CS553 Project

Prasanth Bhagavatula - A20355611

Introduction

The aim of this project is to compare the incurring costs of running applications on public and private clouds. Applications with different computing requirements running on different instances are considered. Cost comparisons are performed between Amazon EC2 instances and Privately build equivalent instances. Below sections provide the necessary details.

Cost on Public Cloud

For the Public cloud system Amazon EC2, we considered computing the cost of running application on 8 different instances. Below table summarizes the cost of running application with different computing requirements (1 GFLOP to 1 PFLOP) on all the 8 different instances. The computed value is the '***$ cost/hr/flop***'.

	Flops						
Instance Type	**1 Gflops**	**10 Gflops**	**100 Gflops**	**1 Tflops**	**10 Tflops**	**100 Tflops**	**1 Pflops**
m4.10xlarge	2.394E-009	2.394E-010	2.394E-011	4.788E-012	3.3516E-012	3.13614E-012	3.119382E-012
m3.large	1.33E-010	1.33E-011	6.65E-012	6.65E-012	6.65E-012	6.65E-012	6.65E-012
m3.2xlarge	5.32E-010	5.32E-011	1.596E-011	1.33E-011	1.33E-011	1.33E-011	1.33E-011
c3.8xlarge	1.68E-009	1.68E-010	1.68E-011	5.04E-012	4.704E-012	4.704E-012	4.68888E-012
g2.2xlarge	6.5E-010	6.5E-011	1.3E-011	8.45E-012	7.865E-012	7.813E-012	7.813E-012
r3.4xlarge	1.33E-009	1.33E-010	1.33E-011	9.31E-012	8.379E-012	8.3125E-012	8.3125E-012
i2.8xlarge	6.82E-009	6.82E-010	6.82E-011	2.728E-011	2.1824E-011	2.13466E-011	2.13125E-011
d2.8xlarge	5.52E-009	5.52E-010	5.52E-011	1.104E-011	8.28E-012	8.004E-012	7.98744E-012

For each and every instance, Amazon charges some particular amount for running the instance for an hour. Based on the instance details, we compute the theoretical FLOPS and use that to determine the number of instances required to satisfy the application computing requirements. So, the cost incurred would the number of instances times the cost of one instance and the FLOPS will the required (expected) number of FLOPS for the application but not the theoretical FLOPS we calculated.

Cost on Private Cloud

For Private cloud, we build a data centre by constructing each and every instance corresponding to the Public cloud (Amazon EC2). All the factors which will cost us for building the data centre, such as Hardware, Administration, Power and Cooling etc are considered. Each of the below subsections will provide further details on the cost incurred for constructing each and every instance of Public cloud.

M4.10xlarge

The Public cloud instance M4.10xlarge runs on Intel Xeon® E5-2676 v3 (Haswell) processor with frequency of 2.4 Ghz and 40 vCPUs and has a memory of 160 GB. For constructing a similar private cloud instance, Intel® Xeon® Processor E5-2640 v4 processor is chosen. A Dual-socket motherboard is chosen and so, two M4.10xlarge instances can run simultaneously on a single physical node. The Motherboard has 24 RAM slots and 20 of them are used to provide the necessary 320GB memory requirement. Below table provides the detailed cost breakup for constructing a single physical node.

Component Type	Component Name	Unit cost ($)	# of Units	Total Cost
CPU	Intel® Xeon® Processor E5-2640 v4	989.99	2	1979.98
Motherboard	GIGABYTE MD80-TM0 E-ATX / SSI EEB Server Motherboard Dual LGA 2011-3 Intel C612	659.99	1	659.99
Network Adapter	--	--	--	--
RAM	Kingston ValueRAM 16GB (1 x 16G) DDR4 2133 Server Memory ECC DIMM (288-Pin) RAM KVR21E15D8/16	85.99	20	1719.8
Storage	--	--	--	--
Server Chassis	iStarUSA D-200L-ROHS Steel 2U Rackmount Server Chassis 2 External 5.25" Drive Bays	159.99	1	159.99
PSU	iStarUSA IS-2U35PD8 24Pin 350W Single 2U 80Plus Server Power Supply	114.99	1	114.99
Network Switch	NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E)	849.99	1	849.99
Average Power Cost	Cost per hour	0.045	1	0.045

M3.large

The M3.large instance runs using High Frequency Intel Xeon E5-2670 v2 (Ivy Bridge) Processors 2.5 GHz on 2 vCPUs and has a memory of 7.5 GB. The instance also has a storage of 1 * 32 GB SSD and provides a network performance of 500Mbps. The private cloud instance is built using the same Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5GHz processor. Since, there are a total of 10 cores in each of the processor, a total of 40 instances can be run on a single physical node. Below table summarises the different components for building the instance.

Component Type	Component Name	Unit cost ($)	# of Units	Total Cost
CPU	Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5GHz	1559	2	3118
Motherboard	ASRock EP2C602-4L/D16 SSI EEB Server Motherboard Dual LGA 2011 Intel C602 DDR3 1600/1333/1066	329.99	1	329.99
Network Adapter	Intel X520DA PCI Express x2 Network Adapter (10 Gbps)	179.99	1	179.99
RAM	Black Diamond Memory 64GB (2 x 32GB) 240-Pin DDR3 SDRAM ECC Registered DDR3 1066 (PC3 8500) Server Memory Model BD32GX21066MTR26	439.99	5	2199.95
Storage	Intel DC S3510 2.5" 1.6TB SATA III MLC Enterprise Solid State Drive – OEM	999.99	1	999.99
Server Chassis	iStarUSA D-200L-ROHS Steel 2U Rackmount Server Chassis 2 External 5.25" Drive Bays	159.99	1	159.99
PSU	iStarUSA IS-2U35PD8 24Pin 350W Single 2U 80Plus Server Power Supply	114.99	1	114.99
Network Switch	NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E)	849.99	1	849.99
Average Power Cost	Cost per hour	0.0405	1	0.0405

M3.2xlarge

This instance also uses the High Frequency Intel Xeon E5-2670 v2 (Ivy Bridge) 2.5 GHz Processors with memory of 30 GB and storage of 2 * 80 SSD with a network performance of 1Gbps. The private cloud node has dual Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5GHz processor which can run 20 such instances on a single physical node. Other components are mentioned in the below table.

Component Type	Component Name	Unit cost ($)	# of Units	Total Cost
CPU	Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5GHz	1559	2	3118
Motherboard	ASRock EP2C602-4L/D16 SSI EEB Server Motherboard Dual LGA 2011 Intel C602 DDR3 1600/1333/1066	329.99	1	329.99
Network Adapter	Intel X520DA PCI Express x2 Network Adapter (10 Gbps)	179.99	1	179.99
RAM	NEMIX RAM 64GB PC3-12800 Load Reduced Memory for Dell PowerEdge R920 Server	1159.99	10	11599.9
Storage	SAMSUNG PM863 MZ-7LM3T8E 2.5" 3.84TB SATA III Enterprise Solid State Disk	1988.99	1	1988.99
Server Chassis	iStarUSA D-200L-ROHS Steel 2U Rackmount Server Chassis 2 External 5.25" Drive Bays	159.99	1	159.99
PSU	iStarUSA IS-2U35PD8 24Pin 350W Single 2U 80Plus Server Power Supply	114.99	1	114.99
Network Switch	NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E)	849.99	1	849.99
Average Power Cost	Cost per hour	0.0404	1	0.0404

C3.8xlarge

The public cloud instance runs on High Frequency Intel Xeon E5-2680 v2 (Ivy Bridge) 2.8GHz processors offering 60GB memory and 2 * 320 SSD with 10Gbps network performance. The corresponding private instance runs on a physical node which uses Intel Xeon E5-2680 v2 Ivy Bridge-EP 2.8 GHz processor. The private physical node is capable of running 2 instances and below table summarises the other components.

Component Type	Component Name	Unit cost ($)	# of Units	Total Cost
CPU	Intel Xeon E5-2680 v2 Ivy Bridge-EP 2.8 GHz	1769.99	2	3539.98
Motherboard	ASRock EP2C602-4L/D16 SSI EEB Server Motherboard Dual LGA 2011 Intel C602 DDR3 1600/1333/1066	329.99	1	329.99
Network Adapter	Intel X520DA PCI Express x2 Network Adapter (10 Gbps)	179.99	1	179.99
RAM	16GB (8GB x 2) DDR3-1333 PC3-10600 240-Pin RDIMM Memory ECC REG for ProLiant DL380p Gen8 Base	59.77	8	478.16
Storage	Intel DC S3510 2.5" 1.6TB SATA III MLC Enterprise Solid State Drive – OEM	999.99	1	999.99
Server Chassis	iStarUSA D-200L-ROHS Steel 2U Rackmount Server Chassis 2 External 5.25" Drive Bays	159.99	1	159.99
PSU	iStarUSA IS-2U35PD8 24Pin 350W Single 2U 80Plus Server Power Supply	114.99	1	114.99
Network Switch	NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E)	849.99	1	849.99
Average Power Cost	Cost per hour	0.0433	1	0.0433

G2.2xlarge

This public cloud instance runs on High Frequency Intel Xeon E5-2670 (Sandy Bridge) 2.6 GHz processors and also has 1 GPU, each with 1536 CUDA cores and 4GB of video memory. The private cloud physical node is build using Intel Xeon E5-2670 Sandy Bridge-EP 2.6GHz processor and includes PNY Quadro M4000 VCQM4000-PB 8GB Video Card. The instance components are mentioned below.

Component Type	Component Name	Unit cost ($)	# of Units	Total Cost
CPU	Intel Xeon E5-2670 Sandy Bridge-EP 2.6GHz	354.76	2	709.52
GPU	PNY Quadro M4000 VCQM4000-PB 8GB 256-bit GDDR5 PCI Express 3.0 x16 Full Height Workstation Video Card	827.74	1	827.74
Motherboard	ASRock EP2C602-4L/D16 SSI EEB Server Motherboard Dual LGA 2011 Intel C602 DDR3 1600/1333/1066	329.99	1	329.99
Network Adapter	Intel Ethernet Server Adapter X520-DA1 for Open Compute Project (OCP) (10 Gbps)	139.99	1	139.99
RAM	16GB (8GB x 2) DDR3-1333 PC3-10600 240-Pin RDIMM Memory ECC REG for ProLiant DL380p Gen8 Base	59.77	8	478.16
Storage	Kingston SKC400S37/512G 2.5" 512GB SATA III Business Solid State Disk	161.44	1	161.44
Server Chassis	iStarUSA D-200L-ROHS Steel 2U Rackmount Server Chassis 2 External 5.25" Drive Bays	159.99	1	159.99
PSU	iStarUSA IS-2U35PD8 24Pin 350W Single 2U 80Plus Server Power Supply	114.99	1	114.99
Network Switch	NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E)	849.99	1	849.99
Average Power Cost	Cost per hour	0.0614	1	0.0614

R3.4xlarge

This instance runs on High Frequency Intel Xeon E5-2670 v2 (Ivy Bridge) 2.5GHz processors with 122GB memory, 1 * 320GB SSD with Network performance of 1Gbps. The private instance will run on Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5GHz processor with each physical node running 5 different instances. The detailed components include.

Component Type	Component Name	Unit cost ($)	# of Units	Total Cost
CPU	Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5GHz	1559	2	3118
Motherboard	ASRock EP2C602-4L/D16 SSI EEB Server Motherboard Dual LGA 2011 Intel C602 DDR3 1600/1333/1066	329.99	1	329.99
Network Adapter	Intel Ethernet Server Adapter X520-DA1 for Open Compute Project (OCP) (10 Gbps)	139.99	1	139.99
RAM	NEMIX RAM 64GB PC3-12800 Load Reduced Memory for Dell PowerEdge R920 Server	1159.99	10	11599.9
Storage	Intel DC S3510 2.5" 1.6TB SATA III MLC Enterprise Solid State Drive – OEM	999.99	1	999.99
Server Chassis	iStarUSA D-200L-ROHS Steel 2U Rackmount Server Chassis 2 External 5.25" Drive Bays	159.99	1	159.99
PSU	iStarUSA IS-2U35PD8 24Pin 350W Single 2U 80Plus Server Power Supply	114.99	1	114.99
Network Switch	NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E)	849.99	1	849.99
Average Power Cost	Cost per hour	0.0405	1	0.0405

I2.8xlarge

The I2.8xlarge instance runs on High Frequency Intel Xeon E5-2670 v2 (Ivy Bridge) 2.5GHz processor with 244GB of memory and 8 * 800GB of SSD and provides a network performance of 10Gbps. The private instance runs on Intel Xeon E5-2640 Sandy Bridge-EP 2.5GHz and only one instance will run on a physical node. The details of other components are mentioned below.

Component Type	Component Name	Unit cost ($)	# of Units	Total Cost
CPU	Intel Xeon E5-2640 Sandy Bridge-EP 2.5GH	595	2	1190
Motherboard	ASRock EP2C602-4L/D16 SSI EEB Server Motherboard Dual LGA 2011 Intel C602 DDR3 1600/1333/1066	329.99	1	329.99
Network Adapter	Intel Ethernet Server Adapter X520-DA1 for Open Compute Project (OCP) (10 Gbps)	139.99	1	139.99
RAM	Mushkin Enhanced PROLINE 16GB 240-Pin DDR3 SDRAM ECC Registered DDR3 1600 (PC3 12800) Server Memory Model 992063	74.99	10	749.9
Storage	SAMSUNG PM863 MZ-7LM3T8E 2.5" 3.84TB SATA III Enterprise Solid State Disk	1988.99	1	1988.99
Server Chassis	iStarUSA D-200L-ROHS Steel 2U Rackmount Server Chassis 2 External 5.25" Drive Bays	159.99	1	159.99
PSU	iStarUSA IS-2U35PD8 24Pin 350W Single 2U 80Plus Server Power Supply	114.99	1	114.99
Network Switch	NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E)	849.99	1	849.99
Average Power Cost	Cost per hour	0.0343	1	0.0343

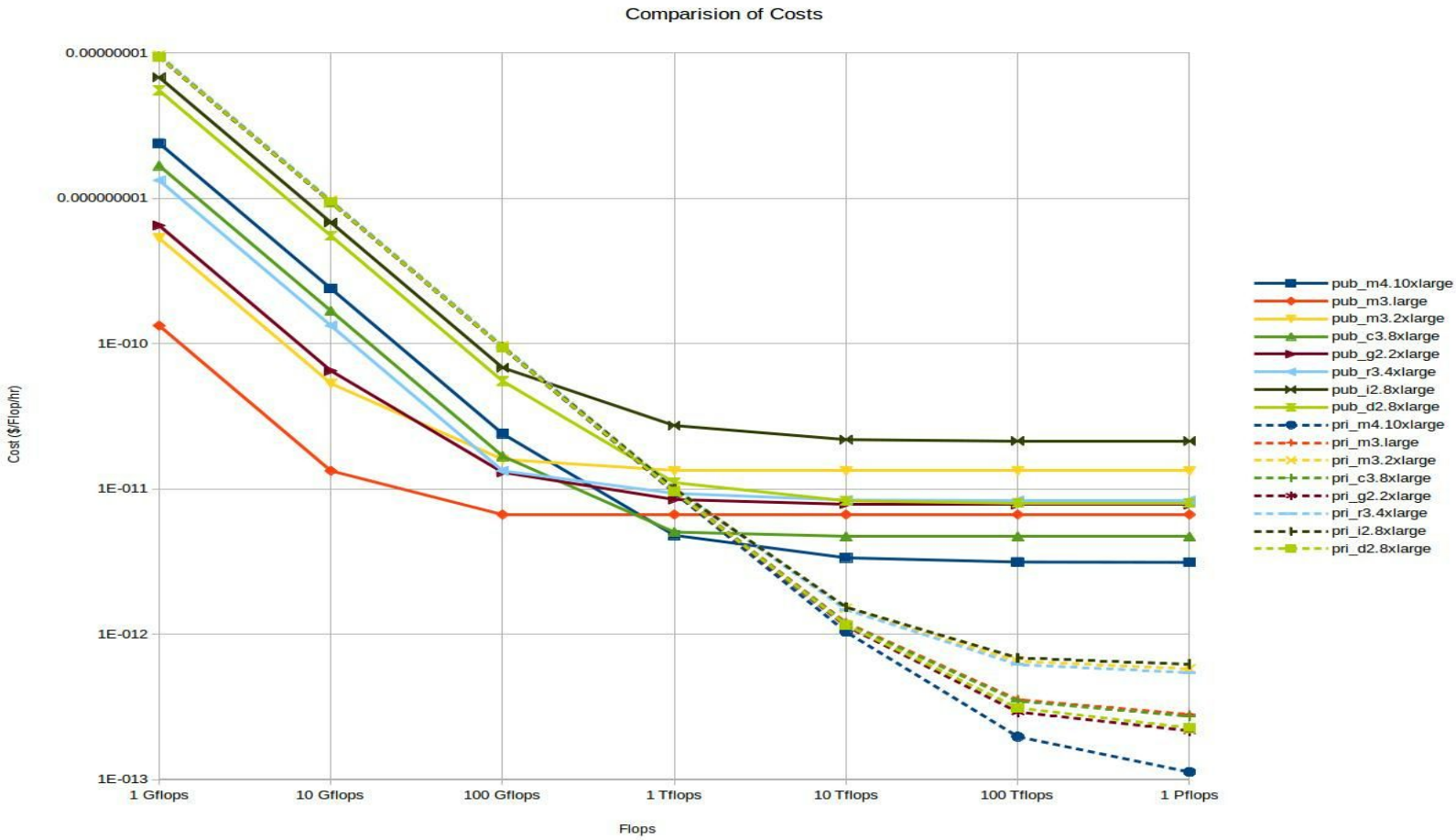
D2.8xlarge

This instance runs on High-frequency Intel Xeon E5-2676v3 (Haswell) 2.4GHz processor with 244GB memory and 24 * 2000GB HDD and provides a network performance of 10Gbps. The private instance runs on a single Intel® Xeon® Processor E5-2640 v4 processor running a single instance. The other components included are mentioned below.

Component Type	Component Name	Unit cost ($)	# of Units	Total Cost
CPU	Intel® Xeon® Processor E5-2640 v4	989.99	1	989.99
Motherboard	SUPERMICRO MBD-X10SRA-F-O ATX Server Motherboard Single Socket R3 (LGA 2011) Intel C612	318	1	318
Network Adapter	Intel Ethernet Server Adapter X520-DA1 for Open Compute Project (OCP) (10 Gbps)	139.99	1	139.99
RAM	Black Diamond Memory 64GB (2 x 32GB) 288-Pin DDR4 SDRAM ECC Registered DDR4 2133 (PC4 17000) Server Memory Model BD32GX22133MQR26	409.99	4	1639.96
Storage	Seagate Archive HDD v2 ST8000AS0002 8TB 128MB Cache SATA 6.0Gb/s 3.5" Internal Hard Drive Bare Drive	214.99	6	1289.94
Server Chassis	iStarUSA D-200L-ROHS Steel 2U Rackmount Server Chassis 2 External 5.25" Drive Bays	159.99	1	159.99
PSU	iStarUSA IS-2U35PD8 24Pin 350W Single 2U 80Plus Server Power Supply	114.99	1	114.99
Network Switch	NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E)	849.99	1	849.99
Average Power Cost	Cost per hour	0.0569	1	0.0569

Cost comparison

This section summarises the cost comparison between different instances running on Public and Private cloud systems.



The above graph depicts the cost of running applications with different computing requirements ranging from 1GFLOP to 1PFLOP. The metric measured is the '*cost per hour per flop*'. The methodology for calculating the metric for Public cloud instance is:

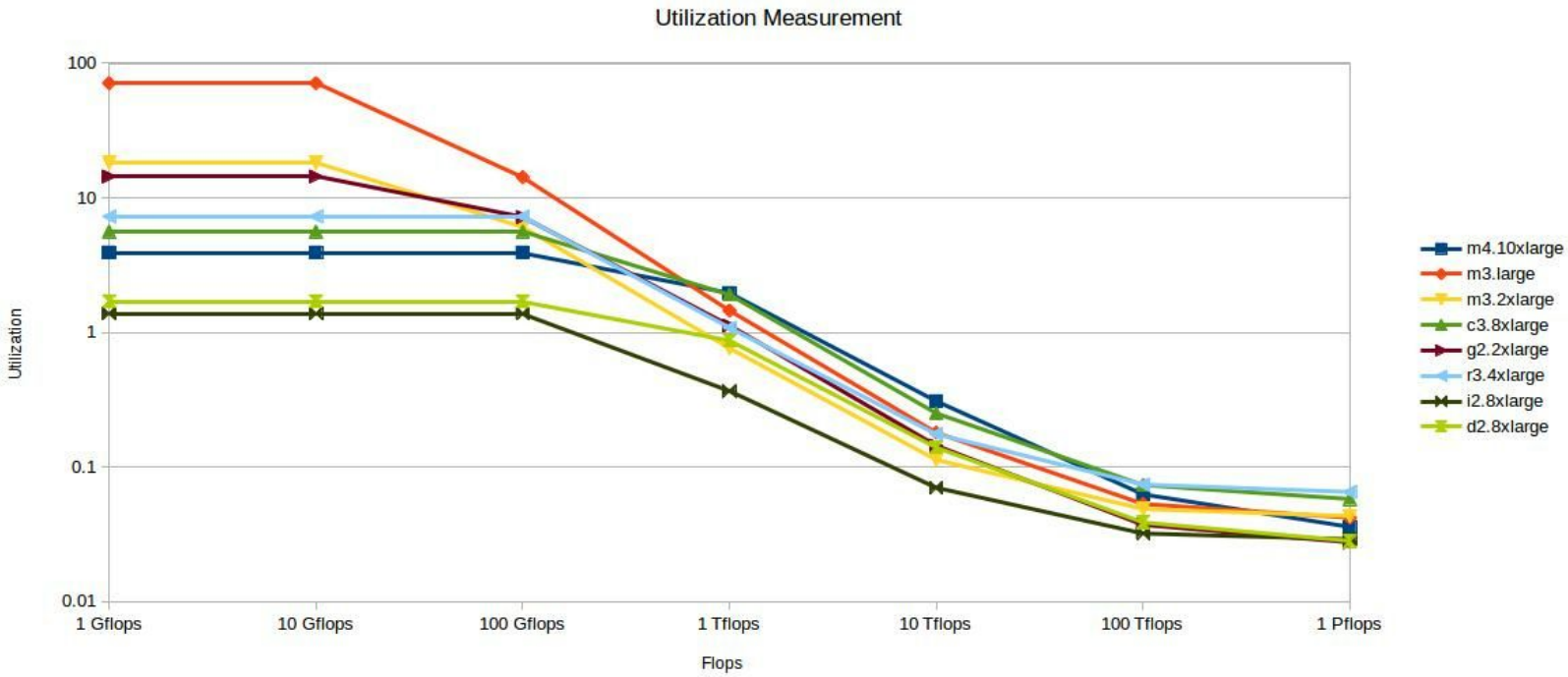
*$ cost/hr/flop = (N * cost of each instance) / (FLOPS at which we are plotting)*

where 'N' is number of instances required to meet the required computing capabilities.

The formula for calculating the metric for Private cloud instance is:

*$ cost/hr/flop = (N * cost of each node for 5 years) / (5 * 365 * 24 * FLOPS at which we are plotting)*

where 'N' is number of instances required to meet the required computing capabilities.



The above graph plots the Utilization measure for each instance with respect to running them in private to public cloud systems. The points are plotted based on the below formula:

Utilization measure = (cost/hr/flop in private cloud) / (cost/hr/flop in public cloud)

Observations

For applications requiring less than 100 GFLOPS, running the application on Public cloud system is better than running the same on Private cloud system. While some private cloud instances work better for running application requiring 1 TFLOPS, all the private instances will start working better once we start running applications requiring more than 10 TFLOPS.

References

- https://www.quora.com/How-did-AWS-customise-an-Intel-CPU-for-its-new-EC2-M4-instance
- http://www.v3.co.uk/v3-uk/news/2412911/aws-rolls-out-larger-m4-instances-powered-by-custom-intel-xeon-chips
- http://www.tomshardware.com/reviews/intel-core-i7-5960x-haswell-e-cpu,3918-13.html
- http://www.bls.gov/regions/midwest/news-release/averageenergyprices_chicago.htm
- http://www.indeed.com/salary/q-System-Administrator-l-Chicago,-IL.html
- http://www.buildcomputers.net/power-consumption-of-pc-components.html

Appendix

Along with this report, printouts of shopping carts of different instances has been submitted. For the M4.10xlarge instance, the chosen RAM was out-of-stock and so it is not present in the printout.