

Cloud Computing Assignment 1

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CPU Benchmark:

All the experiments were done on Prometheus cluster (Intel(R) Xeon(R) CPU E5-2620 v4 @ 2.10GHz).

```
avellineni@prometheus:~$ lscpu
Architecture:          x86_64
CPU op-mode(s):        32-bit, 64-bit
Byte Order:            Little Endian
CPU(s):                8
On-line CPU(s) list:   0-7
Thread(s) per core:    1
Core(s) per socket:    1
Socket(s):             8
NUMA node(s):          1
Vendor ID:             GenuineIntel
CPU family:            6
Model:                 94
Model name:            Intel Core Processor (Skylake)
Stepping:              3
CPU MHz:               2099.998
BogoMIPS:              4199.99
Virtualization:        VT-x
Hypervisor vendor:     KVM
Virtualization type:   full
L1d cache:             32K
L1i cache:             32K
L2 cache:              4096K
L3 cache:              16384K
NUMA node0 CPU(s):     0-7
Flags:                 fpu vme de pse tsc msr pae mce cx8 apic sep mtrr pge mca cmov pat pse36 clflush mmx fxsr sse sse2 ss syscall nx pdpe1gb
rdtscp lm constant_tsc rep_good nopl xtopology eagerfpu pni pclmulqdq vmx ssse3 fma cx16 pcid sse4_1 sse4_2 x2apic movbe popcnt tsc_deadline_
timer aes xsave avx f16c rdrand hypervisor lahf_lm abm 3dnowprefetch invpcid_single retpoline kaiser tpr_shadow vnmi flexpriority ept vpid fsg
sbase tsc_adjust bmi1 hle avx2 smep bmi2 erms invpcid rtm rdseed adx snap xsaveopt arat
```

Products Solutions Support		Support Home > Product Specifications > Processors		Search specifications
Specifications Essentials Performance Supplemental Information Memory Specifications Expansion Options Package Specifications Advanced Technologies Security & Reliability Ordering and Compliance		Performance		
		# of Cores	8	
		# of Threads	16	
		Processor Base Frequency	2.10 GHz	
		Max Turbo Frequency	3.00 GHz	
		Cache	20 MB SmartCache	
		Bus Speed	8 GT/s QPI	
		# of QPI Links	2	
		TDP	85 W	
		VID Voltage Range	0	

Measurements were collected for the following specifications:

Workload: 1 trillion arithmetic operations.

Operations: quarter precision(QP), half precision(HP), single precision(SP), double precision(DP).

Concurrency: 1,2,4 threads.

Results Measurement: Giga ops/sec.

Measurement:

Workload	Concurrency	MyCPUBench (Gops/sec)	Linpack (Gops/sec)	Theoretical (Gops/sec)	MyCPUBench Efficiency	Linpack Efficiency
QP	1	18.887	N/A	535.04	3.530016	N/A
QP	2	18.885	N/A	535.04	3.529643	N/A
QP	4	18.38	N/A	535.04	3.435257	N/A
HP	1	20.75	N/A	535.04	3.878215	N/A
HP	2	19.396	N/A	535.04	3.62515	N/A
HP	4	20.35	N/A	535.04	3.803454	N/A
SP	1	17.15	N/A	535.04	3.205368	N/A
SP	2	16.288	N/A	535.04	3.044258	N/A
SP	4	17.64	N/A	535.04	3.29695	N/A
DP	1	16.39	223.62	535.04	3.063322	41.8
DP	2	16.228	223.62	535.04	3.033044	41.8
DP	4	15.857	223.62	535.04	2.963704	41.8

Theoretical Calculation:

Processor performance = CPU speed * Number of CPU cores * CPI * Number of CPUs

= 2.09 * 8 * 4 * 8

= 535.04 Gops/sec.

Linpack Efficiency:

Efficiency = 223.62/535.04 * 100 = 41.8%

LINPACK Measurement:

```
avellineni@prometheus:~$ cd l_mklb_p_2018.1.009/benchmarks_2018/linux/mkl/benchmarks/linpack/
avellineni@prometheus:~/l_mklb_p_2018.1.009/benchmarks_2018/linux/mkl/benchmarks/linpack$ ./runme_xeon64
This is a SAMPLE run script for running a shared-memory version of
Intel(R) Distribution for LINPACK* Benchmark. Change it to reflect
the correct number of CPUs/threads, problem input files, etc..
*Other names and brands may be claimed as the property of others.
./runme_xeon64: 35: [: -gt: unexpected operator
Fri Mar 23 19:29:53 CDT 2018
Sample data file lininput_xeon64.

Current date/time: Fri Mar 23 19:29:53 2018

CPU frequency:    2.090 GHz
Number of CPUs: 8
Number of cores: 8
Number of threads: 8

Parameters are set to:

Number of tests: 15
Number of equations to solve (problem size) : 1000 2000 5000 10000 15000 18000 20000 22000 25000 26000 27000 30000 35000 40000 45000
Leading dimension of array                   : 1000 2000 5000 10000 15000 18000 20016 22008 25000 26000 27000 30000 35000 40000 45000
Number of trials to run                      : 4    2    2    2    2    2    2    2    2    2    1    1    1    1    1
Data alignment value (in Kbytes)             : 4    4    4    4    4    4    4    4    4    4    4    1    1    1    1

Maximum memory requested that can be used=16200901024, at the size=45000
```

===== Timing linear equation system solver =====

Size	LDA	Align.	Time(s)	GFlops	Residual	Residual(norm)	Check
1000	1000	4	0.020	33.4769	1.076556e-12	3.671331e-02	pass
1000	1000	4	0.007	101.4502	9.394430e-13	3.203742e-02	pass
1000	1000	4	0.007	101.8370	9.394430e-13	3.203742e-02	pass
1000	1000	4	0.005	123.7356	9.394430e-13	3.203742e-02	pass
2000	2000	4	0.040	135.0630	3.842024e-12	3.342090e-02	pass
2000	2000	4	0.038	139.2427	3.842024e-12	3.342090e-02	pass
5000	5008	4	0.432	192.8808	2.288539e-11	3.191183e-02	pass
5000	5008	4	0.440	189.3191	2.288539e-11	3.191183e-02	pass
10000	10000	4	3.079	216.5728	1.143383e-10	4.031683e-02	pass
10000	10000	4	2.891	230.6859	1.143383e-10	4.031683e-02	pass
15000	15000	4	10.260	219.3352	2.246575e-10	3.538393e-02	pass
15000	15000	4	10.191	220.8321	2.246575e-10	3.538393e-02	pass
18000	18008	4	18.114	214.6780	3.144194e-10	3.443279e-02	pass
18000	18008	4	17.974	216.3520	3.144194e-10	3.443279e-02	pass
20000	20016	4	24.050	221.7924	3.805155e-10	3.368396e-02	pass
20000	20016	4	24.978	213.5537	3.805155e-10	3.368396e-02	pass
22000	22008	4	32.623	217.6252	4.432769e-10	3.246829e-02	pass
22000	22008	4	31.951	222.2030	4.432769e-10	3.246829e-02	pass
25000	25000	4	48.275	215.8047	5.639031e-10	3.206715e-02	pass
25000	25000	4	47.421	219.6921	5.639031e-10	3.206715e-02	pass
26000	26000	4	59.193	197.9749	6.635045e-10	3.488906e-02	pass
26000	26000	4	58.474	200.4101	6.051861e-10	3.182250e-02	pass
27000	27000	4	60.259	217.7838	6.293582e-10	3.069070e-02	pass
30000	30000	1	84.666	212.6214	8.056034e-10	3.175697e-02	pass
35000	35000	1	135.822	210.4644	1.134067e-09	3.292025e-02	pass
40000	40000	1	203.713	209.4604	1.604678e-09	3.568859e-02	pass
45000	45000	1	388.456	156.3990	1.909955e-09	3.360364e-02	pass

Performance Summary (GFlops)

Size	LDA	Align.	Average	Maximal
1000	1000	4	90.1249	123.7356
2000	2000	4	137.1529	139.2427
5000	5008	4	191.0999	192.8808
10000	10000	4	223.6293	230.6859
15000	15000	4	220.0836	220.8321
18000	18008	4	215.5150	216.3520
20000	20016	4	217.6731	221.7924
22000	22008	4	219.9141	222.2030
25000	25000	4	217.7484	219.6921
26000	26000	4	199.1925	200.4101
27000	27000	4	217.7838	217.7838
30000	30000	1	212.6214	212.6214
35000	35000	1	210.4644	210.4644
40000	40000	1	209.4604	209.4604
45000	45000	1	156.3990	156.3990

Residual checks PASSED

End of tests

Done: Fri Mar 23 19:58:39 CDT 2018

avellineni@prometheus:~/l_mklb_p_2018.1.009/benchmarks_2018/linux/mkl/benchmarks/linpack\$

MyCPUBench Efficiency is low compared to theoretical and linpack benchmark performance. The resulting lower performance might be because of other background processes running on the computer and using up the CPU time. Maximum efficiency achieved using MyCPUBench is 3.88% and Maximum efficiency achieved using LINPACK is 41.8%.

Memory Benchmark:

All the experiments were done on Prometheus cluster (Intel(R) Xeon(R) CPU E5-2620 v4 @ 2.10GHz).

Measurements were collected for the following specifications:

Workload: 1GB data over 100 times.

Operations: RWS (Read Write Sequentially), RWR (Read Write Randomly).

Concurrency: 1,2,4 threads.

Block Size: 1B,1KB,1MB,10MB.

Results Measurement: GB /sec, Microsec.

Theoretical Performance:

Memory Specifications

Max Memory Size (dependent on memory type) ?	1.54 TB
Memory Types ?	DDR4 1600/1866/2133
Max # of Memory Channels ?	4
Max Memory Bandwidth ?	68.3 GB/s
Physical Address Extensions ?	46-bit
ECC Memory Supported ‡ ?	Yes

Maximum Bandwidth achieved is **68.3 GB/s**.

https://ark.intel.com/products/92986/Intel-Xeon-Processor-E5-2620-v4-20M-Cache-2_10-GHz

← → ↻ ⓘ www.crucial.com/usa/en/memory-performance-speed-latency

SPEED VS. LATENCY AS MEMORY TECHNOLOGY HAS MATURED (INDUSTRY STANDARDS)				
TECHNOLOGY	MODULE SPEED (MT/s)	CLOCK CYCLE TIME (ns)	CAS LATENCY (CL)	TRUE LATENCY (ns)
SDR	100	8.00	3	24.00
SDR	133	7.50	3	22.50
DDR	335	6.00	2.5	15.00
DDR	400	5.00	3	15.00
DDR2	667	3.00	5	15.00
DDR2	800	2.50	6	15.00
DDR3	1333	1.50	9	13.50
DDR3	1600	1.25	11	13.75
DDR4	1866	1.07	13	13.93
DDR4	2133	0.94	15	14.06
DDR4	2400	0.83	17	14.17
DDR4	2666	0.75	18	13.50

$$\text{true latency}^{(ns)} = \text{clock cycle time}^{(ns)} \times \text{number of clock cycles}^{(CL)}$$

$$\text{Latency} = (1/2.09\text{GHZ}) * 13$$

$$= .000478 * 13 = 0.00622 \text{ Microsec.}$$

Measurement:

Work load	Concu rrency	Block Size	MyRAMBench (GB/sec)	Pmbw (GB/sec)	Theoretical (GB/sec)	MyRAMBench Efficiency	Pmbw Efficiency
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RWS	1	1KB	27.792	16.467	63.8	43.56113	24.11
RWS	1	1MB	7.491	20.143	63.8	11.74138	29.49
RWS	1	10MB	8.008	19.762	63.8	12.55172	28.93
RWS	2	1KB	22.02	22.475	63.8	34.51411	32.90
RWS	2	1MB	7.51	36.304	63.8	11.77116	53.15
RWS	2	10MB	7.135	36.586	63.8	11.18339	53.57
RWS	4	1KB	24.98	26.463	63.8	39.15361	38.74
RWS	4	1MB	7.172	38.118	63.8	11.24138	55.81
RWS	4	10MB	3.991	36.567	63.8	6.255486	53.54
RWR	1	1KB	1.55	12.384	63.8	2.429467	18.13
RWR	1	1MB	1.921	13.673	63.8	3.010972	20.02
RWR	1	10MB	2.742	12.887	63.8	4.297806	18.87
RWR	2	1KB	1.727	15.016	63.8	2.706897	21.99
RWR	2	1MB	1.292	19.982	63.8	2.025078	29.26
RWR	2	10MB	2.230	20.291	63.8	3.495298	29.71
RWR	4	1KB	1.534	13.268	63.8	2.404389	19.43
RWR	4	1MB	1.122	21.531	63.8	1.758621	31.52
RWR	4	10MB	1.959	21.051	63.8	3.070533	30.82

Work load	Concu rrency	Block Size	MyRAMBench (Microsec)	Pmbw (Microsec)	Theoretical (Microsec)	MyRAMBench Efficiency	Pmbw Efficiency
RWS	1	1B	0.00857	0.01164	0.00622	72.57876	53.43643
RWS	2	1B	0.00878	0.006589	0.00622	70.84282	94.39976
RWS	4	1B	0.009221	0.0082568	0.00622	67.45472	75.33185
RWR	1	1B	0.1065	0.0119374	0.00622	5.840376	52.10515
RWR	2	1B	0.5886	0.0070053	0.00622	1.056745	88.78992
RWR	4	1B	0.6918	0.0093643	0.00622	0.899104	66.42248

```

avellinenti@hyperionides:~$ srun -n 1 -p interactive --pty /bin/bash
avellinenti@bluecompute-1:~$ pmbw -p 1 -P 1 -s 1024 -S 1024 -f ScanRead64PtrSimpleLoop
Running benchmarks with at least 1 threads.
Running benchmarks with up to 1 threads.
Running benchmarks with array size at least 1024.
Running benchmarks with array size up to 1024.
Running only functions containing 'ScanRead64PtrSimpleLoop'
CPUID: mmx sse avx
Detected 3951 MiB physical RAM and 2 CPUs.

Allocating 2048 MiB for testing.
Skipping ScanWrite64PtrSimpleLoop tests
Skipping ScanWrite64PtrUnrollLoop tests

```

```

Allocating 2048 MiB for testing.
Skipping ScanWrite64PtrSimpleLoop tests
Skipping ScanWrite64PtrUnrollLoop tests
Running nthreads=1 factor=1073741824 areastsize=1024 thrsize=1024 testsize=1024
repeats=1048576 testvol=1073741824 testaccess=134217728
run time = 0.11284 -> rerunning test with repeat factor=14273380738
Running nthreads=1 factor=14273380738 areastsize=1024 thrsize=1024 testsize=1024
repeats=13938849 testvol=14273381376 testaccess=1784172672
run time = 0.891858 -> rerunning test with repeat factor=24006156902
Running nthreads=1 factor=24006156902 areastsize=1024 thrsize=1024 testsize=1024
repeats=23443513 testvol=24006157312 testaccess=3000769664
run time = 1.45779 -> next test with repeat factor=24701253686
RESULT datetime=2018-03-26 01:50:15 host=bluecompute-1 version=0.6.2
funcname=ScanRead64PtrSimpleLoop nthreads=1 areastsize=1024 threadsize=10
24testsize=1024 repeats=23443513 testvol=24006157312 testaccess=3
000769664 time=1.4577898120041936636 bandwidth=16467502457.707490921 rat
e=4.858053017174841547e-10
Skipping ScanRead64PtrSimpleLoop test with 2048 maximum array size due to -S 1
024.

```

MyRambenchmark throughput obtained is lower than the Pmbw benchmark and the theoretical values. Random Read/Write throughput values are lower compared to the sequential Read/Write values, this is due to movement of disk arm over the hard disk tracks randomly (increases seek time). The maximum throughput achieved by MyRambenchmark is 43.56% and for Pmbw benchmark is 55.81%. MyRAMBenchmark highest latency efficiency is 72.58% and for Pmbw benchmark is 94.40%. Efficiency for random Read/Write on MyRAMbenchmark is low compared Pmbw and theoretical values do to movement of disk head for every 1Byte of data read and write.

Disk Benchmark:

All the experiments were done on Prometheus cluster (Intel(R) Xeon(R) CPU E5-2620 v4 @ 2.10GHz.

Disk type is Micron 5100 PRO 2.5"480GB, SATA,6Gb/s,3D NAND,7mm,1.5DWPD 2.

Measurements were collected for the following specifications:

Workload: 1GB data over 100 times.

Operations: RS (Read Sequentially), RR (Read Randomly), WS (Write Sequentially), WR (Write Randomly).

Concurrency: 1,2,4,8,16,32,64,128 threads.

Block Size: 1KB,1MB,10MB,100MB.

Results Measurement: MB /sec, millisec.

Theoretical Performance:

Main Specifications	
Product Type	Server
Storage Capacity	480GB
Form Factor	2.5" Internal
Interface	6.0Gb/s Serial ATA
Series	5100 PRO
Encryption	No Encryption
Z-height	7.0mm
Endurance	1.5x DWPD
Detailed Specifications	
Lifetime Endurance	1,300TB Written
Life Expectancy	2 million hours MTTF
Read IOPS	93,000 IOPS
Write IOPS	43,000 IOPS
Read Speed	540 MB/s
Write Speed	410 MB/s
NAND	Micron 3D TLC NAND

Maximum Performance achieved is **6.0GB/s**.

<https://www.thinkmate.com/product/micron/mtfddak480tcb-1ar1zabyy>

Theoretical read/write latency at 99.9% is 5microseconds.



5100 Series NAND Flash SSD Performance

Table 3: Drive Performance – PRO 2.5"

Parameter	Capacity					Unit
	240GB	480GB	960GB	1920GB	3840GB	
Sequential read (128KB transfer)	540	540	540	540	540	MB/s
Sequential write (128KB transfer)	250	410	520	520	520	MB/s
Random read (4KB transfer)	78,000	93,000	93,000	93,000	93,000	IOPS
Random write (4KB transfer)	26,000	43,000	37,000	37,000	30,000	IOPS
Random 70/30 R/W (4KB transfer)	43,000	55,000	54,000	57,000	54,000	IOPS
READ latency (99.9%)	500	500	500	500	500	µs
WRITE latency (99.9%)	500	500	500	500	500	µs
READ latency (99.999%)	9.0	9.0	9.0	9.0	9.0	ms
WRITE latency (99.999%)	5.0	5.0	5.0	5.0	5.0	ms

Work load	Concu rrency	Block Size	MyDiskBench (MB/sec)	Iozone (MB/sec)	Theoretical (MB/sec)	MyDiskBench Efficiency	Iozone Efficiency
RS	1	1MB	3281.48	452.18	6000	54.69133	7.536333
RS	1	10MB	2089.887	5129.455	6000	34.83145	85.49092
RS	1	100MB	340.4338	2985.789	6000	5.673897	49.76315
RS	2	1MB	1927.834	416.927	6000	32.13057	6.948783
RS	2	10MB	259.462	2606.957	6000	4.324367	43.44928
RS	2	100MB	23.993	3111.611	6000	0.399883	51.86018
RS	4	1MB	1065.882	245.718	6000	17.7647	4.0953
RS	4	10MB	107.386	227.020	6000	1.789767	3.783667
RS	4	100MB	9.8664	242.292	6000	0.16444	4.0382
WS	1	1MB	856.368	820.795	6000	14.2728	13.67992
WS	1	10MB	729.989	693.699	6000	12.16648	11.56165
WS	1	100MB	263.54	948.107	6000	4.392333	15.80178
WS	2	1MB	244.819	525.087	6000	4.080317	8.75145
WS	2	10MB	152.266	517.818	6000	2.537767	8.6303
WS	2	100MB	21.682	412.663	6000	0.361367	6.877717
WS	4	1MB	314.627	257.647	6000	5.243783	4.294117
WS	4	10MB	76.72	264.335	6000	1.278667	4.405583
WS	4	100MB	7.1153	245.477	6000	0.118588	4.091283
RR	1	1MB	1224.734	383.541	6000	20.41223	6.39235
RR	1	10MB	2146.74	5202.418	6000	35.779	86.70697
RR	1	100MB	340.11	3533.458	6000	5.6685	58.89097
RR	2	1MB	652.325	300.029	6000	10.87208	5.000483

RR	2	10MB	147.299	3346.238	6000	2.454983	55.77063
RR	2	100MB	25.211	3149.734	6000	0.420183	52.49557
RR	4	1MB	1052.1468	299.134	6000	17.53578	4.985567
RR	4	10MB	106.181	286.944	6000	1.769683	4.7824
RR	4	100MB	8.609	241.231	6000	0.143483	4.020517
WR	1	1MB	1013.033	839.676	6000	16.88388	13.9946
WR	1	10MB	889.286	1376.797	6000	14.82143	22.94662
WR	1	100MB	272.287	1365.876	6000	4.538117	22.7646
WR	2	1MB	438.414	487.508	6000	7.3069	8.125133
WR	2	10MB	215.937	640.434	6000	3.59895	10.6739
WR	2	100MB	21.199	612.443	6000	0.353317	10.20738
WR	4	1MB	359.255	244.477	6000	5.987583	4.074617
WR	4	10MB	91.503	189.205	6000	1.52505	3.153417
WR	4	100MB	10.303	276.235	6000	0.171717	4.603917

Work load	Concu rrency	Block Size	MyDiskBench (msec)	lozone (msec)	Theoretical (msec)	MyDiskBench Efficiency	lozone Efficiency
RR	1	1kB	.000227	.002711	0.5	46.4896	5.422
RR	2	1kB	.000220	.002699	0.5	45.056	5.398
RR	4	1kB	.000226	.014168	0.5	46.2848	28.336
RR	8	1kB	.000248	.00387	0.5	50.7904	7.74
RR	16	1kB	.000264	.00286	0.5	54.0672	5.72
RR	32	1kB	.000236	.00996	0.5	48.3328	19.92
RR	64	1kB	.000252	.010589	0.5	51.6096	21.178
RR	128	1kB	.000293	.00951	0.5	60.0064	19.02
WR	1	1kB	.00017	.01952	0.5	34.816	39.04
WR	2	1kB	.00019	.00883	0.5	38.912	17.66
WR	4	1kB	.00016	.02238	0.5	32.768	44.76
WR	8	1kB	.00016	.03334	0.5	32.768	66.68
WR	16	1kB	.00017	.02298	0.5	34.816	45.96
WR	32	1kB	.00028	.006995	0.5	57.344	13.99
WR	64	1kB	.00020	.009113	0.5	40.96	18.226
WR	128	1kB	.00035	.008664	0.5	71.68	17.328

Work load	Concu rrency	Block Size	MyDiskBench (lops)	lozone (lops)	Theoretical (lops)	MyDiskBench Efficiency	lozone Efficiency
RR	1	1kB	4405.286	4833.23	23250	18.94747	20.78809
RR	2	1kB	4545.455	5610.33	23250	19.55034	24.13045
RR	4	1kB	4424.779	4118.73	23250	19.03131	17.71497
RR	8	1kB	4032.258	2030.23	23250	17.34305	8.732172
RR	16	1kB	3787.879	1442.82	23250	16.29195	6.205677
RR	32	1kB	4237.288	600.68	23250	18.22489	2.58357
RR	64	1kB	3968.254	510.12	23250	17.06776	2.194065
RR	128	1kB	3412.969	328.09	23250	14.67944	1.41114
WR	1	1kB	5882.353	779.49	10750	54.71956	7.25107
WR	2	1kB	5263.158	471.29	10750	48.95961	4.384093
WR	4	1kB	6250	373.24	10750	58.13953	3.472
WR	8	1kB	6250	225.22	10750	58.13953	2.09507
WR	16	1kB	5882.353	150.73	10750	54.71956	1.40214
WR	32	1kB	3571.429	90.88	10750	33.2226	0.845395
WR	64	1kB	5000	34.16	10750	46.51163	0.317767
WR	128	1kB	2857.143	19.113	10750	26.57807	0.177795

```
avellinenti@bluecompute-2:/tmp$ iozone -t 1 -i 0 -i 1 -i 2 -s 10g -r 1m
Iozone: Performance Test of File I/O
Version $Revision: 3.471 $
Compiled for 64 bit mode.
Build: linux-AMD64

Contributors:William Norcott, Don Capps, Isom Crawford, Kirby Collins
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              Steve Landherr, Brad Smith, Mark Kelly, Dr. Alain CYR,
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              Jean-Marc Zucconi, Jeff Blomberg, Benny Halevy, Dave Boone,
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              Fabrice Bacchella, Zhenghua Xue, Qin Li, Darren Sawyer,
              Vangel Bojaxhi, Ben England, Vikentsi Lapa,
              Alexey Skidanov.

Run began: Mon Mar 26 04:24:48 2018

File size set to 10485760 kB
Record Size 1024 kB
Command line used: iozone -t 1 -i 0 -i 1 -i 2 -s 10g -r 1m
Output is in kBytes/sec
Time Resolution = 0.000001 seconds.
Processor cache size set to 1024 kBytes.
Processor cache line size set to 32 bytes.
File stride size set to 17 * record size.
Throughput test with 1 process
Each process writes a 10485760 kByte file in 1024 kByte records
```

Children see throughput for	1 initial writers	= 820795.38 kB/sec
Parent sees throughput for	1 initial writers	= 804048.70 kB/sec
Min throughput per process		= 820795.38 kB/sec
Max throughput per process		= 820795.38 kB/sec
Avg throughput per process		= 820795.38 kB/sec
Min xfer		= 10485760.00 kB
Children see throughput for	1 rewriters	= 1096699.88 kB/sec
Parent sees throughput for	1 rewriters	= 1064790.11 kB/sec
Min throughput per process		= 1096699.88 kB/sec
Max throughput per process		= 1096699.88 kB/sec
Avg throughput per process		= 1096699.88 kB/sec
Min xfer		= 10485760.00 kB
Children see throughput for	1 readers	= 452183.00 kB/sec
Parent sees throughput for	1 readers	= 452158.77 kB/sec
Min throughput per process		= 452183.00 kB/sec
Max throughput per process		= 452183.00 kB/sec
Avg throughput per process		= 452183.00 kB/sec
Min xfer		= 10485760.00 kB
Children see throughput for	1 re-readers	= 414915.84 kB/sec
Parent sees throughput for	1 re-readers	= 414896.76 kB/sec
Min throughput per process		= 414915.84 kB/sec
Max throughput per process		= 414915.84 kB/sec
Avg throughput per process		= 414915.84 kB/sec
Min xfer		= 10485760.00 kB

```

Children see throughput for 1 re-readers      = 414915.84 kB/sec
Parent sees throughput for 1 re-readers      = 414896.76 kB/sec
Min throughput per process                   = 414915.84 kB/sec
Max throughput per process                   = 414915.84 kB/sec
Avg throughput per process                   = 414915.84 kB/sec
Min xfer                                     = 10485760.00 kB

Children see throughput for 1 random readers  = 383541.38 kB/sec
Parent sees throughput for 1 random readers  = 383525.19 kB/sec
Min throughput per process                   = 383541.38 kB/sec
Max throughput per process                   = 383541.38 kB/sec
Avg throughput per process                   = 383541.38 kB/sec
Min xfer                                     = 10485760.00 kB

Children see throughput for 1 random writers  = 839676.19 kB/sec
Parent sees throughput for 1 random writers  = 823083.09 kB/sec
Min throughput per process                   = 839676.19 kB/sec
Max throughput per process                   = 839676.19 kB/sec
Avg throughput per process                   = 839676.19 kB/sec
Min xfer                                     = 10485760.00 kB

iozone test complete.

```

```

avellineni@compute-1:/tmp$ head -10 Child_0_randrol.dat
Offset in kBytes   Latency in microseconds   Transfer size in bytes
367999             727                       1024
232928             3                         1024
136028             1                         1024
478078             2                         1024
975762             1                         1024
708491             2                         1024
148241             1                         1024
794172             1                         1024
653179             2                         1024

```

MyDiskBenchmark Read sequential and random operations obtained higher than the write sequential and random operations. Maximum throughput obtained for Sequential/Random read/write operations for MyDiskBenchmark is 54.70% and for Iozone benchmark is 86.7%. Latency efficiency obtained by MyDiskBenchmark is slightly better than the Iozone benchmark. Maximum latency efficiency obtained by MyDiskBenchmark is 71.68% on the other hand Iozone obtained 66.68%. Both the benchmarks obtained slightly lower IOPS around 20-50% compared to the theoretical performance.

Network Benchmarking:

All the experiments were done on Prometheus cluster (Intel(R) Xeon(R) CPU E5-2620 v4 @ 2.10GHz.

Measurements were collected for the following specifications:

Workload: 1GB data over 100 times.

Operations: RS (Read Sequentially), RR (Read Randomly), WS (Write Sequentially), WR (Write Randomly).

Concurrency: 1,2,4,8 threads.

Block Size: 1KB,32KB,1B.

Results Measurement: MB /sec, millisec.

Measurement:

Work load	Concu rrency	Block Size	MyNETBench (MB/sec)	Iperf (MB/sec)	Theoretical (MB/sec)	MyNETBench Efficiency	Iperf Efficiency
TCP	1	1KB	767.0359	564	10000	7.670359	5.64
TCP	1	32KB	2434.177	3620	10000	24.34177	36.2
TCP	2	1KB	893.0326	580	10000	8.930326	5.8
TCP	2	32KB	2560.531	3703	10000	25.60531	37.03
TCP	4	1KB	740.286	523	10000	7.40286	5.23
TCP	4	32KB	2501.405	3691	10000	25.01405	36.91
TCP	8	1KB	785.081	559	10000	7.85081	5.59
TCP	8	32KB	2416.131	3726	10000	24.16131	37.26
UDP	1	1KB	301.508	561	10000	3.01508	5.61
UDP	1	32KB	2179.502	7750	10000	21.79502	77.5
UDP	2	1KB	275.463	605	10000	2.75463	6.05
UDP	2	32KB	3146.451	7802	10000	31.46451	78.02
UDP	4	1KB	284.091	597	10000	2.84091	5.97
UDP	4	32KB	3178.387	7844	10000	31.78387	78.44
UDP	8	1KB	262.593	588	10000	2.62593	5.88
UDP	8	32KB	2778.32	7906	10000	27.7832	79.06

Work load	Concu rrency	Message Size	MyNETBench (msec)	ping (msec)	Theoretical (msec)	MyNETBench Efficiency	Iperf Efficiency
TCP	1	1B	.001207	.001818	.009375	12.87467	19.392
TCP	2	1B	.001354	.001823	.009375	14.44267	19.44533
TCP	4	1B	.001162	.001819	.009375	12.39467	19.40267
TCP	8	1B	.001276	.001820	.009375	13.61067	19.41333
UDP	1	1B	.002759	.001838	.009375	29.42933	19.60533
UDP	2	1B	.002562	.001837	.009375	27.328	19.59467
UDP	4	1B	.002451	.001849	.009375	26.144	19.72267
UDP	8	1B	.002566	.001828	.009375	27.37067	19.49867

Theoretical Performance:

<https://ark.intel.com/products/60020/Intel-Ethernet-Controller-X540-AT2>

Secure | https://ark.intel.com/products/60020/Intel-Ethernet-Controller-X540-AT2

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Networking Specifications

Port Configuration	Dual
Data Rate Per Port	100Mb/1000Mb/10Gb
System Interface Type	PCIe v2.1 (5.0 GT/s)
NC Sideband Interface	Yes
Jumbo Frames Supported	Yes
Speed & Slot Width	5.0 GT/s, x8 Lane
Interfaces Supported	100Base-T, 1000Base-T, 10GBase-T

Package Specifications

Package Size	25mm x 25mm
Low Halogen Options Available	See MDDS

```
avellineni@compute-3:~/cs553-pa1/network$ iperf -c 172.16.1.5 -l 1KB
-----
Client connecting to 172.16.1.5, TCP port 5001
TCP window size: 45.0 KByte (default)
-----
[ 3] local 172.16.1.15 port 41116 connected with 172.16.1.5 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 3]  0.0-10.0 sec  672 MBytes  564 Mbits/sec
avellineni@compute-3:~/cs553-pa1/network$
```

```
avellineni@compute-3:~/cs553-pa1/network$ iperf -c 172.16.1.5 -l 32KB
-----
Client connecting to 172.16.1.5, TCP port 5001
TCP window size: 45.0 KByte (default)
-----
[ 3] local 172.16.1.15 port 41118 connected with 172.16.1.5 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 3]  0.0-10.0 sec  4.21 GBytes  3.62 Gbits/sec
avellineni@compute-3:~/cs553-pa1/network$
```

```
avellineni@compute-3:~/cs553-pa1/network$ iperf -c 172.16.1.5 -l 1B
WARNING: option -l has implied compatibility mode
-----
Client connecting to 172.16.1.5, TCP port 5001
TCP window size: 45.0 KByte (default)
-----
[ 3] local 172.16.1.15 port 41120 connected with 172.16.1.5 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 3]  0.0-10.0 sec   671 KBytes   550 Kbits/sec
avellineni@compute-3:~/cs553-pa1/network$
```

```
avellineni@compute-3:~/cs553-pa1/network$ iperf -c 172.16.1.5 -l 1KB -b 10000m -u
WARNING: option -b implies udp testing
-----
Client connecting to 172.16.1.5, UDP port 5001
Sending 1024 byte datagrams
UDP buffer size: 208 KByte (default)
-----
[ 3] local 172.16.1.15 port 57005 connected with 172.16.1.5 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 3]  0.0-10.0 sec   669 MBytes   561 Mbits/sec
[ 3] Sent 685052 datagrams
[ 3] Server Report:
[ 3]  0.0-10.0 sec   648 MBytes   544 Mbits/sec   0.321 ms 5132/685051 (0.75%)
[ 3]  0.0-10.0 sec    1 datagrams received out-of-order
avellineni@compute-3:~/cs553-pa1/network$
```

```

avellineni@compute-3:~/cs553-pa1/network$ iperf -c 172.16.1.5 -l 32KB -b 10000m -u
WARNING: option -b implies udp testing
-----
Client connecting to 172.16.1.5, UDP port 5001
Sending 32768 byte datagrams
UDP buffer size: 208 KByte (default)
-----
[ 3] local 172.16.1.15 port 52789 connected with 172.16.1.5 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 3] 0.0-10.0 sec  9.02 GBytes 7.75 Gbits/sec
[ 3] Sent 295591 datagrams
[ 3] Server Report:
[ 3] 0.0-10.2 sec 100 MBytes 82.2 Mbits/sec 16.200 ms 292279/295570 (99%)
avellineni@compute-3:~/cs553-pa1/network$

```

```

avellineni@compute-3:~/cs553-pa1/network$ iperf -c 172.16.1.5 -l 1B -b 10000m -u
WARNING: option -l has implied compatibility mode
WARNING: option -b implies udp testing
-----
Client connecting to 172.16.1.5, UDP port 5001
Sending 1 byte datagrams
UDP buffer size: 208 KByte (default)
-----
[ 3] local 172.16.1.15 port 48065 connected with 172.16.1.5 port 5001
[ ID] Interval      Transfer    Bandwidth
[ 3] 0.0-10.0 sec  664 KBytes  544 Kbits/sec
[ 3] Sent 680120 datagrams
avellineni@compute-3:~/cs553-pa1/network$

```

MyNetBenchmark TCP and UDP had lower through put for 1KB block transfer compared to 32K block transfer because more data can be sent with less packets from the client to the server same goes with the iperf benchmark. Maximum efficiency obtained by MyNETBenchmark is 27.78% and the iperf benchmark measured 79.06% this deviation of the efficiency cold be due to multiple clients sending data in the same channel which resulted in the reduced bandwidth. MyNETBenchmark efficiency for latency with 1Byte transfer varies from 12-29.5% while that of Iperf benchmark efficiency is around 19-20%.