
         sum:                               478980.55

Threads fairness:
    events (avg/stddev):          95297.3750/427.51
    execution time (avg/stddev):  29.9363/0.01
```

QEMU (2 Cores, 4G)


```
File operations:
    reads/s:                      24353.71
    writes/s:                     16235.86
    fsyncs/s:                     52020.35

Throughput:
    read, MiB/s:                  380.53
    written, MiB/s:               253.69

General statistics:
    total time:                          30.0146s
    total number of events:              2777648

Latency (ms):
         min:                                    0.00
         avg:                                    0.17
         max:                                   21.77
         95th percentile:                        0.56
         sum:                               478579.71

Threads fairness:
    events (avg/stddev):          173603.0000/1648.10
    execution time (avg/stddev):  29.9112/0.00
```


```
File operations:
    reads/s:                      27380.85
    writes/s:                     18253.84
    fsyncs/s:                     58477.01

Throughput:
    read, MiB/s:                  427.83
    written, MiB/s:               285.22

General statistics:
    total time:                          30.0139s
    total number of events:              3122807

Latency (ms):
         min:                                    0.00
         avg:                                    0.15
         max:                                   34.28
         95th percentile:                        0.49
         sum:                               478331.25

Threads fairness:
    events (avg/stddev):          195175.4375/1660.29
    execution time (avg/stddev):  29.8957/0.00
```

```
File operations:
    reads/s:                      27154.45
    writes/s:                     18102.95
    fsyncs/s:                     57996.60

Throughput:
    read, MiB/s:                  424.29
    written, MiB/s:               282.86

General statistics:
    total time:                          30.0106s
    total number of events:              3096722

Latency (ms):
         min:                                    0.00
         avg:                                    0.15
         max:                                   18.24
         95th percentile:                        0.49
         sum:                               478329.24

Threads fairness:
    events (avg/stddev):           193545.1250/1883.60
    execution time (avg/stddev):   29.8956/0.00
```


```
File operations:
    reads/s:                      25116.81
    writes/s:                     16744.54
    fsyncs/s:                     53648.73

Throughput:
    read, MiB/s:                  392.45
    written, MiB/s:               261.63

General statistics:
    total time:                          30.0128s
    total number of events:              2864531

Latency (ms):
         min:                                    0.00
         avg:                                    0.17
         max:                                   18.51
         95th percentile:                        0.52
         sum:                               478663.68

Threads fairness:
    events (avg/stddev):           179033.1875/2115.86
    execution time (avg/stddev):   29.9165/0.00
```


```
File operations:
    reads/s:                      26897.37
    writes/s:                     17931.58
    fsyncs/s:                     57446.23

Throughput:
    read, MiB/s:                  420.27
    written, MiB/s:               280.18

General statistics:
    total time:                          30.0136s
    total number of events:              3067648

Latency (ms):
         min:                                    0.00
         avg:                                    0.16
         max:                                    6.79
         95th percentile:                        0.50
         sum:                               478352.39

Threads fairness:
    events (avg/stddev):           191728.0000/1222.84
    execution time (avg/stddev):   29.8970/0.00
```

Docker (2 Cores, 2G)

```
File operations:
    reads/s:                      10554.75
    writes/s:                     7036.23
    fsyncs/s:                     22582.34

Throughput:
    read, MiB/s:                  164.92
    written, MiB/s:               109.94

General statistics:
    total time:                          30.0662s
    total number of events:              1205825

Latency (ms):
         min:                                    0.00
         avg:                                    0.40
         max:                                   39.84
         95th percentile:                        1.12
         sum:                                 479234.56

Threads fairness:
    events (avg/stddev):           75364.0625/561.75
    execution time (avg/stddev):   29.9522/0.00
```


```
File operations:
    reads/s:                      11074.28
    writes/s:                     7382.58
    fsyncs/s:                     23692.27

Throughput:
    read, MiB/s:                  173.04
    written, MiB/s:               115.35

General statistics:
    total time:                          30.0644s
    total number of events:              1265153

Latency (ms):
         min:                                    0.00
         avg:                                    0.38
         max:                                   34.89
         95th percentile:                        1.08
         sum:                                 479196.14

Threads fairness:
    events (avg/stddev):           79072.0625/486.92
    execution time (avg/stddev):   29.9498/0.00
```


```
File operations:
    reads/s:                      10559.10
    writes/s:                     7039.29
    fsyncs/s:                     22592.79

Throughput:
    read, MiB/s:                  164.99
    written, MiB/s:               109.99

General statistics:
    total time:                          30.0535s
    total number of events:              1205853

Latency (ms):
         min:                                    0.00
         avg:                                    0.40
         max:                                   28.23
         95th percentile:                        1.12
         sum:                                 479194.31

Threads fairness:
    events (avg/stddev):           75365.8125/498.69
    execution time (avg/stddev):   29.9496/0.00
```

```
File operations:
    reads/s:                      10182.03
    writes/s:                     6787.69
    fsyncs/s:                     21787.53

Throughput:
    read, MiB/s:                  159.09
    written, MiB/s:               106.06

General statistics:
    total time:                          30.0532s
    total number of events:              1162744

Latency (ms):
         min:                                    0.00
         avg:                                    0.41
         max:                                   23.23
         95th percentile:                        1.14
         sum:                                  479130.81

Threads fairness:
    events (avg/stddev):           72671.5000/541.26
    execution time (avg/stddev):   29.9457/0.00
```


```
File operations:
    reads/s:                      10207.82
    writes/s:                     6804.99
    fsyncs/s:                     21843.59

Throughput:
    read, MiB/s:                  159.50
    written, MiB/s:               106.33

General statistics:
    total time:                          30.0594s
    total number of events:              1165964

Latency (ms):
         min:                                    0.00
         avg:                                    0.41
         max:                                   19.32
         95th percentile:                        1.12
         sum:                                  479157.48

Threads fairness:
    events (avg/stddev):           72872.7500/285.34
    execution time (avg/stddev):   29.9473/0.00
```

Docker (4 Cores, 2G)


```
File operations:
    reads/s:                      10215.22
    writes/s:                     6809.87
    fsyncs/s:                     21856.65

Throughput:
    read, MiB/s:                  159.61
    written, MiB/s:               106.40

General statistics:
    total time:                          30.0435s
    total number of events:              1166111

Latency (ms):
         min:                                    0.00
         avg:                                    0.41
         max:                                   25.99
         95th percentile:                        1.12
         sum:                                  479109.78

Threads fairness:
    events (avg/stddev):           72881.9375/530.12
    execution time (avg/stddev):   29.9444/0.01
```

```
File operations:
    reads/s:                      10310.54
    writes/s:                     6873.49
    fsyncs/s:                     22060.79

Throughput:
    read, MiB/s:                  161.10
    written, MiB/s:               107.40

General statistics:
    total time:                          30.0432s
    total number of events:              1177005

Latency (ms):
         min:                                    0.00
         avg:                                    0.41
         max:                                   36.51
         95th percentile:                        1.12
         sum:                                  479125.51

Threads fairness:
    events (avg/stddev):          73562.8125/475.64
    execution time (avg/stddev):  29.9453/0.00
```


```
File operations:
    reads/s:                      10197.80
    writes/s:                     6798.26
    fsyncs/s:                     21820.94

Throughput:
    read, MiB/s:                  159.34
    written, MiB/s:               106.22

General statistics:
    total time:                          30.0654s
    total number of events:              1165016

Latency (ms):
         min:                                    0.00
         avg:                                    0.41
         max:                                   22.05
         95th percentile:                        1.12
         sum:                                  479123.80

Threads fairness:
    events (avg/stddev):          72813.5000/428.58
    execution time (avg/stddev):  29.9452/0.00
```

S

```
File operations:
    reads/s:                      9821.22
    writes/s:                     6547.43
    fsyncs/s:                     21018.29

Throughput:
    read, MiB/s:                  153.46
    written, MiB/s:               102.30

General statistics:
    total time:                          30.0632s
    total number of events:              1121937

Latency (ms):
         min:                                    0.00
         avg:                                    0.43
         max:                                   20.26
         95th percentile:                        1.18
         sum:                                  479163.47

Threads fairness:
    events (avg/stddev):          70121.0625/357.92
    execution time (avg/stddev):  29.9477/0.00
```

```
File operations:
    reads/s:                      10147.34
    writes/s:                     6765.06
    fsyncs/s:                     21714.54

Throughput:
    read, MiB/s:                  158.55
    written, MiB/s:               105.70

General statistics:
    total time:                          30.0427s
    total number of events:              1158423

Latency (ms):
         min:                                    0.00
         avg:                                    0.41
         max:                                   18.54
         95th percentile:                        1.16
         sum:                                  479145.59

Threads fairness:
    events (avg/stddev):           72401.4375/438.85
    execution time (avg/stddev):   29.9466/0.00
```

Docker (2 Cores, 4G)


```
File operations:
    reads/s:                      12603.12
    writes/s:                     8402.02
    fsyncs/s:                     26952.87

Throughput:
    read, MiB/s:                  196.92
    written, MiB/s:               131.28

General statistics:
    total time:                          30.0494s
    total number of events:              1439080

Latency (ms):
         min:                                    0.00
         avg:                                    0.33
         max:                                   12.00
         95th percentile:                        1.01
         sum:                                  479121.84

Threads fairness:
    events (avg/stddev):           89942.5000/1239.97
    execution time (avg/stddev):   29.9451/0.00
```


```
File operations:
    reads/s:                      12778.82
    writes/s:                     8519.21
    fsyncs/s:                     27327.58

Throughput:
    read, MiB/s:                  199.67
    written, MiB/s:               133.11

General statistics:
    total time:                          30.0587s
    total number of events:              1459595

Latency (ms):
         min:                                    0.00
         avg:                                    0.33
         max:                                   40.76
         95th percentile:                        0.97
         sum:                                  479120.53

Threads fairness:
    events (avg/stddev):           91224.6875/1724.82
    execution time (avg/stddev):   29.9450/0.00
```

```
File operations:
    reads/s:                      12780.84
    writes/s:                     8520.67
    fsyncs/s:                     27331.35

Throughput:
    read, MiB/s:                  199.70
    written, MiB/s:               133.14

General statistics:
    total time:                          30.0585s
    total number of events:              1459802

Latency (ms):
         min:                                    0.00
         avg:                                    0.33
         max:                                   21.20
         95th percentile:                        0.97
         sum:                                 479101.52

Threads fairness:
    events (avg/stddev):          91237.6250/732.37
    execution time (avg/stddev):  29.9438/0.00
```


```
File operations:
    reads/s:                      12948.08
    writes/s:                     8632.11
    fsyncs/s:                     27687.84

Throughput:
    read, MiB/s:                  202.31
    written, MiB/s:               134.88

General statistics:
    total time:                          30.0596s
    total number of events:              1478948

Latency (ms):
         min:                                    0.00
         avg:                                    0.32
         max:                                   16.79
         95th percentile:                        0.97
         sum:                                 479115.29

Threads fairness:
    events (avg/stddev):          92434.2500/977.63
    execution time (avg/stddev):  29.9447/0.00
```


```
File operations:
    reads/s:                      12723.88
    writes/s:                     8482.59
    fsyncs/s:                     27211.72

Throughput:
    read, MiB/s:                  198.81
    written, MiB/s:               132.54

General statistics:
    total time:                          30.0612s
    total number of events:              1453479

Latency (ms):
         min:                                    0.00
         avg:                                    0.33
         max:                                   23.55
         95th percentile:                        0.99
         sum:                                 479122.60

Threads fairness:
    events (avg/stddev):          90842.4375/1733.64
    execution time (avg/stddev):  29.9452/0.00
```