COEN 241: Homework 1

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a) Detailed configurations

System:MacBook Pro (13-inch, M1, 2020)
Processor: Apple M1 8 core
Memory: 16Gb

QEMU experimental setup

The following thre configurations were used for QEMU setup

1. 1GB memory and 1 core
2. 2GB memory and 2 cores
3. 3GB memory and 3 cores

Docker experimental setup

A similar configuration as QEMU was used for experiments in docker

1. 1GB memory and 1 core
2. 2GB memory and 2 cores
3. 3GB memory and 3 cores

b) Steps to install QEMU

The following steps were used:

1. Download ISO image.
2. Install homebrew.
3. Installing QEMU using:
   brew install qemu
4. Creating the QEMU image using:
   sudo qemu-img create ubuntu.img 10G -f qcow2

5. Installing QEMU using:

```
qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2G \
-smp 2 \
-drivefile=/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="trial_2" \
-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
```

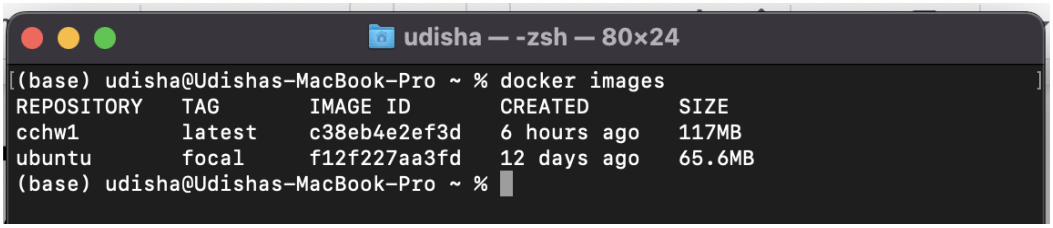
6. To run QEMU with a memory of 2Gb and 2 cores use:

```
qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2G \
-smp 2 \
-drivefile=/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="trial_2" \
-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
```

c) Steps taken while installing Docker

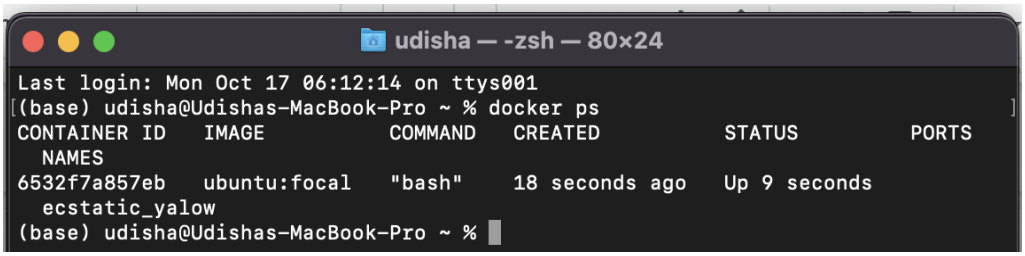
1. Download docker dmg image from the link, and drag the dmg image into applications to install docker
2. Pull ubuntu image using

   Docker pull ubuntu:focal



3. Creating your own image on top of the base image:
    a. Start the base image using:
        docker run -d ubuntu:focal
    b. Install sysbench using:
        sudo apt-get install sysbench

4. To create a new image use:
    a. Get container ID of base image using below; run this on another terminal:
        docker ps



    b. docker container stop 6532f7a857eb
    c. docker commit 6532f7a857eb cchw1
    d. docker run -it cchw1

d) Proof of experiment

Experiments are conducted in the following manner:

1. CPU mode
    a. –cpu-max-prime = 2000 and time = 30
    b. –cpu-max-prime = 20000 and time = 30
    c. –cpu-max-prime = 2000000 and time = 30

2. FileIO mode
    a. Sequential write (SEQWR)
    b. Combined random Read/Write (RNDRW)

Configuration 1: Running on 1GB memory and 1 core

QEMU

```
qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 1G \
-smp 1\
-drivefile=/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="trial_2" \
-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

a. CPU Mode

i. sysbench --test=cpu --cpu-max-prime=2000 --time=30 run

```
magupta@mridulgupta:~/cchw1$ sh qemu_2000_cpu_test_mode.sh
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time


Prime numbers limit: 2000

Initializing worker threads...

Threads started!

CPU speed:
    events per second: 77894.39

General statistics:
    total time:                          30.0001s
    total number of events:              2336876

Latency (ms):
         min:                                    0.01
         avg:                                    0.01
         max:                                   15.54
         95th percentile:                        0.05
         sum:                                29752.41

Threads fairness:
    events (avg/stddev):           2336876.0000/0.00
    execution time (avg/stddev):   29.7524/0.00
```

Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.01 Max: 15.54 Avg: 0.01	77894.39
2	Min: 0.01 Max: 639.53 Avg: 0.08	12659.85
3	Min: 0.01 Max: 730.02 Avg: 0.07	13930.02
4	Min: 0.01 Max: 1312.58	31789.11

	Avg: 0.03	
5	Min: 0.01 Max: 418.17 Avg: 0.01	68350.00

ii. sysbench --test=cpu --cpu-max-prime=20000 --time=30 run

```
magupta@mridulgupta:~/cchw1$ sh qemu_20000_cpu_test_mode.sh
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time


Prime numbers limit: 20000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:  2983.50

General statistics:
    total time:                          30.0001s
    total number of events:              89510

Latency (ms):
         min:                                    0.24
         avg:                                    0.33
         max:                                    9.38
         95th percentile:                        1.21
         sum:                                29984.29

Threads fairness:
    events (avg/stddev):           89510.0000/0.00
    execution time (avg/stddev):   29.9843/0.00
```

Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.24 Max: 9.38 Avg: 0.33	2983.50
2	Min: 0.24 Max: 14.41 Avg: 0.35	2876.02
3	Min: 0.24 Max: 11.20 Avg: 0.35	2856.72
4	Min: 0.24 Max: 10.93	2861.62

	Avg: 0.35	
5	Min: 0.24 Max: 47.40 Avg: 0.35	2882.71

iii. sysbench --test=cpu --cpu-max-prime=2000000 --time=30 run

```
Running the test with following options:
Number of threads: 1
Initializing random number generator from current time


Prime numbers limit: 2000000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:     5.55

General statistics:
    total time:                          30.0839s
    total number of events:              167

Latency (ms):
         min:                                  145.12
         avg:                                  180.14
         max:                                  265.72
         95th percentile:                      207.82
         sum:                                30082.86

Threads fairness:
    events (avg/stddev):           167.0000/0.00
    execution time (avg/stddev):   30.0829/0.00

WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)
```

Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 145.12 Max: 265.72 Avg: 180.14	5.55
2	Min: 138.15 Max: 3929.39 Avg: 414.04	2.42
3	Min: 387.12 Max: 2366.51 Avg: 1140.33	0.88
4	Min: 150.88 Max: 1985.62	1.53

	Avg: 653.81	
5	Min: 129.84 Max: 233.92 Avg: 189.83	5.27

b. Fileio

i. SEQWR

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr prepare

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr run

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr cleanup

```
Running the test with following options:
Number of threads: 16
Initializing random number generator from current time


Extra file open flags: (none)
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential rewrite test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      0.00
    writes/s:                     11887.94
    fsyncs/s:                     15283.45

Throughput:
    read, MiB/s:                  0.00
    written, MiB/s:               185.75

General statistics:
    total time:                          30.0798s
    total number of events:              815292

Latency (ms):
         min:                                    0.00
         avg:                                    0.58
         max:                                   55.42
         95th percentile:                        2.86
         sum:                               476093.66

Threads fairness:
    events (avg/stddev):           50955.7500/1076.72
    execution time (avg/stddev):   29.7559/0.02
```

Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Throughput
1	Min: 0.00 Max: 55.42 Avg: 0.58	Read, MiB/s: 0.00 Written, MiB/s: 185.75

2	Min: 0.00 Max: 72.29 Avg: 0.58	Read, MiB/s: 0.00 Written, MiB/s: 187.73
3	Min: 0.00 Max: 49.45 Avg: 0.58	Read, MiB/s: 0.00 Written, MiB/s: 186.58
4	Min: 0.00 Max: 59.45 Avg: 0.56	Read, MiB/s: 0.00 Written, MiB/s: 195.84
5	Min: 0.00 Max: 54.11 Avg: 0.61	Read, MiB/s: 0.00 Written, MiB/s: 178.10

ii. RNDRW

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw prepare
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw run
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw cleanup

```
Running the test with following options:
Number of threads: 16
Initializing random number generator from current time


Extra file open flags: (none)
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      5791.15
    writes/s:                     3860.45
    fsyncs/s:                     12418.40

Throughput:
    read, MiB/s:                  90.49
    written, MiB/s:               60.32

General statistics:
    total time:                          30.0962s
    total number of events:              662199

Latency (ms):
         min:                                    0.00
         avg:                                    0.72
         max:                                   45.42
         95th percentile:                        3.13
         sum:                               478280.55

Threads fairness:
    events (avg/stddev):           41387.4375/423.74
    execution time (avg/stddev):   29.8925/0.01
```

Iteration 1

The above step was run five more times producing the following results:

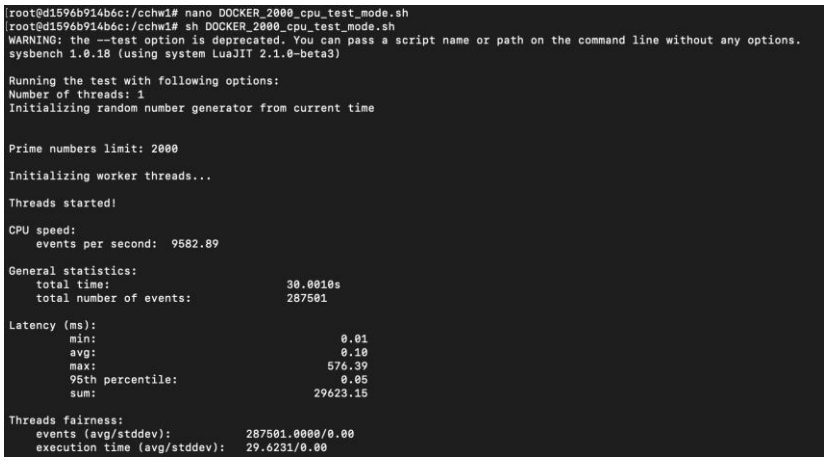
Iteration	Latency	Throughput
1	Min: 0.00 Max: 45.42 Avg: 0.72	Read, MiB/s: 90.49 Written, MiB/s: 60.32
2	Min: 0.00 Max: 77.82 Avg: 0.74	Read, MiB/s: 88.27 Written, MiB/s: 58.84
3	Min: 0.00 Max: 37.45 Avg: 0.71	Read, MiB/s: 92.66 Written, MiB/s: 61.77
4	Min: 0.00 Max: 70.36 Avg: 0.73	Read, MiB/s: 89.05 Written, MiB/s: 59.36
5	Min: 0.00 Max: 48.30 Avg: 0.76	Read, MiB/s: 86.46 Written, MiB/s: 57.64

Docker

docker run -it --memory=1G --cpuset-cpus=0 cchw1

a. CPU Mode

i. sysbench --test=cpu --cpu-max-prime=2000 --time=30 run



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.01 Max: 576.39 Avg: 0.10	9582.80
2	Min: 0.01 Max: 410.65 Avg: 0.02	47479.22
3	Min: 0.01 Max: 1017.12 Avg: 0.02	42046.77
4	Min: 0.01 Max: 1090.10 Avg: 0.17	5864.79
5	Min: 0.01 Max: 258.27 Avg: 0.01	70229.38

ii. sysbench --test=cpu --cpu-max-prime=20000 --time=30 run

```
root@d1596b914b6c:/cchw1# nano DOCKER_20000_cpu_test_mode.sh
root@d1596b914b6c:/cchw1# sh DOCKER_20000_cpu_test_mode.sh
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time


Prime numbers limit: 20000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:   560.52

General statistics:
    total time:                          30.0003s
    total number of events:              16816

Latency (ms):
         min:                                    0.24
         avg:                                    1.78
         max:                                  464.06
         95th percentile:                        1.23
         sum:                                29994.25

Threads fairness:
    events (avg/stddev):           16816.0000/0.00
    execution time (avg/stddev):   29.9942/0.00
```

Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.24 Max: 464.06 Avg: 1.78	560.52
2	Min: 0.24 Max: 483.78 Avg: 2.23	446.26
3	Min: 0.24 Max: 554.74 Avg: 2.51	398.13
4	Min: 0.24 Max: 574.88 Avg: 2.22	451.29
5	Min: 0.24 Max: 558.79 Avg: 1.64	609.96

iii. sysbench --test=cpu --cpu-max-prime=2000000 --time=30 run

```
root@d1596b914b6c:/cchw1# sh DOCKER_2000000_cpu_test_mode.sh
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time


Prime numbers limit: 2000000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:     4.39

General statistics:
    total time:                          30.0610s
    total number of events:              132

Latency (ms):
         min:                                  139.26
         avg:                                  227.71
         max:                                 2472.67
         95th percentile:                      303.33
         sum:                                30057.70

Threads fairness:
    events (avg/stddev):           132.0000/0.00
    execution time (avg/stddev):   30.0577/0.00
```

Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 139.26 Max: 2472.71 Avg: 227.71	4.39
2	Min: 138.27 Max: 2718.86 Avg: 259.78	3.85
3	Min: 129.84 Max: 564.55 Avg: 191.41	5.22
4	Min: 138.58 Max: 240.91 Avg: 181.15	5.52
5	Min: 138.51 Max: 229.16 Avg: 180.3	5.54

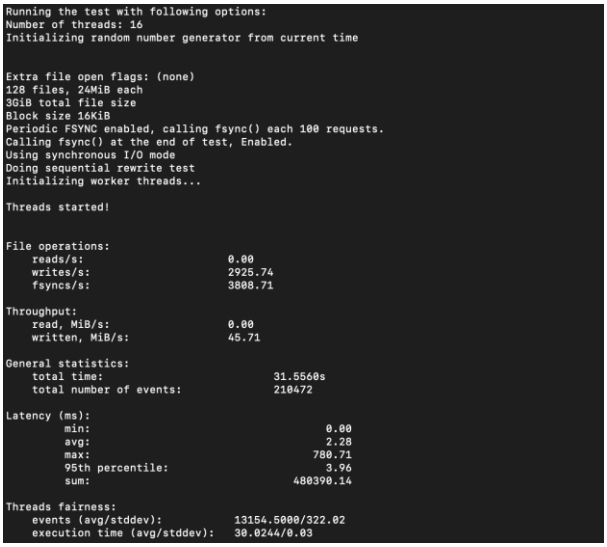
b. Fileio

i. SEQWR

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr prepare

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr run

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr cleanup



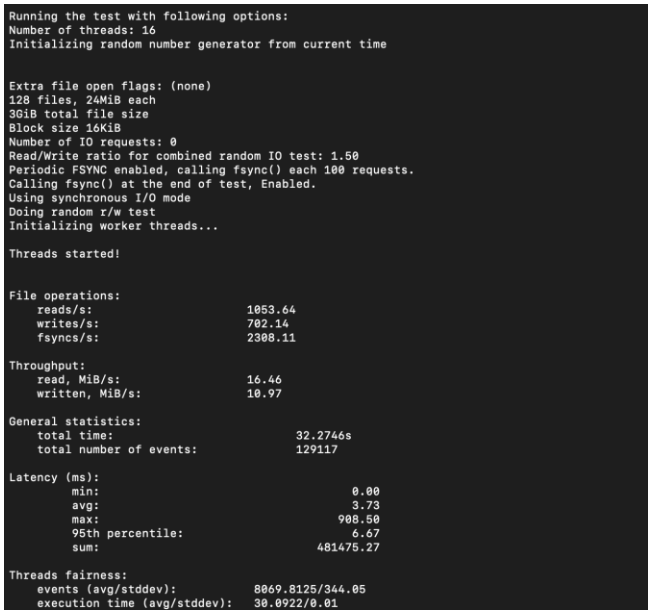
Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Throughput
1	Min: 0.00 Max: 780.71 Avg: 2.28	Read, MiB/s: 0.00 Written, MiB/s: 45.7
2	Min: 0.00 Max: 103.98 Avg: 1.04	Read, MiB/s: 0.00 Written, MiB/s: 104.90
3	Min: 0.00 Max: 763.09 Avg: 1.77	Read, MiB/s: 0.00 Written, MiB/s: 57.80
4	Min: 0.00 Max: 1242.97 Avg: 2.43	Read, MiB/s: 0.00 Written, MiB/s: 44.24
5	Min: 0.00 Max: 792.26 Avg: 1.88	Read, MiB/s: 0.00 Written, MiB/s: 54.34

ii. RNDRW

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw prepare
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw run
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw cleanup



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Throughput
1	Min: 0.00 Max: 908.50 Avg: 3.73	Read, MiB/s: 16.46 Written, MiB/s: 10.97
2	Min: 0.00 Max: 1672.20 Avg: 2.24	Read, MiB/s: 25.95 Written, MiB/s: 17.29
3	Min: 0.00 Max: 707.34 Avg: 2.21	Read, MiB/s: 27.77 Written, MiB/s: 18.51
4	Min: 0.00 Max: 1370.01 Avg: 2.75	Read, MiB/s: 21.41 Written, MiB/s: 14.27
5	Min: 0.00 Max: 738.94 Avg: 2.08	Read, MiB/s: 28.19 Written, MiB/s: 18.79

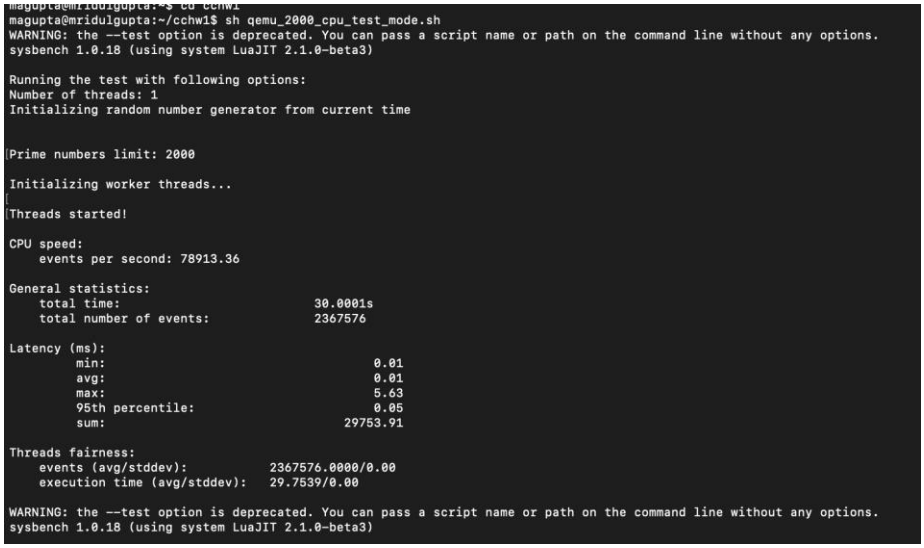
Configuration 2: Running on 2GB memory and 2 core

QEMU

```
qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2G \
-smp 2 \
-drivefile=/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="trial_2" \
-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
```

a. CPU Mode

i. sysbench --test=cpu --cpu-max-prime=2000 --time=30 run

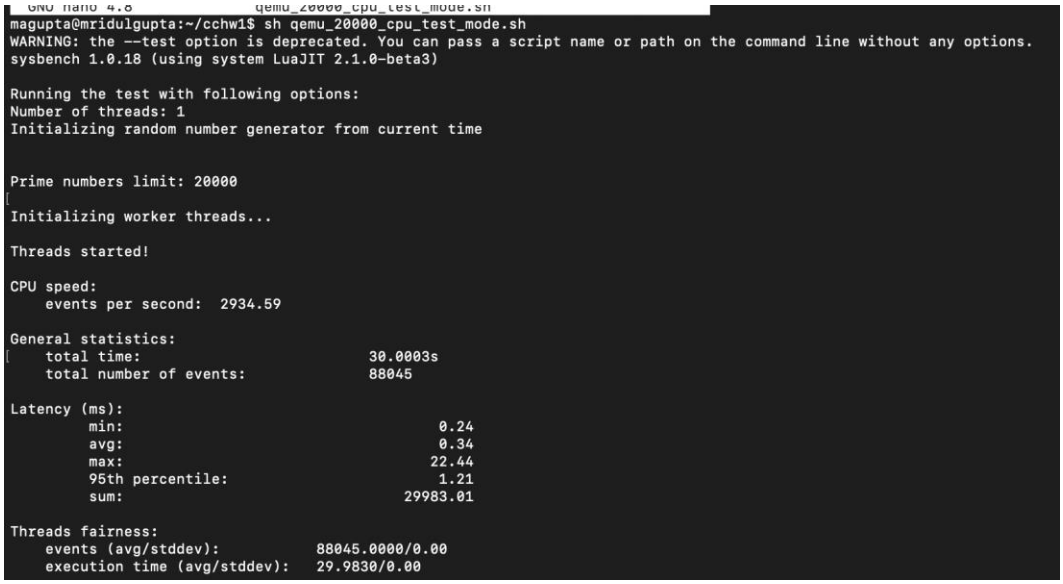


Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.01 Max: 5.63 Avg: 0.01	78913.36
2	Min: 0.01 Max: 22.61 Avg: 0.01	75219.64
3	Min: 0.01 Max: 8.29 Avg: 0.01	75286.24
4	Min: 0.01 Max: 9.75 Avg: 0.01	74969.58
5	Min: 0.01 Max: 19.81 Avg: 0.01	76582.80

ii. sysbench --test=cpu --cpu-max-prime=20000 --time=30 run

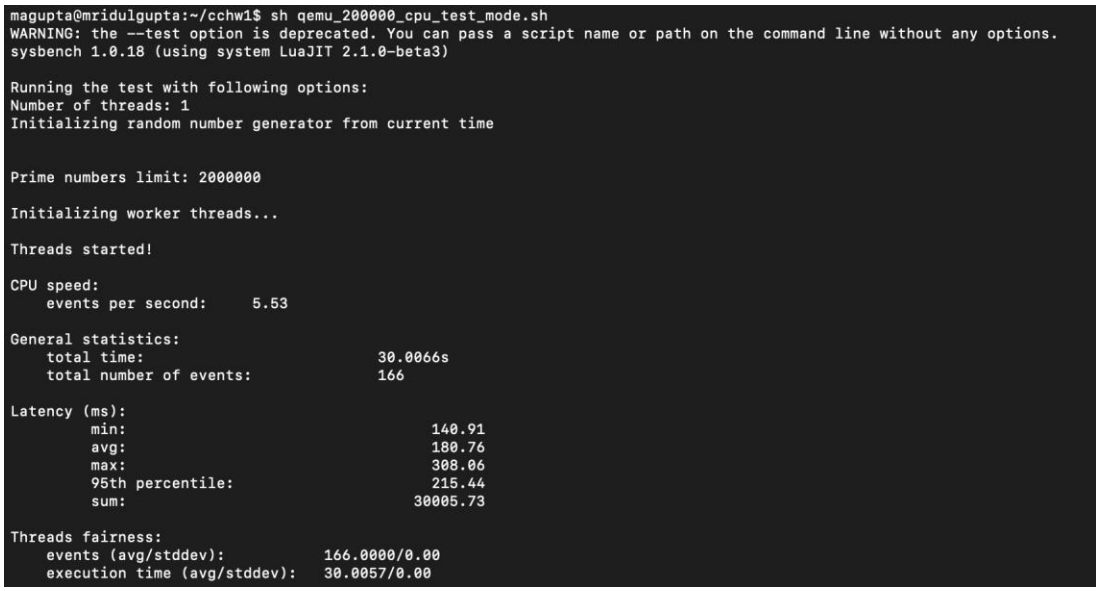


Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.24 Max: 22.44 Avg: 0.34	2934.59
2	Min: 0.24 Max: 8.40 Avg: 0.35	2868.67
3	Min: 0.24 Max: 8.96 Avg: 0.35	2873.96
4	Min: 0.24 Max: 8.34 Avg: 0.35	2877.00
5	Min: 0.24 Max: 12.18 Avg: 0.34	2923.64

iii. sysbench --test=cpu --cpu-max-prime=2000000 --time=30 run



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 140.91 Max: 388.06 Avg: 180.76	5.53
2	Min: 141.44 Max: 245.92 Avg: 184.72	5.41
3	Min: 129.88 Max: 222.62 Avg: 186.74	5.35
4	Min: 138.23 Max: 238.25 Avg: 188.42	5.31
5	Min: 154.62 Max: 235.55 Avg: 183.47	5.45

b. Fileio

i. SEQWR

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr prepare

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr run

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr cleanup

```
Running the test with following options:
Number of threads: 16
Initializing random number generator from current time


Extra file open flags: (none)
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential rewrite test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      0.00
    writes/s:                     16204.83
    fsyncs/s:                     20809.73

Throughput:
    read, MiB/s:                  0.00
    written, MiB/s:               253.20

General statistics:
    total time:                          30.0331s
    total number of events:              1109657

Latency (ms):
         min:                                    0.00
         avg:                                    0.43
         max:                                   40.71
         95th percentile:                        1.96
         sum:                               478545.18

Threads fairness:
    events (avg/stddev):           69353.5625/1607.73
    execution time (avg/stddev):   29.9091/0.01
```

Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Throughput
1	Min: 0.00 Max: 40.71 Avg: 0.43	Read, MiB/s: 0.00 Written, MiB/s: 253.20
2	Min: 0.00 Max: 67.38 Avg: 0.39	Read, MiB/s: 0.00 Written, MiB/s: 186.58
3	Min: 0.00 Max: 20.11	Read, MiB/s: 0.00 Written, MiB/s: 294.57

	Avg: 0.37	
4	Min: 0.00 Max: 38.89 Avg: 0.36	Read, MiB/s: 0.00 Written, MiB/s: 299.66
5	Min: 0.00 Max: 42.76 Avg: 0.37	Read, MiB/s: 0.00 Written, MiB/s: 295.02

ii. RNDRW

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw prepare
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw run
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw cleanup

```
Running the test with following options:
Number of threads: 16
Initializing random number generator from current time


Extra file open flags: (none)
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      7823.74
    writes/s:                     5215.72
    fsyncs/s:                     16757.40

Throughput:
    read, MiB/s:                  122.25
    written, MiB/s:               81.50

General statistics:
    total time:                          30.0407s
    total number of events:              893106

Latency (ms):
         min:                                    0.00
         avg:                                    0.54
         max:                                   37.68
         95th percentile:                        1.93
         sum:                               479069.36

Threads fairness:
    events (avg/stddev):           55819.1250/452.27
    execution time (avg/stddev):   29.9418/0.01
```

Iteration 1

The above step was run five more times producing the following results:

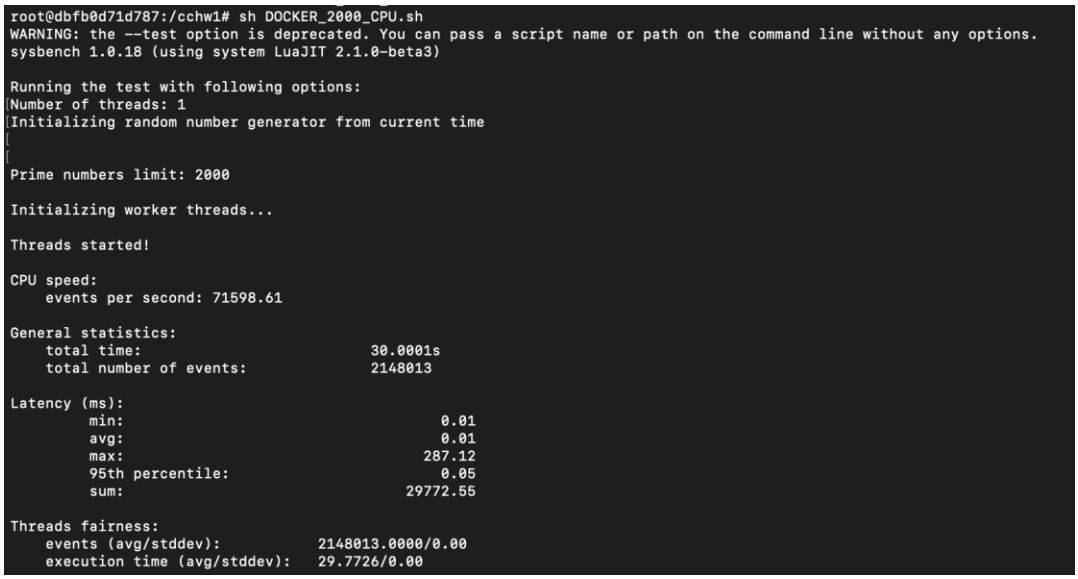
Iteration	Latency	Throughput
1	Min: 0.00 Max: 37.68 Avg: 0.54	Read, MiB/s: 122.25 Written, MiB/s: 81.50
2	Min: 0.00 Max: 41.79 Avg: 0.57	Read, MiB/s: 115.32 Written, MiB/s: 76.88
3	Min: 0.00 Max: 40.04 Avg: 0.51	Read, MiB/s: 128.41 Written, MiB/s: 85.60
4	Min: 0.00 Max: 57.34 Avg: 0.54	Read, MiB/s: 121.44 Written, MiB/s: 80.96
5	Min: 0.00 Max: 104.31 Avg: 0.53	Read, MiB/s: 124.61 Written, MiB/s: 83.07

Docker

docker run -it --memory=2G --cpuset-cpus=1 cchw1

a. CPU Mode

i. sysbench --test=cpu --cpu-max-prime=2000 --time=30 run



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.01 Max: 287.12 Avg: 0.01	71598.61
2	Min: 0.01 Max: 10.04 Avg: 0.01	80141.33
3	Min: 0.01 Max: 22.44 Avg: 0.01	78599.47
4	Min: 0.01 Max: 12.35 Avg: 0.01	72551.82
5	Min: 0.01 Max: 6.56 Avg: 0.01	72493.34

ii. sysbench --test=cpu --cpu-max-prime=20000 --time=30 run

```
root@dbfb0d71d787:/cchw1# sh DOCKER_20000_CPU.sh
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
Number of threads: 1
Initializing random number generator from current time


Prime numbers limit: 20000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:  2749.64

General statistics:
    total time:                          30.0003s
    total number of events:              82492

Latency (ms):
         min:                                    0.24
         avg:                                    0.36
         max:                                  533.43
         95th percentile:                        1.21
         sum:                                29982.13

Threads fairness:
    events (avg/stddev):           82492.0000/0.00
    execution time (avg/stddev):   29.9821/0.00
```

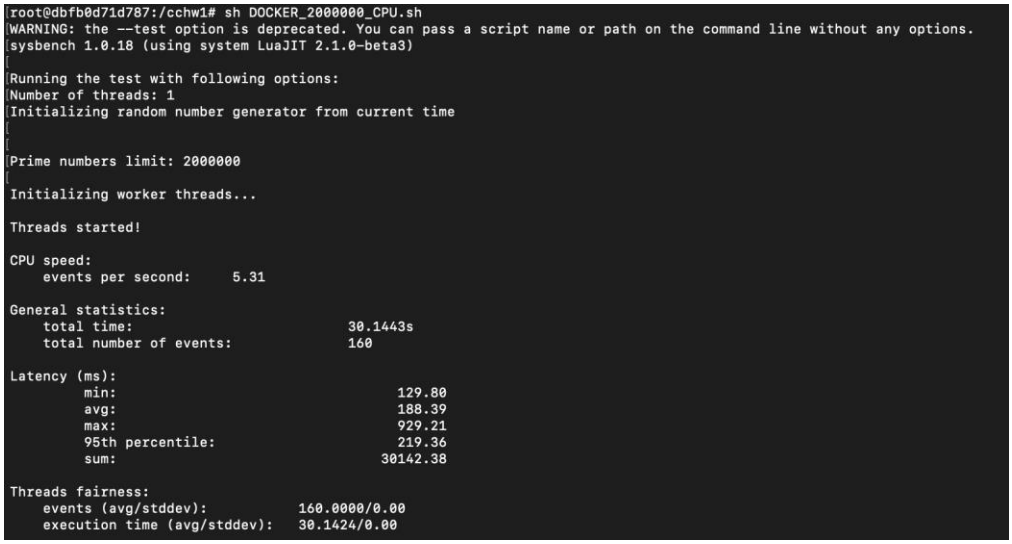
Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec

1	Min: 0.24 Max: 533.43 Avg: 0.36	2749.64
2	Min: 0.24 Max: 17.41 Avg: 0.34	2927.13
3	Min: 0.24 Max: 948.27 Avg: 1.33	742.97
4	Min: 0.24 Max: 1580.80 Avg: 0.95	1049.18
5	Min: 0.24 Max: 29.42 Avg: 0.34	2929.02

iii. sysbench --test=cpu --cpu-max-prime=2000000 --time=30 run



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 129.80 Max: 929.21 Avg: 188.39	5.31

2	Min: 140.90 Max: 1971.53 Avg: 222.93	4.49
3	Min: 1413.49 Max: 4736.80 Avg: 2381.80	0.42
4	Min: 147.56 Max: 4985.87 Avg: 411.70	2.43
5	Min: 144.99 Max: 221.68 Avg: 187.13	5.34

b. Fileio

i. SEQWR

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr prepare
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr run
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr cleanup

```
Running the test with following options:
Number of threads: 16
Initializing random number generator from current time


Extra file open flags: (none)
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential rewrite test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      0.00
    writes/s:                     271.59
    fsyncs/s:                     409.63

Throughput:
    read, MiB/s:                  0.00
    written, MiB/s:               4.24

General statistics:
    total time:                          31.6642s
    total number of events:              19523

Latency (ms):
         min:                                    0.00
         avg:                                   24.79
         max:                                 1119.43
         95th percentile:                      179.94
         sum:                                483965.16

Threads fairness:
    events (avg/stddev):           1220.1875/227.03
    execution time (avg/stddev):   30.2478/0.03
```

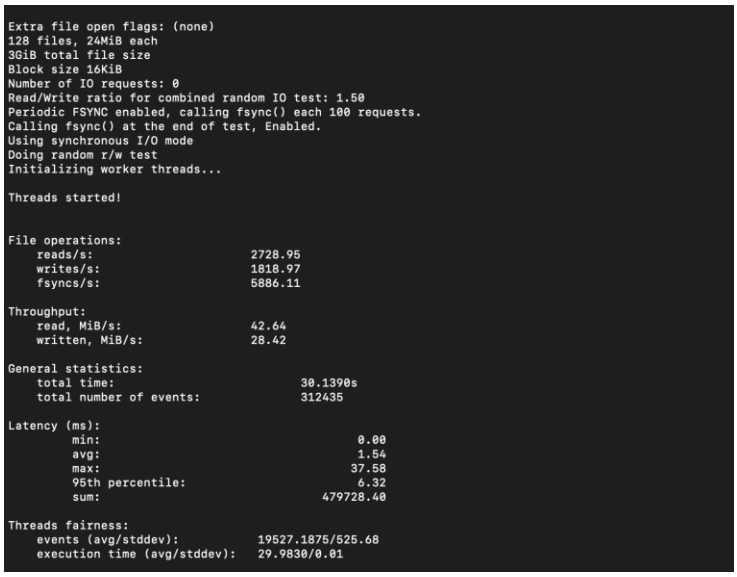
Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Throughput
1	Min: 0.00 Max: 1119.43 Avg: 24.79	Read, MiB/s: 0.00 Written, MiB/s: 4.24
2	Min: 0.00 Max: 1025.17 Avg: 2.42	Read, MiB/s: 0.00 Written, MiB/s: 42.48
3	Min: 0.00 Max: 766.62 Avg: 1.25	Read, MiB/s: 0.00 Written, MiB/s: 84.11
4	Min: 0.00 Max: 48.64 Avg: 1.10	Read, MiB/s: 0.00 Written, MiB/s: 98.99
5	Min: 0.00 Max: 47.27 Avg: 1.13	Read, MiB/s: 0.00 Written, MiB/s: 96.65

ii. RNDRW

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw prepare
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw run
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw cleanup



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Throughput
1	Min: 0.00 Max: 37.58 Avg: 1.54	Read, MiB/s: 42.64 Written, MiB/s: 28.42
2	Min: 0.00 Max: 1354.36 Avg: 3.21	Read, MiB/s: 19.37 Written, MiB/s: 12.91
3	Min: 0.00 Max: 56.58 Avg: 1.68	Read, MiB/s: 39.08 Written, MiB/s: 26.06
4	Min: 0.00 Max: 37.59 Avg: 1.54	Read, MiB/s: 42.36 Written, MiB/s: 28.24
5	Min: 0.00 Max: 897.13 Avg: 3.06	Read, MiB/s: 16.08 Written, MiB/s: 10.72

Configuration 3: Running on 3GB memory and 3 core

QEMU

```
qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 3G \
-smp 3 \
-drivefile=/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="trial_2" \
-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
```

a. CPU Mode

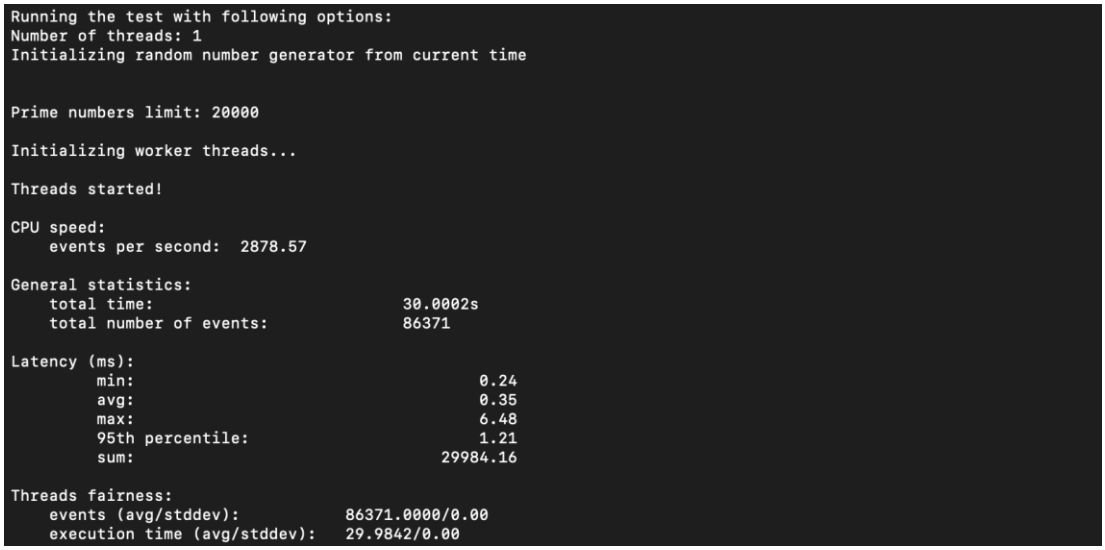
i. sysbench --test=cpu --cpu-max-prime=2000 --time=30 run

Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.01 Max: 566.47 Avg: 0.04	25626.20
2	Min: 0.01 Max: 986.84 Avg: 0.14	7088.37
3	Min: 0.01 Max: 1442.87 Avg: 0.13	7417.98
4	Min: 0.01 Max: 950.64 Avg: 0.18	5458.28
5	Min: 0.01 Max: 390.89 Avg: 0.03	39136.38

ii. sysbench --test=cpu --cpu-max-prime=20000 --time=30 run

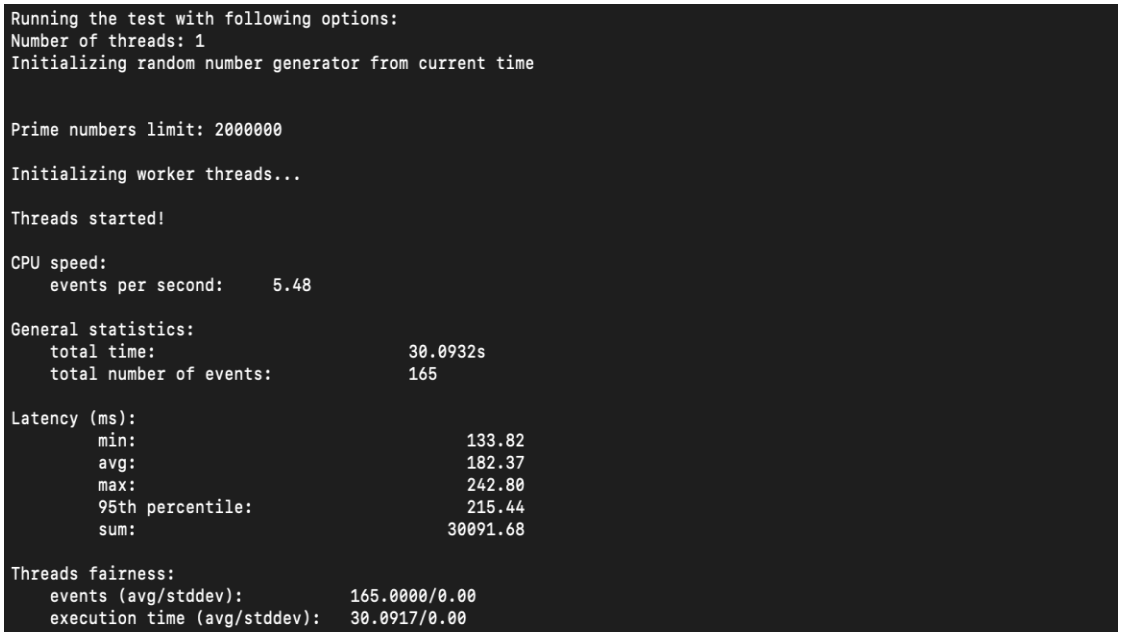


Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.24 Max: 6.48 Avg: 0.35	2878.57
2	Min: 0.24 Max: 15.54 Avg: 0.35	2867.60
3	Min: 0.24 Max: 11.74 Avg: 0.35	2850.86
4	Min: 0.24 Max: 38.91 Avg: 0.34	2926.39
5	Min: 0.24 Max: 16.82 Avg: 0.34	2900.71

iii. sysbench --test=cpu --cpu-max-prime=2000000 --time=30 run



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 133.82 Max: 242.80 Avg: 182.37	5.48
2	Min: 144.28 Max: 254.39 Avg: 185.08	5.40
3	Min: 147.14 Max: 242.96 Avg: 187.35	5.34
4	Min: 140.51 Max: 239.42 Avg: 180.70	5.53
5	Min: 138.60 Max: 228.78 Avg: 184.50	5.42

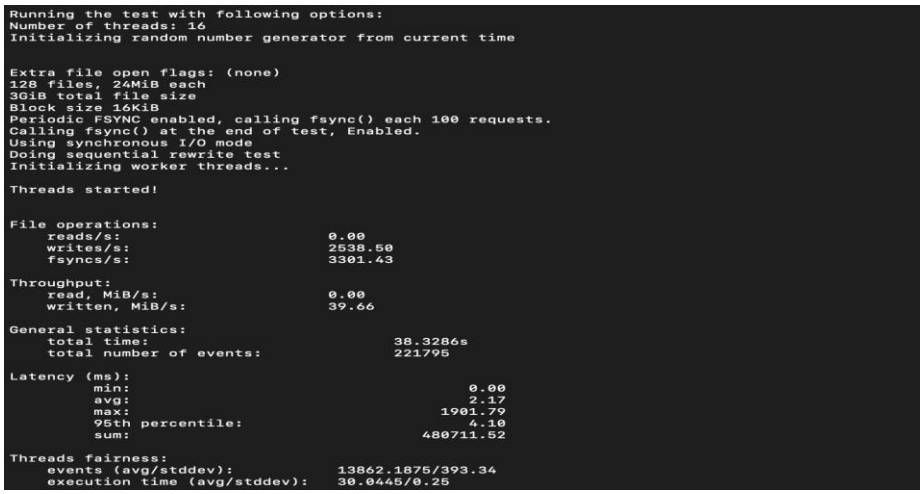
b. Fileio

i. SEQWR

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr prepare

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr run

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr cleanup



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Throughput
1	Min: 0.00 Max: 1901.79 Avg: 2.17	Read, MiB/s: 0.00 Written, MiB/s: 39.66
2	Min: 0.00 Max: 1087.07 Avg: 2.66	Read, MiB/s: 0.00 Written, MiB/s: 38.79
3	Min: 0.00 Max: 71.26 Avg: 1.15	Read, MiB/s: 0.00 Written, MiB/s: 95.01
4	Min: 0.00 Max: 760.84 Avg: 1.79	Read, MiB/s: 0.00 Written, MiB/s: 54.84
5	Min: 0.00 Max: 1016.32 Avg: 2.09	Read, MiB/s: 0.00 Written, MiB/s: 52.37

ii. RNDRW

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw prepare

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw run

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw cleanup

```
Running the test with following options:
Number of threads: 16
Initializing random number generator from current time


Extra file open flags: (none)
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      676.68
    writes/s:                     451.12
    fsyncs/s:                     1500.96

Throughput:
    read, MiB/s:                  10.57
    written, MiB/s:               7.05

General statistics:
    total time:                          33.6925s
    total number of events:              86525

Latency (ms):
         min:                                    0.00
         avg:                                    5.57
         max:                                  869.47
         95th percentile:                        4.57
         sum:                               481620.32

Threads fairness:
    events (avg/stddev):           5407.8125/258.71
    execution time (avg/stddev):   30.1013/0.06
```

Iteration 1

The above step was run five more times producing the following results:

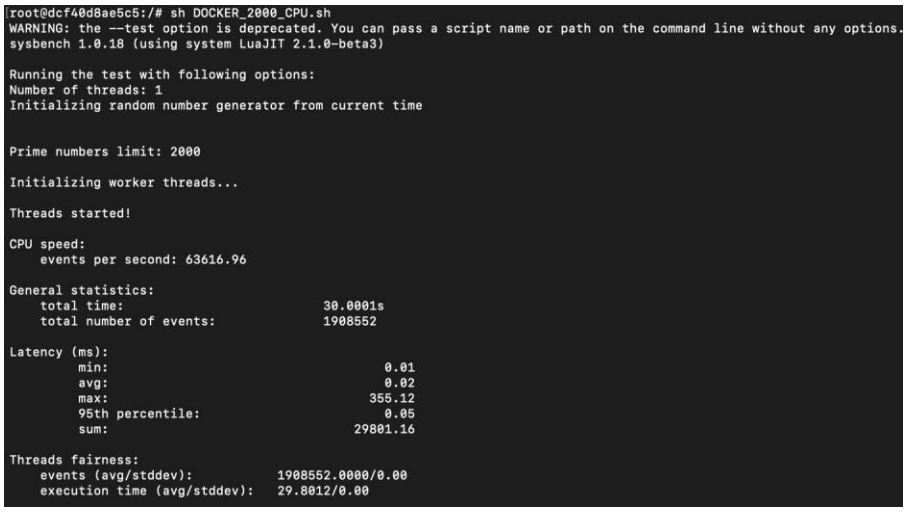
Iteration	Latency	Throughput
1	Min: 0.00 Max: 869.47 Avg: 5.57	Read, MiB/s: 10.57 Written, MiB/s: 7.05
2	Min: 0.00 Max: 759.10 Avg: 1.18	Read, MiB/s: 45.72 Written, MiB/s: 30.48
3	Min: 0.00 Max: 90.71 Avg: 1.01	Read, MiB/s: 64.57 Written, MiB/s: 43.04
4	Min: 0.00 Max: 994.25 Avg: 1.72	Read, MiB/s: 38.20 Written, MiB/s: 25.47
5	Min: 0.00 Max: 845.91 Avg: 2.30	Read, MiB/s: 25.28 Written, MiB/s: 16.85

Docker

docker run -it --memory=3G --cpuset-cpus=2 cchw1

a. CPU Mode

i. sysbench --test=cpu --cpu-max-prime=2000 --time=30 run

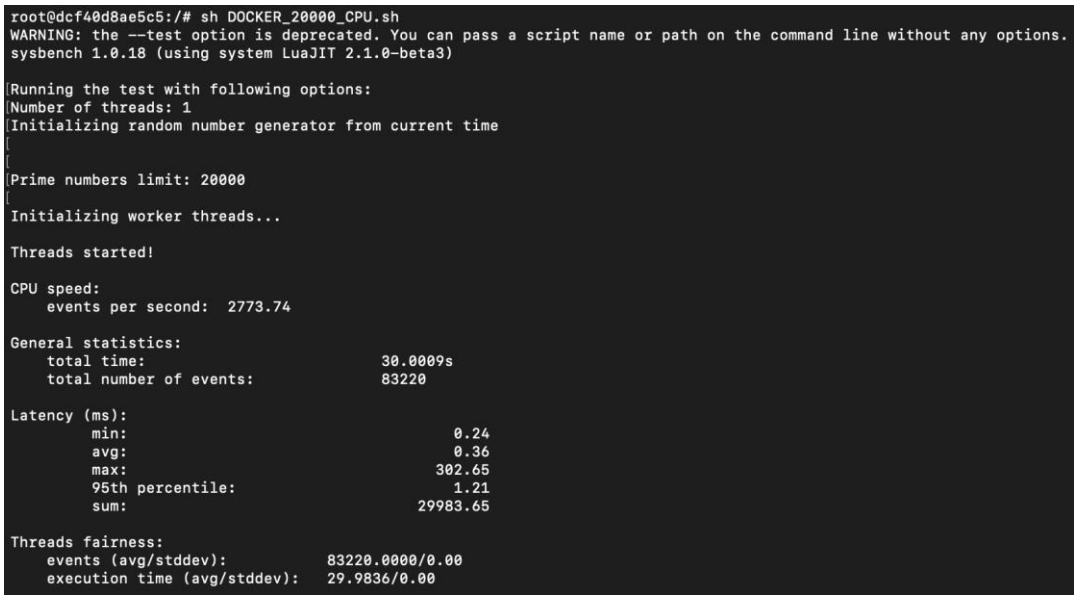


Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 0.01 Max: 355.12 Avg: 0.02	63616.96
2	Min: 0.01 Max: 8.22 Avg: 0.01	77032.62
3	Min: 0.01 Max: 30.38 Avg: 0.01	75091.52
4	Min: 0.01 Max: 11.12 Avg: 0.01	75644.14
5	Min: 0.01 Max: 495.44 Avg: 0.02	58865.08

ii. sysbench --test=cpu --cpu-max-prime=20000 --time=30 run



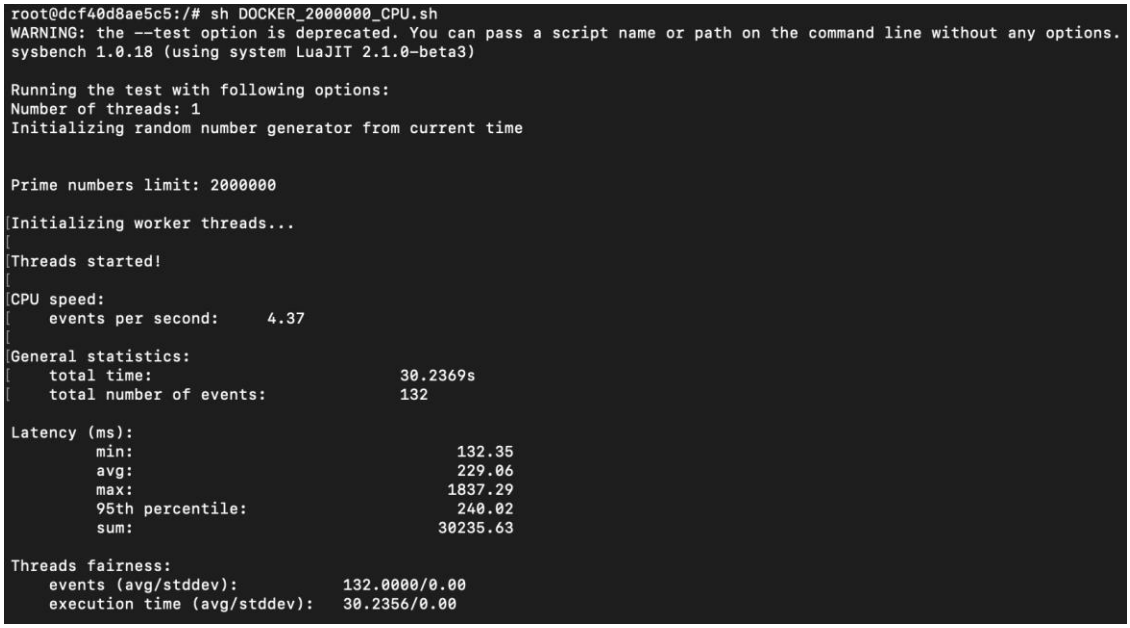
Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec

1	Min: 0.24 Max: 302.65 Avg: 0.36	2773.74
2	Min: 0.24 Max: 26.92 Avg: 0.35	2850.46
3	Min: 0.24 Max: 635.76 Avg: 0.55	1818.35
4	Min: 0.24 Max: 1194.50 Avg: 5.01	199.73
5	Min: 0.24 Max: 685.31 Avg: 2.98	335.71

iii. sysbench --test=cpu --cpu-max-prime=2000000 --time=30 run



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Events/sec
1	Min: 132.35 Max: 1837.29	4.37

	Avg: 229.06	
2	Min: 138.33 Max: 1356.69 Avg: 192.45	5.20
3	Min: 164.91 Max: 6154.58 Avg: 1568.39	0.63
4	Min: 140.12 Max: 1907.52 Avg: 239.47	4.18
5	Min: 136.64 Max: 252.00 Avg: 184.21	5.43

b. Fileio

i. SEQWR

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr prepare

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr run

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=seqrewr cleanup

```
Running the test with following options:
Number of threads: 16
Initializing random number generator from current time


Extra file open flags: (none)
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential rewrite test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      0.00
    writes/s:                     1490.13
    fsyncs/s:                     1974.52

Throughput:
    read, MiB/s:                  0.00
    written, MiB/s:               23.28

General statistics:
    total time:                          30.1975s
    total number of events:              102580

Latency (ms):
         min:                                    0.00
         avg:                                    4.68
         max:                                 1033.45
         95th percentile:                        4.74
         sum:                               479799.62

Threads fairness:
    events (avg/stddev):           6411.2500/325.83
    execution time (avg/stddev):   29.9875/0.02
```

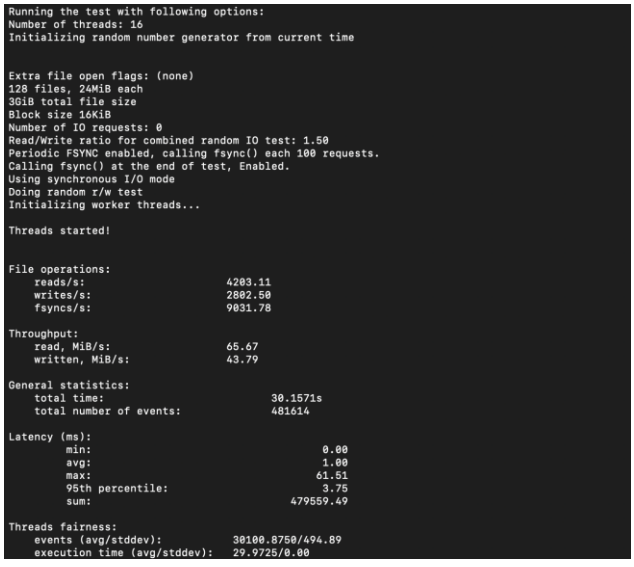
Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Throughput
1	Min: 0.00 Max: 1033.45 Avg: 4.68	Read, MiB/s: 0.00 Written, MiB/s: 23.28
2	Min: 0.00 Max: 625.92 Avg: 1.26	Read, MiB/s: 0.00 Written, MiB/s: 86.58
3	Min: 0.00 Max: 67.57 Avg: 1.19	Read, MiB/s: 0.00 Written, MiB/s: 91.25
4	Min: 0.00 Max: 71.93 Avg: 1.18	Read, MiB/s: 0.00 Written, MiB/s: 92.00
5	Min: 0.00 Max: 27.84 Avg: 1.12	Read, MiB/s: 0.00 Written, MiB/s: 97.51

ii. RNDRW

sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw prepare
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw run
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw cleanup



Iteration 1

The above step was run five more times producing the following results:

Iteration	Latency	Throughput
1	Min: 0.00 Max: 61.51 Avg: 1.00	Read, MiB/s: 65.67 Written, MiB/s: 43.79
2	Min: 0.00 Max: 68.89 Avg: 1.02	Read, MiB/s: 64.44 Written, MiB/s: 42.96
3	Min: 0.00 Max: 26.28 Avg: 0.96	Read, MiB/s: 68.06 Written, MiB/s: 45.38
4	Min: 0.00 Max: 41.73 Avg: 0.99	Read, MiB/s: 66.21 Written, MiB/s: 44.14
5	Min: 0.00 Max: 630.09 Avg: 1.67	Read, MiB/s: 37.62 Written, MiB/s: 25.08

CONCLUSION(CPU TEST MODE): We note that the number of events further decrease as we continue to increase the cpu-max-prime argument value. QEMU VM continues to be faster than Docker desktop for M1 MacBooks.

Based on our findings, we can safely conclude that as we increase the cpu-max-prime argument value, our number of events per second continue to decrease, as in, greater the value of cpu-max-prime argument, lower the number of events per second for sysbench CPU testing.

CONCLUSION(FILEIO TEST MODE): We see that the file I/O performance actually decreases if we increase resource allocation according to the experiments conducted above. Docker performs similar to QEMU although most times QEMU outperforms docker.

Presentation and analysis of the performance data

QEMU Analysis:

1. CPU utilization of QEMU:

    Percentage of CPU used = 101.5
    Kernel Usage

User = 9.71%
System = 9.80%
Idle = 80.48%

2. Disk Utilization
    a. 1Gb memory and 1 core
        i. Sequential write
        1. Read (MiB/s) = 0.0
        2. Written (MiB/s) = 184.72
        ii. Combined random read write
        1. Read (MiB/s) = 85.32
        2. Written (MiB/s) = 156.61

    b. 2Gb memory and 2 core
        i. Sequential write
        1. Read (MiB/s) = 0.0
        2. Written (MiB/s) = 294.42

        ii. Combined random read write
        1. Read (MiB/s) = 123.94
        2. Written (MiB/s) = 82.48

    c. 3Gb memory and 3 core
        i. Sequential write
        1. Read (MiB/s) = 0.0
        2. Written (MiB/s) = 38.81

        ii. Combined random read write
        1. Read (MiB/s) = 9.08
        2. Written (MiB/s) = 6.67

Docker Analysis:

1. CPU utilization of Docker:

    Percentage of CPU used = 102.3
    Kernel Usage
        User = 14.31%
        System = 18.62%
        Idle = 67.07%

2. Disk Utilization
    a. 1Gb memory and 1 core
        i. Sequential write

1. Read (MiB/s) = 0.0
2. Written (MiB/s) = 44.38

ii. Combined random read write

1. Read (MiB/s) = 15.26
2. Written (MiB/s) = 9.67

b. 2Gb memory and 2 core

i. Sequential write

1. Read (MiB/s) = 0.00
2. Written (MiB/s) = 3.23

ii. Combined random read write

1. Read (MiB/s) = 41.63
2. Written (MiB/s) = 27.19

c. 3Gb memory and 3 core

i. Sequential write

1. Read (MiB/s) = 0.0
2. Written (MiB/s) = 22.64

ii. Combined random read write

1. Read (MiB/s) = 52.64
2. Written (MiB/s) = 35.10

I created the following docker file to build my image as shown:
The contents of my dockerfile are pasted on my github.

```
(base) udisha@Udishas-MacBook-Pro Desktop % docker build -t dockerfileimage:3.0 .
[+] Building 8.0s (7/7) FINISHED
 => [internal] load build definition from Dockerfile                      2.6s
 => => transferring dockerfile: 36B                                       0.5s
 => [internal] load .dockerignore                                         2.4s
 => => transferring context: 2B                                           0.5s
 => [internal] load metadata for docker.io/library/ubuntu:focal           0.0s
 => [1/3] FROM docker.io/library/ubuntu:focal                             0.0s
 => CACHED [2/3] RUN apt-get update                                       0.0s
 => CACHED [3/3] RUN apt-get install sudo                                 0.0s
 => exporting to image                                                    1.4s
 => => exporting layers                                                   0.0s
 => => writing image sha256:95ccd261fb885124fa9f1f982abed39aa8d68ee08bd6e  0.2s
 => => naming to docker.io/library/dockerfileimage:3.0                    0.5s

Use 'docker scan' to run Snyk tests against images to find vulnerabilities and learn how to fix them
(base) udisha@Udishas-MacBook-Pro Desktop % docker images
REPOSITORY        TAG       IMAGE ID       CREATED          SIZE
<none>            <none>    e6efb3b3dfcf   13 minutes ago   97.4MB
dockerfileimage   1.0       95ccd261fb88   13 minutes ago   97.4MB
dockerfileimage   2.0       95ccd261fb88   13 minutes ago   97.4MB
dockerfileimage   3.0       95ccd261fb88   13 minutes ago   97.4MB
cchw1             latest    c38eb4e2ef3d   17 hours ago     117MB
ubuntu            focal     f12f227aa3fd   13 days ago      65.6MB
(base) udisha@Udishas-MacBook-Pro Desktop % docker run 95ccd261fb88
Hello World...! from my first docker image
(base) udisha@Udishas-MacBook-Pro Desktop %
```

Github Repository Information

Account Name – mridul1998
Repository Name – COEN241_Cloud_Computing
A folder called Homework1 is created which contains the shell script, the Dockerfile and the Report for the assignment.
Link to Repository - https://github.com/mridul1998/COEN241_Cloud_Computing
commit id - d3cf8d4f3b6d7d9fb3e6a8f5221e8d9fa9c56678