COEN -241 Cloud Computing

HW1: System Vs OS Virtualization Report

Name: Saurabh Thalkari
SCU ID: 1648455

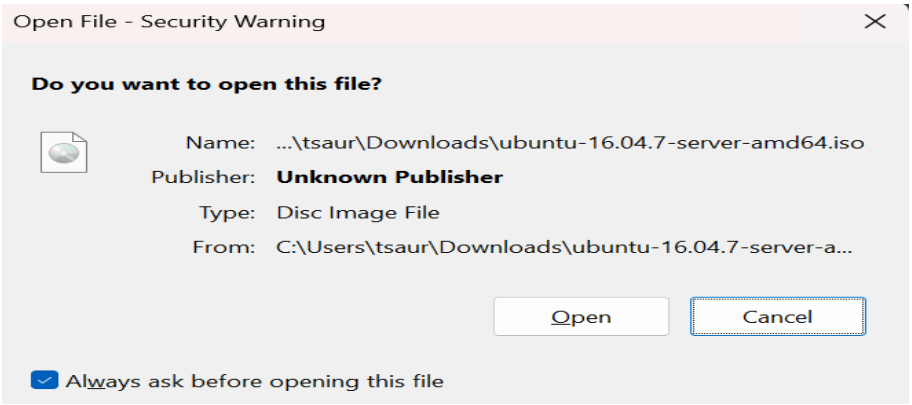
Host System Configuration:

1) Chip: Intel core i7 (11^{th} gen)
2) CPU: 8
3) Memory:16GB
4) Free Disk space:19.4GB
5)Operating System: Windows 11

QEMU Installation and creation of QEMU image

Step 1: Download the ubuntu image using the link provided on Camino:
https://releases.ubuntu.com

And install the same on PC



Download QEMU using the following link (provided on Camino) :
https://www.qemu.org/download/#windows

After downloading, install it and add the path for QEMU in environment variables.

Step 2:
Open command prompt and go to the directory where you've installed QEMU.

C:\Program Files\qemu

Ubuntu image needs to be created. Use this command to do so:

qemu-img create -f qcow2 ubuntu.img 20G

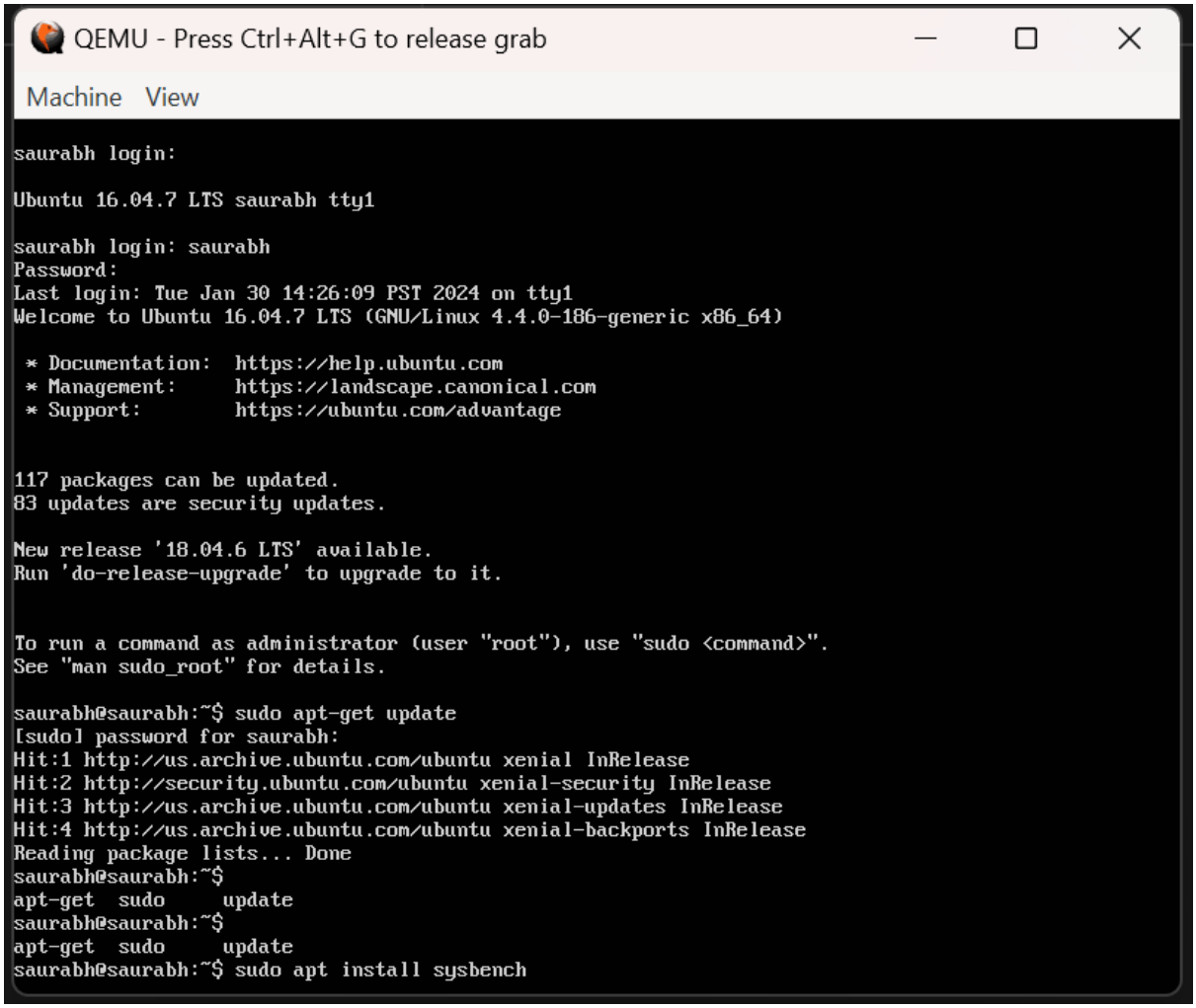
Boot iso file on QEMU with the following command

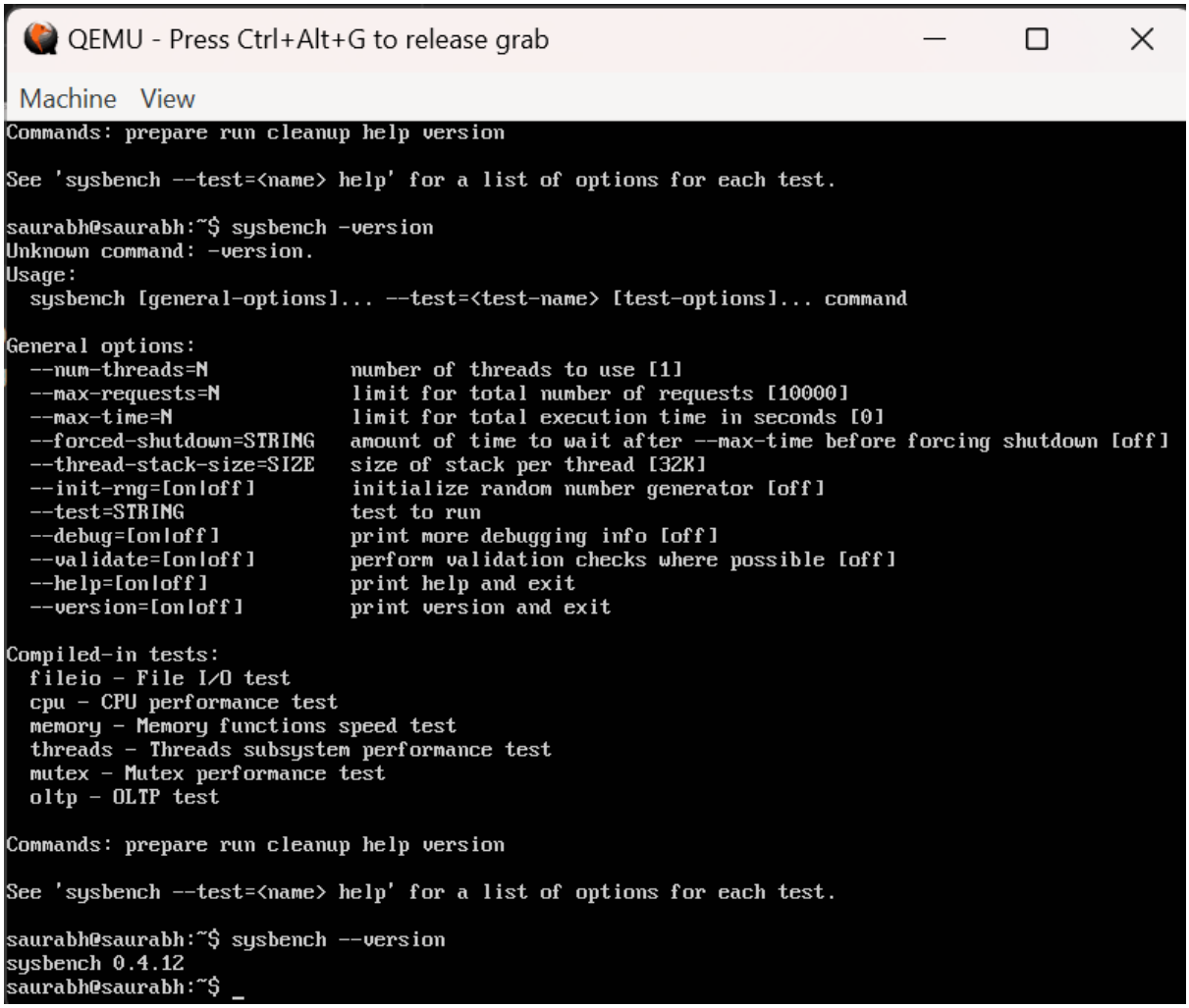
qemu-system-x86_64 -hda ubuntu.img -boot d –cdrom

Following commands installs sysbench on QEMU

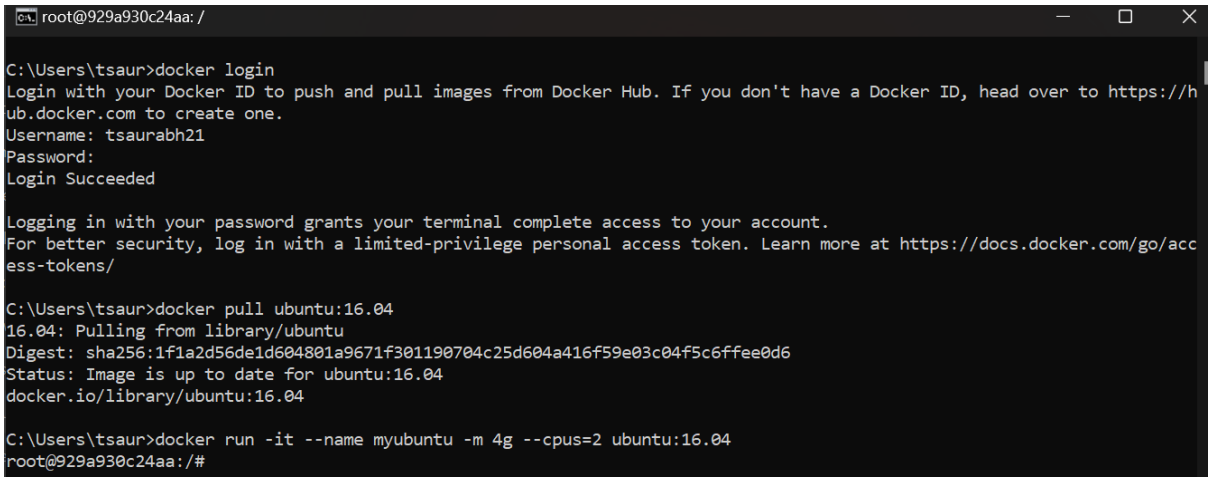
sudo apt-get update

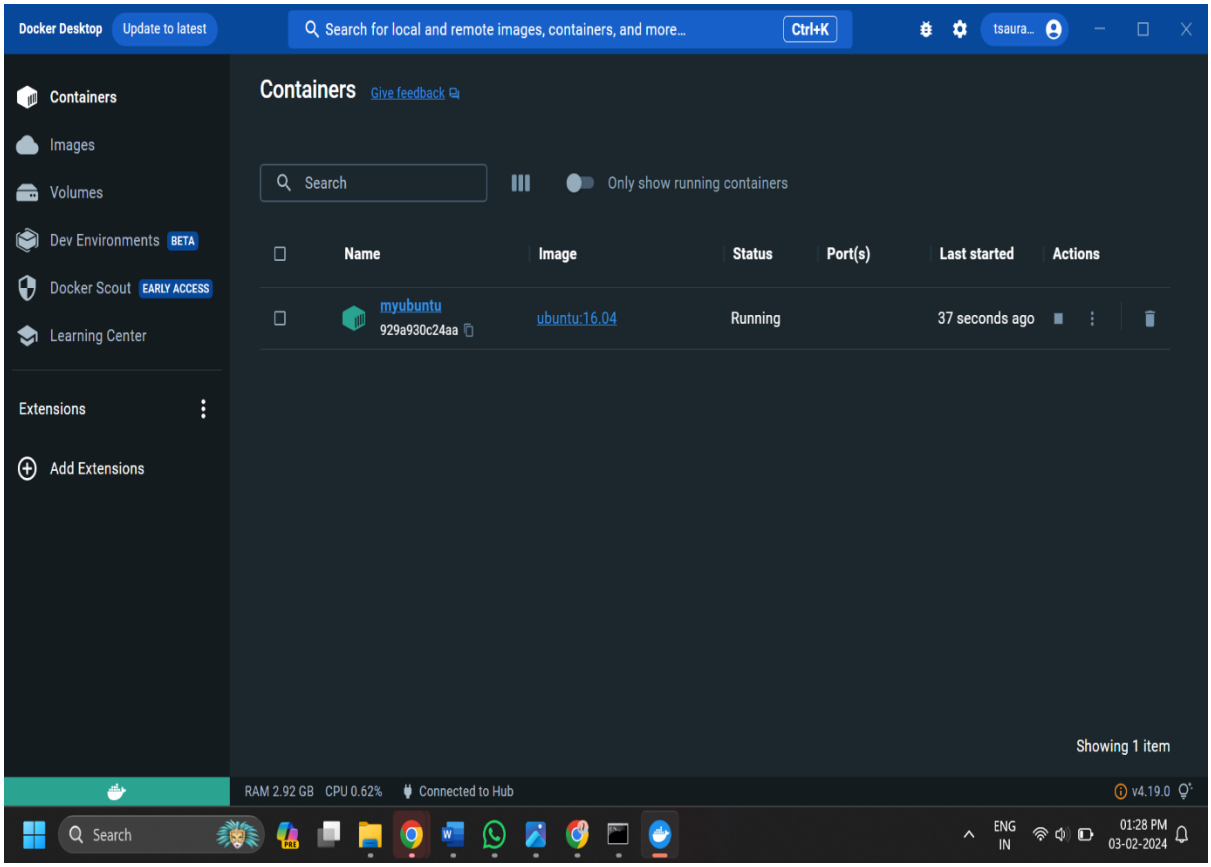
sudo apt install sysbench


QEMU - Press Ctrl+Alt+G to release grab
Machine View
saurabh login:
Ubuntu 16.04.7 LTS saurabh tty1
saurabh login: saurabh
Password:
Last login: Tue Jan 30 14:26:09 PST 2024 on tty1
Welcome to Ubuntu 16.04.7 LTS (GNU/Linux 4.4.0-186-generic x86_64)
* Documentation: https://help.ubuntu.com
* Management: https://landscape.canonical.com
* Support: https://ubuntu.com/advantage
117 packages can be updated.
83 updates are security updates.
New release '18.04.6 LTS' available.
Run 'do-release-upgrade' to upgrade to it.
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.
saurabh@saurabh:~$ sudo apt-get update
[sudo] password for saurabh:
Hit:1 http://us.archive.ubuntu.com/ubuntu xenial InRelease
Hit:2 http://security.ubuntu.com/ubuntu xenial-security InRelease
Hit:3 http://us.archive.ubuntu.com/ubuntu xenial-updates InRelease
Hit:4 http://us.archive.ubuntu.com/ubuntu xenial-backports InRelease
Reading package lists... Done
saurabh@saurabh:~$
apt-get sudo update
saurabh@saurabh:~$
apt-get sudo update
saurabh@saurabh:~$ sudo apt install sysbench



Docker Setup:





1. Initiate and launch a fresh container using the Ubuntu image:
   - docker container run Ubuntu

2. Access a bash shell within the Ubuntu container:
   - docker container run -it ubuntu bash

Test Configurations

To carry out the VM experiment, we will examine four test conditions outlined in the table below. To maintain consistency in the results, we will apply identical test conditions for both QEMU & Docker.

Memory	Cores
2Gb	2
4Gb	2
2GB	3
4GB	3

Proof of Experiment

This section focuses on test scenarios specifically associated with sysbench commands related to CPU, memory, and File I/O. Additionally, we will experiment with various QEMU VM configurations to determine if altering these configurations yields distinct results.

1. CPU Testing

Use following bash script to evaluate CPU performance.

```
#!/bin/bash
# First CPU Test Case: High Prime Number Calculation
echo "Running First CPU Test: High Prime Number Calculation"
for i in {1..5}
do
   echo "Iteration $i"
   sysbench --test=cpu --cpu-max-prime=20000 run
   echo ""
done
# Second CPU Test Case: Multiple Threads
echo "Running Second CPU Test: Multiple Threads"
for i in {1..5}
do
   echo "Iteration $i"
   sysbench --test=cpu --num-threads=4 --cpu-max-prime=10000 run
   echo ""
done
echo "All CPU tests are completed."
```

2. FILE I/O Testing

Use following bash script to evaluate File read/write.

```
#!/bin/bash
# First File I/O Test Case: Sequential Write
echo "Running First File I/O Test: Sequential Write"
for i in {1..5}
do
   echo "Iteration $i"
   sysbench --test=fileio --file-total-size=250M --file-test-mode=seqwr prepare
   sysbench --test=fileio --file-total-size=250M --file-test-mode=seqwr run
   sysbench --test=fileio --file-total-size=250M cleanup
   echo ""
done
# Second File I/O Test Case: Random Read
echo "Running Second File I/O Test: Random Read"
for i in {1..5}
do
   echo "Iteration $i"
   sysbench --test=fileio --file-total-size=300M --file-test-mode=rndrd prepare
   sysbench --test=fileio --file-total-size=300M --file-test-mode=rndrd run
   sysbench --test=fileio --file-total-size=300M cleanup
   echo ""
done
echo "All File I/O tests are completed."
```

3. Memory Testing

Use following bash script for memory testing.

```
#!/bin/bash
# First Memory Test Case: Sequential Memory Access
echo "Running First Memory Test: Sequential Access"
for i in {1..5}
do
   echo "Iteration $i"
   sysbench --test=memory --memory-block-size=1K --memory-total-size=100G --memory-access-mode=seq run
   echo ""
done

# Second Memory Test Case: Random Memory Access
echo "Running Second Memory Test: Random Access"
for i in {1..5}
do
   echo "Iteration $i"
   sysbench --test=memory --memory-block-size=1K --memory-total-size=100G --memory-access-mode=rnd run
   echo ""
done
echo "All Memory tests are completed."
```

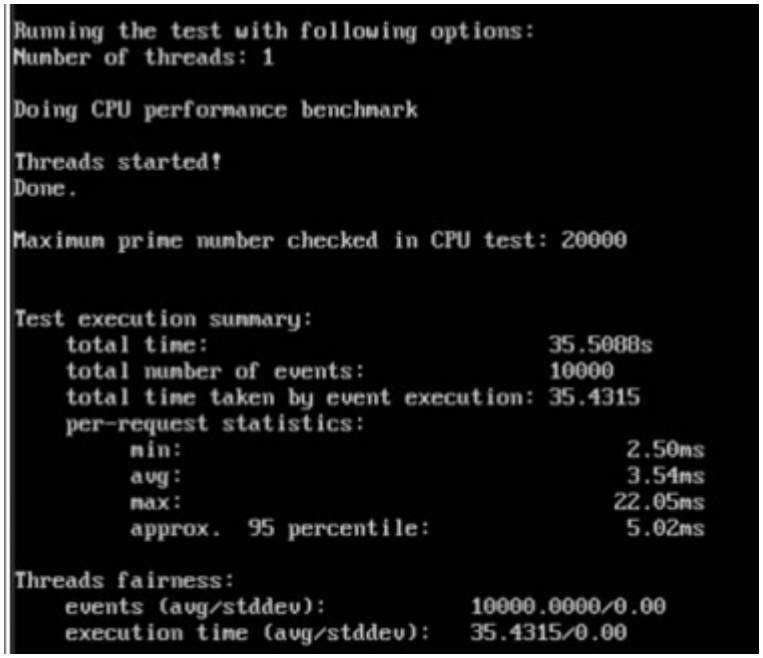
Results

QEMU Screenshots and Observations:

1. Configuration 1: 2 GB RAM with 2 Cores

Qcow2 disk image

CPU Test for max-prime = 20000



Observations:

Iteration 1: 3.54ms

Iteration 2: 3.20ms

Iteration 3: 3.43ms

Iteration 4: 3.82ms

Iteration 5: 3.41ms

Avg. Time	Min. Time	Max. Time
3.48ms	0.97ms	43.12ms

CPU Test for max-prime = 10000

```
Maximum prime number checked in CPU test: 10000


Test execution summary:
    total time:                          1.9028s
    total number of events:              10000
    total time taken by event execution: 7.6065
    per-request statistics:
         min:                                  0.46ms
         avg:                                  0.76ms
         max:                                  8.75ms
         approx.  95 percentile:               0.99ms

Threads fairness:
    events (avg/stddev):           2500.0000/54.67
    execution time (avg/stddev):   1.9016/0.00
```

Observations:

Iteration 1: 0.76ms

Iteration 2: 1.20ms

Iteration 3: 0.93ms

Iteration 4: 0.82ms

Iteration 5: 0.91ms

Avg. Time	Min. Time	Max. Time
0.98ms	0.38ms	13.42ms

File I/O Test for Sequential Write:

```
Operations performed:  0 Read, 131072 Write, 128 Other = 131200 Total
Read 0b  Written 2Gb  Total transferred 2Gb  (65.316Mb/sec)
 4180.20 Requests/sec executed

Test execution summary:
    total time:                          31.3554s
    total number of events:              131072
    total time taken by event execution: 26.2282
    per-request statistics:
         min:                                  0.09ms
         avg:                                  0.20ms
         max:                                 32.97ms
         approx.  95 percentile:               0.38ms
```

Observations:

Iteration 1: 0.20ms

Iteration 2: 0.32ms

Iteration 3: 0.23ms

Iteration 4: 0.11ms

Iteration 5: 0.32ms

Avg. Time	Min. Time	Max. Time
0.236ms	0.08ms	32.97ms

File I/O Test for Random Read:

```
Operations performed:  10000 Read, 0 Write, 0 Other = 10000 Total
Read 156.25Mb  Written 0b  Total transferred 156.25Mb  (2.1026Gb/sec)
137793.69 Requests/sec executed

Test execution summary:
    total time:                          0.0726s
    total number of events:              10000
    total time taken by event execution: 0.0706
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.01ms
         max:                                 10.32ms
         approx.  95 percentile:               0.01ms
```

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.02ms

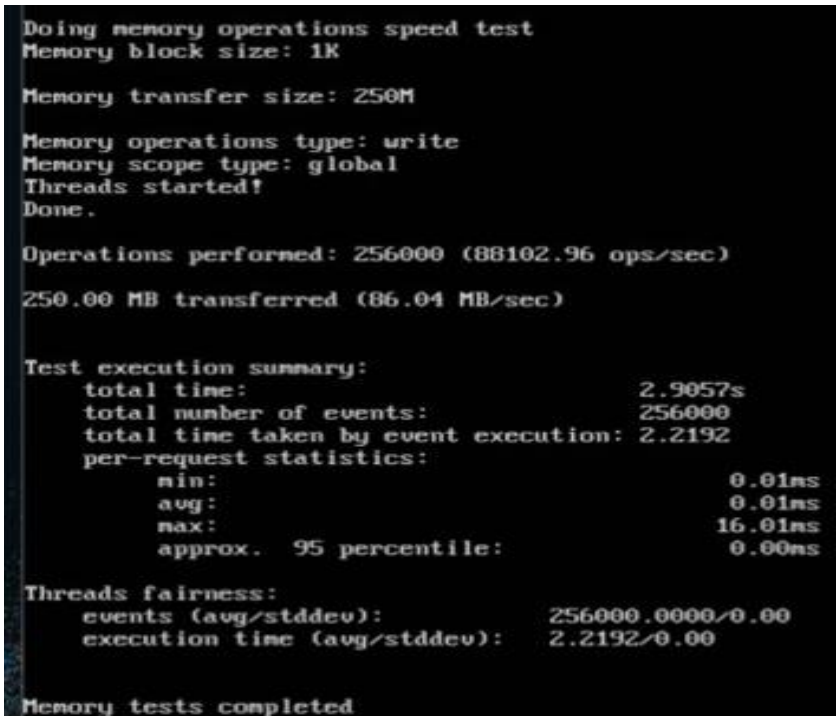
Iteration 3: 0.01ms

Iteration 4: 0.03ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.1ms	0.00ms	19.82ms

Memory Test for Sequential Memory Access:



Observations:

Iteration 1: 0.01ms

Iteration 2: 0.23ms

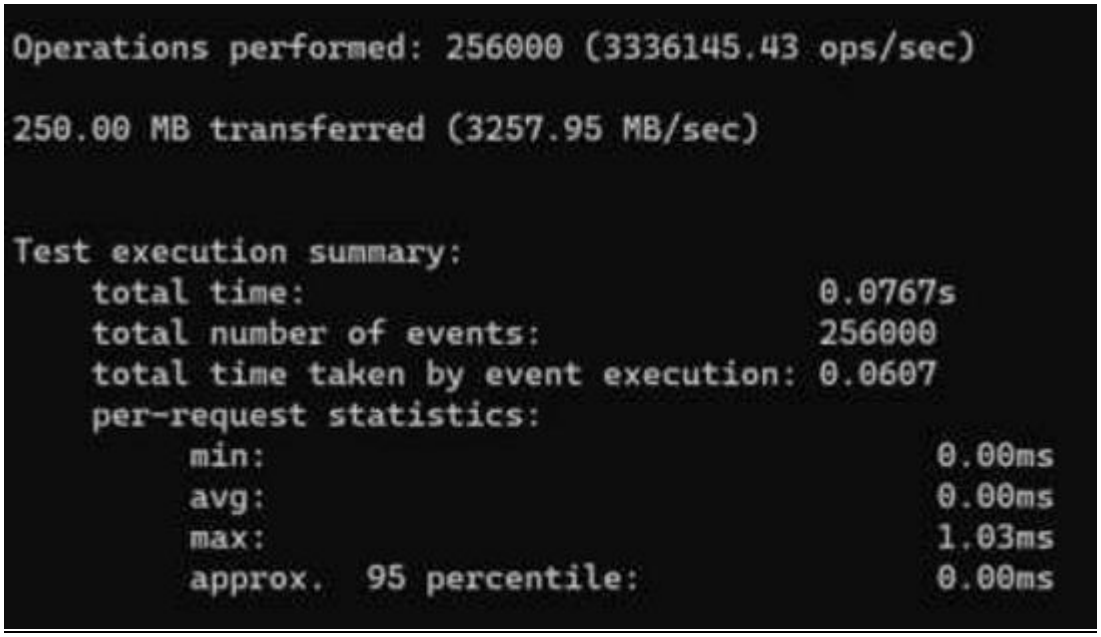
Iteration 3: 0.21ms

Iteration 4: 0.08ms

Iteration 5: 0.02ms

Avg. Time	Min. Time	Max. Time
0.11ms	0.01ms	53.89ms

Memory Test for Random Memory Access:



Observations:

Iteration 1: 0.01ms

Iteration 2: 0.02ms

Iteration 3: 0.02ms

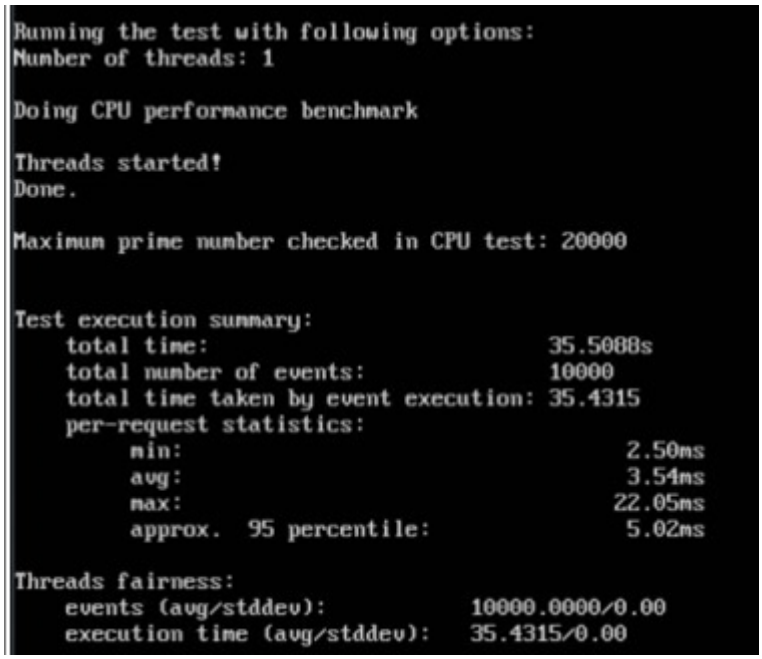
Iteration 4: 0.00ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.1ms	0.00ms	11.35ms

Raw disk image

CPU Test for max-prime 20000



Observations:

Iteration 1: 2.54ms

Iteration 2: 1.20ms

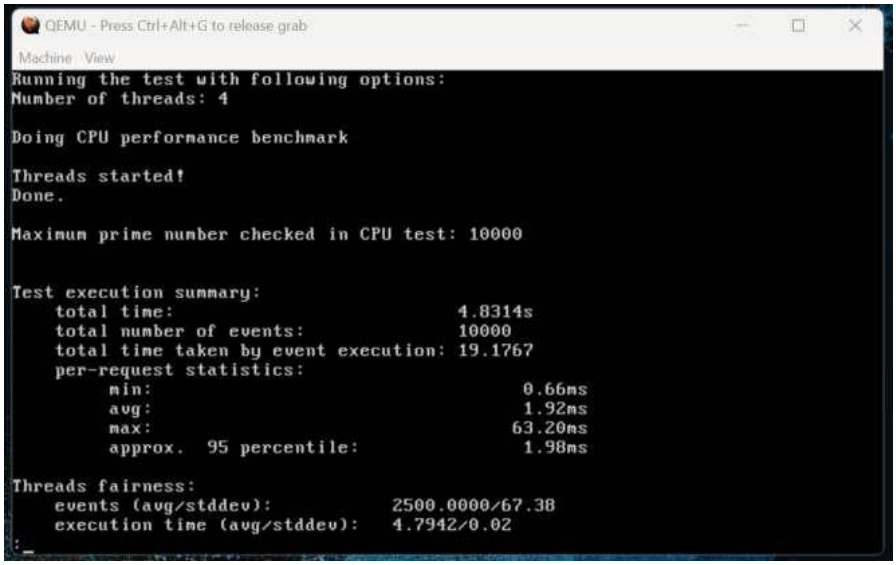
Iteration 3: 4.43ms

Iteration 4: 2.82ms

Iteration 5: 3.41ms

Avg. Time	Min. Time	Max. Time
3.48ms	0.97ms	43.12ms

CPU Test for max-prime=10000



Observations:

Iteration 1: 1.92ms

Iteration 2: 2.30ms

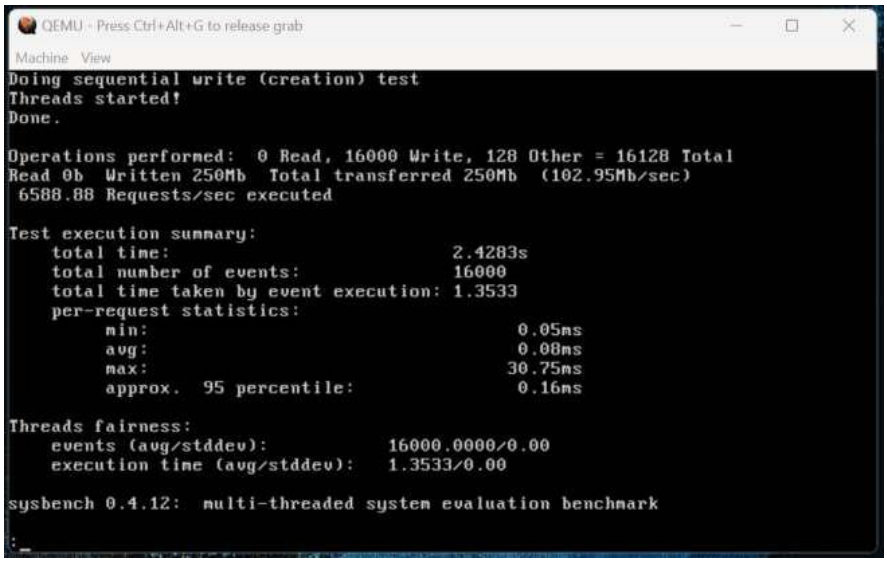
Iteration 3: 2.09ms

Iteration 4: 1.99ms

Iteration 5: 2.23ms

Avg. Time	Min. Time	Max. Time
2.06ms	0.59ms	74.28ms

File I/O Test for Sequential write



Observations:

Iteration 1: 0.08ms

Iteration 2: 0.06ms

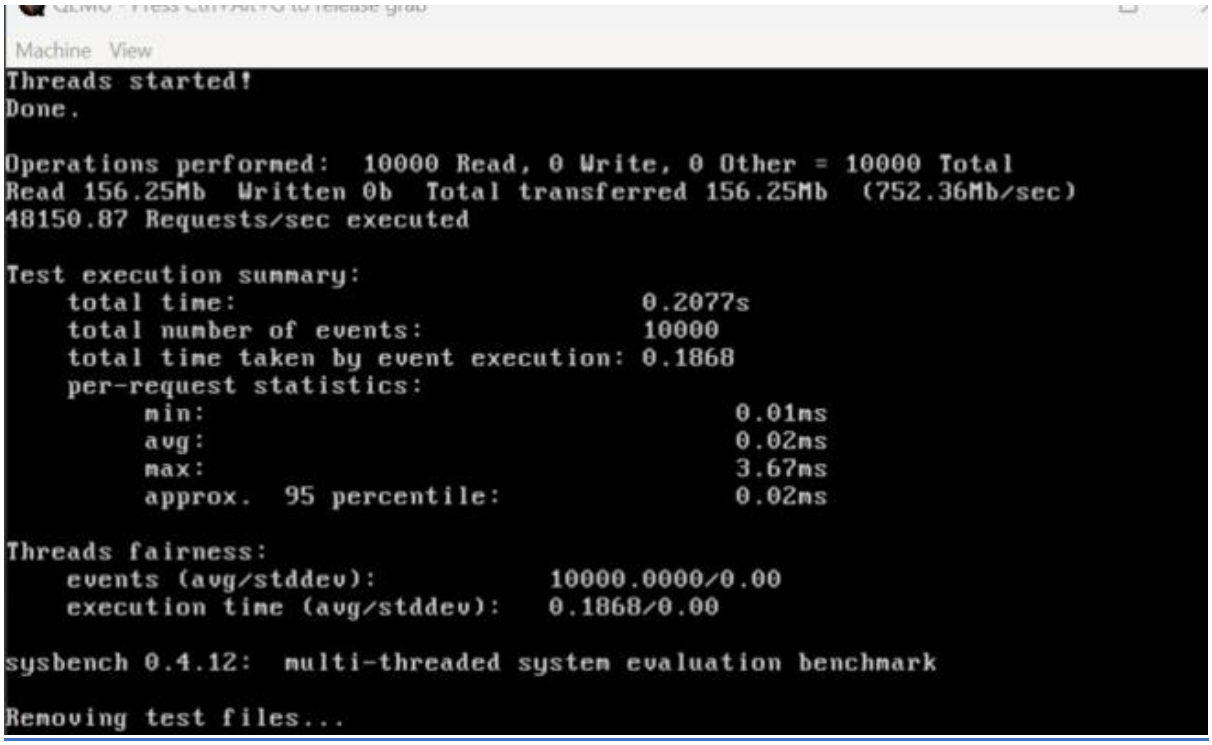
Iteration 3: 0.07ms

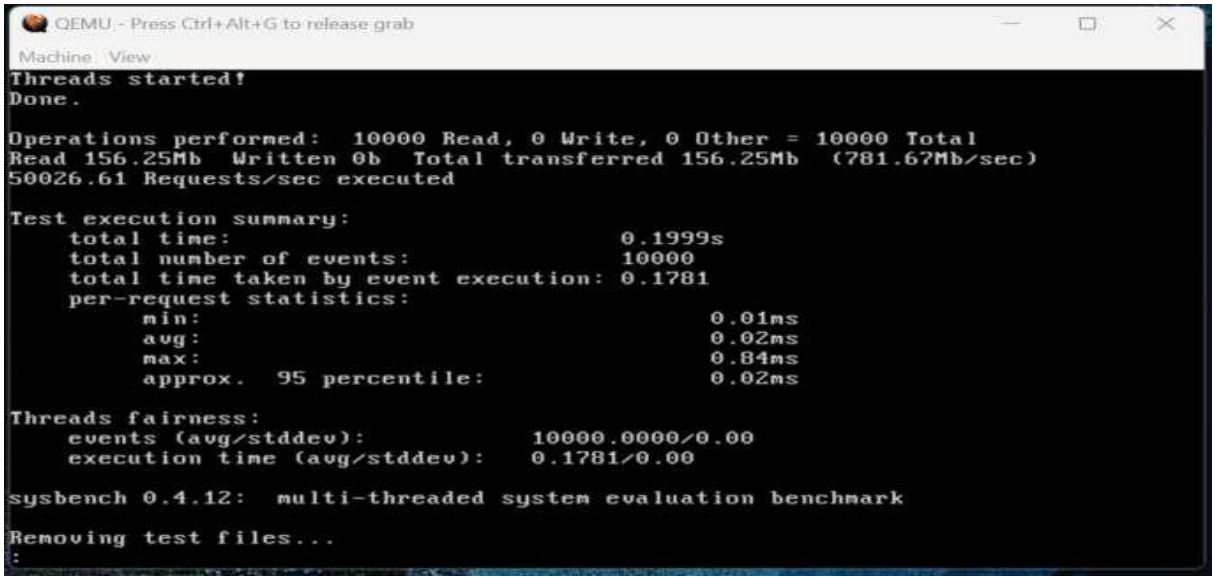
Iteration 4: 0.08ms

Iteration 5: 0.10ms

Avg. Time	Min. Time	Max. Time
0.08ms	0.02ms	36.97ms

File I/O Test for Random Read





Observations:

Iteration 1: 0.01ms

Iteration 2: 0.02ms

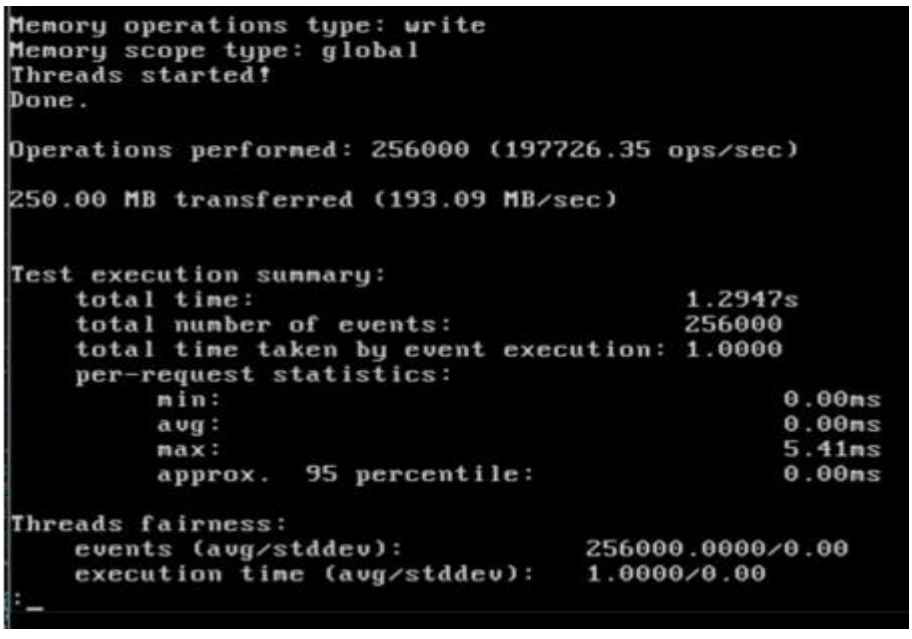
Iteration 3: 0.01ms

Iteration 4: 0.00ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.01ms	0.0ms	2.97ms

Memory Test for Sequential Memory Access



Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

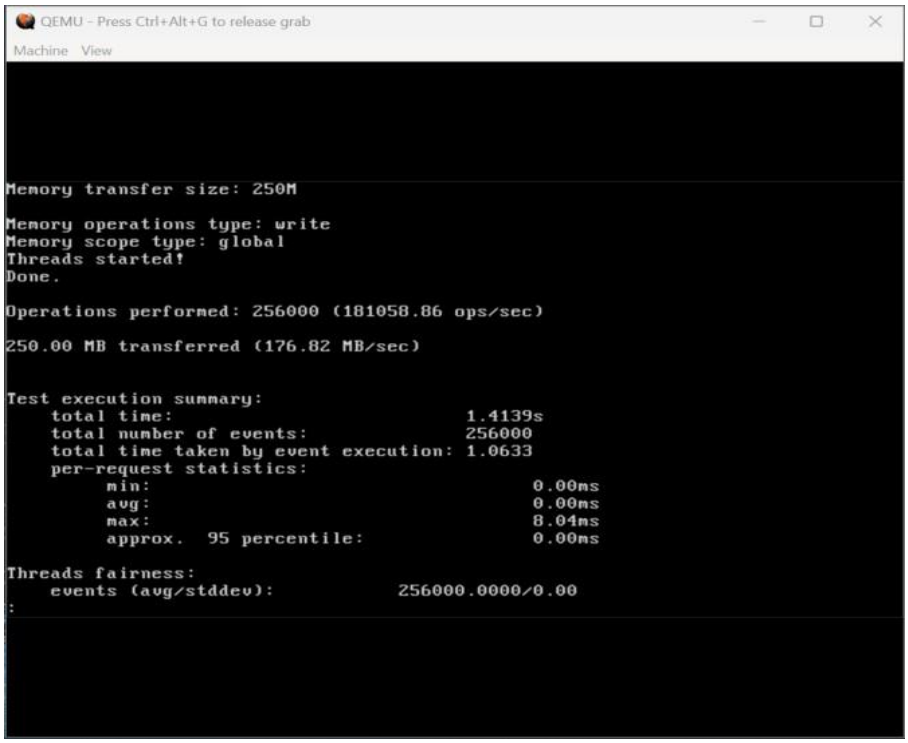
Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	7.51ms

Memory Test for Random Memory Access



Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

Iteration 3: 0.00ms

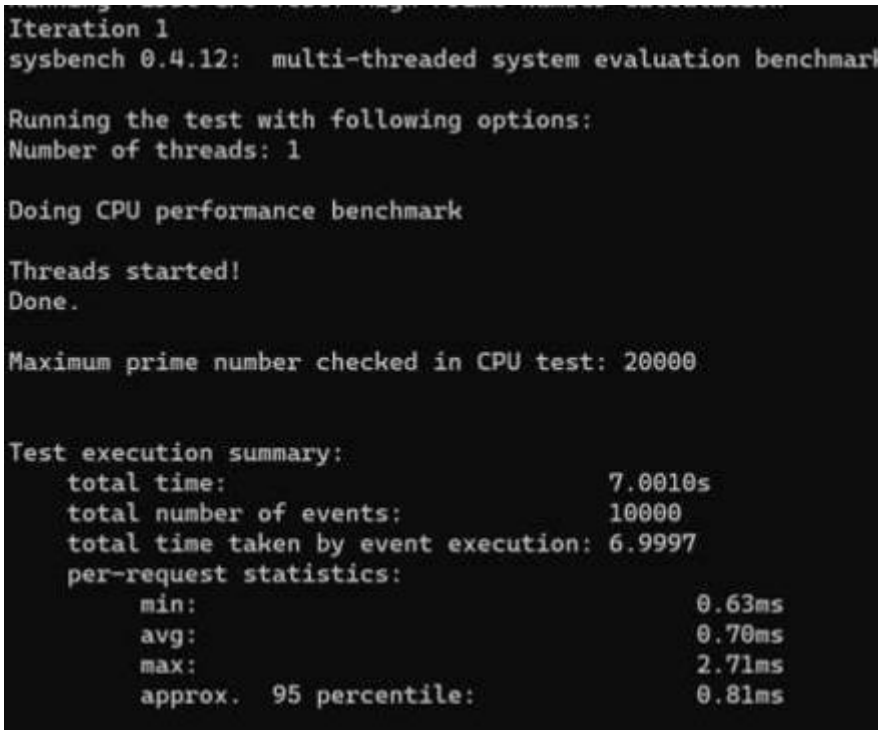
Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	8.04ms

Docker

CPU Test for max-prime 20000



Observations:

Iteration 1: 0.7ms

Iteration 2: 0.75ms

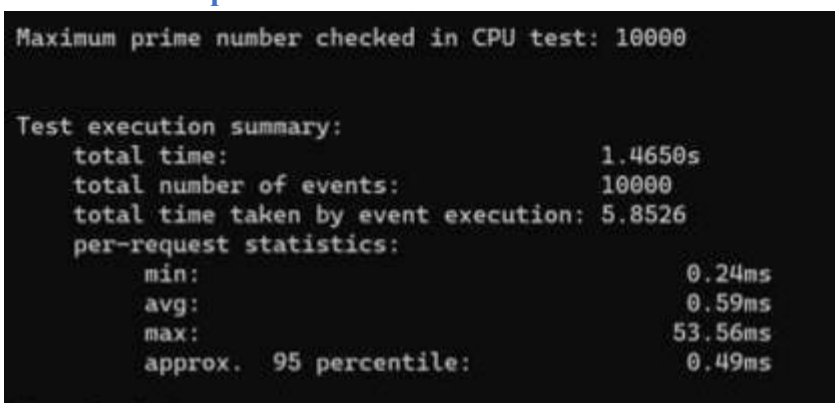
Iteration 3: 0.69ms

Iteration 4: 0.72ms

Iteration 5: 0.71ms

Avg. Time	Min. Time	Max. Time
0.71ms	0.52ms	5.2ms

CPU Test for max-prime=10000



Observations:

Iteration 1: 0.59ms

Iteration 2: 0.61ms

Iteration 3: 0.67ms

Iteration 4: 0.54ms

Iteration 5: 0.69ms

Avg. Time	Min. Time	Max. Time
0.62ms	0.19ms	55.21ms

File I/O Test for Sequential write

```
Operations performed:  0 Read, 16000 Write, 128 Other = 16128 Total
Read 0b  Written 250Mb  Total transferred 250Mb  (883.12Mb/sec)
56519.79 Requests/sec executed

Test execution summary:
    total time:                          0.2831s
    total number of events:              16000
    total time taken by event execution: 0.0877
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.01ms
         max:                                  1.79ms
         approx.  95 percentile:               0.01ms

Threads fairness:
    events (avg/stddev):           16000.0000/0.00
    execution time (avg/stddev):   0.0877/0.00
```

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.02ms

Iteration 3: 0.01ms

Iteration 4: 0.01ms

Iteration 5: 0.02ms

Avg. Time	Min. Time	Max. Time
0.01ms	0.0ms	0.49ms

File I/O Test for Random Read

```
Operations performed:  10000 Read, 0 Write, 0 Other = 10000 Total
Read 156.25Mb  Written 0b  Total transferred 156.25Mb  (6.6067Gb/sec)
432976.64 Requests/sec executed

Test execution summary:
    total time:                          0.0231s
    total number of events:              10000
    total time taken by event execution: 0.0220
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.00ms
         max:                                  0.14ms
         approx.  95 percentile:               0.00ms

Threads fairness:
    events (avg/stddev):           10000.0000/0.00
    execution time (avg/stddev):   0.0220/0.00
```

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

Iteration 3: 0.01ms

Iteration 4: 0.00ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.23ms

Memory Test for Sequential Memory Access

```
Doing memory operations speed test
Memory block size: 1K

Memory transfer size: 250M

Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 256000 (5377224.93 ops/sec)

250.00 MB transferred (5251.20 MB/sec)


Test execution summary:
    total time:                          0.0476s
    total number of events:              256000
    total time taken by event execution: 0.0386
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.00ms
         max:                                  0.07ms
         approx.  95 percentile:               0.00ms

Threads fairness:
    events (avg/stddev):           256000.0000/0.00
    execution time (avg/stddev):   0.0386/0.00
```

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.01ms

Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.39ms

Memory Test for Random Memory Access

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.55ms

2. Configuration 2: RAM 4Gb, 2 Cores

QEMU

Qcow2 disk image

CPU Test for max-prime:20000 & 10000

```
Running CPU Test 1: High Prime Number Calculation
Iteration 1
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing CPU performance benchmark

Threads started!
Done.
```

```
Test execution summary:
    total time:                          12.5249s
    total number of events:              10000
    total time taken by event execution: 12.4962
    per-request statistics:
         min:                                  0.97ms
         avg:                                  1.25ms
         max:                                  4.65ms
         approx.  95 percentile:               1.38ms

Threads fairness:
    events (avg/stddev):           10000.0000/0.00
    execution time (avg/stddev):   12.4962/0.00

Iteration 2
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1
```

```
Test execution summary:
    total time:                          13.5590s
    total number of events:              10000
    total time taken by event execution: 13.5234
    per-request statistics:
         min:                                  0.99ms
         avg:                                  1.35ms
         max:                                  5.27ms
         approx.  95 percentile:               1.52ms

Threads fairness:
    events (avg/stddev):           10000.0000/0.00
    execution time (avg/stddev):   13.5234/0.00

Iteration 3
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing CPU performance benchmark

Threads started!
Done.
```

```
Test execution summary:
    total time:                          13.9869s
    total number of events:              10000
    total time taken by event execution: 13.9616
    per-request statistics:
         min:                                  1.01ms
         avg:                                  1.40ms
         max:                                 12.89ms
         approx.  95 percentile:               1.58ms

Threads fairness:
    events (avg/stddev):           10000.0000/0.00
    execution time (avg/stddev):   13.9616/0.00
```

Observations:

Iteration 1: 1.25ms

Iteration 2: 1.35ms

Iteration 3: 1.4ms

Iteration 4: 1.32ms

Iteration 5: 1.43ms

Avg. Time	Min. Time	Max. Time
1.33ms	0.97ms	13.49ms

File I/O Test:

```
Running the test with following options:
Number of threads: 1

Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential write (creation) test
Threads started!
Done.

Operations performed:  0 Read, 131072 Write, 128 Other = 131200 Total
Read 0b  Written 2Gb  Total transferred 2Gb  (65.316Mb/sec)
 4180.20 Requests/sec executed

Test execution summary:
    total time:                          31.3554s
    total number of events:              131072
    total time taken by event execution: 26.2282
    per-request statistics:
         min:                                  0.09ms
         avg:                                  0.20ms
         max:                                 32.97ms
         approx.  95 percentile:               0.38ms
```

```
Extra file open flags: 0
128 files, 16Mb each
2Gb total file size
Block size 16Kb
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential write (creation) test
Threads started!
Done.

Operations performed:  0 Read, 131072 Write, 128 Other = 131200 Total
Read 0b  Written 2Gb  Total transferred 2Gb  (84.316Mb/sec)
 5396.22 Requests/sec executed

Test execution summary:
    total time:                          24.2896s
    total number of events:              131072
    total time taken by event execution: 19.0220
    per-request statistics:
         min:                                  0.07ms
         avg:                                  0.15ms
         max:                                 11.45ms
         approx.  95 percentile:               0.27ms

Threads fairness:
    events (avg/stddev):           131072.0000/0.00
    execution time (avg/stddev):   19.0220/0.00

sysbench 0.4.12:  multi-threaded system evaluation benchmark

Removing test files...

Iteration 3
sysbench 0.4.12:  multi-threaded system evaluation benchmark

:_
```

Observations:

Iteration 1: 0.20ms

Iteration 2: 0.15ms

Iteration 3: 0.22ms

Iteration 4: 0.18ms

Iteration 5: 0.32ms

Avg. Time	Min. Time	Max. Time
0.236ms	0.08ms	39.3ms

Memory Test

```
Running Memory Test 1: Sequential Access
Iteration 1
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 2K

Memory transfer size: 2048M

Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 1048576 (100283.33 ops/sec)

2048.00 MB transferred (195.87 MB/sec)


Test execution summary:
    total time:                          10.4561s
    total number of events:              1048576
    total time taken by event execution: 8.0902
    per-request statistics:
         min:                                  0.01ms
         avg:                                  0.01ms
         max:                                  9.06ms
         approx.  95 percentile:               0.00ms

Threads fairness:
    events (avg/stddev):           1048576.0000/0.00
    execution time (avg/stddev):   8.0902/0.00

:
```

```
Iteration 2
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 2K

Memory transfer size: 2048M

Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 1048576 (98611.51 ops/sec)

2048.00 MB transferred (192.60 MB/sec)


Test execution summary:
    total time:                          10.6334s
    total number of events:              1048576
    total time taken by event execution: 8.0982
    per-request statistics:
         min:                                  0.01ms
         avg:                                  0.01ms
         max:                                  7.05ms
         approx.  95 percentile:               0.00ms

Threads fairness:
    events (avg/stddev):           1048576.0000/0.00
    execution time (avg/stddev):   8.0982/0.00

:_
```

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.01ms

Iteration 3: 0.21ms

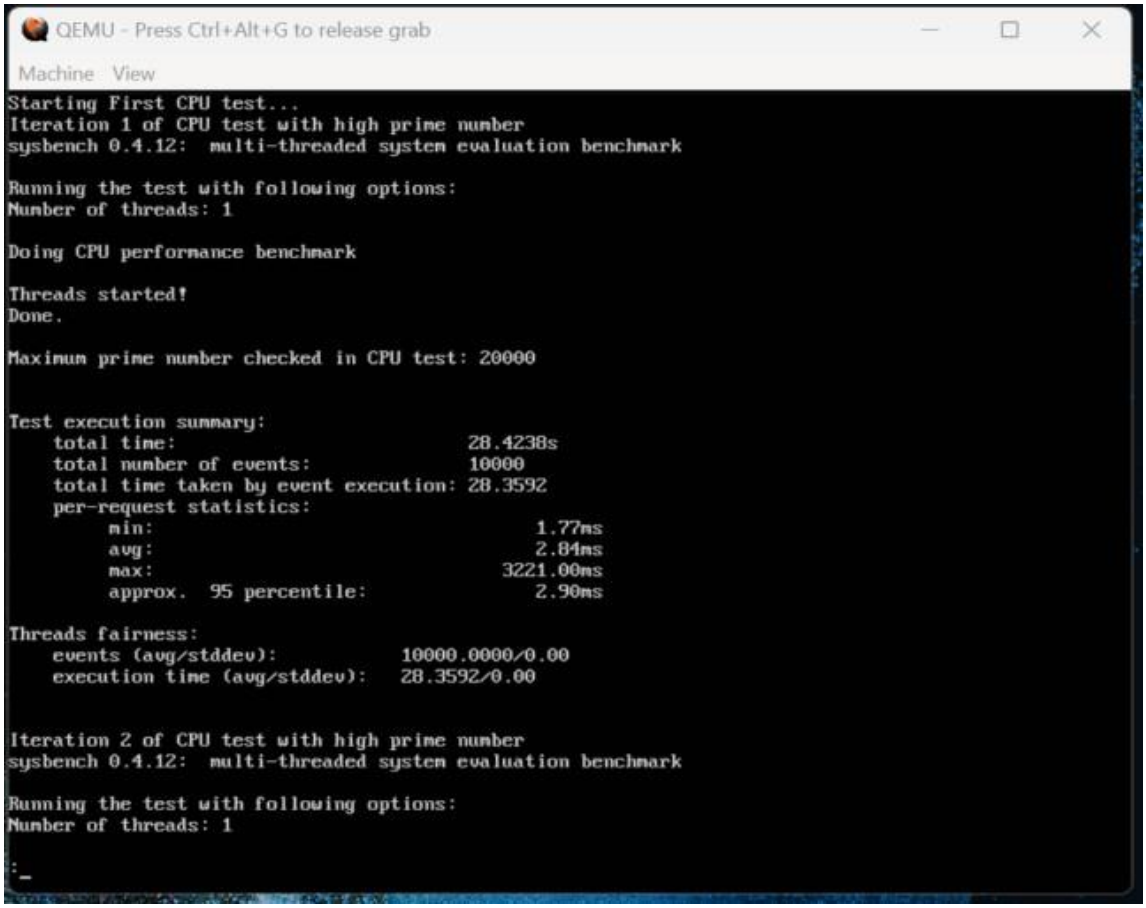
Iteration 4: 0.08ms

Iteration 5: 0.02ms

Avg. Time	Min. Time	Max. Time
0.11ms	0.01ms	53.89ms

Raw disk image

CPU Test for max-prime=20000



Observations:

Iteration 1: 2.84ms

Iteration 2: 3.24ms

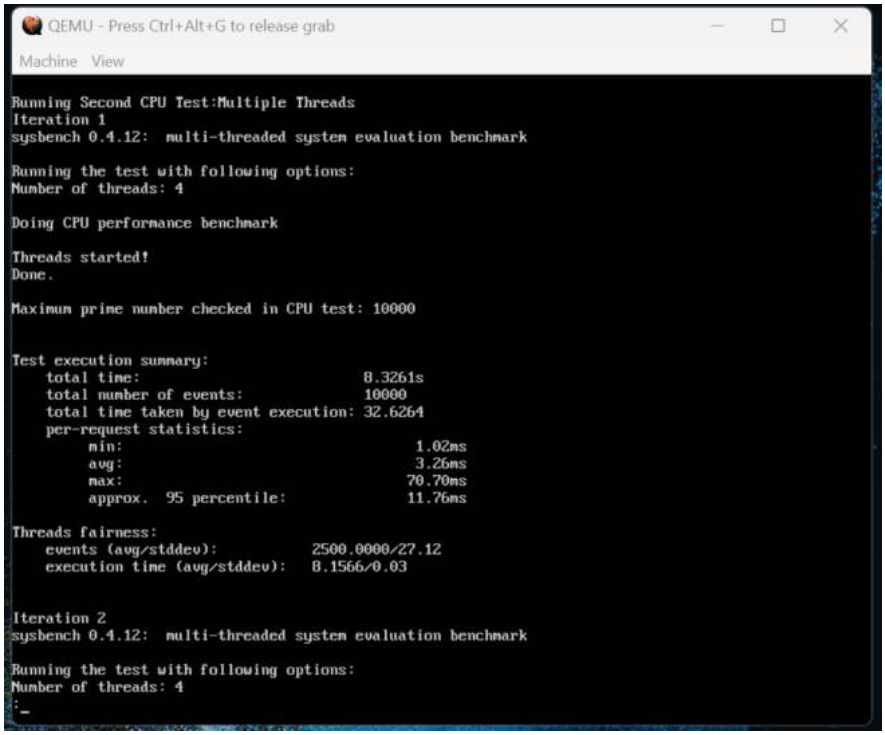
Iteration 3: 3.43ms

Iteration 4: 2.98ms

Iteration 5: 2.66ms

Avg. Time	Min. Time	Max. Time
2.96ms	0.97ms	43.12ms

CPU Test for max-prime=10000



Observations:

Iteration 1: 3.26ms

Iteration 2: 2.95ms

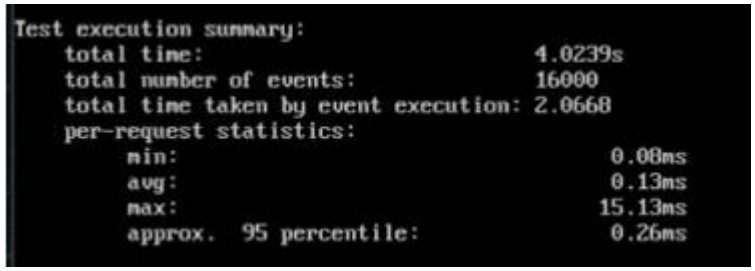
Iteration 3: 3.09ms

Iteration 4: 3.55ms

Iteration 5: 2.23ms

Avg. Time	Min. Time	Max. Time
3.01ms	0.59ms	83.47ms

File I/O Test for Sequential write



Observations:

Iteration 1: 0.13ms

Iteration 2: 0.15ms

Iteration 3: 0.12ms

Iteration 4: 0.17ms

Iteration 5: 0.10ms

Avg. Time	Min. Time	Max. Time
0.12ms	0.02ms	29.34ms

File I/O Test for Random Read

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.02ms

Iteration 3: 0.03ms

Iteration 4: 0.03ms

Iteration 5: 0.02ms

Avg. Time	Min. Time	Max. Time
0.02ms	0.0ms	11.99ms

Memory Test for Sequential Memory Access

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

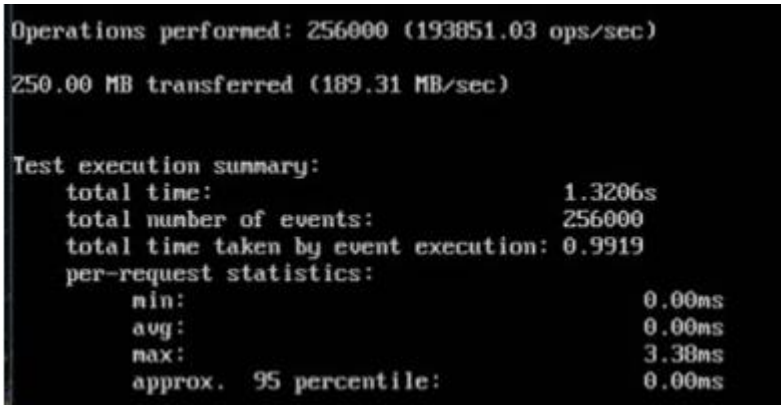
Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	4.51ms

Memory Test for Random Memory Access



Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

Iteration 3: 0.01ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	21.87ms

Docker

CPU Test for max-prime 20000

Observations:

Iteration 1: 0.71ms

Iteration 2: 0.66ms

Iteration 3: 0.72ms

Iteration 4: 0.73ms

Iteration 5: 0.79ms

Avg. Time	Min. Time	Max. Time
0.73ms	0.49ms	5.32ms

CPU Test for max-prime=10000

```
Running Second CPU Test: Multiple Threads
Iteration 1
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Done.

Maximum prime number checked in CPU test: 10000


Test execution summary:
    total time:                          0.7276s
    total number of events:              10000
    total time taken by event execution: 2.9016
    per-request statistics:
         min:                                  0.27ms
         avg:                                  0.29ms
         max:                                  5.94ms
         approx.  95 percentile:               0.32ms

Threads fairness:
    events (avg/stddev):           2500.0000/23.14
    execution time (avg/stddev):   0.7254/0.00
```

Observations:

Iteration 1: 0.29ms

Iteration 2: 0.26ms

Iteration 3: 0.38ms

Iteration 4: 0.40ms

Iteration 5: 0.31ms

Avg. Time	Min. Time	Max. Time
0.32ms	0.23ms	6.2ms

File I/O Test for Sequential write

```
Operations performed:  0 Read, 16000 Write, 128 Other = 16128 Total
Read 0b  Written 250Mb  Total transferred 250Mb  (935.34Mb/sec)
59861.64 Requests/sec executed

Test execution summary:
    total time:                          0.2673s
    total number of events:              16000
    total time taken by event execution: 0.0893
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.01ms
         max:                                  0.57ms
         approx.  95 percentile:               0.01ms
```

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.01ms

Iteration 3: 0.02ms

Iteration 4: 0.01ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.01ms	0.0ms	4.97ms

File I/O Test for Random Read

```
300Mb total file size
Block size 16Kb
Number of random requests for random IO: 10000
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 read test
Threads started!
Done.

Operations performed:  10000 Read, 0 Write, 0 Other = 10000 Total
Read 156.25Mb  Written 0b  Total transferred 156.25Mb  (5.6717Gb/sec)
371697.98 Requests/sec executed

Test execution summary:
    total time:                          0.0269s
    total number of events:              10000
    total time taken by event execution: 0.0257
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.00ms
         max:                                  0.47ms
         approx.  95 percentile:               0.00ms
```

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

Iteration 3: 0.01ms

Iteration 4: 0.00ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.49ms

Memory Test for Sequential Memory Access

```
Doing memory operations speed test
Memory block size: 1K

Memory transfer size: 250M

Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 256000 (5313875.91 ops/sec)

250.00 MB transferred (5189.33 MB/sec)


Test execution summary:
    total time:                          0.0482s
    total number of events:              256000
    total time taken by event execution: 0.0391
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.00ms
         max:                                  0.17ms
         approx.  95 percentile:               0.00ms
```

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.01ms

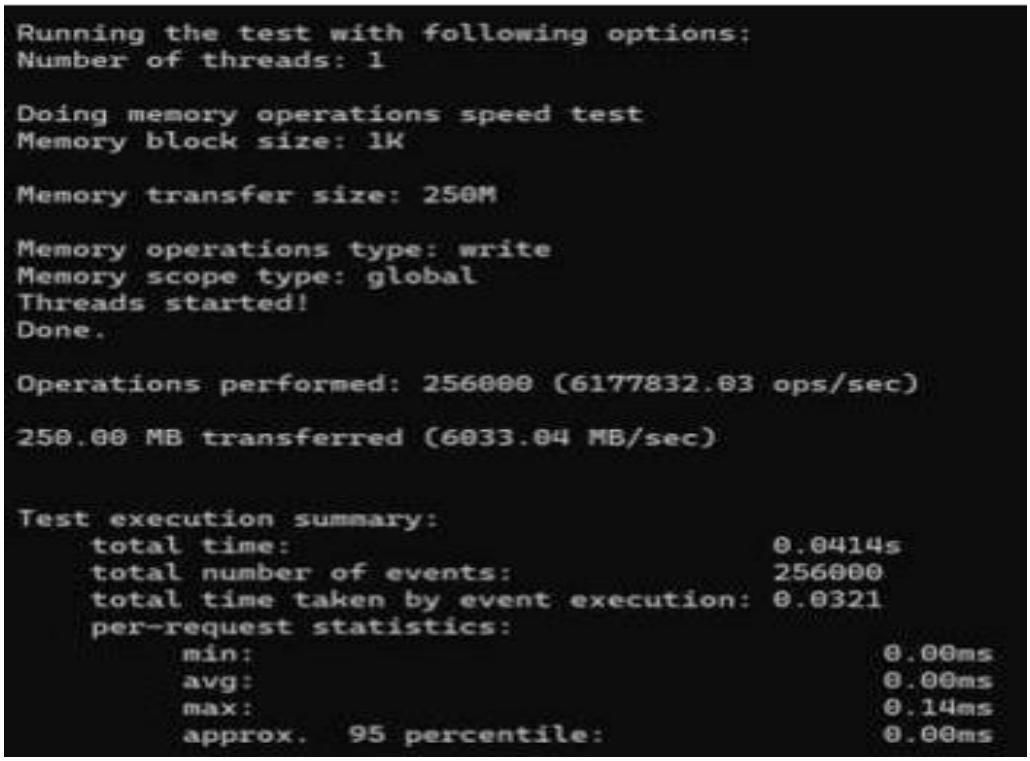
Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.25ms

Memory Test for Random Memory Access



Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

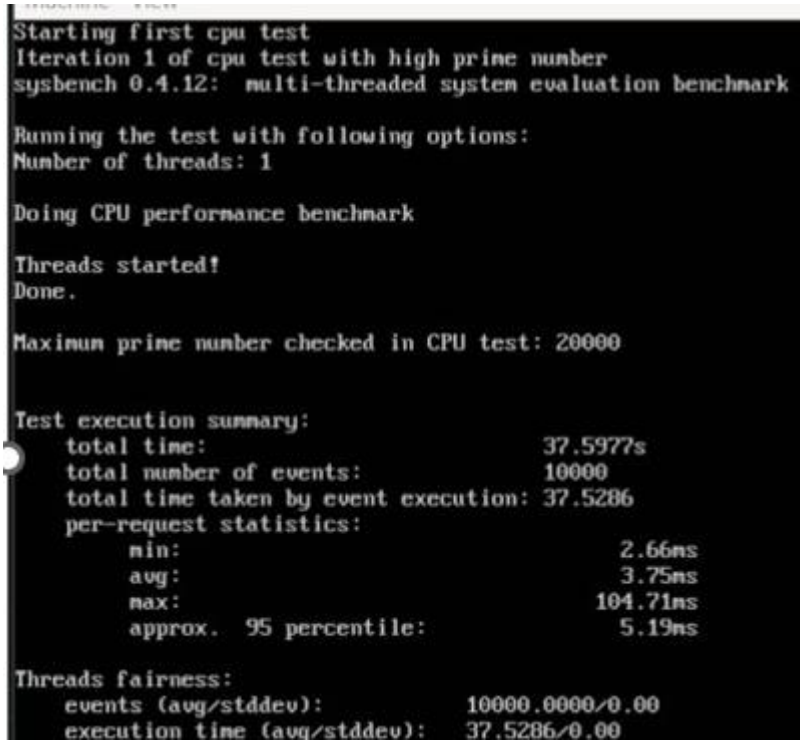
Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.29ms

Configuration 3: 2 GB RAM ,3 Cores

QEMU

Qcow2 disk image

CPU Test for max_prime: 20000



Observations:

Iteration 1: 3.54ms

Iteration 2: 3.90ms

Iteration 3: 3.73ms

Iteration 4: 3.22ms

Iteration 5: 3.41ms

Avg. Time	Min. Time	Max. Time
3.498ms	1.38ms	104.71ms

CPU Test for max-prime: 10000

```
Starting second cpu test(Multiple thread)
Iteration 1 of CPU test with multiple threads
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Done.

Maximun prime number checked in CPU test: 10000


Test execution summary:
    total time:                          5.0125s
    total number of events:              10000
    total time taken by event execution: 19.9456
    per-request statistics:
         min:                                  1.05ms
         avg:                                  1.99ms
         max:                                 17.85ms
         approx.  95 percentile:               2.67ms

Threads fairness:
    events (avg/stddev):           2500.0000/24.93
    execution time (avg/stddev):   4.9864/0.00
```

Observations:

Iteration 1: 2.07ms

Iteration 2: 1.93ms

Iteration 3: 1.95ms

Iteration 4: 2.11ms

Iteration 5: 1.99ms

Avg. Time	Min. Time	Max. Time
2.02ms	1.01ms	19.42ms

File I/O Test for sequential write:

```
Extra file open flags: 0
128 files, 1.9531Mb each
250Mb total file size
Block size 16Kb
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential write (creation) test
Threads started!
Done.

Operations performed:  0 Read, 16000 Write, 128 Other = 16128 Total
Read 0b  Written 250Mb  Total transferred 250Mb  (59.25Mb/sec)
 3792.03 Requests/sec executed

Test execution summary:
    total time:                          4.2194s
    total number of events:              16000
    total time taken by event execution: 1.8421
    per-request statistics:
         min:                                  0.06ms
         avg:                                  0.12ms
         max:                                 18.46ms
         approx.  95 percentile:               0.22ms
```

Observations:

Iteration 1: 0.12ms

Iteration 2: 0.15ms

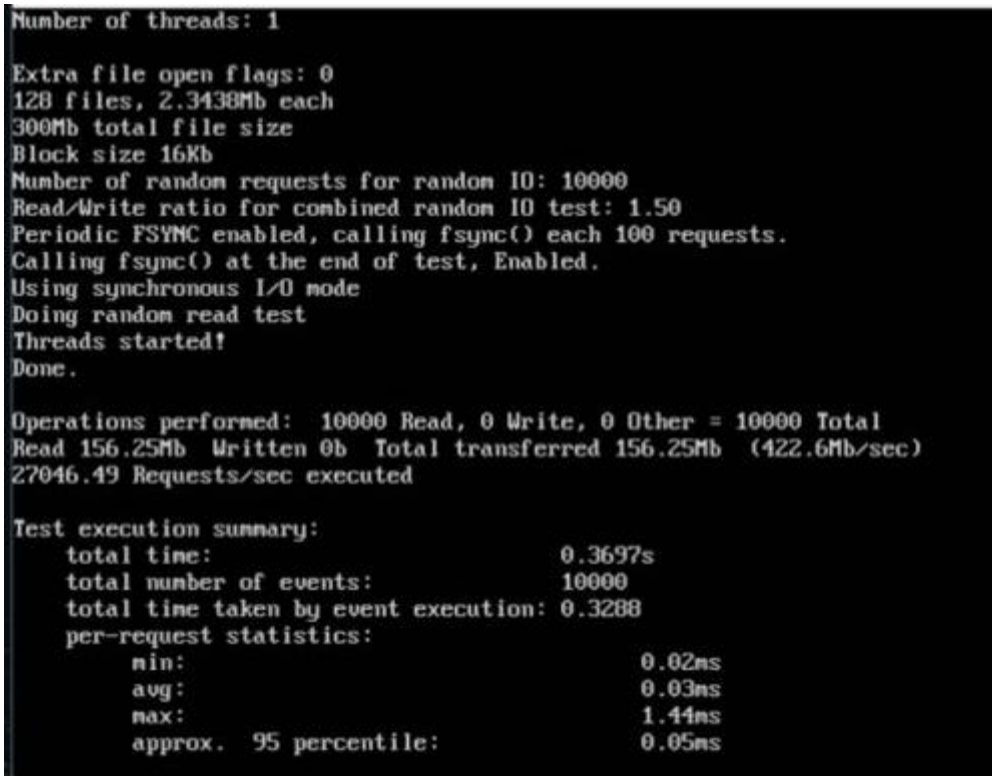
Iteration 3: 0.17ms

Iteration 4: 0.16ms

Iteration 5: 0.10ms

Avg. Time	Min. Time	Max. Time
0.13ms	0.05ms	23.55ms

File I/O Test for Random read:



Observations:

Iteration 1: 0.03ms

Iteration 2: 0.04ms

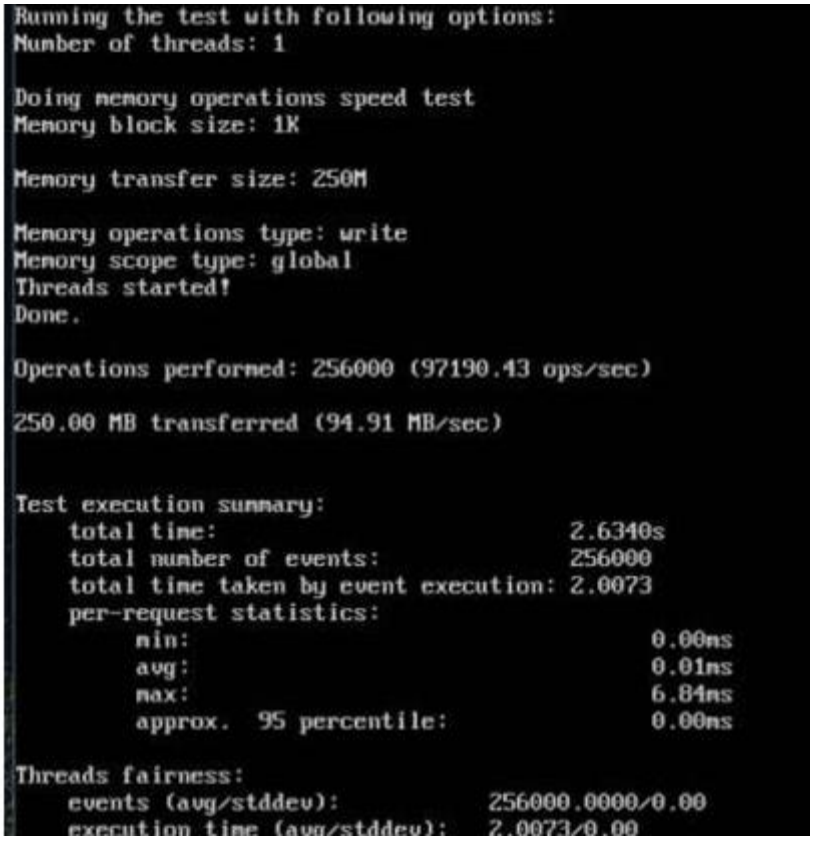
Iteration 3: 0.04ms

Iteration 4: 0.2ms

Iteration 5: 0.4ms

Avg. Time	Min. Time	Max. Time
0.03ms	0.01ms	5.76ms

Memory Test for Sequential Memory Access



Observations:

Iteration 1: 0.01ms

Iteration 2: 0.01ms

Iteration 3: 0.02ms

Iteration 4: 0.01ms

Iteration 5: 0.03ms

Avg. Time	Min. Time	Max. Time
0.11ms	0.00ms	26.41ms

Memory Test for Random Memory Access

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.01ms

Iteration 3: 0.02ms

Iteration 4: 0.01ms

Iteration 5: 0.03ms

Avg. Time	Min. Time	Max. Time
0.1ms	0.00ms	39.57ms

Raw disk image

CPU Test for max-prime 20000

```
Doing CPU performance benchmark

Threads started!
Done.

Maximum prime number checked in CPU test: 20000


Test execution summary:
    total time:                          22.1646s
    total number of events:              10000
    total time taken by event execution: 22.1286
    per-request statistics:
         min:                                  1.48ms
         avg:                                  2.21ms
         max:                               1944.73ms
         approx.  95 percentile:               2.36ms

Threads fairness:
    events (avg/stddev):           10000.0000/0.00
    execution time (avg/stddev):   22.1286/0.00
```

Observations:

Iteration 1: 2.21ms

Iteration 2: 2.81ms

Iteration 3: 2.38ms

Iteration 4: 2.09ms

Iteration 5: 2.46ms

Avg. Time	Min. Time	Max. Time
2.37ms	1.49ms	102.45ms

CPU Test for max-prime=10000

```
Test execution summary:
    total time:                          4.9731s
    total number of events:              10000
    total time taken by event execution: 19.8081
    per-request statistics:
         min:                                  1.06ms
         avg:                                  1.98ms
         max:                                 18.38ms
         approx.  95 percentile:               3.02ms
```

Observations:

Iteration 1: 1.98ms

Iteration 2: 2.95ms

Iteration 3: 2.09ms

Iteration 4: 2.01ms

Iteration 5: 3.04ms

Avg. Time	Min. Time	Max. Time
2.57ms	1.02ms	42.12ms

File I/O Test for Sequential write

```
Threads started!
Done.

Operations performed:  0 Read, 16000 Write, 128 Other = 16128 Total
Read 0b  Written 250Mb  Total transferred 250Mb  (105.3Mb/sec)
 6739.19 Requests/sec executed

Test execution summary:
    total time:                          2.3742s
    total number of events:              16000
    total time taken by event execution: 1.1712
    per-request statistics:
         min:                                  0.04ms
         avg:                                  0.07ms
         max:                                  5.27ms
         approx.  95 percentile:               0.11ms

Threads fairness:
    events (avg/stddev):           16000.0000/0.00
    execution time (avg/stddev):   1.1712/0.00

sysbench 0.4.12:  multi-threaded system evaluation benchmark

Removing test files...
:
```

Observations:

Iteration 1: 0.07ms

Iteration 2: 0.09ms

Iteration 3: 0.06ms

Iteration 4: 0.07ms

Iteration 5: 0.08ms

Avg. Time	Min. Time	Max. Time
0.07ms	0.02ms	5.48ms

File I/O Test for Random Read

```
Threads started!
Done.

Operations performed:  10000 Read, 0 Write, 0 Other = 10000 Total
Read 156.25Mb  Written 0b  Total transferred 156.25Mb  (672.22Mb/sec)
43022.12 Requests/sec executed

Test execution summary:
    total time:                          0.2324s
    total number of events:              10000
    total time taken by event execution: 0.2079
    per-request statistics:
         min:                                  0.01ms
         avg:                                  0.02ms
         max:                                  5.50ms
         approx.  95 percentile:               0.02ms

Threads fairness:
    events (avg/stddev):           10000.0000/0.00
    execution time (avg/stddev):   0.2079/0.00

sysbench 0.4.12:  multi-threaded system evaluation benchmark

Removing test files...
```

Observations:

Iteration 1: 0.02ms

Iteration 2: 0.02ms

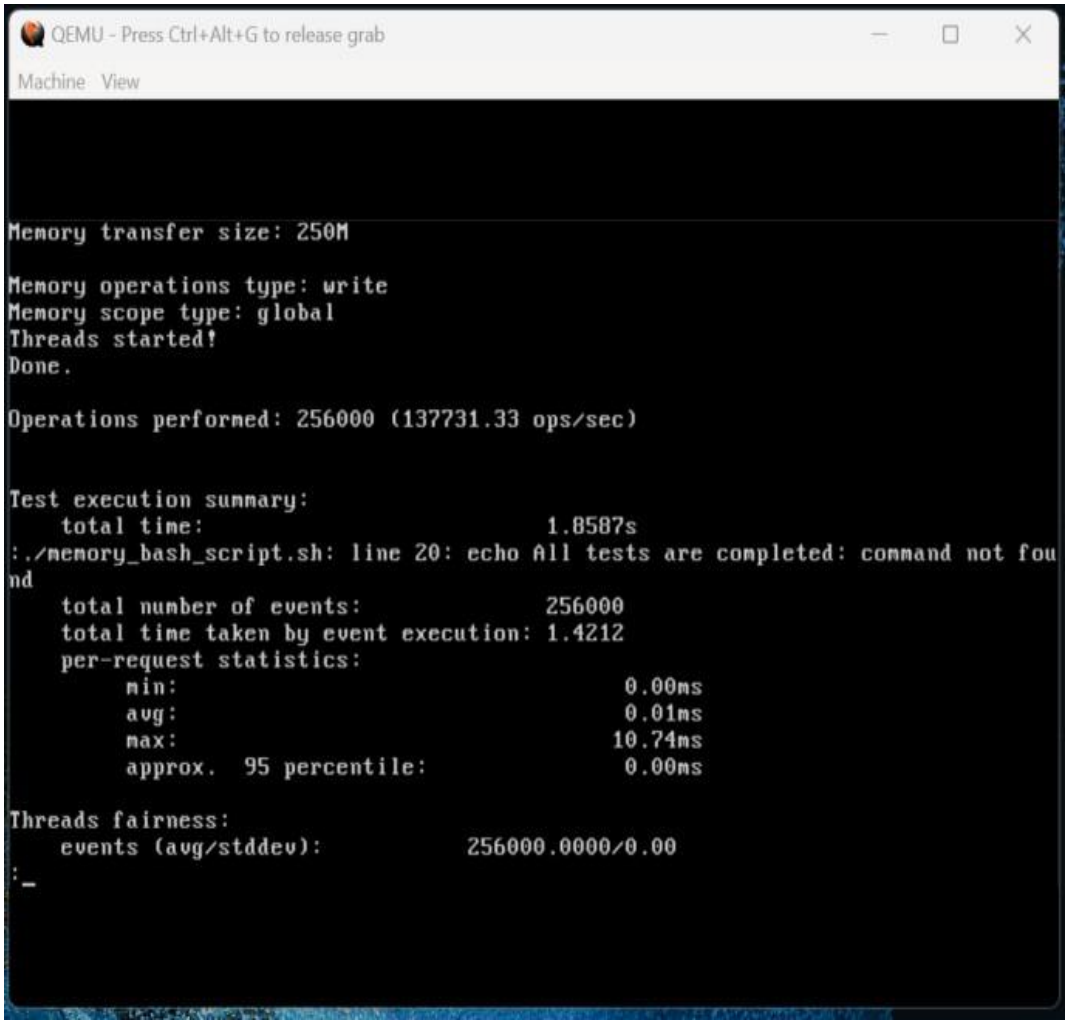
Iteration 3: 0.01ms

Iteration 4: 0.03ms

Iteration 5: 0.02ms

Avg. Time	Min. Time	Max. Time
0.02ms	0.0ms	9.32ms

Memory Test for Sequential Memory Access



Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

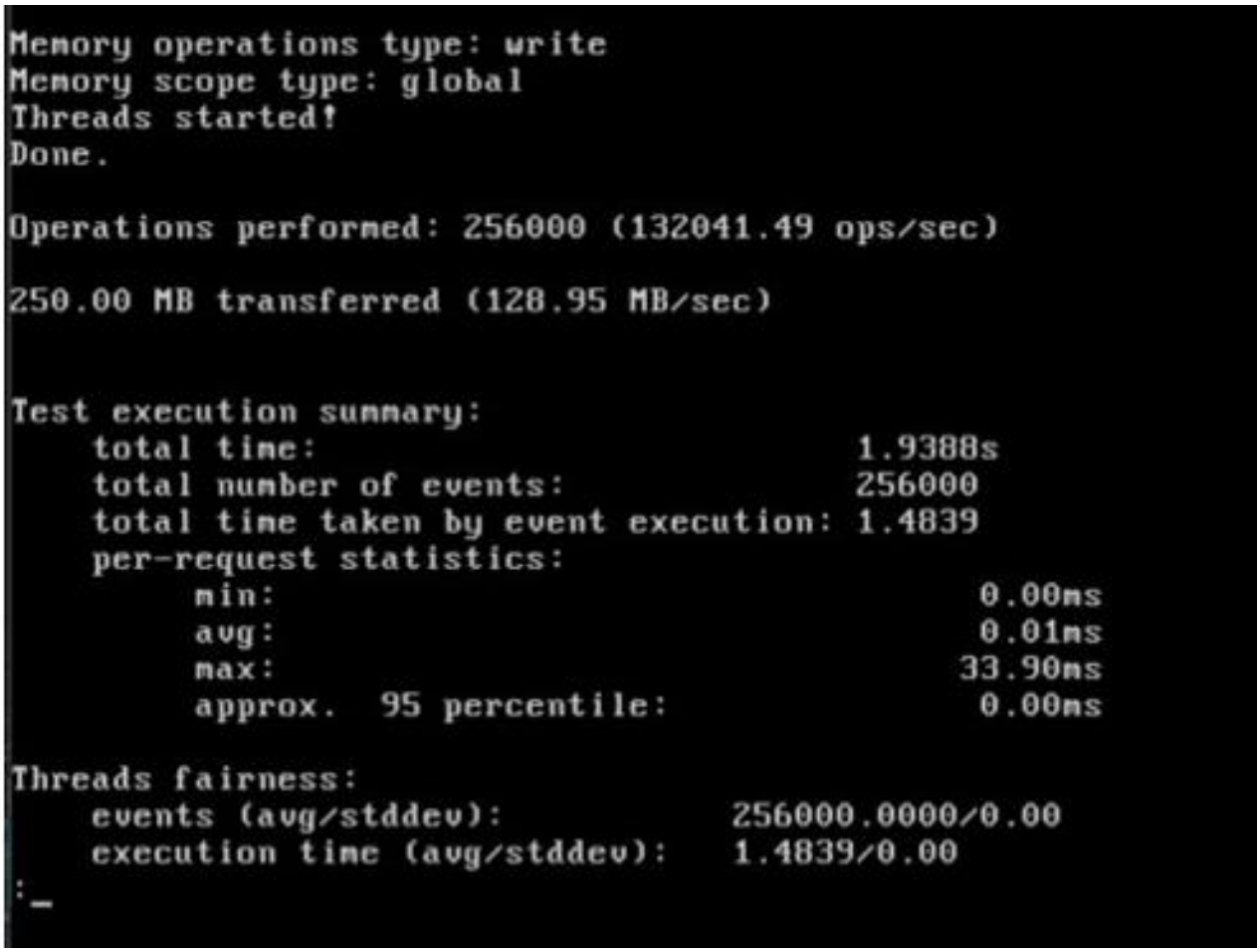
Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	9.89ms

Memory Test for Random Memory Access



Observations:

Iteration 1: 0.01ms

Iteration 2: 0.00ms

Iteration 3: 0.01ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	34.89ms

Docker

CPU Test for max-prime 20000

```
root@679e92ea7ab8:/# chmod +x cpu_bash_script.sh
root@679e92ea7ab8:/# ./cpu_bash_script.sh
Running First CPU Test: High Prime Number Calculation
Iteration 1
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 1

Doing CPU performance benchmark

Threads started!
Done.

Maximum prime number checked in CPU test: 20000


Test execution summary:
    total time:                          7.0846s
    total number of events:              10000
    total time taken by event execution: 7.0834
    per-request statistics:
         min:                                  0.63ms
         avg:                                  0.71ms
         max:                                  5.01ms
         approx.  95 percentile:               0.83ms
```

Observations:

Iteration 1: 0.71ms

Iteration 2: 0.71ms

Iteration 3: 0.69ms

Iteration 4: 0.72ms

Iteration 5: 0.80ms

Avg. Time	Min. Time	Max. Time
0.7ms	0.53ms	3.87ms

CPU Test for max-prime=10000

```
Running Second CPU Test: Multiple Threads
Iteration 1
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Done.

Maximum prime number checked in CPU test: 10000


Test execution summary:
    total time:                          0.7276s
    total number of events:              10000
    total time taken by event execution: 2.9016
    per-request statistics:
         min:                                  0.27ms
         avg:                                  0.29ms
         max:                                  5.94ms
         approx.  95 percentile:               0.32ms

Threads fairness:
    events (avg/stddev):           2500.0000/23.14
    execution time (avg/stddev):   0.7254/0.00
```

```
Iteration 2
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Done.

Maximum prime number checked in CPU test: 10000


Test execution summary:
    total time:                          0.7324s
    total number of events:              10000
    total time taken by event execution: 2.9265
    per-request statistics:
         min:                                  0.27ms
         avg:                                  0.29ms
         max:                                  1.45ms
         approx.  95 percentile:               0.33ms

Threads fairness:
    events (avg/stddev):           2500.0000/3.32
    execution time (avg/stddev):   0.7316/0.00
```

```
Iteration 3
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Done.

Maximum prime number checked in CPU test: 10000


Test execution summary:
    total time:                          0.7308s
    total number of events:              10000
    total time taken by event execution: 2.9200
    per-request statistics:
         min:                                  0.27ms
         avg:                                  0.29ms
         max:                                  1.14ms
         approx.  95 percentile:               0.32ms

Threads fairness:
    events (avg/stddev):           2500.0000/9.35
    execution time (avg/stddev):   0.7300/0.00
```

```
Iteration 4
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Done.

Maximum prime number checked in CPU test: 10000


Test execution summary:
    total time:                          0.7382s
    total number of events:              10000
    total time taken by event execution: 2.9502
    per-request statistics:
         min:                                  0.27ms
         avg:                                  0.30ms
         max:                                  1.12ms
         approx.  95 percentile:               0.33ms

Threads fairness:
    events (avg/stddev):           2500.0000/7.84
    execution time (avg/stddev):   0.7375/0.00
```

```
Iteration 5
sysbench 0.4.12:  multi-threaded system evaluation benchmark

Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Done.

Maximum prime number checked in CPU test: 10000


Test execution summary:
    total time:                          0.7487s
    total number of events:              10000
    total time taken by event execution: 2.9922
    per-request statistics:
         min:                                  0.27ms
         avg:                                  0.30ms
         max:                                  0.96ms
         approx.  95 percentile:               0.33ms

Threads fairness:
    events (avg/stddev):           2500.0000/18.80
    execution time (avg/stddev):   0.7480/0.00


CPU tests completed.
```

Observations:

Iteration 1: 0.29ms

Iteration 2: 0.29ms

Iteration 3: 0.29ms

Iteration 4: 0.30ms

Iteration 5: 0.30ms

Avg. Time	Min. Time	Max. Time
0.29ms	0.27ms	5.94ms

File I/O Test for Sequential write

```
Running the test with following options:
Number of threads: 1

Extra file open flags: 0
128 files, 1.9531Mb each
250Mb total file size
Block size 16Kb
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential write (creation) test
Threads started!
Done.

Operations performed:  0 Read, 16000 Write, 128 Other = 16128 Total
Read 0b  Written 250Mb  Total transferred 250Mb  (935.34Mb/sec)
59861.64 Requests/sec executed

Test execution summary:
    total time:                          0.2673s
    total number of events:              16000
    total time taken by event execution: 0.0893
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.01ms
         max:                                  0.57ms
         approx.  95 percentile:               0.01ms

Threads fairness:
    events (avg/stddev):           16000.0000/0.00
    execution time (avg/stddev):   0.0893/0.00
```

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.01ms

Iteration 3: 0.01ms

Iteration 4: 0.01ms

Iteration 5: 0.02ms

Avg. Time	Min. Time	Max. Time
0.01ms	0.0ms	5.96ms

File I/O Test for Random Read

```
Number of threads: 1

Extra file open flags: 0
128 files, 2.3438Mb each
300Mb total file size
Block size 16Kb
Number of random requests for random IO: 10000
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 read test
Threads started!
Done.

Operations performed:  10000 Read, 0 Write, 0 Other = 10000 Total
Read 156.25Mb  Written 0b  Total transferred 156.25Mb  (5.6717Gb/sec)
371697.98 Requests/sec executed

Test execution summary:
    total time:                          0.0269s
    total number of events:              10000
    total time taken by event execution: 0.0257
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.00ms
         max:                                  0.47ms
         approx.  95 percentile:               0.00ms

Threads fairness:
    events (avg/stddev):           10000.0000/0.00
    execution time (avg/stddev):   0.0257/0.00
```

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

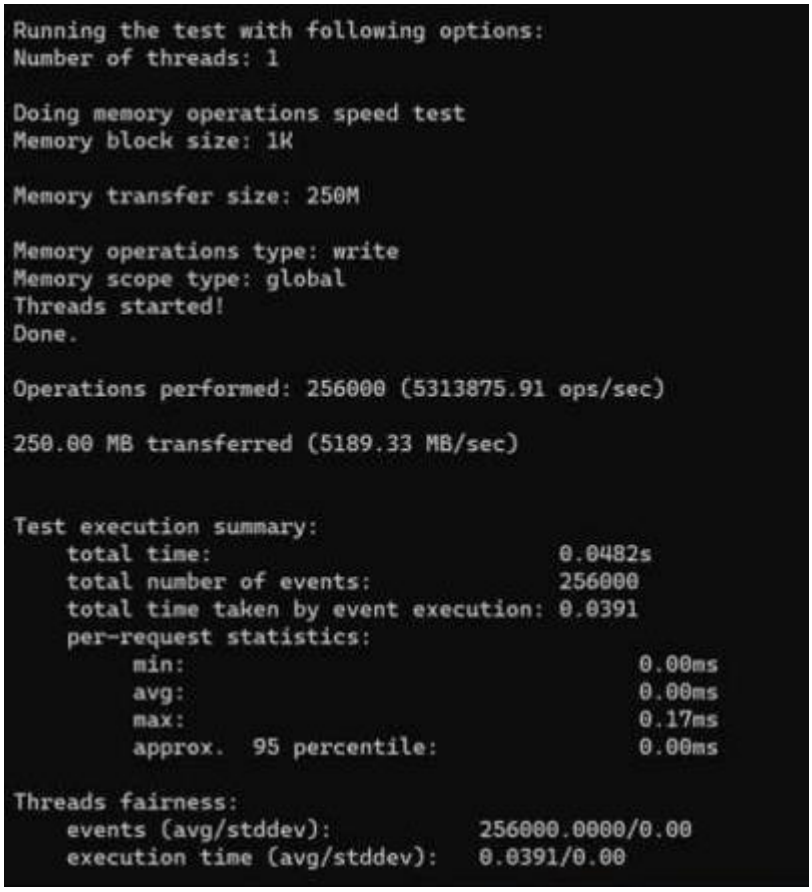
Iteration 3: 0.01ms

Iteration 4: 0.00ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.57ms

Memory Test for Sequential Memory Access



Observations:

Iteration 1: 0.00ms

Iteration 2: 0.01ms

Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.27ms

Memory Test for Random Memory Access

```
Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 1K

Memory transfer size: 250M

Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 256000 (6064091.19 ops/sec)

250.00 MB transferred (5921.96 MB/sec)


Test execution summary:
    total time:                          0.0422s
    total number of events:              256000
    total time taken by event execution: 0.0321
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.00ms
         max:                                  0.10ms
         approx.  95 percentile:               0.00ms

Threads fairness:
    events (avg/stddev):           256000.0000/0.00
    execution time (avg/stddev):   0.0321/0.00
```

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.25ms

Configuration 4: 4 GB RAM,3 Cores

QEMU

qcow2 Disk Image:

CPU Test for max-prime - 20000

Observations:

Iteration 1: 3.48ms

Iteration 2: 3.60ms

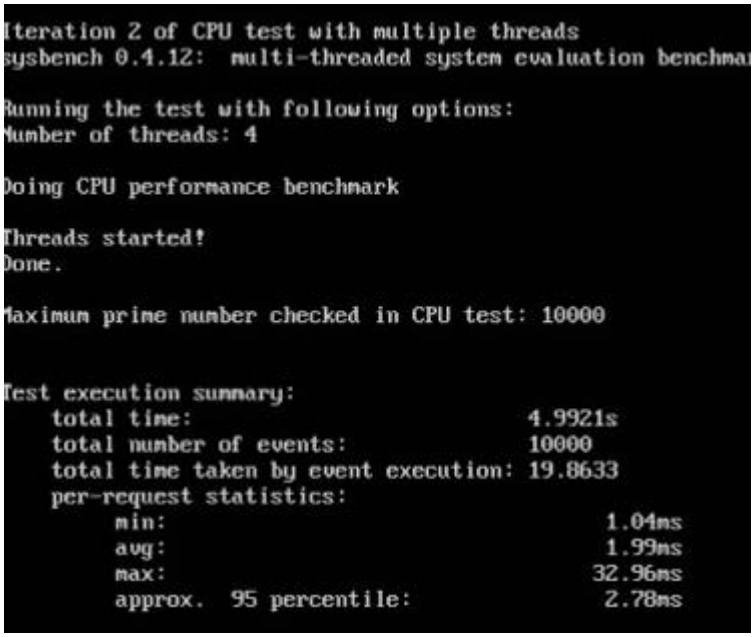
Iteration 3: 3.52ms

Iteration 4: 3.32ms

Iteration 5: 3.41ms

Avg. Time	Min. Time	Max. Time
3.47ms	1.38ms	5.71ms

CPU Test for max-prime - 10000



Observations:

Iteration 1: 1.99ms

Iteration 2: 1.93ms

Iteration 3: 2.03ms

Iteration 4: 2.07ms

Iteration 5: 1.92ms

Avg. Time	Min. Time	Max. Time
1.982ms	0.65ms	30.94ms

File I/O Test for sequential write:

```
Running the test with following options:
Number of threads: 1

Extra file open flags: 0
128 files, 1.9531Mb each
250Mb total file size
Block size 16Kb
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential write (creation) test
Threads started!
Done.

Operations performed:  0 Read, 16000 Write, 128 Other = 16128 Total
Read 0b  Written 250Mb  Total transferred 250Mb  (51.766Mb/sec)
 3313.03 Requests/sec executed

Test execution summary:
    total time:                          4.8294s
    total number of events:              16000
    total time taken by event execution: 2.4462
    per-request statistics:
         min:                                  0.07ms
         avg:                                  0.15ms
         max:                                  9.23ms
         approx.  95 percentile:               0.31ms

Threads fairness:
    events (avg/stddev):           16000.0000/0.00
    execution time (avg/stddev):   2.4462/0.00

sysbench 0.4.12:  multi-threaded system evaluation benchmark

Removing test files
```

Observations:

Iteration 1: 0.15ms

Iteration 2: 0.16ms

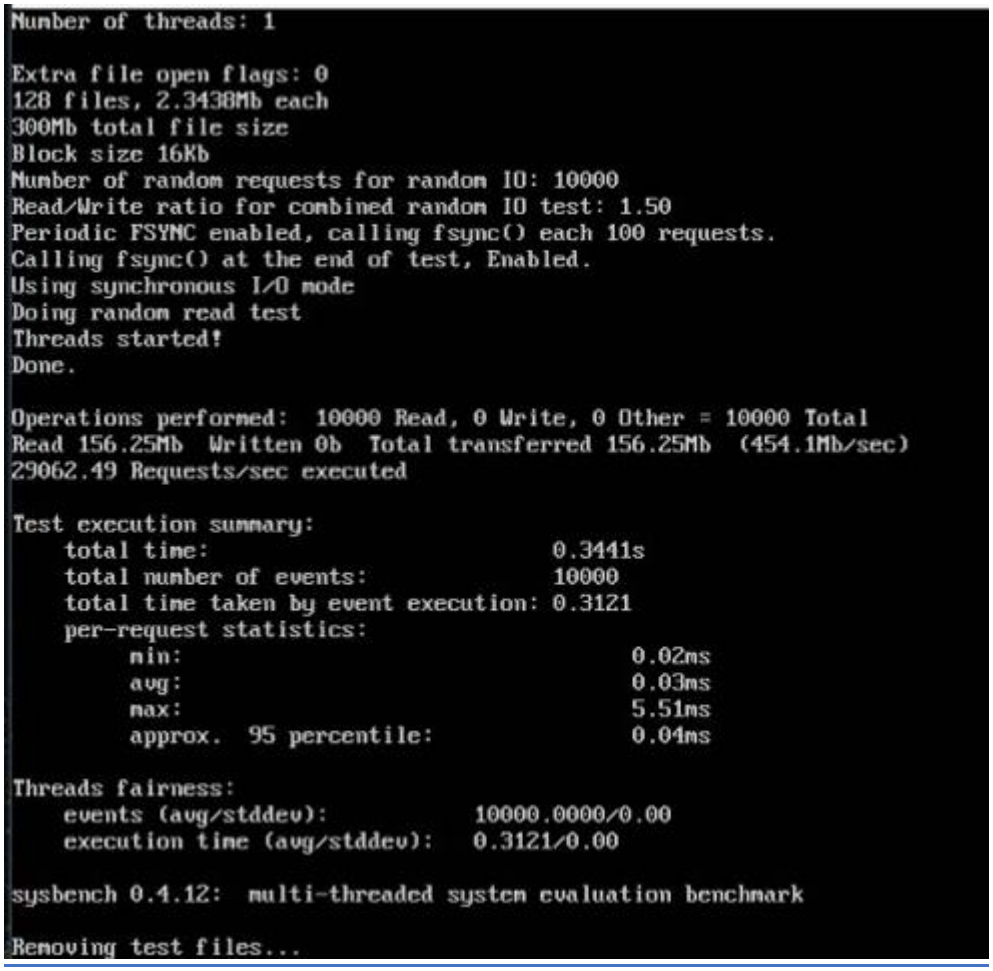
Iteration 3: 0.17ms

Iteration 4: 0.28ms

Iteration 5: 0.10ms

Avg. Time	Min. Time	Max. Time
0.18ms	0.05ms	76.55ms

File I/O Test for Random read:



Observations:

Iteration 1: 0.03ms

Iteration 2: 0.04ms

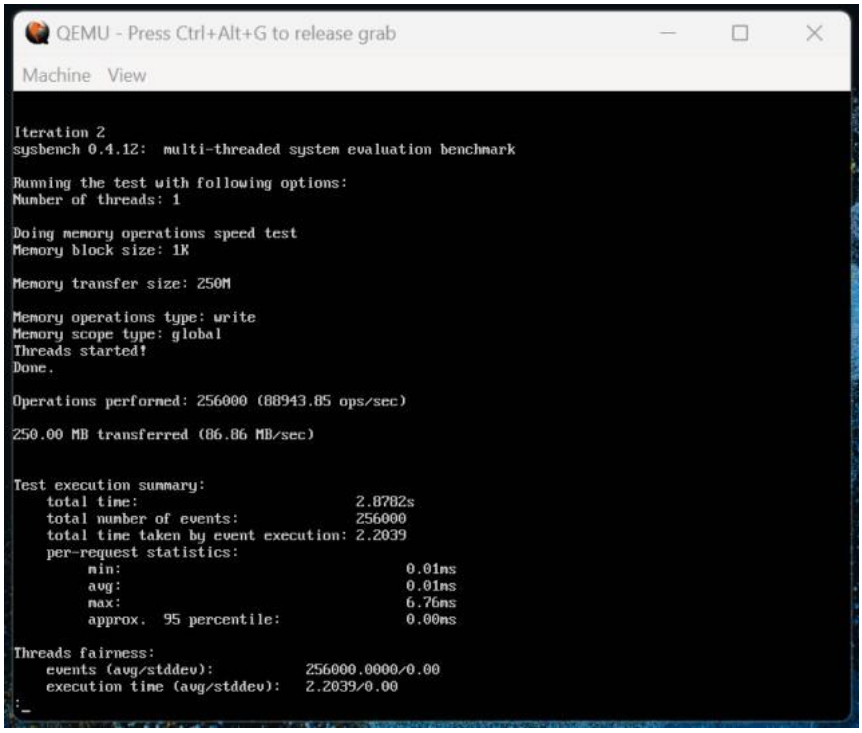
Iteration 3: 0.04ms

Iteration 4: 0.2ms

Iteration 5: 0.3ms

Avg. Time	Min. Time	Max. Time
0.03ms	0.01ms	7.85ms

Memory Test for Sequential Memory Access



Observations:

Iteration 1: 0.01ms

Iteration 2: 0.01ms

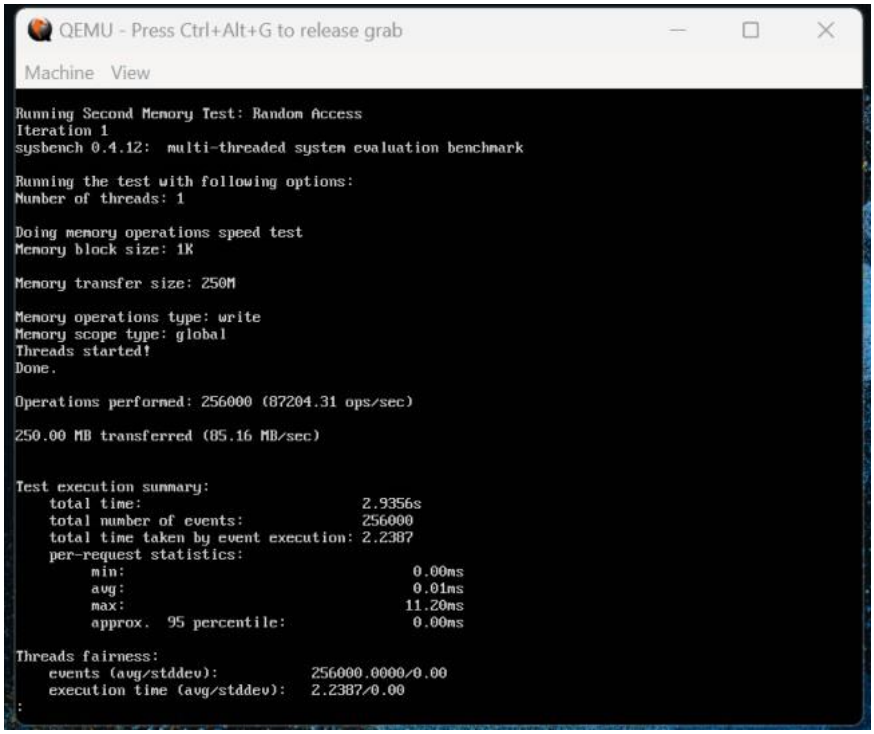
Iteration 3: 0.01ms

Iteration 4: 0.01ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.11ms	0.00ms	15.57ms

Memory Test for Random Memory Access



Observations:

Iteration 1: 0.01ms

Iteration 2: 0.01ms

Iteration 3: 0.01ms

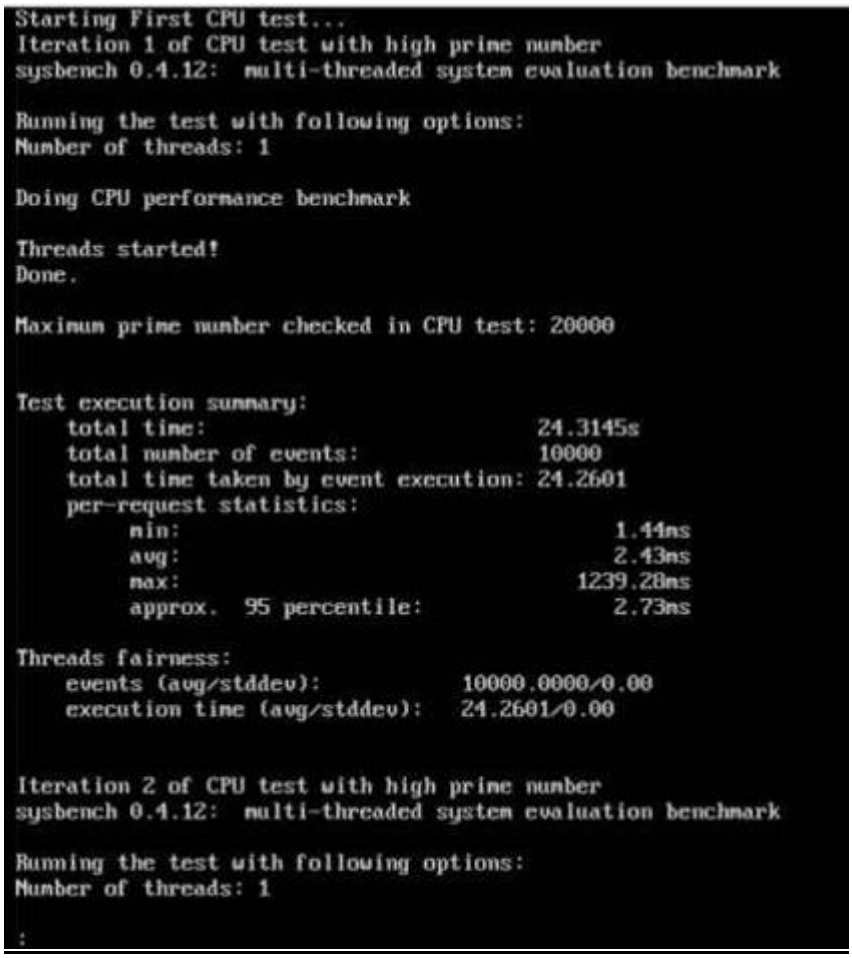
Iteration 4: 0.01ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.1ms	0.00ms	13.42ms

Raw disk image

CPU Test for max-prime 20000



Observations:

Iteration 1: 2.43ms

Iteration 2: 2.21ms

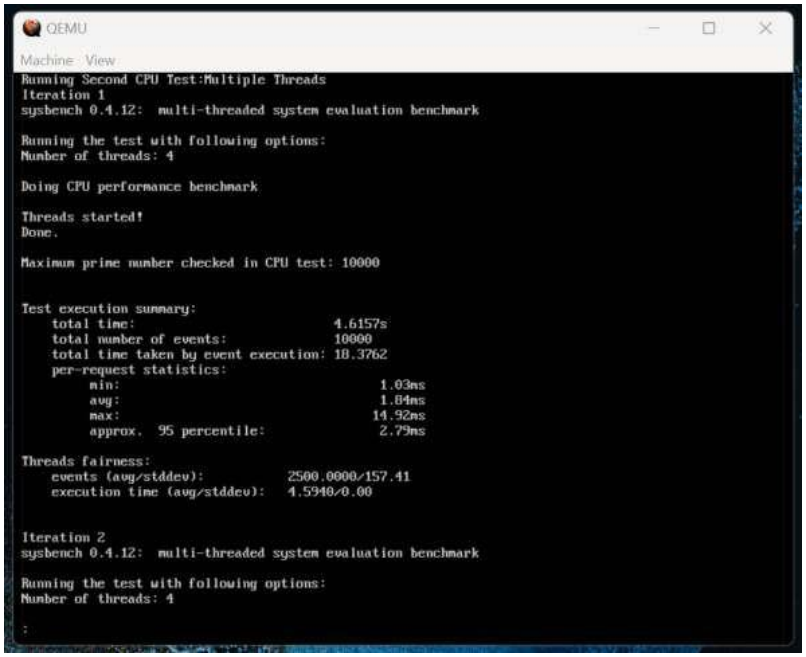
Iteration 3: 2.16ms

Iteration 4: 2.58ms

Iteration 5: 2.46ms

Avg. Time	Min. Time	Max. Time
2.34ms	1.49ms	145.3ms

CPU Test for max-prime=10000



Observations:

Iteration 1: 1.84ms

Iteration 2: 1.67ms

Iteration 3: 1.87ms

Iteration 4: 1.78ms

Iteration 5: 2.63ms

Avg. Time	Min. Time	Max. Time
1.79ms	1.02ms	35.64ms

File I/O Test for Sequential write

```
Running the test with following options:
Number of threads: 1

Extra file open flags: 0
128 files, 1.9531Mb each
250Mb total file size
Block size 16Kb
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential write (creation) test
Threads started!
Done.

Operations performed:  0 Read, 16000 Write, 128 Other = 16128 Total
Read 0b  Written 250Mb  Total transferred 250Mb  (88.079Mb/sec)
 5637.03 Requests/sec executed

Test execution summary:
    total time:                          2.8384s
    total number of events:              16000
    total time taken by event execution: 1.3433
    per-request statistics:
         min:                                  0.05ms
         avg:                                  0.08ms
         max:                                  9.80ms
         approx.  95 percentile:               0.15ms

Threads fairness:
    events (avg/stddev):           16000.0000/0.00
    execution time (avg/stddev):   1.3433/0.00

sysbench 0.4.12:  multi-threaded system evaluation benchmark
```

Observations:

Iteration 1: 0.08ms

Iteration 2: 0.09ms

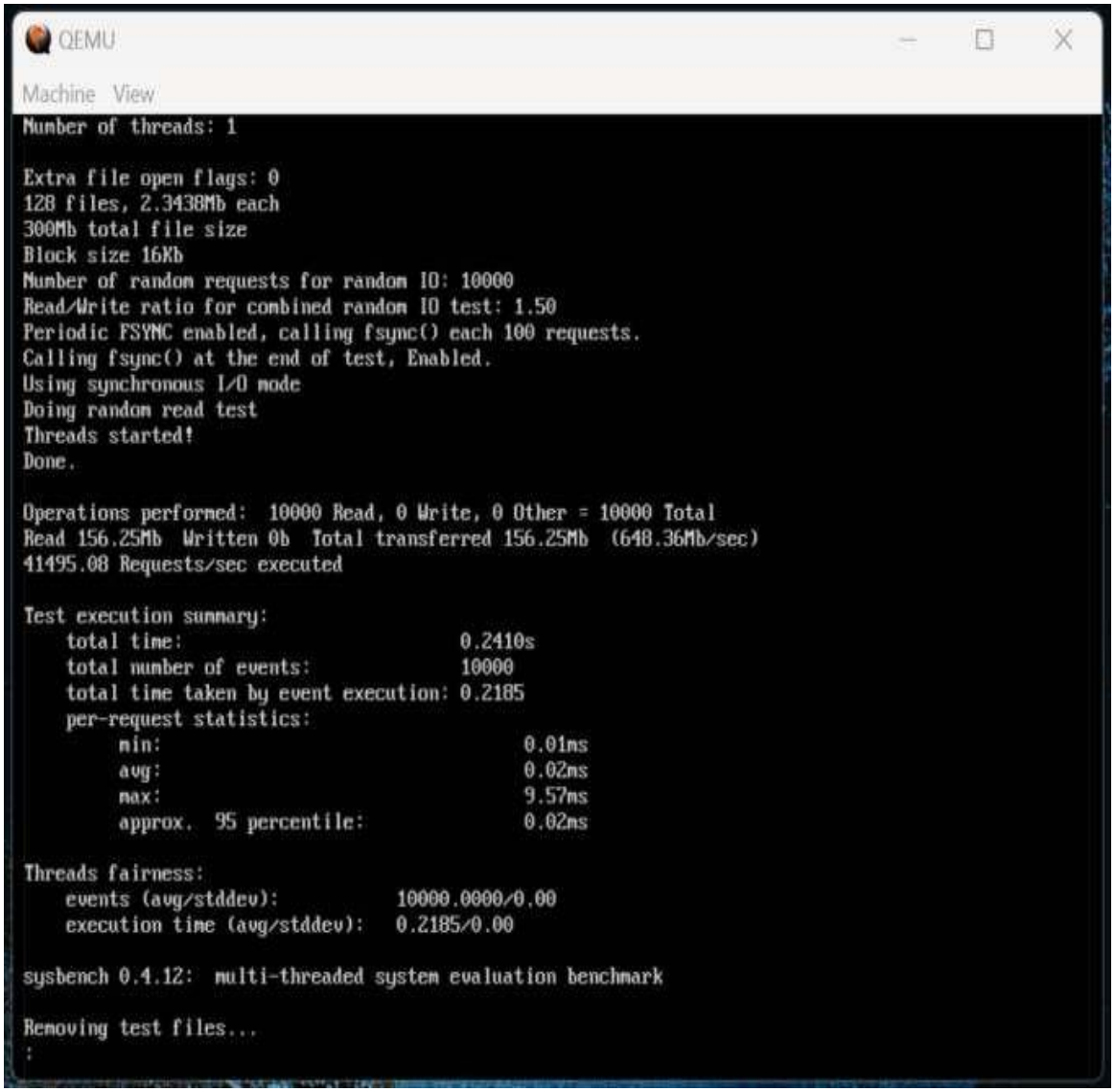
Iteration 3: 0.08ms

Iteration 4: 0.07ms

Iteration 5: 0.09ms

Avg. Time	Min. Time	Max. Time
0.08ms	0.02ms	11.45ms

File I/O Test for Random Read



Observations:

Iteration 1: 0.02ms

Iteration 2: 0.02ms

Iteration 3: 0.01ms

Iteration 4: 0.03ms

Iteration 5: 0.02ms

Avg. Time	Min. Time	Max. Time
0.02ms	0.0ms	14.27ms

Memory Test for Sequential Memory Access

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.01ms

Iteration 3: 0.01ms

Iteration 4: 0.01ms

Iteration 5: 0.01ms

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	8.72ms

Memory Test for Random Memory Access

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.00ms

Iteration 3: 0.01ms

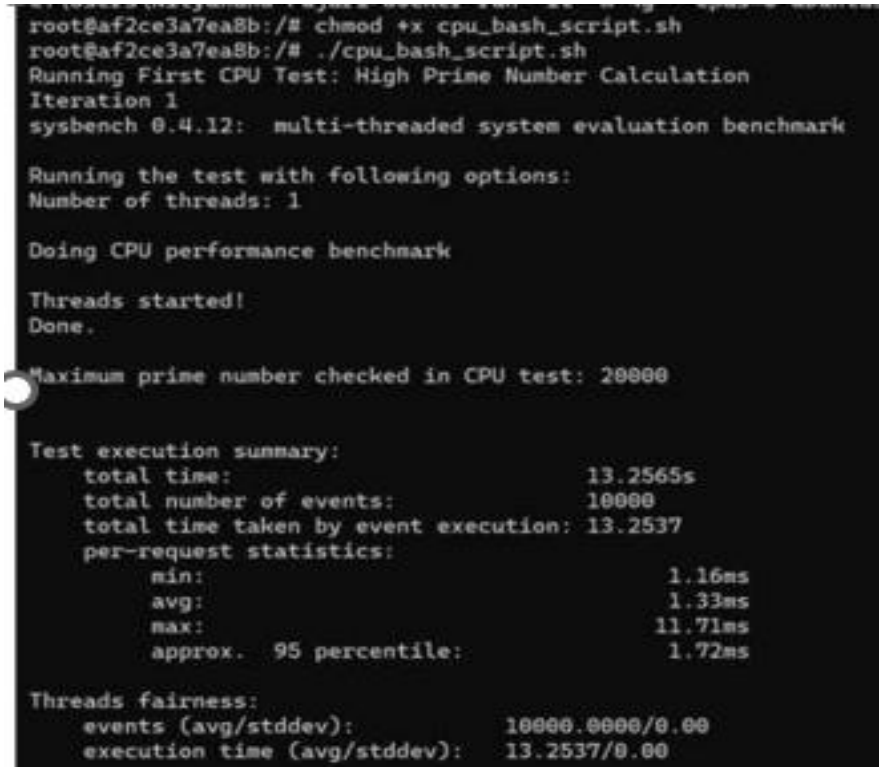
Iteration 4: 0.00ms

Iteration 5: 0.00ms

Avg. Time	Min. Time	Max. Time
0.01ms	0.0ms	67.39ms

Docker

CPU Test for max-prime 20000



Observations:

Average time for each iteration:

Iteration 1- 1.29

Iteration 2- 1.36

Iteration 3- 1.39

Iteration 4- 1.34

Iteration 5- 1.32

Avg. Time	Min. Time	Max. Time
1.34ms	0.98ms	35.32ms

CPU Test for max-prime=10000

```
Running the test with following options:
Number of threads: 4

Doing CPU performance benchmark

Threads started!
Done.

Maximum prime number checked in CPU test: 10000


Test execution summary:
    total time:                          1.8393s
    total number of events:              10000
    total time taken by event execution: 7.3471
    per-request statistics:
         min:                                  0.46ms
         avg:                                  0.73ms
         max:                                  4.57ms
         approx.  95 percentile:               0.98ms
```

Observations:

Average time for each iteration:

Iteration 1- 0.73

Iteration 2- 0.70

Iteration 3- 79

Iteration 4- 0.71

Iteration 5- 0.68

Avg. Time	Min. Time	Max. Time
1.34ms	0.40ms	6.57ms

File I/O Test for Sequential Write

```
Running the test with following options:
Number of threads: 1

Extra file open flags: 0
128 files, 1.9531Mb each
250Mb total file size
Block size 16Kb
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing sequential write (creation) test
Threads started!
Done.

Operations performed:  0 Read, 16000 Write, 128 Other = 16128 Total
Read 0b  Written 250Mb  Total transferred 250Mb  (418.99Mb/sec)
26815.27 Requests/sec executed

Test execution summary:
    total time:                          0.5967s
    total number of events:              16000
    total time taken by event execution: 0.1680
    per-request statistics:
         min:                                  0.01ms
         avg:                                  0.01ms
         max:                                  0.81ms
         approx.  95 percentile:               0.01ms

Threads fairness:
    events (avg/stddev):           16000.0000/0.00
    execution time (avg/stddev):   0.1680/0.00
```

Observations:

Average time for each iteration:

Iteration 1- 0.01

Iteration 2- 0.02

Iteration 3- 0.02

Iteration 4- 0.02

Iteration 5- 0.00

Avg. Time	Min. Time	Max. Time
0.02ms	0.0ms	0.91ms

File I/O Test for Random read

```
Number of threads: 1

Extra file open flags: 0
128 files, 2.3438Mb each
300Mb total file size
Block size 16Kb
Number of random requests for random IO: 10000
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 read test
Threads started!
Done.

Operations performed:  10000 Read, 0 Write, 0 Other = 10000 Total
Read 156.25Mb  Written 0b  Total transferred 156.25Mb  (3.05Gb/sec)
199886.20 Requests/sec executed

Test execution summary:
    total time:                          0.0500s
    total number of events:              10000
    total time taken by event execution: 0.0478
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.00ms
         max:                                  1.62ms
         approx.  95 percentile:               0.01ms

Threads fairness:
    events (avg/stddev):           10000.0000/0.00
    execution time (avg/stddev):   0.0478/0.00
```

Observations:

Average time for each iteration:

Iteration 1- 0.00

Iteration 2- 0.01

Iteration 3- 0.00

Iteration 4- 0.00

Iteration 5- 0.01

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	0.69ms

Memory Test for Sequential Memory Access

```
Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 1K

Memory transfer size: 250M

Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 256000 (2474795.25 ops/sec)

250.00 MB transferred (2416.79 MB/sec)


Test execution summary:
    total time:                          0.1034s
    total number of events:              256000
    total time taken by event execution: 0.0835
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.00ms
         max:                                  0.42ms
         approx.  95 percentile:               0.00ms

Threads fairness:
    events (avg/stddev):           256000.0000/0.00
    execution time (avg/stddev):   0.0835/0.00
```

Observations:

Average time for each iteration:

Iteration 1- 0.00

Iteration 2- 0.01

Iteration 3- 0.02

Iteration 4- 0.00

Iteration 5- 0.01

Avg. Time	Min. Time	Max. Time
0.01ms	0.0ms	0.64ms

Memory Test for random memory access

```
Running the test with following options:
Number of threads: 1

Doing memory operations speed test
Memory block size: 1K

Memory transfer size: 250M

Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 256000 (3436923.04 ops/sec)

250.00 MB transferred (3356.37 MB/sec)


Test execution summary:
    total time:                          0.0745s
    total number of events:              256000
    total time taken by event execution: 0.0586
    per-request statistics:
         min:                                  0.00ms
         avg:                                  0.00ms
         max:                                  0.69ms
         approx.  95 percentile:               0.00ms

Threads fairness:
    events (avg/stddev):           256000.0000/0.00
    execution time (avg/stddev):   0.0586/0.00
```

Observations:

Average time for each iteration:

Iteration 1- 0.00

Iteration 2- 0.00

Iteration 3- 0.01

Iteration 4- 0.00

Iteration 5- 0.01

Avg. Time	Min. Time	Max. Time
0.00ms	0.0ms	1.39ms

Analysis

The detailed observations from all the tests performed indicates that Docker consistently surpasses QEMU in performance across a range of benchmarks including CPU performance, memory efficiency, and disk I/O operations. This comprehensive performance evaluation showcases Docker's architectural advantages, which enable it to leverage the host system's resources more directly and efficiently compared to QEMU's full hardware emulation approach.

In CPU benchmarks, Docker exhibits superior efficiency with notably lower execution times, reflecting its optimized processing capabilities. Memory performance tests further illustrate Docker's ability to manage and utilize system memory more effectively, with faster access times and reduced latency. For disk I/O operations, Docker demonstrates enhanced throughput and lower latency in both sequential and random read/write tasks, underscoring its advanced disk management techniques.

These findings are attributed to Docker's lightweight containerization model, which avoids the overhead associated with traditional virtualization methods used by QEMU. By operating at the OS level and sharing the host kernel, Docker provides a more streamlined execution environment. This results in improved resource allocation, lower overheads, and ultimately, better performance across the board.

Conclusion

The comprehensive conclusion from the document's analysis of Docker and QEMU performance metrics across various configurations and tests for CPU, memory, and File I/O operations demonstrates Docker's significant efficiency and performance advantage over QEMU. Docker's containerization approach, which allows direct utilization of the host system's resources, leads to markedly better performance outcomes in terms of execution times and resource utilization. This efficiency is evident across all tested parameters, highlighting Docker's suitability for high-performance applications where resource optimization is crucial. Conversely, while QEMU's full-system emulation offers broader compatibility and isolation, it does so at the cost of higher resource consumption and reduced performance efficiency. This analysis provides a clear demonstration of Docker's advantages in environments where performance and efficiency are paramount, positioning it as the preferred solution for deploying applications that demand rapid response times and efficient resource use.