COEN 241 – CLOUD COMPUTING

ASSIGNMENT 1 REPORT

Windows Subsystem for Linux Installation

Steps for installation:

1. Enable the Windows Subsystem for Linux
   Open PowerShell as Administrator and enter the command:
   dism.exe /online /enable-feature /featurename:Microsoft-Windows-Subsystem-Linux /all /norestart

2. Enable the VM Feature
   Open PowerShell as administrator and run:
   dism.exe /online /enable-feature /featurename:VirtualMachinePlatform /all /norestart

3. Download the Linux Kernel Update Package from Microsoft store.

4. Set WSL as the Default Version

   Open PowerShell and run the command:

   wsl --set-default-version 2

5. Install Linux Distribution of your choice. For the purpose of this assignment, the Linux Distribution installed was Ubuntu from the Microsoft Store.
6. Create User Account and Password for the Ubuntu Distribution.

QEMU Installation

Steps for installation

1. Install QEMU first on windows and set the environment variable for QEMU.

2. On WSL, create the Ubuntu image with partition size
   sudo qemu-img create ubuntu.img 10G -f qcow2

3. Download the disk image for UBUNTU and run
   sudo qemu-system-x86_64 -hda ubuntu.img -boot d -cdrom
   ./ubuntu-20.04.5-live-server-amd64.iso -m 2046 -boot strict=on

4. Post installation, run
   sudo qemu-system-x86_64 -hda ubuntu.img -boot d
   -m 2046 -boot strict=on
   The above command started the Ubuntu terminal.

5. Run lscpu command for the configuration details

   1 CPU

```
vik@vik:~$ lscpu
Architecture:              x86_64
CPU op-mode(s):            32-bit, 64-bit
Byte Order:                Little Endian
Address sizes:             40 bits physical, 48 bits virtual
CPU(s):                    1
On-line CPU(s) list:       0
Thread(s) per core:        1
Core(s) per socket:        1
Socket(s):                 1
NUMA node(s):              1
Vendor ID:                 AuthenticAMD
CPU family:                6
Model:                     6
Model name:                QEMU Virtual CPU version 2.5+
Stepping:                  3
CPU MHz:                   1689.601
BogoMIPS:                  3379.20
Virtualization:            AMD-V
L1d cache:                 64 KiB
L1i cache:                 64 KiB
L2 cache:                  512 KiB
L3 cache:                  16 MiB
NUMA node0 CPU(s):         0
Vulnerability Itlb multihit:     Not affected
Vulnerability L1tf:              Not affected
Vulnerability Mds:               Not affected
Vulnerability Meltdown:          Not affected
Vulnerability Mmio stale data:   Not affected
Vulnerability Retbleed:          Not affected
Vulnerability Spec store bypass: Vulnerable
Vulnerability Spectre v1:        Mitigation; usercopy/swapgs barriers and __user pointer sanitization
Vulnerability Spectre v2:        Mitigation; Retpolines, STIBP disabled, RSB filling, PBRSB-eIBRS Not affected
Vulnerability Srbds:             Not affected
Vulnerability Tsx async abort:   Not affected
Flags:                     fpu de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush mmx fxsr sse sse2 s
                           yscall nx lm nopl cpuid pni cx16 hypervisor lahf_lm svm 3dnowprefetch vmmcall

vik@vik:~$ _
```

2 CPU's

```
cpu
Architecture:              x86_64
CPU op-mode(s):            32-bit, 64-bit
Byte Order:                Little Endian
Address sizes:             40 bits physical, 48 bits virtual
CPU(s):                    2
On-line CPU(s) list:       0,1
Thread(s) per core:        1
Core(s) per socket:        1
Socket(s):                 2
NUMA node(s):              1
Vendor ID:                 AuthenticAMD
CPU family:                6
Model:                     6
Model name:                QEMU Virtual CPU version 2.5+
Stepping:                  3
CPU MHz:                   1689.605
BogoMIPS:                  3379.21
Virtualization:            AMD-V
L1d cache:                 128 KiB
L1i cache:                 128 KiB
L2 cache:                  1 MiB
L3 cache:                  32 MiB
NUMA node0 CPU(s):         0,1
Vulnerability Itlb multihit:    Not affected
Vulnerability L1tf:             Not affected
Vulnerability Mds:              Not affected
Vulnerability Meltdown:         Not affected
Vulnerability Mmio stale data:  Not affected
Vulnerability Retbleed:         Not affected
Vulnerability Spec store bypass: Vulnerable
Vulnerability Spectre v1:       Mitigation: usercopy/swapgs barriers and __user pointer sanitization
Vulnerability Spectre v2:       Mitigation: Retpolines, STIBP disabled, RSB filling, PBRSB-eIBRS Not affected
Vulnerability Srbds:            Not affected
Vulnerability Tsx async abort:  Not affected
Flags:                     fpu de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush mmx fxsr sse sse2 s
                           yscall nx lm nopl cpuid pni cx16 hypervisor lahf_lm svm 3dnowprefetch vmmcall
vik@vik:~$ [  194.598825] aufs aufs_fill_super:918:mount[3582]: no arg
```

System Information:

System Information of Windows

```
vik97@DESKTOP-JP8NREN:~$ inxi -Fx
System:    Host: DESKTOP-JP8NREN Kernel: 5.15.79.1-microsoft-standard-WSL2 x86_64 bits: 64 compiler: N/A Desktop: N/A
           Distro: Ubuntu 20.04.5 LTS (Focal Fossa)
Machine:   Message: No machine data: try newer kernel. Is dmidecode installed? Try -M --dmidecode.
Battery:   ID-1: BAT1 charge: 1.8 Wh condition: 5.0/5.0 Wh (100%) model: Microsoft Hyper-V Virtual BatterVirtual
           status: Discharging
CPU:       Topology: Quad Core model: 11th Gen Intel Core i7-1165G7 bits: 64 type: MT MCP arch: Tiger Lake rev: 1
           L2 cache: 12.0 MiB
           flags: avx avx2 lm nx pae sse sse2 sse3 sse4_1 sse4_2 ssse3 bogomips: 27033
           Speed: 1690 MHz min/max: N/A Core speeds (MHz): 1: 1690 2: 1690 3: 1690 4: 1690 5: 1690 6: 1690 7: 1690 8: 1690
Graphics:  Device-1: Microsoft driver: dxgkrnl v: 2.0.1 bus ID: 6868:00:00.0
           Display: wayland-0 server: Microsoft Corporation X.org 1.20.13 driver: dxgkrnl resolution: 1920x1080~60Hz
           OpenGL: renderer: D3D12 (Intel Iris Xe Graphics) v: 3.3 Mesa 21.2.6 direct render: Yes
Audio:     Message: No Device data found.
Network:   Message: No Device data found.
           IF-ID-1: bond0 state: down mac: 02:b9:43:d2:50:b2
           IF-ID-2: bonding_masters state: N/A speed: N/A duplex: N/A mac: N/A
           IF-ID-3: dummy0 state: down mac: 02:db:cc:e1:01:68
           IF-ID-4: eth0 state: up speed: 10000 Mbps duplex: full mac: 00:15:5d:c1:a8:e6
           IF-ID-5: sit0 state: down mac: 00:00:00:00
           IF-ID-6: tun10 state: down mac: 00:00:00:00
Drives:    Local Storage: total: 2.25 TiB used: 121.80 GiB (5.3%)
           ID-1: /dev/sda model: Virtual Disk size: 363.1 MiB
           ID-2: /dev/sdb model: Virtual Disk size: 2.00 GiB
           ID-3: /dev/sdd model: Virtual Disk size: 1024.00 GiB
           ID-4: /dev/sde model: Virtual Disk size: 256.00 GiB
           ID-5: /dev/sdg model: Virtual Disk size: 1024.00 GiB
Partition: ID-1: / size: 250.92 GiB used: 8.14 GiB (3.2%) fs: ext4 dev: /dev/sde
           ID-2: swap-1 size: 2.00 GiB used: 268 KiB (0.0%) fs: swap dev: /dev/sdb
Sensors:   Message: No sensors data was found. Is sensors configured?
Info:      Processes: 39 Uptime: 1h 04m Memory: 7.64 GiB used: 663.5 MiB (8.5%) Init: N/A Compilers: gcc: N/A Shell: bash
           v: 5.0.17 inxi: 3.0.38
vik97@DESKTOP-JP8NREN:~$
```

System Information of VM Ubuntu

```
vik@vik:~$ inxi -Fx

System:     Host: vik Kernel: 5.4.0-137-generic x86_64 bits: 64 compiler: gcc v: 9.4.0 Console: tty 1
            Distro: Ubuntu 20.04.5 LTS (Focal Fossa)
Machine:    Type: Qemu System: QEMU product: Standard PC (i440FX + PIIX, 1996) v: pc-i440fx-focal
            serial: <superuser/root required>
            Mobo: N/A model: N/A serial: N/A BIOS: SeaBIOS v: 1.13.0-1ubuntu1.1 date: 04/01/2014
CPU:        Topology: Single Core model: QEMU Virtual version 2.5+ bits: 64 type: UP arch: K7 Palomino+ rev: 3
            L2 cache: 512 KiB
            flags: lm nx pae sse sse2 sse3 svm bogomips: 3373
            Speed: 1687 MHz min/max: N/A Core speed (MHz): 1: 1687
Graphics:   Device-1: vendor: Red Hat driver: bochs-drm v: N/A bus ID: 00:02.0
            Display: server: No display server data found. Headless machine? tty: 128x48
            Message: Advanced graphics data unavailable in console. Try -G --display
Audio:      Message: No Device data found.
Network:    Device-1: Intel 82371AB/EB/MB PIIX4 ACPI vendor: Red Hat Qemu virtual machine type: network bridge
            driver: piix4_smbus v: N/A port: c040 bus ID: 00:01.3
            Device-2: Intel 82540EM Gigabit Ethernet vendor: Red Hat QEMU Virtual Machine driver: e1000 v: 7.3.21-k8-NAPI
            port: c000 bus ID: 00:03.0
            IF: ens3 state: up speed: 1000 Mbps duplex: full mac: 52:54:00:12:34:56
Drives:     Local Storage: total: 10.00 GiB used: 4.51 GiB (45.1%)
            ID-1: /dev/sda vendor: QEMU model: HARDDISK size: 10.00 GiB
Partition:  ID-1: / size: 8.02 GiB used: 4.41 GiB (55.0%) fs: ext4 dev: /dev/dm-0
            ID-2: /boot size: 1.69 GiB used: 105.7 MiB (6.1%) fs: ext4 dev: /dev/sda2
Sensors:    Message: No sensors data was found. Is sensors configured?
Info:       Processes: 107 Uptime: 19m Memory: 1.94 GiB used: 272.4 MiB (13.7%) Init: systemd runlevel: 5 Compilers: gcc: N/A
            Shell: bash v: 5.0.17 inxi: 3.0.38
vik@vik:~$
vik@vik:~$
```

Docker Installation

For Docker installation for windows go to https://docs.docker.com/desktop/install/windows-install/

Execute the command `docker run ubuntu`, this will download the latest image of ubuntu.

Then run the ubuntu in interactive mode by using `docker run -it ubuntu` to start the ubuntu.

Then install sysbench using:
```
$ apt update
```

```
$ apt install sysbench
```

Then install nano using the command `apt install nano`

Docker Version

Command Prompt

```
Microsoft Windows [Version 10.0.19044.2486]
(c) Microsoft Corporation. All rights reserved.

C:\Users\vikra>docker version
Client:
 Cloud integration: v1.0.29
 Version:           20.10.22
 API version:       1.41
 Go version:        go1.18.9
 Git commit:        3a2c30b
 Built:             Thu Dec 15 22:36:18 2022
 OS/Arch:           windows/amd64
 Context:           default
 Experimental:      true

Server: Docker Desktop 4.16.3 (96739)
 Engine:
  Version:          20.10.22
  API version:      1.41 (minimum version 1.12)
  Go version:       go1.18.9
  Git commit:       42c8b31
  Built:            Thu Dec 15 22:26:14 2022
  OS/Arch:          linux/amd64
  Experimental:     false
 containerd:
  Version:          1.6.14
  GitCommit:        9ba4b250366a5ddde94bb7c9d1def331423aa323
 runc:
  Version:          1.1.4
  GitCommit:        v1.1.4-0-g5fd4c4d
 docker-init:
  Version:          0.19.0
  GitCommit:        de40ad0

C:\Users\vikra>
```

QEMU Experiment

1. CPU Testing

   Scenario 1:

   The CPU is tested using the cpu-max-prime where the max prime number is found under the given limit. Command used: CPU Time - sysbench --test=cpu --cpu-max-prime=10000 run.

   Test Case 1

```
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!

[ 1278.960463] aufs aufs_fill_super:918:mount[8282]: no arg
[ 1279.943509] overlayfs: missing 'lowerdir'
CPU speed:
    events per second:    129.58

General statistics:
    total time:                          10.0028s
    total number of events:              1298

Latency (ms):
         min:                                    2.53
         avg:                                    7.59
         max:                                   29.88
         95th percentile:                       12.75
         sum:                                 9853.10

Threads fairness:
    events (avg/stddev):           1298.0000/0.00
    execution time (avg/stddev):   9.8531/0.00

Test Case: 2
```

Test Case 2

```
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!

[ 1387.056499] aufs aufs_fill_super:918:mount[8837]: no arg
[ 1388.224251] overlayfs: missing 'lowerdir'
CPU speed:
    events per second:    123.38

General statistics:
    total time:                   10.0083s
    total number of events:       1236

Latency (ms):
         min:                                2.60
         avg:                                7.95
         max:                               32.94
         95th percentile:                   13.70
         sum:                             9827.12

Threads fairness:
    events (avg/stddev):           1236.0000/0.00
    execution time (avg/stddev):   9.8271/0.00

Test Case: 3
```

Test Case 3

```
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!

[ 1502.613606] aufs aufs_fill_super:918:mount[9483]: no arg
[ 1503.596148] overlayfs: missing 'lowerdir'
CPU speed:
    events per second:   131.99

General statistics:
    total time:                          10.0064s
    total number of events:              1323

Latency (ms):
         min:                                  2.47
         avg:                                  7.46
         max:                                 54.40
         95th percentile:                     12.52
         sum:                               9873.14

Threads fairness:
    events (avg/stddev):          1323.0000/0.00
    execution time (avg/stddev):   9.8731/0.00

Test Case: 4
WARNING: the  test option is deprecated. You can pass a script name or path on the command line without any options
```

Test Case 4

```
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!

[ 1614.276915] aufs aufs_fill_super:918:mount[10088]: no arg
[ 1615.214816] overlayfs: missing 'lowerdir'
CPU speed:
    events per second:   119.81

General statistics:
    total time:                          10.0153s
    total number of events:              1201

Latency (ms):
         min:                                  1.85
         avg:                                  8.20
         max:                                 90.80
         95th percentile:                     14.46
         sum:                               9842.72

Threads fairness:
    events (avg/stddev):          1201.0000/0.00
    execution time (avg/stddev):   9.8427/0.00

Test Case: 5
```

Test Case 5

```
Test Case: 5
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 10000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:    121.74

General statistics:
    total time:                          10.0138s
    total number of events:              1221

Latency (ms):
         min:                                    2.78
         avg:                                    8.07
         max:                                   47.53
         95th percentile:                       13.46
         sum:                                 9857.89

Threads fairness:
    events (avg/stddev):           1221.0000/0.00
    execution time (avg/stddev):   9.8579/0.00

vik@vik:~$ [ 1778.572735] aufs aufs_fill_super:918:mount[11111]: no arg
```

Scenario 2

The CPU is tested using the cpu-max-prime where the max prime number is found under the given limit. Command used: CPU Time - sysbench --test=cpu --cpu-max-prime=30000 run

Test Case 1

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


Prime numbers limit: 30000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:     29.43

General statistics:
    total time:                         10.0074s
    total number of events:             295

Latency (ms):
         min:                                21.90
         avg:                                33.71
         max:                                60.18
         95th percentile:                    48.34
         sum:                              9943.14

Threads fairness:
    events (avg/stddev):           295.0000/0.00
    execution time (avg/stddev):   9.9431/0.00

Test Case: 2
```

Test Case 2

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


Prime numbers limit: 30000

Initializing worker threads...

Threads started!

[ 3130.900750] aufs aufs_fill_super:918:mount[20463]: no arg
[ 3131.690793] overlayfs: missing 'lowerdir'
CPU speed:
    events per second:     27.81

General statistics:
    total time:                       10.0944s
    total number of events:           282

Latency (ms):
        min:                             13.52
        avg:                             35.30
        max:                            121.34
        95th percentile:                 53.85
        sum:                           9954.73

Threads fairness:
    events (avg/stddev):         282.0000/0.00
    execution time (avg/stddev):   9.9547/0.00

Test Case: 3
```

Test Case 3

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


Prime numbers limit: 30000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:     29.76

General statistics:
    total time:                       10.0280s
    total number of events:           299

Latency (ms):
        min:                             18.82
        avg:                             33.23
        max:                             73.16
        95th percentile:                 48.34
        sum:                           9935.15

Threads fairness:
    events (avg/stddev):         299.0000/0.00
    execution time (avg/stddev):   9.9351/0.00

Test Case: 4
```

Test Case 4

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


Prime numbers limit: 30000

Initializing worker threads...

Threads started!

[ 3447.192506] aufs aufs_fill_super:918:mount[22387]: no arg
[ 3448.215221] overlayfs: missing 'lowerdir'
CPU speed:
    events per second:     28.19

General statistics:
    total time:                          10.0388s
    total number of events:              284

Latency (ms):
         min:                                   16.07
         avg:                                   34.96
         max:                                  111.72
         95th percentile:                       45.79
         sum:                                 9927.83

Threads fairness:
    events (avg/stddev):           284.0000/0.00
    execution time (avg/stddev):   9.9278/0.00

Test Case: 5
```

Test Case 5

```
Test Case: 5
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 30000

Initializing worker threads...

Threads started!

[ 3749.525741] aufs aufs_fill_super:918:mount[24490]: no arg
[ 3750.530715] overlayfs: missing 'lowerdir'
CPU speed:
    events per second:     29.79

General statistics:
    total time:                          10.0430s
    total number of events:              300

Latency (ms):
         min:                                   16.58
         avg:                                   33.12
         max:                                   90.18
         95th percentile:                       50.11
         sum:                                 9936.02

Threads fairness:
    events (avg/stddev):           300.0000/0.00
    execution time (avg/stddev):   9.9360/0.00

vik@vik:~$ _
```

Scenario 3

The CPU is tested using the cpu-max-prime where the max prime number is found under the given limit. Command used: CPU Time - sysbench --test=cpu --cpu-max-prime=50000 run.

Test Case 1

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


Prime numbers limit: 50000

Initializing worker threads...

Threads started!

[ 5044.505001] aufs aufs_fill_super:918:mount[36862]: no arg
[ 5045.496977] overlayfs: missing 'lowerdir'
CPU speed:
    events per second:     12.83

General statistics:
    total time:                          10.0396s
    total number of events:              129

Latency (ms):
         min:                                     41.02
         avg:                                     77.31
         max:                                    156.65
         95th percentile:                        123.28
         sum:                                   9973.00

Threads fairness:
    events (avg/stddev):           129.0000/0.00
    execution time (avg/stddev):   9.9730/0.00

Test Case: 2
```

Test Case 2

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


Prime numbers limit: 50000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:     13.25

General statistics:
    total time:                          10.0200s
    total number of events:              133

Latency (ms):
         min:                                  44.64
         avg:                                  74.65
         max:                                 181.19
         95th percentile:                     108.68
         sum:                                9927.98

Threads fairness:
    events (avg/stddev):           133.0000/0.00
    execution time (avg/stddev):   9.9280/0.00

Test Case: 3
```

Test Case 3

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


Prime numbers limit: 50000

Initializing worker threads...

Threads started!

[ 5261.524166] aufs aufs_fill_super:918:mount[37958]: no arg
CPU speed:
    events per second:     13.64

General statistics:
    total time:                          10.0338s
    total number of events:              137

Latency (ms):
         min:                                  36.48
         avg:                                  72.60
         max:                                 129.68
         95th percentile:                     102.97
         sum:                                9946.33

Threads fairness:
    events (avg/stddev):           137.0000/0.00
    execution time (avg/stddev):   9.9463/0.00

Test Case: 4
```

Test Case 4

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


Prime numbers limit: 50000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:     13.47

General statistics:
    total time:                          10.0653s
    total number of events:              136

Latency (ms):
         min:                                50.79
         avg:                                73.41
         max:                               163.17
         95th percentile:                   116.80
         sum:                              9983.70

Threads fairness:
    events (avg/stddev):           136.0000/0.00
    execution time (avg/stddev):   9.9837/0.00

Test Case: 5
```

Test Case 5:

```
Test Case: 5
WARNING: the --test option is deprecated. You can pass a script name or path on the command line without any options.
sysbench 1.0.18 (using system LuaJIT 2.1.0-beta3)

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


Prime numbers limit: 50000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:     12.83

General statistics:
    total time:                          10.0391s
    total number of events:              129

Latency (ms):
         min:                                37.86
         avg:                                77.06
         max:                               143.38
         95th percentile:                   108.68
         sum:                              9941.16

Threads fairness:
    events (avg/stddev):           129.0000/0.00
    execution time (avg/stddev):   9.9412/0.00

vik@vik:~$ [ 5556.782275] aufs aufs_fill_super:918:mount[39459]: no arg
```

2. File IO Testing

Scenario 1

Command used:

sysbench --test=fileio --file-total-size=2G --file-test-mode=rndrw --max-time=30 -- max-requests=0 --file- extra-flags=direct prepare

sysbench --test=fileio --file-total-size=2G --file-test-mode=rndrw --max-time=30 -- max-requests=0 -- file-extra-flags=direct run

sleep 60

sysbench --test=fileio --file-total-size=2G --file-test-mode=rndrw --max-time=30 -- max-requests=0 -- file-extra-flags=direct cleanup

Test Case 1:

```
Threads started!

[10872.014483] aufs aufs_fill_super:918:mount[63403]: no arg

File operations:
    reads/s:                    154.69
    writes/s:                   103.13
    fsyncs/s:                   330.57

Throughput:
    read, MiB/s:                2.42
    written, MiB/s:             1.61

General statistics:
    total time:                 30.2155s
    total number of events:     17673

Latency (ms):
          min:                          0.21
          avg:                          1.65
          max:                        864.13
          95th percentile:              5.00
          sum:                      29158.33

Threads fairness:
    events (avg/stddev):        17673.0000/0.00
    execution time (avg/stddev):  29.1583/0.00
```

Test Case 2:

```
Extra file open flags: directio
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!

[11268.460682] overlayfs: missing 'lowerdir'

File operations:
    reads/s:                      194.84
    writes/s:                     129.89
    fsyncs/s:                     417.77

Throughput:
    read, MiB/s:                  3.04
    written, MiB/s:               2.03

General statistics:
    total time:                       30.1473s
    total number of events:           22280

Latency (ms):
         min:                             0.21
         avg:                             1.31
         max:                           112.92
         95th percentile:                 4.18
         sum:                         29120.47

Threads fairness:
    events (avg/stddev):          22280.0000/0.00
    execution time (avg/stddev):  29.1205/0.00
```

Test Case 3

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


Extra file open flags: directio
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!

[11669.453072] aufs aufs_fill_super:918:mount[65309]: no arg
[11674.522585] overlayfs: missing 'lowerdir'

File operations:
    reads/s:                    127.84
    writes/s:                   85.23
    fsyncs/s:                   274.63

Throughput:
    read, MiB/s:                2.00
    written, MiB/s:             1.33

General statistics:
    total time:                 30.2547s
    total number of events:     14647

Latency (ms):
         min:                                0.25
         avg:                                1.99
         max:                              920.23
         95th percentile:                    6.32
         sum:                            29152.25

Threads fairness:
    events (avg/stddev):        14647.0000/0.00
    execution time (avg/stddev):  29.1522/0.00
```

Test Case 4

```
Threads started!

[11920.737228] aufs aufs_fill_super:918:mount[66426]: no arg
[11921.687210] overlayfs: missing 'lowerdir'
[11935.315617] aufs aufs_fill_super:918:mount[66481]: no arg
[11936.247059] overlayfs: missing 'lowerdir'

File operations:
    reads/s:                    350.80
    writes/s:                   233.87
    fsyncs/s:                   751.66

Throughput:
    read, MiB/s:                5.48
    written, MiB/s:             3.65

General statistics:
    total time:                         30.0851s
    total number of events:             40099

Latency (ms):
        min:                                    0.15
        avg:                                    0.73
        max:                                    56.12
        95th percentile:                        2.57
        sum:                                    29277.14

Threads fairness:
    events (avg/stddev):        40099.0000/0.00
    execution time (avg/stddev):    29.2771/0.00

[11949.173326] aufs aufs_fill_super:918:mount[66538]: no arg
```

Test Case 5

```
Extra file open flags: directio
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!

[12234.788534] aufs aufs_fill_super:918:mount[67588]: no arg
[12236.043761] overlayfs: missing 'lowerdir'

File operations:
    reads/s:                    241.04
    writes/s:                   160.68
    fsyncs/s:                   518.32

Throughput:
    read, MiB/s:                3.77
    written, MiB/s:             2.51

General statistics:
    total time:                      30.1121s
    total number of events:          27591

Latency (ms):
        min:                                 0.15
        avg:                                 1.06
        max:                                23.17
        95th percentile:                     3.75
        sum:                             29239.62

Threads fairness:
    events (avg/stddev):        27591.0000/0.00
    execution time (avg/stddev):    29.2396/0.00
```

Scenario 2

File size=3G

Test Case 1

```
WARNING: --max-time is deprecated, use --time instead
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


Extra file open flags: directio
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                    507.37
    writes/s:                   338.24
    fsyncs/s:                   1083.81

Throughput:
    read, MiB/s:                7.93
    written, MiB/s:             5.29

General statistics:
    total time:                          30.0333s
    total number of events:              57827

Latency (ms):
         min:                                   0.14
         avg:                                   0.50
         max:                                  55.51
         95th percentile:                       1.01
         sum:                               29123.37

Threads fairness:
    events (avg/stddev):          57827.0000/0.00
    execution time (avg/stddev):    29.1234/0.00
```

Test Case 2

```
WARNING: --max-time is deprecated, use --time instead
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


Extra file open flags: directio
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      411.43
    writes/s:                     274.29
    fsyncs/s:                     880.82

Throughput:
    read, MiB/s:                  6.43
    written, MiB/s:               4.29

General statistics:
    total time:                          30.0385s
    total number of events:              46933

Latency (ms):
         min:                                  0.14
         avg:                                  0.62
         max:                                 54.60
         95th percentile:                      1.12
         sum:                              29277.15

Threads fairness:
    events (avg/stddev):          46933.0000/0.00
    execution time (avg/stddev):  29.2772/0.00
```

Test Case 3

```
WARNING: --max-time is deprecated, use --time instead
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


Extra file open flags: directio
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      532.81
    writes/s:                     355.20
    fsyncs/s:                     1136.87

Throughput:
    read, MiB/s:                  8.33
    written, MiB/s:               5.55

General statistics:
    total time:                          30.0578s
    total number of events:              60743

Latency (ms):
         min:                                  0.14
         avg:                                  0.48
         max:                                 54.46
         95th percentile:                      0.86
         sum:                              29169.57

Threads fairness:
    events (avg/stddev):          60743.0000/0.00
    execution time (avg/stddev):  29.1696/0.00
```

Test Case 4

```
WARNING: --max-time is deprecated, use --time instead
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


Extra file open flags: directio
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                    506.89
    writes/s:                   337.95
    fsyncs/s:                   1081.66

Throughput:
    read, MiB/s:                7.92
    written, MiB/s:             5.28

General statistics:
    total time:                          30.0512s
    total number of events:              57778

Latency (ms):
         min:                                    0.14
         avg:                                    0.51
         max:                                   52.50
         95th percentile:                        0.92
         sum:                                29192.59

Threads fairness:
    events (avg/stddev):           57778.0000/0.00
    execution time (avg/stddev):   29.1926/0.00
```

Test Case 5

```
WARNING: --max-time is deprecated, use --time instead
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


Extra file open flags: directio
128 files, 24MiB each
3GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                    472.80
    writes/s:                   315.20
    fsyncs/s:                   1011.04

Throughput:
    read, MiB/s:                7.39
    written, MiB/s:             4.93

General statistics:
    total time:                          30.0721s
    total number of events:              53980

Latency (ms):
         min:                                    0.14
         avg:                                    0.54
         max:                                   56.26
         95th percentile:                        0.97
         sum:                                29197.44

Threads fairness:
    events (avg/stddev):           53980.0000/0.00
    execution time (avg/stddev):   29.1974/0.00
```

Scenario 3

File size=4G

Test Case 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


Extra file open flags: directio
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      579.84
    writes/s:                     386.55
    fsyncs/s:                     1239.83

Throughput:
    read, MiB/s:                  9.06
    written, MiB/s:               6.04

General statistics:
    total time:                        30.0369s
    total number of events:            66153

Latency (ms):
         min:                              0.14
         avg:                              0.44
         max:                             54.45
         95th percentile:                  0.75
         sum:                          29109.15

Threads fairness:
    events (avg/stddev):          66153.0000/0.00
    execution time (avg/stddev):  29.1092/0.00
```

Test Case 2

```
WARNING: --max-time is deprecated, use --time instead
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


Extra file open flags: directio
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      541.37
    writes/s:                     360.92
    fsyncs/s:                     1158.68

Throughput:
    read, MiB/s:                  8.46
    written, MiB/s:               5.64

General statistics:
    total time:                         30.0400s
    total number of events:             61800

Latency (ms):
         min:                                    0.14
         avg:                                    0.47
         max:                                   16.06
         95th percentile:                        0.86
         sum:                                29092.17

Threads fairness:
    events (avg/stddev):           61800.0000/0.00
    execution time (avg/stddev):   29.0922/0.00
```


Test Case 3

```
WARNING: --max-time is deprecated, use --time instead
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


Extra file open flags: directio
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                      548.96
    writes/s:                     366.00
    fsyncs/s:                     1171.62

Throughput:
    read, MiB/s:                  8.58
    written, MiB/s:               5.72

General statistics:
    total time:                         30.0372s
    total number of events:             62561

Latency (ms):
         min:                                    0.14
         avg:                                    0.47
         max:                                   15.66
         95th percentile:                        0.83
         sum:                                29138.62

Threads fairness:
    events (avg/stddev):           62561.0000/0.00
    execution time (avg/stddev):   29.1386/0.00
```

Test Case 4

```
WARNING: --max-time is deprecated, use --time instead
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


Extra file open flags: directio
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                    542.49
    writes/s:                   361.68
    fsyncs/s:                   1161.21

Throughput:
    read, MiB/s:                8.48
    written, MiB/s:             5.65

General statistics:
    total time:                          30.0801s
    total number of events:              62025

Latency (ms):
         min:                                    0.14
         avg:                                    0.47
         max:                                   22.67
         95th percentile:                        0.87
         sum:                                29076.80

Threads fairness:
    events (avg/stddev):         62025.0000/0.00
    execution time (avg/stddev):   29.0768/0.00
```

Test Case 5

```
WARNING: --max-time is deprecated, use --time instead
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


Extra file open flags: directio
128 files, 16MiB each
2GiB total file size
Block size 16KiB
Number of IO requests: 0
Read/Write ratio for combined random IO test: 1.50
Periodic FSYNC enabled, calling fsync() each 100 requests.
Calling fsync() at the end of test, Enabled.
Using synchronous I/O mode
Doing random r/w test
Initializing worker threads...

Threads started!


File operations:
    reads/s:                    612.18
    writes/s:                   408.12
    fsyncs/s:                   1305.98

Throughput:
    read, MiB/s:                9.57
    written, MiB/s:             6.38

General statistics:
    total time:                 30.0773s
    total number of events:     69868

Latency (ms):
         min:                         0.14
         avg:                         0.42
         max:                        19.51
         95th percentile:             0.77
         sum:                     29021.96

Threads fairness:
    events (avg/stddev):        69868.0000/0.00
    execution time (avg/stddev):   29.0220/0.00
```

Docker Experiment

1. CPU Testing

   Scenario 1

   -cpu-max-prime=10000

   Test Case 1

```
Prime numbers limit: 10000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:   3333.73

General statistics:
    total time:                          10.0003s
    total number of events:              33344

Latency (ms):
         min:                                  0.25
         avg:                                  0.30
         max:                                  6.26
         95th percentile:                      0.42
         sum:                               9989.07

Threads fairness:
    events (avg/stddev):           33344.0000/0.00
    execution time (avg/stddev):   9.9891/0.00

Test Case: 2
```

Test Case 2

```
Threads started!

CPU speed:
    events per second:  3366.89

General statistics:
    total time:                     10.0004s
    total number of events:         33676

Latency (ms):
        min:                          0.25
        avg:                          0.30
        max:                         10.40
        95th percentile:              0.42
        sum:                       9988.69

Threads fairness:
    events (avg/stddev):        33676.0000/0.00
    execution time (avg/stddev):   9.9887/0.00

Test Case: 3
```

Test Case 3

```
Threads started!

CPU speed:
    events per second:  3681.56

General statistics:
    total time:                     10.0003s
    total number of events:         36823

Latency (ms):
        min:                          0.25
        avg:                          0.27
        max:                          7.90
        95th percentile:              0.36
        sum:                       9991.17

Threads fairness:
    events (avg/stddev):        36823.0000/0.00
    execution time (avg/stddev):   9.9912/0.00

Test Case: 4
```

Test Case 4

```
Threads started!

CPU speed:
    events per second:  3764.55

General statistics:
    total time:                          10.0003s
    total number of events:              37653

Latency (ms):
         min:                                 0.25
         avg:                                 0.27
         max:                                10.54
         95th percentile:                     0.35
         sum:                              9990.97

Threads fairness:
    events (avg/stddev):           37653.0000/0.00
    execution time (avg/stddev):   9.9910/0.00

Test Case: 5
```

Test Case 5

```
Threads started!

CPU speed:
    events per second:  3524.95

General statistics:
    total time:                          10.0004s
    total number of events:              35257

Latency (ms):
         min:                                 0.25
         avg:                                 0.28
         max:                                11.58
         95th percentile:                     0.35
         sum:                              9991.39

Threads fairness:
    events (avg/stddev):           35257.0000/0.00
    execution time (avg/stddev):   9.9914/0.00
```

Scenario 2

-cpu-max-prime=30000

Test Case 1

```
Prime numbers limit: 30000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:    777.55

General statistics:
    total time:                          10.0015s
    total number of events:              7778

Latency (ms):
         min:                                  1.12
         avg:                                  1.29
         max:                                  4.98
         95th percentile:                      1.82
         sum:                               9996.62

Threads fairness:
    events (avg/stddev):           7778.0000/0.00
    execution time (avg/stddev):   9.9966/0.00

Test Case: 2
```

Test Case 2

```
Threads started!

CPU speed:
    events per second:    747.78

General statistics:
    total time:                      10.0012s
    total number of events:          7480

Latency (ms):
        min:                                 1.12
        avg:                                 1.34
        max:                                10.95
        95th percentile:                     1.93
        sum:                              9996.51

Threads fairness:
    events (avg/stddev):         7480.0000/0.00
    execution time (avg/stddev):   9.9965/0.00

Test Case: 3
```

Test Case 3

```
Threads started!

CPU speed:
    events per second:    756.99

General statistics:
    total time:                      10.0011s
    total number of events:          7572

Latency (ms):
        min:                                 1.12
        avg:                                 1.32
        max:                                14.34
        95th percentile:                     1.86
        sum:                              9996.26

Threads fairness:
    events (avg/stddev):         7572.0000/0.00
    execution time (avg/stddev):   9.9963/0.00

Test Case: 4
```

Test Case 4

```
Initializing worker threads...

Threads started!

CPU speed:
    events per second:    758.17

General statistics:
    total time:                          10.0013s
    total number of events:              7584

Latency (ms):
        min:                                    1.12
        avg:                                    1.32
        max:                                    6.33
        95th percentile:                        1.89
        sum:                                 9997.08

Threads fairness:
    events (avg/stddev):           7584.0000/0.00
    execution time (avg/stddev):   9.9971/0.00

Test Case: 5
```

Test Case 5

```
Prime numbers limit: 30000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:    744.32

General statistics:
    total time:                          10.0007s
    total number of events:              7445

Latency (ms):
        min:                                    1.12
        avg:                                    1.34
        max:                                   13.98
        95th percentile:                        1.96
        sum:                                 9996.18

Threads fairness:
    events (avg/stddev):           7445.0000/0.00
    execution time (avg/stddev):   9.9962/0.00
```

Scenario 3

-cpu-max-prime=50000

Test Case 1

```
Prime numbers limit: 50000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:    377.31

General statistics:
    total time:                         10.0006s
    total number of events:             3774

Latency (ms):
        min:                                2.25
        avg:                                2.65
        max:                               15.36
        95th percentile:                    3.68
        sum:                             9997.66

Threads fairness:
    events (avg/stddev):           3774.0000/0.00
    execution time (avg/stddev):   9.9977/0.00

Test Case: 2
```

Test Case 2

```
Prime numbers limit: 50000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:    379.95

General statistics:
    total time:                          10.0020s
    total number of events:              3801

Latency (ms):
        min:                                   2.25
        avg:                                   2.63
        max:                                  14.62
        95th percentile:                       3.68
        sum:                                9999.10

Threads fairness:
    events (avg/stddev):           3801.0000/0.00
    execution time (avg/stddev):   9.9991/0.00

Test Case: 3
```

Test Case 3:

```
Prime numbers limit: 50000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:    374.33

General statistics:
    total time:                          10.0026s
    total number of events:              3745

Latency (ms):
        min:                                     2.26
        avg:                                     2.67
        max:                                    15.74
        95th percentile:                         3.75
        sum:                                  9999.42

Threads fairness:
    events (avg/stddev):           3745.0000/0.00
    execution time (avg/stddev):   9.9994/0.00

Test Case: 4
```

Test Case 4:

```
Prime numbers limit: 50000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:    373.50

General statistics:
    total time:                          10.0010s
    total number of events:              3736

Latency (ms):
        min:                                  2.25
        avg:                                  2.68
        max:                                 16.91
        95th percentile:                      3.75
        sum:                               9997.94

Threads fairness:
    events (avg/stddev):           3736.0000/0.00
    execution time (avg/stddev):   9.9979/0.00

Test Case: 5
```

Test Case 5:

```
Prime numbers limit: 50000

Initializing worker threads...

Threads started!

CPU speed:
    events per second:    374.18

General statistics:
    total time:                        10.0013s
    total number of events:            3743

Latency (ms):
        min:                                 2.25
        avg:                                 2.67
        max:                                12.93
        95th percentile:                     3.82
        sum:                              9998.35

Threads fairness:
    events (avg/stddev):        3743.0000/0.00
    execution time (avg/stddev):    9.9983/0.00
```

2. File Io Testing

   Scenario 1

   File size=2G

   Test Case 1

```
Threads started!


File operations:
    reads/s:                    2452.87
    writes/s:                   1635.24
    fsyncs/s:                   5234.35

Throughput:
    read, MiB/s:                38.33
    written, MiB/s:             25.55

General statistics:
    total time:                         30.0124s
    total number of events:             279675

Latency (ms):
        min:                                0.04
        avg:                                0.11
        max:                               17.07
        95th percentile:                    0.19
        sum:                            29839.13

Threads fairness:
    events (avg/stddev):        279675.0000/0.00
    execution time (avg/stddev):   29.8391/0.00
```

Test Case 2

```
File operations:
    reads/s:                    2562.86
    writes/s:                   1708.57
    fsyncs/s:                   5467.83

Throughput:
    read, MiB/s:                40.04
    written, MiB/s:             26.70

General statistics:
    total time:                     30.0118s
    total number of events:         292180

Latency (ms):
        min:                                0.04
        avg:                                0.10
        max:                               14.84
        95th percentile:                    0.18
        sum:                            29837.17

Threads fairness:
    events (avg/stddev):        292180.0000/0.00
    execution time (avg/stddev):    29.8372/0.00
```

Test Case 3

```
Threads started!

File operations:
    reads/s:                    2632.86
    writes/s:                   1755.24
    fsyncs/s:                   5618.04

Throughput:
    read, MiB/s:                41.14
    written, MiB/s:             27.43

General statistics:
    total time:                     30.0113s
    total number of events:         300186

Latency (ms):
        min:                                0.05
        avg:                                0.10
        max:                               17.08
        95th percentile:                    0.16
        sum:                            29837.17

Threads fairness:
    events (avg/stddev):        300186.0000/0.00
    execution time (avg/stddev):    29.8372/0.00
```

Test Case 4

```
Threads started!

File operations:
    reads/s:                    2560.85
    writes/s:                   1707.23
    fsyncs/s:                   5464.74

Throughput:
    read, MiB/s:                40.01
    written, MiB/s:             26.68

General statistics:
    total time:                     30.0115s
    total number of events:         291988

Latency (ms):
        min:                                0.05
        avg:                                0.10
        max:                               27.06
        95th percentile:                    0.16
        sum:                            29842.36

Threads fairness:
    events (avg/stddev):        291988.0000/0.00
    execution time (avg/stddev):    29.8424/0.00
```

Test Case 5

```
Threads started!


File operations:
    reads/s:                    2600.59
    writes/s:                   1733.73
    fsyncs/s:                   5551.97

Throughput:
    read, MiB/s:                40.63
    written, MiB/s:             27.09

General statistics:
    total time:                     30.0157s
    total number of events:         296633

Latency (ms):
        min:                            0.05
        avg:                            0.10
        max:                           18.89
        95th percentile:                0.14
        sum:                        29834.76

Threads fairness:
    events (avg/stddev):        296633.0000/0.00
    execution time (avg/stddev):    29.8348/0.00
```

Scenario 2

File size=3G

Test Case 1:

```
Threads started!


File operations:
    reads/s:                    3206.77
    writes/s:                   2137.85
    fsyncs/s:                   6842.94

Throughput:
    read, MiB/s:                50.11
    written, MiB/s:             33.40

General statistics:
    total time:                         30.0101s
    total number of events:             365639

Latency (ms):
        min:                                    0.04
        avg:                                    0.08
        max:                                    20.85
        95th percentile:                        0.10
        sum:                                    29843.74

Threads fairness:
    events (avg/stddev):        365639.0000/0.00
    execution time (avg/stddev):    29.8437/0.00
```

Test Case 2

```
Threads started!


File operations:
    reads/s:                      3286.71
    writes/s:                     2191.14
    fsyncs/s:                     7012.38

Throughput:
    read, MiB/s:                  51.35
    written, MiB/s:               34.24

General statistics:
    total time:                        30.0100s
    total number of events:            374726

Latency (ms):
         min:                                  0.04
         avg:                                  0.08
         max:                                 14.87
         95th percentile:                      0.09
         sum:                              29844.73

Threads fairness:
    events (avg/stddev):          374726.0000/0.00
    execution time (avg/stddev):  29.8447/0.00
```

Test Case 3

```
Threads started!


File operations:
    reads/s:                   3344.58
    writes/s:                  2229.72
    fsyncs/s:                  7135.21

Throughput:
    read, MiB/s:               52.26
    written, MiB/s:            34.84

General statistics:
    total time:                        30.0113s
    total number of events:            381319

Latency (ms):
        min:                                 0.04
        avg:                                 0.08
        max:                                13.45
        95th percentile:                     0.09
        sum:                             29840.55

Threads fairness:
    events (avg/stddev):       381319.0000/0.00
    execution time (avg/stddev):   29.8406/0.00
```

Test Case 4

```
Threads started!

File operations:
    reads/s:                    3276.79
    writes/s:                   2184.53
    fsyncs/s:                   6994.62

Throughput:
    read, MiB/s:                51.20
    written, MiB/s:             34.13

General statistics:
    total time:                     30.0097s
    total number of events:         373688

Latency (ms):
        min:                                0.04
        avg:                                0.08
        max:                               15.80
        95th percentile:                    0.10
        sum:                            29846.08

Threads fairness:
    events (avg/stddev):        373688.0000/0.00
    execution time (avg/stddev):  29.8461/0.00
```

Test Case 5

```
Threads started!


File operations:
    reads/s:                    2796.92
    writes/s:                   1864.61
    fsyncs/s:                   5968.16

Throughput:
    read, MiB/s:                43.70
    written, MiB/s:             29.13

General statistics:
    total time:                     30.0103s
    total number of events:         318886

Latency (ms):
        min:                                0.04
        avg:                                0.09
        max:                               18.73
        95th percentile:                    0.11
        sum:                            29861.53

Threads fairness:
    events (avg/stddev):        318886.0000/0.00
    execution time (avg/stddev):    29.8615/0.00
```

Scenario 3

File size=4G

Test Case 1

```
Threads started!

File operations:
    reads/s:                    2854.31
    writes/s:                   1902.87
    fsyncs/s:                   6089.26

Throughput:
    read, MiB/s:                44.60
    written, MiB/s:             29.73

General statistics:
    total time:                      30.0164s
    total number of events:          325458

Latency (ms):
         min:                              0.04
         avg:                              0.09
         max:                             18.32
         95th percentile:                  0.11
         sum:                          29867.29

Threads fairness:
    events (avg/stddev):        325458.0000/0.00
    execution time (avg/stddev):   29.8673/0.00
```

Test Case 2

```
Threads started!


File operations:
    reads/s:                     2903.67
    writes/s:                    1935.76
    fsyncs/s:                    6196.13

Throughput:
    read, MiB/s:                 45.37
    written, MiB/s:              30.25

General statistics:
    total time:                         30.0148s
    total number of events:             331117

Latency (ms):
         min:                                  0.04
         avg:                                  0.09
         max:                                 24.13
         95th percentile:                      0.12
         sum:                              29855.74

Threads fairness:
    events (avg/stddev):         331117.0000/0.00
    execution time (avg/stddev):  29.8557/0.00
```

Test Case 3

```
Threads started!


File operations:
    reads/s:                    2874.63
    writes/s:                   1916.42
    fsyncs/s:                   6132.94

Throughput:
    read, MiB/s:                44.92
    written, MiB/s:             29.94

General statistics:
    total time:                       30.0130s
    total number of events:           327748

Latency (ms):
        min:                                 0.04
        avg:                                 0.09
        max:                                18.74
        95th percentile:                     0.10
        sum:                             29860.19

Threads fairness:
    events (avg/stddev):        327748.0000/0.00
    execution time (avg/stddev):  29.8602/0.00
```

Test Case 4

```
Threads started!


File operations:
    reads/s:                2810.28
    writes/s:               1873.52
    fsyncs/s:               5995.44

Throughput:
    read, MiB/s:            43.91
    written, MiB/s:         29.27

General statistics:
    total time:                      30.0169s
    total number of events:          320445

Latency (ms):
        min:                             0.03
        avg:                             0.09
        max:                             23.02
        95th percentile:                 0.11
        sum:                             29867.70

Threads fairness:
    events (avg/stddev):      320445.0000/0.00
    execution time (avg/stddev):   29.8677/0.00
```

Test Case 5

```
Threads started!


File operations:
    reads/s:                   2722.95
    writes/s:                  1815.30
    fsyncs/s:                  5811.79

Throughput:
    read, MiB/s:               42.55
    written, MiB/s:            28.36

General statistics:
    total time:                        30.0103s
    total number of events:            310493

Latency (ms):
         min:                              0.04
         avg:                              0.10
         max:                             18.42
         95th percentile:                  0.15
         sum:                          29859.50

Threads fairness:
    events (avg/stddev):          310493.0000/0.00
    execution time (avg/stddev):  29.8595/0.00
```

1. CPU Performance Results:

A) QEMU

Scenario 1

Case	Total Time(s)	CPU Speed(events/sec)	Avg. Latency(ms)
1	10.0028	129.58	7.59
2	10.0083	123.38	7.95
3	10.0064	131.99	7.46
4	10.0153	119.81	8.2
5	10.0138	121.74	8.07
Minimum	10.0028	119.81	7.46
Maximum	10.0153	129.58	8.2
Average	10.00932	125.3	7.854
StdDev	0.00519394	5.23389434	0.31643325

Scenario 2

Case	Total Time(s)	CPU Speed(events/sec)	Avg. Latency(ms)
1	10.0074	29.43	33.71
2	10.0944	27.81	35.3
3	10.028	29.76	33.23
4	10.0388	28.19	34.96
5	10.043	29.79	33.12
Minimum	10.0074	27.81	33.12
Maximum	10.0944	29.79	35.3
Average	10.0447714	28.94	34.105714
StdDev	0.03220888	0.92988171	1.0053009

Scenario 3

Case	Total Time(s)	CPU Speed(events/sec)	Avg. Latency (ms)
1	10.0396	12.83	77.31
2	10.02	13.25	74.65
3	10.0338	13.64	72.6
4	10.0653	13.47	73.41
5	10.0391	12.83	77.06
Minimum	10.02	12.83	72.6
Maximum	10.0653	13.64	77.31
Average	10.0404429	13.2128571	74.9914286
StdDev	0.01642051	0.36834766	2.12073808

B) Docker

Scenario 1

Case	Total Time(s)	CPU Speed(events/sec)	Avg. Latency(ms)
1	10.0003	3333.73	0.3
2	10.0004	3366.89	0.3
3	10.0003	3681.56	0.27
4	10.0003	3764.55	0.27
5	10.0004	3524.95	0.28
Minimum	10.0003	3333.73	0.27
Maximum	10.0004	3764.55	0.3
Average	10.0003429	3538.56571	0.28428571
StdDev	5.4772E-05	189.104746	0.01516575

Scenario 2

Case	Total Time(s)	CPU Speed(events/sec)	Avg. Latency(ms)
1	10.0015	777.55	1.29
2	10.0012	747.78	1.34
3	10.0011	756.99	1.32
4	10.0013	758.17	1.32
5	10.0007	744.32	1.34
Minimum	10.0007	744.32	1.29
Maximum	10.0015	777.55	1.34
Average	10.0011429	758.097143	1.32
StdDev	0.00029665	12.936915	0.0204939

Scenario 3

Case	Total Time(s)	CPU Speed(events/s)	Avg. Latency
1	10.0006	377.31	2.65
2	10.002	379.95	2.63
3	10.0026	374.33	2.67
4	10.001	373.5	2.68
5	10.0013	374.18	2.67
Minimum	10.0006	373.5	2.63
Maximum	10.0026	379.95	2.68
Average	10.0015	376.102857	2.65857143
StdDev	0.0008	2.7186081	0.02

2. File IO Testing

A) QEMU

Scenario 1

Case	Read Throughput(MiB/s)	Write Throughput(MiB/s)	Total Time(s)
1	2.42	1.61	30.2155
2	3.04	2.03	30.1473
3	2	1.33	30.2547
4	5.48	3.65	30.0851
5	3.77	2.51	30.1121
Minimum	2	1.33	30.0851
Maximum	5.48	3.65	30.2547
Average	3.45571429	2.30142857	30.1649286
StdDev	1.36898503	0.91229381	0.07083578

Scenario 2

Case	Read Throughput(MiB/s)	Write Throughput(MiB/s)	Total Time (s)
1	7.93	5.29	30.0333
2	6.43	4.29	30.0385
3	8.33	5.55	30.0578
4	7.92	5.28	30.0512
5	7.39	4.93	30.0721
Minimum	6.43	4.29	30.0333
Maximum	8.33	5.55	30.0721
Average	7.53714286	5.02571429	30.0511857
StdDev	0.73437048	0.48756538	0.01549313

Scenario 3

Case	Read Throughput(MiB/s)	Write Throughput(MiB/s)	Total Time (s)
1	9.06	6.04	30.0369
2	8.46	5.64	30.04
3	8.58	5.72	30.0372
4	8.48	5.65	30.0801
5	9.57	6.38	30.0773
Minimum	8.46	5.64	30.0369
Maximum	9.57	6.38	30.0801
Average	8.88285714	5.92142857	30.0555
StdDev	0.48020829	0.32074912	0.02232879

B) Docker

Scenario 1

Case	Read Throughput(MiB/s)	Write Throughput(MiB/s)	Total Time(s)
1	38.33	25.55	30.0124
2	40.04	26.7	30.0118
3	41.14	27.43	30.0113
4	40.01	26.68	30.0115
5	40.63	27.09	30.0157
Minimum	38.33	25.55	30.0113
Maximum	41.14	27.43	30.0157
Average	39.9457143	26.6328571	30.0128143
StdDev	1.05860758	0.70841372	0.00181466

Scenario 2

Case	Read Throughput(MiB/s)	Write Throughput(MiB/s)	Total Time(s)
1	50.11	33.4	30.0101
2	51.35	34.24	30.01
3	52.26	34.84	30.0113
4	51.2	34.13	30.0097
5	43.7	29.13	30.0103
Minimum	43.7	29.13	30.0097
Maximum	52.26	34.84	30.0113
Average	49.2257143	32.8157143	30.0103429
StdDev	3.45294512	2.30366447	0.00060992

Scenario 3

Case	Read Throughput(MiB/S)	Write Throughput(MiB/s)	Total Time(s)
1	44.6	29.73	30.0164
2	45.37	30.25	30.0148
3	44.92	29.94	30.013
4	43.91	29.27	30.0169
5	42.55	28.36	30.0103
Minimum	42.55	28.36	30.0103
Maximum	45.37	30.25	30.0169
Average	44.1814286	29.4514286	30.0140857
StdDev	1.09879479	0.73501701	0.00269759

Conclusion

From the experiments performed above we observed that Docker executes the instructions faster than the QEMU Ubuntu Virtual Machine which is the ideal case. In most cases Docker outperforms VMs, except security.