HW 1 COEN 241

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QEMU Installation and making QEMU disk image:

1. Download ISO
   Ubuntu guest VM is needed which requires server ISO image. We can use the following link:
   ARM (Apple Silicon): Ubuntu 20.04 Server for ARM
2. Use the Following commands for installing QEMU on Macbook Air M1 Chip
   brew install qemu
3. To create QEMU image, use the following command:
   qemu-img create ubuntu.img 20G -f qcow2
4. Install VM by running the following:
   qemu-system-aarch64 \-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2G \-smp 2 \-drive file=/opt/homebrew/Cellar/qemu/7.2.0/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-20.04.5-live-server-arm64.iso \-device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic
   Follow the instructions given while installing VM to get it installed successfully.
5. To run the image, use the following:
   qemu-system-aarch64 \-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2G \-smp 2 \-drive file=/opt/homebrew/Cellar/qemu/7.2.0/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

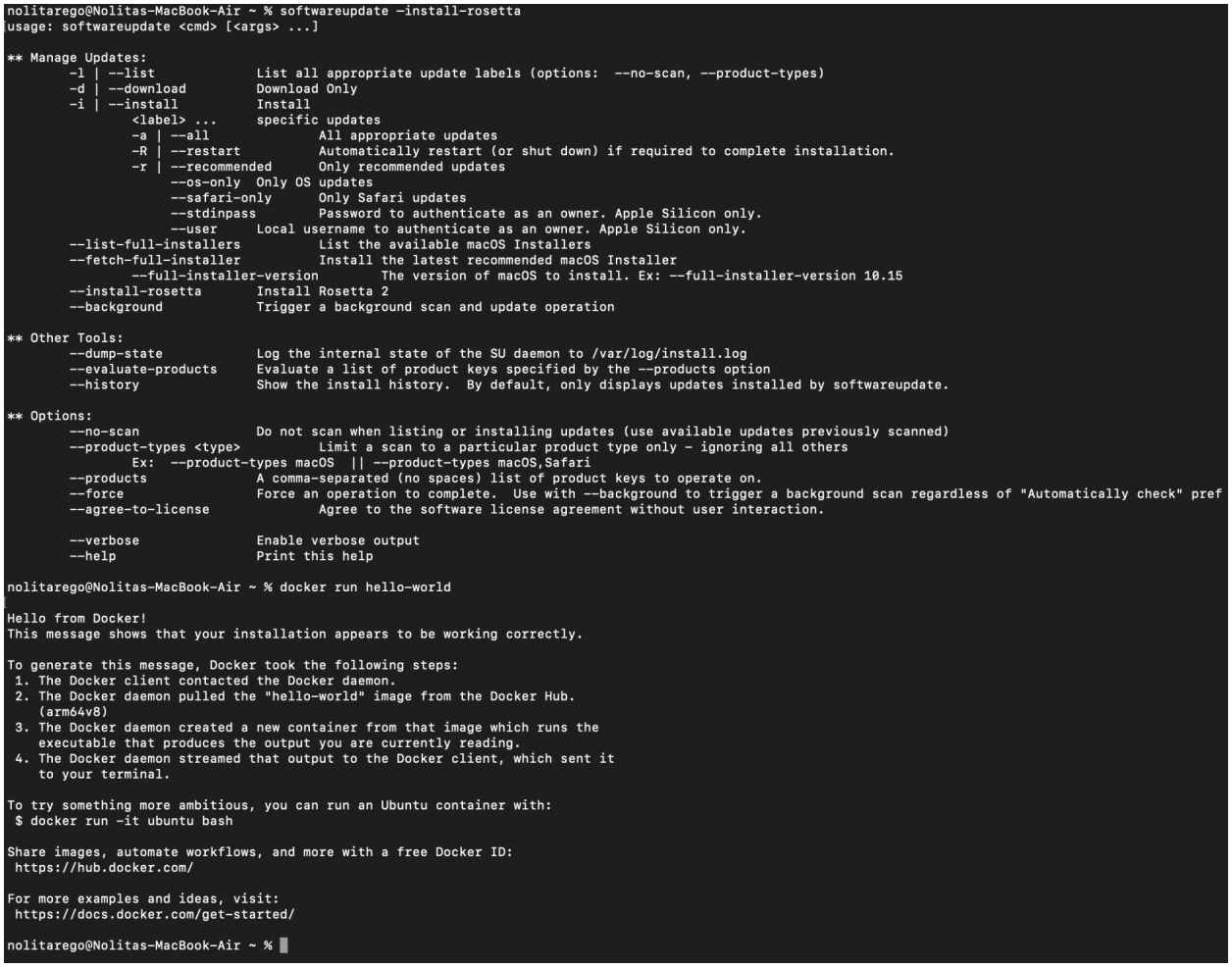
Experimental Setup:
System Configuration:
Macbook Air M1 Chip (2021), 8GB Memory

Testing 3 configurations:

- 2 cores with 2GB memory allocation
- 4 cores with 4GB memory allocation
- 6 cores with 6GB memory allocation

Docker Installation:

1. Install Rosetta 2 for docker.
   softwareupdate-install-rosetta
2. Install docker engine, download docker dmg image here.
3. Check if docker is installed correctly by running the command:
   docker run hello-world



Experiments: QEMU and Docker Results

Configuration 1: 2GB RAM and 2 cores

Tests:

1. Max-prime=2000, time=30 seconds
2. Max-prime=20000, time=30 seconds
3. Max-prime=200000, time=30 seconds

Install sysbench before running the below command:
Brew install sysbench

Sysbench command:
sysbench cpu --cpu-max-prime={some_value} --num-threads={some_value} --time= {some_value} run

QEMU Results:

- Test 1:

```
WARNING: the --test option is deprecated. You can pass
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: 117629.79

General statistics:
    total time:                          30.0033s
    total number of events:              3531502

Latency (ms):
         min:                                    0.01
         avg:                                    0.01
         max:                                    5.08
         95th percentile:                        0.01
         sum:                                29710.69

Threads fairness:
    events (avg/stddev):           3531502.0000/0.00
    execution time (avg/stddev):   29.7107/0.00
```

Iteration 1

```
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: 115037.16

General statistics:
    total time:                          30.0113s
    total number of events:              3458529

Latency (ms):
         min:                                    0.01
         avg:                                    0.01
         max:                                  132.41
         95th percentile:                        0.01
         sum:                                29714.81

Threads fairness:
    events (avg/stddev):           3458529.0000/0.00
    execution time (avg/stddev):   29.7148/0.00
```

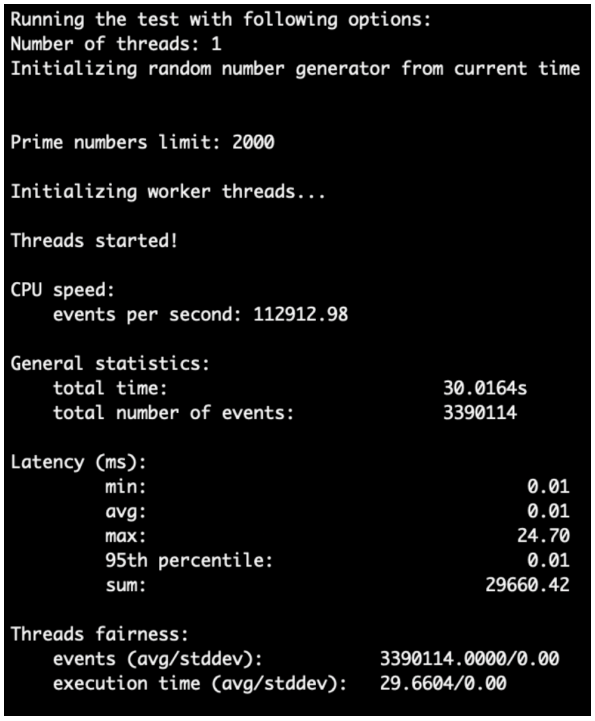
Iteration 2

```
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: 115160.19

General statistics:
    total time:                          30.0204s
    total number of events:              3459362

Latency (ms):
         min:                                    0.01
         avg:                                    0.01
         max:                                   16.17
         95th percentile:                        0.01
         sum:                                29501.63

Threads fairness:
    events (avg/stddev):           3459362.0000/0.00
    execution time (avg/stddev):   29.5016/0.00
```

Iteration 3

```
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: 110559.19

General statistics:
    total time:                          30.0076s
    total number of events:              3318943

Latency (ms):
         min:                                    0.01
         avg:                                    0.01
         max:                                   36.13
         95th percentile:                        0.01
         sum:                                29494.88

Threads fairness:
    events (avg/stddev):           3318943.0000/0.00
    execution time (avg/stddev):   29.4949/0.00
```

Iteration 4



Iteration 5

Iteration no.	Events per second
1	117629.79 - max
2	115037.16
3	115160.19
4	110559.19 - min
5	112912.98
Average	114259.86

- Test 2:

```
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:  4301.90

General statistics:
    total time:                          30.0070s
    total number of events:              129154

Latency (ms):
         min:                                    0.23
         avg:                                    0.23
         max:                                    7.74
         95th percentile:                        0.24
         sum:                                29968.78

Threads fairness:
    events (avg/stddev):           129154.0000/0.00
    execution time (avg/stddev):   29.9688/0.00
```

Iteration 1

```
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:  4319.10

General statistics:
    total time:                          30.0002s
    total number of events:              129581

Latency (ms):
         min:                                    0.23
         avg:                                    0.23
         max:                                    2.00
         95th percentile:                        0.24
         sum:                                29949.83

Threads fairness:
    events (avg/stddev):           129581.0000/0.00
    execution time (avg/stddev):   29.9498/0.00
```

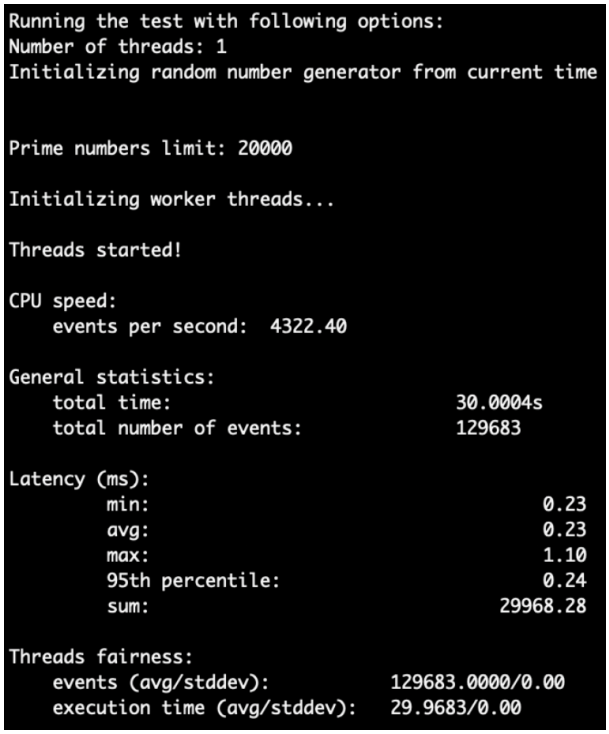
Iteration 2

```
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:  4326.48

General statistics:
    total time:                          30.0005s
    total number of events:              129821

Latency (ms):
         min:                                    0.23
         avg:                                    0.23
         max:                                    9.91
         95th percentile:                        0.24
         sum:                                29973.12

Threads fairness:
    events (avg/stddev):           129821.0000/0.00
    execution time (avg/stddev):   29.9731/0.00
```

Iteration 3

```
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:  4331.81

General statistics:
    total time:                          30.0013s
    total number of events:              129987

Latency (ms):
         min:                                    0.23
         avg:                                    0.23
         max:                                    0.84
         95th percentile:                        0.24
         sum:                                29970.90

Threads fairness:
    events (avg/stddev):           129987.0000/0.00
    execution time (avg/stddev):   29.9709/0.00
```

Iteration 4



Iteration 5

Iteration no.	Events per second
1	4301.90 - min
2	4319.10
3	4326.8
4	4331.81 - max
5	4322.40
Average	4320.33

- Test 3:

```
WARNING: the --test option is deprecated. You can pass a
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: 200000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:   189.83

General statistics:
    total time:                          30.0041s
    total number of events:              5698

Latency (ms):
         min:                                    5.18
         avg:                                    5.26
         max:                                    7.48
         95th percentile:                        5.37
         sum:                                29957.30

Threads fairness:
    events (avg/stddev):           5698.0000/0.00
    execution time (avg/stddev):   29.9573/0.00
```

Iteration 1

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


Prime numbers limit: 200000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:   190.20

General statistics:
    total time:                          30.0087s
    total number of events:              5710

Latency (ms):
         min:                                    5.19
         avg:                                    5.25
         max:                                    7.94
         95th percentile:                        5.28
         sum:                                29968.41

Threads fairness:
    events (avg/stddev):           5710.0000/0.00
    execution time (avg/stddev):   29.9684/0.00
```

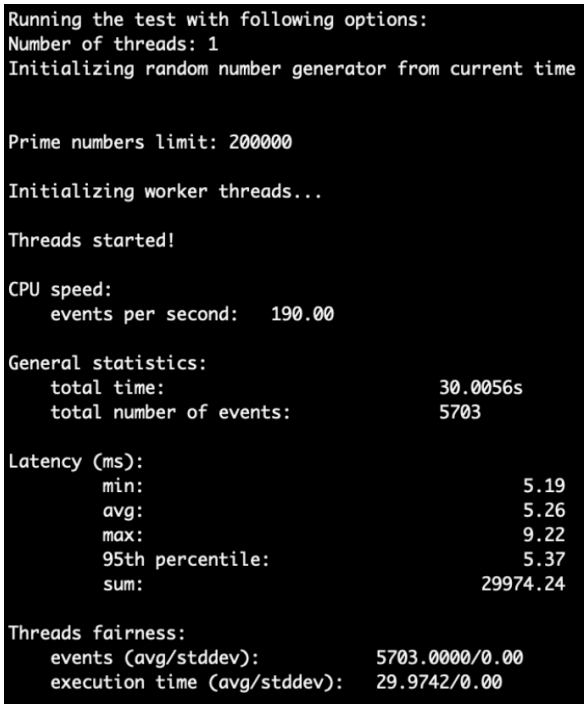
Iteration 2

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


Prime numbers limit: 200000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:   190.30

General statistics:
    total time:                          30.0040s
    total number of events:              5712

Latency (ms):
         min:                                    5.18
         avg:                                    5.25
         max:                                    8.63
         95th percentile:                        5.37
         sum:                                29973.66

Threads fairness:
    events (avg/stddev):           5712.0000/0.00
    execution time (avg/stddev):   29.9737/0.00
```

Iteration 3

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


Prime numbers limit: 200000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:   190.59

General statistics:
    total time:                          30.0005s
    total number of events:              5718

Latency (ms):
         min:                                    5.18
         avg:                                    5.24
         max:                                   16.02
         95th percentile:                        5.28
         sum:                                29972.36

Threads fairness:
    events (avg/stddev):           5718.0000/0.00
    execution time (avg/stddev):   29.9724/0.00
```

Iteration 4



Iteration 5

Iteration no.	Events per second
1	189.90 - min
2	190.20
3	190.30
4	190.59 - max
5	190.00
Average	190.20

Docker Results:

- Test 1:

```
WARNING: the --test option is deprecated. You can pass a
sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-b

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: 55705.48

General statistics:
    total time:                          30.0061s
    total number of events:              1671610

Latency (ms):
         min:                                    0.02
         avg:                                    0.02
         max:                                    6.59
         95th percentile:                        0.02
         sum:                                29847.15

Threads fairness:
    events (avg/stddev):           1671610.0000/0.00
    execution time (avg/stddev):   29.8471/0.00
```

Iteration 1

```
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: 53339.24

General statistics:
    total time:                          30.0035s
    total number of events:              1600418

Latency (ms):
         min:                                    0.02
         avg:                                    0.02
         max:                                  647.49
         95th percentile:                        0.02
         sum:                                29799.64

Threads fairness:
    events (avg/stddev):           1600418.0000/0.00
    execution time (avg/stddev):   29.7996/0.00

sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-beta2)
```

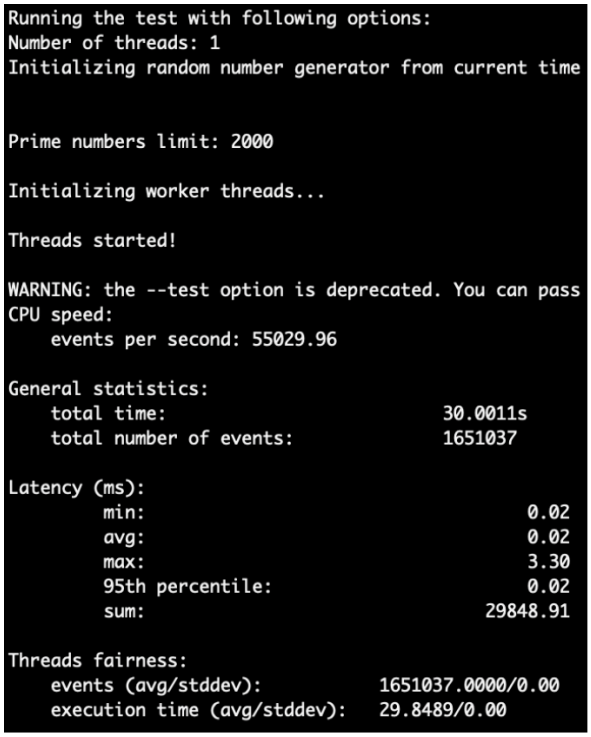
Iteration 2

```
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!

WARNING: the --test option is deprecated. You can pass
CPU speed:
    events per second: 53770.33

General statistics:
    total time:                          30.0019s
    total number of events:              1613486

Latency (ms):
         min:                                    0.02
         avg:                                    0.02
         max:                                   75.10
         95th percentile:                        0.02
         sum:                                29750.40

Threads fairness:
    events (avg/stddev):           1613486.0000/0.00
    execution time (avg/stddev):   29.7504/0.00
```

Iteration 3

```
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: 54454.38

General statistics:
    total time:                          30.0011s
    total number of events:              1633769

Latency (ms):
         min:                                    0.02
         avg:                                    0.02
         max:                                   19.96
         95th percentile:                        0.02
         sum:                                29839.23

Threads fairness:
    events (avg/stddev):           1633769.0000/0.00
    execution time (avg/stddev):   29.8392/0.00

sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-b
```

Iteration 4



Iteration 5

Iteration no.	Events per second
1	55705.48 - max
2	53339.24 - min
3	53770.33
4	54454.38
5	55029.96
Average	54459.88

- Test 2:

```
WARNING: the --test option is deprecated. You can pass
sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-

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:  3203.72

General statistics:
    total time:                          30.0012s
    total number of events:              96123

Latency (ms):
         min:                                    0.30
         avg:                                    0.31
         max:                                    9.90
         95th percentile:                        0.33
         sum:                                29927.79

Threads fairness:
    events (avg/stddev):           96123.0000/0.00
    execution time (avg/stddev):   29.9278/0.00
```

Iteration 1

```
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:  3190.15

General statistics:
    total time:                          30.0207s
    total number of events:              95901

Latency (ms):
         min:                                    0.30
         avg:                                    0.31
         max:                                    8.36
         95th percentile:                        0.33
         sum:                                29967.28

Threads fairness:
    events (avg/stddev):           95901.0000/0.00
    execution time (avg/stddev):   29.9673/0.00

WARNING: the --test option is deprecated. You can pass
sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-
```

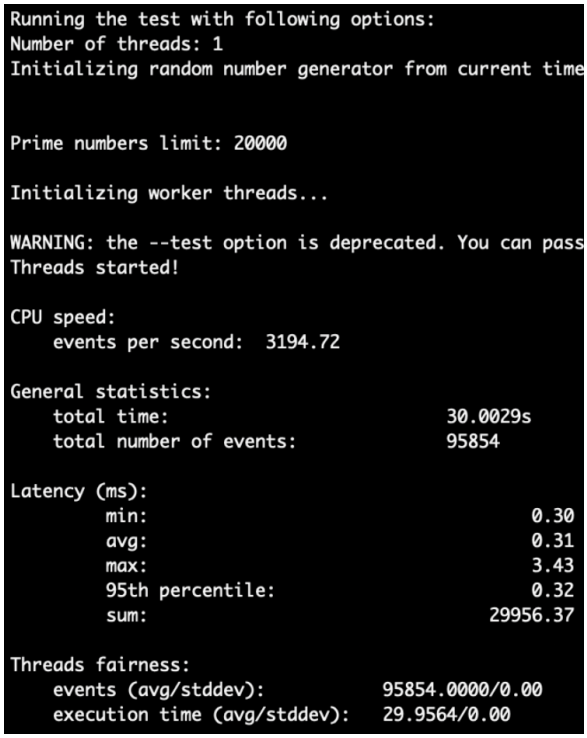
Iteration 2

```
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:  3207.99

General statistics:
    total time:                          30.0007s
    total number of events:              96245

Latency (ms):
         min:                                    0.30
         avg:                                    0.31
         max:                                    4.64
         95th percentile:                        0.32
         sum:                                29963.17

Threads fairness:
    events (avg/stddev):           96245.0000/0.00
    execution time (avg/stddev):   29.9632/0.00

WARNING: the --test option is deprecated. You can pass
sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-
```

Iteration 3

```
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:  3197.21

General statistics:
    total time:                          30.0010s
    total number of events:              95924

Latency (ms):
         min:                                    0.30
         avg:                                    0.31
         max:                                    1.89
         95th percentile:                        0.32
         sum:                                29963.23

Threads fairness:
    events (avg/stddev):           95924.0000/0.00
    execution time (avg/stddev):   29.9632/0.00

sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-beta2)
```

Iteration 4



Iteration 5

Iteration no.	Events per second
1	3203.72
2	3190.15 - min
3	3207.99 - max
4	3197.21
5	3194.72
Average	3198.75

- Test 3:

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


Prime numbers limit: 200000

Initializing worker threads...

Threads started!

WARNING: the --test option is deprecated. You can pass
CPU speed:
    events per second:   171.87

General statistics:
    total time:                          30.0043s
    total number of events:              5157

Latency (ms):
         min:                                    5.72
         avg:                                    5.81
         max:                                   15.25
         95th percentile:                        5.99
         sum:                                29967.81

Threads fairness:
    events (avg/stddev):           5157.0000/0.00
    execution time (avg/stddev):   29.9678/0.00
```

Iteration 1

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


Prime numbers limit: 200000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:   170.92

General statistics:
    total time:                          30.0060s
    total number of events:              5129

Latency (ms):
         min:                                    5.72
         avg:                                    5.85
         max:                                   13.94
         95th percentile:                        6.09
         sum:                                29982.56

Threads fairness:
    events (avg/stddev):           5129.0000/0.00
    execution time (avg/stddev):   29.9826/0.00

sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-beta2)
```

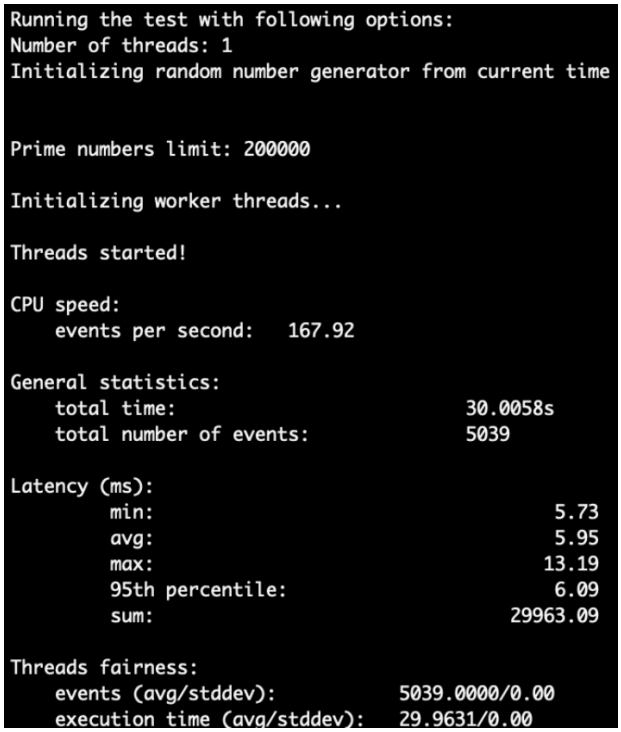
Iteration 2

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


Prime numbers limit: 200000

Initializing worker threads...

WARNING: the --test option is deprecated. You can pass a s
Threads started!

CPU speed:
    events per second:   170.08

General statistics:
    total time:                          30.0068s
    total number of events:              5104

Latency (ms):
         min:                                    5.72
         avg:                                    5.87
         max:                                   16.41
         95th percentile:                        6.09
         sum:                                29981.24

Threads fairness:
    events (avg/stddev):           5104.0000/0.00
    execution time (avg/stddev):   29.9812/0.00

sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-bet
```

Iteration 3

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


Prime numbers limit: 200000

Initializing worker threads...

WARNING: the --test option is deprecated. You can pass a scrip
Threads started!

CPU speed:
    events per second:   168.58

General statistics:
    total time:                          30.0064s
    total number of events:              5059

Latency (ms):
         min:                                    5.72
         avg:                                    5.93
         max:                                   18.57
         95th percentile:                        6.21
         sum:                                29978.28

Threads fairness:
    events (avg/stddev):           5059.0000/0.00
    execution time (avg/stddev):   29.9783/0.00

WARNING: the --test option is deprecated. You can pass a scrip
sysbench 1.0.20-f6f6117dc4 (using bundled LuaJIT 2.1.0-beta2)
```

Iteration 4



Iteration 5

Iteration no.	Events per second
1	171.87 - max
2	170.92
3	170.08
4	168.58
5	167.92 - min
Average	169.87

Conclusion:

Even after using more resources for both QEMU and Docker, there is very slight deviation in the performance. Also, when we increase max-prime value, events per seconds decreases.

File I/O Testing QEMU Vs. Docker:

For file I/O testing, 2 mods are supported by sysbench:

- Sequential Rewrite (seqrewr)
- Combined random read/write (rndrw)

file size =3 GB

Performance is tested using experimental setups.

Two modes are used which sysbench supports, which are: We will keep the file size constant at 3GB and will test the performance against our experimental setups accordingly.

QEMU execution:

1. Sequential Rewrite

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

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:                     18410.73
    fsyncs/s:                     23633.23

Throughput:
    read, MiB/s:                  0.00
    written, MiB/s:               287.67

General statistics:
    total time:                          30.0458s
    total number of events:              1261733

Latency (ms):
         min:                                    0.00
         avg:                                    0.38
         max:                                  469.79
         95th percentile:                        1.47
         sum:                               477690.18

Threads fairness:
    events (avg/stddev):           78858.3125/1462.36
    execution time (avg/stddev):   29.8556/0.07
```

Iteration no.	Output
1	reads/s = 0 writes/s = 18410.73 fsyncs/s = 23633.23 events/s = 21028.88
2	reads/s = 0 writes/s = 44361.77 fsyncs/s = 56848.83 events/s = 101252.66
3	reads/s = 0 writes/s = 44132.92 fsyncs/s = 56554.27 events/s = 100665.5
4	reads/s = 0 writes/s = 42941.03 fsyncs/s = 55031.80 events/s = 97985.86
5	reads/s = 0 writes/s = 40869.42 fsyncs/s = 52379.79

	events/s = 93235.5

2. Random read Write (rndrw)

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

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:                      11594.62
    writes/s:                     7729.41
    fsyncs/s:                     24799.34

Throughput:
    read, MiB/s:                  181.17
    written, MiB/s:               120.77

General statistics:
    total time:                          30.0235s
    total number of events:              1323432

Latency (ms):
         min:                                    0.00
         avg:                                    0.36
         max:                                   84.02
         95th percentile:                        1.42
         sum:                               478877.93

Threads fairness:
    events (avg/stddev):           82714.5000/459.07
    execution time (avg/stddev):   29.9299/0.00
```

Iteration no.	Output
1	reads/s = 11594.62 writes/s = 7729.41 fsyncs/s = 24799.34 events/s = 22057.2
2	reads/s = 12925.26 writes/s = 8616.51 fsyncs/s = 27637.79 events/s = 49145.3
3	reads/s = 10645.87 writes/s = 7096.89 fsyncs/s = 22777.00 events/s = 40479.13
4	reads/s = 11293.72 writes/s = 7529.37

	fsyncs/s = 24157.81 events/s = 42946.03
5	reads/s = 12491.06 writes/s = 8327.07 fsyncs/s = 26713.69 events/s = 47486.16

Docker execution:

1. Sequential Rewrite

Iteration no.	Output
1	reads/s = 0 writes/s = 33944.01 fsyncs/s = 43579.68 events/s = 77564.73
2	reads/s = 0 writes/s = 35435.34 fsyncs/s = 42342.32 events/s = 75343.24
3	reads/s = 0 writes/s = 33958.73 fsyncs/s = 43684.54 events/s = 77846.34
4	reads/s = 0 writes/s = 32091.93 fsyncs/s = 41321.54

	events/s = 73654.18
5	reads/s = 0 writes/s = 34546.54 fsyncs/s = 44323.20 events/s = 78234.32

2. Random read Write

Iteration no.	Output
1	reads/s = 13950.71 writes/s = 9300.24 fsyncs/s = 29826.54 events/s = 53024.66
2	reads/s = 13155.49 writes/s = 8769.99 fsyncs/s = 28129.15 events/s = 50019.5
3	reads/s = 14353.95 writes/s = 9569.02 fsyncs/s = 30688.31 events/s = 54574.26
4	reads/s = 14674.66 writes/s = 9782.83 fsyncs/s = 31370.93 events/s = 55796.33
5	reads/s = 14488.90

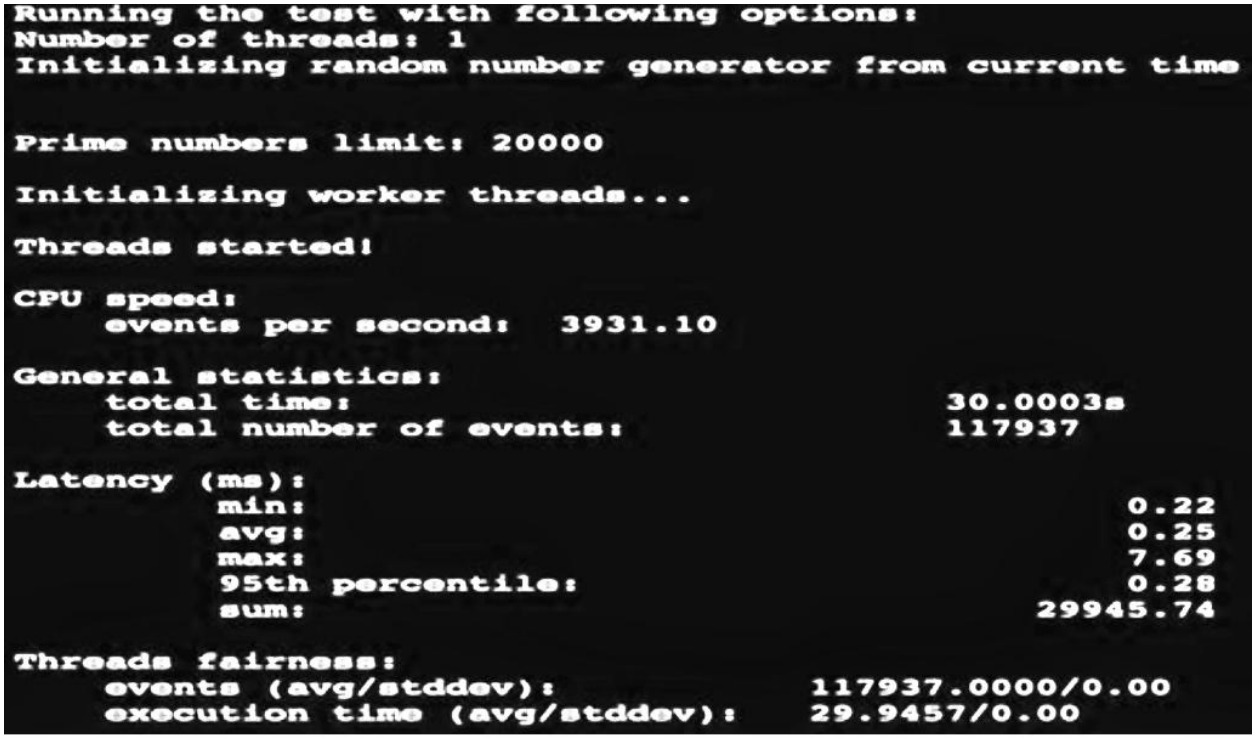
	writes/s = 9659.14 fsyncs/s = 30975.53 events/s = 55094.1

Conclusion:
Sequential rewrite operations is faster on QEMU than Docker. While for combined read write, docker is faster than QEMU.

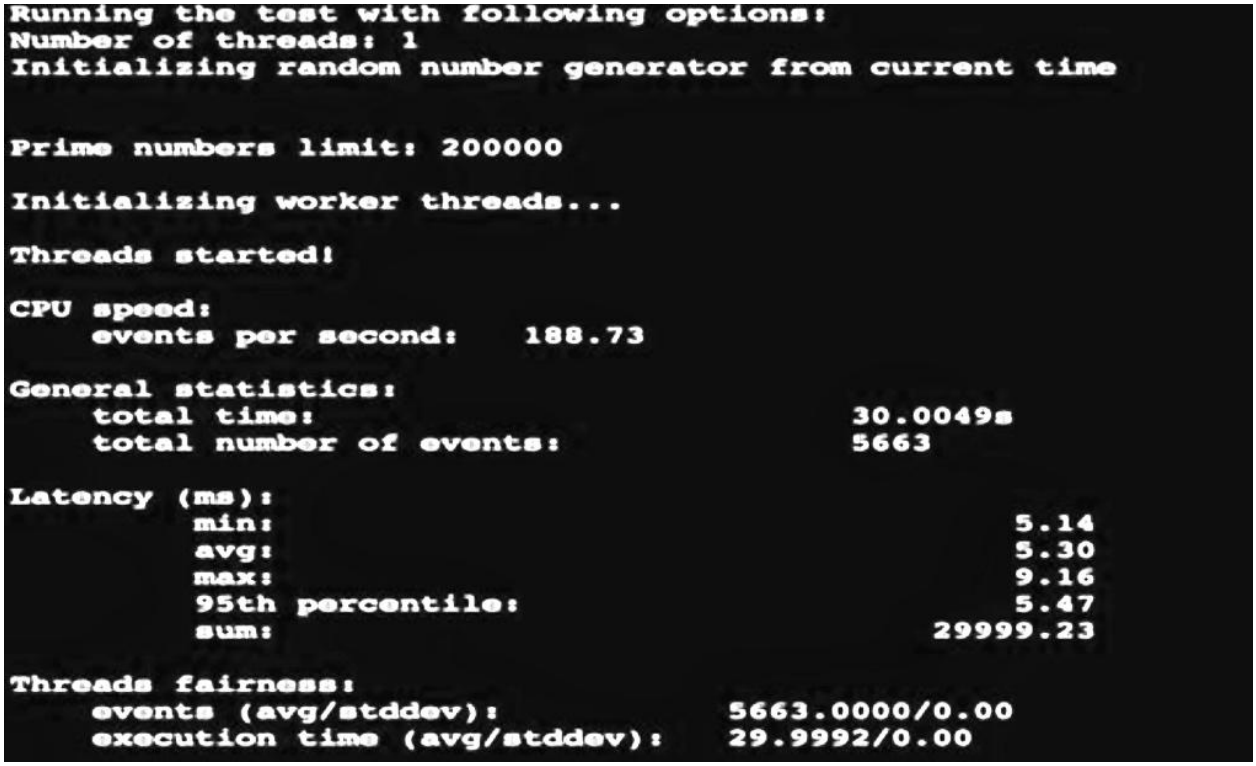
Configuration 2: 4GB RAM and 4 cores
QEMU Results:

```
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: 113926.26

General statistics:
    total time:                          30.0001s
    total number of events:              3417869

Latency (ms):
         min:                                    0.01
         avg:                                    0.01
         max:                                    6.30
         95th percentile:                        0.01
         sum:                                29596.91

Threads fairness:
    events (avg/stddev):           3417869.0000/0.00
    execution time (avg/stddev):   29.5969/0.00
```

Iteration no.	Events per second
1	3931.10
2	3933.90
3	4281.01 - max
4	4051.55 - min
5	3972.59
Average	4034.03

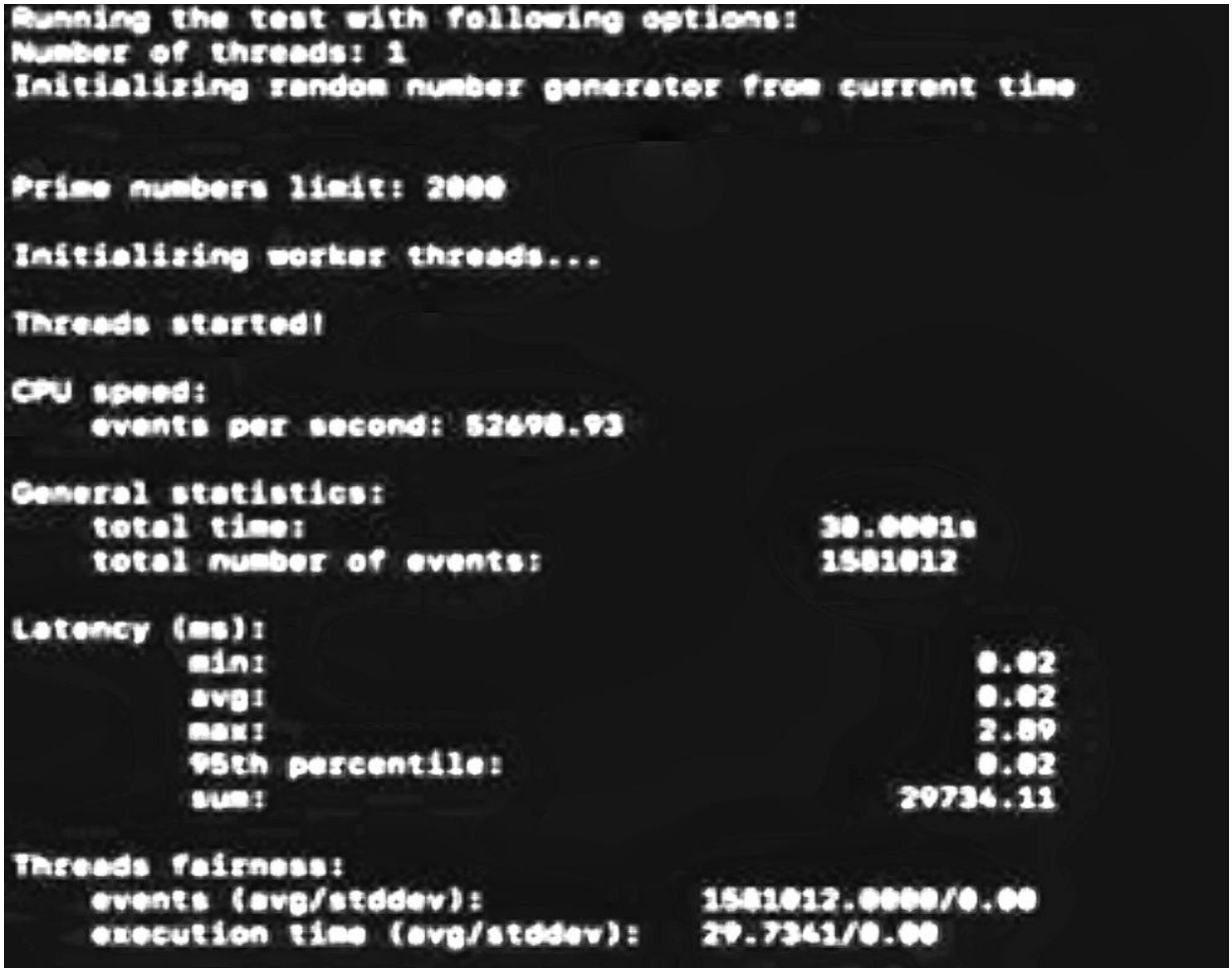


Iteration no.	Events per second
1	3931.10
2	3933.90
3	4281.01 - max
4	4051.55 - min
5	3972.59
Average	4034.03

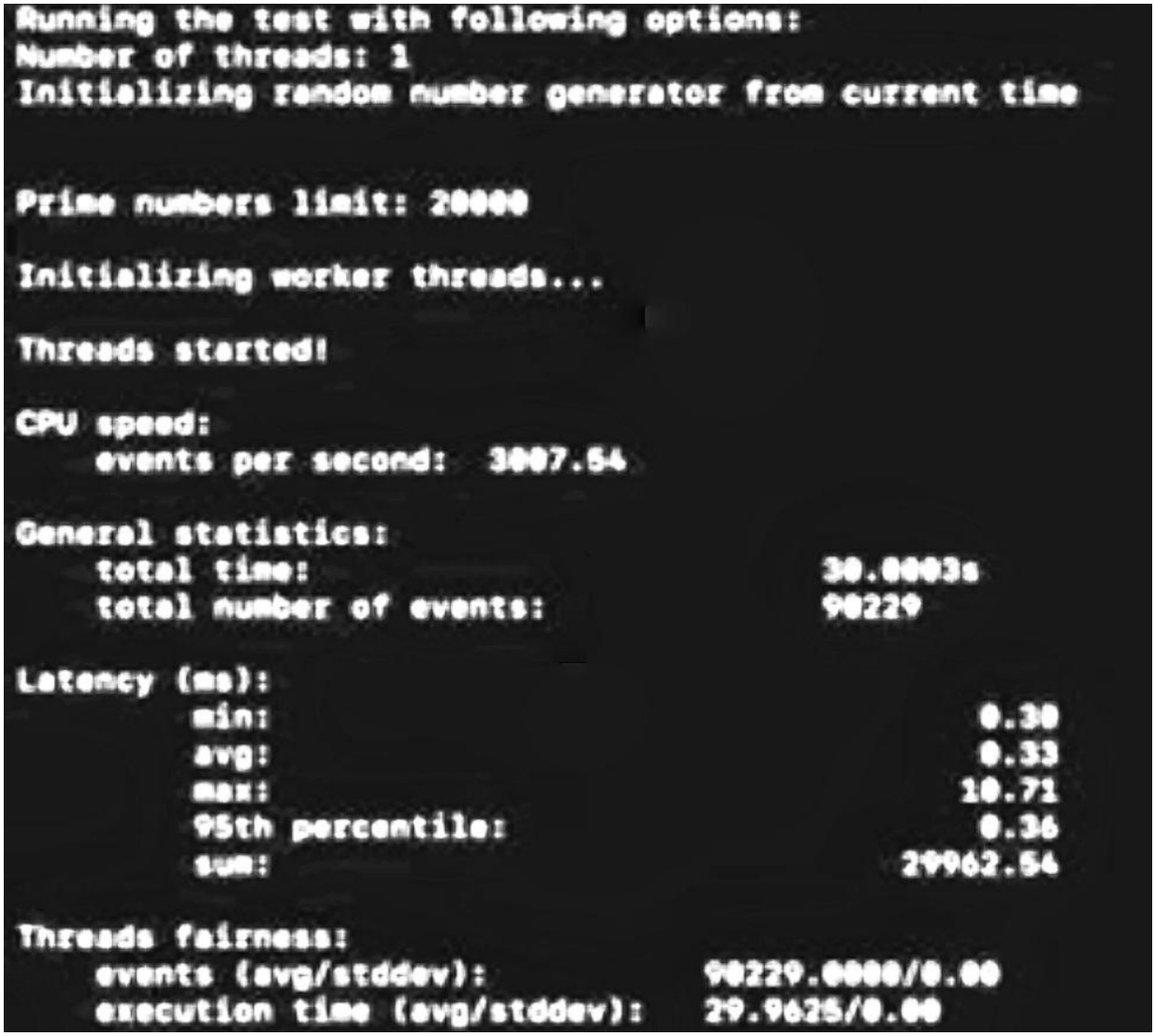


Iteration no.	Events per second
1	188.73 - max
2	188.33
3	185.49 - min
4	189.86
5	189.83
Average	188.44

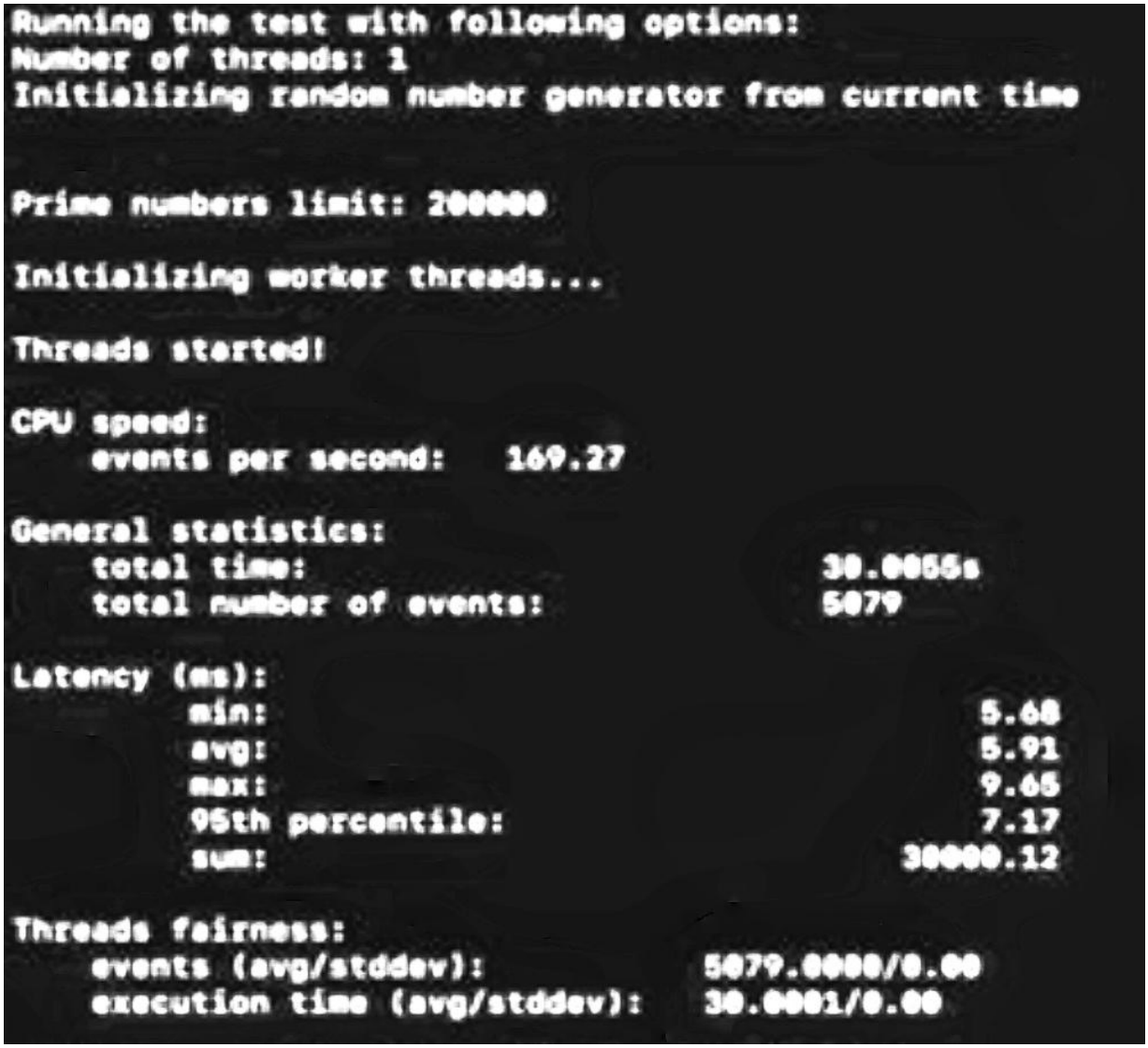
Docker Results:



Iteration no.	Events per second
1	52698.93
2	52132.09
3	51893.90 - min
4	56403.96 - max
5	56134.25
Average	53852.62



Iteration no.	Events per second
1	3007.54
2	3247.12 - max
3	3181.35
4	3164.53
5	2917.72 - min
Average	3103.65



Iteration no.	Events per second
1	169.27
2	172.51
3	172.34
4	171.67
5	173.24
Average	171.80

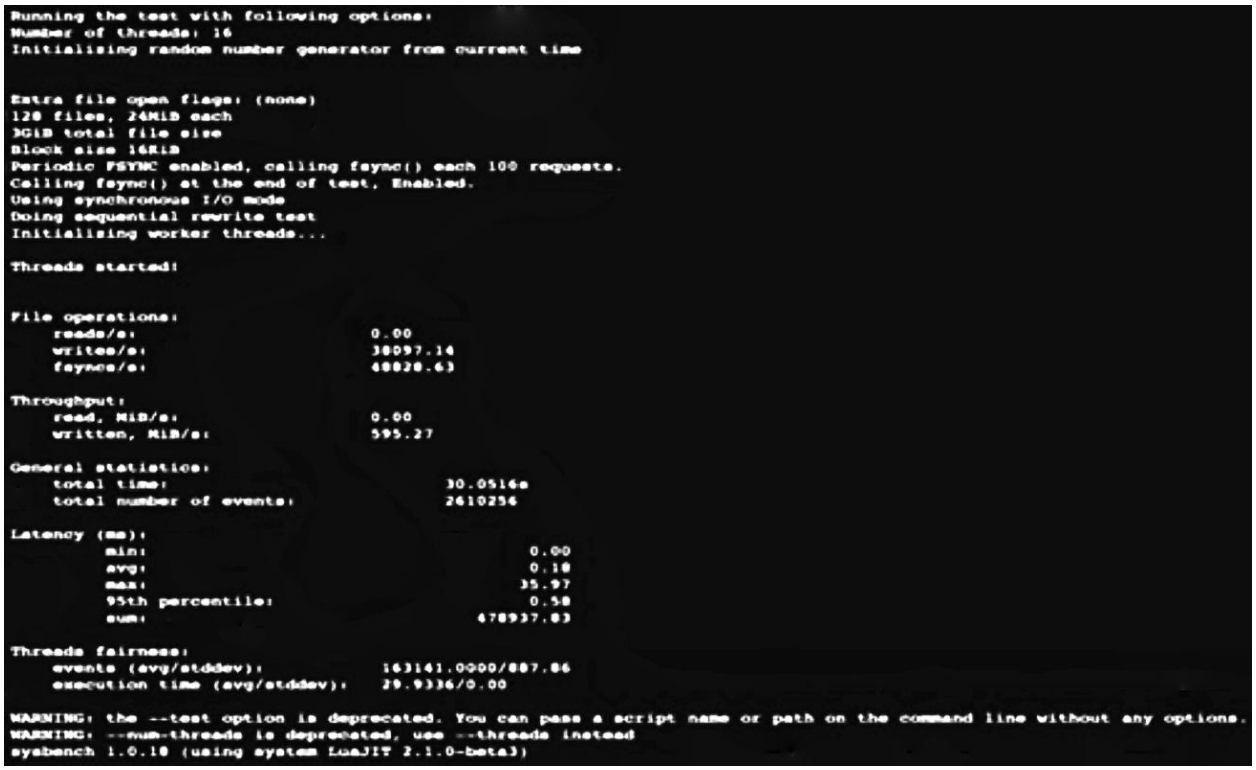
Conclusion:

QEMU is faster than docker. But, change in configuration does not have significant effect on performance.

File I/O Testing QEMU Vs. Docker:

QEMU execution:

1. Sequential Rewrite



Iteration no.	Output
1	reads/s = 0 writes/s = 38097.14 fsyncs/s = 48828.63 events/s = 87008.56
2	reads/s = 0 writes/s = 39530.62 fsyncs/s = 50644.21 events/s = 90199.3
3	reads/s = 0 writes/s = 35866.20 fsyncs/s = 46000.81 events/s = 81888.26
4	reads/s = 0 writes/s = 33329.60 fsyncs/s = 42727.80 events/s = 76088.93
5	reads/s = 0 writes/s = 33704.58 fsyncs/s = 43206.91 events/s = 76908.83

2. Random Read Write

Iteration no.	Output
1	reads/s = 14887.51 writes/s = 9898.23 fsyncs/s = 31798.38 events/s = 56464.43
2	reads/s = 13910 writes/s = 9273 fsyncs/s = 29740 events/s = 52915.76
3	reads/s = 14165.54 writes/s = 9443.58 fsyncs/s = 30284.24 events/s = 53880.36
4	reads/s = 12349.31 writes/s = 8232.87 fsyncs/s = 26409.53 events/s = 46994.56
5	reads/s = 12001.06 writes/s = 8000.63 fsyncs/s = 25669.69 events/s = 45638.56

Docker Execution:

1. Sequential Rewrite

Iteration no.	Output
1	reads/s = 0 writes/s = 21687.04 fsyncs/s = 27826.67 events/s = 87008.56
2	reads/s = 0 writes/s = 22690.64 fsyncs/s = 29019.49 events/s = 51806.5
3	reads/s = 0 writes/s = 25688.43 fsyncs/s = 32946.24 events/s =58659.23
4	reads/s = 0 writes/s = 22382.72 fsyncs/s = 28716.33 events/s = 51146.33

5	reads/s = 0 writes/s = 21880.69 fsyncs/s = 28071.27 events/s = 49996.26

Iteration no.	Output
1	reads/s = 13850.71 writes/s = 9320.24 fsyncs/s = 28826.54 events/s =53032.66
2	reads/s = 14155.49 writes/s = 8754.94 fsyncs/s = 27129.15 events/s = 50045.5
3	reads/s = 14251.83 writes/s = 9545.02 fsyncs/s = 30457.31 events/s = 54375.26
4	reads/s = 14324.66 writes/s = 9231.83 fsyncs/s = 31432.93 events/s = 55987.33
5	reads/s = 14231.90 writes/s = 9658.14

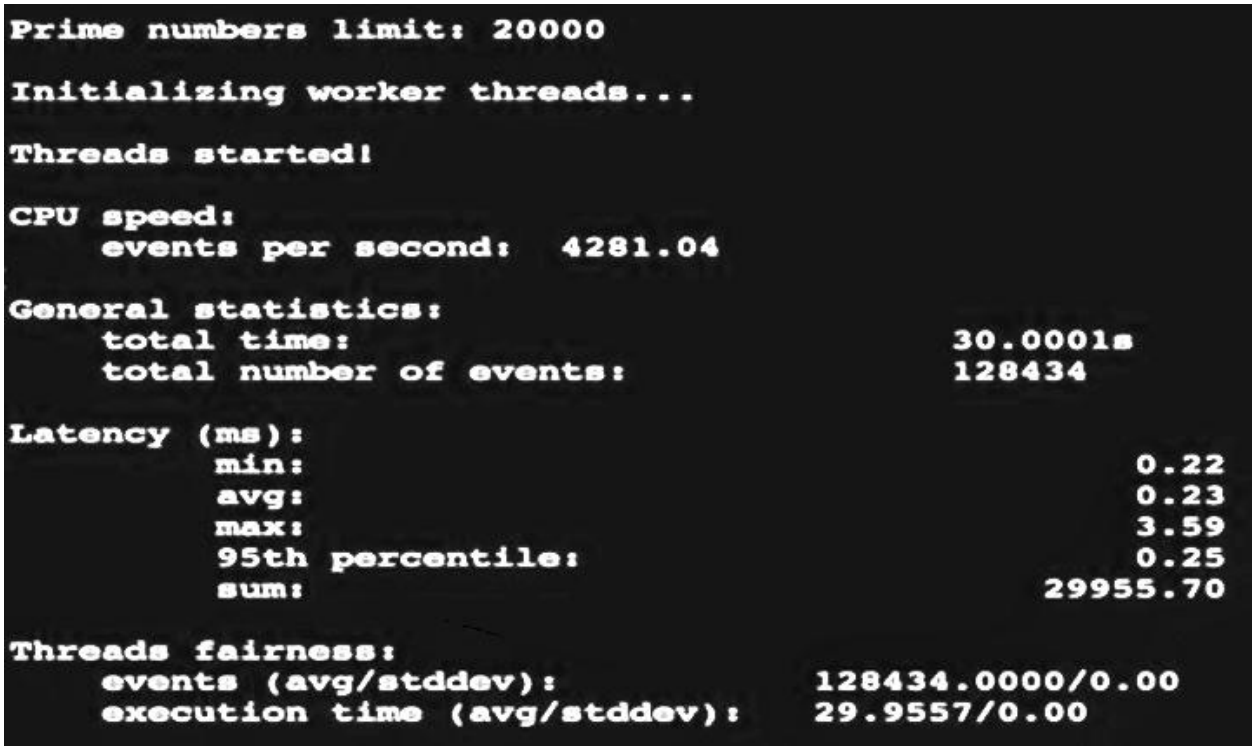
	fsyncs/s = 30324.53 events/s = 55432.1

Conclusion:
As compared with 2GB 2 core config, there is decrease in file i/o for QEMU and Docker.

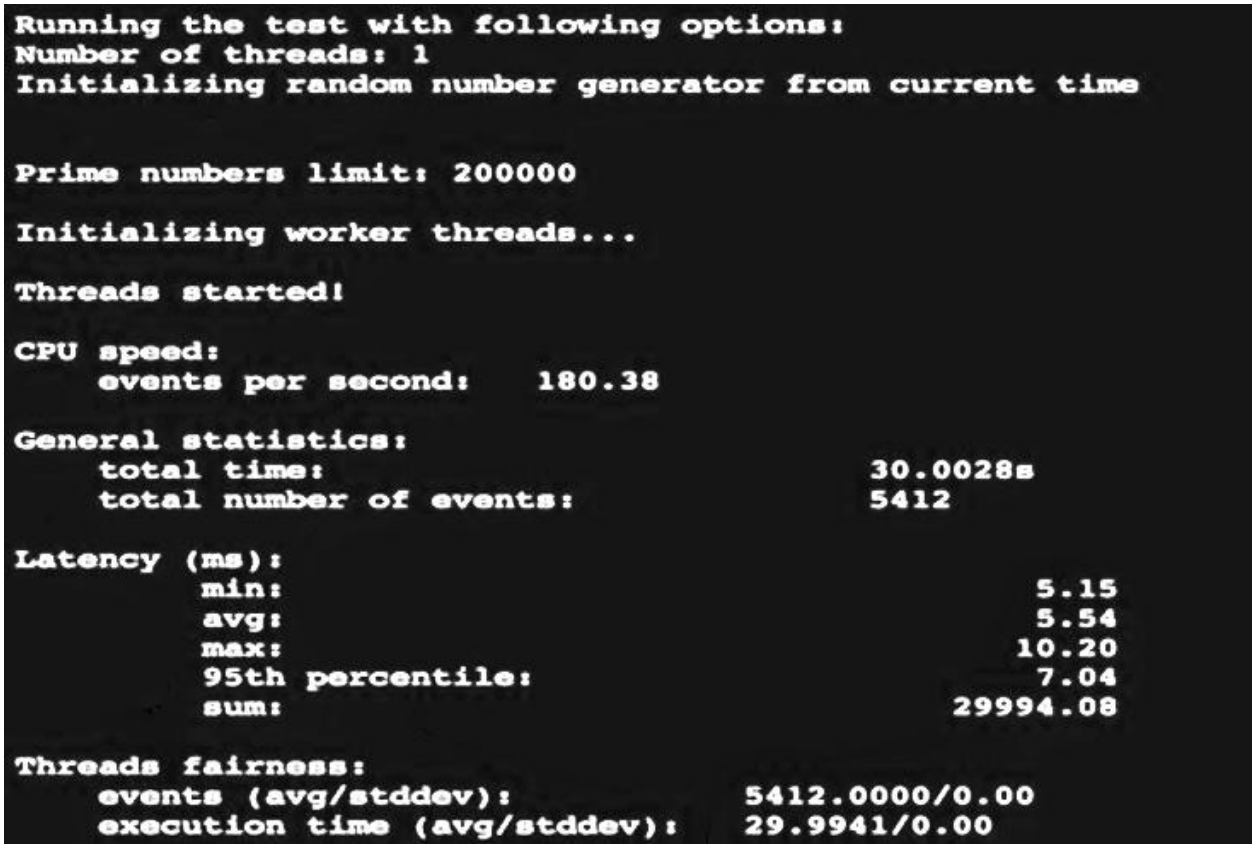
Configuration 2: 6GB RAM and 6 cores
QEMU Results:

```
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: 113197.63

General statistics:
    total time:                          30.0002s
    total number of events:              3396025

Latency (ms):
         min:                                    0.01
         avg:                                    0.01
         max:                                    2.88
         95th percentile:                        0.01
         sum:                                29571.95

Threads fairness:
    events (avg/stddev):           3396025.0000/0.00
    execution time (avg/stddev):   29.5720/0.00
```

Iteration no.	Events per second
1	113197.63 - min
2	114251.46
3	113318.53
4	114254.59 - max
5	113529.89
Average	113710.42

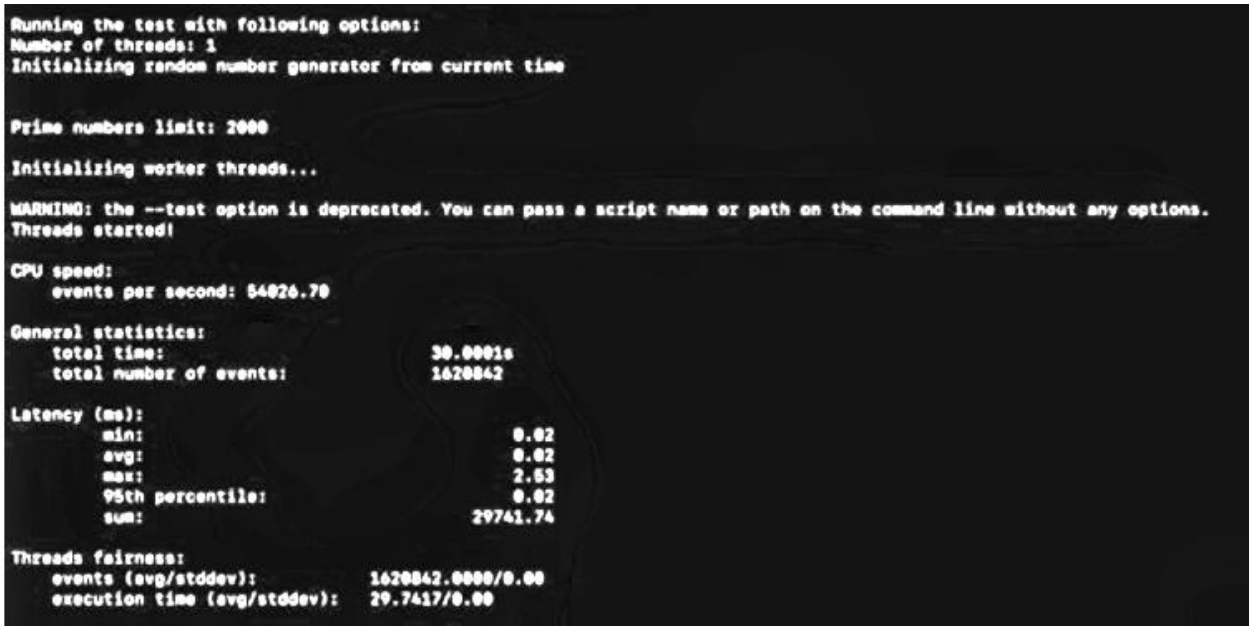


Iteration no.	Events per second
1	4281.04 - max
2	3954.40
3	4284.01
4	4054.45
5	3942.69 - min
Average	4101.51

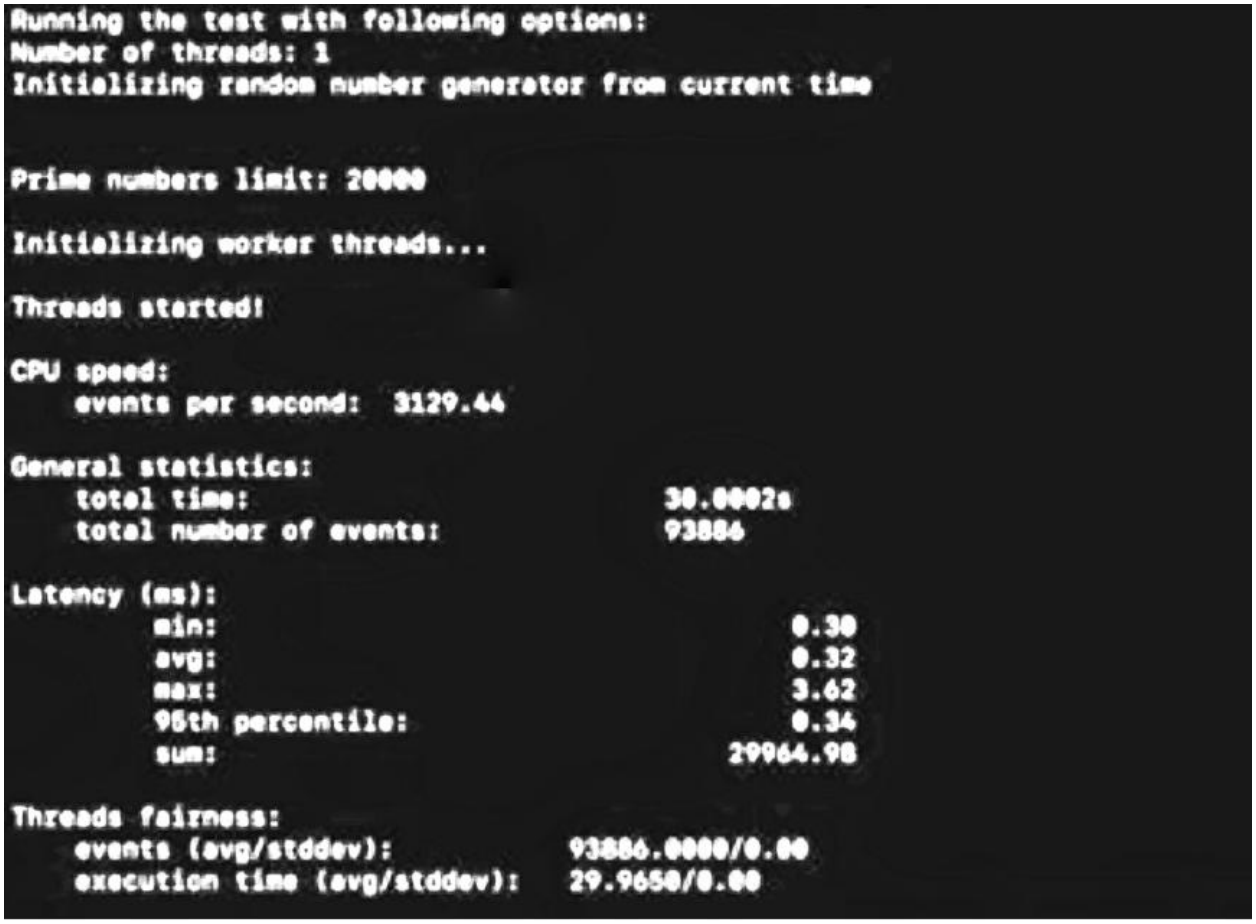


Iteration no.	Events per second
1	180.38 - min
2	182.33
3	184.49 - max
4	180.86
5	181.83
Average	181.97

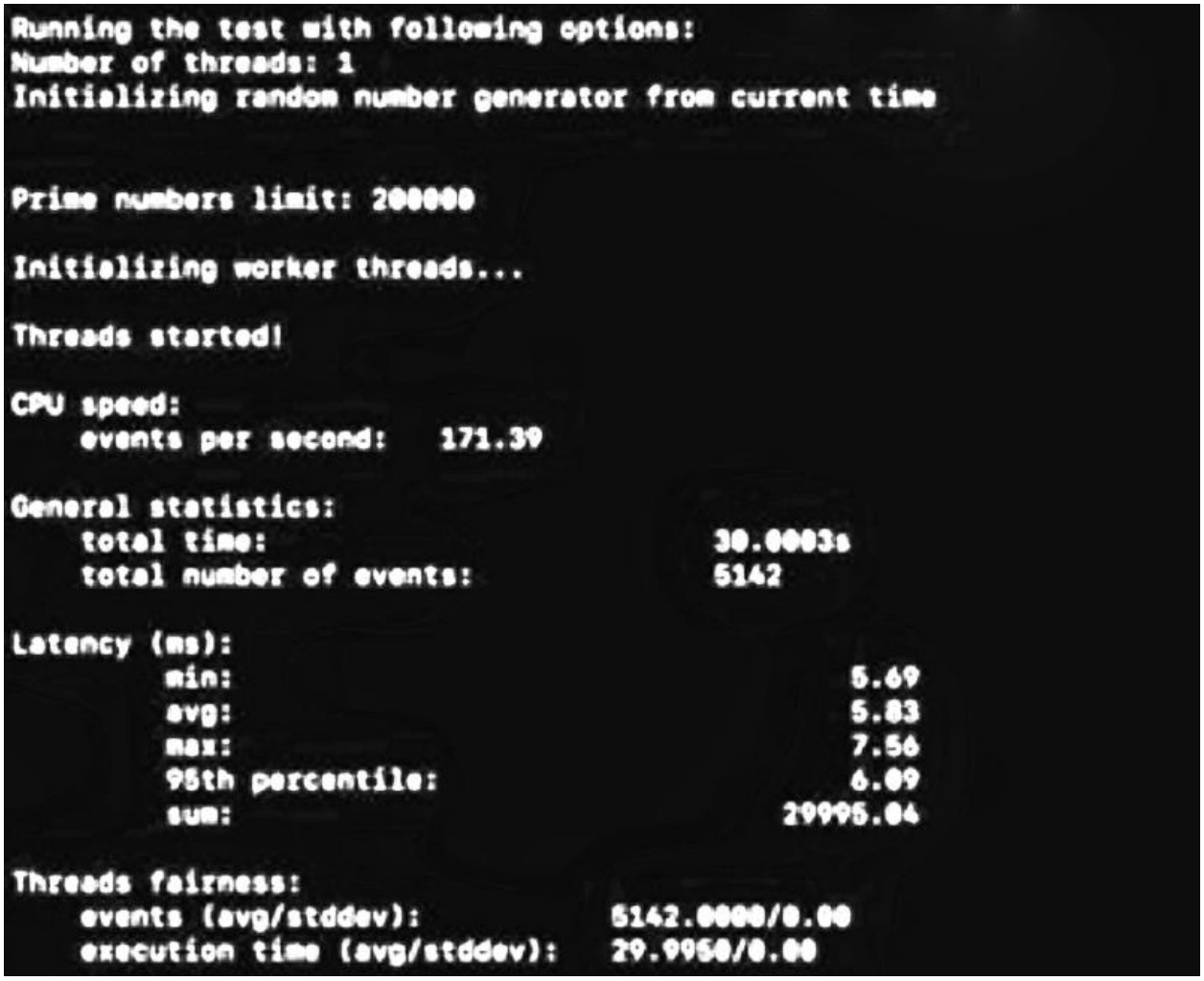
Docker Results:



Iteration no.	Events per second
1	54026.70
2	52534.09
3	52843.95 - min
4	53403.88
5	56479.38 - max
Average	53857.6



Iteration no.	Events per second
1	3129.44
2	3147.42
3	3141.35
4	3264.53 - max
5	3024.72 - min
Average	3141.49

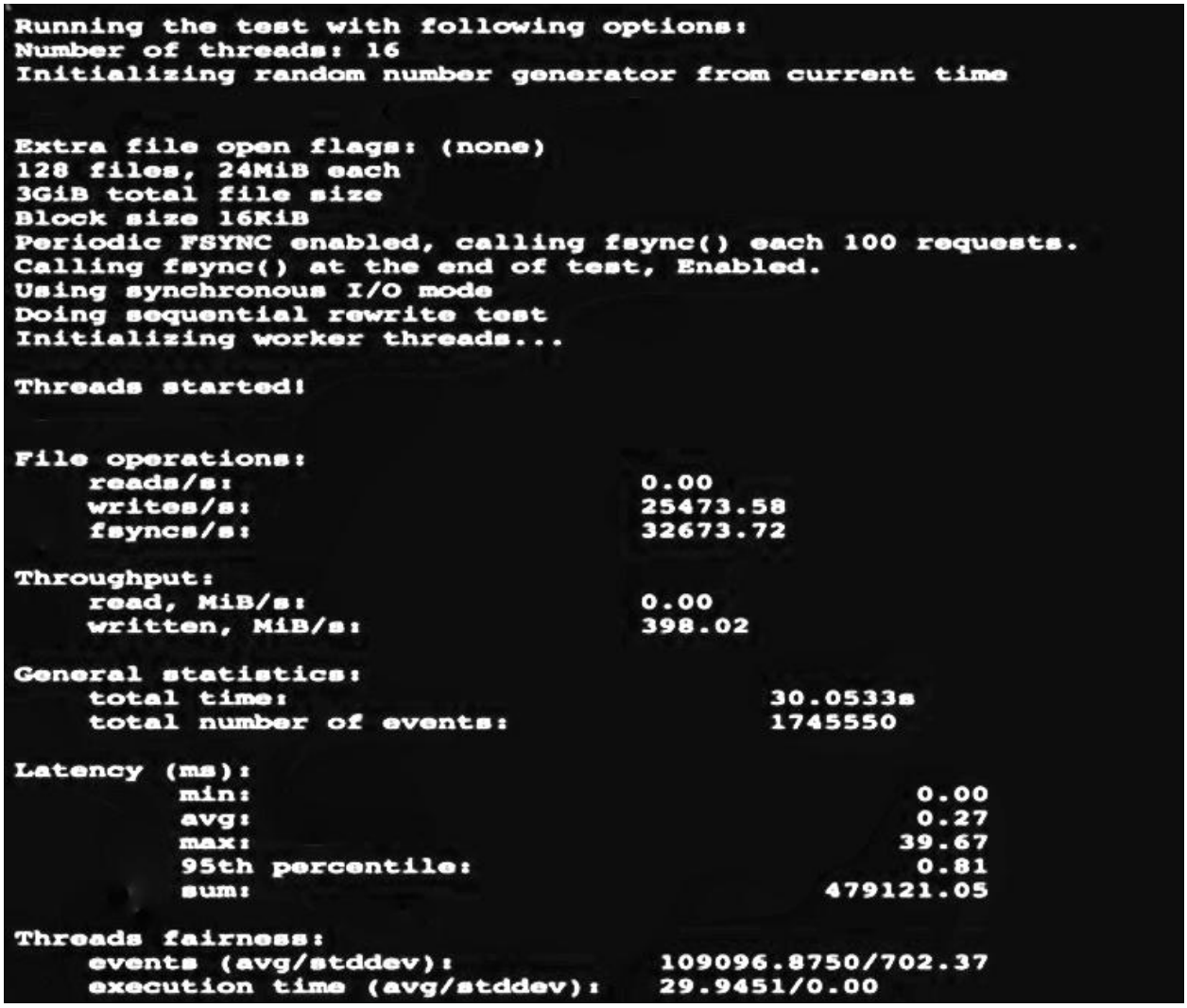


Iteration no.	Events per second
1	171.39
2	172.47
3	171.34 - min
4	172.67
5	174.24 - max
Average	172.42

Conclusion:
There is no significant change in CPU performance after adding resources.

File I/O Testing QEMU Vs. Docker:
QEMU execution:

1. Sequential Rewrite



Iteration no.	Output
1	reads/s = 0 writes/s = 25473.58 fsyncs/s = 32673.72 events/s = 58185
2	reads/s = 0 writes/s=27687.54 fsyncs/s = 33764.65 events/s = 59124.32
3	reads/s = 0 writes/s = 24534.32 fsyncs/s = 31986.87 events/s = 56126.76
4	reads/s = 0 writes/s = 25765.32 fsyncs/s = 32675.83

	events/s = 58234.21
5	reads/s = 0 writes/s = 28675.77 fsyncs/s = 35687.32 events/s = 59543.65

2. Random read Write

```
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:                      9938.58
    writes/s:                     6625.83
    fsyncs/s:                     21268.99

Throughput:
    read, MiB/s:                  155.29
    written, MiB/s:               103.53

General statistics:
    total time:                          30.0701s
    total number of events:              1135621

Latency (ms):
         min:                                    0.00
         avg:                                    0.42
         max:                                   37.10
         95th percentile:                        1.44
         sum:                               479198.63

Threads fairness:
    events (avg/stddev):           70976.3125/665.20
    execution time (avg/stddev):   29.9499/0.00
```

Iteration no.	Output
1	reads/s = 9938.58 writes/s = 6625.83 fsyncs/s = 21268.98 events/s = 37854.03
2	reads/s = 9845.43 writes/s = 6541.32 fsyncs/s = 20267.32

	events/s = 35643.76
3	reads/s = 9876.73 writes/s = 6543.21 fsyncs/s = 21124.43 events/s = 35541.28
4	reads/s = 9765.53 writes/s = 7021.32 fsyncs/s = 30382.11 events/s = 39878.32
5	reads/s = 9763.23 writes/s = 6312.63 fsyncs/s = 24569.69 events/s = 34532.56

Docker Execution:

1. Sequential Rewrite

Iteration no.	Output
1	reads/s = 0 writes/s = 13778.77 fsyncs/s = 17701.47 events/s = 31506.16
2	reads/s = 0 writes/s = 13543.64 fsyncs/s = 17634.49 events/s = 30234.5
3	reads/s = 0 writes/s = 12456.32 fsyncs/s = 16323.87 events/s = 29876.36
4	reads/s = 0 writes/s = 14328.87 fsyncs/s = 18785.62 events/s = 32324.32
5	reads/s = 0 writes/s = 13534.11 fsyncs/s = 17431.89 events/s = 31232.21

2. Random read Write

Iteration no.	Output
1	reads/s = 9501.28 writes/s = 6334.24 fsyncs/s = 20336.56 events/s = 36197.8
2	reads/s = 9323.32 writes/s = 6213.41 fsyncs/s = 20223.12 events/s = 36097.87
3	reads/s = 9674.98 writes/s = 6984.73 fsyncs/s = 20989.89 events/s = 37019.21
4	reads/s = 9594.32 writes/s = 6434.43 fsyncs/s = 20214.43 events/s = 35788.33
5	reads/s = 9287.90 writes/s = 6021.14 fsyncs/s = 18673.53 events/s = 32764.12

Conclusion:
Performance of file io decreases if resources are increased. Sometimes QEMU is better than Docker.

Performance Analysis:

QEMU:
Disk:
2GB 2cores
1. Sequential rewrite
    a. read,MiB/s=0
    b. written,MiB/s=715.68
2. Random Read Write
    a. read, MiB/s=188.23
    b. written, MiB/s=122.43

4GB 4 cores
1. Sequential rewrite
    a. read,MiB/s=0
    b. written,MiB/s=595.27
2. Random Read Write
    a. read, MiB/s=231.99

b. written, MiB/s=154.66

6GB 6 cores
1. Sequential rewrite
   a. read,MiB/s=0
   b. written,MiB/s=398.02
2. Random Read Write
   a. read, MiB/s=155.29
   b. written, MiB/s=103.53

CPU:
Percentage of CPU used – 34.2%
Kernel Usage – user = 9.71% , System = 9.71%, Idle = 80.48%

Docker:
Disk:
2GB 2 cores
1. Sequential rewrite
   a. read,MiB/s=0
   b. written,MiB/s=531.16
2. Random Read Write
   a. read, MiB/s=217.98
   b. written, MiB/s=145.32

4GB 4 cores
1. Sequential rewrite
   a. read,MiB/s=0
   b. written,MiB/s=338.86
2. Random Read Write
   a. read, MiB/s=213.43
   b. written, MiB/s=142.28

6GB 6 cores
1. Sequential rewrite
   a. read,MiB/s=0
   b. written,MiB/s=215.29
2. Random Read Write
   a. read, MiB/s=148.46
   b. written, MiB/s=98.97

CPU:
CPU Time used – 4hrs 45mins
Kernel used – 921604Kb => 115.2 MB

Git Repository:
Username : nolita26
Repository name: COEN241
Folder: CC_HW1
Link: https://github.com/nolita26/COEN241
Commit ID: aa5f92c2196451a00cbc1225640261861ef125a6