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1. Introduction

This document contains the details related to different Benchmarks run on Amazon EC2 t2.micro system. Experiments dealing with different sizes and threads are run to measure the efficiency of CPU, Memory and Disk. The following sections will have elaborate details with respect to each of the Benchmark experiment.

2. Design of Benchmark experiments

This section outlines the details on the problem statement of the Benchmark experiment and approach taken for the logic for each of the categories.

2.1 CPU Benchmark

The aim of the benchmark experiment is to determine the **GIOPS** (Giga Integer Operations Per Second) and **GFLOPS** (Giga Floating Operations Per Second) of the processor. The experiment must also include varying levels of concurrency by running 1 thread, 2 threads and 4 threads.

The Operations are measured using matrix multiplication. Based on the data type, we generate two matrices of size 400 X 400. Based on the number of threads, the multiplication process is divided equally among different threads. Time is measured in each of the threads and finally the Operations per second is determined.

2.2 Memory Benchmark

The aim of this benchmark experiment is to determine the Throughput (MB/sec) and Latency (ms) of the memory. The experiment should measure these values using different memory sizes of 1 byte, 1 KB and 1 MB and be capable of running in 1 thread or 2 threads. The experiment should also take into consideration the sequential access and random access of the memory.

The experiment uses the '**memcpy**' command to measure the throughput and latency. Based on the number of threads, each thread needs to copy strings of different sizes from one memory location to another memory location. A total of 400 strings will be copied. The sizes of each of the string for each set of experiments will be 1 byte, 1KB and 1 MB.

2.3 Disk Benchmark

The aim of this benchmark experiment is to determine the Throughput (MB/Sec) and Latency (ms) of the disk. The experiment should measure these values using different memory sizes of 1 byte, 1 KB and 1 MB and be capable of running in 1 thread or 2 threads. The experiment should also take into consideration the sequential access and random

access of the memory while doing both read and write operations.

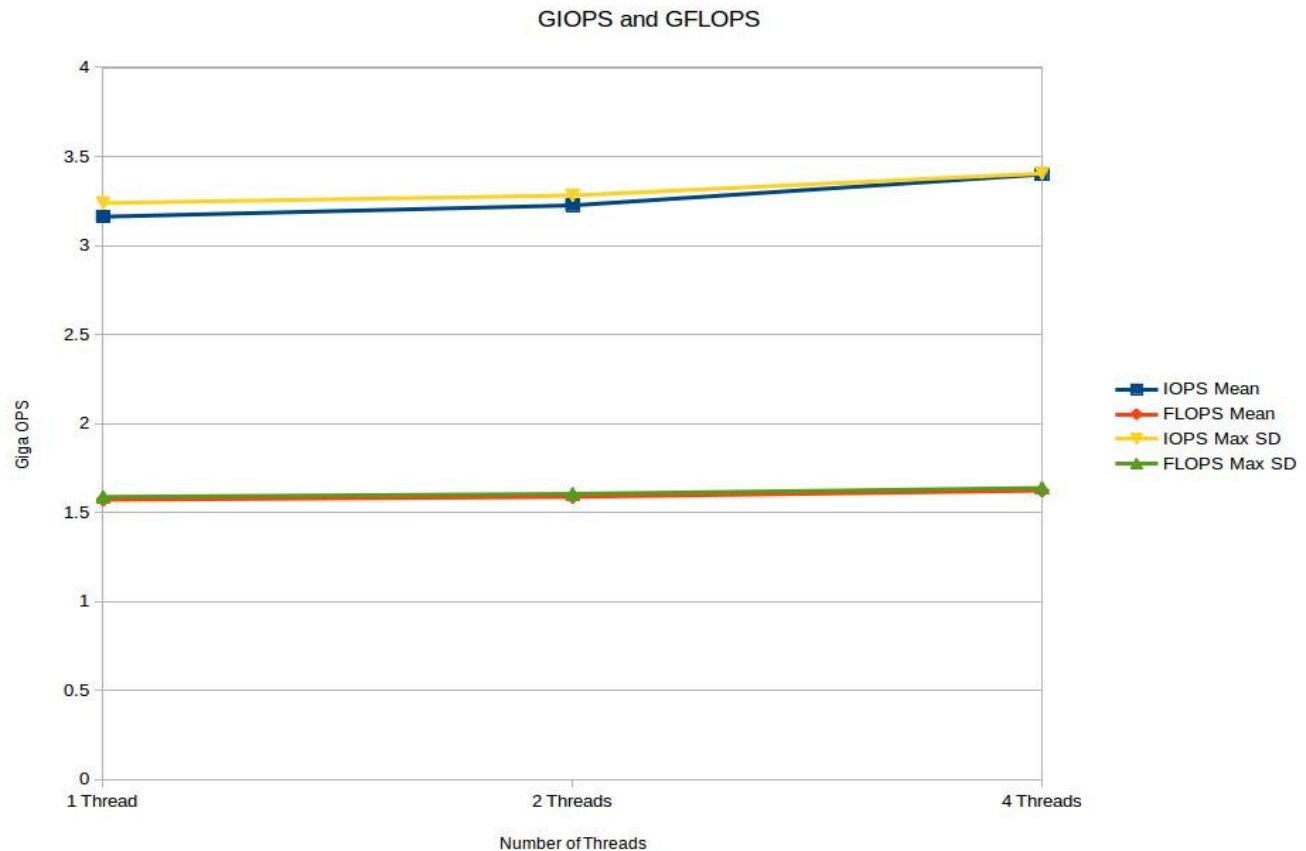
The experiment uses '**fseek**', '**fread**' and '**fwrite**' operations to measure the throughput and latency. In each of the experiments, different size strings will be written and read from disk (i.e., file). Each experiment will deal with 1200 of such strings and the file processing of strings is equally distributed across multiple threads. For sequential access of disk (i.e., file), the experiment performs only one '**fseek**' operation, whereas for random access of disk (i.e., file), the experiment runs multiple '**fseek**' operations.

3. Performance Analysis of Benchmarks

3.1 CPU Benchmark

Below are the results of different CPU Benchmark Experiments.

Giga Ops	IOPS Mean	FLOPS Mean	IOPS Max SD	FLOPS Max SD	Theoretical	LINPACK
1 Thread	3.16182	1.57163	3.23868	1.58788	10	19.1702
2 Threads	3.22534	1.58765	3.28146	1.60465		
4 Threads	3.39909	1.62289	3.40482	1.63770		

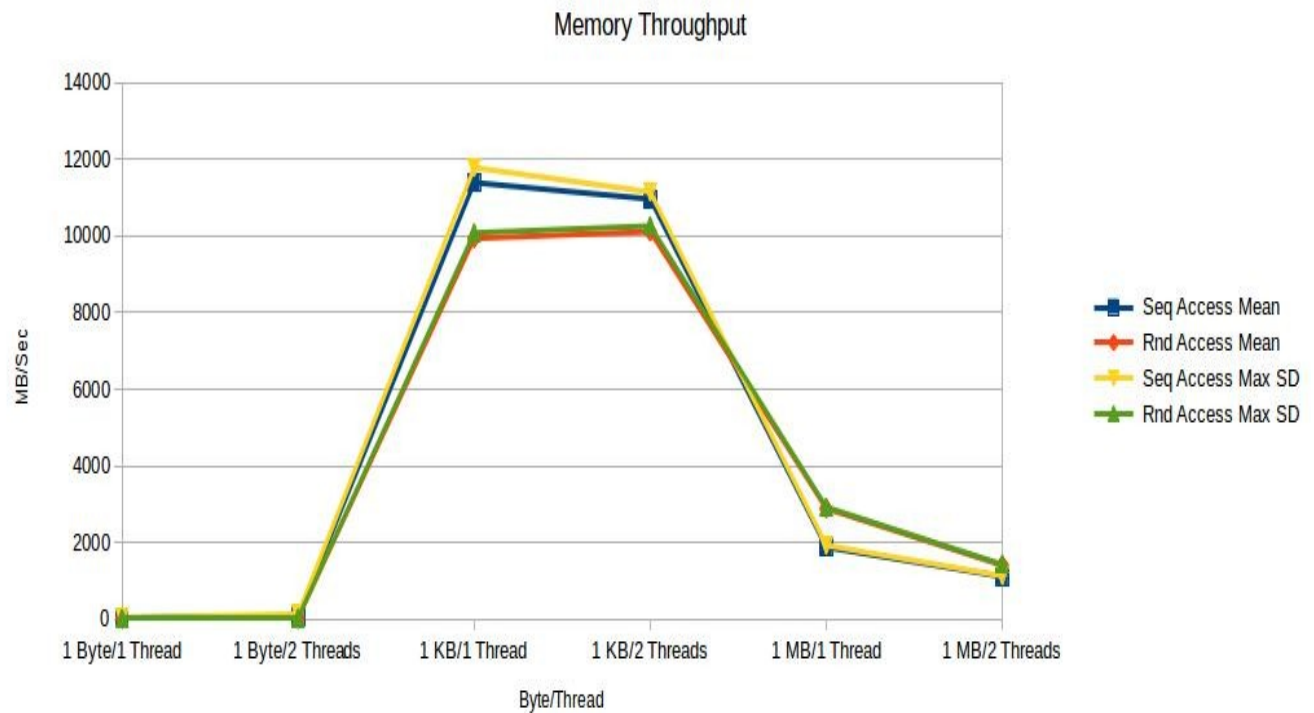


3.2 Memory Benchmark

Below are the results of different Memory Benchmark Experiments.

3.2.1.Throughput

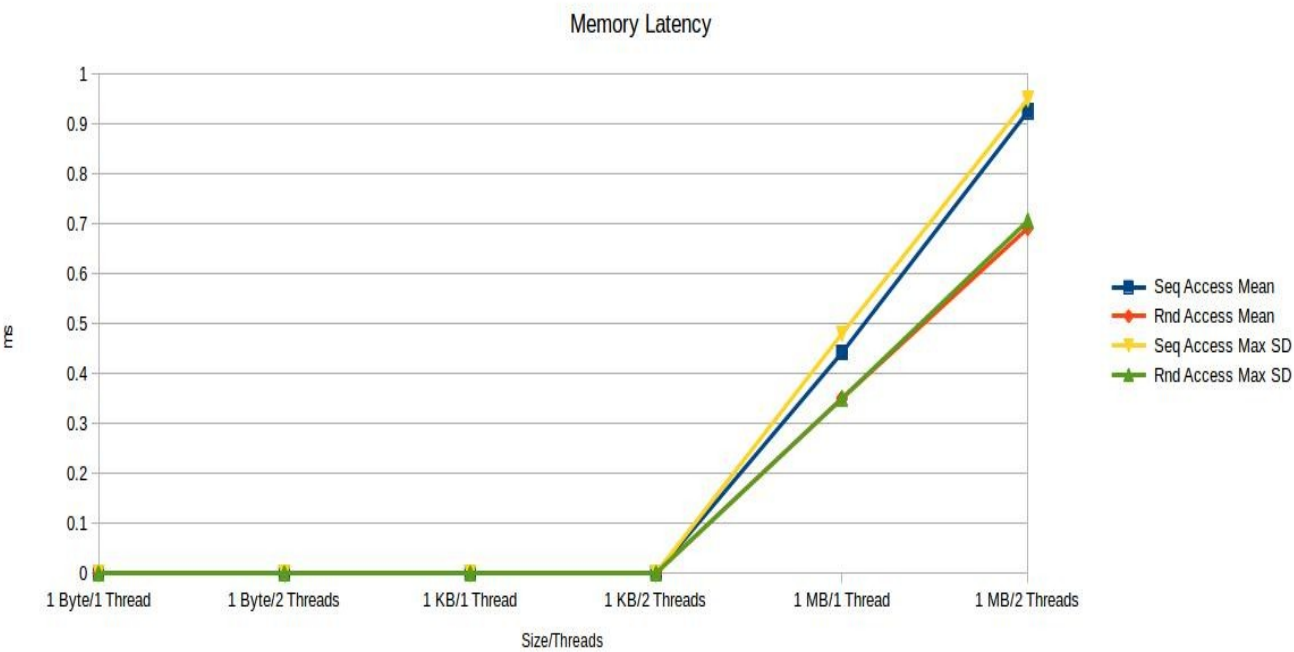
Throughput (MB/Sec)	Sequential Access Mean	Random Access Mean	Sequential Access Max SD	Random Access Max SD
1 Byte/1 Thread	37.24789	24.37167	41.69721	25.28935
1 Byte/2 Threads	92.33989	30.27537	137.99828	32.8973
1 KB/1 Thread	11386.18326	9932.55876	11776.70698	10077.1276
1 KB/2 Threads	10957.07380	10108.27851	11141.328253	10256.6518
1 MB/1 Thread	1879.819040	2887.75455	1928.45505	2922.85315
1 MB/ 2 Threads	1113.30072	1410.60141	1133.26426	1431.03243



The “STREAM” standard benchmark result value is 8684.4336 MB/Sec

3.2.2.Latency

Latency (ms)	Sequential Access Mean	Random Access Mean	Sequential Access Max SD	Random Access Max SD
1 Byte/1 Thread	0	0	0	0
1 Byte/2 Threads	0	0	0	0
1 KB/1 Thread	0	0	0	0
1 KB/2 Threads	0	0	0	0
1 MB/1 Thread	0.4417	0.35	0.4799	0.35
1 MB/ 2 Threads	0.925	0.6917	0.95	0.7061

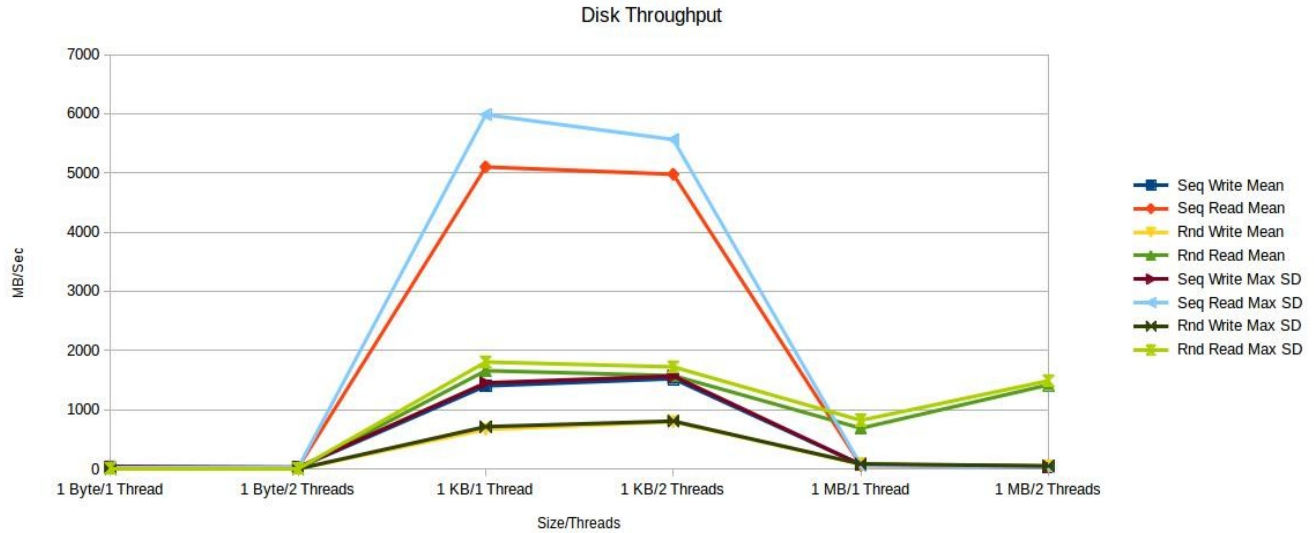


3.3 Disk Benchmark

Below are the results of different Disk Benchmark Experiments.

3.3.1.Throughput

Throughput (MB/Sec)	Seq Write Mean	Seq Read Mean	Random Write Mean	Random Read Mean	Seq Write Max SD	Seq Read Max SD	Random Write Max SD	Random Read Max SD
1 Byte/ 1 Thread	28.94874	25.759	1.2085	5.8246	30.9705	28.0478	1.3345	6.7484
1 Byte/ 2 Threads	24.2561	17.0625	1.1869	4.2157	25.8256	18.006	1.2282	4.37
1 KB/ 1 Thread	1400.2197	5099.8713	664.5291	1657.8694	1451.8461	5984.0171	710.8855	1803.3776
1 KB/ 2 Threads	1522.0842	4976.8035	793.4414	1574.7967	1567.7583	5563.737	804.7501	1721.2039
1 MB/ 1 Thread	69.9961	57.3348	79.1026	685.225	70.0271	57.3941	81.4308	818.7908
1 MB/ 2 Threads	34.9556	31.7918	46.7680	1418.44	35.1181	31.8492	47.5009	1487.515

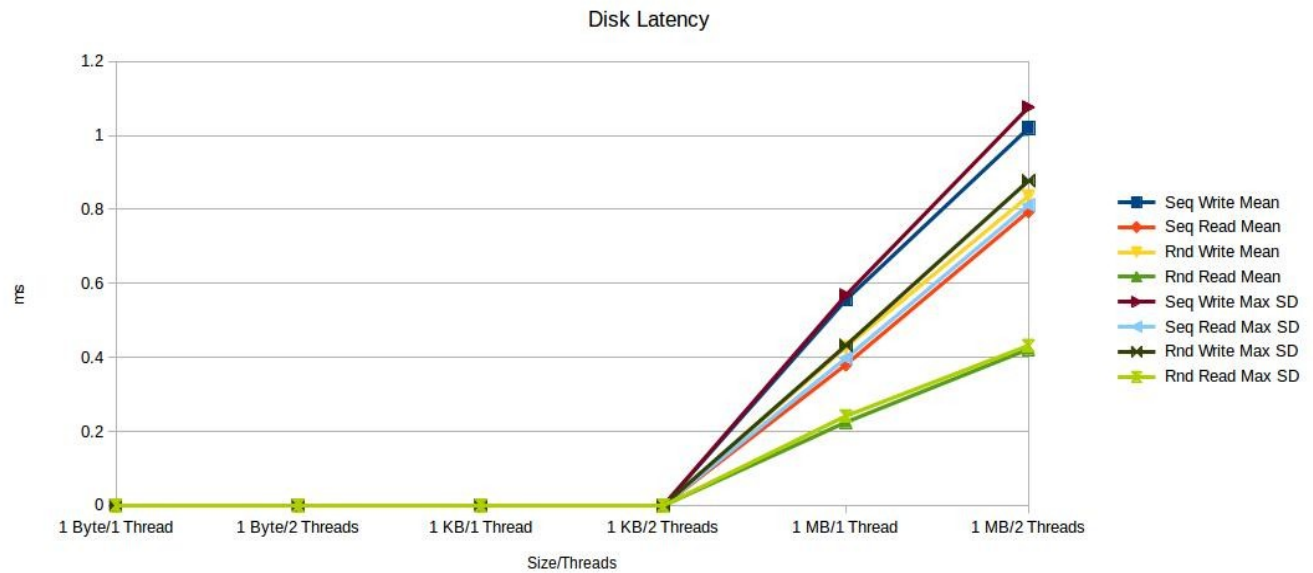


The “IOZONE” standard benchmark results are

Throughput	Sequential Write	Sequential Read	Random Write	Random Read
MB/Sec	1950.1074	12640.8438	3519.2842	10438.6367

3.3.2.Latency

Latency (ms)	Seq Write Mean	Seq Read Mean	Random Write Mean	Random Read Mean	Seq Write Max SD	Seq Read Max SD	Random Write Max SD	Random Read Max SD
1 Byte/ 1 Thread	0	0	0	0	0	0	0	0
1 Byte/ 2 Threads	0	0	0	0	0	0	0	0
1 KB/ 1 Thread	0	0	0	0	0	0	0	0
1 KB/ 2 Threads	0	0	0	0	0	0	0	0
1 MB/ 1 Thread	0.5556	0.3805	0.4277	0.225	0.5683	0.3979	0.4326	0.2417
1 MB/ 2 Threads	1.0194	0.7944	0.8361	0.4222	1.0762	0.8118	0.8772	0.4318



4. References

- <http://www.cs.virginia.edu/stream/> - STREAM Benchmark Download
- <http://iozone.org/> - IOZONE Benchmark Download
- <https://software.intel.com/en-us/articles/intel-mkl-benchmarks-suite> – LINPACK Benchmark Download
- <http://aws.amazon.com/ec2/instance-types/> - EC2 T2 Micro Instance Details
- <http://www.crucial.com/usa/en/memory-performance-speed-latency> – Latency calculation equation
- https://en.wikipedia.org/wiki/Memory_bandwidth – Memory Bandwidth Information