COEN -241 Cloud Computing

HW1: System Vs OS Virtualization Report

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Host System Configuration:

1	Chip	Apple M1 (Apple Silicon)
2	CPU	8 (4 performance and 4 efficiency)
3	Memory	8 GB
4	Free disk space	110GB
5	Operating System	Mac OS Monterey

We will be using Three different configuration for QEMU and Docker, it is explained in the report further.

QEMU Installation and creation of QEMU image

In this section, we will walk through the steps of installing QEMU and creating a QEMU image. This image would be used for all our experiments.

1. Downloading Ubuntu Guest Virtual Machine

We will first download the required ISO image based on our system configuration. The system's architecture is:

```
Last login: Tue Jan 24 09:34:31 on console
(base) sumit@Sumits-MacBook-Air ~ % arch
arm64
```

Therefore, we will be using Arm64v8 architecture. To download a ISO file check the below link.

ARM (Apple Silicon) - Ubuntu 20.04 Server for ARM

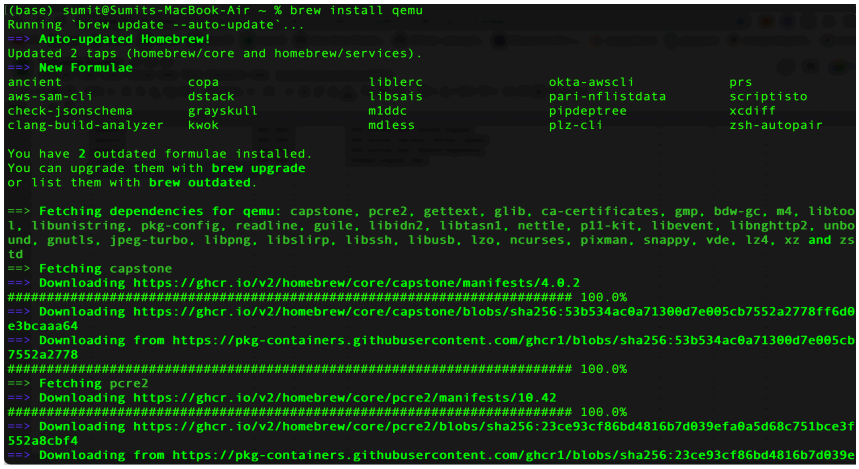
Create one folder to store the ubuntu image and a ISO file

```
(base) sumit@Sumits-MacBook-Air ~ % cd Desktop/Winter2023/Cloud\ computing/qemu
(base) sumit@Sumits-MacBook-Air qemu % ls
ubuntu-20.04.5-live-server-arm64.iso
```

2. Install QEMU

Run the following command in the terminal. homebrew must be installed before running this command.

brew install qemu



If homebrew is not installed, then check below link or use this command to install it. (https://brew.sh/):

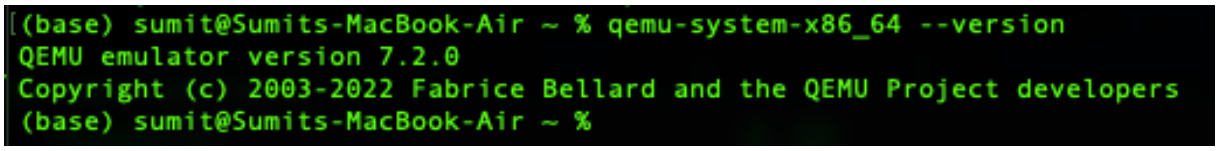
```
/bin/bash -c "$(curl -fsSL https://raw.githubusercontent.com/Homebrew/install/HEAD/install.sh)"
```

3. Check QEMU version

We have to make sure that the QEMU version should be 6.2.0+ which is the minimum supported by Apple Silicon.

```
qemu-system-x86_64 --version
```

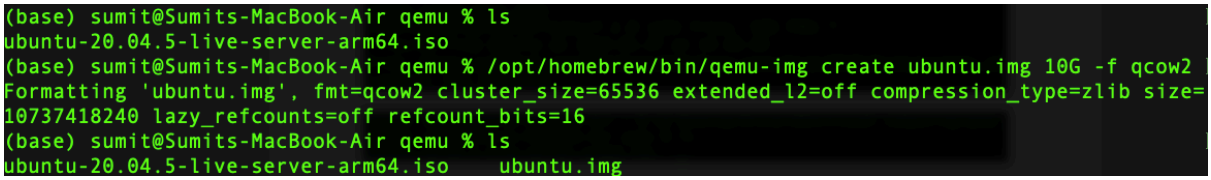
We have a QEMU 7.2.0 version.



4. Create QEMU image

Then we'll make a QEMU image. This image will be created in the same folder where the Ubuntu guest virtual machine ISO file was copied. In the terminal, type the following command:

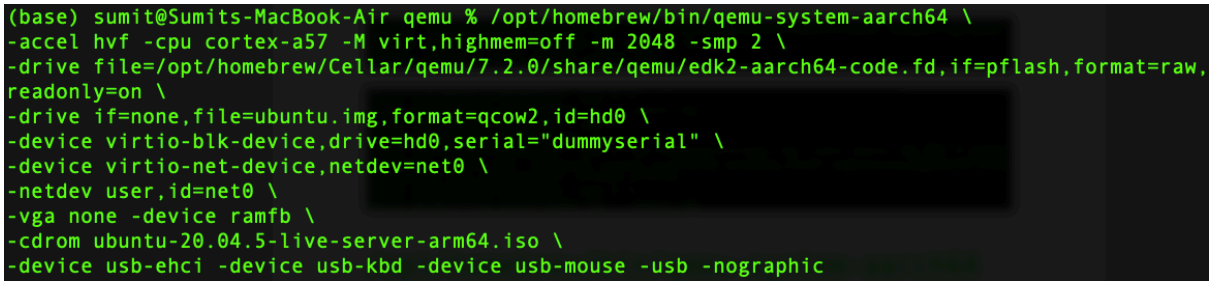
```
qemu-img create ubuntu.img 10G -f qcow2
```

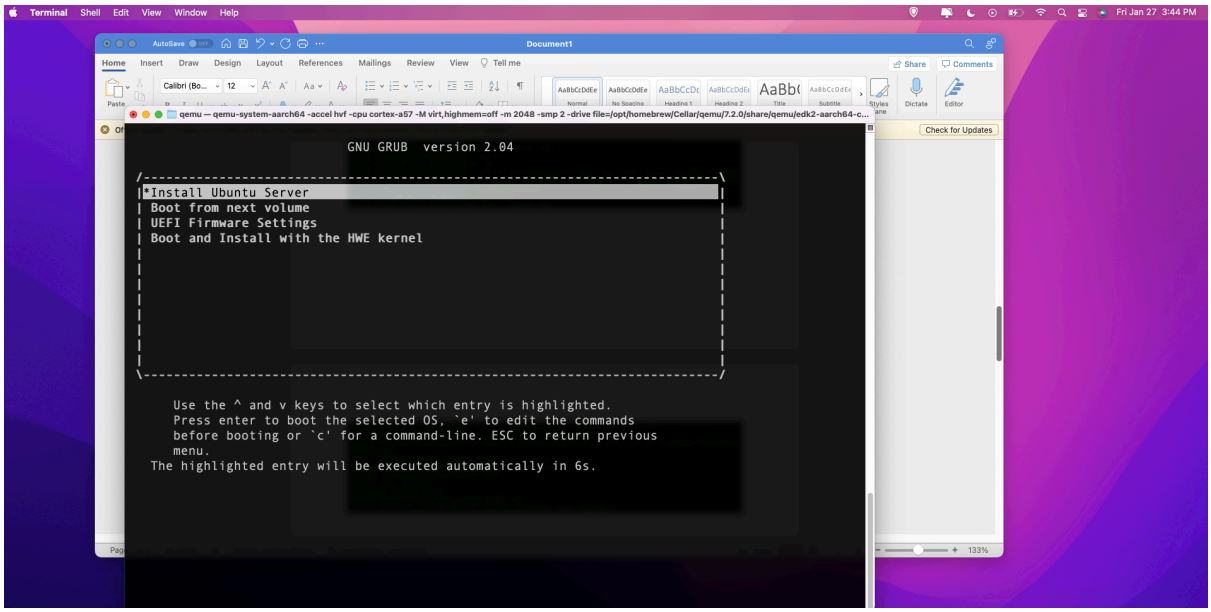


5. Install Ubuntu VM

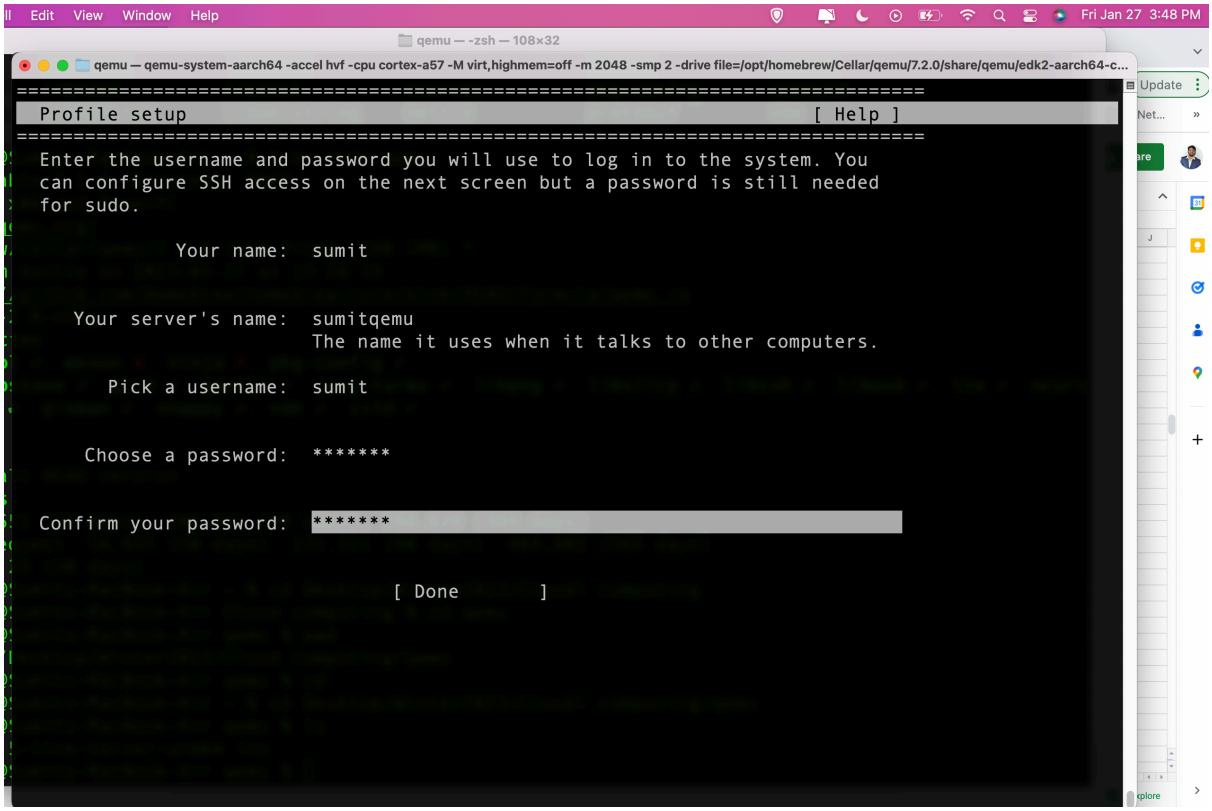
Run the below command to install Ubuntu VM:

```
/opt/homebrew/bin/qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2048 -smp 2 \
-drive file=/opt/homebrew/Cellar/qemu/7.2.0/share/qemu/edk2-aarch64-code.fd,if=pflash,format=raw,readonly=on \
-drive if=none,file=ubuntu.img,format=qcow2,id=hd0 \
-device virtio-blk-device,drive=hd0,serial="dummyserial" \
-device virtio-net-device,netdev=net0 \
-netdev user,id=net0 \
-vga none -device ramfb \
-cdrom ubuntu-20.04.5-live-server-arm64.iso \
-device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic
```

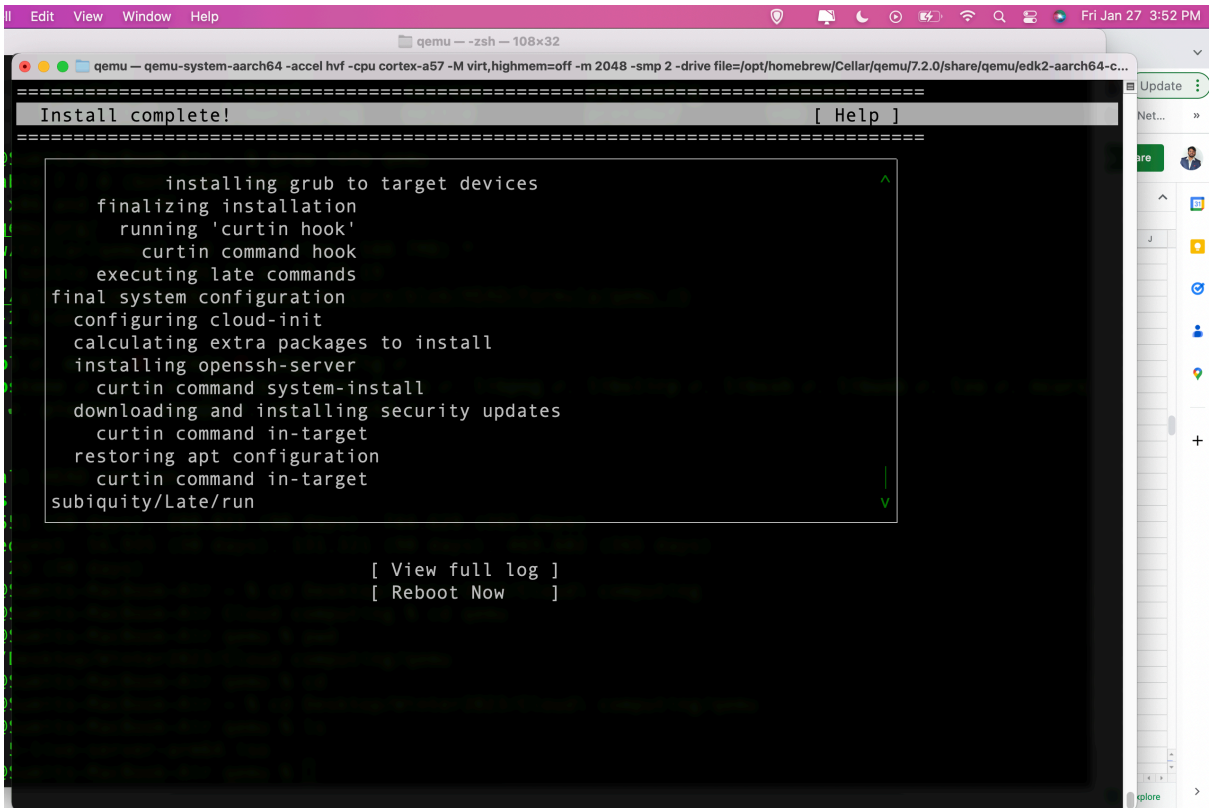




While installing it, you must provide a server name, username, and password which will be use to login.

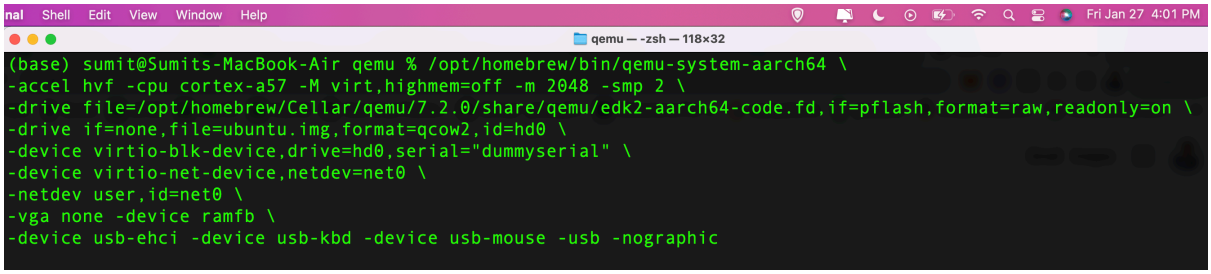


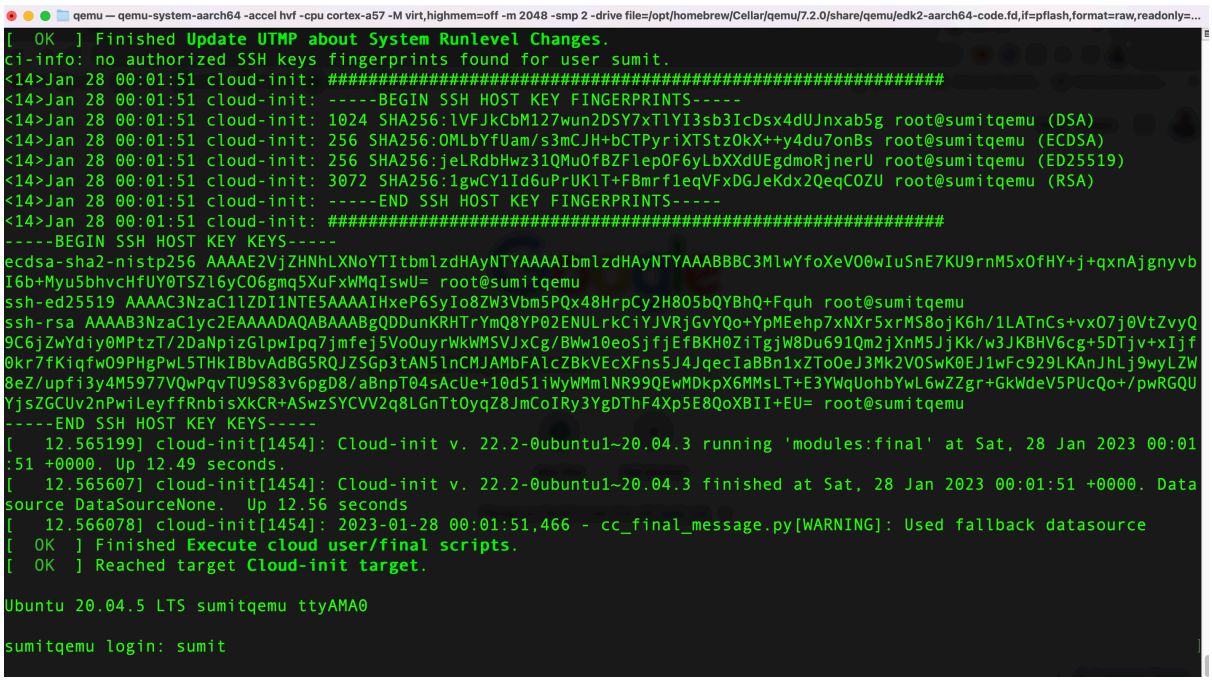
Then Select reboot option.



We can try logging in with the following command (we must remove the cdrom argument). It will prompt you for your username and password:

```
/opt/homebrew/bin/qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 2048 -smp 2 \
-drive file=/opt/homebrew/Cellar/qemu/7.2.0/share/qemu/edk2-aarch64-
code.fd,if=pflash,format=raw,readonly=on \
-drive if=none,file=ubuntu.img,format=qcow2,id=hd0 \
-device virtio-blk-device,drive=hd0,serial="dummyserial" \
-device virtio-net-device,netdev=net0 \
-netdev user,id=net0 \
-vga none -device ramfb \
-device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic
```





Below is the explanation of arguments used in the command.

-accel	Activates an accelerator. Kvm, xen, hax, hvf, nvmm, whpx, or tcg could be available depending on the target architecture.
-m	This symbol represents memory. We are currently using 2G as the argument value, which means that we are allocating 2GB RAM memory to our VM.
-smp	Denotes the number of cores. We have currently set the argument value to 2, indicating that we have allocated two cores to our VM.

-cdrom	Use file as CD-ROM image (you cannot use -hdc and -cdrom at the same time). You can use the host CD-ROM by using /dev/cdrom as filename.
-device	Mainly to add a device driver where prop=value sets the driver properties.

When running for different configurations, we would update the -m and -smp values.

Docker Installation, Building Docker Image, and Enabling Docker Containers

1. Installation

Now we'll walk through the Docker installation process, which is used to create and manage containers, which are then used to run and manage various images.
Documentation can be found at https://docs.docker.com/desktop/mac/apple-silicon/

We will use the above link to install Docker desktop, which includes the Docker cli and Docker engine by default. Run the following commands in terminal to see if Docker is properly installed:

```
docker pull hello-world
docker images
docker run hello-world
```

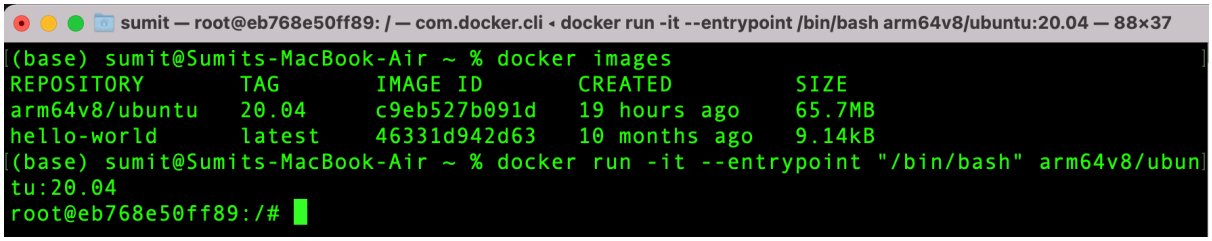
```
(base) sumit@Sumits-MacBook-Air ~ % docker pull hello-world
Using default tag: latest
latest: Pulling from library/hello-world
7050e35b49f5: Pull complete
Digest: sha256:aa0cc8055b82dc2509bed2e19b275c8f463506616377219d9642221ab53cf9fe
Status: Downloaded newer image for hello-world:latest
docker.io/library/hello-world:latest
(base) sumit@Sumits-MacBook-Air ~ % docker images
REPOSITORY       TAG       IMAGE ID       CREATED         SIZE
arm64v8/ubuntu   20.04     c9eb527b091d   19 hours ago    65.7MB
hello-world      latest    46331d942d63   10 months ago   9.14kB
(base) sumit@Sumits-MacBook-Air ~ % docker run hello-world

Hello from Docker!
This message shows that your installation appears to be working correctly.

To generate this message, Docker took the following steps:
 1. The Docker client contacted the Docker daemon.
 2. The Docker daemon pulled the "hello-world" image from the Docker Hub.
    (arm64v8)
 3. The Docker daemon created a new container from that image which runs the
    executable that produces the output you are currently reading.
 4. The Docker daemon streamed that output to the Docker client, which sent it
    to your terminal.

To try something more ambitious, you can run an Ubuntu container with:
 $ docker run -it ubuntu bash

Share images, automate workflows, and more with a free Docker ID:
 https://hub.docker.com/

For more examples and ideas, visit:
 https://docs.docker.com/get-started/
```

2. Basic docker image creation and running docker image:

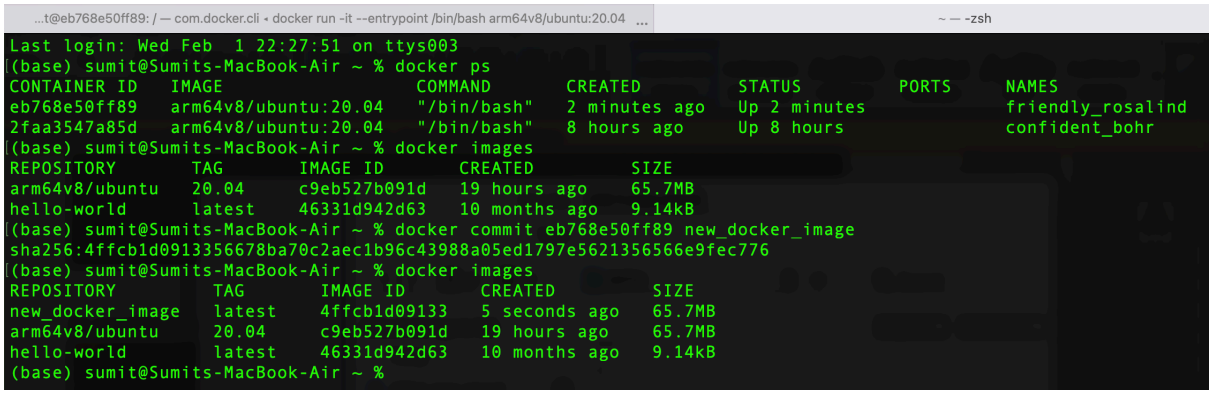
We will make a docker image from dockerfile to run experiments. Below is basic step to create a docker image:

Terminal 1:	Terminal 2:
docker images sudo docker run -it –entrypoint “bin/bash/ arm64v8/ubuntu:20.04 apt update apt install <package>	docker ps docker commit <container_id> <image_name> docker images docker history <image_name>

Terminal 1:



Terminal 2:



Following are descriptions of the docker commands:

docker pull image-name:tag	To pull a docker image
docker images	To list out all docker images
docker run image-name	To run a docker image
docker run [container] image [command]	To run a container
docker ps -a	To list out all containers; running as well as exited.
docker commit <container_id> <image_name>	To commit a container's file changes or settings into a new image
docker history <image_name>	To show history of an image

docker inspect container id	To check all details about containers
docker system prune -a	To delete all docker images
Docker exec -it containerID /bin/bash	To go inside the running container

3. Sysbench Installation.

We must make sure that we have a same version of sysbench in QEMU and in Docker. To install use the below command

For Docker, we are using the sysbench library package:
Link: https://github.com/akopytov/sysbench

```
apt update;
apt install sysbench;
```

Test Conditions: To conduct the experiment with the VM, we will consider three test conditions showed in the table below. To ensure consistency between results, the same test conditions will be used for Docker as well as for QEMU

.

Cores	Memory allocation
2	2 GB
3	3 GB
6	3 GB

Proof of experiment - Reports and Findings

In this section, we will look at test cases that are specifically related to sysbench CPU and File I/O commands. We will also test different QEMU VM configurations to see if we get different results by changing the VM configurations.

1. CPU Testing

We will use the following three test cases to evaluate CPU performance between QEMU and Docker. For our testing, we will use the sysbench command and the test cases listed below:

```
sysbench cpu --threads={Value} --cpu-max-prime={Value} --time={Value} run

1. max-prime = 1000 and time = 30 seconds
2. max-prime = 10,000 and time = 30 seconds
3. max-prime = 100,000 and time = 30 seconds
```

2. FILEIO Testing

For File I/O testing we will be using random read/write (rndrw). Also, for our testing purposes, we will use the following sysbench commands, and changing the values for different configuration.

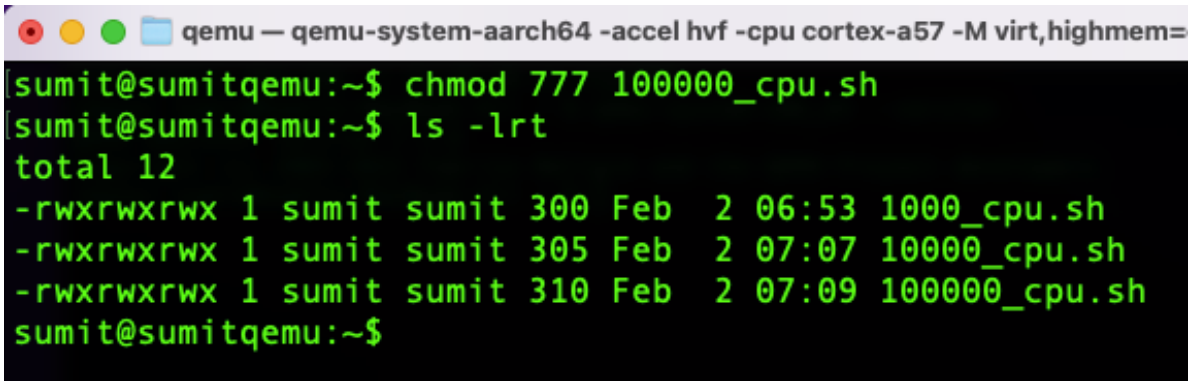
```
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndwr prepare
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw run
sysbench --num-threads=16 --test=fileio --file-total-size=3G --time=30 --file-test-mode=rndrw cleanup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

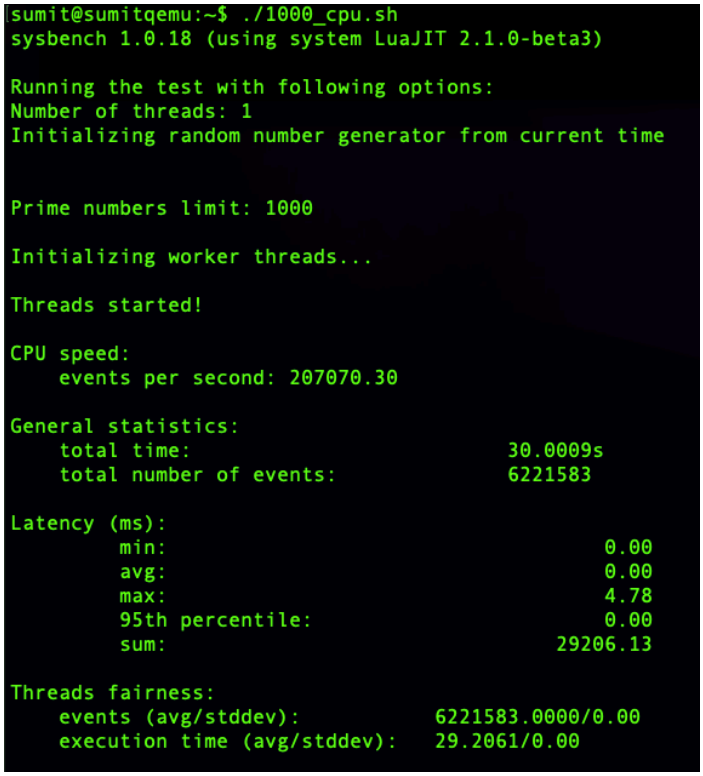
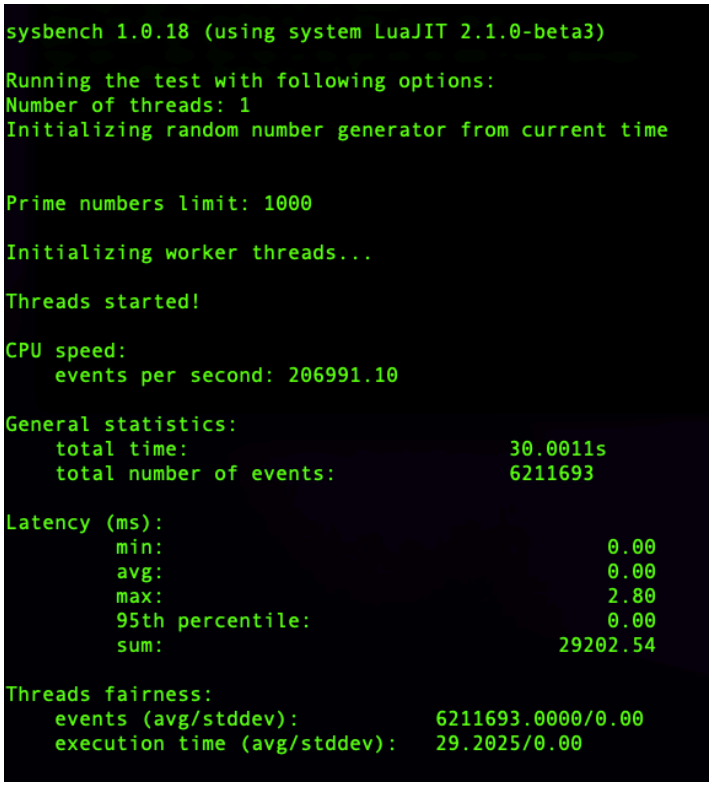
3. Results

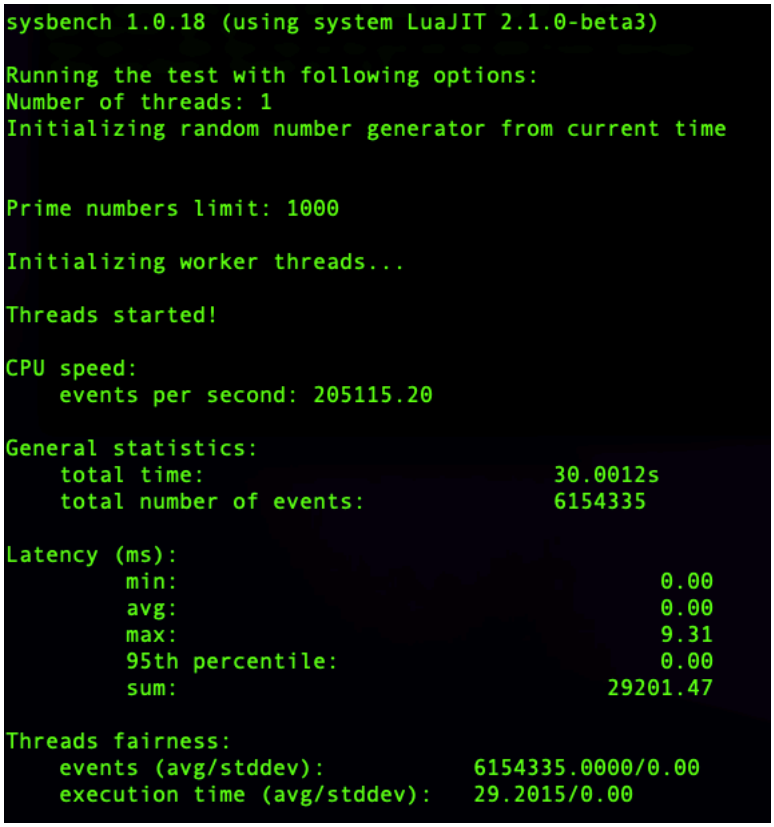
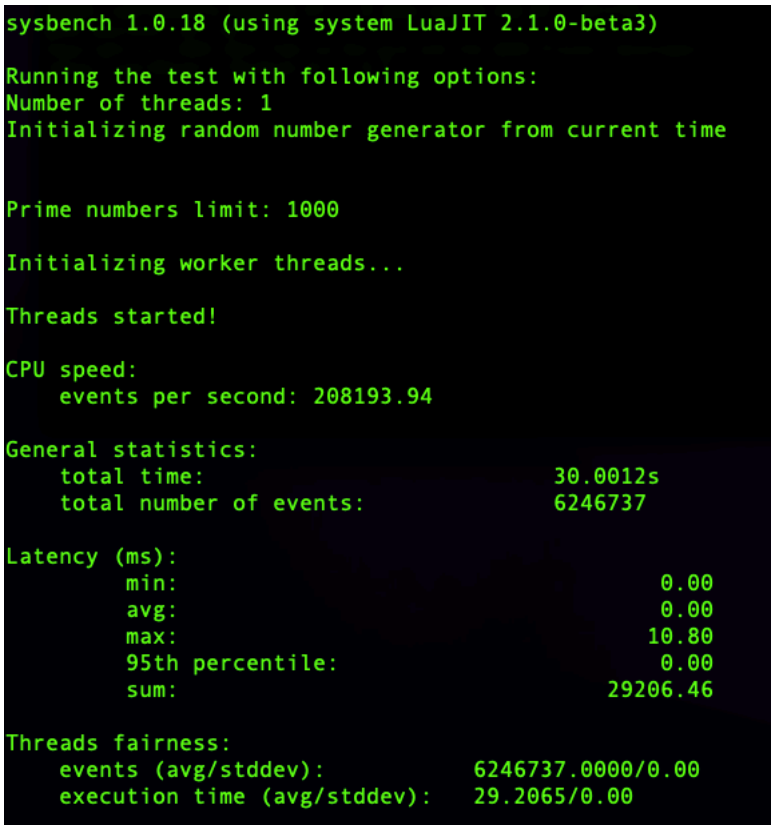
1. Configuration 1: 2 GB RAM with 2 Cores

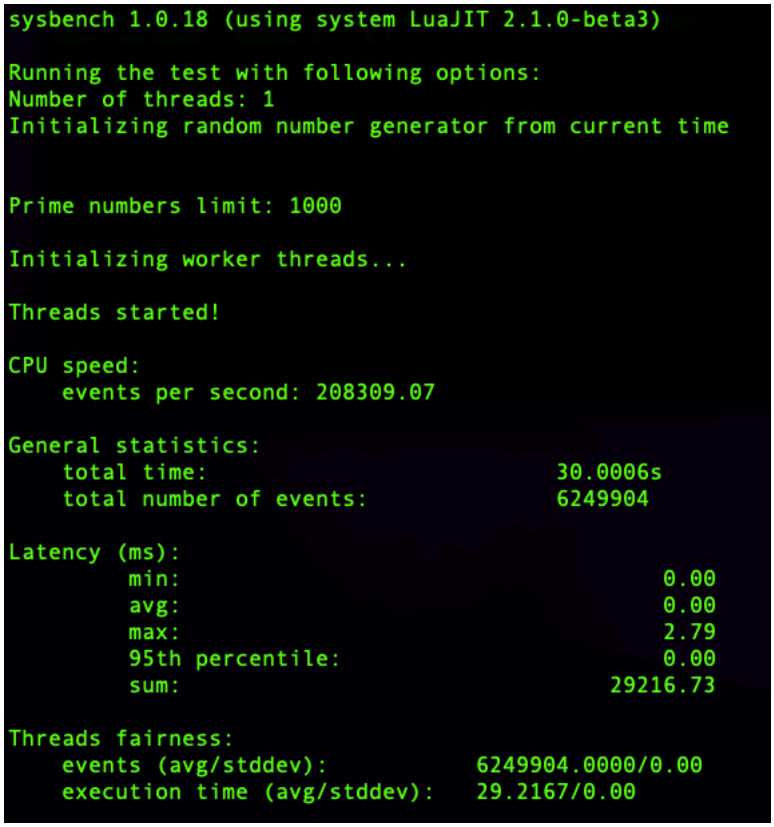
1.1 CPU Testing

To conduct these experiments, I wrote three bash scripts, each with a different max-prime value and five iterations:



QEMU Results, Configuration: 2 GB 2 cores for max-prime = 1000 and time = 30 seconds	
Iteration	Screenshot
1	
2	

3	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 1000 Initializing worker threads... Threads started! CPU speed: events per second: 205115.20 General statistics: total time: 30.0012s total number of events: 6154335 Latency (ms): min: 0.00 avg: 0.00 max: 9.31 95th percentile: 0.00 sum: 29201.47 Threads fairness: events (avg/stddev): 6154335.0000/0.00 execution time (avg/stddev): 29.2015/0.00
4	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 1000 Initializing worker threads... Threads started! CPU speed: events per second: 208193.94 General statistics: total time: 30.0012s total number of events: 6246737 Latency (ms): min: 0.00 avg: 0.00 max: 10.80 95th percentile: 0.00 sum: 29206.46 Threads fairness: events (avg/stddev): 6246737.0000/0.00 execution time (avg/stddev): 29.2065/0.00

5	

Detailed report:

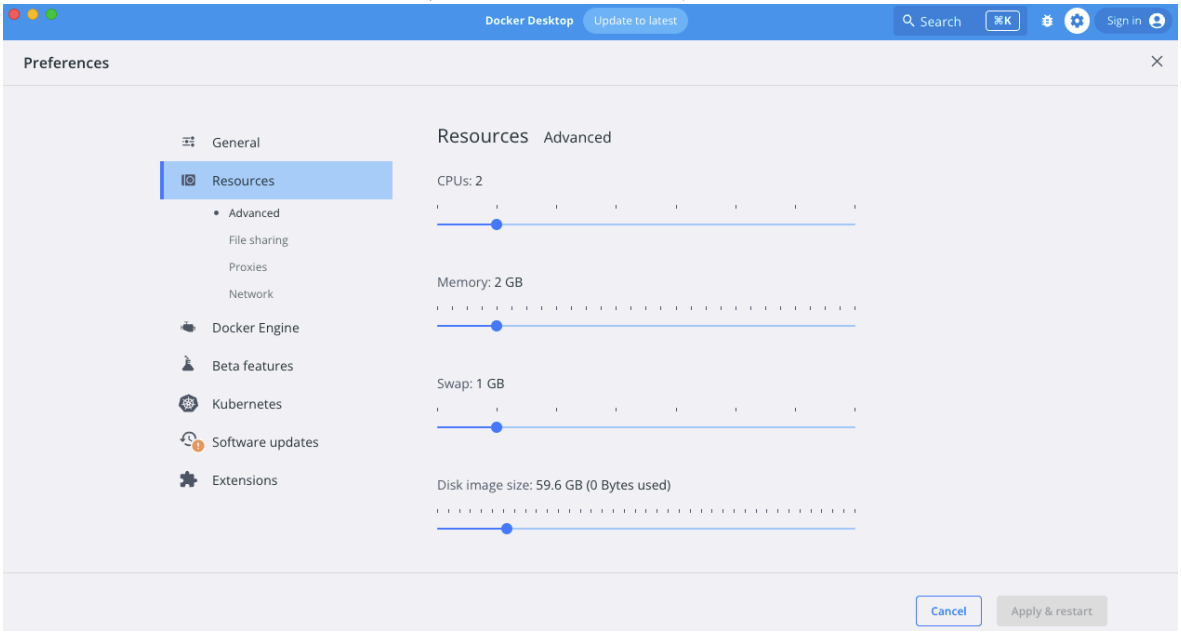
Iteration No	Events/second
1	207070.30
2	206991.10
3	205115.20
4	208193.94
5	208309.07

Observations:

Average events per second	207135.922
Minimum Number of events per second recorded	205115.20
Maximum Number of events per second recorded	208309.07

Docker Results, Configuration: 2 GB 2 cores for max-prime = 1000 and time = 30 seconds

Setting CPU count and memory in docker desktop:



Dockerfile, sysbench command, building docker image and running it:

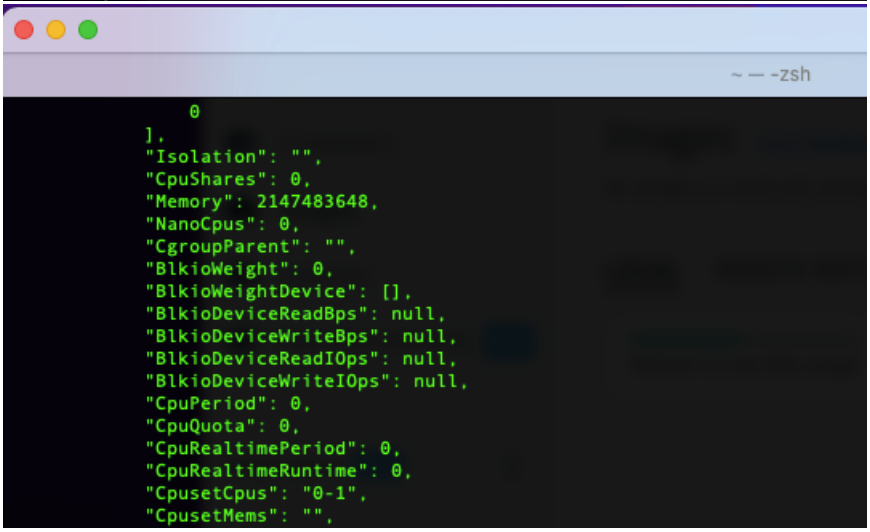
```
(base) sumit@Sumits-MacBook-Air ~ % cat 1000_CPU_Dockerfile
FROM arm64v8/ubuntu:20.04
RUN apt-get update
RUN apt-get install -y sysbench
COPY 1000_cpu.sh /
ENTRYPOINT ["./1000_cpu.sh"]
(base) sumit@Sumits-MacBook-Air ~ % cat 1000_cpu.sh
#!/bin/bash
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
(base) sumit@Sumits-MacBook-Air ~ %
```

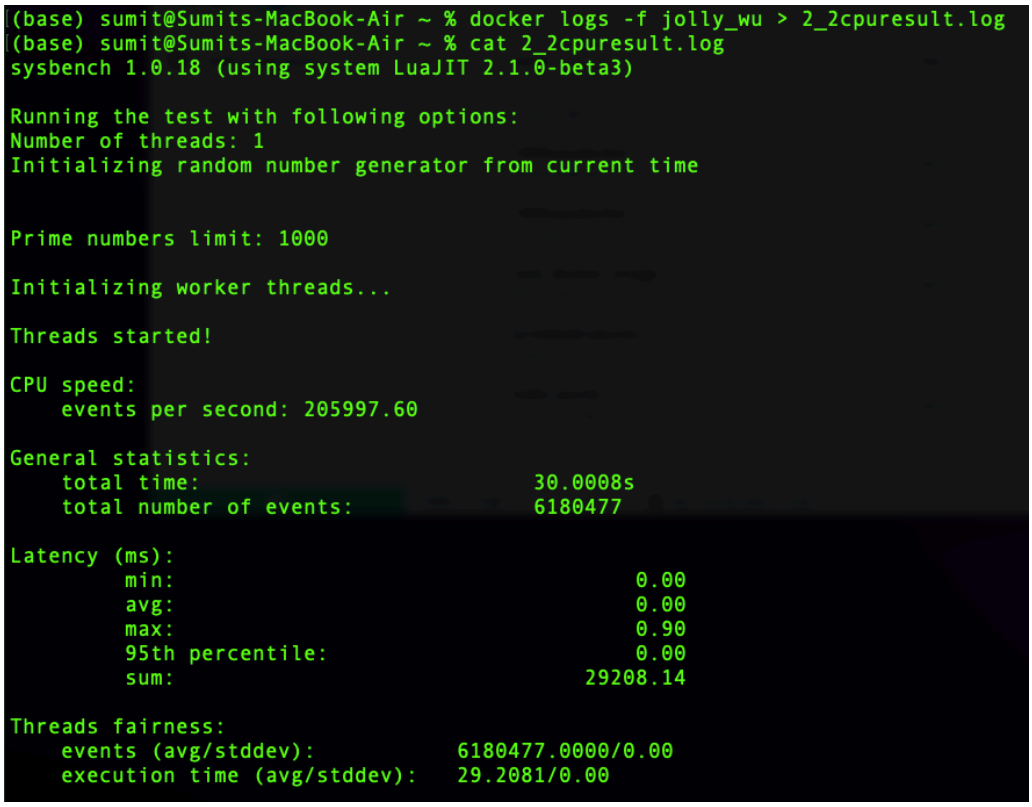
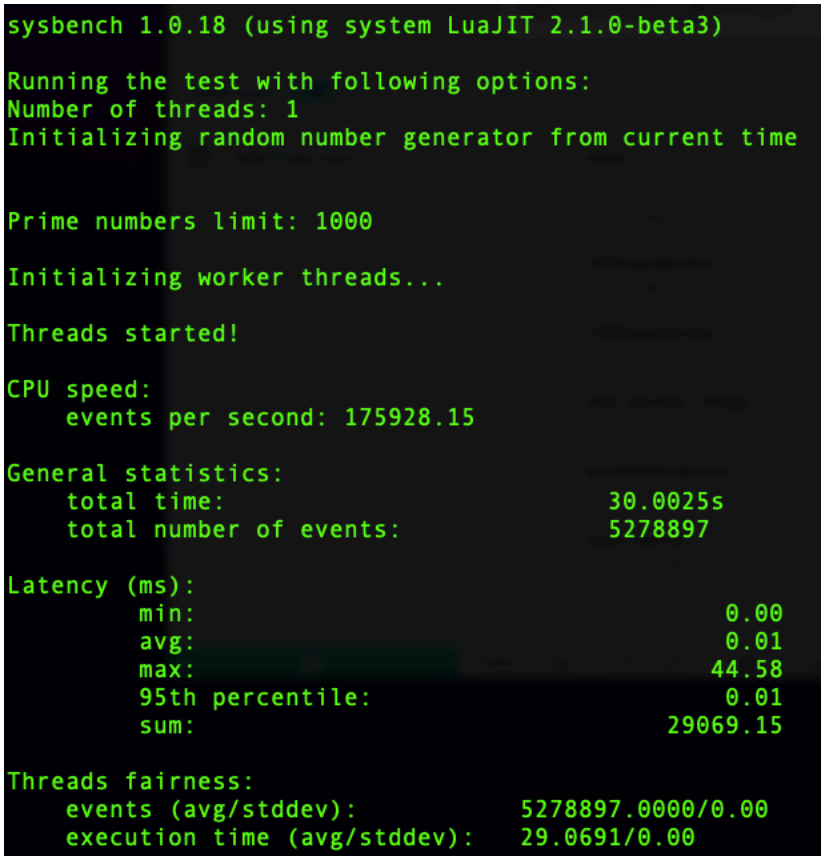
```
(base) sumit@Sumits-MacBook-Air ~ % docker build -t 1000cpudocker1 . -f 1000_CPU_Dockerfile
[+] Building 0.2s (9/9) FINISHED
 => [internal] load build definition from 1000_CPU_Dockerfile
 => => transferring dockerfile: 176B
 => [internal] load .dockerignore
 => => transferring context: 2B
 => [internal] load metadata for docker.io/arm64v8/ubuntu:20.04
 => [1/4] FROM docker.io/arm64v8/ubuntu:20.04
 => [internal] load build context
 => => transferring context: 33B
 => CACHED [2/4] RUN apt-get update
 => CACHED [3/4] RUN apt-get install -y sysbench
 => CACHED [4/4] COPY 1000_cpu.sh /
 => exporting to image
 => => exporting layers
 => => writing image sha256:06d58584b4ba6dd79d5bd5e9b85d7336d97032bb59b54c3d88d6b6fc1b2afa1e
 => => naming to docker.io/library/1000cpudocker1

Use 'docker scan' to run Snyk tests against images to find vulnerabilities and learn how to fix them
(base) sumit@Sumits-MacBook-Air ~ % docker run -it --memory="2g" --cpuset-cpus="0-1" -d 1000cpudocker1
e41453ffea3cda9df0fa6fb28c6cbced5d191736e2528c1be6e0a6cca658793b
(base) sumit@Sumits-MacBook-Air ~ % docker images
REPOSITORY         TAG       IMAGE ID       CREATED          SIZE
<none>             <none>    276b5558b578   13 minutes ago   116MB
1000cpudocker1     latest    06d58584b4ba   13 minutes ago   116MB
1000cpudocker      latest    7ad29dcc6c7a   26 minutes ago   116MB
new_docker_image   latest    4ffcb1d09133   2 hours ago      65.7MB
arm64v8/ubuntu     20.04     c9eb527b091d   21 hours ago     65.7MB
hello-world        latest    46331d942d63   10 months ago    9.14kB
(base) sumit@Sumits-MacBook-Air ~ %
```

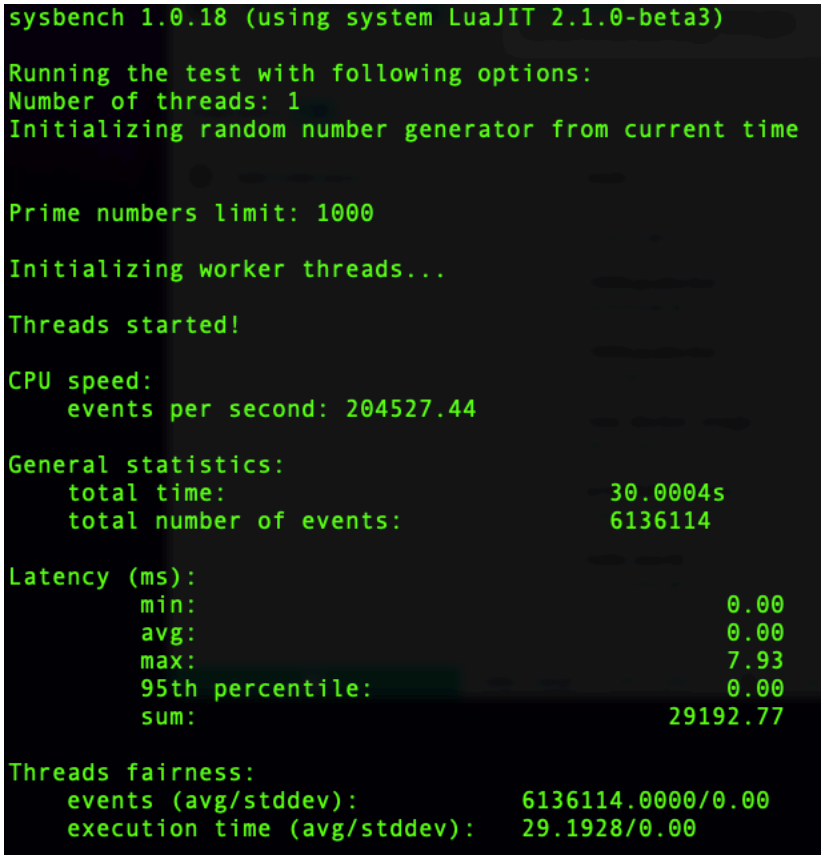
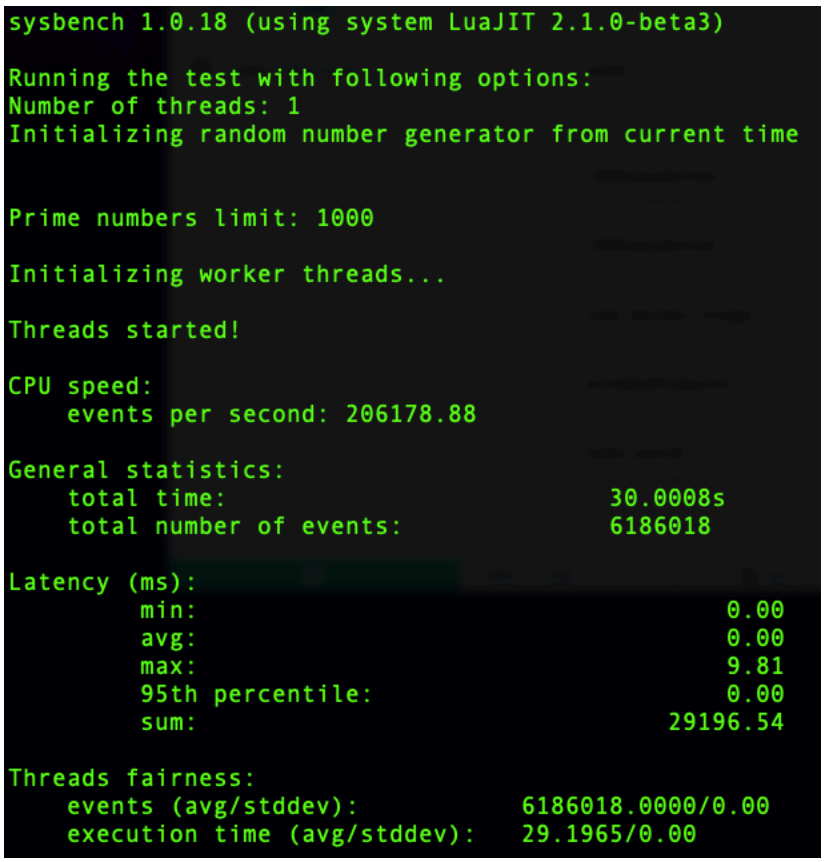
```
(base) sumit@Sumits-MacBook-Air ~ % docker logs -f jolly_wu > 2_2cpuresult.log
(base) sumit@Sumits-MacBook-Air ~ % cat 2_2cpuresult.log
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)
```

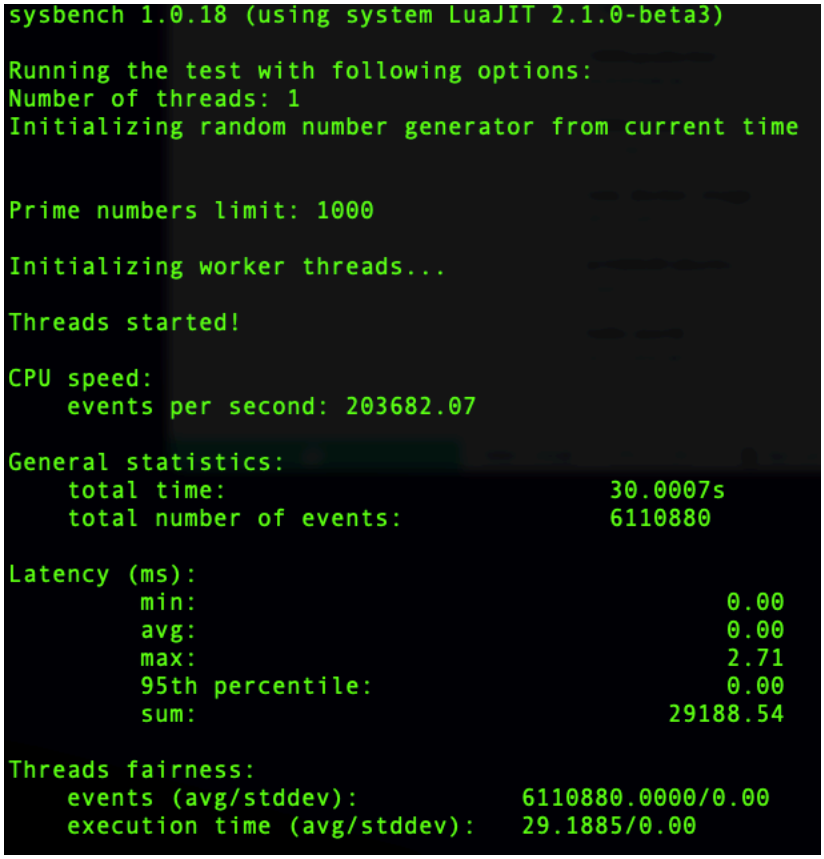
Docker inspect shows us the memory and cores set for running container:

```
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE            COMMAND          CREATED          STATUS          PORTS     NAMES
e41453ffea3c   1000cpudocker1   "./1000_cpu.sh"   24 seconds ago   Up 23 seconds             nice_lalande
(base) sumit@Sumits-MacBook-Air ~ % docker inspect e41453ffea3c
[
    {
        "Id": "e41453ffea3cda9df0fa6fb28c6cbced5d191736e2528c1be6e0a6cca658793b",
        "Created": "2023-02-02T08:33:10.559151418Z",
        "Path": "./1000_cpu.sh",
        "Args": [],
        "State": {
            "Status": "running",
            "Running": true,
            "Paused": false,
            "Restarting": false,
            "OOMKilled": false,
            "Dead": false,
            "Pid": 4052,
            "ExitCode": 0,
            "Error": "",
            "StartedAt": "2023-02-02T08:33:10.97802771Z",
            "FinishedAt": "0001-01-01T00:00:00Z"
        },
        "Image": "sha256:06d58584b4ba6dd79d5bd5e9b85d7336d97032bb59b54c3d88d6b6fc1b2afa1e",
```



Iteration	Screenshot
1	
2	

3	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 1000 Initializing worker threads... Threads started! CPU speed: events per second: 204527.44 General statistics: total time: 30.0004s total number of events: 6136114 Latency (ms): min: 0.00 avg: 0.00 max: 7.93 95th percentile: 0.00 sum: 29192.77 Threads fairness: events (avg/stddev): 6136114.0000/0.00 execution time (avg/stddev): 29.1928/0.00
4	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 1000 Initializing worker threads... Threads started! CPU speed: events per second: 206178.88 General statistics: total time: 30.0008s total number of events: 6186018 Latency (ms): min: 0.00 avg: 0.00 max: 9.81 95th percentile: 0.00 sum: 29196.54 Threads fairness: events (avg/stddev): 6186018.0000/0.00 execution time (avg/stddev): 29.1965/0.00

5	

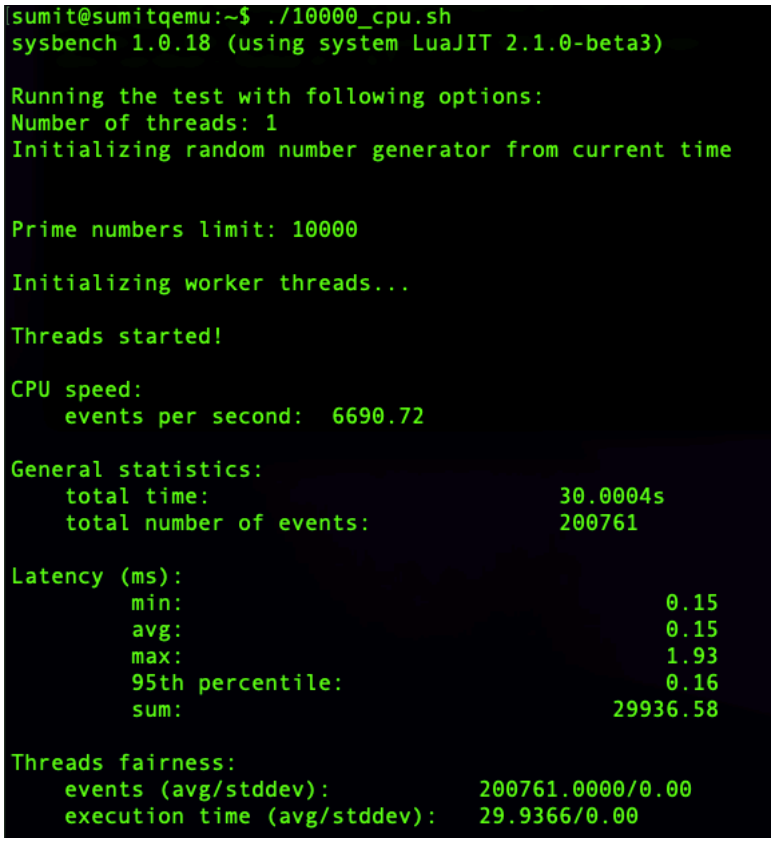
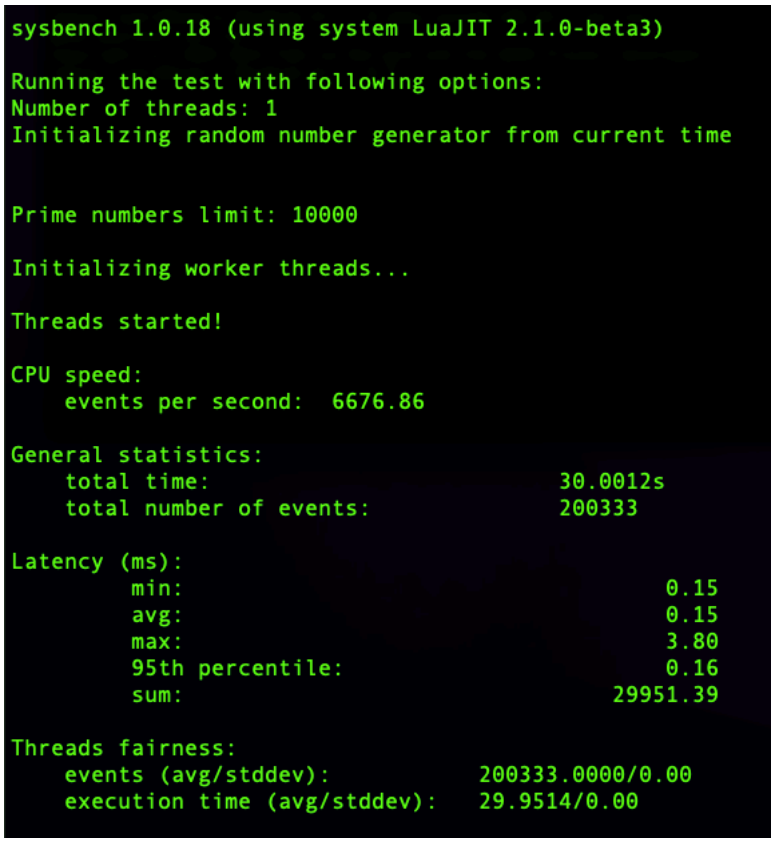
Detailed report:

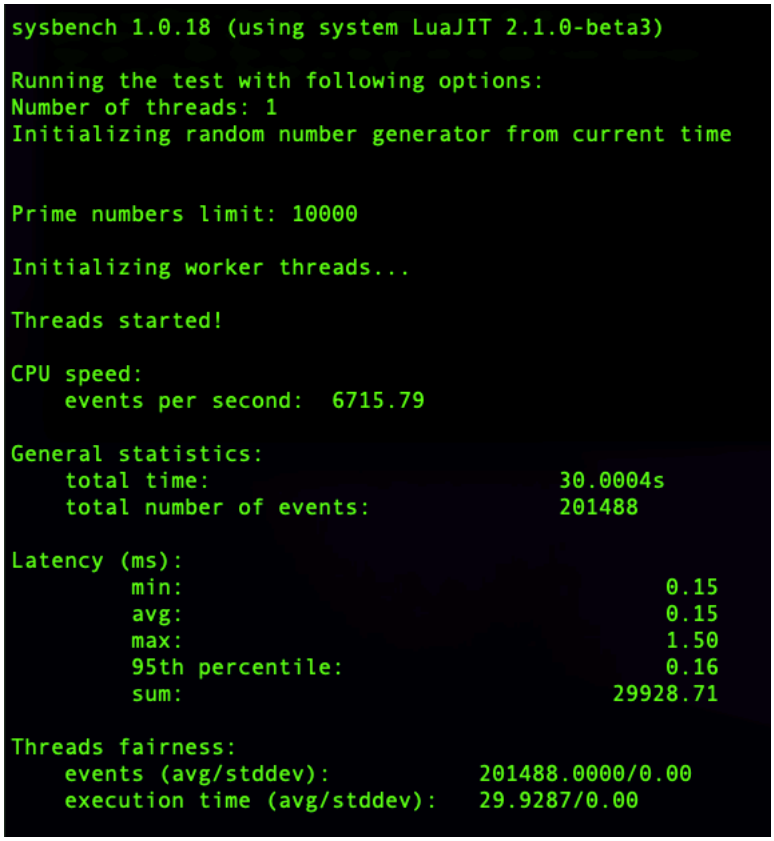
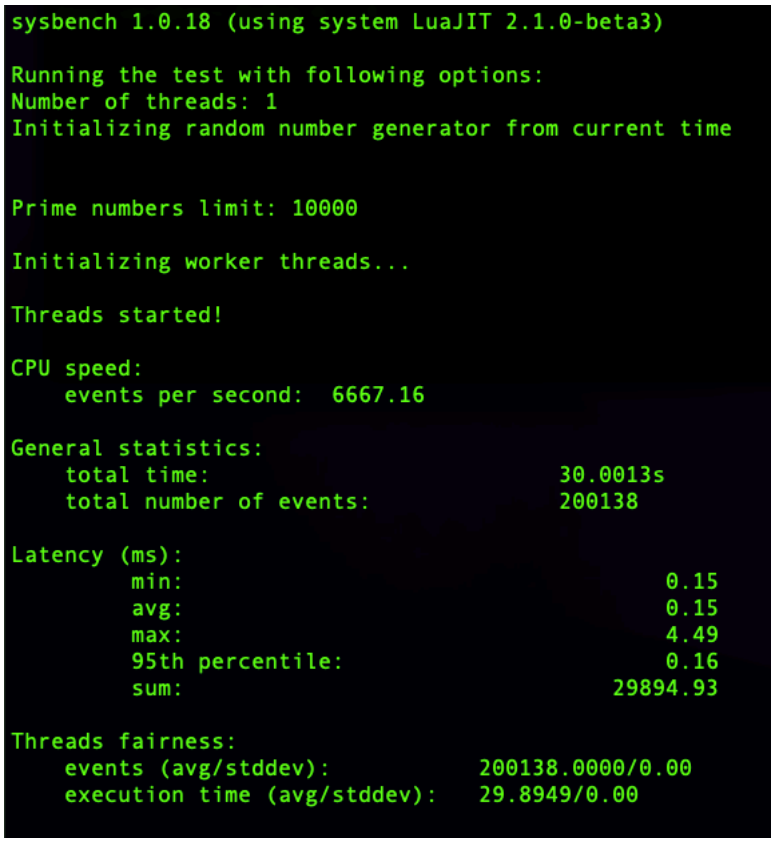
Iteration No	Events per second
1	205997.60
2	175928.15
3	204527.44
4	206178.88
5	203682.07

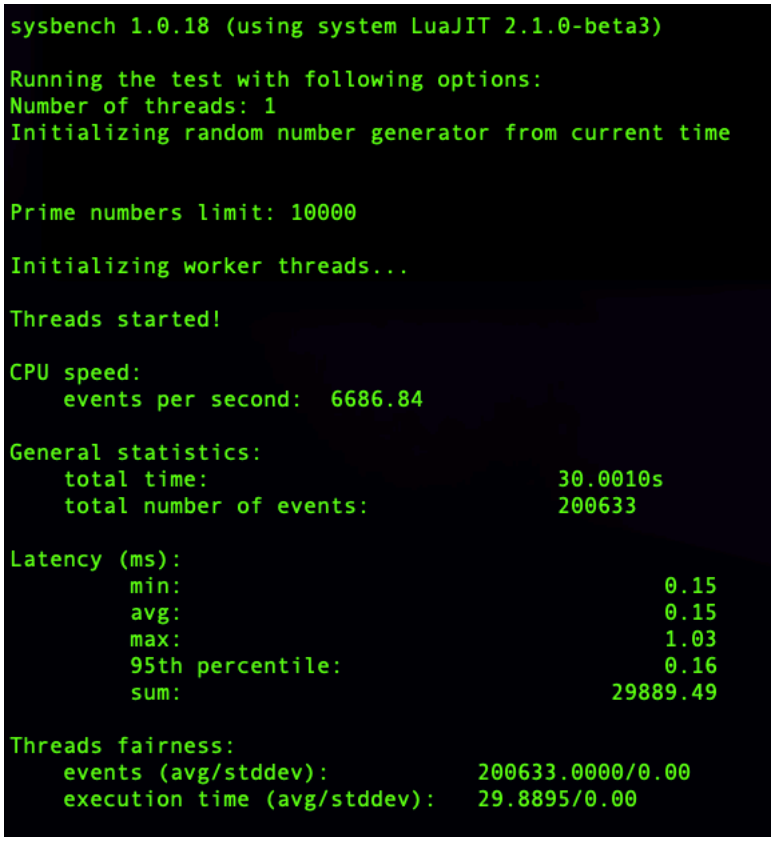
Observations:

Average events per second	199262.828
Minimum Number of events per second recorded	175928.15
Maximum Number of events per second recorded	206178.88

Conclusion: We can conclude that QEMU is faster than Docker as per this experiment.

QEMU Results for 2 GB 2 cores for max-prime = 10000 and time = 30 seconds	
1	
2	

3	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 10000 Initializing worker threads... Threads started! CPU speed: events per second: 6715.79 General statistics: total time: 30.0004s total number of events: 201488 Latency (ms): min: 0.15 avg: 0.15 max: 1.50 95th percentile: 0.16 sum: 29928.71 Threads fairness: events (avg/stddev): 201488.0000/0.00 execution time (avg/stddev): 29.9287/0.00
4	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 10000 Initializing worker threads... Threads started! CPU speed: events per second: 6667.16 General statistics: total time: 30.0013s total number of events: 200138 Latency (ms): min: 0.15 avg: 0.15 max: 4.49 95th percentile: 0.16 sum: 29894.93 Threads fairness: events (avg/stddev): 200138.0000/0.00 execution time (avg/stddev): 29.8949/0.00

5	

Detailed report:

Iteration No	Events per second
1	6690.72
2	6676.86
3	6715.79
4	6667.16
5	6686.84

Observations:

Average events per second	6687.474
Minimum Number of events per second recorded	6667.16
Maximum Number of events per second recorded	6715.79

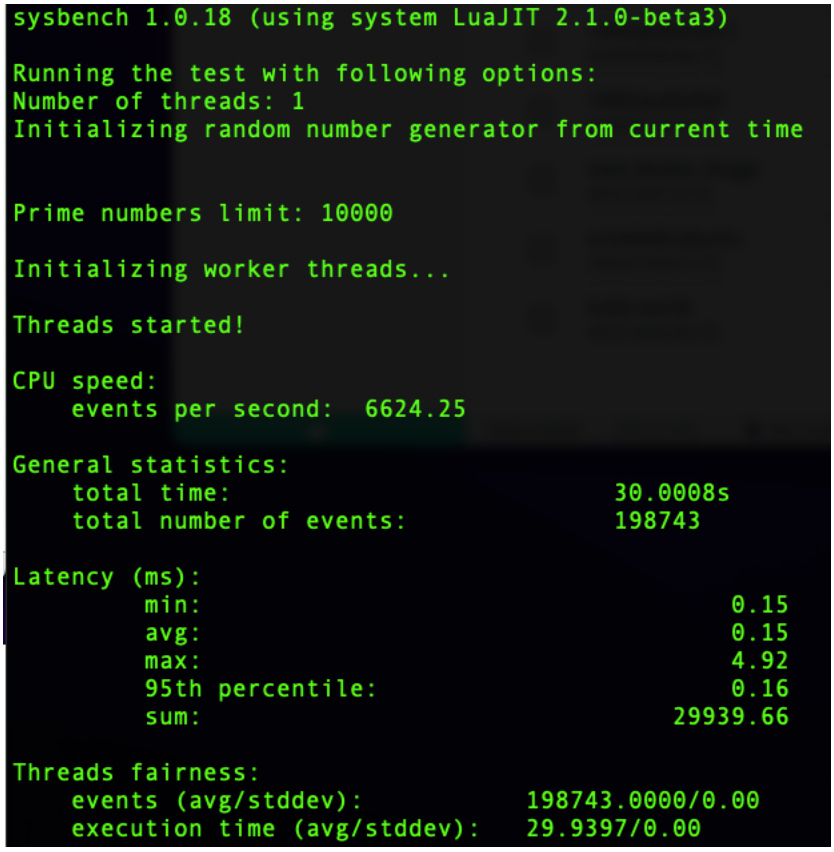
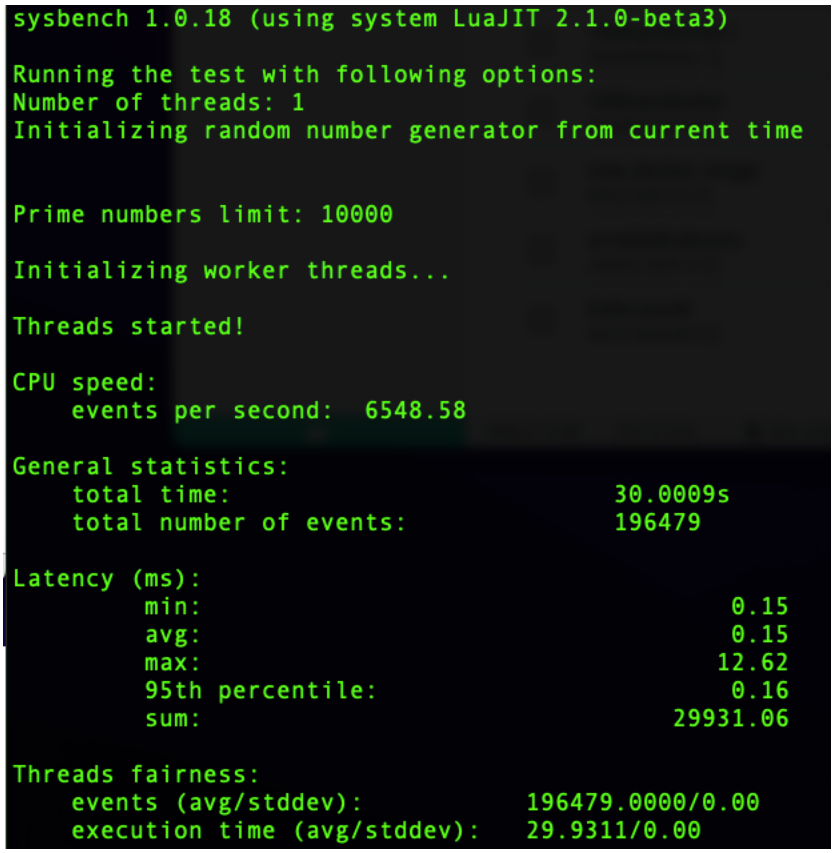
Docker results for 2 GB 2 cores for max-prime = 10000 and time = 30 seconds
Dockerfile, sysbench command, building docker image and running it:

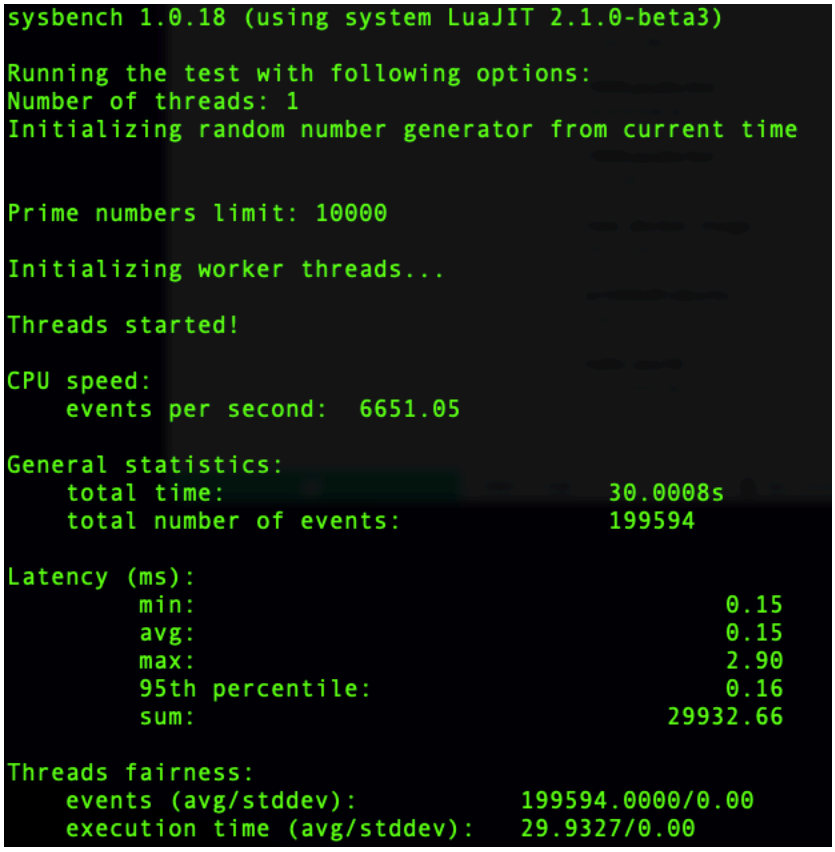
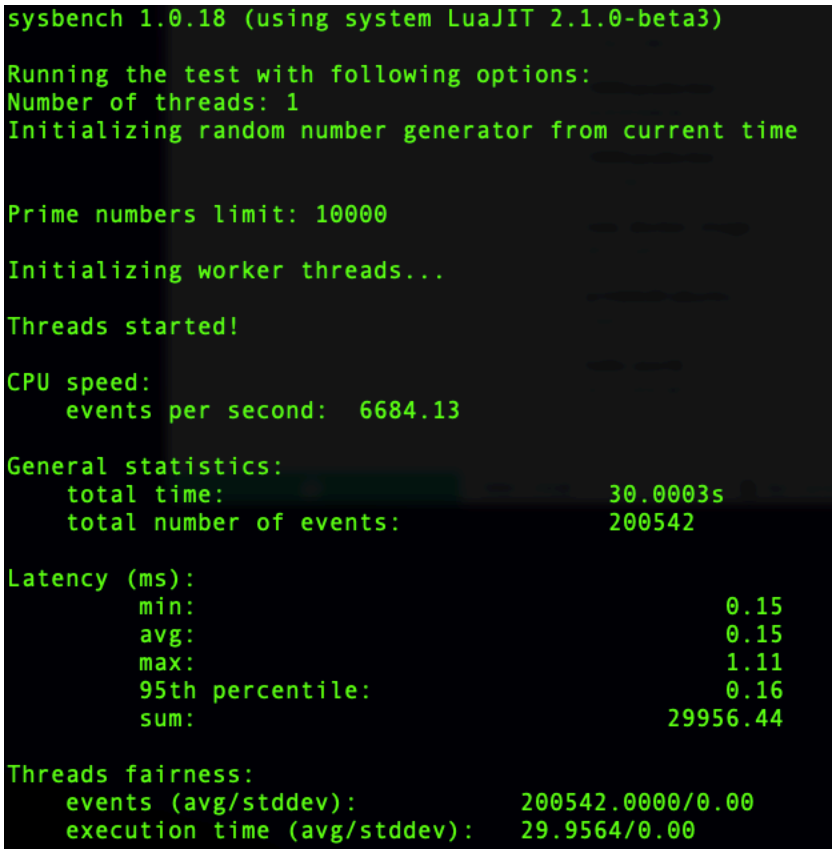
```
(base) sumit@Sumits-MacBook-Air ~ % cat 10000_cpu.sh
#!/bin/bash
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
(base) sumit@Sumits-MacBook-Air ~ % cat 10000_CPU_Dockerfile
FROM arm64v8/ubuntu:20.04
RUN apt-get update
RUN apt-get install -y sysbench
COPY 10000_cpu.sh /
ENTRYPOINT ["./10000_cpu.sh"]
(base) sumit@Sumits-MacBook-Air ~ %
```

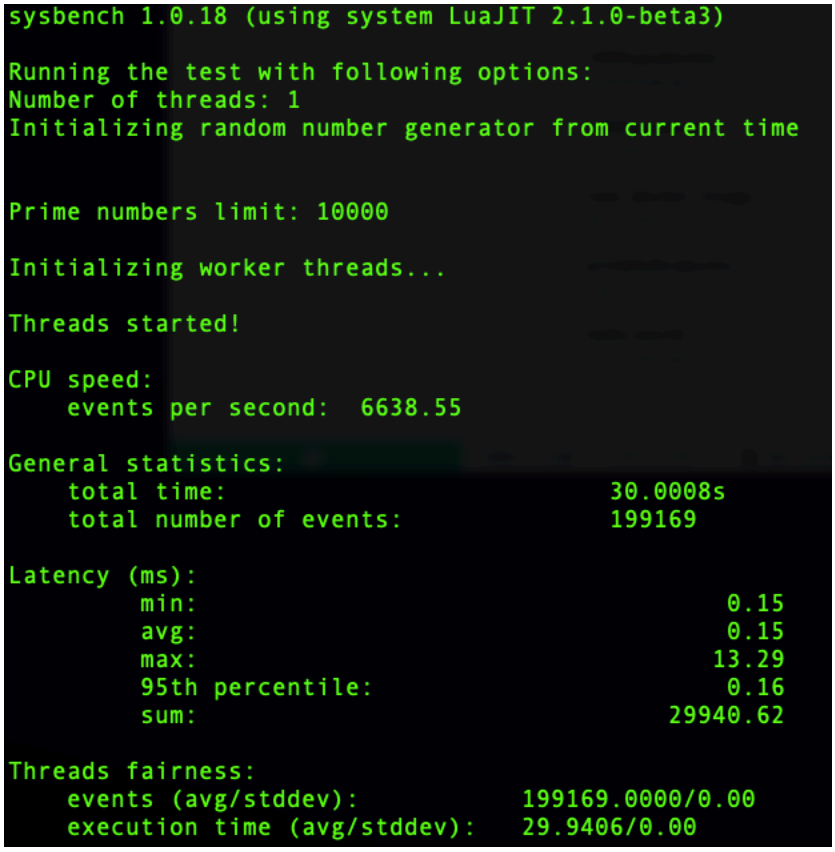
```
(base) sumit@Sumits-MacBook-Air ~ % docker build -t 10000cpudocker . -f 10000_CPU_Dockerfile
[+] Building 0.1s (9/9) FINISHED
 => [internal] load build definition from 10000_CPU_Dockerfile
 => => transferring dockerfile: 179B
 => [internal] load .dockerignore
 => => transferring context: 2B
 => [internal] load metadata for docker.io/arm64v8/ubuntu:20.04
 => [1/4] FROM docker.io/arm64v8/ubuntu:20.04
 => [internal] load build context
 => => transferring context: 358B
 => CACHED [2/4] RUN apt-get update
 => CACHED [3/4] RUN apt-get install -y sysbench
 => [4/4] COPY 10000_cpu.sh /
 => exporting to image
 => => exporting layers
 => => writing image sha256:9a9867686617e7f4a6ad822a8511e6d7565b3ccbfcaf0139dff26c78120c26f1
 => => naming to docker.io/library/10000cpudocker

Use 'docker scan' to run Snyk tests against images to find vulnerabilities and learn how to fix them
(base) sumit@Sumits-MacBook-Air ~ % docker run -it --memory="2g" --cpuset-cpus="0-1" -d 10000cpudocker
4356ef4715d9607b8bbe647d75b479957a0a49255def39d18fadcb2474f3b609
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE            COMMAND            CREATED         STATUS         PORTS     NAMES
4356ef4715d9   10000cpudocker   "./10000_cpu.sh"   8 seconds ago   Up 7 seconds             crazy_bartik
(base) sumit@Sumits-MacBook-Air ~ %
```

```
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE            COMMAND            CREATED         STATUS         PORTS     NAMES
4356ef4715d9   10000cpudocker   "./10000_cpu.sh"   8 seconds ago   Up 7 seconds             crazy_bartik
(base) sumit@Sumits-MacBook-Air ~ % docker logs -f crazy_bartik > 2_2_10000_cpuresult.log
(base) sumit@Sumits-MacBook-Air ~ % cat 2_2_10000_cpuresult.log
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)
```

Iteration	Screenshot

1	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 10000 Initializing worker threads... Threads started! CPU speed: events per second: 6624.25 General statistics: total time: 30.0008s total number of events: 198743 Latency (ms): min: 0.15 avg: 0.15 max: 4.92 95th percentile: 0.16 sum: 29939.66 Threads fairness: events (avg/stddev): 198743.0000/0.00 execution time (avg/stddev): 29.9397/0.00
2	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 10000 Initializing worker threads... Threads started! CPU speed: events per second: 6548.58 General statistics: total time: 30.0009s total number of events: 196479 Latency (ms): min: 0.15 avg: 0.15 max: 12.62 95th percentile: 0.16 sum: 29931.06 Threads fairness: events (avg/stddev): 196479.0000/0.00 execution time (avg/stddev): 29.9311/0.00

3	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 10000 Initializing worker threads... Threads started! CPU speed: events per second: 6651.05 General statistics: total time: 30.0008s total number of events: 199594 Latency (ms): min: 0.15 avg: 0.15 max: 2.90 95th percentile: 0.16 sum: 29932.66 Threads fairness: events (avg/stddev): 199594.0000/0.00 execution time (avg/stddev): 29.9327/0.00
4	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 10000 Initializing worker threads... Threads started! CPU speed: events per second: 6684.13 General statistics: total time: 30.0003s total number of events: 200542 Latency (ms): min: 0.15 avg: 0.15 max: 1.11 95th percentile: 0.16 sum: 29956.44 Threads fairness: events (avg/stddev): 200542.0000/0.00 execution time (avg/stddev): 29.9564/0.00

5	

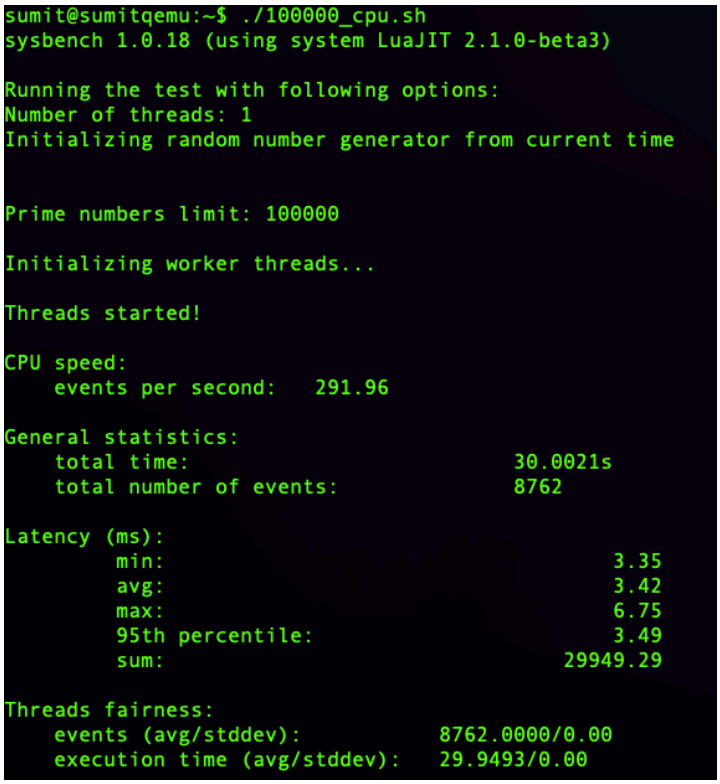
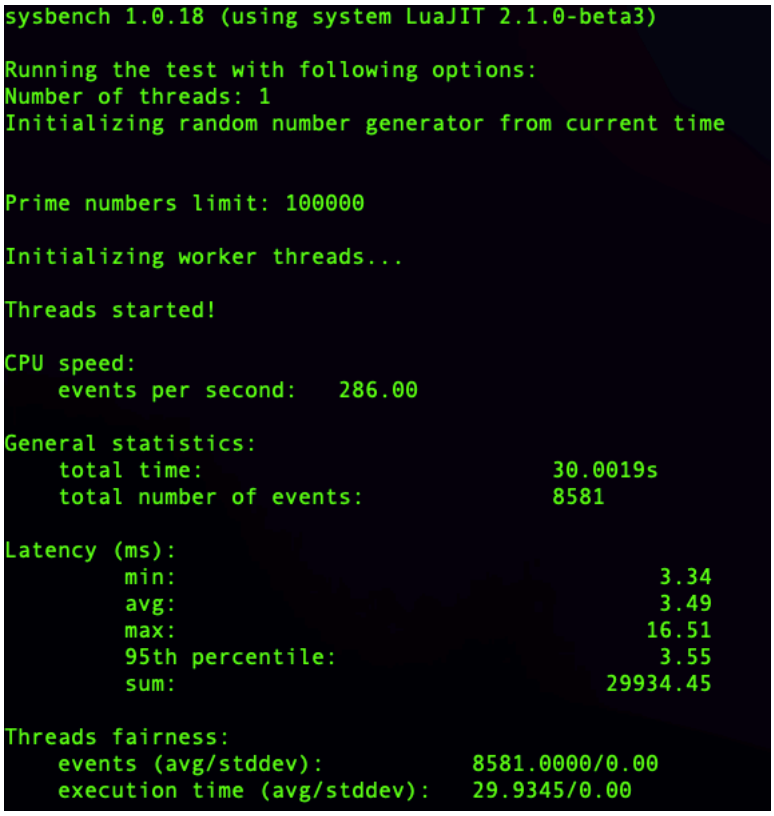
Detailed report:

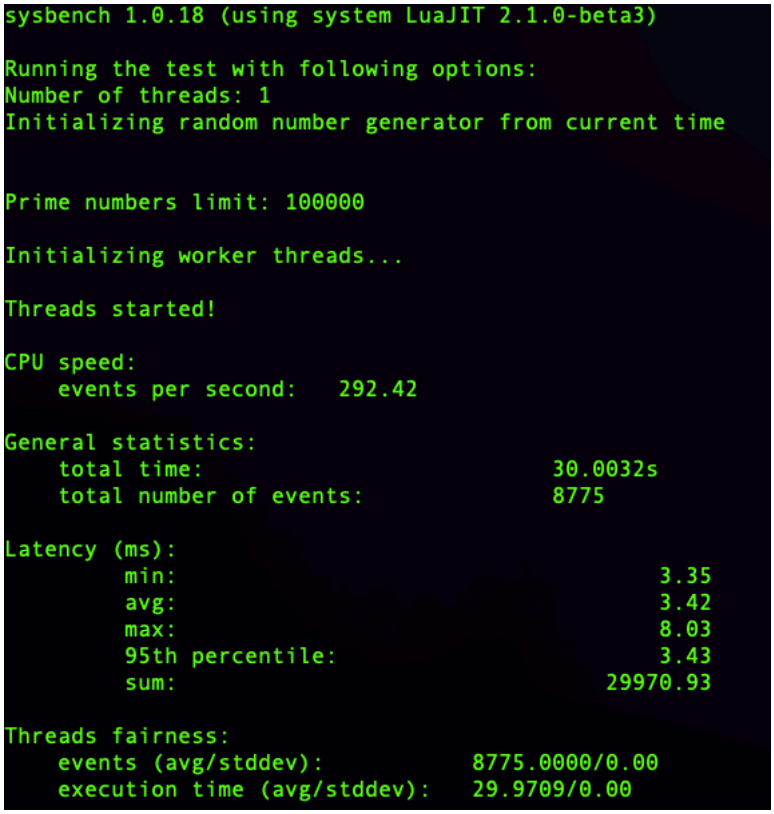
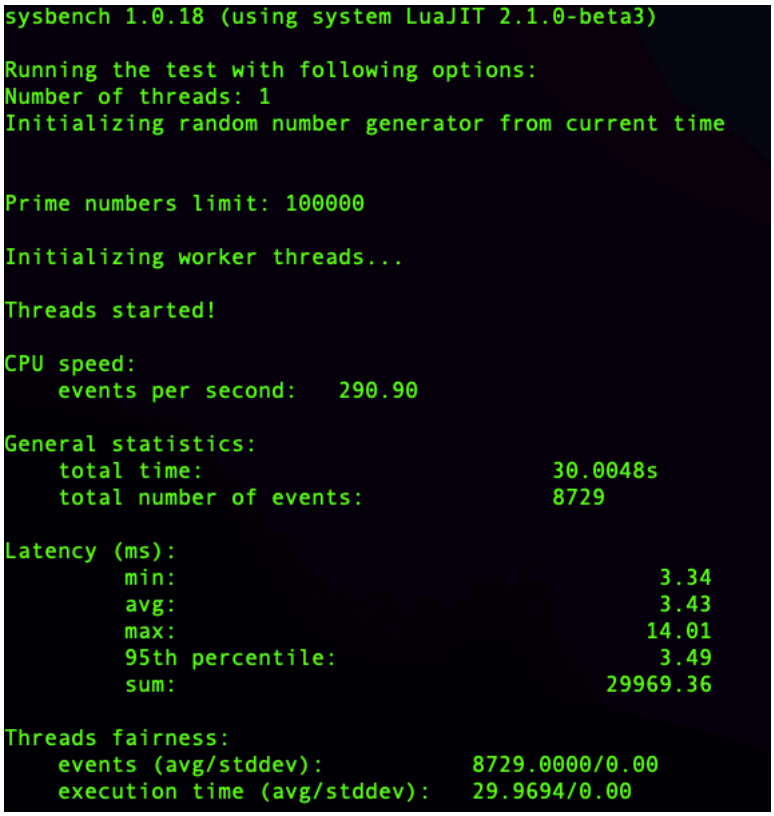
Iteration No	Events per second
1	6624.25
2	6548.58
3	6651.05
4	6684.13
5	6638.55

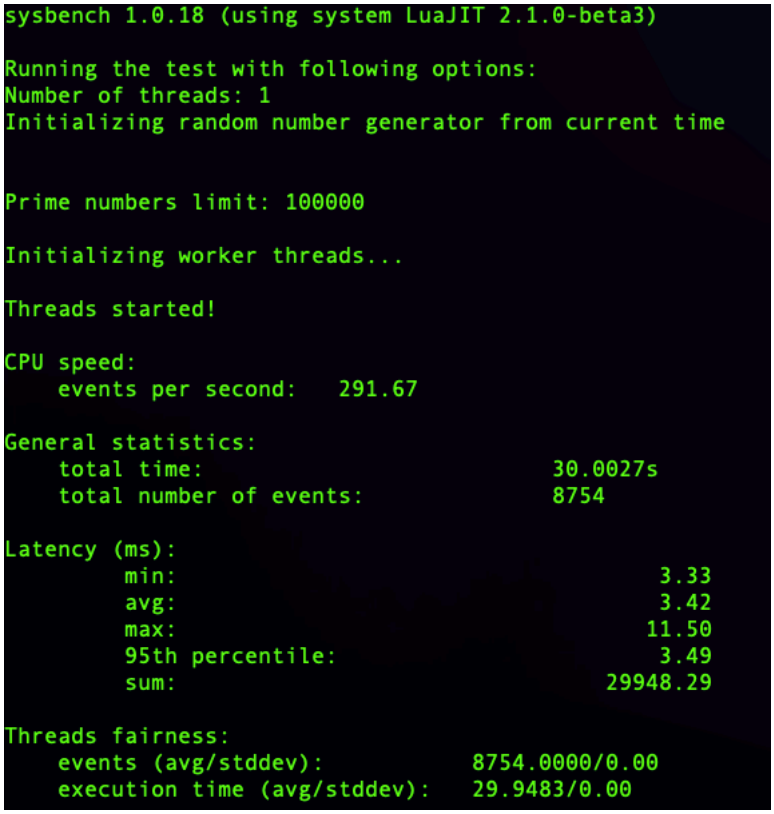
Observations:

Average events per second	6629.312
Minimum Number of events per second recorded	6548.58
Maximum Number of events per second recorded	6684.13

Conclusion: As we can see, increasing the cpu-max-prime argument value reduces the no. of events/second for our current experimental configuration. On this MacBook chip, QEMU is faster than Docker desktop.

QEMU Results for 2 GB 2 cores for max-prime = 100000 and time = 30 seconds	
Iteration	Screenshot
1	
2	

3	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 100000 Initializing worker threads... Threads started! CPU speed: events per second: 292.42 General statistics: total time: 30.0032s total number of events: 8775 Latency (ms): min: 3.35 avg: 3.42 max: 8.03 95th percentile: 3.43 sum: 29970.93 Threads fairness: events (avg/stddev): 8775.0000/0.00 execution time (avg/stddev): 29.9709/0.00
4	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 100000 Initializing worker threads... Threads started! CPU speed: events per second: 290.90 General statistics: total time: 30.0048s total number of events: 8729 Latency (ms): min: 3.34 avg: 3.43 max: 14.01 95th percentile: 3.49 sum: 29969.36 Threads fairness: events (avg/stddev): 8729.0000/0.00 execution time (avg/stddev): 29.9694/0.00

5	

Detailed report:

Iteration No	Events per second
1	291.96
2	286.00
3	292.42
4	290.90
5	291.67

Observations:

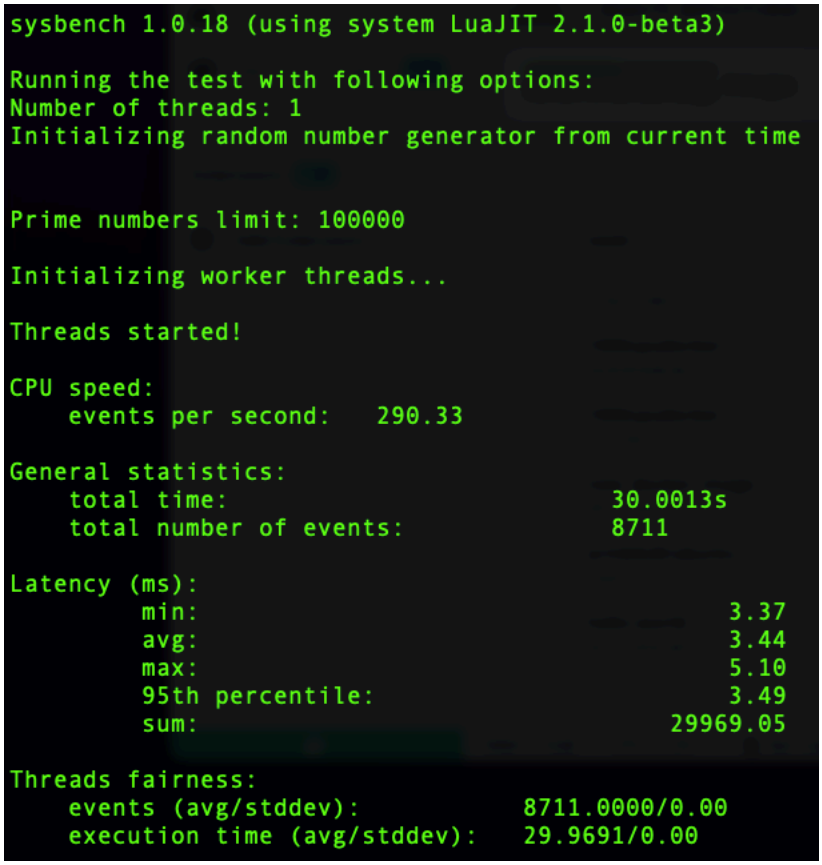
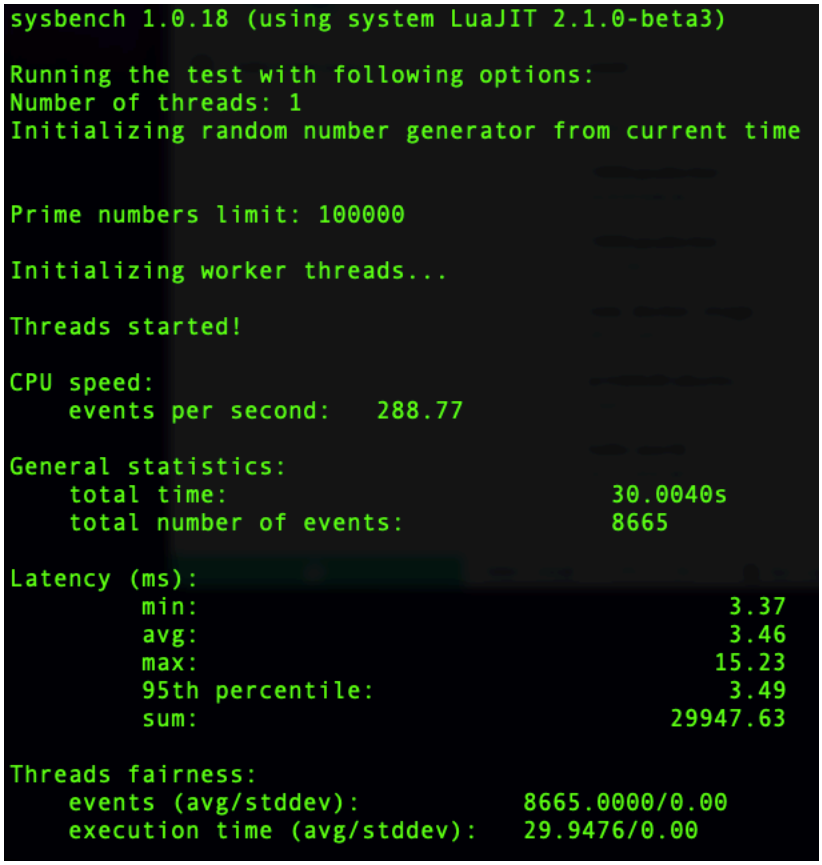
Average events per second	290.59
Minimum Number of events per second recorded	286.00
Maximum Number of events per second recorded	292.42

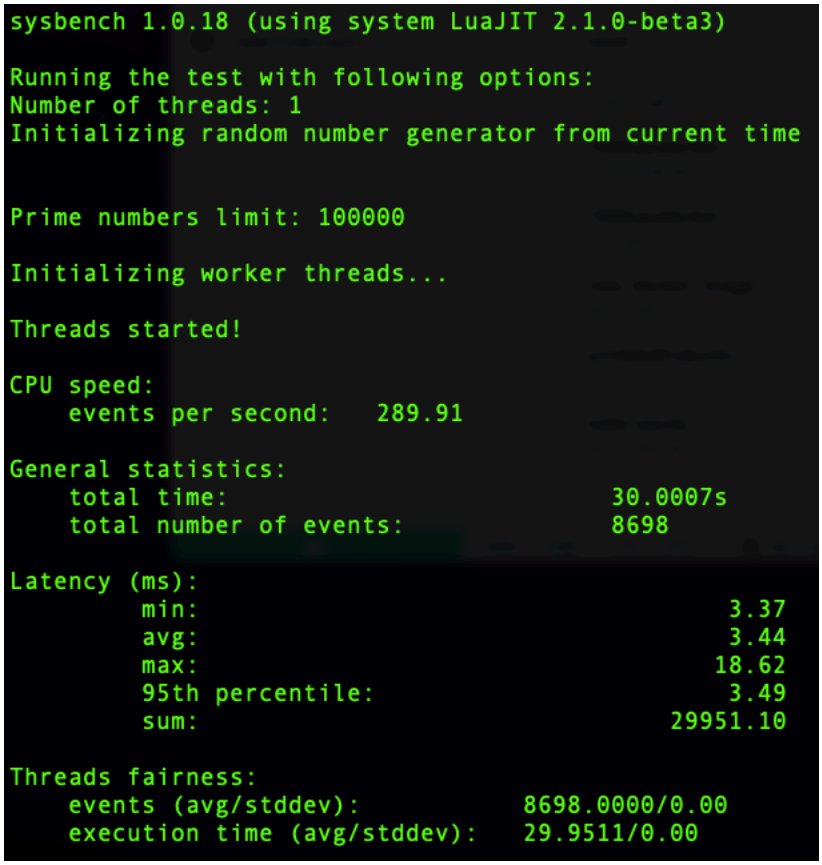
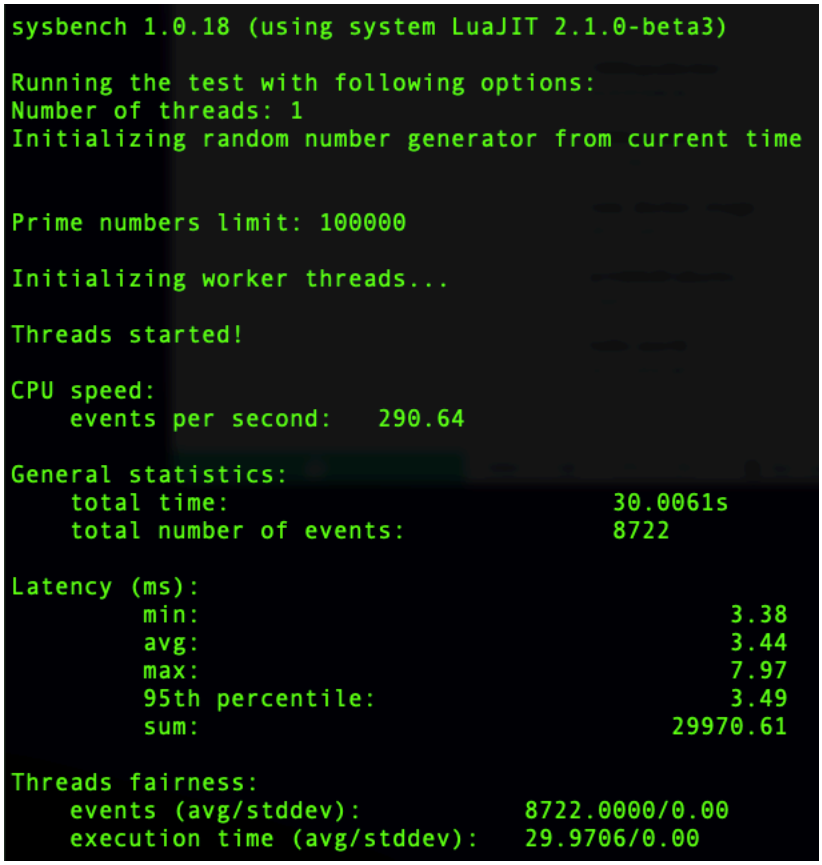
Docker results for 2 GB 2 cores for max-prime = 100000 and time = 30 seconds

Dockerfile, sysbench command, building docker image and running it:

```
(base) sumit@Sumits-MacBook-Air ~ % cat 100000_cpu.sh
#!/bin/bash
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
(base) sumit@Sumits-MacBook-Air ~ % cat 100000_CPU_Dockerfile
FROM arm64v8/ubuntu:20.04
RUN apt-get update
RUN apt-get install -y sysbench
COPY 100000_cpu.sh /
ENTRYPOINT ["./100000_cpu.sh"]
(base) sumit@Sumits-MacBook-Air ~ % docker build -t 100000cpudocker . -f 100000_CPU_Dockerfile
[+] Building 0.3s (9/9) FINISHED
 => [internal] load build definition from 100000_CPU_Dockerfile
 => => transferring dockerfile: 184B
 => [internal] load .dockerignore
 => => transferring context: 2B
 => [internal] load metadata for docker.io/arm64v8/ubuntu:20.04
 => [internal] load build context
 => => transferring context: 364B
 => [1/4] FROM docker.io/arm64v8/ubuntu:20.04
 => CACHED [2/4] RUN apt-get update
 => CACHED [3/4] RUN apt-get install -y sysbench
 => [4/4] COPY 100000_cpu.sh /
 => exporting to image
 => => exporting layers
 => => writing image sha256:3e9a4bf1e4e1192c9aaa2e466d45ca8b783385d45296a2dd9e3f71b656a0ba32
 => => naming to docker.io/library/100000cpudocker

Use 'docker scan' to run Snyk tests against images to find vulnerabilities and learn how to fix them
(base) sumit@Sumits-MacBook-Air ~ % docker run -it --memory="2g" --cpuset-cpus="0-1" -d 100000cpudocker
6c1c1d294e5d72a21d7110e5508e89d99b7cc84cae1ff7c47bf14dcb97a312c0
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE             COMMAND             CREATED         STATUS         PORTS     NAMES
6c1c1d294e5d   100000cpudocker   "./100000_cpu.sh"   5 seconds ago   Up 4 seconds             frosty_jang
(base) sumit@Sumits-MacBook-Air ~ % docker logs -f frosty_jang > 2_2_100000_cpuresult.log
```

Iteration	Screenshot
1	(base) sumit@Sumits-MacBook-Air ~ % cat 2_2_100000_cpuresult.log sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 100000 Initializing worker threads... Threads started! CPU speed: events per second: 290.32 General statistics: total time: 30.0026s total number of events: 8711 Latency (ms): min: 3.37 avg: 3.44 max: 14.49 95th percentile: 3.49 sum: 29965.81 Threads fairness: events (avg/stddev): 8711.0000/0.00 execution time (avg/stddev): 29.9658/0.00

2	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 100000 Initializing worker threads... Threads started! CPU speed: events per second: 290.33 General statistics: total time: 30.0013s total number of events: 8711 Latency (ms): min: 3.37 avg: 3.44 max: 5.10 95th percentile: 3.49 sum: 29969.05 Threads fairness: events (avg/stddev): 8711.0000/0.00 execution time (avg/stddev): 29.9691/0.00
3	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 100000 Initializing worker threads... Threads started! CPU speed: events per second: 288.77 General statistics: total time: 30.0040s total number of events: 8665 Latency (ms): min: 3.37 avg: 3.46 max: 15.23 95th percentile: 3.49 sum: 29947.63 Threads fairness: events (avg/stddev): 8665.0000/0.00 execution time (avg/stddev): 29.9476/0.00

4	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 100000 Initializing worker threads... Threads started! CPU speed: events per second: 289.91 General statistics: total time: 30.0007s total number of events: 8698 Latency (ms): min: 3.37 avg: 3.44 max: 18.62 95th percentile: 3.49 sum: 29951.10 Threads fairness: events (avg/stddev): 8698.0000/0.00 execution time (avg/stddev): 29.9511/0.00
5	 sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3) Running the test with following options: Number of threads: 1 Initializing random number generator from current time Prime numbers limit: 100000 Initializing worker threads... Threads started! CPU speed: events per second: 290.64 General statistics: total time: 30.0061s total number of events: 8722 Latency (ms): min: 3.38 avg: 3.44 max: 7.97 95th percentile: 3.49 sum: 29970.61 Threads fairness: events (avg/stddev): 8722.0000/0.00 execution time (avg/stddev): 29.9706/0.00

Detailed report:

Iteration No	Events per second
1	290.32
2	290.33
3	288.77
4	289.91
5	290.64

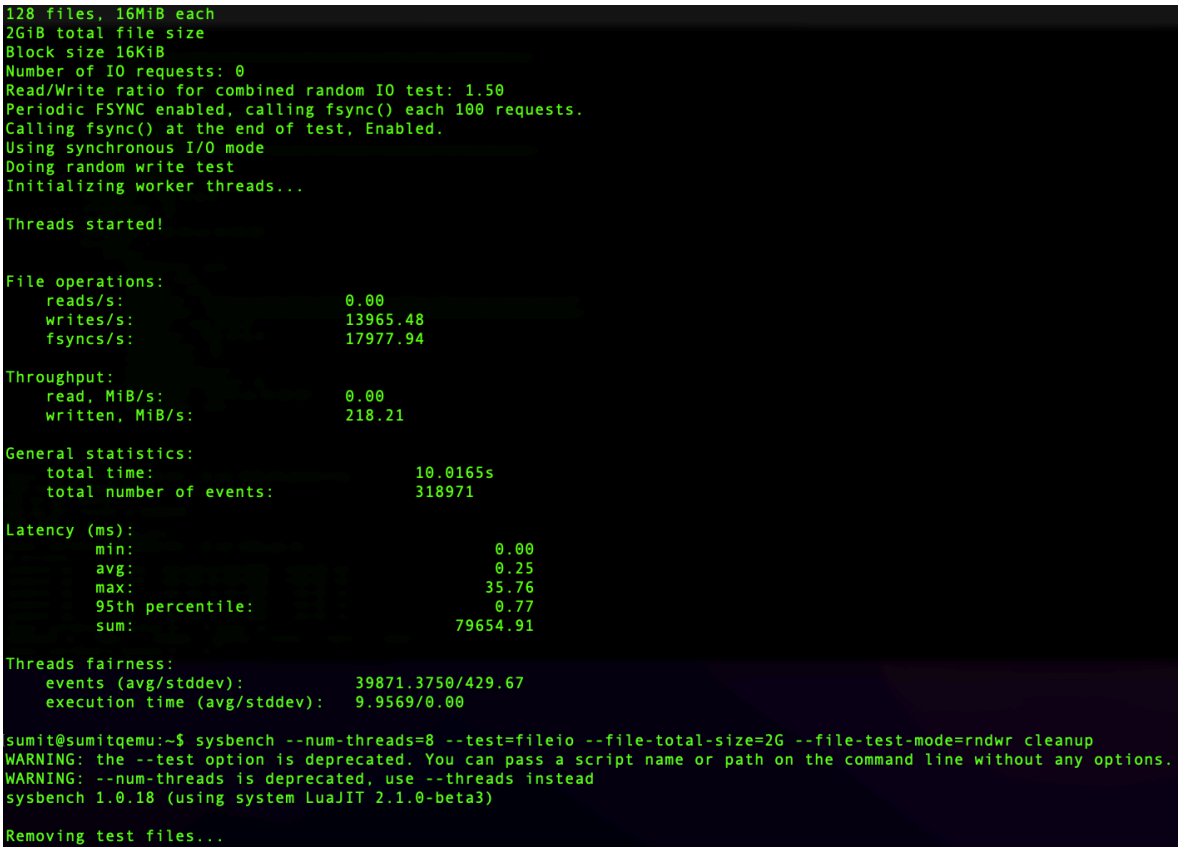
Observations:

Average events per second	289.994
Minimum Number of events per second recorded	288.77
Maximum Number of events per second recorded	290.64

Conclusion: As we can see, increasing the cpu-max-prime argument value reduces the no. of events/second for our current experimental configuration. QEMU is slightly faster than the Docker but the overall result is very close.

1.2 FILE I/O Testing

QEMU Results for 2 GB 2 cores for Combined random read/write (rndrw)



Iteration	Results
1	reads/s: 0.00 writes/s: 13965.48 fsyncs/s: 17977.94
2	reads/s: 0.00 writes/s: 15485.85 fsyncs/s: 19915.19
3	reads/s: 0.00 writes/s: 13610.93 fsyncs/s: 17516.29
4	reads/s: 0.00 writes/s: 12708.62 fsyncs/s: 16357.61
5	reads/s: 0.00 writes/s: 14108.83 fsyncs/s: 18155.79

Docker Results for 2 GB 2 cores for Combined random read/write (rndrw)

Iteration	Results
1	reads/s: 0.00 writes/s: 13146.47 fsyncs/s: 16925.64
2	reads/s: 0.00 writes/s: 13246.90 fsyncs/s: 17053.29
3	reads/s: 0.00 writes/s: 11504.98 fsyncs/s: 14820.90
4	reads/s: 0.00 writes/s: 12673.63 fsyncs/s: 16312.28
5	reads/s: 0.00 writes/s: 13016.04 fsyncs/s: 16755.58

Conclusion: As we see, QEMU is faster than the docker desktop

2. Configuration 2: 3 GB RAM with 3 Cores

```
(base) sumit@Sumits-MacBook-Air qemu % /opt/homebrew/bin/qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 3072 -smp 3 \
-drive file=/opt/homebrew/Cellar/qemu/7.2.0/share/qemu/edk2-aarch64-code.fd,if=pflash,format=raw,readonly=on \
-drive if=none,file=ubuntu.img,format=qcow2,id=hd0 \
-device virtio-blk-device,drive=hd0,serial="dummyserial" \
-device virtio-net-device,netdev=net0 \
-netdev user,id=net0 \
-vga none -device ramfb \
-device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic
```

2.1 CPU Testing

QEMU Results for 3 GB 3 cores for max-prime = 1000 and time = 30 seconds
Screenshot

```
sumit@sumitqemu:~$ ./1000_cpu.sh
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 1000

Initializing worker threads...

Threads started!

CPU speed:
    events per second: 340901.54

General statistics:
    total time:                          30.0009s
    total number of events:              10228006

Latency (ms):
         min:                                    0.00
         avg:                                    0.00
         max:                                    4.78
         95th percentile:                        0.00
         sum:                                29207.12

Threads fairness:
    events (avg/stddev):           10228006.0000/0.00
    execution time (avg/stddev):   29.2071/0.00
```

Detailed report:

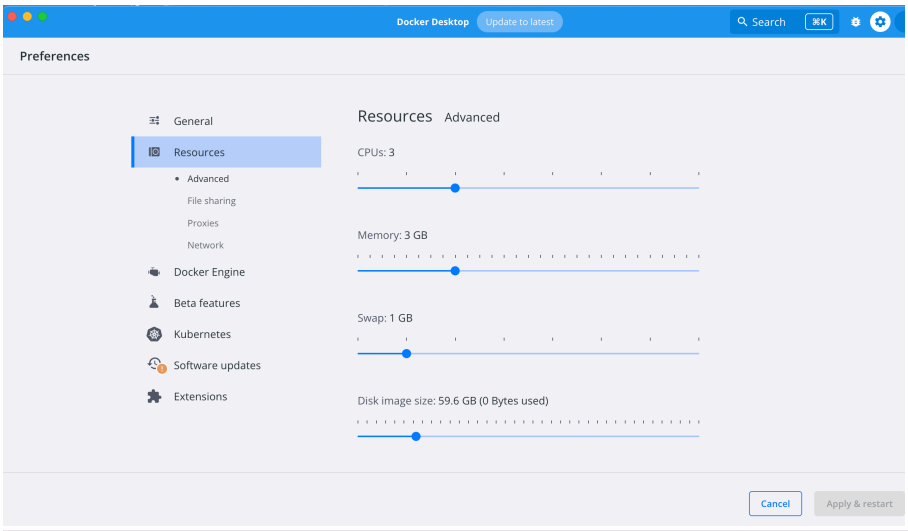
Iteration No	Events per second
1	340901.54
2	336953.57
3	333870.77

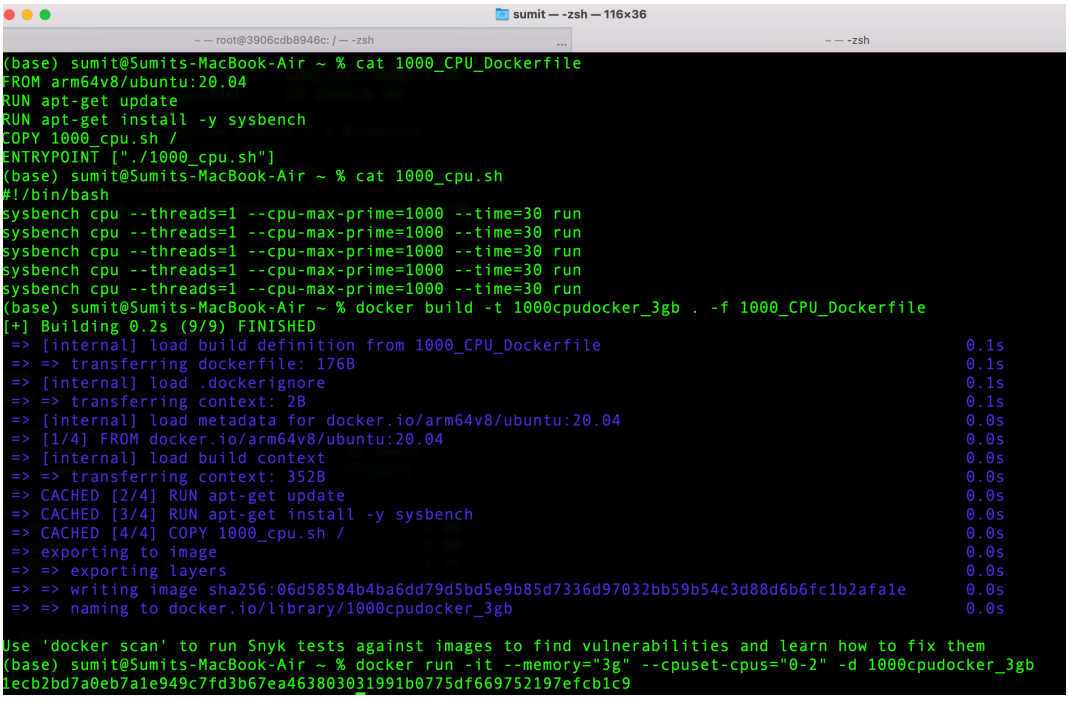
4	334280.58
5	333166.36

Observations:

Average events per second	334203.858
Minimum Number of events per second recorded	333166.36
Maximum Number of events per second recorded	340901.54

Docker results for 3 GB 3 cores for max-prime = 1000 and time = 30 seconds





```
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE              COMMAND          CREATED             STATUS             PORTS     NAMES
1ecb2bd7a0eb   1000cpudocker_3gb   "./1000_cpu.sh"   About a minute ago   Up About a minute            sweet_shockley
(base) sumit@Sumits-MacBook-Air ~ % docker logs -f sweet_shockley > 3_3_cpu1000.log
(base) sumit@Sumits-MacBook-Air ~ % cat 3_3_cpu1000.log
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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

```
(base) sumit@Sumits-MacBook-Air ~ % docker inspect 1ecb2bd7a0eb
[
    {
        "Id": "1ecb2bd7a0eb7a1e949c7fd3b67ea463803031991b0775df669752197efcb1c9",
        "Created": "2023-02-02T20:50:05.070517011Z",
        "Path": "./1000_cpu.sh",
        "Args": [],
        "State": {
            "Status": "exited",
            "Running": false,
            "Paused": false,
            "Restarting": false,
            "OOMKilled": false,
            "Dead": false,
            "Pid": 0,
            "ExitCode": 0,
            "Error": "",
            "StartedAt": "2023-02-02T20:50:05.550347803Z",
            "FinishedAt": "2023-02-02T20:52:35.686180969Z"
        },
        "Image": "sha256:06d58584b4ba6dd79d5bd5e9b85d7336d97032bb59b54c3d88d6b6fc1b2afa1e",
```

```
            ],
            "Isolation": "",
            "CpuShares": 0,
            "Memory": 3221225472,
            "NanoCpus": 0,
            "CgroupParent": "",
            "BlkioWeight": 0,
            "BlkioWeightDevice": [],
            "BlkioDeviceReadBps": null,
            "BlkioDeviceWriteBps": null,
            "BlkioDeviceReadIOps": null,
            "BlkioDeviceWriteIOps": null,
            "CpuPeriod": 0,
            "CpuQuota": 0,
            "CpuRealtimePeriod": 0,
            "CpuRealtimeRuntime": 0,
            "CpusetCpus": "0-2",
            "CpusetMems": "",
            "Devices": [],
            "DeviceCgroupRules": null,
            "DeviceRequests": null,
```

Screenshot

```
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 1000

Initializing worker threads...

Threads started!

CPU speed:
    events per second: 331730.09

General statistics:
    total time:                          30.0008s
    total number of events:              9952546

Latency (ms):
         min:                                    0.00
         avg:                                    0.00
         max:                                   11.36
         95th percentile:                        0.00
         sum:                                29201.06

Threads fairness:
    events (avg/stddev):           9952546.0000/0.00
    execution time (avg/stddev):   29.2011/0.00
```

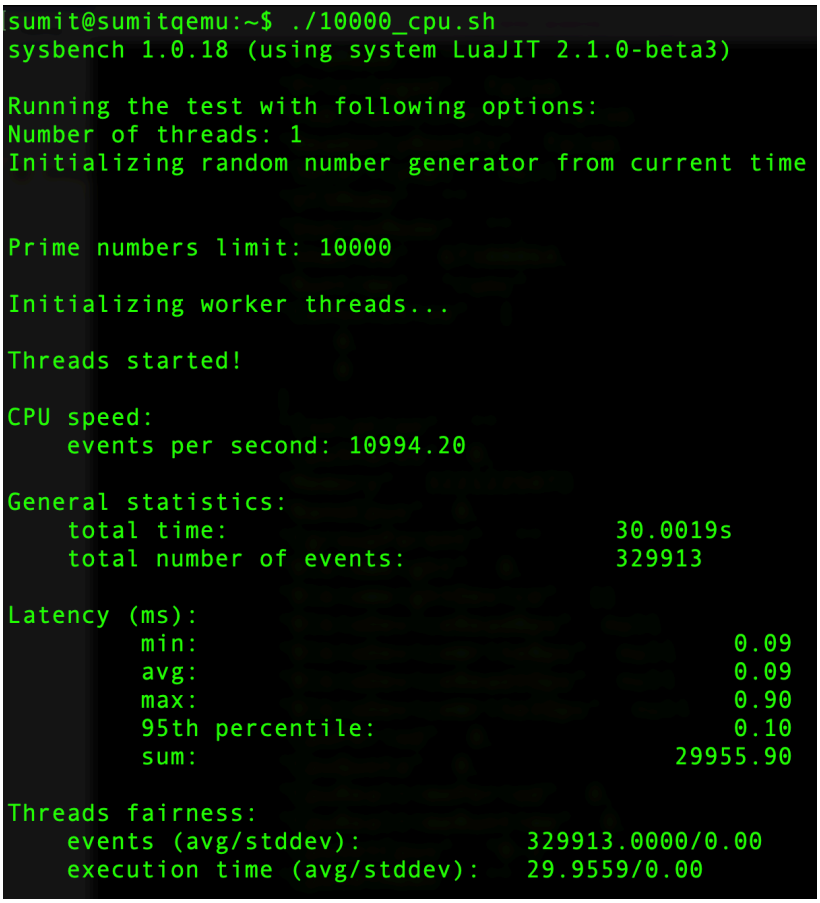
Detailed report:

Iteration No	Events per second
1	331730.09
2	335519.61
3	332949.22
4	331667.16
5	333345.60

Observations:

Average events per second	333042.336
Minimum Number of events per second recorded	331667.16
Maximum Number of events per second recorded	335519.61

QEMU Results for 3 GB 3 cores for max-prime = 10000 and time = 30 seconds
Screenshot



Detailed report:

Iteration No	Events per second
1	10994.20
2	10931.65
3	10983.04
4	10895.02
5	10911.60

Observations:

Average events per second	10943.102
Minimum Number of events per second recorded	10895.02
Maximum Number of events per second recorded	10994.20

Docker Results for 3 GB 3 cores for max-prime = 10000 and time = 30 seconds

```
(base) sumit@Sumits-MacBook-Air ~ % cat 10000_CPU_Dockerfile
FROM arm64v8/ubuntu:20.04
RUN apt-get update
RUN apt-get install -y sysbench
COPY 10000_cpu.sh /
ENTRYPOINT ["./10000_cpu.sh"]
(base) sumit@Sumits-MacBook-Air ~ % cat 10000_cpu.sh
#!/bin/bash
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
```

```
(base) sumit@Sumits-MacBook-Air ~ % docker build -t 10000cpudocker_3gb . -f 10000_CPU_Dockerfile
[+] Building 0.2s (9/9) FINISHED
 => [internal] load build definition from 10000_CPU_Dockerfile                                0.1s
 => => transferring dockerfile: 179B                                                          0.1s
 => [internal] load .dockerignore                                                             0.1s
 => => transferring context: 2B                                                               0.1s
 => [internal] load metadata for docker.io/arm64v8/ubuntu:20.04                               0.0s
 => [internal] load build context                                                             0.0s
 => => transferring context: 358B                                                             0.0s
 => [1/4] FROM docker.io/arm64v8/ubuntu:20.04                                                 0.0s
 => CACHED [2/4] RUN apt-get update                                                           0.0s
 => CACHED [3/4] RUN apt-get install -y sysbench                                              0.0s
 => CACHED [4/4] COPY 10000_cpu.sh /                                                          0.0s
 => exporting to image                                                                        0.0s
 => => exporting layers                                                                       0.0s
 => => writing image sha256:9a9867686617e7f4a6ad822a8511e6d7565b3ccbfcaf0139dff26c78120c26f1  0.0s
 => => naming to docker.io/library/10000cpudocker_3gb                                         0.0s

Use 'docker scan' to run Snyk tests against images to find vulnerabilities and learn how to fix them
(base) sumit@Sumits-MacBook-Air ~ % docker run -it --memory="3g" --cpuset-cpus="0-2" -d 10000cpudocker_3gb
aef7d9a7cb7e145f8cc8daa27571f781344fa6346cc976cfa99364a8b11ca669
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE              COMMAND           CREATED          STATUS         PORTS     NAMES
aef7d9a7cb7e   10000cpudocker_3gb   "./10000_cpu.sh"   11 seconds ago   Up 9 seconds             adoring_payne
(base) sumit@Sumits-MacBook-Air ~ % docker logs -f adoring_payne > 3_3_cpu10000.log
(base) sumit@Sumits-MacBook-Air ~ % cat 3_3_cpu10000.log
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
```

Screenshot

```
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 10000

Initializing worker threads...

Threads started!

CPU speed:
    events per second: 10945.48

General statistics:
    total time:                          30.0005s
    total number of events:              328381

Latency (ms):
         min:                                    0.09
         avg:                                    0.09
         max:                                    6.07
         95th percentile:                        0.10
         sum:                                29964.14

Threads fairness:
    events (avg/stddev):           328381.0000/0.00
    execution time (avg/stddev):   29.9641/0.00
```

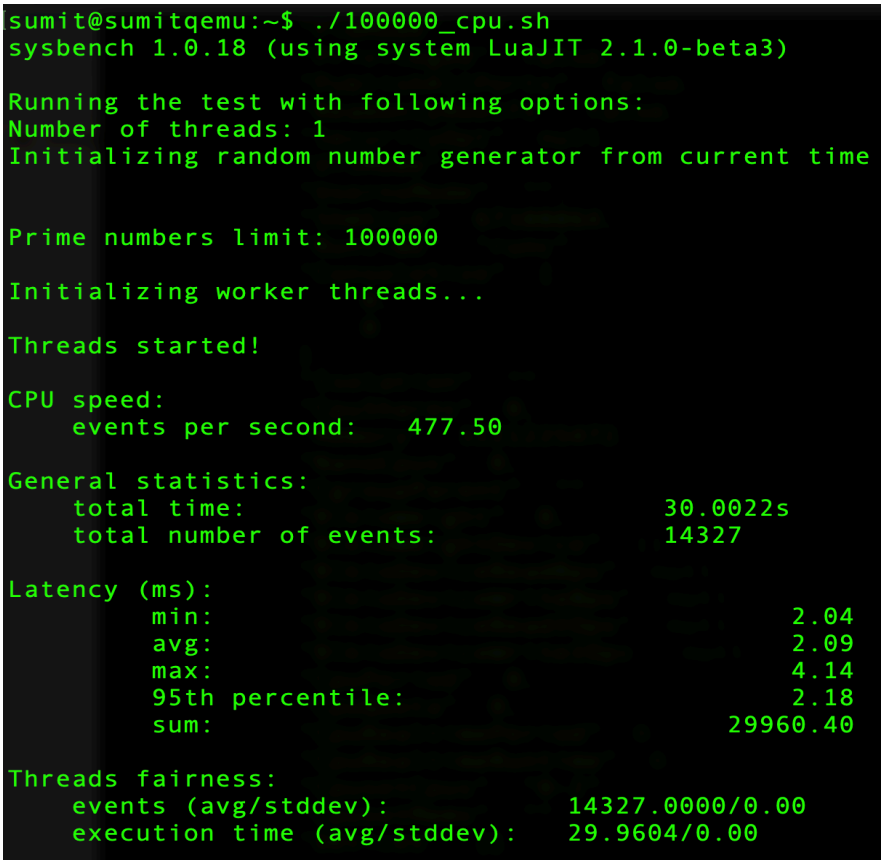
Detailed report:

Iteration No	Events per second
1	10945.48
2	10942.04
3	10981.41
4	10868.70
5	10959.65

Observations:

Average events per second	10939.456
Minimum Number of events per second recorded	10868.70
Maximum Number of events per second recorded	10981.41

QEMU Results for 3 GB 3 cores for max-prime = 100000 and time = 30 seconds
Screenshot



Detailed report:

Iteration No	Events per second
1	477.50
2	475.11
3	475.29
4	472.13
5	475.37

Observations:

Average events per second	475.08
Minimum Number of events per second recorded	472.13
Maximum Number of events per second recorded	477.50

Docker Results for 3 GB 3 cores for max-prime = 100000 and time = 30 seconds

```
(base) sumit@Sumits-MacBook-Air ~ % cat 100000_CPU_Dockerfile
FROM arm64v8/ubuntu:20.04
RUN apt-get update
RUN apt-get install -y sysbench
COPY 100000_cpu.sh /
ENTRYPOINT ["./100000_cpu.sh"]
(base) sumit@Sumits-MacBook-Air ~ % cat 100000_cpu.sh
#!/bin/bash
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=100000 --time=30 run
(base) sumit@Sumits-MacBook-Air ~ % docker build -t 100000cpudocker_3gb . -f 100000_CPU_Dockerfile
[+] Building 0.1s (9/9) FINISHED
 => [internal] load build definition from 100000_CPU_Dockerfile
 => => transferring dockerfile: 184B
 => [internal] load .dockerignore
 => => transferring context: 2B
 => [internal] load metadata for docker.io/arm64v8/ubuntu:20.04
 => [internal] load build context
 => => transferring context: 364B
 => [1/4] FROM docker.io/arm64v8/ubuntu:20.04
 => CACHED [2/4] RUN apt-get update
 => CACHED [3/4] RUN apt-get install -y sysbench
 => CACHED [4/4] COPY 100000_cpu.sh /
 => exporting to image
 => => exporting layers
 => => writing image sha256:3e9a4bf1e4e1192c9aaa2e466d45ca8b783385d45296a2dd9e3f71b656a0ba32
 => => naming to docker.io/library/100000cpudocker_3gb

Use 'docker scan' to run Snyk tests against images to find vulnerabilities and learn how to fix them
(base) sumit@Sumits-MacBook-Air ~ % docker run -it --memory="3g" --cpuset-cpus="0-2" -d 100000cpudocker_3gb
9898aaaa26d8a9875395192bef104905d67b8aaf09ab18bbb962fe8777789257
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE                COMMAND            CREATED         STATUS         PORTS     NAMES
9898aaaa26d8   100000cpudocker_3gb   "./100000_cpu.sh"   3 seconds ago   Up 3 seconds             cranky_khayyam
(base) sumit@Sumits-MacBook-Air ~ % docker logs -f cranky>khayyam > 3_3_cpu100000.log
Error: No such container: cranky
(base) sumit@Sumits-MacBook-Air ~ % docker logs -f cranky_khayyam > 3_3_cpu100000.log
```

Screenshot

```
(base) sumit@Sumits-MacBook-Air ~ % cat 3_3_cpu100000.log
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 100000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:   473.65

General statistics:
    total time:                          30.0011s
    total number of events:              14211

Latency (ms):
         min:                                    2.05
         avg:                                    2.11
         max:                                    3.90
         95th percentile:                        2.18
         sum:                                29968.05

Threads fairness:
    events (avg/stddev):           14211.0000/0.00
    execution time (avg/stddev):   29.9680/0.00
```

Detailed report:

Iteration No	Events per second
1	473.65
2	473.98
3	476.43
4	468.36
5	475.49

observations:

Average events per second	473.582
Minimum Number of events per second recorded	468.36
Maximum Number of events per second recorded	476.43

Conclusion: In terms of CPU performance, QEMU continues to outperform Docker Desktop. We notice that increasing the system configuration has no major effect on performance.

2.2 FILE I/O Testing

QEMU Results for 3 GB 3 cores for Combined random read/write (rndrw)

```
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      0.00
    writes/s:                     14329.82
    fsyncs/s:                     18409.85

Throughput:
    read, MiB/s:                  0.00
    written, MiB/s:               223.90

General statistics:
    total time:                          30.0344s
    total number of events:              981297

Latency (ms):
         min:                                    0.00
         avg:                                    0.49
         max:                                   69.30
         95th percentile:                        1.52
         sum:                               479067.75

Threads fairness:
    events (avg/stddev):           61331.0625/477.57
    execution time (avg/stddev):   29.9417/0.00
```

Iteration	Results
1	reads/s: 0.00 writes/s: 14329.82 fsyncs/s: 18409.85
2	reads/s: 0.00 writes/s: 14139.47 fsyncs/s: 18165.80

3	reads/s: 0.00 writes/s: 14532.74 fsyncs/s: 18668.68
4	reads/s: 0.00 writes/s: 13995.19 fsyncs/s: 17850.40
5	reads/s: 0.00 writes/s: 14317.42 fsyncs/s: 18228.44

Docker Results for 3 GB 3 cores for Combined random read/write (rndrw)

```
3GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      0.00
    writes/s:                     13675.22
    fsyncs/s:                     17570.21

Throughput:
    read, MiB/s:                  0.00
    written, MiB/s:               213.68

General statistics:
    total time:                          30.0458s
    total number of events:              936785

Latency (ms):
         min:                                    0.00
         avg:                                    0.51
         max:                                  100.68
         95th percentile:                        1.58
         sum:                               479062.16

Threads fairness:
    events (avg/stddev):           58549.0625/617.58
    execution time (avg/stddev):   29.9414/0.00
```

Iteration	Results
1	reads/s: 0.00 writes/s: 13675.22 fsyncs/s: 17570.21
2	reads/s: 0.00 writes/s: 14518.05 fsyncs/s: 18650.54

3	reads/s: 0.00 writes/s: 13791.48 fsyncs/s: 17717.81
4	reads/s: 0.00 writes/s: 12034.29 fsyncs/s: 15468.43
5	reads/s: 0.00 writes/s: 10943.55 fsyncs/s: 14073.20

Conclusion: When compared to previous experiment configurations, we can observe that result are very similar.

---

3. Configuration 3 : 3 GB RAM with 6 Cores

3.1 CPU Testing

QEMU results for 3 GB 6 cores for max-prime = 1000 and time = 30 seconds
Screenshot

```
(base) sumit@Sumits-MacBook-Air ~ % cd Desktop/Winter2023/Cloud\ computing/qemu
(base) sumit@Sumits-MacBook-Air qemu % /opt/homebrew/bin/qemu-system-aarch64 \
-accel hvf -cpu cortex-a57 -M virt,highmem=off -m 3072 -smp 6 \
-drive file=/opt/homebrew/Cellar/qemu/7.2.0/share/qemu/edk2-aarch64-code.fd,if=pflash,format=raw,readonly=on \
-drive if=none,file=ubuntu.img,format=qcow2,id=hd0 \
-device virtio-blk-device,drive=hd0,serial="dummyserial" \
-device virtio-net-device,netdev=net0 \
-netdev user,id=net0 \
-vga none -device ramfb \
-device usb-ehci -device usb-kbd -device usb-mouse -usb -nographic
```

```
sumit@sumitqemu:~$ ./1000_cpu.sh
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 1000

Initializing worker threads...

Threads started!

CPU speed:
    events per second: 206756.81

General statistics:
    total time:                          30.0017s
    total number of events:              6204108

Latency (ms):
         min:                                    0.00
         avg:                                    0.00
         max:                                   13.93
         95th percentile:                        0.00
         sum:                                29161.22

Threads fairness:
    events (avg/stddev):           6204108.0000/0.00
    execution time (avg/stddev):   29.1612/0.00
```

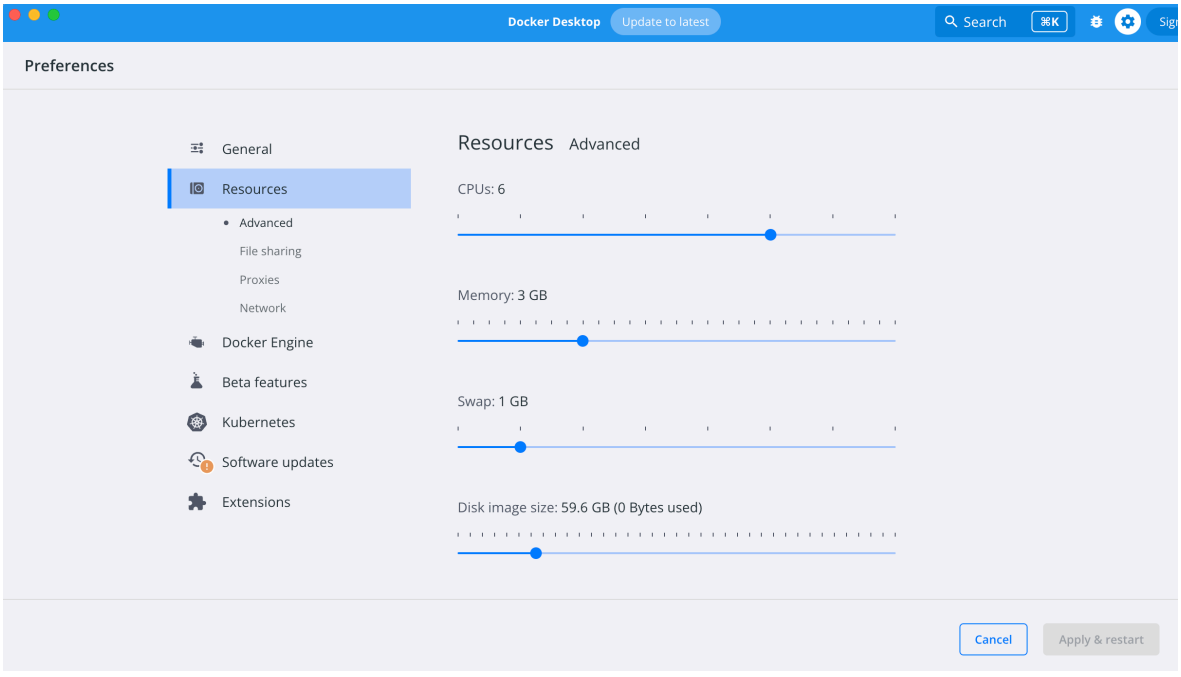
Detailed report:

Iteration No	Events per second
1	206756.81
2	202822.32
3	204940.54
4	206212.28
5	206690.08

observations:

Average events per second	205484.406
Minimum Number of events per second recorded	202822.32
Maximum Number of events per second recorded	206756.81

Docker Results for 3 GB 6 cores for max-prime = 1000 and time = 30 seconds
Screenshot



```
(base) sumit@Sumits-MacBook-Air ~ % cat 1000_CPU_Dockerfile
FROM arm64v8/ubuntu:20.04
RUN apt-get update
RUN apt-get install -y sysbench
COPY 1000_cpu.sh /
ENTRYPOINT ["./1000_cpu.sh"]
(base) sumit@Sumits-MacBook-Air ~ % cat 1000_cpu.sh
#!/bin/bash
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=1000 --time=30 run
(base) sumit@Sumits-MacBook-Air ~ %
```

```
(base) sumit@Sumits-MacBook-Air ~ % docker build -t 1000cpudocker_6 . -f 1000_CPU_Dockerfile
[+] Building 0.2s (9/9) FINISHED
 => [internal] load build definition from 1000_CPU_Dockerfile                                0.0s
 => => transferring dockerfile: 176B                                                         0.0s
 => [internal] load .dockerignore                                                            0.0s
 => => transferring context: 2B                                                              0.0s
 => [internal] load metadata for docker.io/arm64v8/ubuntu:20.04                              0.0s
 => [internal] load build context                                                            0.0s
 => => transferring context: 352B                                                            0.0s
 => [1/4] FROM docker.io/arm64v8/ubuntu:20.04                                                0.0s
 => CACHED [2/4] RUN apt-get update                                                          0.0s
 => CACHED [3/4] RUN apt-get install -y sysbench                                             0.0s
 => CACHED [4/4] COPY 1000_cpu.sh /                                                          0.0s
 => exporting to image                                                                       0.0s
 => => exporting layers                                                                      0.0s
 => => writing image sha256:06d58584b4ba6dd79d5bd5e9b85d7336d97032bb59b54c3d88d6b6fc1b2afa1e 0.0s
 => => naming to docker.io/library/1000cpudocker_6                                           0.0s

Use 'docker scan' to run Snyk tests against images to find vulnerabilities and learn how to fix them
(base) sumit@Sumits-MacBook-Air ~ % docker run -it --memory="3g" --cpuset-cpus="0-5" -d 1000_cpudocker_6
Unable to find image '1000_cpudocker_6:latest' locally
docker: Error response from daemon: pull access denied for 1000_cpudocker_6, repository does not exist or may require 'docker login': denied: requested access to the resource is denied.
See 'docker run --help'.
(base) sumit@Sumits-MacBook-Air ~ % docker run -it --memory="3g" --cpuset-cpus="0-5" -d 1000cpudocker_6
247f97799d091b395b4ee520af1ee10d9a65e6d1078a85e841f580fb5b76649e
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE             COMMAND          CREATED         STATUS         PORTS     NAMES
247f97799d09   1000cpudocker_6   "./1000_cpu.sh"   4 seconds ago   Up 3 seconds             blissful_blackburn
(base) sumit@Sumits-MacBook-Air ~ % docker logs -f blissful_blackburn > 3_6_cpu1000.log
```

```
(base) sumit@Sumits-MacBook-Air ~ % cat 3_6_cpu1000.log
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 1000

Initializing worker threads...

Threads started!

CPU speed:
    events per second: 204987.20

General statistics:
    total time:                          30.0006s
    total number of events:              6150021

Latency (ms):
         min:                                    0.00
         avg:                                    0.00
         max:                                    0.99
         95th percentile:                        0.00
         sum:                                29184.18

Threads fairness:
    events (avg/stddev):           6150021.0000/0.00
    execution time (avg/stddev):   29.1842/0.00
```

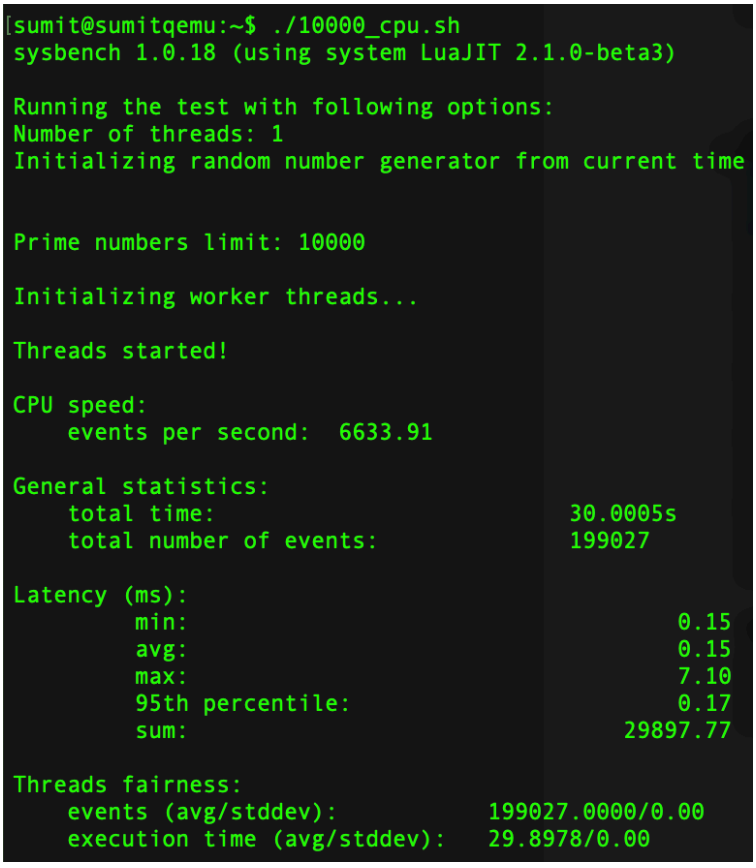
Detailed report:

Iteration No	Events per second
1	204987.20
2	205311.25
3	203469.36
4	203823.34
5	204282.94

observations:

Average events per second	204374.818
Minimum Number of events per second recorded	203469.36
Maximum Number of events per second recorded	204987.20

QEMU Results for 3 GB 6 cores for max-prime = 10000 and time = 30 seconds
Screenshot



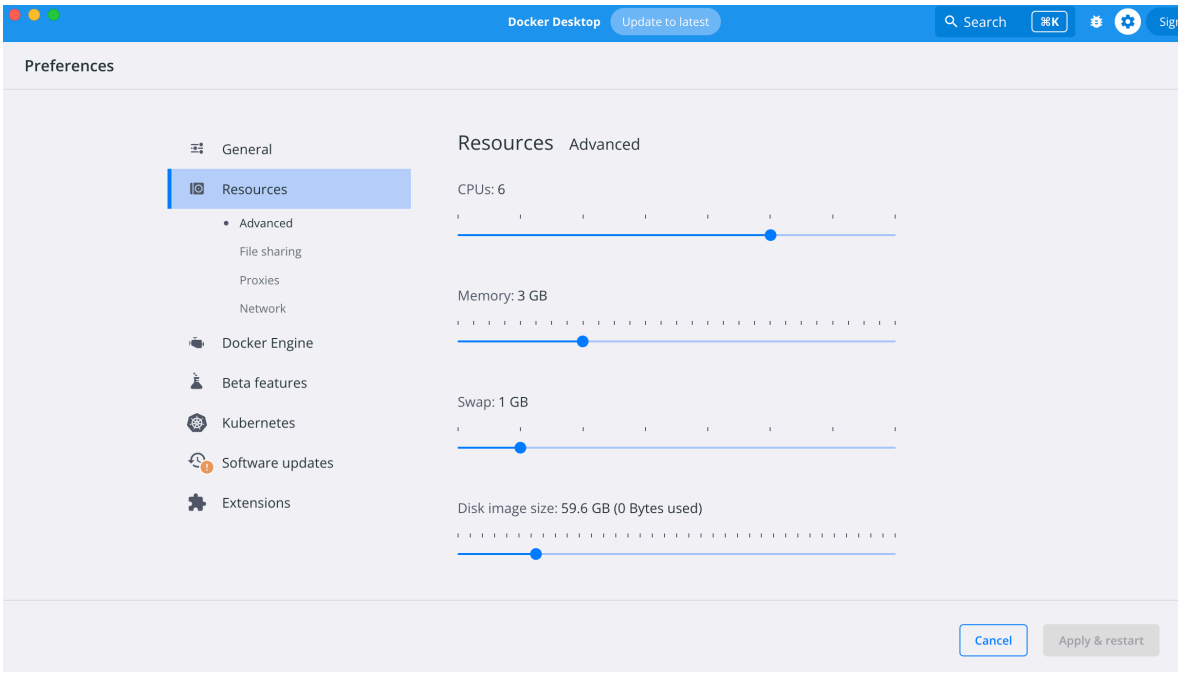
Detailed report:

Iteration No	Events per second
1	6633.91
2	6666.30
3	6678.28
4	6702.64
5	6662.45

observations:

Average events per second	6668.716
Minimum Number of events per second recorded	6633.91
Maximum Number of events per second recorded	6702.64

Docker results for 3 GB 6 cores for max-prime = 10000 and time = 30 seconds



```
(base) sumit@Sumits-MacBook-Air ~ % cat 10000_cpu.sh
#!/bin/bash
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
sysbench cpu --threads=1 --cpu-max-prime=10000 --time=30 run
(base) sumit@Sumits-MacBook-Air ~ % docker build -t 10000cpudocker_6 . -f 10000_CPU_Dockerfile
[+] Building 0.2s (9/9) FINISHED
 => [internal] load build definition from 10000_CPU_Dockerfile
 => => transferring dockerfile: 179B
 => [internal] load .dockerignore
 => => transferring context: 2B
 => [internal] load metadata for docker.io/arm64v8/ubuntu:20.04
 => [1/4] FROM docker.io/arm64v8/ubuntu:20.04
 => [internal] load build context
 => => transferring context: 358B
 => CACHED [2/4] RUN apt-get update
 => CACHED [3/4] RUN apt-get install -y sysbench
 => CACHED [4/4] COPY 10000_cpu.sh /
 => exporting to image
 => => exporting layers
 => => writing image sha256:9a9867686617e7f4a6ad822a8511e6d7565b3ccbfcaf0139dff26c78120c26f1
 => => naming to docker.io/library/10000cpudocker_6

Use 'docker scan' to run Snyk tests against images to find vulnerabilities and learn how to fix them
(base) sumit@Sumits-MacBook-Air ~ % docker run -it --memory="3g" --cpuset-cpus="0-5" -d 10000cpudocker_6
99f5ed63cc5f96ec05b1d7d7fe9d0bad9a8b7f63b7a62a54b980f9520bc0e091
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE              COMMAND           CREATED         STATUS         PORTS     NAMES
99f5ed63cc5f   10000cpudocker_6   "./10000_cpu.sh"   4 seconds ago   Up 3 seconds             quirky_cannon
```

```
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE              COMMAND           CREATED         STATUS         PORTS     NAMES
99f5ed63cc5f   10000cpudocker_6   "./10000_cpu.sh"   4 seconds ago   Up 3 seconds             quirky_cannon
(base) sumit@Sumits-MacBook-Air ~ % docker logs -f quirky_cannon > 3_6_cpu10000.log
(base) sumit@Sumits-MacBook-Air ~ % cat 3_6_cpu10000.log
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

Running the test with following options:
```

Screenshot

```
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 10000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:  6488.84

General statistics:
    total time:                          30.0010s
    total number of events:              194684

Latency (ms):
         min:                                    0.15
         avg:                                    0.15
         max:                                   20.59
         95th percentile:                        0.17
         sum:                                29934.68

Threads fairness:
    events (avg/stddev):           194684.0000/0.00
    execution time (avg/stddev):   29.9347/0.00
```

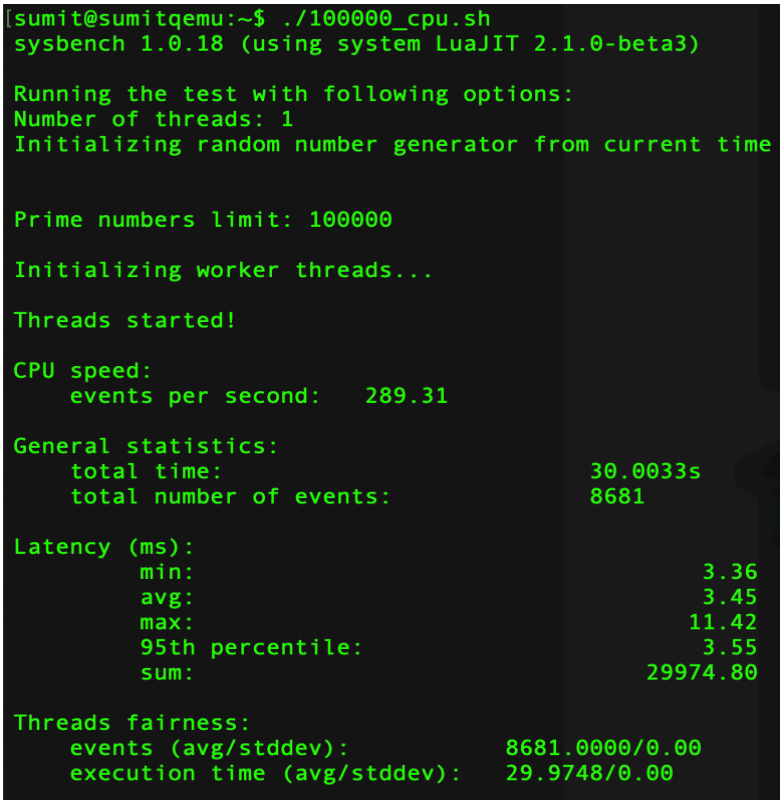
Detailed report:

Iteration No	Events per second
1	6488.84
2	6477.29
3	6627.75
4	6630.42
5	6617.29

observations:

Average events per second	6568.318
Minimum Number of events per second recorded	6477.29
Maximum Number of events per second recorded	6630.42

QEMU Results for 3 GB 6 cores for max-prime = 100000 and time = 30 seconds
Screenshot



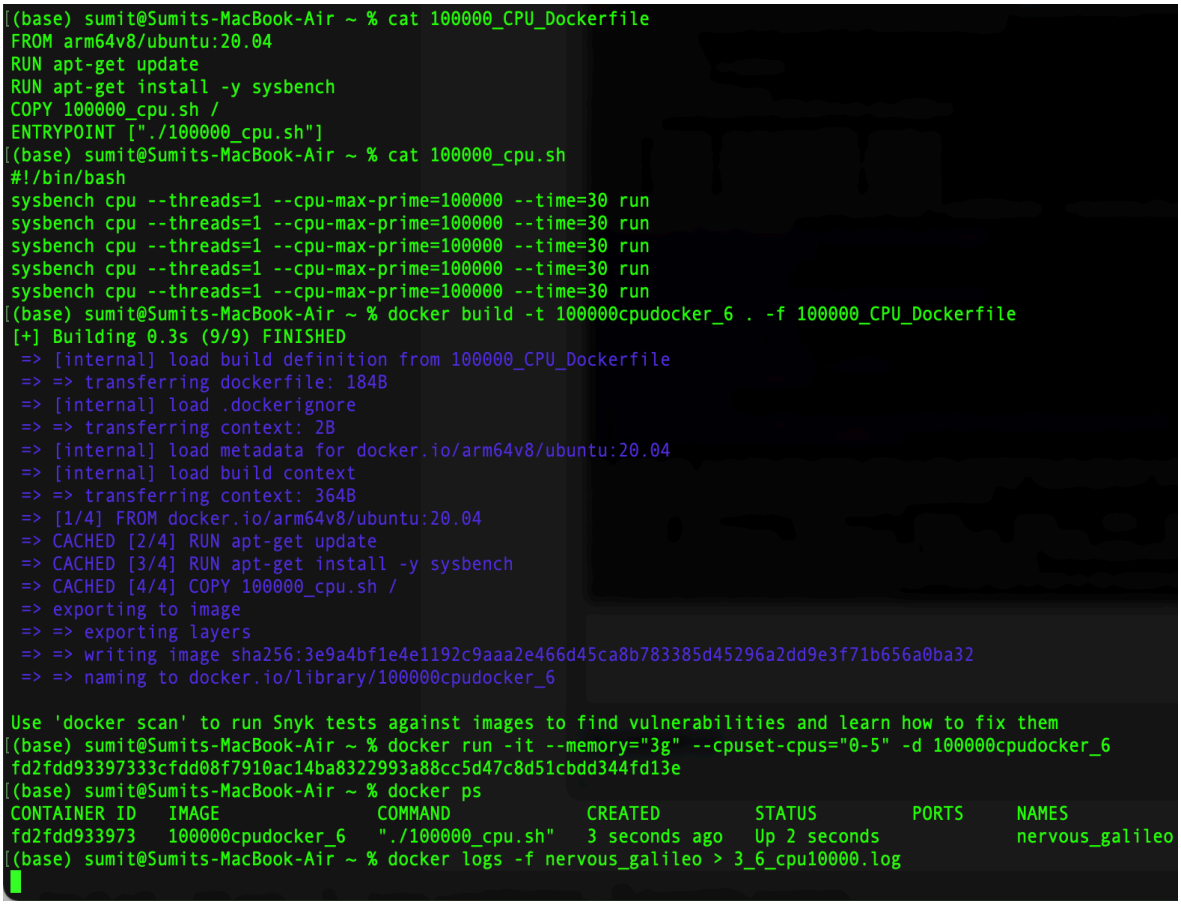
Detailed report:

Iteration No	Events per second
1	289.31
2	289.84
3	290.23
4	290.01
5	291.77

observations:

Average events per second	290.232
Minimum Number of events per second recorded	291.77
Maximum Number of events per second recorded	289.31

Docker results for 3 GB 6 cores for max-prime = 100000 and time = 30 seconds



Screenshot

```
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 100000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:   289.17

General statistics:
    total time:                          30.0015s
    total number of events:              8676

Latency (ms):
         min:                                    3.37
         avg:                                    3.46
         max:                                    7.17
         95th percentile:                        3.49
         sum:                                29983.72

Threads fairness:
    events (avg/stddev):           8676.0000/0.00
    execution time (avg/stddev):   29.9837/0.00
```

Detailed report:

Iteration No	Events per second
1	289.17
2	286.87
3	283.76
4	288.26
5	288.80

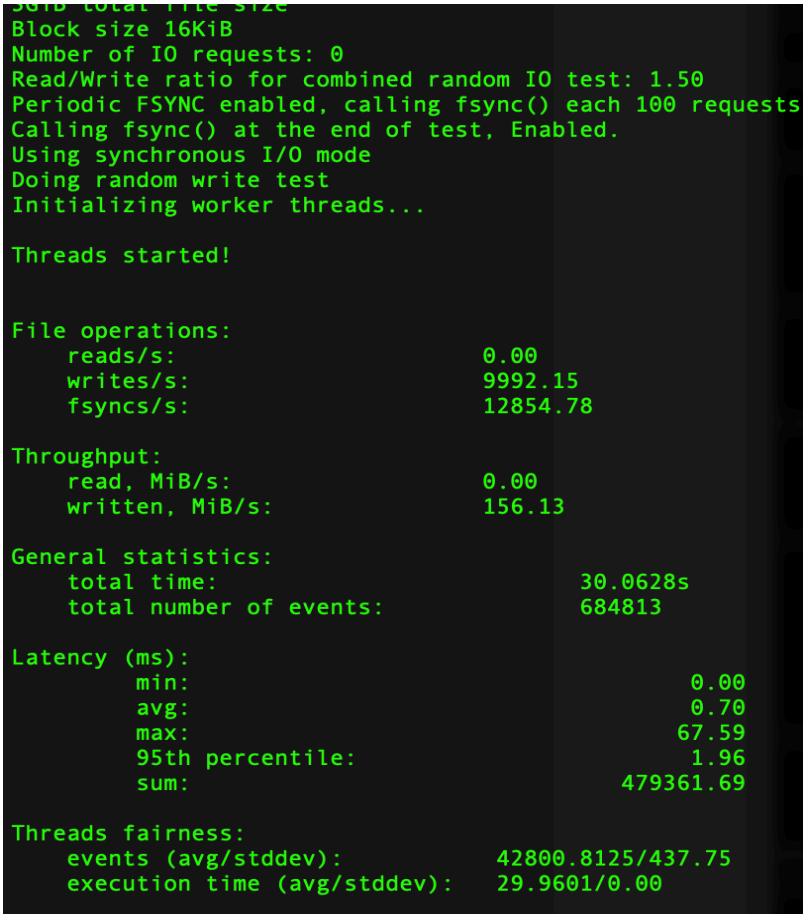
observations:

Average events per second	287.372
Minimum Number of events per second recorded	283.76
Maximum Number of events per second recorded	289.17

Conclusion: Even after changing the configuration and increasing the resource, there is no major difference in performance for Docker and QEMU. QEMU is performing slightly better than Docker.

3.2 FILE I/O Testing

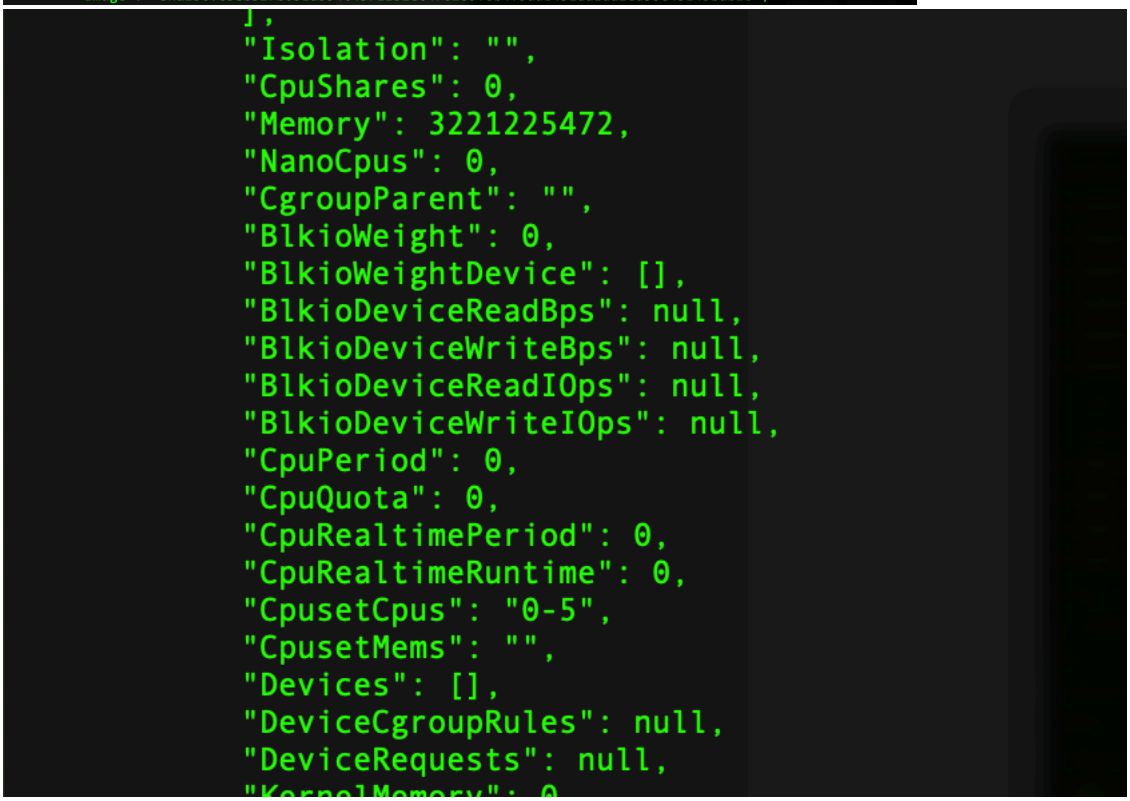
QEMU Results for 3 GB 6 cores for Combined random read/write (rndrw)



Iteration	Results
1	reads/s: 0.00 writes/s: 9992.15 fsyncs/s: 12854.78
2	reads/s: 0.00 writes/s: 9658.93 fsyncs/s: 12429.61
3	reads/s: 0.00 writes/s: 8924.33 fsyncs/s: 11487.49
4	reads/s: 0.00 writes/s: 9860.38 fsyncs/s: 12686.89
5	reads/s: 0.00 writes/s: 9674.05 fsyncs/s: 12448.82

Docker Results for 3 GB 6 cores for Combined random read/write (rndrw)

```
(base) sumit@Sumits-MacBook-Air ~ % docker images
REPOSITORY            TAG       IMAGE ID       CREATED         SIZE
100000cpudocker       latest    3e9a4bf1e4e1   14 hours ago    116MB
100000cpudocker_3gb   latest    3e9a4bf1e4e1   14 hours ago    116MB
100000cpudocker_6     latest    3e9a4bf1e4e1   14 hours ago    116MB
10000cpudocker_6      latest    9a9867686617   15 hours ago    116MB
10000cpudocker        latest    9a9867686617   15 hours ago    116MB
10000cpudocker_3gb    latest    9a9867686617   15 hours ago    116MB
<none>                <none>    cb211e545529   15 hours ago    116MB
<none>                <none>    276b5558b578   15 hours ago    116MB
1000cpudocker1        latest    06d58584b4ba   15 hours ago    116MB
1000cpudocker_3gb     latest    06d58584b4ba   15 hours ago    116MB
1000cpudocker_6       latest    06d58584b4ba   15 hours ago    116MB
1000cpudocker         latest    7ad29dcc6c7a   16 hours ago    116MB
new_docker_image      latest    4ffcb1d09133   17 hours ago    65.7MB
arm64v8/ubuntu        20.04     c9eb527b091d   36 hours ago    65.7MB
hello-world           latest    46331d942d63   10 months ago   9.14kB
(base) sumit@Sumits-MacBook-Air ~ % docker run -it --memory="3g" --cpuset-cpus="0-5" -d arm64v8/ubuntu:20.04
b82ceef4c50d5c9b27f38f9c982cb7636428547ed242f77036c01e6256405768
(base) sumit@Sumits-MacBook-Air ~ % docker ps
CONTAINER ID   IMAGE                  COMMAND       CREATED         STATUS         PORTS     NAMES
b82ceef4c50d   arm64v8/ubuntu:20.04   "/bin/bash"   7 seconds ago   Up 6 seconds             vigorous_newton
(base) sumit@Sumits-MacBook-Air ~ % docker inspect b82ceef4c50d
[
    {
        "Id": "b82ceef4c50d5c9b27f38f9c982cb7636428547ed242f77036c01e6256405768",
        "Created": "2023-02-02T23:48:30.906904511Z",
        "Path": "/bin/bash",
        "Args": [],
        "State": {
            "Status": "running",
            "Running": true,
            "Paused": false,
            "Restarting": false,
            "OOMKilled": false,
            "Dead": false,
            "Pid": 3129,
            "ExitCode": 0,
            "Error": "",
            "StartedAt": "2023-02-02T23:48:31.376306886Z",
            "FinishedAt": "0001-01-01T00:00:00Z"
        },
        "Image": "sha256:c9eb527b091d53464371291e6470289f0b4f9aab431da2da2ed35e43149bab2b",
```



```
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random write test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      0.00
    writes/s:                     7418.32
    fsyncs/s:                     9560.44

Throughput:
    read, MiB/s:                  0.00
    written, MiB/s:               115.91

General statistics:
    total time:                          30.1268s
    total number of events:              509490

Latency (ms):
         min:                                    0.00
         avg:                                    0.94
         max:                                  104.91
         95th percentile:                        2.76
         sum:                               479404.83

Threads fairness:
    events (avg/stddev):           31843.1250/516.16
    execution time (avg/stddev):   29.9628/0.00
```

Iteration	Results
1	reads/s: 0.00 writes/s: 7418.32 fsyncs/s: 9560.44
2	reads/s: 0.00 writes/s: 7408.39 fsyncs/s: 9548.02
3	reads/s: 0.00 writes/s: 7220.23 fsyncs/s: 9309.59
4	reads/s: 0.00 writes/s: 7310.45 fsyncs/s: 9421.63
5	reads/s: 0.00 writes/s: 6752.18 fsyncs/s: 8708.85

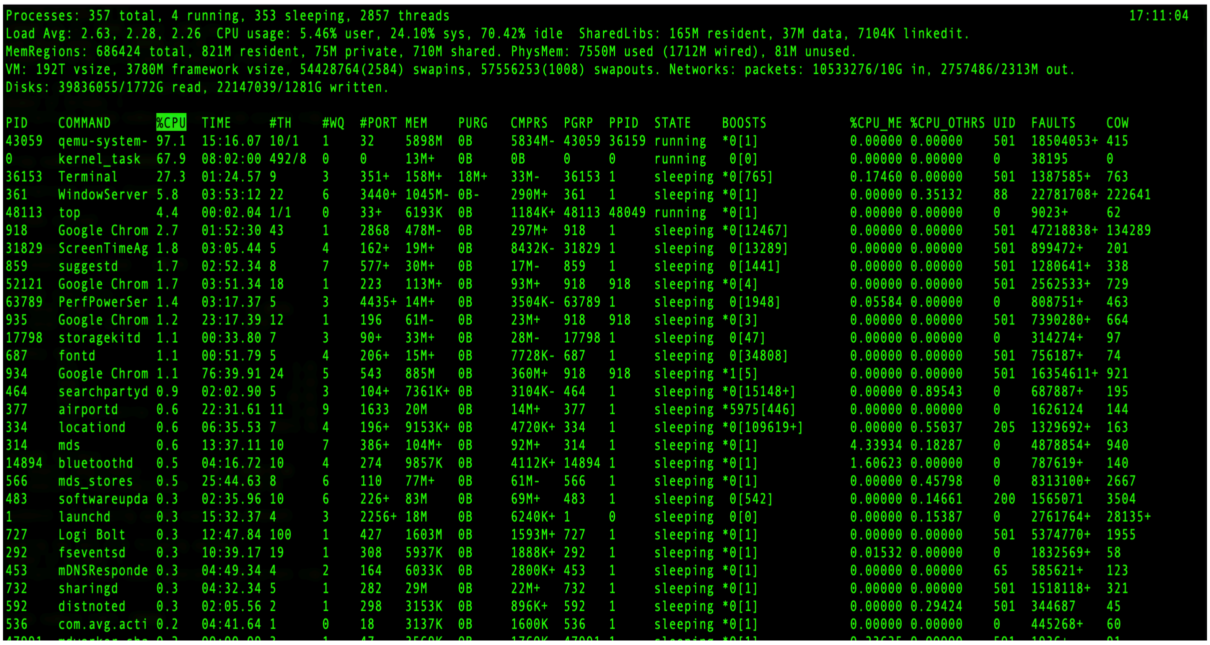
Conclusion: If we compare the results with the 3GB and 3 core settings then we can conclude the File I/O operations performed well.

Performance Analysis

In this section, we have listed out the disk and CPU utilization for both QEMU and docker desktop.

1. **QEMU Disk Utilization**

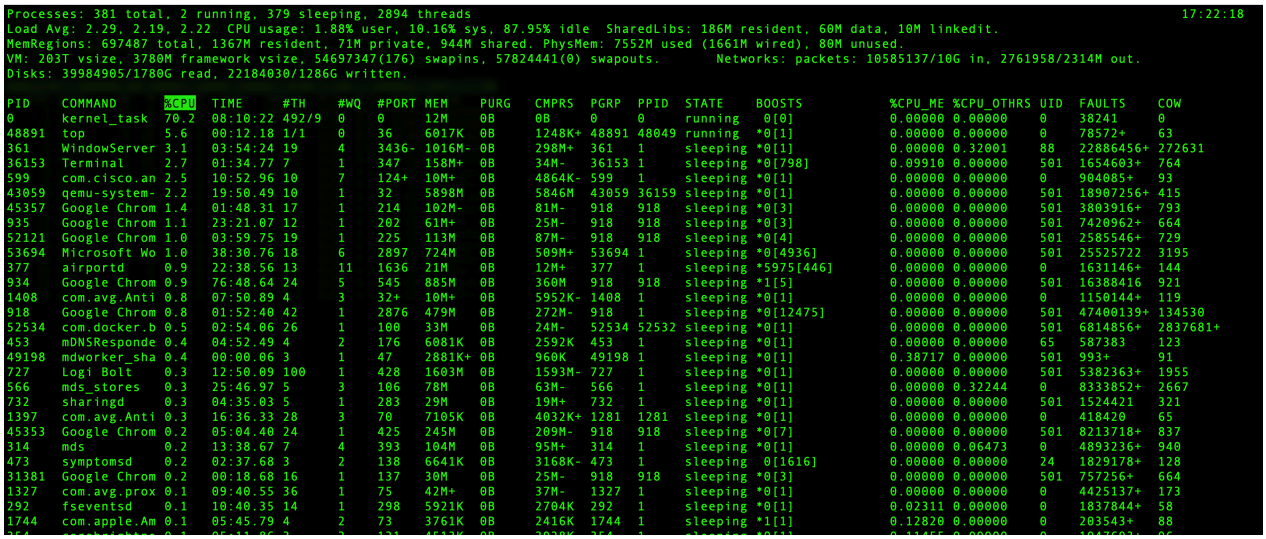
2 GB RAM 2 Cores	Random Read Write	written, MiB/s = 769.38
3 GB RAM 3 Cores	Random Read Write	written, MiB/s = 767.96
3 GB RAM 6 Cores	Random Read Write	written, MiB/s = 789.35

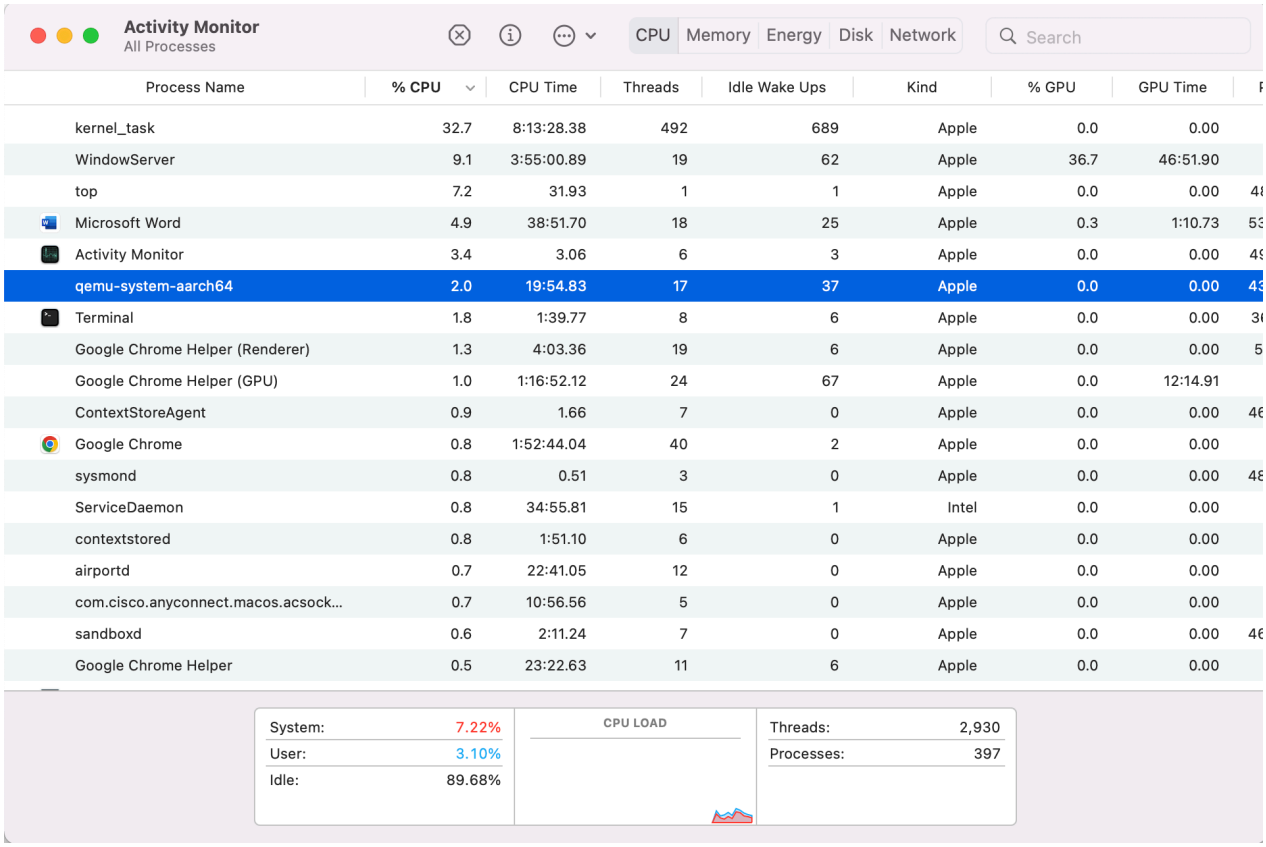


```
Processes: 357 total, 4 running, 353 sleeping, 2857 threads                                                          17:11:04
Load Avg: 2.63, 2.28, 2.26  CPU usage: 5.46% user, 24.10% sys, 70.42% idle  SharedLibs: 165M resident, 37M data, 7104K linkedit.
MemRegions: 686424 total, 821M resident, 75M private, 710M shared. PhysMem: 7550M used (1712M wired), 81M unused.
VM: 192T vsize, 3780M framework vsize, 54428764(2584) swapins, 57556253(1008) swapouts. Networks: packets: 10533276/10G in, 2757486/2313M out.
Disks: 39836055/1772G read, 22147039/1281G written.

PID    COMMAND      %CPU TIME     #TH   #WQ  #PORT MEM    PURG   CMPRS  PGRP  PPID  STATE    BOOSTS          %CPU_ME %CPU_OTHRS UID  FAULTS    COW
43059  qemu-system- 97.1 15:16.07 10/1  1    32    5898M  0B     5834M- 43059 36159 running  *0[1]           0.00000 0.00000    501  18504053+ 415
0      kernel_task  67.9 08:02:00 492/8 0    0     13M+   0B     0B     0     0     running   0[0]           0.00000 0.00000    0    38195     0
36153  Terminal     27.3 01:24.57 9     3    351+  158M+  18M+   33M-   36153 1     sleeping *0[765]         0.17460 0.00000    501  1387585+  763
361    WindowServer 5.8  03:53:12 22    6    3440+ 1045M- 0B-    290M+  361   1     sleeping *0[1]           0.00000 0.35132    88   22781708+ 222641
48113  top          4.4  00:02.04 1/1   0    33+   6193K  0B     1184K+ 48113 48049 running  *0[1]           0.00000 0.00000    0    9023+     62
918    Google Chrom 2.7  01:52:30 43    1    2868  478M-  0B     297M+  918   1     sleeping *0[12467]       0.00000 0.00000    501  47218838+ 134289
31829  ScreenTimeAg 1.8  03:05.44 5     4    162+  19M+   0B     8432K- 31829 1     sleeping  0[13289]       0.00000 0.00000    501  899472+   201
859    suggestd     1.7  02:52.34 8     7    577+  30M+   0B     17M-   859   1     sleeping  0[1441]        0.00000 0.00000    501  1280641+  338
52121  Google Chrom 1.7  03:51.34 18    1    223   113M+  0B     93M+   918   918   sleeping *0[4]           0.00000 0.00000    501  2562533+  729
63789  PerfPowerSer 1.4  03:17.37 5     3    4435+ 14M+   0B     3504K- 63789 1     sleeping  0[1948]        0.05584 0.00000    0    808751+   463
935    Google Chrom 1.2  23:17.39 12    1    196   61M-   0B     23M+   918   918   sleeping *0[3]           0.00000 0.00000    501  7390280+  664
17798  storagekitd  1.1  00:33.80 7     3    90+   33M+   0B     28M-   17798 1     sleeping  0[47]          0.00000 0.00000    0    314274+   97
687    fontd        1.1  00:51.79 5     4    206+  15M+   0B     7728K- 687   1     sleeping  0[34808]       0.00000 0.00000    501  756187+   74
934    Google Chrom 1.1  76:39.91 24    5    543   885M   0B     360M+  918   918   sleeping *1[5]           0.00000 0.00000    501  16354611+ 921
464    searchpartyd 0.9  02:02.90 5     3    104+  7361K+ 0B     3104K- 464   1     sleeping *0[15148+]      0.00000 0.89543    0    687887+   195
377    airportd     0.6  22:31.61 11    9    1633  20M    0B     14M+   377   1     sleeping *5975[446]      0.00000 0.00000    0    1626124   144
334    locationd    0.6  06:35.53 7     4    196+  9153K+ 0B     4720K+ 334   1     sleeping *0[109619+]     0.00000 0.55037    205  1329692+  163
314    mds          0.6  13:37.11 10    7    386+  104M+  0B     92M+   314   1     sleeping *0[1]           4.33934 0.18287    0    4878854+  940
14894  bluetoothd   0.5  04:16.72 10    4    274   9857K  0B     4112K+ 14894 1     sleeping *0[1]           1.60623 0.00000    0    787619+   140
566    mds_stores   0.5  25:44.63 8     6    110   77M+   0B     61M-   566   1     sleeping *0[1]           0.00000 0.45798    0    8313100+  2667
483    softwareupda 0.3  02:35.96 10    6    226+  83M    0B     69M+   483   1     sleeping  0[542]         0.00000 0.14661    200  1565071   3504
1      launchd      0.3  15:32.37 4     3    2256+ 18M    0B     6240K+ 1     0     sleeping  0[0]           0.00000 0.15387    0    2761764+  28135+
727    Logi Bolt    0.3  12:47.84 100   1    427   1603M  0B     1593M+ 727   1     sleeping *0[1]           0.00000 0.00000    501  5374770+  1955
292    fseventsd    0.3  10:39.17 19    1    308   5937K  0B     1888K+ 292   1     sleeping *0[1]           0.01532 0.00000    0    1832569+  58
453    mDNSResponde 0.3  04:49.34 4     2    164   6033K  0B     2800K+ 453   1     sleeping *0[1]           0.00000 0.00000    65   585621+   123
732    sharingd     0.3  04:32.34 5     1    282   29M    0B     22M+   732   1     sleeping *0[1]           0.00000 0.00000    501  1518118+  321
592    distnoted    0.3  02:05.56 2     1    298   3153K  0B     896K+  592   1     sleeping *0[1]           0.00000 0.29424    501  344687    45
536    com.avg.acti 0.2  04:41.64 1     0    18    3137K  0B     1600K  536   1     sleeping *0[1]           0.00000 0.00000    0    445268+   60
```

2. QEMU CPU Utilization

Percentage of CPU used – 2.2%
System – 10.16%
Idle – 87.95%
Kernel Usage – user = 1.88%



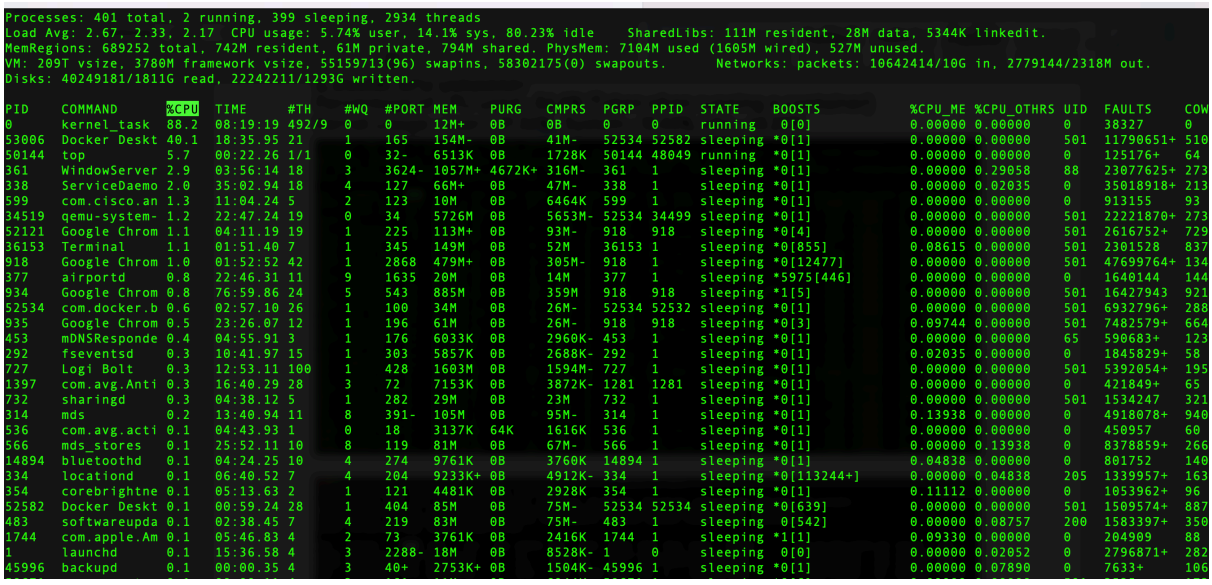


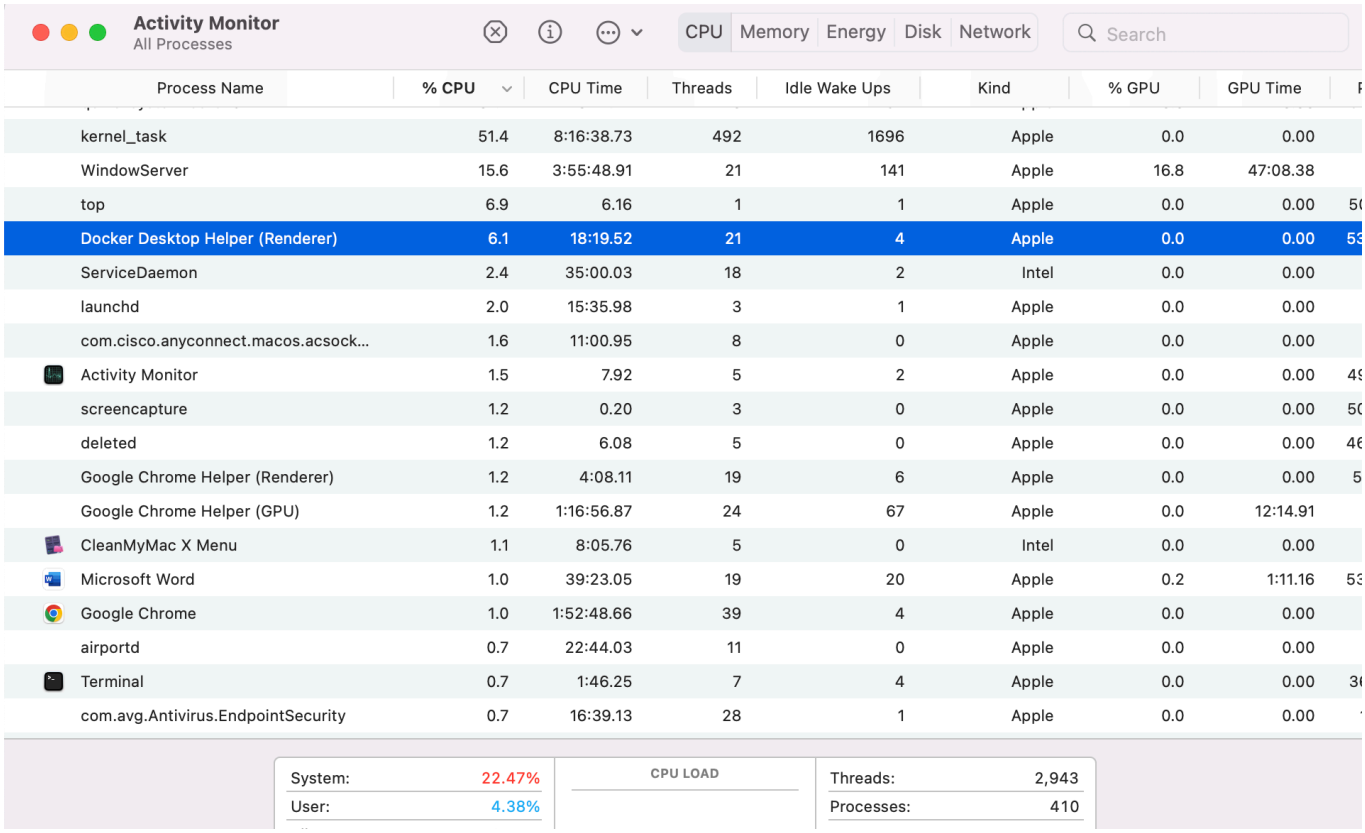
1. Docker Disk Utilization

2 GB RAM 2 Cores	Random Read Write	written, MiB/s = 286.00
3 GB RAM 3 Cores	Random Read Write	written, MiB/s = 162.36
3 GB RAM 6 Cores	Random Read Write	written, MiB/s = 90.01

2. Docker CPU Utilization

CPU% used – 40.1% when container is running
Idle – 60.23%
System – 14.1%,
Kernel User usage = 5.74%





Git Repository Information:

Account name	Sumit8698
Repository name	COEN-241-Cloud-Computing
Folder which contains HW1	HW1
Link to repository	https://github.com/sumit8698/COEN241-Cloud-Computing

Optional Part:

Docker File

```
FROM sumit8698/sysbench_ubuntu_docker

COPY docker-script.sh /docker-script.sh

COPY cpu-script.sh /cpu-script.sh

COPY fileio-script.sh /fileio-script.sh

RUN chmod +x docker-script.sh

RUN chmod +x cpu-script.sh

RUN chmod +x fileio-script.sh

ENTRYPOINT bash docker-script.sh
```

Vagrant File:

```
Vagrant.configure("2") do |config|
  config.vm.box = "ubuntu/hirsute64"
  config.vm.provider "virtualbox" do |vb|
    vb.memory = "2048"
    vb.cpus = 2
  end
  config.vm.synced_folder "qemu", "/"
  config.vm.provision "shell", path: "vagrant_setup.sh"
end
```

For all the automation scripts, please check the link below.

Link: https://github.com/sumit8698/COEN241-Cloud-Computing