CS 553: Cloud Computing - HA1

Saptarshi Chatterjee
CWID: A20413922

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1 Hardware Specification

Experiments are run on 2 different clusters -

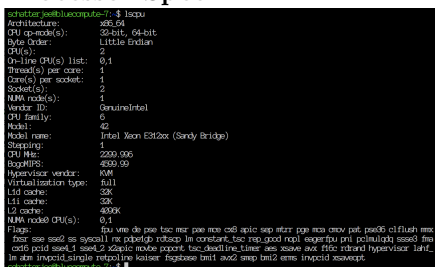
- **Hyperion** : Intel Xeon E312xx (Sandy Bridge). MemTotal: 4046452 kB . Ethernet interface product: Virtio network device
- **Promethus** Disk- is Micron 5100 PRO 2.5"480GB,SATA,6Gb/s,3D NAND,7mm,1.5DWPD2, NIC- Super Micro Computer Inc Ethernet Controller 10-Gigabit X540-AT2, CPU - Intel(R) Xeon(R) CPU E5-2620 v4 @ 2.10GHz , 8GiB DIMM Synchronous 2400 MHz (0.4 ns, 64bit)

2 CPU Benchmarking (Run on Hyperion)

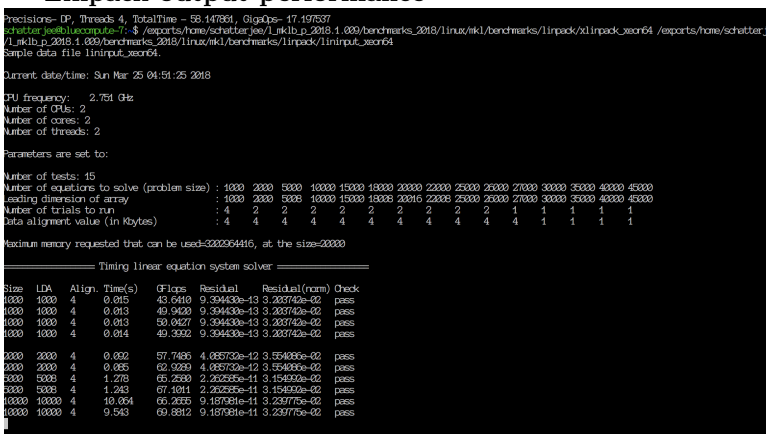
We were asked to perform 1 trillion arithmetic (quarter precision, half precision, single precision, double precision) using 1, 2 and 4 threads.

$$\begin{aligned}\text{FLOPS} &= sockets \times \frac{cores}{socket} \times \frac{cycles}{second} \times \frac{FLOPs}{cycle} \\ &= 2 * 1 * 2.299 * 8 \\ &= 36.78(ForDP)\text{(Sandy Bridge -8 DP FLOPs/cycle)} \\ &= 73.56(forSP)\text{(16 SP FLOPs/cycle: 8-wide AVX addition + 8-wide AVX multiplication)} \\ &= 147.136(forQP) \\ &= 147.136(forHP)\end{aligned}$$

Processor Spec



Linpack output performance



*CPU performance Table

Workload	Concurrency	MyCPUBench Measured Ops/Sec	HPL Measured Ops/Sec (GigaOPS)	Theoretical Ops/Sec (GigaOPS)	MyCPUBench Efficiency (%)	HPL Efficiency (%)
QP	1	45.393182	N/A	73.568	61.70234613	N/A
QP	2	90.078258	N/A	147.136	61.22108661	N/A
QP	4	85.05064	N/A	294.272	28.9020498	N/A
HP	1	46.200567	N/A	73.568	62.79981378	N/A
HP	2	86.669638	N/A	147.136	58.90444079	N/A
HP	4	85.924472	N/A	294.272	29.19899685	N/A
SP	1	23.579637	N/A	36.784	64.1029714	N/A
SP	2	46.652203	N/A	73.568	63.41371656	N/A
SP	4	43.583872	N/A	147.136	29.6214876	N/A
DP	1	8.508647	11.1738	18.392	46.26276098	60.75358852
DP	2	16.862083	24.9512	36.784	45.8408085	67.83166594
DP	4	17.197537	69.218	73.568	23.37638239	94.08710309

Synopsis for CPU performance

- Getting best result for QP with 2 threads . 90.07 GIOPS.
- GFLOPS is lowest for DP with 1 thread as we are not optimally using the available CPU power.
- I'm getting around 23% to 69% efficiency varying between different pre-

cision and concurrency using AVX. Where as Linpack gets 60%-94% efficiency

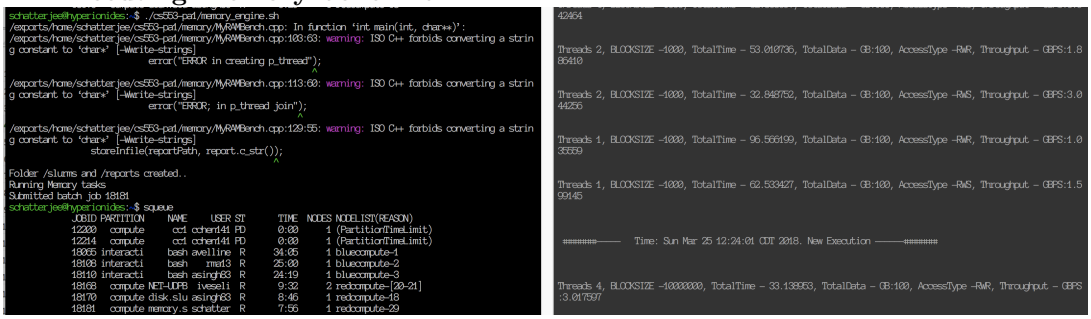
- It's not a Quad-core machine so using 4 threads actually hurts performance than 2 threads as a lot of time is spent in context switch .
- Linpack gets a best performance of 69.2180 GFLOPS for problem size 20000.

3 Memory Benchmarking (Run on Hyperion)

We were asked to perform random and Sequential Read/Write Ops on memory 1GB Workload. Operated over it 100X times with various access patterns (RWS, RWR) , various block sizes (1KB, 1MB, 10MB) and Concurrency (1 thread, 2 threads, 4 threads)

$$
\begin{aligned}
\text{Theoratical Bandwidth} &= \text{Base DRAM clock frequency} \times \text{Number of data transfers per clock} \\
&\quad \times \text{Memory bus (interface) width} \times \text{Number of interfaces} \\
&= 2133,000,000 * 2 * 64 * 1/(8 * 1000 * 1000 * 1000) \\
&\ldots \text{Assuming clock frequency 2133MHz} \\
&= 34.128 GBps
\end{aligned}
$$

Executing Memory benchmark



pmbw - Parallel Memory Bandwidth Benchmark / Measurement

corresponding results re kept in /cs553-pa1/memory/pmbw.txt

Theoratical Latency

$Latency(ns) = clockcycletime(ns) x number of clock cycles =$

Memory benchmark Table

Workload	Concurrency	Block Size	MyRAMBench Measured Throughput (GB/sec)	pmbw Measured Throughput (GB/sec)	Theoretical Throughput (GB/sec)	MyRAMBench Efficiency (%)	pmbw Efficiency (%)
RWS	1	1KB	1.63132	17.3	34.128	4.78000469	50.6915143
RWS	1	1MB	1.69056	16.22	34.128	4.9535865	47.52695734
RWS	1	10MB	1.616496	15.59	34.128	4.73656821	45.68096578
RWS	2	1KB	3.151194	29.77	34.128	9.2334564	87.23042663
RWS	2	1MB	3.269755	29.92	34.128	9.58085736	87.66994843
RWS	2	10MB	2.97559	30.67	34.128	8.71891116	89.86755743
RWS	4	1KB	3.150432	26.42	34.128	9.23122363	77.41443976
RWS	4	1MB	3.234842	34.08	34.128	9.4785572	99.85935302
RWS	4	10MB	3.008679	30.71	34.128	8.81586674	89.98476324
RWR	1	1KB	1.137239	17.3	34.128	3.33227555	50.6915143
RWR	1	1MB	1.53018	16.22	34.128	4.48364979	47.52695734
RWR	1	10MB	1.566664	15.59	34.128	4.59055321	45.68096578
RWR	2	1KB	1.975065	29.77	34.128	5.7872275	87.23042663
RWR	2	1MB	2.928384	29.92	34.128	8.58059072	87.66994843
RWR	2	10MB	3.030498	30.67	34.128	8.87979958	89.86755743
RWR	4	1KB	2.065833	26.42	34.128	6.05319093	77.41443976
RWR	4	1MB	2.978313	34.08	34.128	8.72688994	99.85935302
RWR	4	10MB	3.017597	30.71	34.128	8.84199777	89.98476324

Memory Latency

Workload	Concurrency	Block Size	MyRAMBench Measured Latency (us)	pmbw Measured Latency (us),	Theoretical Latency (us)	MyRAMBench Efficiency (%)	pmbw Efficiency (%)
RWS	1	1B	0.000613001	5.78035E-05	0.004	84.67498713	98.55491329
RWS	2	1B	0.00031734	3.35909E-05	0.004	92.06649924	99.16022842
RWS	4	1B	0.000317417	3.78501E-05	0.004	92.06458035	99.05374716
RWR	1	1B	0.000879323	5.78035E-05	0.004	78.016934	98.55491329
RWR	2	1B	0.000506312	3.35909E-05	0.004	87.34218874	99.16022842
RWR	4	1B	0.000484066	3.78501E-05	0.004	87.89834415	99.05374716

Synopsis for Memory Benchmark

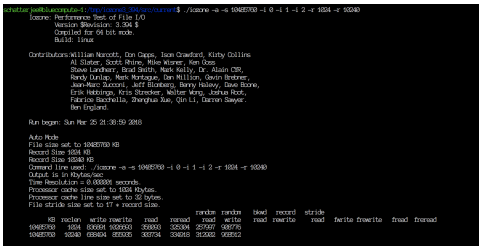
- Benchmark works best 1MB Block Size and 2 cores. For block Size 10MB It's closer but not optimal.
- 10MB block , Single thread Random Access gives worst performance .
- Benchmark Provide better performance for Sequential memory access than Random Access. Sequential access is around 12% better than random for the best case ($\frac{3.26-2.92}{2.92}$ case 1MB Block , 2 thread)

- Generally a CPU fetches a batch of RAM positions at once. It then keeps those in a cache while it?s working on this. So if the data in RAM is sequential, the CPU has to wait on such fetching a lot less than if the data it needs to work on is scattered throughout RAM.
- It's not a Quad-core machine so using 4 threads actually hurts performance than 2 threads as a lot of time is spent in context switching.
- Interestingly sequential access for 10MB data 4 threads takes more time than Random Access 4 thread 10 MB . As these are first 2 operations done on the machine looks like cache is not warmed up , so this perticular test case results in anomaly.
- pmbw also gives optimal output for block size of 1MB , but instead of 2 threads , result of 4 thread is better . Which is a deviation from my code result.

4 DISK Benchmarking (Run on Hyperion)

We were asked to Write and Read 10GB data. With various access patterns (RWS, RWR) and various block sizes (1MB, 10MB, 100MB) using 1 thread, 2 threads and 4 threads.

IOZone benchmark



corresponding results re kept in /cs553-pa1/disk/iozone.sh

Running Disk Program

Disk benchmark Table

Work- load	Concurrency	Block Size	MyDiskBench Measured Throughput (MB/sec)	IOZone Measured Throughput (MB/sec)	Theoretical Throughput (MB/sec)	MyDiskBench Efficiency (%)	IOZone Efficiency (%)
RS	1	1MB	24.240029	35[illegible]3	1200	2.020002417	29.84108333
RS	1	10MB	22.722776	303.734	1200	1.893564667	25.31116667
RS	1	100MB	17.949336	341.998	1200	1.495778	28.49983333
RS	2	1MB	26.432186	358.093	1200	2.202682167	29.84108333
RS	2	10MB	30.5996	303.734	1200	2.549966667	25.31116667
RS	2	100MB	31.167425	341.998	1200	2.597285417	28.49983333
RS	4	1MB	43.434794	358.093	1200	3.619566167	29.84108333
RS	4	10MB	50.746256	303.734	1200	4.228854667	25.31116667
RS	4	100MB	38.324509	341.998	1200	3.193709083	28.49983333
WS	1	1MB	43.196197	836.891	1200	3.599683083	69.74091667
WS	1	10MB	36.822835	688.494	1200	3.068569583	57.3745
WS	1	100MB	38.265487	546.319	1200	3.188790583	45.52658333
WS	2	1MB	43.337197	836.891	1200	3.611433083	69.74091667
WS	2	10MB	45.127668	688.494	1200	3.760639	57.3745
WS	2	100MB	45.08773	546.319	1200	3.757310833	45.52658333
WS	4	1MB	48.600181	836.891	1200	4.050015083	69.74091667
WS	4	10MB	38.434767	688.494	1200	3.20289725	57.3745
WS	4	100MB	38.099094	546.319	1200	3.1749245	45.52658333
RR	1	1MB	11230.61736	257.997	1200	935.8847798	21.49975
RR	1	10MB	3317.251299	312.902	1200	276.4376083	26.07516667
RR	1	100MB	3015.231274	337.239	1200	251.2692728	28.10325
RR	2	1MB	1019.43294	257.997	1200	84.952745	21.49975
RR	2	10MB	382.129398	312.902	1200	31.8441165	26.07516667
RR	2	100MB	106.100706	337.239	1200	8.8417255	28.10325
RR	4	1MB	7148.759976	257.997	1200	595.729998	21.49975
RR	4	10MB	5366.675414	312.902	1200	447.2229512	26.07516667
RR	4	100MB	527.133318	337.239	1200	43.9277765	28.10325
WR	1	1MB	232.433107	908.776	1200	19.36942558	75.73133333
WR	1	10MB	850.706823	968.512	1200	70.89223525	80.70933333
WR	1	100MB	841.7931621	851.317	1200	70.14943018	70.94308333
WR	2	1MB	270.136348	908.776	1200	22.51136233	75.73133333
WR	2	10MB	169.15893	968.512	1200	14.0965775	80.70933333
WR	2	100MB	193.636534	851.317	1200	16.13637783	70.94308333
WR	4	1MB	244.584262	908.776	1200	20.38202183	75.73133333
WR	4	10MB	172.471967	968.512	1200	14.37266392	80.70933333
WR	4	100MB	235.074646	851.317	1200	19.58955383	70.94308333

Synopsis for Disk Benchmark

theoretical throughput = one lane rate * 2 lane per port * 1 port per stack = 600 MB/sec * 2 * 1 = 1200 MB/sec.

- Divided all 36 different disk throughput operations in 9 groups and parallely run them on 9 nodes.
- Disk gives highest throughput when in Sequential Read , using 1 thread and read in 100 MB chunk.
- Creating Disk Write first followed by Read so no need to copy temp files .
-

5 Network Benchmarking

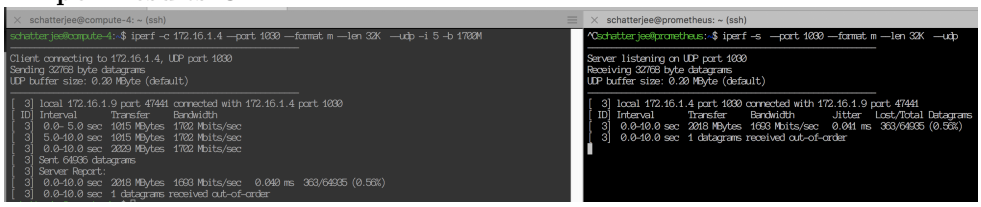
We were asked to implement Server-Client software using both TCP and UDP protocols with Workload: 1GB data. We operated over it 100X times with various block sizes (1KB, 32KB) with Concurrency: 1 thread, 2 threads, 4 threads and 8 threads.

Theoretical network bandwidth calculation

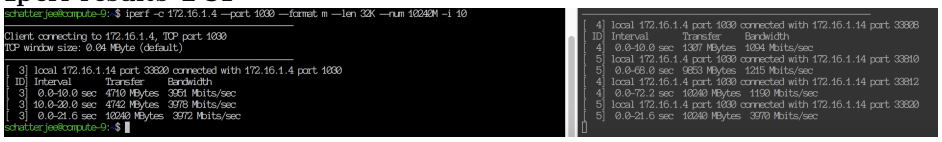
$$\text{Theoretical Throughput} = \frac{RWIN}{RTT}$$

Where RWIN is the TCP Receive Window and RTT is the round-trip time for the path. The Max TCP Window size in the absence of TCP window scale option is 65,535 bytes.

Iperf results UDP

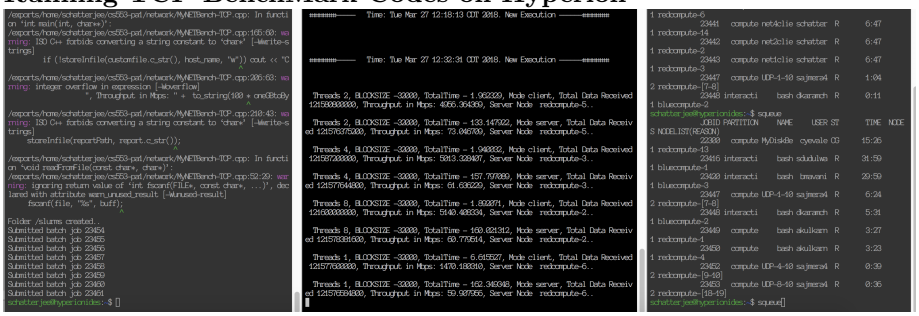


Iperf results TCP



Rest of the Iperf commands are detailed in iperf.sh

Running TCP BenchMark Codes on Hyperion



Throughput calculation Table

Protocol	Concurrency	Block Size	MyNETBench Measured Throughput (Mb/sec)	iperf Measured Throughput (Mb/sec)	Theoretical Throughput (Mb/sec)	MyNETBench Efficiency (%)	iperf Efficiency (%)
TCP	1	1KB	1.2389	564	1323.939394	0.09357679	42.6001373
TCP	1	32KB	1.6784	3626	1137.266811	0.1475819	318.834592
TCP	2	1KB	1.2389	566	1323.939394	0.09357679	42.7512016
TCP	2	32KB	1.6784	3666	1137.266811	0.1475819	322.351797
TCP	4	1KB	1.2389	562	1323.939394	0.09357679	42.449073
TCP	4	32KB	1.6784	3,524.00	1137.266811	0.1475819	309.865721
TCP	8	1KB	1.2389	563	1323.939394	0.09357679	42.5246052
TCP	8	32KB	1.6784	3585	1137.266811	0.1475819	315.229458
UDP	1	1KB	0.9765	559	1323.939394	0.07375715	42.2224765
UDP	1	32KB	0.9218	1693	1137.266811	0.08105398	148.865682
UDP	2	1KB	0.9765	892	1323.939394	0.07375715	67.3746853
UDP	2	32KB	0.9218	1761	1137.266811	0.08105398	154.84493
UDP	4	1KB	0.9765	987	1323.939394	0.07375715	74.5502403
UDP	4	32KB	0.9218	1198	1137.266811	0.08105398	105.340276
UDP	8	1KB	0.9765	959	1323.939394	0.07375715	72.4353399
UDP	8	32KB	0.9218	1399	1137.266811	0.08105398	123.014229

Synopsis for bandwidth calculation

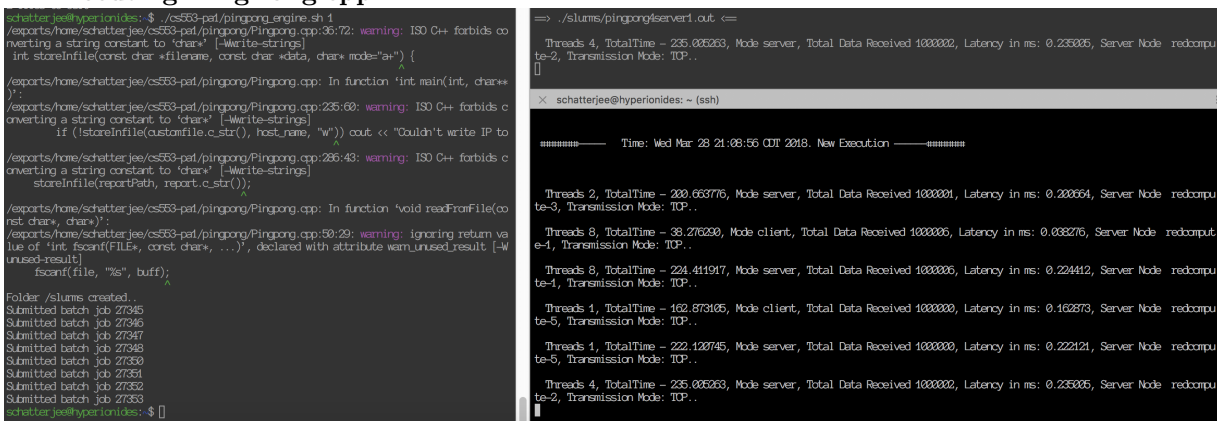
- Increasing No of thread does have significant +ve effect on Measured Throughput . Looks like 1 thread cant max out TCP buffer , If we use 8 threads then TCP throughput is maximal . For UDP it's 2 threads
- for TCP best result is obtained when block size is 32kb and thread count is 8.
- TCP is giving effectively higher Thoughput than UDP . Each frame goes through several buffers we send it: The application buffer, The Protocol Buffer, The Software interface buffer and the Hardware interface buffer. As we start stressing the stack by sending high speed data you will fill up these buffers and TCP is performing better as TCP is optimized for high speed bulk transfers.
- Throughput is dependent on Block size as higher block size yeilds in greater utilization of the available bandwidth and less no of iteration.

Latency calculation using Pingpong.cpp and 'PING' utility tool

Implemented similar Server-Client software to check latency, where server and client need to acknowledge the reciept of 1B data. And iterated it 1 million times.

Theoratical Latency: Ultimately response time over a network is limited by the speed of light. In a vacuum, light travels with a speed of 299 792 458 m / s. So, if we assume that a ?ping? travels with the speed of light, which are the best possible response times we can get ? Assuming machines are 10m apart . Latency should be $\frac{10*2*1000}{299792458} MiliSecond = 0.000066ms$

Executing PingPong.cpp



Latencty calculation Table

Protocol	Concurrency	Message Size	MyNETBench Measured Latency (ms)	ping Measured Latency (ms)	Theoretical Latency (ms)	MyNETBench Efficiency (%)	Ping Efficiency
TCP	1	1B	0.186475	0.00396	0.000066	0.035393484	1.6666667
TCP	2	1B	0.100287	0.00396	0.000066	0.065811122	1.6666667
TCP	4	1B	0.168867	0.00396	0.000066	0.039084013	1.6666667
TCP	8	1B	0.224412	0.00396	0.000066	0.029410192	1.6666667
UDP	1	1B	0.051648	0.00396	0.000066	0.127788104	1.6666667
UDP	2	1B	0.163044	0.00396	0.000066	0.04047987	1.6666667
UDP	4	1B	0.107404	0.00396	0.000066	0.061450225	1.6666667
UDP	8	1B	0.057742	0.00396	0.000066	0.114301548	1.6666667

Synopsis for Latencty calculation

- UDP is faster than TCP, and the simple reason is because its nonexistent acknowledge packet (ACK) that permits a continuous packet stream, instead of TCP that acknowledges a set of packets, calculated by using the TCP window size and round-trip time (RTT).
- UDP latencies are less compared to TCP
- For TCP we get best latenct with 2 threads. And for UDP it's 1 thread.

References

[1] Measuring network throughput
$https://en.wikipedia.org/wiki/Measuring_network_throughput$

[2] UDP Latency
$https://stackoverflow.com/questions/47903/udp-vs-tcp-how-much-faster-is-it$

[3] TCP Bandwidth
$https://serverfault.com/questions/432101/why-is-udp-slower-than-tcp-on-ubuntu-server$