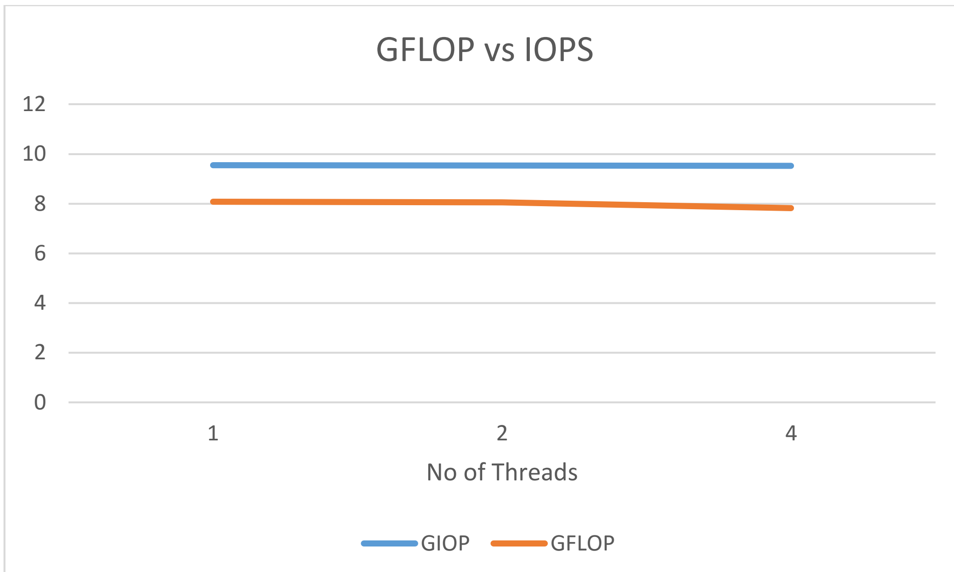
Performance

1. CPU Benchmarking

- The GFLOPS and GIOPS are calculated for different levels of concurrency the readings are as below

No Of Threads	GIOP	GFLOP
1	9.547633	8.074828
2	9.54145	8.053263
4	9.528669	7.81456

The graphical representation –



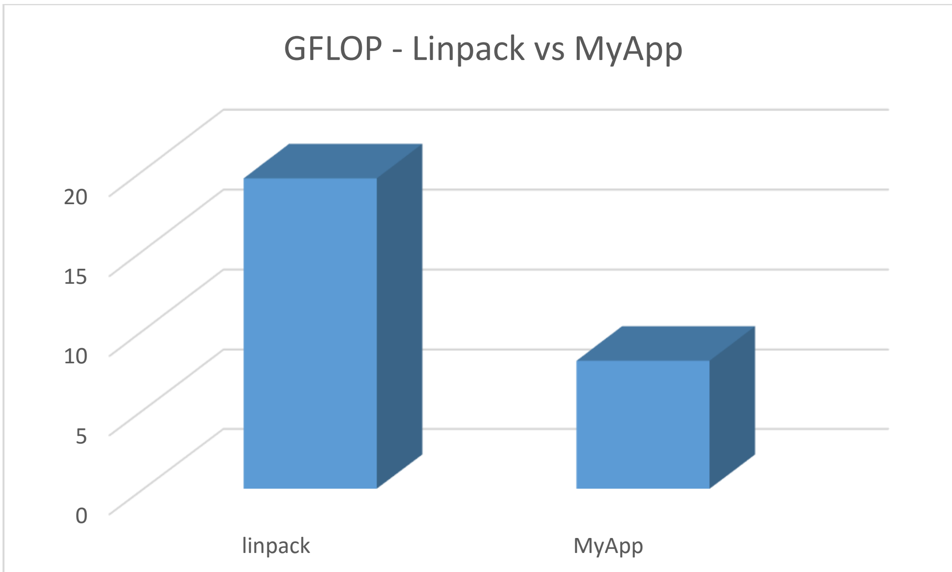
- The **Linpack** GFLOPS on t2.micro –

Linpack Readings
16.788
17.7403
18.1753
18.0819
19.3923
19.836
20.9029
21.399
21.7463
20.794

Avg	19.4856

- **Comparison with linpack readings**
  The maximum GFLOPS achieved by myApp is 8.074828 GFLOPS. And the average of the linpacks FLOPS values is 19.4856 GFLOPS

	GFLOP
linpack	19.4856
MyApp	8.074828



- **Theoretical value of GFLOPS**
  The theoretical value is calculated using below formula

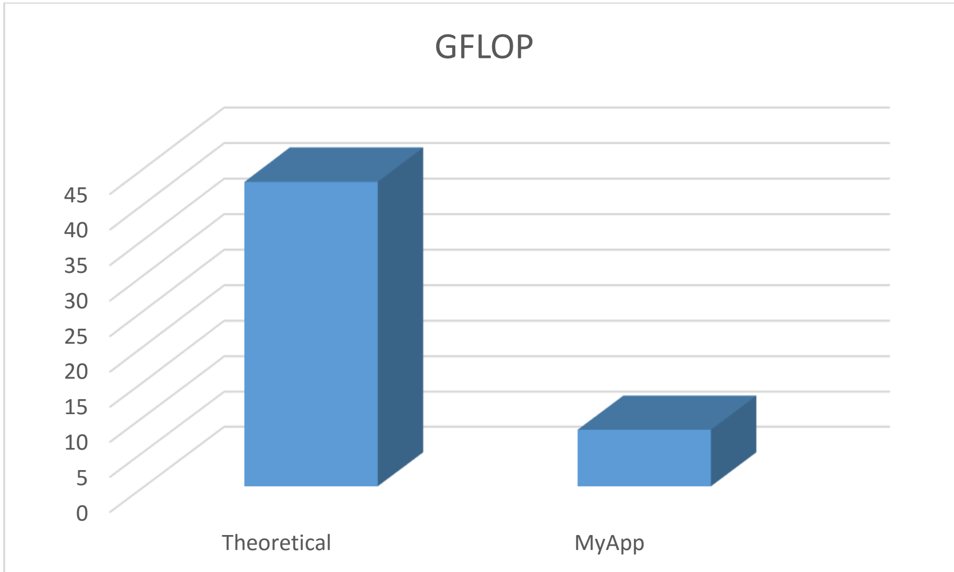
  GFLOPS = CPU Frequency * no of cores * no of threads per core * IPC

  Calculating GFLOPS for t2.micro using above formula-
  GFLOPS = 2.69 * 1 * 1 * 16
  = 43.04

The value for IPC is assumed as 8. I found few sources on the internet talking about IPC values for modern CPU. I assumed IPC 6 for Intel-Xeon-Processor-E5-2670 based on the internet sources.

- **Comparison with theoretical value**

	GFLOP
Theoretical	43.04
MyApp	8.074828



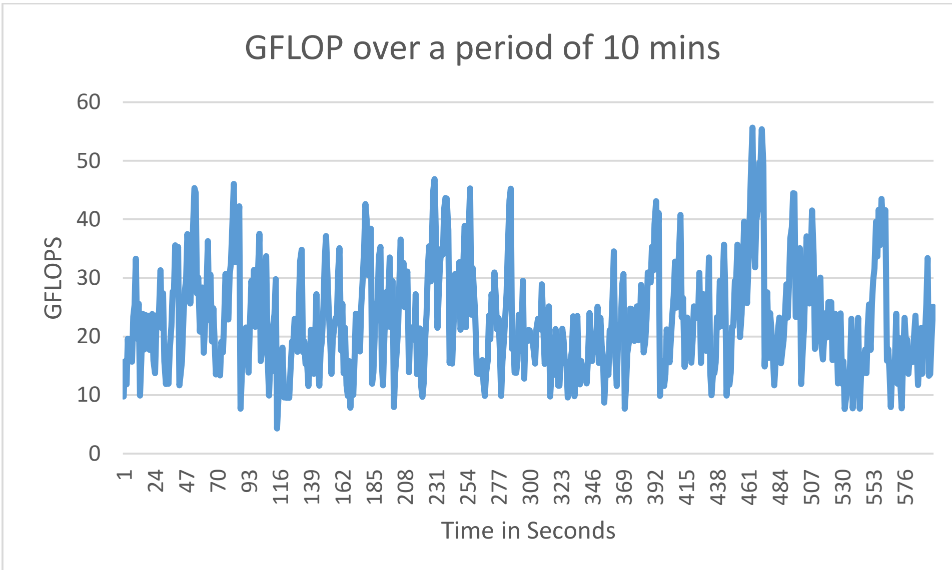
18.76 % of the theoretical value is achieved

- **Conclusion:**
  - The GFLOPS achieved are **41.43%** of the GFLOPS achieved by linkpach benchmarking tool
  - The GFLOPS achieved are **18.76%** of the theoretical value of GFLOPS.

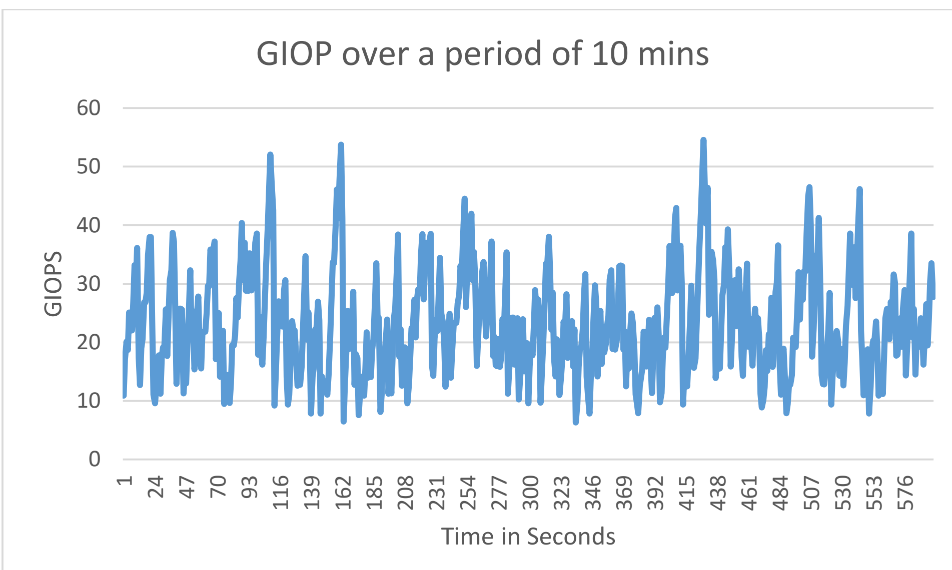
2. CPU Benchmarking Experiment 2

- The readings of experiment 2 are collected in a log file and the values are plotted to see the trend in the GFLOPS values over a period of 10 mins

- GFLOPS over the period of 10 mins-



- IOPS over a period of 10 mins-



- **Conclusion:** During the experiment the maximum throughput (the pikes in graph) achieved is very much close to the theoretical value.

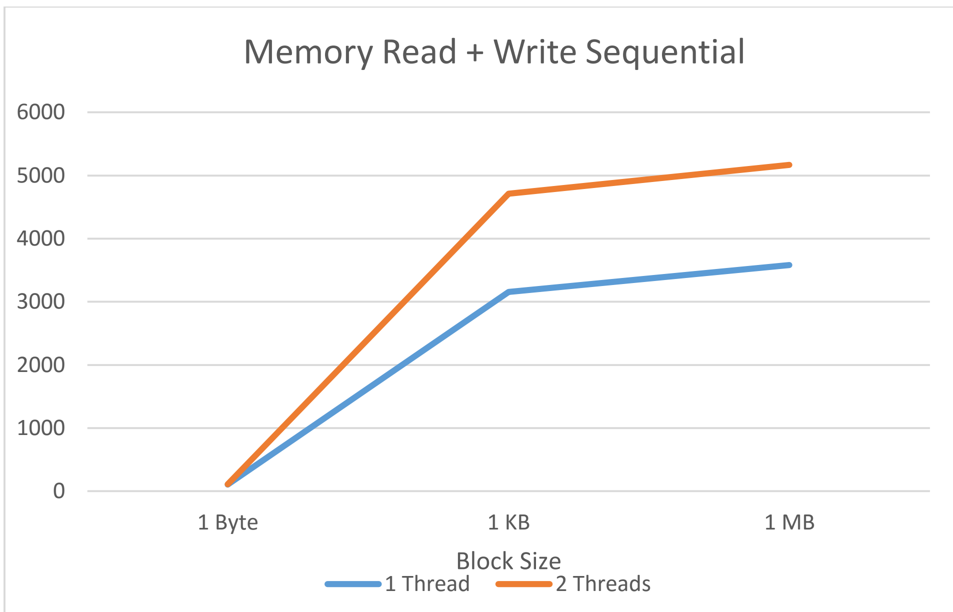
3. Memory Benchmarking

- The experiment is run for read + write operations sequentially and randomly with different levels of concurrency. Below are the readings for different configurations

- **Throughput**
  - Comparing throughput of **Sequential** read + write operations for different level of concurrency.

Block Size	1 Thread	2 Threads
1 Byte	105.608442 MB/s	109.5721 MB/s
1 KB	3156.013068 MB/s	4710.428 MB/s
1 MB	3579.00198 MB/s	5168.2 MB/s

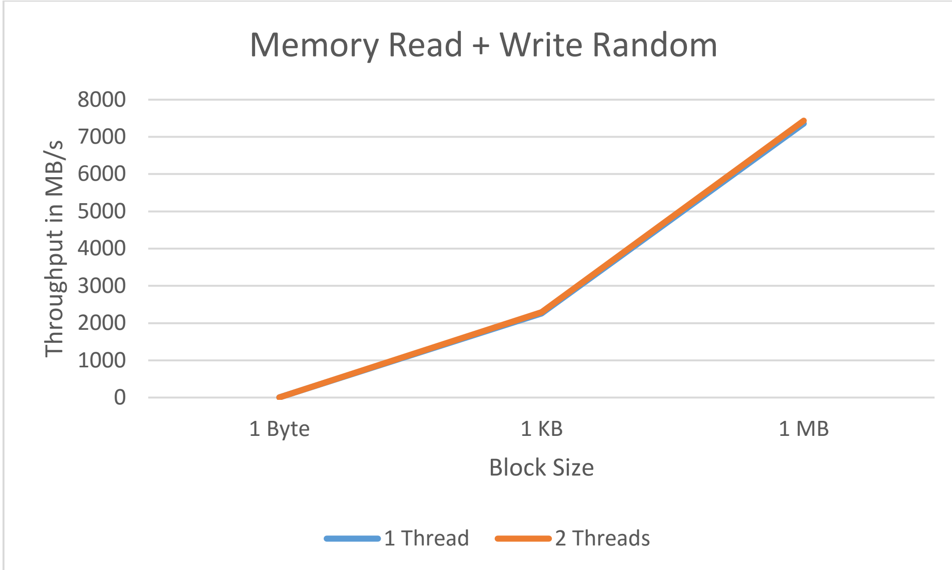
Graphical representation



  - Comparing throughput of **Random** read + write operations for different level of concurrency

Block Size	1 Thread	2 Threads
1 Byte	8.71904 MB/s	8.837693 MB/s
1 KB	2254.860943 MB/s	2296.247 MB/s
1 MB	7356.363126 MB/s	7438.82 MB/s

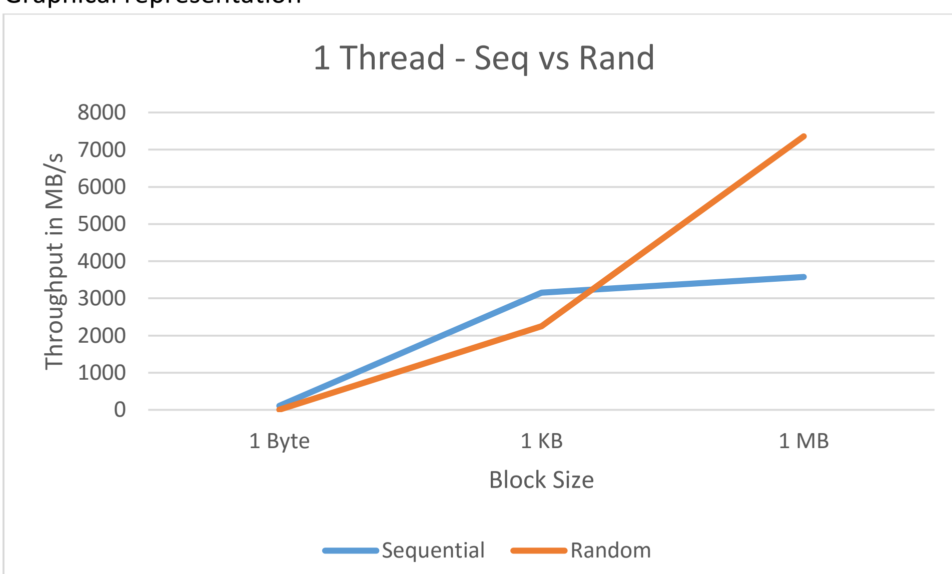
Graphical representation



- Comparing throughput sequential and random read + write operations for 1 thread

Block Size	Sequential	Random
1 Byte	105.608442 MB/s	8.71904 MB/s
1 KB	3156.013068 MB/s	2254.861 MB/s
1 MB	3579.00198 MB/s	7356.363 MB/s

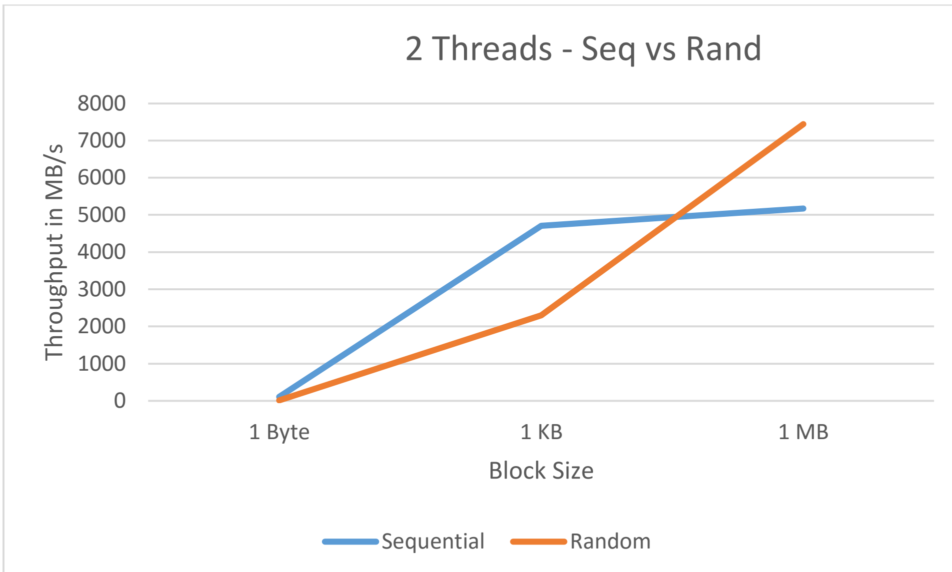
Graphical representation



- Comparing throughput sequential and random read + write operations for 2 threads

Block Size	Sequential	Random
1 Byte	109.57205 MB/s	8.837693 MB/s
1 KB	4710.428263 MB/s	2296.247 MB/s
1 MB	5168.199517 MB/s	7438.82 MB/s

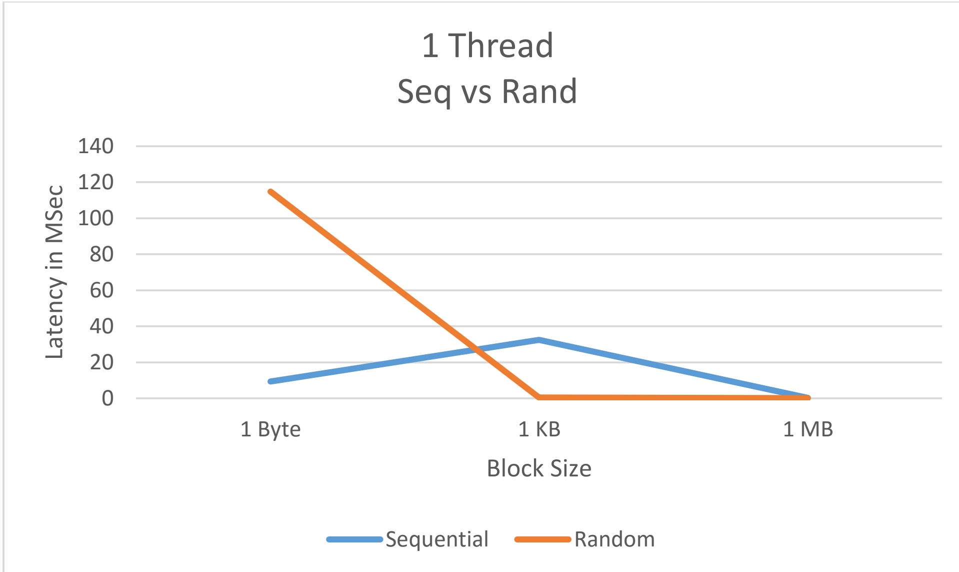
Graphical representation



- **Latency**
  - Comparing latency between sequential and random read + write operations for 1 thread.
    The Latency is calculated for total of 1Mb data movement

Block Size	Sequential	Random
1 Byte	9.46894 MSec	114.69152 MSec
1 KB	32.446 MSec	0.443486 MSec
1 MB	0.279408 MSec	0.135937 MSec

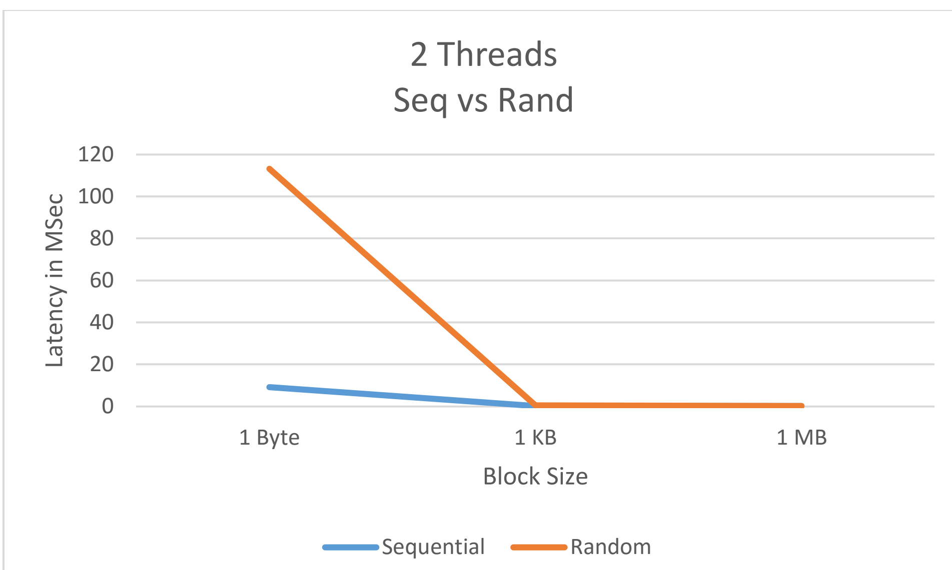
Graphical Representation



- Comparing latency between sequential and random read + write operations for 1 thread
  The Latency is calculated for total of 1Mb data movement

Block Size	Sequential	Random
1 Byte	9.126415 MSec	113.151705 MSec
1 KB	0.212295 MSec	0.435493 MSec
1 MB	0.193491 MSec	0.13443 MSec

Graphical Representation



- **Theoretical value of memory bandwidth**
  The theoretical value of memory bandwidth is calculated for the local system because it is hard to get the memory clock frequency of the t2.micro RAM.
  The bandwidth is calculated as below – it is for DDR3 RAM

  Bandwidth = DRAM clock Frequency * no of data transferred per clock (2 for DDR3) * memory bus interface width * no of interfaces
  = 1600 * 2 * 64 * 2
  = 409600 MegaBits per second
  = 51200 MB/s
  = **51.2 GB/s**

  * (use *lshw -c memory* command to find out the memory parameters)
  * Modern personal computers typically use two memory interfaces (dual-channel mode)

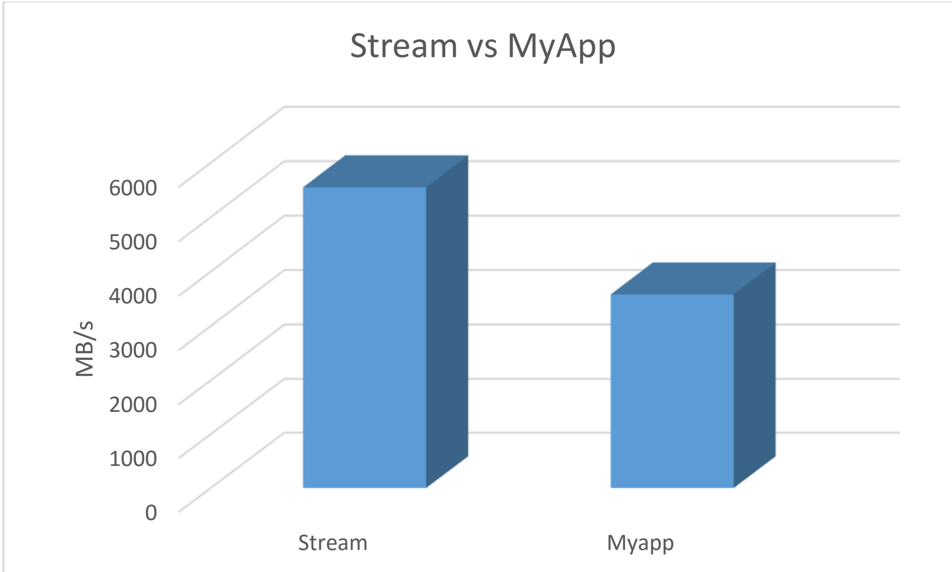
- Throughput by STREAM benchmarking tool
  Below are the bandwidths achieved by STREAM

```
-------------------------------------------------------------
Function    Best Rate MB/s  Avg time     Min time     Max time
Copy:           5548.2     0.028954     0.028838     0.029063
Scale:          5414.8     0.029697     0.029549     0.030000
Add:            7750.2     0.031176     0.030967     0.031589
Triad:          7279.6     0.033083     0.032969     0.033219
-------------------------------------------------------------
```

- **Comparing results with STREAM**
  Below is comparison between the bandwidth achieved by STREAM and MyApp.
  The thoughtput achieved is **64.5%** of the bandwidth reported by STREAM

	Read + Write
Stream	5548.2
Myapp	3579.00198

Graphical representation –



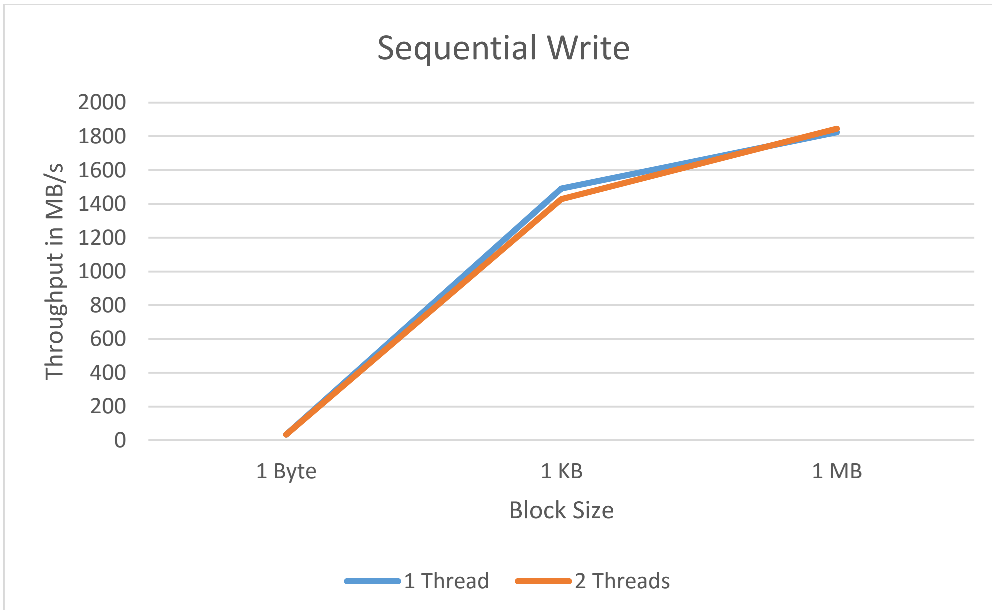
- **Conclusion:**
  - Maximum throughput is achieved with 1 MB block size.
  - As the block size increases the bandwidth also increases.
  - With small block size the program flow goes to the memory large number of times hence increases the overall processing time
  - The time required to store a set of data with small block size will be always greater than the time when using larger block size.
  - The maximum throughput achieved by the application is **64.5%** of the throughput recorded by STREAM memory benchmarking tool.

4. Disk Write - Read Operation Benchmarking

- **Throughput**
  - Comparing throughput of **Sequential write** operations for different level of concurrency

Block Size	1 Thread	2 Threads
1 Byte	34.397654 MB/s	34.354687 MB/s
1 KB	1490.950918 MB/s	1428.930256 MB/s
1 MB	1824.181483 MB/s	1845.402228 MB/s

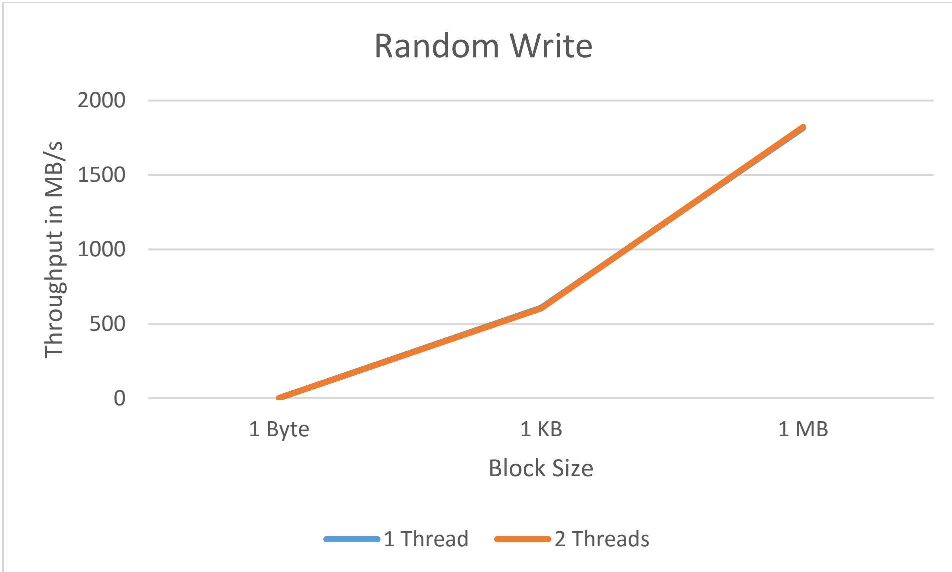
Graphical Representation



  - Comparing throughput of **Random write** operations for different level of concurrency

Block Size	1 Thread	2 Threads
1 Byte	0.853664 MB/s	0.767256 MB/s
1 KB	607.725954 MB/s	602.895547 MB/s
1 MB	1816.628264 MB/s	1822.501086 MB/s

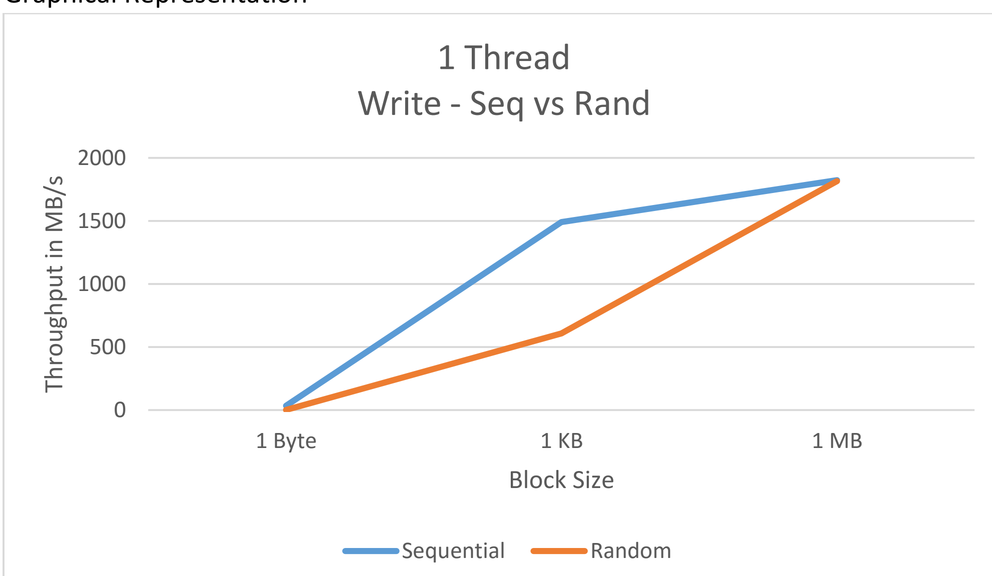
Graphical Representation



- Comparing **sequential and random write** operations for 1 thread

Block Size	Sequential	Random
1 Byte	34.397654 MB/s	0.853664 MB/s
1 KB	1490.950918 MB/s	607.725954 MB/s
1 MB	1824.181483 MB/s	1816.628264 MB/s

Graphical Representation

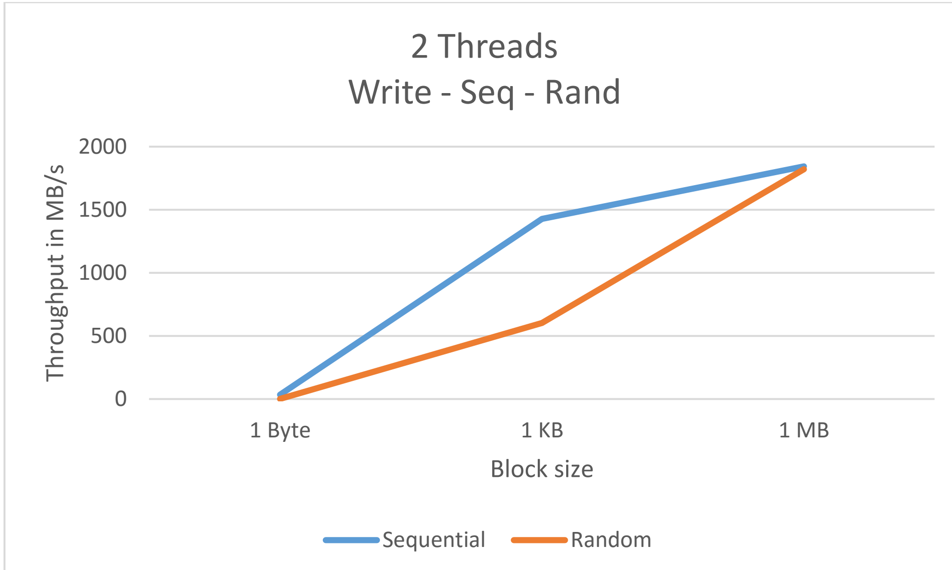


- Comparing **Sequential and random write** operations for 2 threads

Block Size	Sequential	Random
1 Byte	34.354687 MB/s	0.767256 MB/s
1 KB	1428.930256 MB/s	602.895547 MB/s

1 MB	1845.402228 MB/s	1822.501086 MB/s

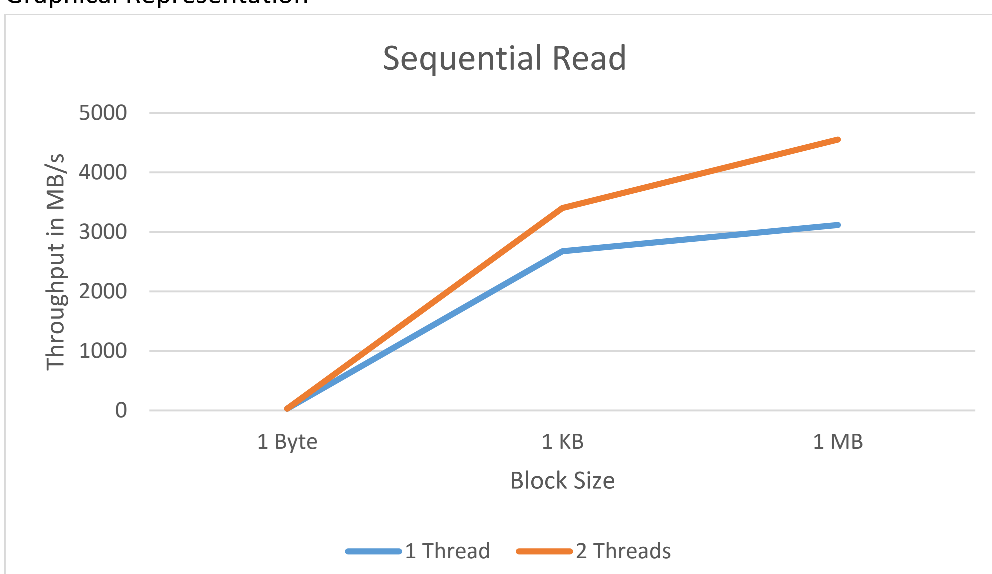
Graphical Representation



- Comparing throughput of **Sequential read** operations for different level of concurrency

Block Size	1 Thread	2 Threads
1 Byte	31.856691 MB/s	32.117277 MB/s
1 KB	2674.327501 MB/s	3401.032931 MB/s
1 MB	3113.903902 MB/s	4549.136659 MB/s

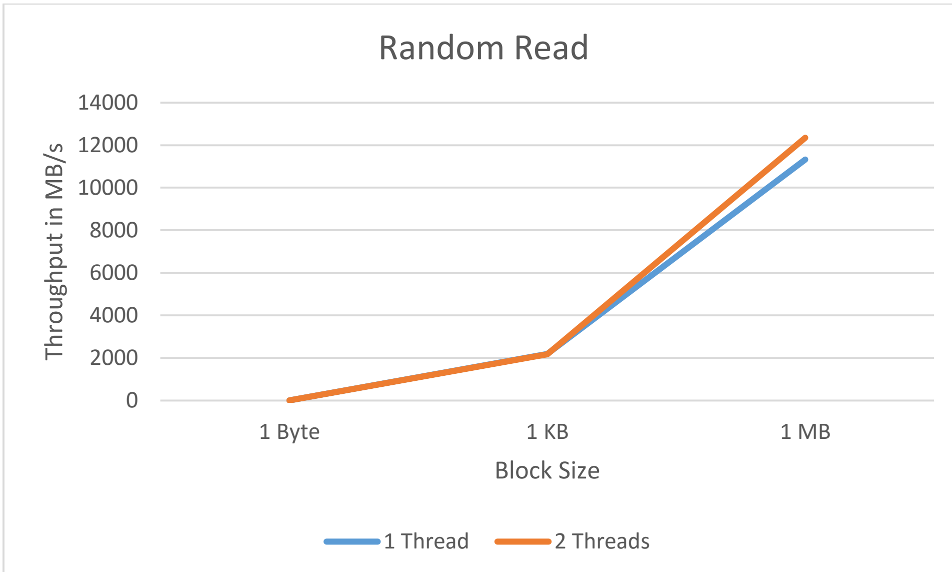
Graphical Representation



- Comparing throughput of **Random read** operations for different level of concurrency

Block Size	1 Thread	2 Threads
1 Byte	3.025605 MB/s	2.995089 MB/s
1 KB	2185.839008 MB/s	2166.622587 MB/s
1 MB	11328.60847 MB/s	12353.62865 MB/s

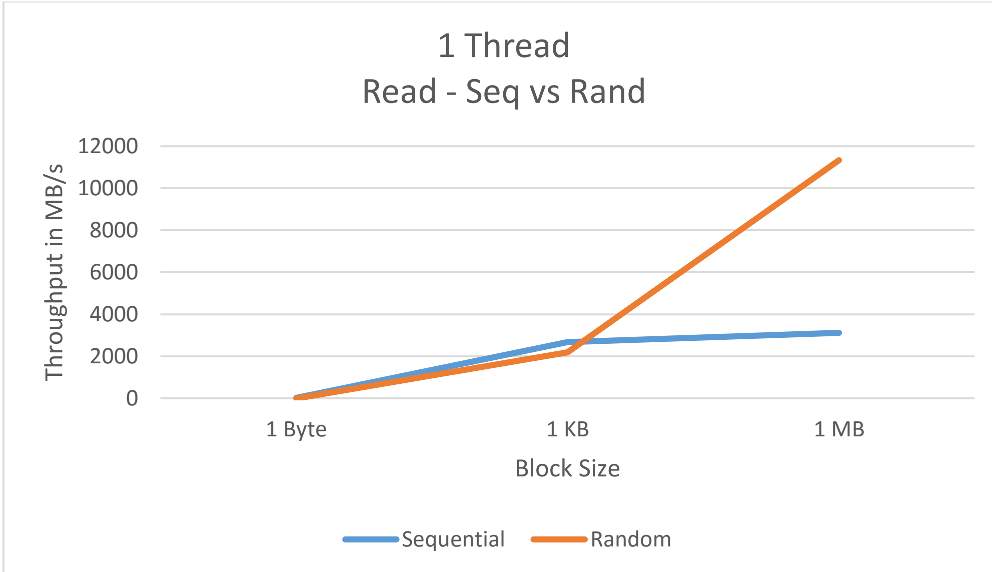
Graphical Representation



- Comparing **sequential and random read** operations for 1 thread

Block Size	Sequential	Random
1 Byte	31.856691 MB/s	3.025605 MB/s
1 KB	2674.327501 MB/s	2185.839008 MB/s
1 MB	3113.903902 MB/s	11328.60847 MB/s

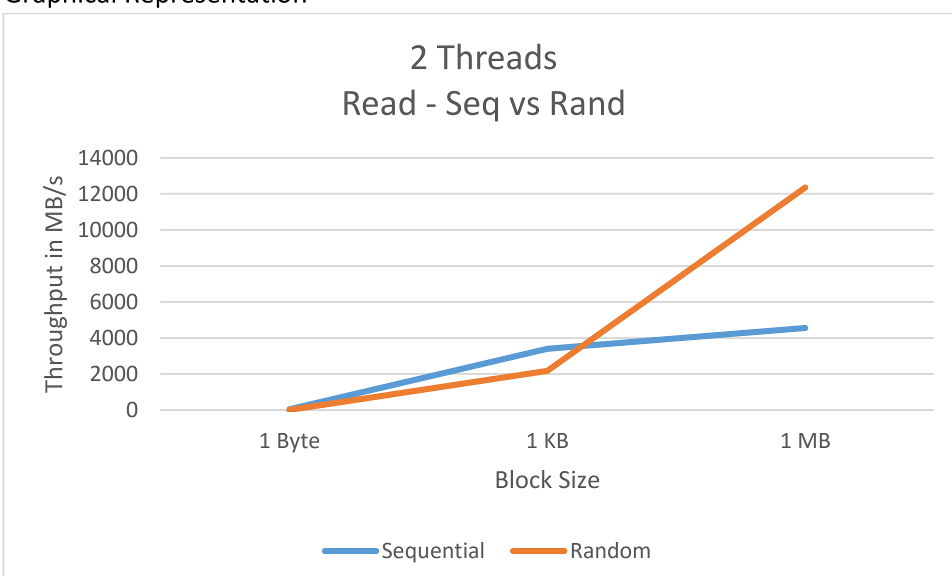
Graphical Representation



- Comparing **Sequential and random read** operations for 2 threads

Block Size	Sequential	Random
1 Byte	32.117277 MB/s	2.995089 MB/s
1 KB	3401.032931 MB/s	2166.622587 MB/s
1 MB	4549.136659 MB/s	12353.62865 MB/s

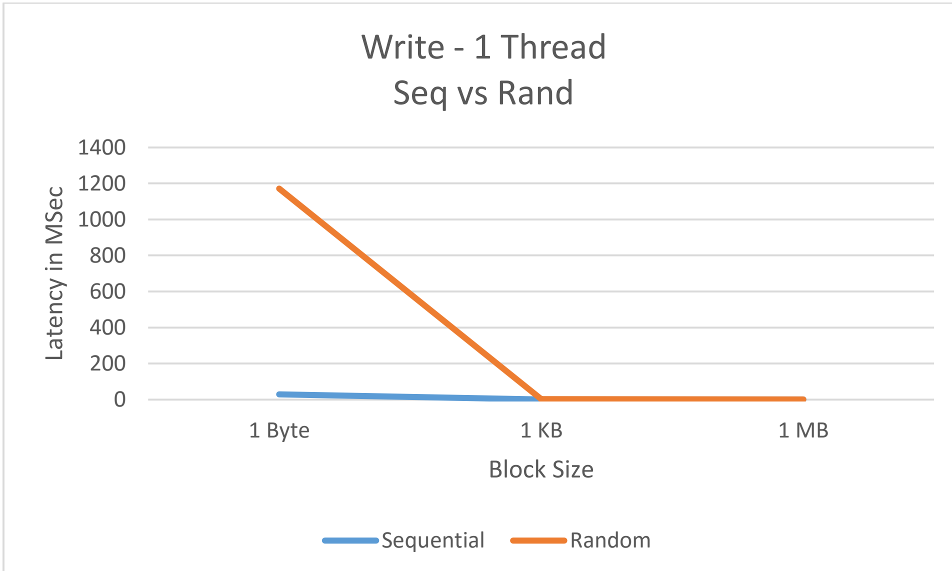
Graphical Representation



- **Latency**
  - Comparing latency between sequential and random write operations for 1 thread
    The Latency is calculated for total of 1Mb data movement

Block Size	Sequential	Random
1 Byte	29.07175 MSec	1171.42164 MSec
1 KB	0.670713 MSec	1.645479 MSec
1 MB	0.548191 MSec	0.55047 MSec

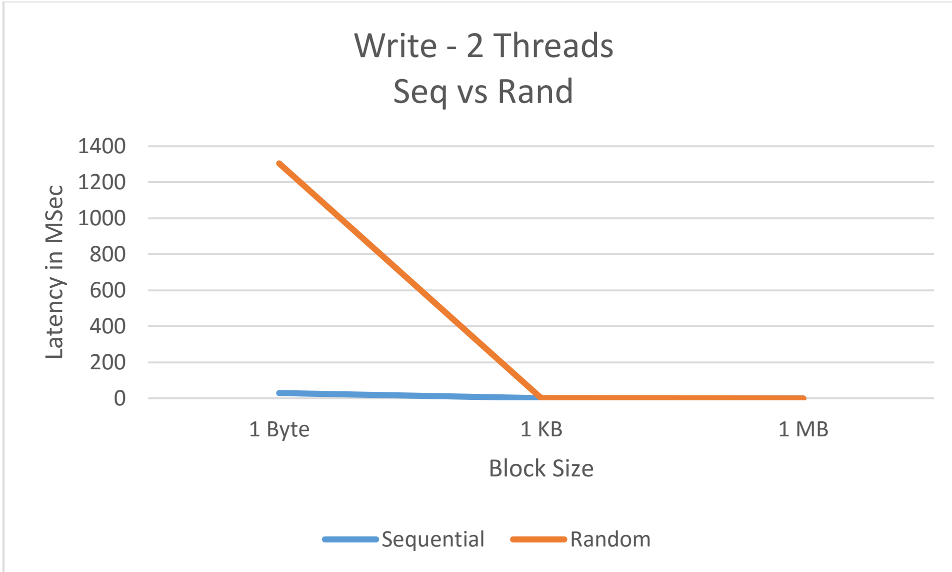
Graphical Representation



- Comparing latency between sequential and random write operations for 2 threads
  The Latency is calculated for total of 1Mb data movement

Block Size	Sequential	Random
1 Byte	29.10811 MSec	1303.345595 MSec
1 KB	0.699824 MSec	1.658662 MSec
1 MB	0.541887 MSec	0.548697 MSec

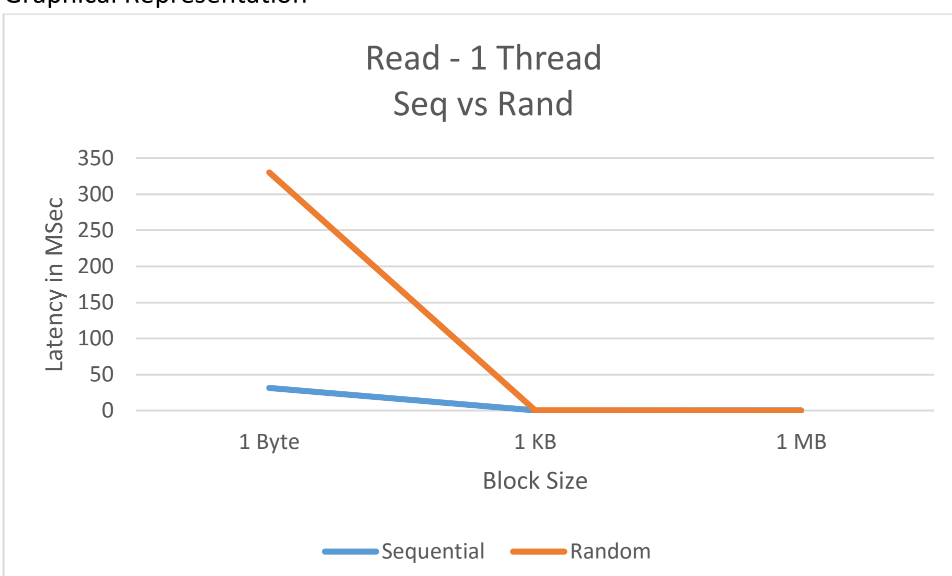
Graphical Representation



- Comparing latency between sequential and random read operations for 1 thread
  The Latency is calculated for total of 1Mb data movement

Block Size	Sequential	Random
1 Byte	31.39058 MSec	330.51244 MSec
1 KB	0.373926 MSec	0.45749 MSec
1 MB	0.32114 MSec	0.088272 MSec

Graphical Representation

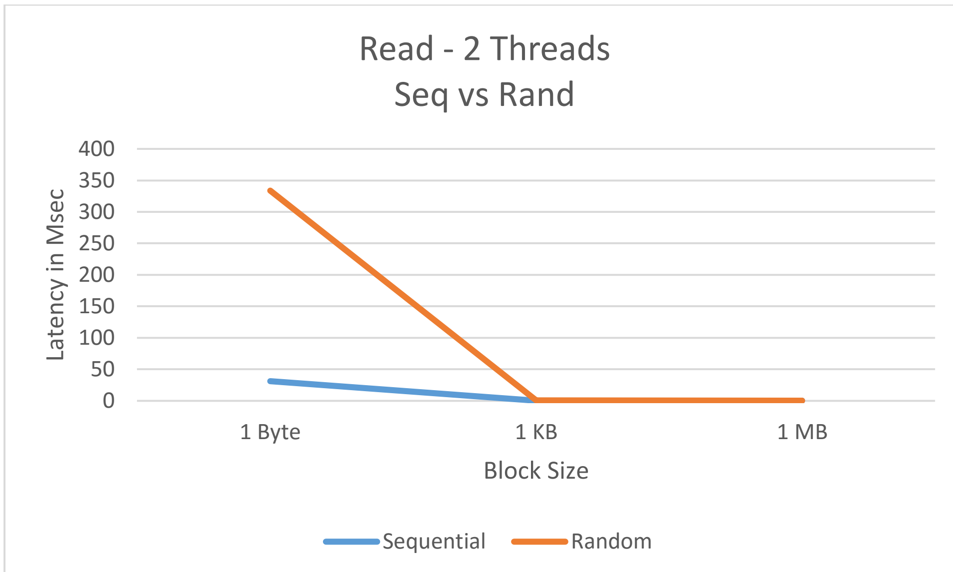


- Comparing latency between sequential and random read operations for 2 threads

The Latency is calculated for total of 1Mb data movement

Block Size	Sequential	Random
1 Byte	31.13589 MSec	333.879845 MSec
1 KB	0.294028 MSec	0.461548 MSec
1 MB	0.219822 MSec	0.080948 MSec

Graphical Representation



- Comparing bandwidth achieved with the bandwidth achieved using **IOZone** memory benchmarking tool
  The readings of IOZone memory benchmarking tool for 1024 block size are compared with the readings of MyApp taken for the same block size

IOZone readings for 1024 bock size

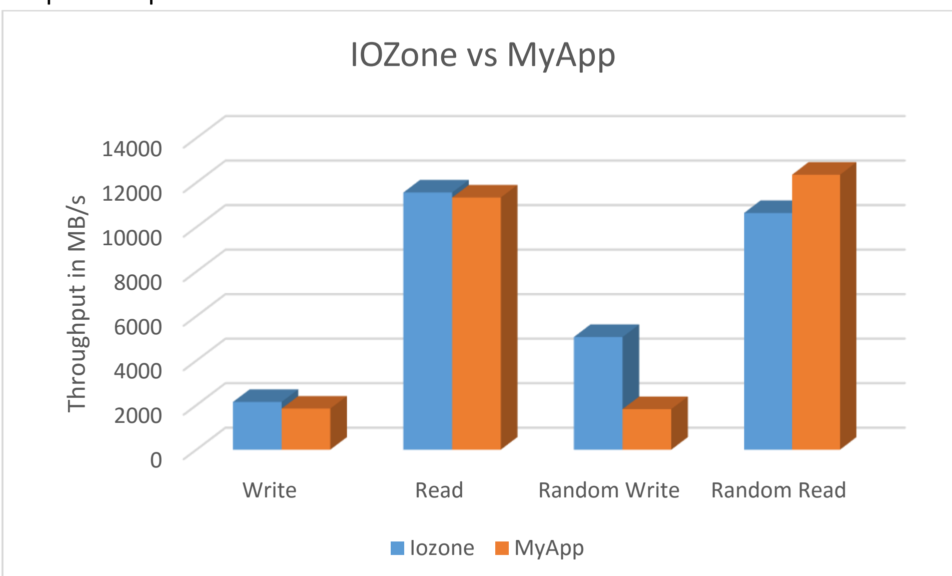
	Write	read	Random Write	Random Read
	1783.768 MB/s	10230.845 MB/s	1600.327 MB/s	8680.108 MB/s
	2270.3 MB/s	13863.422 MB/s	4995.276 MB/s	8970.167 MB/s
	1848.247 MB/s	14044.758 MB/s	5536.137 MB/s	11903.823 MB/s
	2192.645 MB/s	12983.353 MB/s	6025.439 MB/s	13264.026 MB/s
	2173.78 MB/s	7590.887 MB/s	5356.618 MB/s	10878.686 MB/s
	2592.318 MB/s	11520.658 MB/s	6059.442 MB/s	10769.573 MB/s
	2310.605 MB/s	9045.736 MB/s	5071.963 MB/s	9485.232 MB/s
	1917.562 MB/s	11773.301 MB/s	5917.516 MB/s	10990.032 MB/s
	2202.766 MB/s	12944.224 MB/s	4995.276 MB/s	10769.573 MB/s
avg	2143.554 MB/s	11555.242 MB/s	5061.999 MB/s	10634.58 MB/s

- Comparing IOZone average value with the maximum bandwidth achieved.
  The maximum bandwidth for the write operation achieved is 86.09% of the bandwidth recorded by

	Write	Read	Random Write	Random Read
Iozone	2143.555 MB/s	11555.24 MB/s	5061.99 MB/s	10634.58 MB/s
MyApp	1845.402 MB/s	11328.61 MB/s	1822.501 MB/s	12353.628 MB/s

Performance achieved by the application compared to IOZone is as below –
Write – **86.09%**
Read – **98.03%**
Random Write – **36%**
Random Read – **116.16%**

Graphical representation



- Comparing results with **theoretical** values –
  The t2 micro instance uses General purpose SSD GP2. The maximum throughput stated on Amazon AWS is **160 MB/s**
  (http://docs.aws.amazon.com/AWSEC2/latest/UserGuide/EBSVolumeTypes.html#IOcredit)
  Whereas the throughput recorded by IOZone and My applications are greater as mentioned above.

- **Conclusion:**
  - The maximum throughput is achieved using 1MB block sizes. The bigger block size reduces the IO overheads.
  - For a small block size, the number of times the IO requests are made is greater than in case of bigger block size.

- Hence by using bigger block size the IOs can be reduced hence increasing the response time.