CS553: Cloud Computing

Project Report

Spring 2016

By,

Pavan Rao Chickbellavagala Raghavendra

A20354970

Purpose of the project:

The purpose of this project is that in a business model which deals with a huge data and require computational power or any other resource requirement it has to decide on whether to just procure it from a public hosting or a build their own dedicated private hosting in house which has to be maintained and replaced over time. The project thus try to find the point beyond which it is profitable to build once own private cloud when compared to public cloud.

The comparison of public and private instances are described using 2 plots and 9 tables. The instance whose comparisons are M4.10XLarge, M3.Large, M3.2XLarge, C3.8XLarge, G2.2XLarge, R3.4XLarge, I2.8XLarge, D2.8XLarge. The description of the 2 plots are as follows

- Plot 1: This is the Chart which plots the graph between the different requirements of GFLOPS VS the Cost/GFlops/Hour with each of the instances as series. The series in the plot different type of instances which are mentioned above as well as its comparison with its private and public versions.
- Plot 2: This is the chart which plots the percentage increase in the price of private cloud when compared to public cloud. This is another way of looking at the same data as above. This graph becomes useful if we are considering the points only when the private cloud becomes lesser than the public cloud as the problem statement is to find a point from which it becomes cheaper to build our own private cloud instead of procuring a public cloud

The factor that contribute to cost of build a private cloud could be many such as

- Hardware Required
    - Processor
    - RAM
    - Disk
    - Mother Boards
    - GPU
    - Cooling System
    - Chases
    - Rack
    - Network Adapter
    - Switch
    - UPS
- Other Requirements
    - Administrator
    - Data Center Cooling
    - Power Requirement

The factor that affects the number of nodes required per data center running at a time is the number of instance required to achieve the given requirement of GFLOPS which is different in each column in the following table and in turn how many instances can be hosted on each node.

The cost in the table mentioned is amortized to run the machines for 5 years. The GFLOPS for each of the node is calculated by the formula

Node performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle) x (number of CPUs per node)

Cost/GFLOPS/Hour for AWS public instances

Type	1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
m4.10xlarge.public	2.3940	0.2394	0.0239	0.0048	0.0034	0.0031	0.0031
m3.large.public	0.1330	0.0133	0.0067	0.0067	0.0067	0.0067	0.0067
m3.2xlarge.public	0.5320	0.0532	0.0106	0.0069	0.0067	0.0067	0.0067
c3.8xlarge.public	1.6800	0.1680	0.0168	0.0050	0.0047	0.0047	0.0047
g2.2xlarge.public	0.6500	0.0650	0.0130	0.0085	0.0079	0.0078	0.0078
r3.4xlarge.public	1.3300	0.1330	0.0133	0.0093	0.0084	0.0083	0.0083
i2.8xlarge.public	6.8200	0.6820	0.0682	0.0273	0.0218	0.0213	0.0213
d2.8xlarge.public	5.5200	0.5520	0.0552	0.0110	0.0083	0.0080	0.0080

The above table gives an overall view of how the Cost/GFLOP/Hour varies across different types of instances and how it reacts to the scalability factor. As we can see in the table that the scaling is done from 1GFLOPS to 1PFLOPS with a multiplier of 10 at every stage.

How are the values calculated?

- First the performance of the instance is calculated using

  Performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle)

- Once the performance is calculated the number of instances required to achieve the target GFLOPS is calculated by using

  Number of Instances = Celling ((Required GFLOPS)/(Performance in GFLOPS))

- Cost of each instance is multiplied with number of instances required to get the total cost of procuring the resource is calculated
- Cost/GFLOP/Hour is then calculated using:

Cost/GFLOPS/Hour = (Total Cost)/(Required Number of GFLOPS)

Private Instances

1. M4.10XLarge

Category	Description	Cost/unit	# Of Units	Total Cost
Processor	Intel Xeon E5-2640 V4 2.4 GHz 25MB L3 Cache LGA 2011 90W BX80660E52640V4 Server Processor	$989.99	2	$1,979.98
RAM	SAMSUNG 32GB 288-Pin DDR4 SDRAM DDR4 2133	$222.99	5	$1,114.95
Disk	Biwin® 16GB SATA III 6Gb/s mSATA Internal Solid State Drive SSD	$24.99	1	$24.99
Mother Boards	GIGABYTE MD80-TM0 E-ATX / SSI EEB Server Motherboard Dual LGA 2011-3 Intel C612	$659.99	1	$659.99
GPU	NA	$0.00	0	$0.00
Chases	iStarUSA E-306L Black Aluminum / Steel 3U Rackmount Server Chassis 6 External 5.25" Drive Bays	$303.99	1	$303.99
			TOTAL	**$4,083.90**

The above table gives the cost of constructing the single node

Factors	Cost	1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS

Administrator	Network Administrator	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$300,000.00
Data Center Cooling	1/3rd the amount of power consumed	0.060098	0.060098	0.060098	0.060098	0.180294	1.622646	15.685578	156.55529
Power Requirement	$/KWH = $0.17	0.180294	0.180294	0.180294	0.180294	0.540882	4.867938	47.056734	469.66587
Rack	Norco C-24U 24U Rack Cabinet	$549.99	$549.99	$549.99	$549.99	$549.99	$2,749.95	$24,199.56	$239,245.65
Network Adapter	StarTech.com 1 Port PCI Express 10 Gigabit Ethernet Network Card - PCIe x4 10Gb NIC	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99
Switch	NETGEAR ProSAFE M4300-8X8F Stackable 10 Gigabit 16-Port Managed Switch	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$3,459.98	$29,409.83	$281,988.37
UPS	APC Smart-UPS SMT3000 2880VA 2700 Watts 10 Outlets UPS	$1,059.45	$1,059.45	$1,059.45	$1,059.45	$1,059.45	$2,118.90	$11,653.95	$115,480.05
		TOTAL	**$103,588.66**	**$103,588.66**	**$103,588.66**	**$103,589.14**	**$108,584.31**	**$165,575.07**	**$937,589.28**

This refers to all the dynamic aspects of scaling up from 1GFLOPS to 1PFLOPS

Number of GFLOPS	1	10	100	1000	10000	100000	1000000
Number of Instances	1	1	1	3	27	261	2605
Cost/GFlop/Hour	$11.831084237	$1.183108424	$0.118310842	$0.012498348	$0.002061942	$0.000999891	$0.000917900

This is the table that gives the Cost/GFlop/Hour reading for each scale values

Details:

This type of instance is large instance with 20 dedicated cores which is equivalent to 40 virtual CPUs per instance. This instance is made up of Intel Xeon – E5 2640 v4 CPU which has 10 cores hence we require 2 such CPUs per node to support one instance of M4.10XLarge. We have to select a mother board with 2 sockets with a network adapter of 10 Gbps, Ram of 160 GB. We calculate the GFLOPS for this by using the following formula

Node performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle) x (number of CPUs per node)

i.e,

*Node Performance in GFLOPS = 2.4 * 10 * 16 * 2*

The Cost/GFLOP/hour for each of the GFLOP requirement is provide in the third table.

2. M3.Large

Category	Description	Cost/unit	# Of Units	Total Cost
Processor	Intel Xeon E5-2670 v2	$1,559.99	1	$1,559.99
RAM	SAMSUNG 32GB 288-Pin DDR4 SDRAM DDR4 2133	$222.99	3	$668.97
Disk	Intel 535 Series 2.5" 480GB SATA III MLC Internal	$199.99	1	$199.99
Mother Boards	ASRock EPC612D4I Mini ITX Server Motherboard	$269.99	1	$269.99
GPU	NA	$0.00	0	$0.00
Chases	CHENBRO RM42300-F 1.2 mm SGCC 4U Rackmount	$100.99	1	$100.99
			TOTAL	**$2,799.93**

The above table gives the cost of constructing the single node

Factors			1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
Administrator	Network Administrator	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$500,000.00	$5,000,000.00
Data Center Cooling	1/3rd the amount of power consumed	0.038388333	0.038388333	0.038388333	0.191941667	1.919416667	19.19416667	191.9416667	1919.416667
Power Requirement	$/KWH = $0.17	0.115165	0.115165	0.115165	0.575825	5.75825	57.5825	575.825	5758.25
Rack	Norco C-24U 24U Rack Cabinet	$549.99	$549.99	$549.99	$549.99	$4,949.91	$46,199.16	$458,691.66	$4,583,616.66
Network Adapter	StarTech.com 1 Port PCI Express 10 Gigabit Ethernet Network Card - PCIe x4 10Gb NIC	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99
Switch	NETGEAR ProSAFE M4300-8X8F Stackable 10 Gigabit 16-Port Managed Switch	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$6,919.96	$55,359.68	$541,486.87
UPS	APC Smart-UPS SMT1500 1440VA 1000 Watts 8 Outlets UPS	$457.99	$457.99	$457.99	$457.99	$1,373.97	$9,617.79	$95,719.91	$954,451.16
		TOTAL	**$102,987.11**	**$102,987.11**	**$102,987.73**	**$108,310.54**	**$163,062.68**	**$1,110,788.01**	**$11,087,481.35**

This refers to all the dynamic aspects of scaling up from 1GFLOPS to 1PFLOPS

Number of GFLOPS	1	10	100	1000	10000	100000	1000000
Number of Instances	1	1	5	50	500	5000	50000
Cost/GFlop/Hour	$11.547663419	$1.154766342	$0.118034349	$0.014802232	$0.004482500	$0.003907194	$0.003906728

This is the table that gives the Cost/GFlop/Hour reading for each scale values

Details:

This type of instance is large instance with 1 dedicated core which is equivalent to 2 virtual CPUs per instance. This instance is made up of Intel Xeon – E5 2676 v2 CPU which has 10 cores hence it can support 10 instance of M3.Large. We have to select a mother board with 1 sockets with a network adapter of 10 Gbps, Ram of 96 GB. We calculate the GFLOPS for this by using the following formula

Node performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle) x (number of CPUs per node)

i.e,

*Node Performance in GFLOPS = 2.5 * 10 * 8 * 1*

The Cost/GFLOP/hour for each of the GFLOP requirement is provide in the third table

3. M3.2XLarge

Category	Description	Cost/unit	# Of Units	Total Cost
Processor	Intel Xeon E5-2670 v2	$1,559.99	2	$3,119.98
RAM	SAMSUNG 32GB 288-Pin DDR4 SDRAM DDR4 2133	$222.99	5	$1,114.95
Disk	Kingston SSDNow mS200 mSATA 480GB SATA 6Gb/s	$229.99	2	$459.98
Mother Boards	SUPERMICRO MBD-X10DRI-LN4+-O Enhanced Extended ATX Xeon Server Motherboard Dual LGA 2011 Intel C612	$269.99	1	$269.99
Chases	iStarUSA E-306L Black Aluminum / Steel 3U Rackmount Server Chassis 6 External 5.25" Drive Bays	$303.99	1	$303.99
			TOTAL	**$5,268.89**

The above table gives the cost of constructing the single node

Variable			1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
Administrator	Network Administrator	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$200,000.00	$1,300,000.00
Data Center Cooling	1/3rd the amount of power consumed	0.0768	0.0768	0.0768	0.1536	0.9984	9.6	96	960
Power Requirement	$/KWH = $0.17	0.2304	0.2304	0.2304	0.4608	2.9952	28.8	288	2880
Rack	Norco C-24U 24U Rack Cabinet	$549.99	$549.99	$549.99	$549.99	$1,649.97	$11,549.79	$114,947.91	$1,146,179.16
Network Adapter	Intel PWLA8391GT Desktop Adapter PRO/1000 GT	$29.99	$29.99	$29.99	$29.99	$29.99	$29.99	$29.99	$29.99
Switch	NETGEAR ProSAFE M4300-8X8F Stackable 10 Gigabit 16-Port Managed Switch	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$3,459.98	$27,679.84	$271,608.43
UPS	APC Smart-UPS SMT1500 1440VA 1000 Watts 8 Outlets UPS	$457.99	$457.99	$457.99	$457.99	$457.99	$2,747.94	$24,273.47	$238,612.79
		TOTAL	**$102,768.27**	**$102,768.27**	**$102,768.57**	**$103,871.93**	**$117,826.10**	**$367,315.21**	**$2,960,270.37**

This refers to all the dynamic aspects of scaling up from 1GFLOPS to 1PFLOPS

Number of GFLOPS	1	10	100	1000	10000	100000	1000000
Number of Instances	1	1	2	13	125	1250	12500
Cost/Flop/Hour	$11.599049909	$1.159904991	$0.117193793	$0.013068116	$0.002686281	$0.001770540	$0.001690337

This is the table that gives the Cost/GFlop/Hour reading for each scale values

Details:

This type of instance is medium size instance with 4 dedicated core which is equivalent to 8 virtual CPUs per instance. This instance is made up of Intel Xeon – E5 2670 v2 CPU which has 10 cores each hence it can support 5 instance of M3.2XLarge. We have to select a mother board with 2 sockets with a network adapter of 1 Gbps, Ram of 150 GB. We calculate the GFLOPS for this by using the following formula

Node performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle) x (number of CPUs per node)

i.e,

*Node Performance in GFLOPS = 2.5 * 10 * 8 * 2*

The Cost/GFLOP/hour for each of the GFLOP requirement is provide in the third table

4. C3.8XLarge

Category	Description	Cost/unit	# Of Units	Total Cost
Processor	Intel Xeon E5-2680 v2 Ivy Bridge-EP 2.8 GHz 25MB L3 Cache LGA 2011 115W BX80635E52680V2 Server Processor	$1,769.99	2	$3,539.98
RAM	SAMSUNG 32GB 288-Pin DDR4 SDRAM DDR4 2133	$222.99	2	$445.98
Disk	Kingston SSDNow mS200 mSATA 480GB SATA 6Gb/s	$229.99	2	$459.98
Mother Boards	SUPERMICRO MBD-X9DAi-O Extended ATX Server Motherboard Dual LGA 2011 DDR3 1866/1600/1333/1066/800	$472.99	1	$472.99
GPU	NA	$0.00	0	$0.00
Chases	iStarUSA E-306L Black Aluminum / Steel 3U Rackmount Server Chassis 6 External 5.25" Drive Bays	$303.99	1	$303.99
			TOTAL	**$5,222.92**

The above table gives the cost of constructing the single node

Factors			1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
Administrator	Network Administrator	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$300,000.00
Data Center Cooling	1/3rd the amount of power consumed	0.076933333	0.076933333	0.076933333	0.076933333	0.2308	1.769466667	17.23306667	171.7921333
Power Requirement	$/KWH = $0.17	0.2308	0.2308	0.2308	0.2308	0.6924	5.3084	51.6992	515.3764
Rack	Norco C-24U 24U Rack Cabinet	$549.99	$549.99	$549.99	$549.99	$549.99	$2,199.96	$20,899.62	$205,146.27
Network Adapter	StarTech.com 1 Port PCI Express 10 Gigabit Ethernet Network Card - PCIe x4 10Gb NIC	$1,059.45	$1,059.45	$1,059.45	$1,059.45	$1,059.45	$1,059.45	$1,059.45	$1,059.45
Switch	NETGEAR ProSAFE M4300-8X8F Stackable 10 Gigabit 16-Port Managed Switch	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$3,459.98	$24,219.86	$242,198.60
UPS	APC Smart-UPS SMT1500 1440VA 1000 Watts 8 Outlets UPS	$457.99	$457.99	$457.99	$457.99	$457.99	$457.99	$4,579.90	$43,051.06
		TOTAL	**$103,797.73**	**$103,797.73**	**$103,797.73**	**$103,798.34**	**$107,184.46**	**$150,827.76**	**$792,142.55**

This refers to all the dynamic aspects of scaling up from 1GFLOPS to 1PFLOPS

Number of GFLOPS	1	10	100	1000	10000	100000	1000000
Number of Instances	1	1	1	3	23	224	2233
Cost/Flop/Hour	$11.929202283	$1.192920228	$0.119292023	$0.012783158	$0.002139989	$0.001082175	$0.000998909

This is the table that gives the Cost/GFlop/Hour reading for each scale values

Details:

This type of instance is large computation oriented instance with 16 dedicated core which is equivalent to 32 virtual CPUs per instance. This node is made up of 2 Intel Xeon – E5 2680 v2 CPU which has 10 cores each hence it can support 1 instance of C3.8XLarge. We have to select a mother board with 2 sockets with a network adapter of 10 Gbps, Ram of 60 GB. We calculate the GFLOPS for this by using the following formula

Node performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle) x (number of CPUs per node)

i.e,

*Node Performance in GFLOPS = 2.8 * 10 * 8 * 2*

The Cost/GFLOP/hour for each of the GFLOP requirement is provide in the third table

5. G2.2XLarge

Category	Description	Cost/unit	Number Of Units	Total Cost
Processor	Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz 25MB L3 Cache LGA 2011 115W BX80635E52670V2 Server Processor	$1,559.99	1	$1,559.99
RAM	SAMSUNG 32GB 288-Pin DDR4 SDRAM DDR4 2133	$222.99	2	$445.98
Disk	Kingston SSDNow mS200 mSATA 480GB SATA 6Gb/s	$229.99	1	$229.99
Mother Boards	SUPERMICRO MBD-X10SRI-F Server Motherboard LGA 2011 R3	$269.99	1	$269.99
GPU	Nvidia GRID K520 8GB GDDR5 PCIe gen3 x16 Cloud Gaming Kepler GPU Graphics 900-12055-0020-000	$2,750.00	2	$5,500.00
Chases	CHENBRO RM42300-F 1.2 mm SGCC 4U Rackmount	$100.99	1	$100.99
			TOTAL	**$8,106.94**

The above table gives the cost of constructing the single node

Factors			1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
Administrator	Network Administrator	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$200,000.00
Data Center Cooling	1/3rd the amount of power consumed	0.338466667	0.338466667	0.338466667	0.338466667	0.676933333	6.430866667	63.63173333	633.9480667
Power Requirement	$/KWH = $0.17	1.0154	1.0154	1.0154	1.0154	2.0308	19.2926	190.8952	1901.8442
Rack	Norco C-24U 24U Rack Cabinet	$549.99	$549.99	$549.99	$549.99	$549.99	$2,199.96	$17,599.68	$172,146.87
Network Adapter	Intel PWLA8391GT Desktop Adapter PRO/1000 GT	$29.99	$29.99	$29.99	$29.99	$29.99	$29.99	$29.99	$29.99
Switch	NETGEAR ProSAFE M4300-8X8F Stackable 10 Gigabit 16-Port Managed Switch	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$10,379.94	$102,069.41
UPS	APC Smart-UPS SMT1500 1440VA 1000 Watts 8 Outlets UPS	$457.99	$457.99	$457.99	$457.99	$457.99	$457.99	$3,663.92	$36,181.21
		TOTAL	**$102,769.31**	**$102,769.31**	**$102,769.31**	**$102,770.67**	**$104,443.65**	**$131,928.06**	**$512,963.27**

This refers to all the dynamic aspects of scaling up from 1GFLOPS to 1PFLOPS

Number of GFLOPS	1	10	100	1000	10000	100000	1000000
Number of Instances	1	1	1	2	19	188	1873
Cost/GFlop/Hour	$13.143247945	$1.314324795	$0.131432479	$0.014807775	$0.004314241	$0.003250698	$0.003147578

This is the table that gives the Cost/GFlop/Hour reading for each scale values

Details:

This type of instance is large graphic oriented instance with 4 dedicated core which is equivalent to 8 virtual CPUs per instance. This node is made up of 1 Intel Xeon – E5 2670 v2 CPU which has 10 cores each hence it can support 2 instance of G2.2XLarge. We have to select a mother board with 1 sockets with a network adapter of 10 Gbps, Ram of 120 GB. We calculate the GFLOPS for this by using the following formula

Node performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle) x (number of CPUs per node)

i.e,

*Node Performance in GFLOPS = 2.5 * 10 * 8 * 1*

Since this is a graphic oriented system the GPU performance is also added. The performance of GPU is considered for double precision operations and the performance of GPU which is used in G2.2XLarge is 668.

The Cost/GFLOP/hour for each of the GFLOP requirement is provide in the third table

6. R3.4XLarge

Category	Description	Cost/unit	# Of Units	Total Cost
Processor	Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz 25MB L3 Cache LGA 2011 115W BX80635E52670V2 Server Processor	$1,559.99	1	$1,559.99
RAM	SAMSUNG 32GB 288-Pin DDR4 SDRAM DDR4 2133	$222.99	4	$891.96
Disk	Kingston SSDNow mS200 mSATA 480GB SATA 6Gb/s	$229.99	1	$229.99
Mother Boards	SUPERMICRO MBD-X10SRI-F Server Motherboard LGA 2011 R3	$269.99	1	$269.99
GPU	NA	$0.00	0	$0.00
Chases	CHENBRO RM42300-F 1.2 mm SGCC 4U Rackmount	$100.99	1	$100.99
			TOTAL	**$3,052.92**

The above table gives the cost of constructing the single node

Variable			1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
Administrator	Network Administrator	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$1,000,000.00
Data Center Cooling	1/3rd the amount of power consumed	0.038466667	0.038466667	0.038466667	0.038466667	0.384666667	3.846666667	38.46666667	384.6666667
Power Requirement	$/KWH = $0.17	0.1154	0.1154	0.1154	0.1154	1.154	11.54	115.4	1154
Rack	Norco C-24U 24U Rack Cabinet	$549.99	$549.99	$549.99	$549.99	$1,099.98	$9,349.83	$91,848.33	$916,833.33
Network Adapter	Intel PWLA8391GT Desktop Adapter PRO/1000 GT	$29.99	$29.99	$29.99	$29.99	$29.99	$29.99	$29.99	$29.99
Switch	NETGEAR ProSAFE M4300-8X8F Stackable 10 Gigabit 16-Port Managed Switch	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$6,919.96	$55,359.68	$541,486.87
UPS	APC Smart-UPS SMT1500 1440VA 1000 Watts 8 Outlets UPS	$457.99	$457.99	$457.99	$457.99	$457.99	$2,289.95	$19,235.58	$190,981.83
		TOTAL	**$102,768.11**	**$102,768.11**	**$102,768.11**	**$103,319.49**	**$118,605.12**	**$266,627.45**	**$2,650,870.69**

This refers to all the dynamic aspects of scaling up from 1GFLOPS to 1PFLOPS

Number of GFLOPS	1	10	100	1000	10000	100000	1000000
Number of Instances	1	1	1	10	100	1000	10000
Cost/GFlop/Hour	$11.702288584	$1.170228858	$0.117022886	$0.013726958	$0.003419675	$0.002387843	$0.002387492

This is the table that gives the Cost/GFlop/Hour reading for each scale values

Details:

This type of instance is large instance with 8 dedicated core which is equivalent to 16 virtual CPUs per instance. This node is made up of 1 Intel Xeon – E5 2670 v2 CPU which has 10 cores each hence it can support 1 instance of R3.4XLarge. We have to select a mother board with 1 sockets with a network adapter of 10 Gbps, Ram of 120 GB. We calculate the GFLOPS for this by using the following formula

Node performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle) x (number of CPUs per node)

i.e,

*Node Performance in GFLOPS = 2.5 * 10 * 8 * 1*

The Cost/GFLOP/hour for each of the GFLOP requirement is provide in the third table

7. I2.8XLarge

Category	Description	Cost/unit	# Of Units	Total Cost
Processor	Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz 25MB L3 Cache LGA 2011 115W BX80635E52670V2 Server Processor	$1,559.99	2	$3,119.98
RAM	SAMSUNG 32GB 288-Pin DDR4 SDRAM DDR4 2133	$222.99	8	$1,783.92
Disk	SAMSUNG 850 EVO 2.5" 2 TB SATA III 3-D Vertical Internal Solid State Drive (SSD) MZ-75E2T0B/AM	$229.99	4	$919.96
Mother Boards	ASRock EP2C602-2TS6/D16 SSI EEB Server Motherboard Dual LGA 2011 Intel C602 DDR3 1600/1333/1066	$619.99	1	$619.99
GPU	NA	$0.00	0	$0.00
Chases	SUPERMICRO CSE-825TQ-R700LPB Black 2U Rackmount Server Case w/ 700W Redundant Power Supply	$569.99	1	$569.99
			TOTAL	**$7,013.84**

The above table gives the cost of constructing the single node

Variable			1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
Administrator	Network Administrator	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$500,000.00
Data Center Cooling	1/3rd the amount of power consumed	0.0772	0.0772	0.0772	0.0772	0.386	3.86	38.6	386
Power Requirement	$/KWH = $0.17	0.2316	0.2316	0.2316	0.2316	1.158	11.58	115.8	1158
Rack	Norco C-24U 24U Rack Cabinet	$549.99	$549.99	$549.99	$549.99	$549.99	$4,949.91	$46,199.16	$458,691.66
Network Adapter	StarTech.com 1 Port PCI Express 10 Gigabit Ethernet Network Card - PCIe x4 10Gb NIC	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99
Switch	NETGEAR ProSAFE M4300-8X8F Stackable 10 Gigabit 16-Port Managed Switch	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$6,919.96	$55,359.68	$541,486.87
UPS	APC Smart-UPS SMT1500 1440VA 1000 Watts 8 Outlets UPS	$457.99	$457.99	$457.99	$457.99	$457.99	$1,373.97	$9,617.79	$95,719.91
		TOTAL	**$102,987.27**	**$102,987.27**	**$102,987.27**	**$102,988.50**	**$113,508.27**	**$211,580.02**	**$1,597,691.43**

This refers to all the dynamic aspects of scaling up from 1GFLOPS to 1PFLOPS

Number of GFLOPS	1	10	100	1000	10000	100000	1000000
Number of Instances	1	1	1	5	50	500	5000
Cost/GFlop/Hour	$11.952653881	$1.195265388	$0.119526539	$0.013828387	$0.003517025	$0.002484262	$0.002426770

This is the table that gives the Cost/GFlop/Hour reading for each scale values

Details:

This type of instance is large instance with 16 dedicated core which is equivalent to 32 virtual CPUs per instance. This node is made up of 2 Intel Xeon – E5 2670 v2 CPU which has 10 cores each hence it can support 1 instance of I2.8XLarge. We have to select a mother board with 2 sockets with a network adapter of 10 Gbps, Ram of 244 GB. We calculate the GFLOPS for this by using the following formula

Node performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle) x (number of CPUs per node)

i.e,

*Node Performance in GFLOPS = 2.5 * 10 * 8 * 2*

The Cost/GFLOP/hour for each of the GFLOP requirement is provide in the third table

8. D2.8XLarge

Category	Description	Cost/unit	# Of Units	Total Cost
Processor	Intel Xeon E5-2640 V4 2.4 GHz 25MB L3 Cache LGA 2011 90W BX80660E52640V4 Server Processor	$989.99	2	$1,979.98
RAM	SAMSUNG 32GB 288-Pin DDR4 SDRAM DDR4 2133	$222.99	8	$1,783.92
Disk	WD Red 8TB NAS Hard Disk Drive - 5400 RPM Class SATA 6Gb/s 128MB Cache 3.5 Inch - WD80EFZX	$349.99	6	$2,099.94
Mother Boards	GIGABYTE MD80-TM0 E-ATX / SSI EEB Server Motherboard Dual LGA 2011-3 Intel C612	$659.99	1	$659.99
GPU	NA	$0.00	0	$0.00
Chases	iStarUSA E-306L Black Aluminum / Steel 3U Rackmount Server Chassis 6 External 5.25" Drive Bays	$303.99	1	$303.99
			TOTAL	**$6,827.82**

The above table gives the cost of constructing the single node

Factors			1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
Administrator	Network Administrator	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$100,000.00	$300,000.00
Data Center Cooling	1/3rd the amount of power consumed	0.0608	0.0608	0.0608	0.0608	0.1824	1.6416	15.8688	158.384
Power Requirement	$/KWH = $0.17	0.1824	0.1824	0.1824	0.1824	0.5472	4.9248	47.6064	475.152
Rack	Norco C-24U 24U Rack Cabinet	$549.99	$549.99	$549.99	$549.99	$549.99	$2,749.95	$24,199.56	$239,245.65
Network Adapter	StarTech.com 1 Port PCI Express 10 Gigabit Ethernet Network Card - PCIe x4 10Gb NIC	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99	$248.99
Switch	NETGEAR ProSAFE M4300-8X8F Stackable 10 Gigabit 16-Port Managed Switch	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$1,729.99	$3,459.98	$29,409.83	$281,988.37
UPS	APC Smart-UPS SMT3000 2880VA 2700 Watts 10 Outlets UPS	$1,059.45	$1,059.45	$1,059.45	$1,059.45	$1,059.45	$2,118.90	$11,653.95	$115,480.05
	TOTAL		**$103,588.66**	**$103,588.66**	**$103,588.66**	**$103,589.15**	**$108,584.39**	**$165,575.81**	**$937,596.60**

This refers to all the dynamic aspects of scaling up from 1GFLOPS to 1PFLOPS

Number of GFLOPS	1	10	100	1000	10000	100000	1000000
Number of Instances	1	1	1	3	27	261	2605
Cost/GFlop/Hour	$11.896538813	$1.189653881	$0.118965388	$0.012694711	$0.002238670	$0.001170728	$0.001088409

This is the table that gives the Cost/GFlop/Hour reading for each scale values

Details:

This type of instance is large instance with 18 dedicated core which is equivalent to 36 virtual CPUs per instance. This node is made up of 2 Intel Xeon – E5 2640 v4 CPU which has 10 cores each hence it can support 1 instance of D2.8XLarge. We have to select a mother board with 2 sockets with a network adapter of 10 Gbps, Ram of 244 GB. We calculate the GFLOPS for this by using the following formula

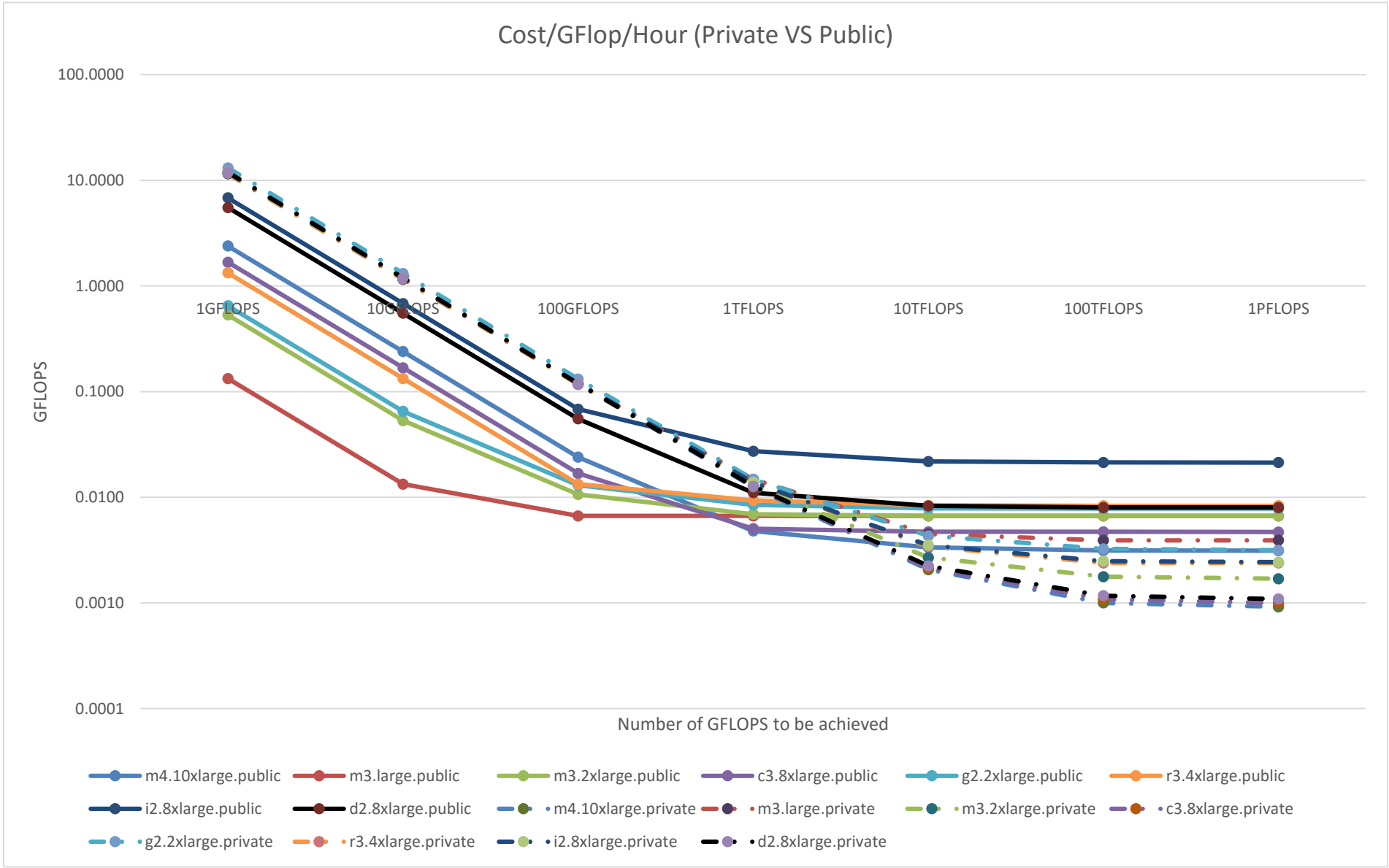
Node performance in GFlops = (CPU speed in GHz) x (number of CPU cores) x (CPU instruction per cycle) x (number of CPUs per node)

i.e,

*Node Performance in GFLOPS = 2.4 * 10 * 16 * 2*

The Cost/GFLOP/hour for each of the GFLOP requirement is provide in the third table

Plot 1:

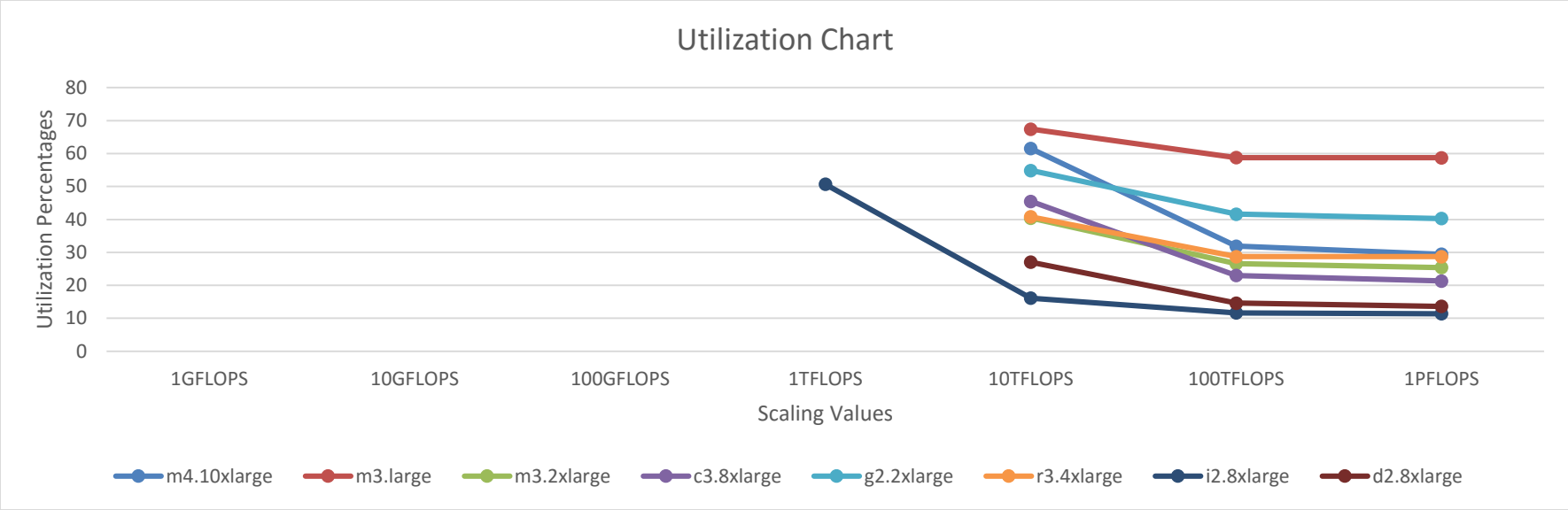

Cost/GFlop/Hour (Private VS Public)
100.0000
10.0000
1.0000
0.1000
0.0100
0.0010
0.0001
GFLOPS
1GFLOPS
100GFLOPS
1TFLOPS
10TFLOPS
100TFLOPS
1PFLOPS
Number of GFLOPS to be achieved
m4.10xlarge.public
m3.large.public
m3.2xlarge.public
c3.8xlarge.public
g2.2xlarge.public
r3.4xlarge.public
i2.8xlarge.public
d2.8xlarge.public
m4.10xlarge.private
m3.large.private
m3.2xlarge.private
c3.8xlarge.private
g2.2xlarge.private
r3.4xlarge.private
i2.8xlarge.private
d2.8xlarge.private

Data:

Type	1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
m4.10xlarge.public	2.3940	0.2394	0.0239	0.0048	0.0034	0.0031	0.0031
m3.large.public	0.1330	0.0133	0.0067	0.0067	0.0067	0.0067	0.0067
m3.2xlarge.public	0.5320	0.0532	0.0106	0.0069	0.0067	0.0067	0.0067
c3.8xlarge.public	1.6800	0.1680	0.0168	0.0050	0.0047	0.0047	0.0047
g2.2xlarge.public	0.6500	0.0650	0.0130	0.0085	0.0079	0.0078	0.0078
r3.4xlarge.public	1.3300	0.1330	0.0133	0.0093	0.0084	0.0083	0.0083
i2.8xlarge.public	6.8200	0.6820	0.0682	0.0273	0.0218	0.0213	0.0213
d2.8xlarge.public	5.5200	0.5520	0.0552	0.0110	0.0083	0.0080	0.0080
m4.10xlarge.private	11.8311	1.1831	0.1183	0.0125	0.0021	0.0010	0.0009
m3.large.private	11.54766342	1.154766342	0.118034349	0.014802232	0.0044825	0.003907194	0.003906728
m3.2xlarge.private	11.59904991	1.159904991	0.117193793	0.013068116	0.002686281	0.00177054	0.001690337
c3.8xlarge.private	11.92920228	1.192920228	0.119292023	0.012783158	0.002139989	0.001082175	0.000998909
g2.2xlarge.private	13.14324795	1.314324795	0.131432479	0.014807775	0.004314241	0.003250698	0.003147578
r3.4xlarge.private	11.70228858	1.170228858	0.117022886	0.013726958	0.003419675	0.002387843	0.002387492
i2.8xlarge.private	11.95265388	1.195265388	0.119526539	0.013828387	0.003517025	0.002484262	0.00242677
d2.8xlarge.private	11.89653881	1.189653881	0.118965388	0.012694711	0.00223867	0.001170728	0.001088409

The above chart is a comparison chart between the private and public instances of all the type of instances of AWS. The points on the chart signify the value COST/GFLOP/HOUR. Every instance from 1TFLOP onwards is worth building a private cloud whereas only I2.8XLarge is worth building a private cloud from 1TFLOP onwards. The private cloud's cost/GFLOP/hour decreases gradually until it reaches an equilibrium after which it becomes more effective to build a private cloud as cost of power and administrator gets amortized for 5 years.

Plot 2:



Data:

Percentage Increase	1GFLOPS	10GFLOPS	100GFLOPS	1TFLOPS	10TFLOPS	100TFLOPS	1PFLOPS
m4.10xlarge					61.52113127	31.88286266	29.42569257
m3.large					67.4060076	58.75479477	58.7477914
m3.2xlarge					40.39519861	26.62465654	25.41859971
c3.8xlarge					45.49295946	23.00541941	21.30378844
g2.2xlarge					54.85367024	41.60627361	40.28642328
r3.4xlarge					40.81244997	28.72593423	28.72170344
i2.8xlarge				50.69056897	16.11539922	11.63773883	11.3866064
d2.8xlarge					27.03707233	14.62678224	13.62650519

The above data and chart show the utilization of private instances of all the 8 instance type when the performance capacity of the cloud is scaled from 1GFLOPS to 1PFLOPS. The graph becomes particularly useful at the point when the private instance breaks even with the cost of procuring a public cloud and all the values after it.

Instance m4.10xlarge, m3.large, m3.2xlarge, c3.8XLarge, g2.2XLarge, r3.4XLarge, d2.8XLarge breaks even with the cloud somewhere between 1TFLOPS to 10TFLOPS and thus stand at a utilization percentage of 61.5, 67.4, 40.4, 45.5, 54.9, 40.8, 27.0 percentages respectively. This means that the utilization above those values would make it profitable to own a private cloud rather than procuring instances from a public instance.

The instance I2.8xlarge on the other hand breaks even earlier somewhere between 100GFLOPS to 1TFLOPS and the utilization percentage of the private cloud is about 50.7% at 1TFLOPS requirement and as mentioned earlier it is recommended to own a private cloud if this point crosses.

The screenshots of the carts are saved as documents in a folder named screenshots which is added in the rar file.

References

https://en.wikipedia.org/wiki/GeForce_600_series

http://www.nvidia.com/content/PDF/sc_2010/CUDA_Tutorial/SC10_Accelerating_GPU_Computation_Through_Mixed-Precision_Methods.pdf

http://www.nextplatform.com/2015/07/08/gpu-computing-still-nascent-on-public-clouds/

http://www.doc.ic.ac.uk/teaching/distinguished-projects/2015/h.dearman.pdf

http://www.novatte.com/our-blog/197-how-to-calculate-peak-theoretical-performance-of-a-cpu-based-hpc-system

https://www.vmguru.com/2011/06/how-to-calculate-electrical-costs-for-cooling-and-power-consumption/

https://aws.amazon.com/ec2/instance-types/

https://www.sans.org/reading-room/whitepapers/recovery/requirements-design-secure-data-center-561

http://www.apcmedia.com/salestools/NRAN-5TE6HE/NRAN-5TE6HE_R3_EN.pdf?sdirect=true

http://www.cisco.com/c/en/us/solutions/collateral/data-center-virtualization/unified-computing/white_paper_c11-680202.pdf

http://wccftech.com/intel-broadwellep-xeon-e52600-v4-skus-leaked/

http://www.nvidia.com/object/cloud-gaming-gpu-boards.html

http://www.newegg.com/Product/ProductList.aspx?Submit=ENE&DEPA=0&Order=BESTMATCH&Description=+Intel+Xeon+E5+2676+v3&N=-1&isNodeId=1

https://www-ssl.intel.com/content/www/us/en/solid-state-drives/data-center-family.html

https://www.ecofinancialtechnology.com/2014/07/build-a-gpu-development-environment-hosted-on-aws/