Understanding the Cost of Computing in Cloud

INTRODUCTION

Cloud computing is a internet based computing that provides on demand shared processing of resources and data to the computers and other devices. The backbone of Cloud computing is virtualization. Virtualization helps in sharing of resources among users, such that more number (scalable) of users can use the services available on the cloud. The services that the cloud can offer can be classified under infrastructure, software and platform. Also, based on ownership of the cloud, it is categorized into public, private and hybrid cloud [1]. Users need to pay for the resources that they are using on the cloud.

Amazon's AWS (Amazon Web Services) is one of the leading on-demand cloud infrastructure provider. The Elastic Cloud Computing (Amazon EC2) [2] is a web service that offers resizable computing capacity in the cloud. It provides an simple and clear interface that allows the users to obtain the resources and configure its capacity at the infrastructure level. It provides you with complete control of computing resources and reduces the time required to acquire and boot the instances to minutes, thus allowing quick scalable capacity based on the requirements.

The project aims at building a private cloud that brings the same performance as of Amazon's EC2 (public cloud) and compare the cost and utilization of the private cloud across various instance types.

Given Amazon EC2 Instance matrix (Fig 1):

	vCPU	Cores	Memory (GiB)	Storage (GB)	Networking (Gbps)	Physical Processor	Clock Speed (GHz)	Price ($)
m4.10xlarge	40	20	160	EBS only	10	Intel Xeon E5-2676 v3	2.4	2.394
m3.large	2	1	7.5	32 SSD	0.5	Intel Xeon E5-2670 v2	2.5	0.133
m3.2xlarge	8	4	30	2x80 SSD	1	Intel Xeon E5-2670 v2	2.5	0.532
c3.8xlarge	32	16	60	2x320 SSD	10	Intel Xeon E5-2680 v2	2.8	1.68
g2.2xlarge	8	4	15	1x60 SSD	1	Intel Xeon E5-2670	2.6	0.65
r3.4xlarge	16	8	122	1x320 SSD	1	Intel Xeon E5-2670 v2	2.5	1.33
i2.8xlarge	32	16	244	8x800 SSD	10	Intel Xeon E5-2670 v2	2.5	6.82
d2.8xlarge	36	18	244	24x2000 HDD	10	Intel Xeon E5-2676 v3	2.4	5.52

The above table gives the total number of virtual CPU's, Cores, Memory, Storage, Networking, Physical Processor, Clock Speed and Price per hour for the various given Amazon EC2 instance types. Each vCPU in the above instance types represents a **hyperthreaded** core. A vCPU in an AWS environment actually represents only half a physical core. For example if you are looking for equivalent compute capacity to, say, an 8-core server, you would need a so-call 4xlarge EC2 instance with 16vCPUs. We need to take this in our account in computing the cost for the instances. The number of cores mentioned in the above table is as per the Amazon's claim mentioned in their documentation for each of the instance types. I have attached the screenshots of the hardware that needs to be purchased from the newegg website for building the private cloud.

The following table gives the total number cores needed in the private cloud which is required to match the total cores in the public cloud.

Public Cloud cores vs Private Cloud cores (Fig 2):

	Public	Private		
Instance type	Cores	Cores	# of processors needed	Total cores achieved
m4.10xlarge	20	12	2	24
m3.large	1	10	1	10
m3.2xlarge	4	10	1	10
c3.8xlarge	16	10	2	20
g2.2xlarge	4	8	1	8
r3.4xlarge	8	10	1	10
i2.8xlarge	16	10	2	20
d2.8xlarge	18	12	2	24

In reality, for building the private cloud the number of cores will vary, since each of the Intel Xeon processor mentioned in Fig 1, will have a predefined number of physical CPU cores associated with it. The total physical CPU cores for each of the Intel Xeon processors can be found from the Intel website. Thus, in order to match the total cores mentioned in the public cloud, we need to buy an extra processor accordingly as needed while building the private cloud. We need to take into account, the total processor cost for each of the instances.

The total cost for building a private cloud depends on various hardware costs such as Processor, Memory, SSD, GPU, Motherboard, Network Card, Rack Chassis, Rack and cables for each instance types. Additionally we need to consider the power cost, cooling cost and system administration costs.

TABLES:

The components for various private instance types and their total costs for five years are listed below. All the cost is rounded off to the nearest integer.

1) m4.10xlarge instance

m4.10xlarge	
Components	**Total cost for 5 years (in $)**
Processor	3951
Memory	2132
Root SSD	20
SSD/HDD	72
GPU	-
Motherboard	1002
Network card	889
Rack Chassis	398
Rack	24
Cables	40
Power	14248
Cooling	4276
Admin	120000
Total	**147052**

2) m3.large instance

m3.large	
Components	**Total cost for 5 years (in $)**
Processor	1560
Memory	51
Root SSD	20
SSD/HDD	46
GPU	-
Motherboard	490
Network card	28
Rack Chassis	110
Rack	24
Cables	20
Power	1547
Cooling	453
Admin	120000
Total	**124349**

3) m3.2xlarge instance

m3.2xlarge	
Components	**Total cost for 5 years (in $)**
Processor	1560
Memory	190
Root SSD	20
SSD/HDD	208
GPU	-
Motherboard	490
Network card	296
Rack Chassis	110
Rack	24
Cables	20
Power	1667
Cooling	489
Admin	120000
Total	**125074**

4) c3.8x large instance

c3.8xlarge	
Components	**Total cost for 5 years (in $)**
Processor	3538
Memory	390
Root SSD	20
SSD/HDD	320
GPU	-
Motherboard	980
Network card	889
Rack Chassis	220
Rack	24
Cables	40
Power	3633
Cooling	1064
Admin	120000
Total	**131118**

5) g2.2x large instance

g2.2xlarge	
Components	**Total cost for 5 years (in $)**
Processor	576
Memory	104
Root SSD	20
SSD/HDD	35
GPU	746
Motherboard	490
Network card	296
Rack Chassis	110
Rack	24
Cables	20
Power	1589
Cooling	466
Admin	120000
Total	**124476**

6) r3.4x large instance

r3.4xlarge	
Components	**Total cost for 5 years (in $)**
Processor	1560
Memory	1170
Root SSD	20
SSD/HDD	160
GPU	-
Motherboard	490
Network card	296
Rack Chassis	189
Rack	24
Cables	20
Power	2114
Cooling	619
Admin	120000
Total	**126662**

7) i2.8x large instance

i2.8xlarge	
Components	**Total cost for 5 years (in $)**
Processor	3120
Memory	3800
Root SSD	20
SSD/HDD	5839
GPU	-
Motherboard	980
Network card	889
Rack Chassis	220
Rack	24
Cables	40
Power	5549
Cooling	1626
Admin	120000
Total	**142107**

8) d2.8x large instance

d2.8xlarge	
Components	**Total cost for 5 years (in $)**
Processor	3951
Memory	3800
Root SSD	20
SSD/HDD	1722
GPU	-
Motherboard	1001
Network card	889
Rack Chassis	378
Rack	24
Cables	40
Power	13936
Cooling	4083
Admin	120000
Total	**149844**

MEMORY, SSD AND PROCESSOR SPECIFICATIONS

The following types of Memory and SSD components were looked upon in the Newegg website for finding the correct combination before buying for respective instance types.

a) Memory

	Memory		Cost in $
1	DDR4	128 (2x64GB)	**1899.99**
2	DDR4	128 (4x32GB)	**1169.99**
3	DDR3	64 GB	**1159.99**
4	DDR3	64 (2x32GB)	**569.99**
5	DDR3	64 (4x16GB)	**389.84**
6	DDR4	64 (4x16GB)	**381.88**
7	DDR4	16 GB (2x8GB)	**109.99**
8	DDR4	16 GB	**94.99**
9	DDR3	16 GB (2x8GB)	**103.99**
10	DDR4	32 GB	**221.99**
11	DDR4	32 GB (2x16GB)	**189.99**
12	DDR3	32 GB (2x16GB)	**197.99**
13	DDR3	32 GB (4x8GB)	**214.99**
14	DDR4	32 GB (4x8GB)	**210.99**
15	DDR3	8 GB	**50.99**
16	DDR3	8 GB (2x4GB)	**59.99**

b) SSD

	SSD/HDD		Cost in $
1	32	SSD	46.01
2	60	SSD	34.99
3	80	SSD	103.99
4	360	SSD	160
5	800	SSD	729.99
6	2000	HDD	71.75

c) PROCESSOR

Power in Watt		
Watts	5 years	**Price**
1004	43975.2	**7123.9824**
218	9548.4	**1546.8408**
235	10293	**1667.466**
256	11212.8	**1816.4736**
224	9811.2	**1589.4144**
298	13052.4	**2114.4888**
391	17125.8	**2774.3796**
982	43011.6	**6967.8792**

Processor	Cost in $
Intel Xeon E5-2676 v3	**1975.5**
Intel Xeon E5-2670 v2	**1559.99**
Intel Xeon E5-2670 v2	**1559.99**
Intel Xeon E5-2680 v2	**1769**
Intel Xeon E5-2670	**576**
Intel Xeon E5-2670 v2	**1559.99**
Intel Xeon E5-2670 v2	**1559.99**
Intel Xeon E5-2676 v3	**1975.5**

ASSUMPTIONS:

1. The power cost for Chicago is assumed as 0.162$ per Watts (as per Comed). The total price mentioned in the below table are per processor.

Processor
Intel Xeon E5-2676 v3
Intel Xeon E5-2670 v2
Intel Xeon E5-2670 v2
Intel Xeon E5-2680 v2
Intel Xeon E5-2670
Intel Xeon E5-2670 v2
Intel Xeon E5-2670 v2
Intel Xeon E5-2676 v3

2. Cooling cost is assumed as 20% of power cost
3. The cost of System Administrator is assumed as 120000 $ for 5 years. Each Admin will be in charge of 1000 instances. For higher number of instances, each additional Admin will share their total costs (Eg. For 2000 instances, 2 Admin will share 60000 $ each)
4. The costs in the above tables, represent 5 year amortized costs.

PUBLIC INSTANCE GFLOPS COST (FROM 1 GFLOPS TO 1 PFLOPS)

Instances	core	Clock Speed	IPC	Total Gflops	GPU Gflops	Cost/hr	Cost of 1GFlops
m4.10xlarge	20	2.4	16	768		2.394	2.394
m3.large	1	2.5	8	20		0.133	0.133
m3.2xlarge	4	2.5	8	80		0.532	0.532
c3.8xlarge	16	2.8	8	358.4		1.68	1.68
g2.2xlarge	4	2.6	8	3296	3213	0.65	0.65
r3.4xlarge	8	2.5	8	160		1.33	1.33
i2.8xlarge	16	2.5	8	320		6.82	6.82
d2.8xlarge	18	2.4	16	691.2		5.52	5.52

Cost of 1GFlops	# of instances	Cost of 10GFlo	# of instances	Cost of 100GFlops	# of instances
2.394	1	0.2394	1	0.02394	1
0.133	1	0.0133	1	0.00665	5
0.532	1	0.0532	1	0.01064	2
1.68	1	0.168	1	0.0168	1
0.65	1	0.065	1	0.0065	1
1.33	1	0.133	1	0.0133	1
6.82	1	0.682	1	0.0682	1
5.52	1	0.552	1	0.0552	1

Cost of 1TFlops	# of instances	Cost of 10TFlops	# of instances	Cost of 100TFlops	# of instances	Cost of 1PFlops	# of instances
0.004788	2	0.0033516	14	0.00313614	131	0.003119382	1303
0.00665	50	0.00665	500	0.00665	5000	0.00665	50000
0.006916	13	0.00665	125	0.00665	1250	0.00665	12500
0.00504	3	0.004704	28	0.004704	280	0.00468888	2791
0.00065	1	0.00026	4	0.0002015	31	0.0001976	304
0.00931	7	0.008379	63	0.0083125	625	0.0083125	6250
0.02728	4	0.021824	32	0.0213466	313	0.0213125	3125
0.01104	2	0.00828	15	0.008004	145	0.00798744	1447

PRIVATE INSTANCE GFLOPS COST (FROM 1 GFLOPS TO 1 PFLOPS)

Instances	Core	Clock Speed	IPC	Total Gflops	GPU Gflops	Cost/hr	Cost of 1GFlops
m4.10xlarge	24	2.4	16	921.6		0.614012376	0.614012376
m3.large	10	2.5	8	200		0.098976373	0.098976373
m3.2xlarge	10	2.5	8	200		0.114829305	0.114829305
c3.8xlarge	20	2.8	8	448		0.252823533	0.252823533
g2.2xlarge	8	2.6	8	3379.4	3213	0.102233193	0.102233193
r3.4xlarge	10	2.5	8	200		0.153228711	0.153228711
i2.8xlarge	20	2.5	8	400		0.503237165	0.503237165
d2.8xlarge	24	2.4	16	921.6		0.680634156	0.680634156

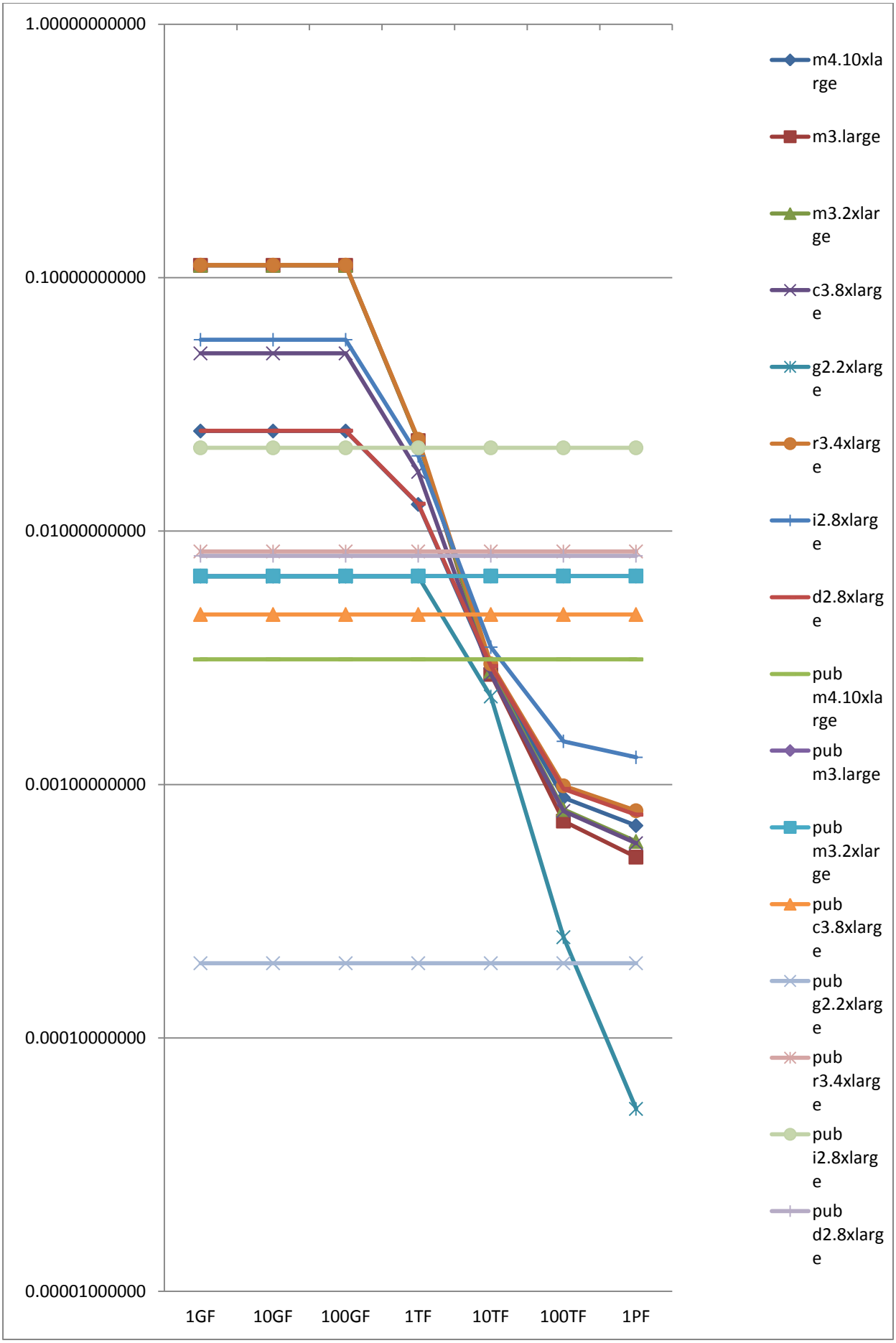
Cost of 1GFlops	# of instances	Cost of 10GFlo	# of instances	Cost of 100GFlops	# of instances
0.614012376	1	0.061401238	1	0.006140124	1
0.098976373	1	0.009897637	1	0.000989764	1
0.114829305	1	0.011482931	1	0.001148293	1
0.252823533	1	0.025282353	1	0.002528235	1
0.102233193	1	0.010223319	1	0.001022332	1
0.153228711	1	0.015322871	1	0.001532287	1
0.503237165	1	0.050323717	1	0.005032372	1
0.680634156	1	0.068063416	1	0.006806342	1

Cost of 1TFlops	# of instances	Cost of 10TFlops	# of instances	Cost of 100TFlops	# of instances	Cost of 1PFlops	# of instances
0.004788	2	0.000675414	11	0.000669273	109	0.000666817	1086
0.004788	5	0.000494882	50	0.000494882	500	0.000494882	5000
0.004788	5	0.000574147	50	0.000574147	500	0.000574147	5000
0.004788	3	0.000581494	23	0.000566325	224	0.000564555	2233
0.004788	1	3.067E-05	3	3.067E-05	30	3.0261E-05	296
0.004788	5	0.000766144	50	0.000766144	500	0.000766144	5000
0.004788	3	0.001258093	25	0.001258093	250	0.001258093	2500
0.004788	2	0.000748698	11	0.000741891	109	0.000739169	1086

The costs of each Flops are measured in units ($ per flop per hour)

GRAPHS

a) PLOT 1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m3.large
m3.2xlarge
c3.8xlarge
g2.2xlarge
r3.4xlarge
i2.8xlarge
d2.8xlarge
pub m4.10xlarge
pub m3.large
pub m3.2xlarge
pub c3.8xlarge
pub g2.2xlarge
pub r3.4xlarge
pub i2.8xlarge
pub d2.8xlarge

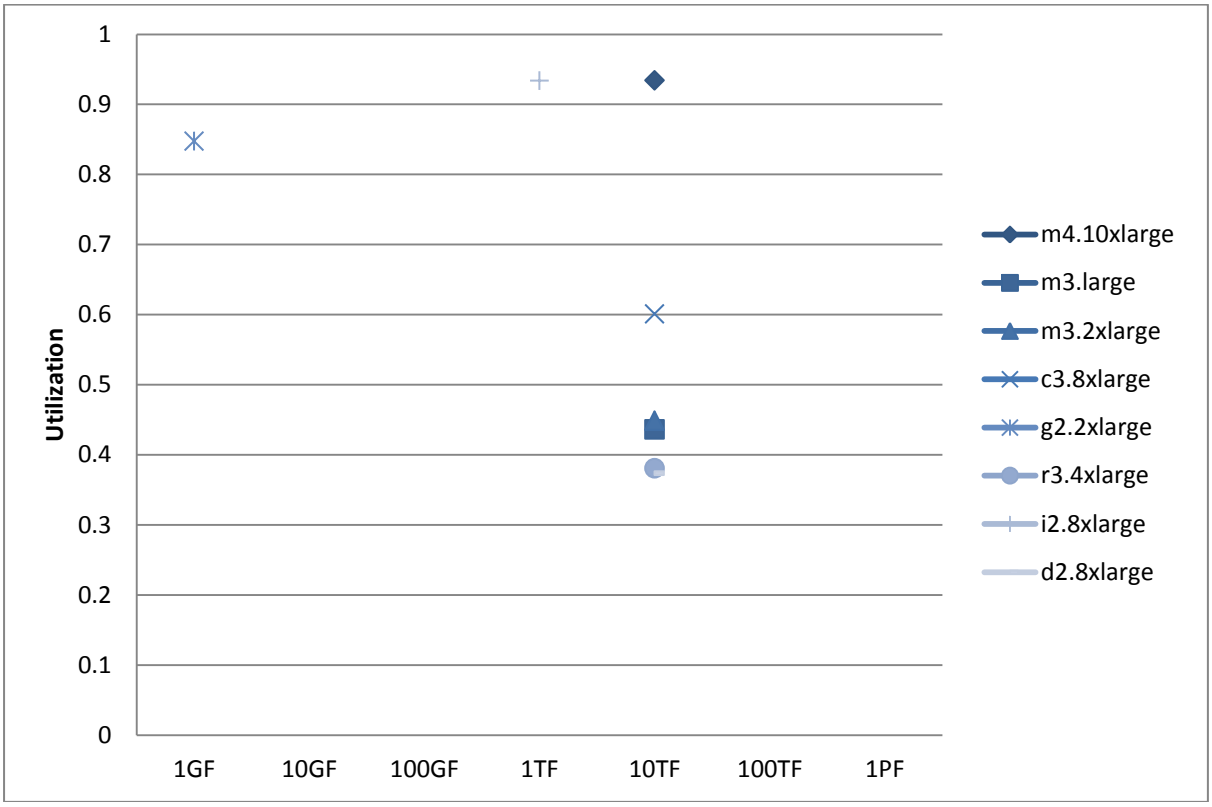
Y Axis - Cost in $ per flop per hour for Public and Private cloud ranging from 1 GFLOPS to 1 PFLOPS
X Axis - 1GF till 1 PF

The above graph shows us the cost factor for various instance type on private and public cloud. We can see that private cloud is breaking even when we are scaling towards 1 PFlop, whereas the cost for public cloud stays constant throughout.

b) PLOT 2

Utilization of private cloud from 1 GFLOP to 1 PFLOP

Utilization can be calculated by the formula (Private cloud cost of each FLOPS / Public cloud cost of each FLOPS). If the value is below 1, that is the breaking point.



Y Axis - Utilization.
X Axis - 1GF till 1 PF

Plot 2 is based on the ratio of compute capacity between the private and public cloud which gives us the utilization when scaled to 1 PFlop. We achieve 100% utilization at the breakeven point and the cost of private cloud reduces thereafter. Plot 2 is closely related to Plot 1. The breakeven point (meeting point of private cloud cost and public cloud cost for each FLOPS) of all the instances except i2.8xlarge and g2.2xlarge happens at 10 TF, which means for achieving 10TF compute capacity, it is wiser to move to private cloud, as it cost less than public cloud for these instances except i2.8xlarge and g2.2xlarge. For g2.2x large, it is wiser to move to private cloud at 1GF compute capacity and for i2.8x large instance, it is wiser to move to private cloud at 1 TF compute capacity.

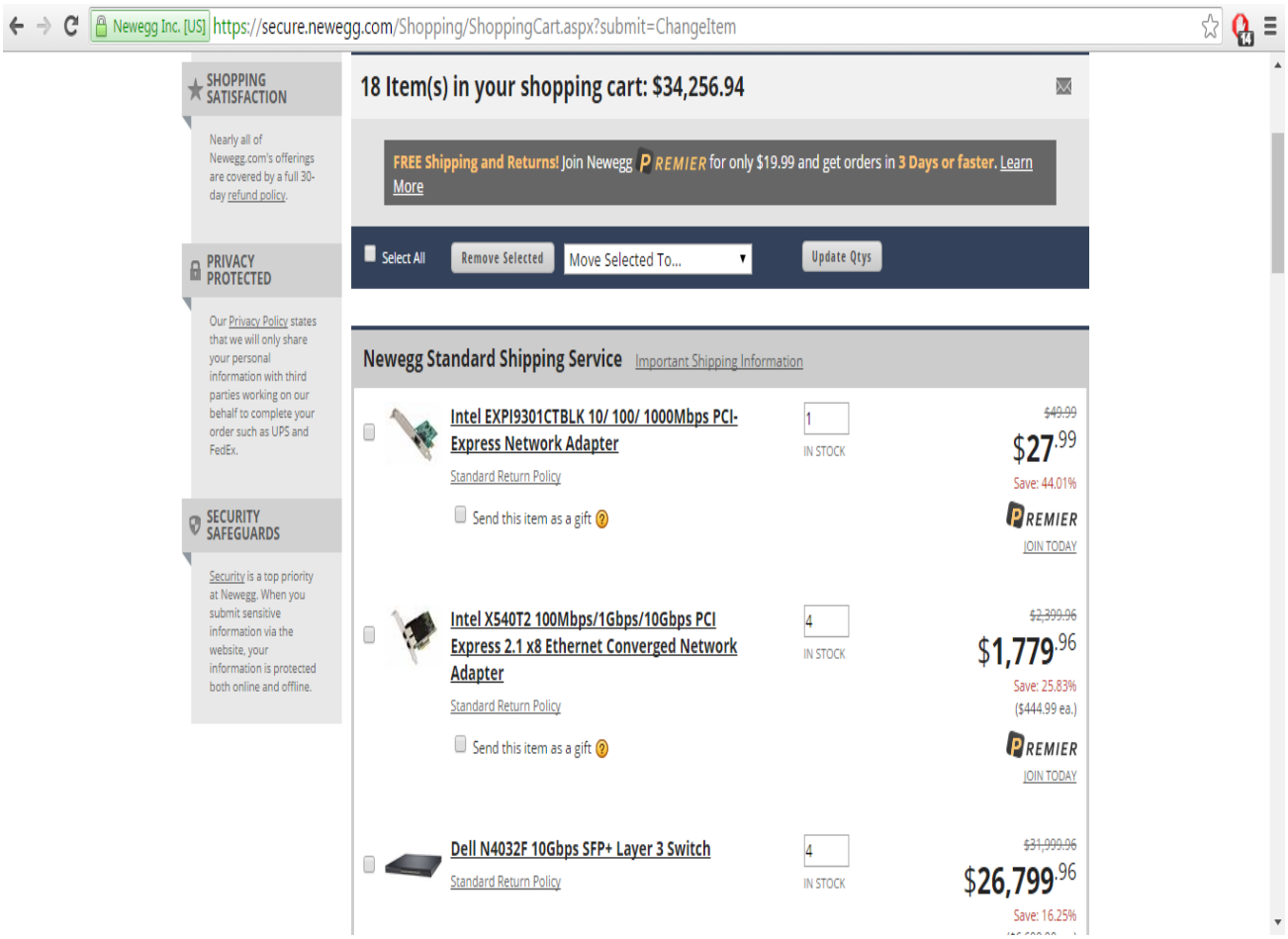
CONCLUSION:

The Decision to choose private or a public infrastructure depends on the application of the compute unit and range of work load. For a short term and small compute tasks we recommend using a public cloud like Amazon EC2 but for a compute intensive application with higher workload it is optimal to build a private cloud.

REFERENCES:

1. **https://en.wikipedia.org/wiki/Cloud_computing**
2. **https://aws.amazon.com/ec2/**
3. **http://www.newegg.com/**

APPENDIX: (Shopping cart screenshots)



Intel X540T2 100Mbps/1Gbps/10Gbps PCI Express 2.1 x8 Ethernet Converged Network Adapter

Standard Return Policy

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4 IN STOCK

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$1,779.96

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($444.99 ea.)

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Newegg Marketplace Direct Delivery Service

Important Shipping Information

Cisco Small Business 500 Series SF500-48-K9-NA Managed Stackable Managed Ethernet Switch

Sold by Flytec Computers

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$499.00

Subtotal:	**$499.00**
Shipping:	**$0.00**

Shipping Options

Choose a delivery method

Standard Shipping (5-7 business days)

Newegg Marketplace Direct Delivery Service

Important Shipping Information

Intel Ethernet Server Adapter I340-T4 1Gbps RJ-45 Copper, PCI Express 2.0 x 4 Lane

Sold by OK,Online

3 IN STOCK

~~$1,467.00~~

$296.07

Save: 79.82%

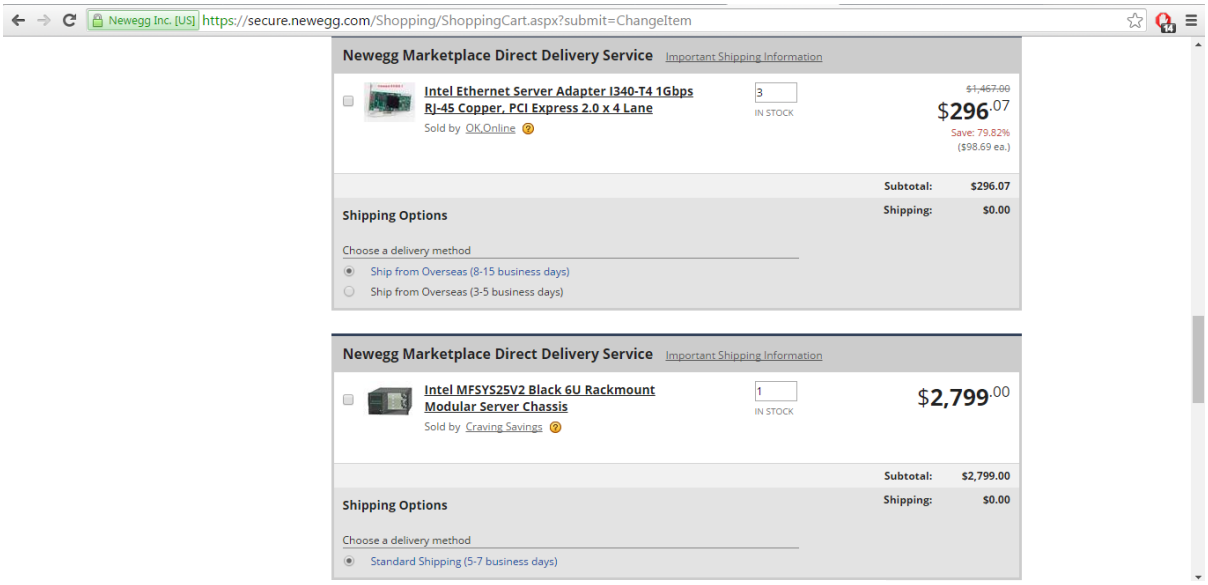
($98.69 ea.)

Subtotal:	**$296.07**
Shipping:	**$0.00**

Shipping Options

Choose a delivery method

Ship from Overseas (8-15 business days)



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