

COEN -241 Cloud Computing

HW1: System Vs OS Virtualization Report

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Github [link](#)

Host System Configuration:

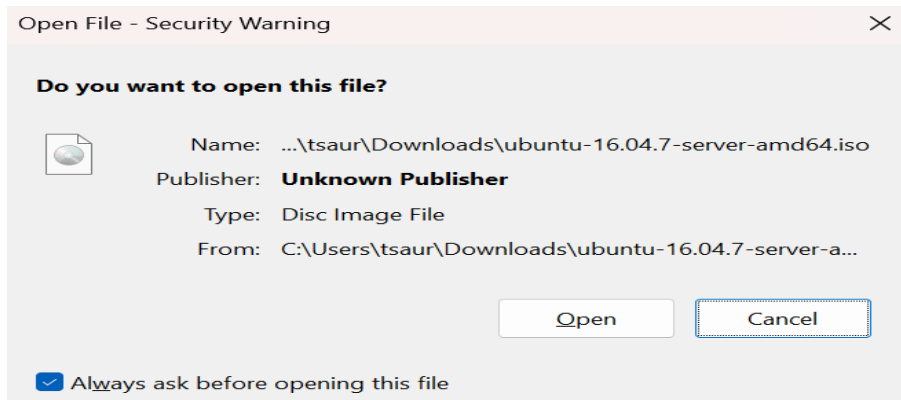
- 1) Chip: Intel core i7 (11th gen)
- 2) CPU: 8
- 3) Memory: 16GB
- 4) Free Disk space: 19.4GB
- 5) Operating System: Windows 11

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

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
```

```
QEMU - Press Ctrl+Alt+G to release grab

Machine View

Commands: prepare run cleanup help version

See 'sysbench --test=<name> help' for a list of options for each test.

saurabh@saurabh:~$ sysbench -version
Unknown command: -version.
Usage:
  sysbench [general-options]... --test=<test-name> [test-options]... command

General options:
  --num-threads=N          number of threads to use [1]
  --max-requests=N         limit for total number of requests [10000]
  --max-time=N            limit for total execution time in seconds [0]
  --forced-shutdown=STRING amount of time to wait after --max-time before forcing shutdown [off]
  --thread-stack-size=SIZE size of stack per thread [32K]
  --init-rng=[on|off]     initialize random number generator [off]
  --test=STRING           test to run
  --debug=[on|off]        print more debugging info [off]
  --validate=[on|off]     perform validation checks where possible [off]
  --help=[on|off]         print help and exit
  --version=[on|off]      print version and exit

Compiled-in tests:
  fileio - File I/O test
  cpu - CPU performance test
  memory - Memory functions speed test
  threads - Threads subsystem performance test
  mutex - Mutex performance test
  oltp - OLTP test

Commands: prepare run cleanup help version

See 'sysbench --test=<name> help' for a list of options for each test.

saurabh@saurabh:~$ sysbench --version
sysbench 0.4.12
saurabh@saurabh:~$ _
```

Docker Setup:

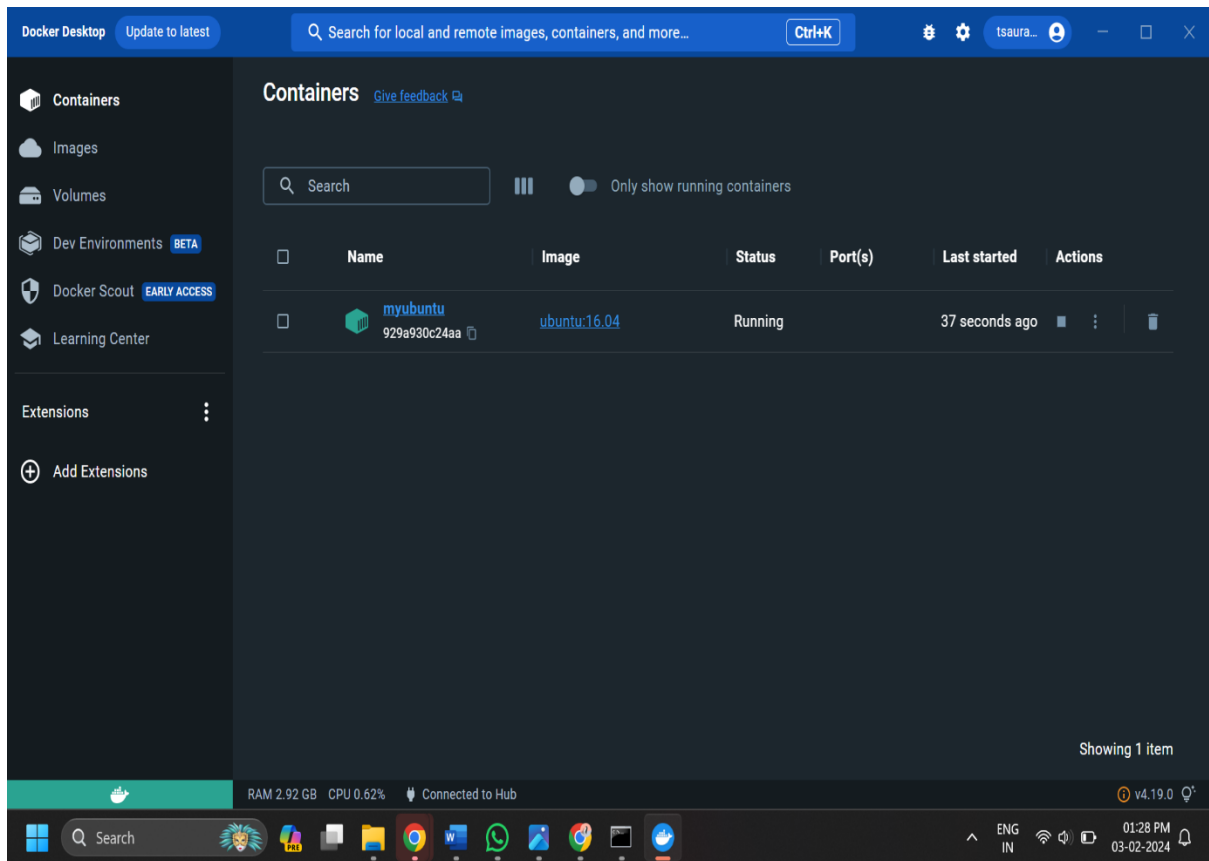
```
root@929a930c24aa: /

C:\Users\tsaur>docker login
Login with your Docker ID to push and pull images from Docker Hub. If you don't have a Docker ID, head over to https://hub.docker.com to create one.
Username: tsaurabh21
Password:
Login Succeeded

Logging in with your password grants your terminal complete access to your account.
For better security, log in with a limited-privilege personal access token. Learn more at https://docs.docker.com/go/access-tokens/

C:\Users\tsaur>docker pull ubuntu:16.04
16.04: Pulling from library/ubuntu
Digest: sha256:1f1a2d56de1d604801a9671f301190704c25d604a416f59e03c04f5c6ffee0d6
Status: Image is up to date for ubuntu:16.04
docker.io/library/ubuntu:16.04

C:\Users\tsaur>docker run -it --name myubuntu -m 4g --cpus=2 ubuntu:16.04
root@929a930c24aa:/#
```



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

```
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:                35.5088s
  total number of events:     10000
  total time taken by event execution: 35.4315
  per-request statistics:
    min:                      2.50ms
    avg:                       3.54ms
    max:                       22.05ms
    approx. 95 percentile:    5.02ms

Threads fairness:
  events (avg/stddev):       10000.0000/0.00
  execution time (avg/stddev): 35.4315/0.00
```

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:

```
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 (88102.96 ops/sec)
250.00 MB transferred (86.04 MB/sec)

Test execution summary:
total time: 2.9057s
total number of events: 256000
total time taken by event execution: 2.2192
per-request statistics:
    min: 0.01ms
    avg: 0.01ms
    max: 16.01ms
    approx. 95 percentile: 0.00ms

Threads fairness:
events (avg/stddev): 256000.0000/0.00
execution time (avg/stddev): 2.2192/0.00

Memory tests completed
```

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:

```
Operations performed: 256000 (3336145.43 ops/sec)

250.00 MB transferred (3257.95 MB/sec)

Test execution summary:
  total time:                                0.0767s
  total number of events:                    256000
  total time taken by event execution: 0.0607
  per-request statistics:
    min:                                     0.00ms
    avg:                                     0.00ms
    max:                                     1.03ms
    approx. 95 percentile:                  0.00ms
```

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

```
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: 35.5088s  
total number of events: 10000  
total time taken by event execution: 35.4315  
per-request statistics:  
  min: 2.50ms  
  avg: 3.54ms  
  max: 22.05ms  
  approx. 95 percentile: 5.02ms  
  
Threads fairness:  
events (avg/stddev): 10000.0000/0.00  
execution time (avg/stddev): 35.4315/0.00
```

Observations:

Iteration 1: 2.54ms

Iteration 2: 1.20ms

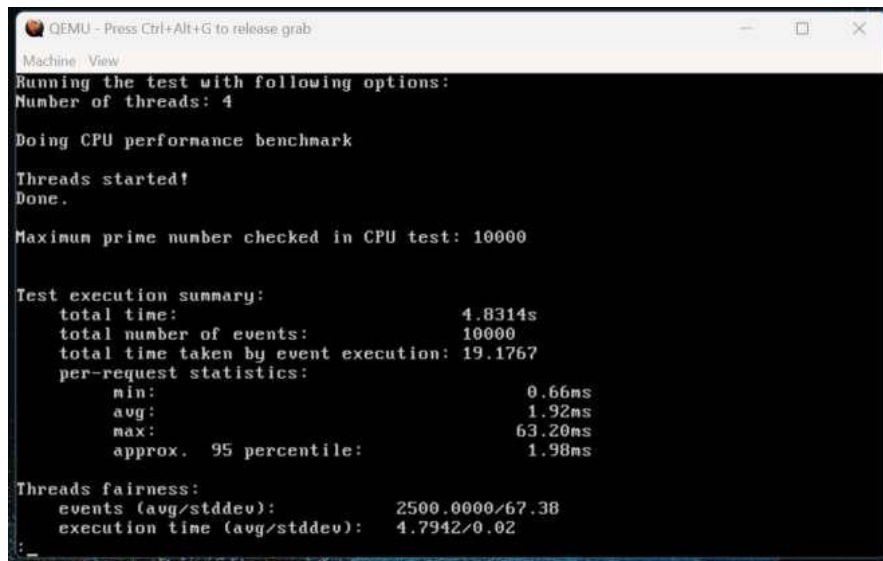
Iteration 3: 4.43ms

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



```
QEMU - Press Ctrl+Alt+G to release grab
Machine View
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: 4.8314s
total number of events: 10000
total time taken by event execution: 19.1767
per-request statistics:
  min: 0.66ms
  avg: 1.92ms
  max: 63.20ms
  approx. 95 percentile: 1.98ms

Threads fairness:
events (avg/stddev): 2500.0000/67.38
execution time (avg/stddev): 4.7942/0.02
```

Observations:

Iteration 1: 1.92ms

Iteration 2: 2.30ms

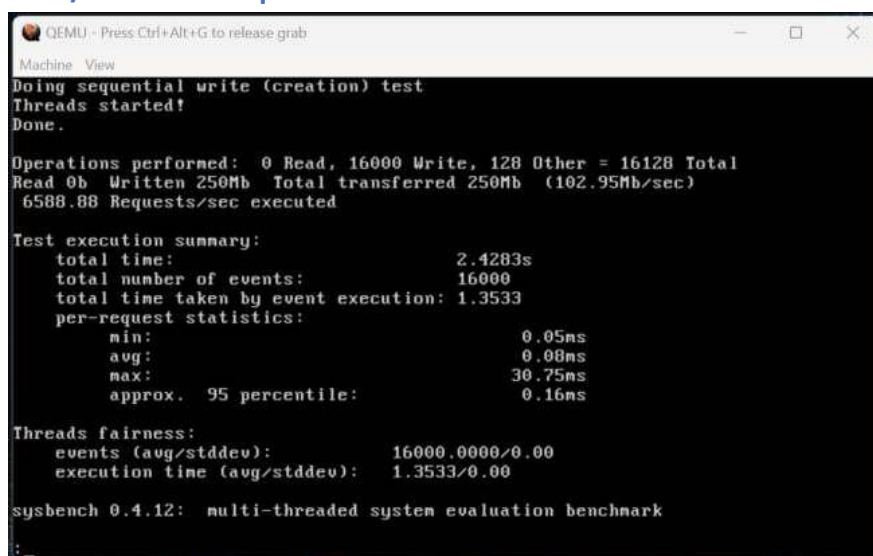
Iteration 3: 2.09ms

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



```
QEMU - Press Ctrl+Alt+G to release grab
Machine View
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 (102.95Mb/sec)
6588.88 Requests/sec executed

Test execution summary:
total time: 2.4283s
total number of events: 16000
total time taken by event execution: 1.3533
per-request statistics:
  min: 0.05ms
  avg: 0.08ms
  max: 30.75ms
  approx. 95 percentile: 0.16ms

Threads fairness:
events (avg/stddev): 16000.0000/0.00
execution time (avg/stddev): 1.3533/0.00

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

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

```
Machine View
Threads started!
Done.

Operations performed: 10000 Read, 0 Write, 0 Other = 10000 Total
Read 156.25Mb Written 0b Total transferred 156.25Mb (752.36Mb/sec)
48150.87 Requests/sec executed

Test execution summary:
  total time: 0.2077s
  total number of events: 10000
  total time taken by event execution: 0.1868
  per-request statistics:
    min: 0.01ms
    avg: 0.02ms
    max: 3.67ms
    approx. 95 percentile: 0.02ms

Threads fairness:
  events (avg/stddev): 10000.0000/0.00
  execution time (avg/stddev): 0.1868/0.00

sysbench 0.4.12: multi-threaded system evaluation benchmark

Removing test files...
```



```
QEMU - Press Ctrl+Alt+G to release grab
Machine View
Threads started!
Done.
Operations performed: 10000 Read, 0 Write, 0 Other = 10000 Total
Read 156.25Mb Written 0b Total transferred 156.25Mb (781.67Mb/sec)
50026.61 Requests/sec executed

Test execution summary:
total time: 0.1999s
total number of events: 10000
total time taken by event execution: 0.1781
per-request statistics:
  min: 0.01ms
  avg: 0.02ms
  max: 0.84ms
  approx. 95 percentile: 0.02ms

Threads fairness:
  events (avg/stddev): 10000.0000/0.00
  execution time (avg/stddev): 0.1781/0.00

sysbench 0.4.12: multi-threaded system evaluation benchmark
Removing test files...
:
```

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

```
Memory operations type: write
Memory scope type: global
Threads started!
Done.
Operations performed: 256000 (197726.35 ops/sec)
250.00 MB transferred (193.09 MB/sec)

Test execution summary:
total time: 1.2947s
total number of events: 256000
total time taken by event execution: 1.0000
per-request statistics:
  min: 0.00ns
  avg: 0.00ns
  max: 5.41ns
  approx. 95 percentile: 0.00ns

Threads fairness:
  events (avg/stddev): 256000.0000/0.00
  execution time (avg/stddev): 1.0000/0.00
:_
```

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

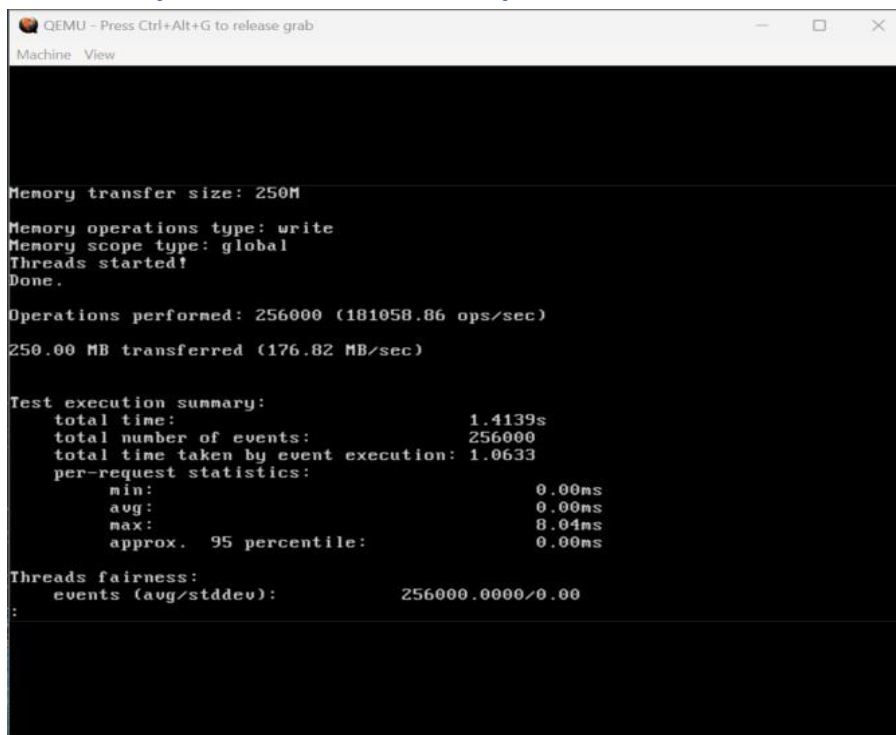
Iteration 3: 0.00ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

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

Memory Test for Random Memory Access

A screenshot of a QEMU terminal window. The window title is "QEMU - Press Ctrl+Alt+G to release grab". The terminal output shows the following text:

```
Machine View

Memory transfer size: 250M
Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 256000 (181058.86 ops/sec)
250.00 MB transferred (176.82 MB/sec)

Test execution summary:
total time: 1.4139s
total number of events: 256000
total time taken by event execution: 1.0633
per-request statistics:
  min: 0.00ms
  avg: 0.00ms
  max: 8.04ms
  approx. 95 percentile: 0.00ms

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

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	8.04ms

Docker

CPU Test for max-prime 20000

```
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:                7.0010s
total number of events:    10000
total time taken by event execution: 6.9997
per-request statistics:
  min:                     0.63ms
  avg:                     0.70ms
  max:                     2.71ms
  approx. 95 percentile:   0.81ms
```

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

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

Test execution summary:
total time:                1.4650s
total number of events:    10000
total time taken by event execution: 5.8526
per-request statistics:
  min:                     0.24ms
  avg:                     0.59ms
  max:                     53.56ms
  approx. 95 percentile:   0.49ms
```

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

```
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 (6158861.61 ops/sec)
250.00 MB transferred (6013.73 MB/sec)

Test execution summary:
total time: 0.0416s
total number of events: 256000
total time taken by event execution: 0.0322
per-request statistics:
  min: 0.00ms
  avg: 0.00ms
  max: 0.55ms
  approx. 95 percentile: 0.00ms

Threads fairness:
  events (avg/stddev): 256000.0000/0.00
  execution time (avg/stddev): 0.0322/0.00
```

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	0.55ms

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

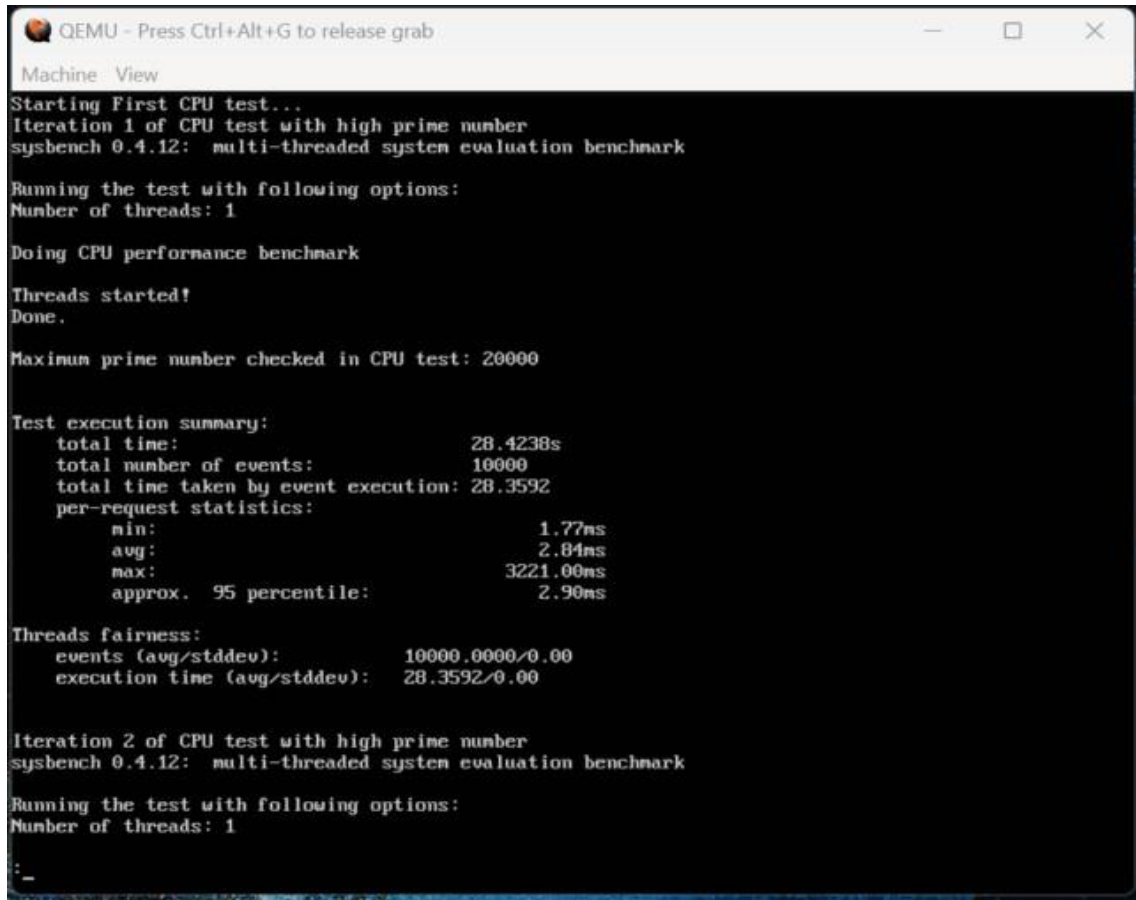
Iteration 4: 0.08ms

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



```
QEMU - Press Ctrl+Alt+G to release grab
Machine View
Starting First CPU test...
Iteration 1 of CPU test with high prime number
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: 28.4238s
total number of events: 10000
total time taken by event execution: 28.3592
per-request statistics:
  min: 1.77ms
  avg: 2.84ms
  max: 3221.00ms
  approx. 95 percentile: 2.90ms

Threads fairness:
  events (avg/stddev): 10000.0000/0.00
  execution time (avg/stddev): 28.3592/0.00

Iteration 2 of CPU test with high prime number
sysbench 0.4.12: multi-threaded system evaluation benchmark

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

Observations:

Iteration 1: 2.84ms

Iteration 2: 3.24ms

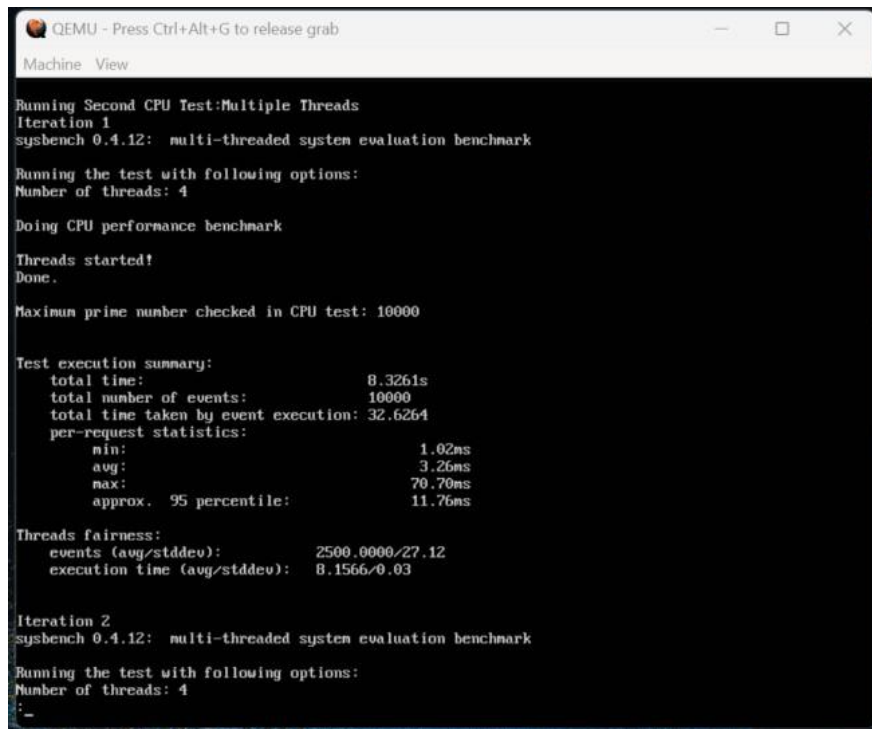
Iteration 3: 3.43ms

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



```
QEMU - Press Ctrl+Alt+G to release grab
Machine View

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:                8.3261s
  total number of events:    10000
  total time taken by event execution: 32.6264
  per-request statistics:
    min:                      1.02ms
    avg:                      3.26ms
    max:                      70.70ms
    approx. 95 percentile:    11.76ms

Threads fairness:
  events (avg/stddev):       2500.0000/27.12
  execution time (avg/stddev): 8.1566/0.03

Iteration 2
sysbench 0.4.12: multi-threaded system evaluation benchmark

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

Observations:

Iteration 1: 3.26ms

Iteration 2: 2.95ms

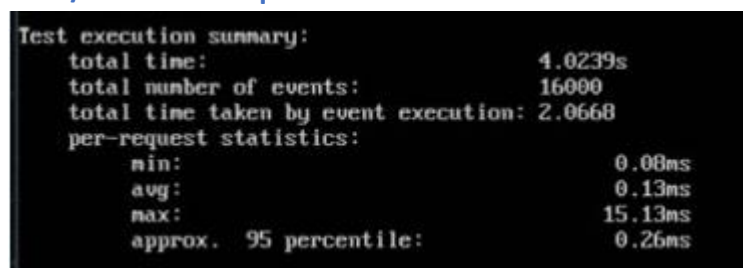
Iteration 3: 3.09ms

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



```
Test execution summary:
  total time:                4.0239s
  total number of events:    16000
  total time taken by event execution: 2.0668
  per-request statistics:
    min:                      0.08ms
    avg:                      0.13ms
    max:                      15.13ms
    approx. 95 percentile:    0.26ms
```

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

```
Machine View
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 (381.87Mb/sec)
24439.45 Requests/sec executed

Test execution summary:
total time: 0.4092s
total number of events: 10000
total time taken by event execution: 0.3400
per-request statistics:
  min: 0.02ms
  avg: 0.03ms
  max: 1.33ms
  approx. 95 percentile: 0.05ms

Threads fairness:
  events (avg/stddev): 10000.0000/0.00
  execution time (avg/stddev): 0.3400/0.00

sysbench 0.4.12: multi-threaded system evaluation benchmark

Removing test files...
:
```

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

```
Running First Memory test: 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: 1K
Memory transfer size: 250M
Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 256000 (175334.84 ops/sec)
250.00 MB transferred (171.23 MB/sec)

Test execution summary:
total time: 1.4601s
total number of events: 256000
total time taken by event execution: 1.1330
per-request statistics:
  min: 0.00ms
  avg: 0.00ms
  max: 5.72ms
  approx. 95 percentile: 0.00ms

Threads fairness:
  events (avg/stddev): 256000.0000/0.00
  execution time (avg/stddev): 1.1330/0.00
```

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	4.51ms

Memory Test for Random Memory Access

```

Operations performed: 256000 (193851.03 ops/sec)
250.00 MB transferred (189.31 MB/sec)

Test execution summary:
  total time:                1.3206s
  total number of events:    256000
  total time taken by event execution: 0.9919
  per-request statistics:
    min:                     0.00ms
    avg:                     0.00ms
    max:                     3.38ms
    approx. 95 percentile:   0.00ms

```

Observations:

Iteration 1: 0.00ms

Iteration 2: 0.00ms

Iteration 3: 0.01ms

Iteration 4: 0.00ms

Iteration 5: 0.00ms

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

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

Threads fairness:
  events (avg/stddev): 10000.0000/0.00
  execution time (avg/stddev): 7.0834/0.00
```

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

```
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 (6177832.03 ops/sec)  
250.00 MB transferred (6033.04 MB/sec)  
  
Test execution summary:  
    total time:                                0.0414s  
    total number of events:                    256000  
    total time taken by event execution: 0.0321  
    per-request statistics:  
        min:                                    0.00ms  
        avg:                                    0.00ms  
        max:                                    0.14ms  
        approx. 95 percentile:                 0.00ms
```

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

```
Starting first cpu test
Iteration 1 of cpu test with high prime number
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: 37.5977s
total number of events: 10000
total time taken by event execution: 37.5286
per-request statistics:
  min: 2.66ms
  avg: 3.75ms
  max: 104.71ms
  approx. 95 percentile: 5.19ms

Threads fairness:
  events (avg/stddev): 10000.0000/0.00
  execution time (avg/stddev): 37.5286/0.00
```

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.

Maximum 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: 0.06ns
  avg: 0.12ns
  max: 18.46ns
  approx. 95 percentile: 0.22ns
```

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:

```
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 (422.6Mb/sec)
27046.49 Requests/sec executed

Test execution summary:
  total time:                0.3697s
  total number of events:    10000
  total time taken by event execution: 0.3288
  per-request statistics:
    min:                    0.02ms
    avg:                    0.03ms
    max:                    1.44ms
    approx. 95 percentile:  0.05ms
```

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

```
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 (97190.43 ops/sec)
250.00 MB transferred (94.91 MB/sec)

Test execution summary:
total time:                2.6340s
total number of events:    256000
total time taken by event execution: 2.0073
per-request statistics:
    min:                    0.00ns
    avg:                    0.01ns
    max:                    6.84ns
    approx. 95 percentile:  0.00ns

Threads fairness:
  events (avg/stddev):      256000.0000/0.00
  execution time (avg/stddev): 2.0073/0.00
```

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

```
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 (174751.61 ops/sec)
250.00 MB transferred (170.66 MB/sec)

Test execution summary:
  total time:                1.4649s
  total number of events:    256000
  total time taken by event execution: 1.1017
  per-request statistics:
    min:                      0.00ns
    avg:                      0.00ns
    max:                      3.88ns
    approx. 95 percentile:    0.00ns

Threads fairness:
  events (avg/stddev):       256000.0000/0.00
  execution time (avg/stddev): 1.1017/0.00
```

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

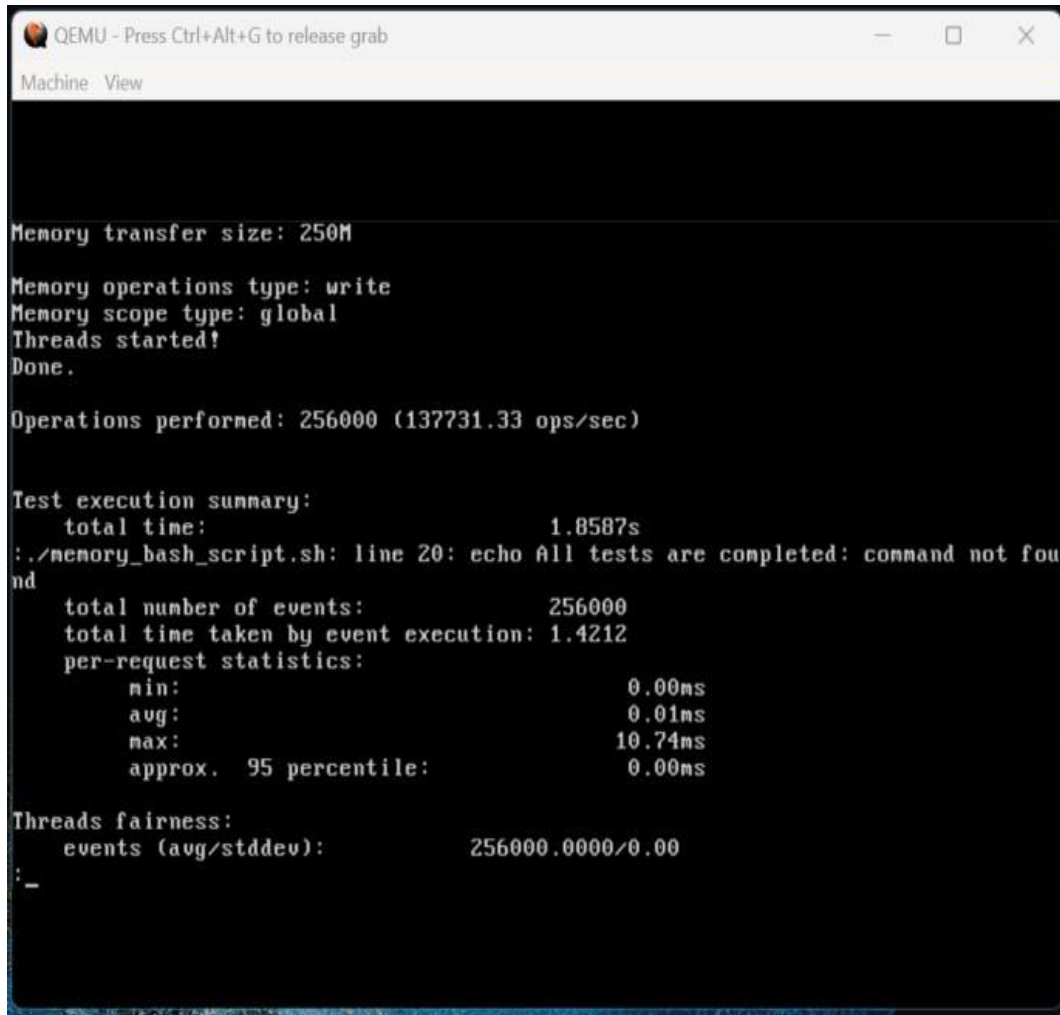
Iteration 3: 0.01ms

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



```
QEMU - Press Ctrl+Alt+G to release grab
Machine View

Memory transfer size: 250M

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

Operations performed: 256000 (137731.33 ops/sec)

Test execution summary:
  total time: 1.8587s
./memory_bash_script.sh: line 20: echo All tests are completed: command not found
  total number of events: 256000
  total time taken by event execution: 1.4212
  per-request statistics:
    min: 0.00ms
    avg: 0.01ms
    max: 10.74ms
    approx. 95 percentile: 0.00ms

Threads fairness:
  events (avg/stddev): 256000.0000/0.00
:_
```

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	9.89ms

Memory Test for Random Memory Access

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

Operations performed: 256000 (132041.49 ops/sec)
250.00 MB transferred (128.95 MB/sec)

Test execution summary:
  total time: 1.9388s
  total number of events: 256000
  total time taken by event execution: 1.4839
  per-request statistics:
    min: 0.00ms
    avg: 0.01ms
    max: 33.90ms
    approx. 95 percentile: 0.00ms

Threads fairness:
  events (avg/stddev): 256000.0000/0.00
  execution time (avg/stddev): 1.4839/0.00
:_
```

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

```
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 (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

Threads fairness:
  events (avg/stddev): 256000.0000/0.00
  execution time (avg/stddev): 0.0391/0.00
```

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	0.27ms

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

```
Starting first cpu test
Iteration 1 of cpu test with high prime number
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:                34.9119s
  total number of events:    10000
  total time taken by event execution: 34.8446
  per-request statistics:
    min:                    2.50ms
    avg:                    3.48ms
    max:                   16.86ms
    approx. 95 percentile:  5.02ms

Threads fairness:
  events (avg/stddev):       10000.0000/0.00
  execution time (avg/stddev): 34.8446/0.00

Iteration 2 of cpu test with high prime number
sysbench 0.4.12: multi-threaded system evaluation benchmark

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

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

```
Iteration 2 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.

Maximum prime number checked in CPU test: 10000

Test execution summary:
  total time:                4.9921s
  total number of events:    10000
  total time taken by event execution: 19.8633
  per-request statistics:
    min:                      1.04ms
    avg:                      1.99ms
    max:                      32.96ms
    approx. 95 percentile:    2.78ms
```

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: 0.07ns
  avg: 0.15ns
  max: 9.23ns
  approx. 95 percentile: 0.31ns

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
Requiring 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:

```

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 (454.1Mb/sec)
29062.49 Requests/sec executed

Test execution summary:
  total time:                0.3441s
  total number of events:    10000
  total time taken by event execution: 0.3121
  per-request statistics:
    nin:                      0.02ms
    avg:                      0.03ms
    max:                      5.51ms
    approx. 95 percentile:    0.04ms

Threads fairness:
  events (avg/stddev):       10000.0000/0.00
  execution time (avg/stddev): 0.3121/0.00

sysbench 0.4.12: multi-threaded system evaluation benchmark
Removing test files...

```

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

 QEMU - Press Ctrl+Alt+G to release grab

Machine View

```
Running First Memory Test: 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: 1K

Memory transfer size: 250M

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

Operations performed: 256000 (103466.69 ops/sec)
250.00 MB transferred (101.04 MB/sec)

Test execution summary:
total time:                2.4742s
total number of events:    256000
total time taken by event execution: 1.8986
per-request statistics:
  min:                      0.00ms
  avg:                      0.01ms
  max:                      6.73ms
  approx. 95 percentile:    0.00ms

Threads fairness:
  events (avg/stddev):      256000.0000/0.00
  execution time (avg/stddev): 1.8986/0.00
```

```
QEMU - Press Ctrl+Alt+G to release grab
Machine View

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: 1K

Memory transfer size: 250M

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

Operations performed: 256000 (88943.85 ops/sec)
250.00 MB transferred (86.86 MB/sec)

Test execution summary:
total time: 2.8782s
total number of events: 256000
total time taken by event execution: 2.2039
per-request statistics:
  min: 0.01ms
  avg: 0.01ms
  max: 6.76ms
  approx. 95 percentile: 0.00ms

Threads fairness:
  events (avg/stddev): 256000.0000/0.00
  execution time (avg/stddev): 2.2039/0.00
```

Observations:

Iteration 1: 0.01ms

Iteration 2: 0.01ms

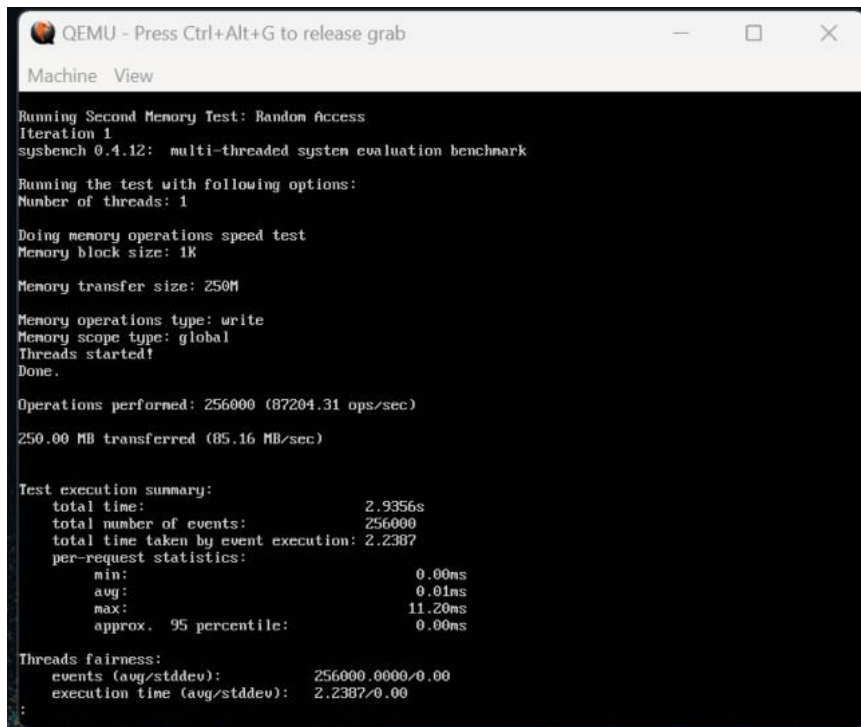
Iteration 3: 0.01ms

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



```
QEMU - Press Ctrl+Alt+G to release grab
Machine View

Running Second Memory Test: Random 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: 1K
Memory transfer size: 250M
Memory operations type: write
Memory scope type: global
Threads started!
Done.

Operations performed: 256000 (87204.31 ops/sec)
250.00 MB transferred (85.16 MB/sec)

Test execution summary:
total time: 2.9356s
total number of events: 256000
total time taken by event execution: 2.2387
per-request statistics:
  min: 0.00ms
  avg: 0.01ms
  max: 11.20ms
  approx. 95 percentile: 0.00ms

Threads fairness:
  events (avg/stddev): 256000.0000/0.00
  execution time (avg/stddev): 2.2387/0.00
```

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

```
Starting First CPU test...
Iteration 1 of CPU test with high prime number
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:                24.3145s
  total number of events:    10000
  total time taken by event execution: 24.2601
  per-request statistics:
    min:                     1.44ns
    avg:                     2.43ns
    max:                    1239.28ns
    approx. 95 percentile:   2.73ns

Threads fairness:
  events (avg/stddev):       10000.0000/0.00
  execution time (avg/stddev): 24.2601/0.00

Iteration 2 of CPU test with high prime number
sysbench 0.4.12: multi-threaded system evaluation benchmark

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

:
```

Observations:

Iteration 1: 2.43ms

Iteration 2: 2.21ms

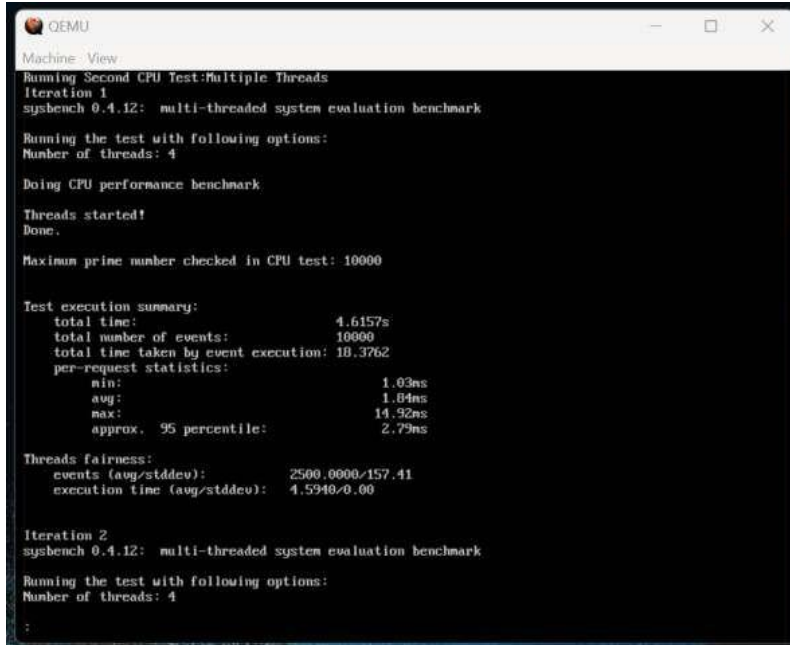
Iteration 3: 2.16ms

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



```
QEMU
Machine: View
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: 4.6157s
total number of events: 10000
total time taken by event execution: 18.3762
per-request statistics:
  min: 1.03ms
  avg: 1.84ms
  max: 14.92ms
  approx. 95 percentile: 2.79ms

Threads fairness:
  events (avg/stddev): 2500.0000/157.41
  execution time (avg/stddev): 4.5940/0.00

Iteration 2
sysbench 0.4.12: multi-threaded system evaluation benchmark

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

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

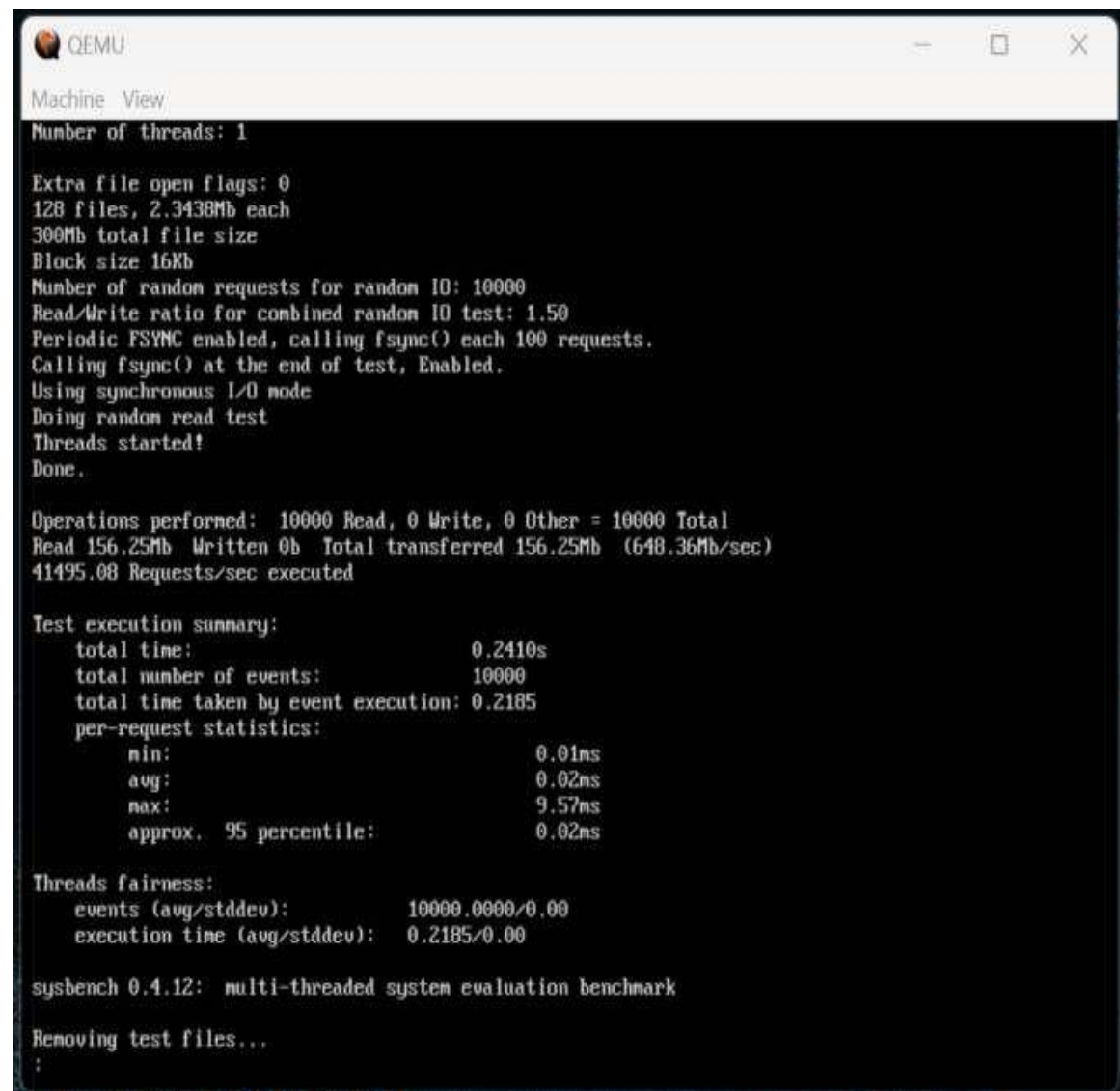
Iteration 3: 0.08ms

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



```
QEMU
Machine View
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 PSYNC 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 (648.36Mb/sec)
41495.08 Requests/sec executed

Test execution summary:
total time: 0.2410s
total number of events: 10000
total time taken by event execution: 0.2185
per-request statistics:
  min: 0.01ms
  avg: 0.02ms
  max: 9.57ms
  approx. 95 percentile: 0.02ms

Threads fairness:
  events (avg/stddev): 10000.0000/0.00
  execution time (avg/stddev): 0.2185/0.00

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	14.27ms

Memory Test for Sequential Memory Access

```
Operations performed: 256000 (135628.17 ops/sec)
250.00 MB transferred (132.45 MB/sec)

Test execution summary:
  total time:                1.8875s
  total number of events:    256000
  total time taken by event execution: 1.4374
  per-request statistics:
    min:                     0.00ms
    avg:                     0.01ms
    max:                     8.33ms
    approx. 95 percentile:   0.00ms
```

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

```
Machine View
Running Second Memory Test: Random 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: 1K

Memory transfer size: 250M

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

Operations performed: 256000 (71946.15 ops/sec)
250.00 MB transferred (70.26 MB/sec)

Test execution summary:
total time: 3.5582s
total number of events: 256000
total time taken by event execution: 2.6996
per-request statistics:
  min: 0.01ms
  avg: 0.01ms
  max: 16.11ms
  approx. 95 percentile: 0.00ms

Threads fairness:
  events (avg/stddev): 256000.0000/0.00
  execution time (avg/stddev): 2.6996/0.00
```

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

```
root@af2ce3a7ea8b:/# chmod +x cpu_bash_script.sh
root@af2ce3a7ea8b:/# ./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: 13.2565s
total number of events: 10000
total time taken by event execution: 13.2537
per-request statistics:
  min: 1.16ms
  avg: 1.33ms
  max: 11.71ms
  approx. 95 percentile: 1.72ms

Threads fairness:
events (avg/stddev): 10000.0000/0.00
execution time (avg/stddev): 13.2537/0.00
```

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.