

Project Report

Understanding the cost of Computing in the Cloud

Abstract – The main purpose of this project is to understand the importance of economics concerns regarding cloud computing. Since cloud has become one of the widespread and trending technology within the industry, but one major concern is management of the prices over the years. We are here to study the advantages of establishing a public cloud over a private cloud.

CS 553 : Cloud Computing

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In this project, we will estimate the cost of building a private cloud for a startup company and compare the costs with the public cloud Amazon AWS. The cost estimation for building the AWS equivalent instances is done by generating a quotation for the components. The running cost of the private cost over 5 years is then compared with the AWS instances. Here we will consider different cloud size expressed in Flops, (floating point operations per second). Finally we will see in what extent it is interesting to use public resources rather than buying and setting up a private cloud from scratch.

Whenever a company wants to switch to cloud or a new company wants to design their own Data Centre for the purpose of their customer base, Trade-offs will always be there whether to opt for a public cloud such as Amazon Ec2, Google App Engine, and Microsoft Azure or design your own Data Centre which is nothing but private cloud. While making a choice, many factors are needed to be considered to come to the final conclusion between both.

Factors needed to be considered while deciding between private or public cloud are listed as below.

- 1) Cost of computing
- 2) Demand/ Usage
- 3) Security
- 4) Maintenance
- 5) Future usage
- 6) Scalability
- 7) Reliability

1. COST OF AMAZON INSTANCES

In today's industry cost is one of the deciding factor to decide what to buy be it a public cloud setting or setting your own private cloud. The cost is also one main concern for start-ups. We will make use of the EC2 instance and compute the cost of the compute cloud for every following type an Amazon instance: t2.small, d2.8xlarge, r3.large, p3.16xlarge, m4.4xlarge, c5.large, and p2.xlarge. The cost of the private cloud is being calculated on basis of each hardware that is needed to create one own private cloud. The following are some of the listed hardware needed like Processor cost, Memory cost, Motherboard, Disk cost, Power needed to run cloud, cooling cost, admin cost etc. The costs have been calculated considering the 5 year margin.

The cost is calculated based on \$/FLOP/Hour basis to better compare with the private cloud and it would remain constant even if the usage scales up in the range of 1GFLOP to 1 PFLOP.

We have even calculated the power cost based on Illinois State power charge considered for this project report with cost being 8.83¢/kWh. The equipments need to be cooled down too for which we have taken in this project the cooling cost to be $1/3^{\text{rd}}$ of the power consumption.

GFLOPS for Public Cloud Amazon Instance:

INSTANCE TYPE	PROCESSOR	Hourly Price/GFlop
t2.2xlarge	Intel Xeon processors	\$0.371
d2.8xlarge	2.3 GHz Intel Xeon® E5-2686 v4 (Broadwell) processors OR 2.4 GHz Intel Xeon® E5-2676 v3 (Haswell) processors	\$5.52
r3.large	Intel Xeon E5-2670 v2 (Ivy Bridge) Processors	\$0.166
p3.16xlarge	Intel Xeon E5-2686 v4 (Broadwell) processors	\$24.48
m4.16xlarge	Intel Xeon E5-2676 v3 OR Intel Xeon E5-2686 v4 (Broadwell) processor	\$3.2
c5.large	3.0 GHz Intel Xeon Platinum processors	\$0.085
p2.8xlarge	Intel Xeon E5-2686 v4 (Broadwell) processors	\$7.2

Given that for a small amount of FLOPS, we might not need more instances to increase the amount of Flop. But then, the price per FLOP becomes greater because we cannot rent '*small parts*' of instances. Now we are able to compute the hourly price per instance type using the hourly pricing from Amazon instances and we plot it on the following graph:

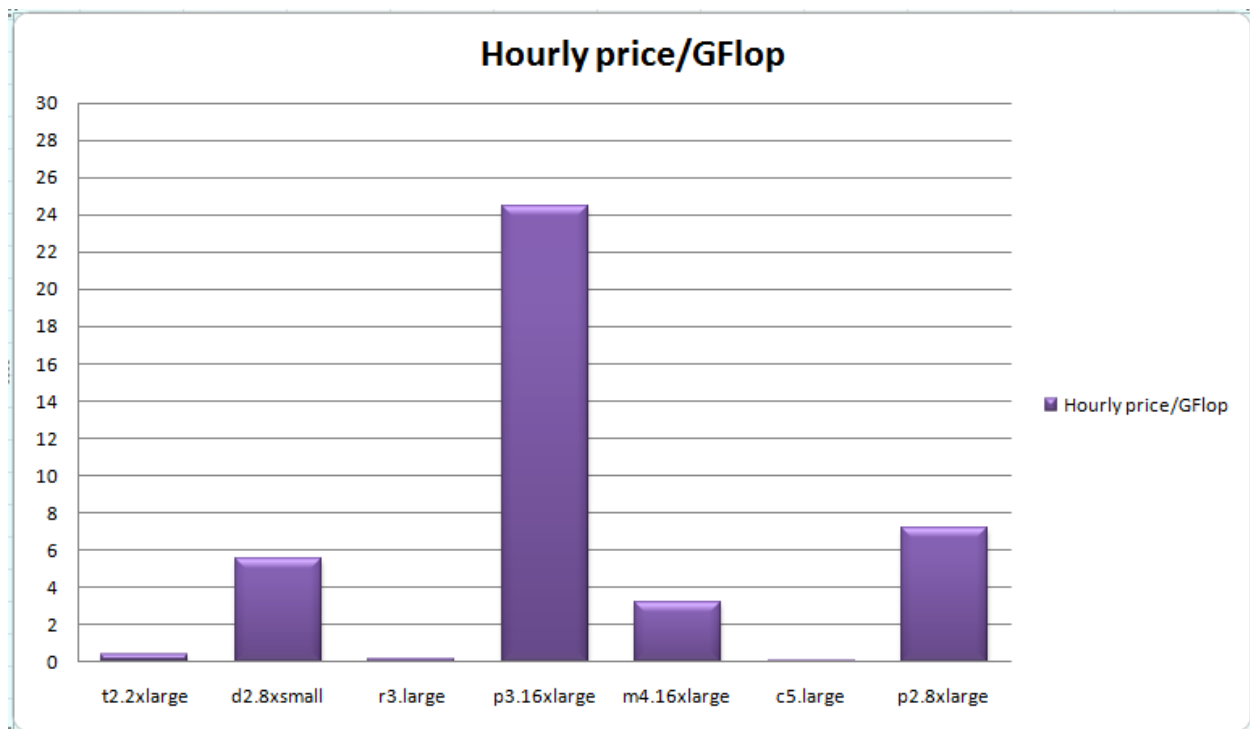


Fig 1. Public Cloud Price

2. COST OF PRIVATE CLOUD

In this section we are going to compute the cost to create own private cloud by buying and setting up items needed to create on own cloud for own purposes. Similar to the Amazon's instances, which means we will be computing 5 years amortized cost usage considering the same as Amazon instance.

Here, we are taking into consideration the cost of the power needed to keep the instances running along with the cost needed to cooling the hardware installed along with the administration cost which is one of the very important factors of the budget. For example, for one of the instance of FLOP amount, the administration maintenance cost will be important because the person is going to be paid for handling the and monitoring the instance, but the moment the FLOP increases FLOPS, this cost will be decline until more administrators handle the instances. As more the usage and increment of FLOPS more administrators are needed to take care of the cloud instance.

First we will calculate the cost of the instances which we will built using the installing the items and then compare them with the cost of the Amazon instances to see the cost comparison. Below are the tables we are using to calculate the cost of the cloud being built.

2.1 Configuration 1 - d2.8xlarge

The following is the d2.8xlarge configuration information obtained for Amazon instance with respect to the memory storage and network performance and clock speed.

REQUIREMENT - Hadoop/Spark Cluster with 32K-cores, 256TB memory, 50PB HDD, and 10Gb/s Ethernet Fat-Tree network (each VM should be equivalent to the d2.8xlarge instance); in addition to the compute resources, a 100PB distributed storage shared across the entire cloud should be procured, with enough capacity for 100GB/sec throughput.

vCPUs	36
Memory (GiB)	244
Storage(GB)	24 x 2000 HDD
Network performance	10 GigaBit
Processor used	Intel Xeon E5-2676 v3 (Haswell) processors
Clock Speed(GHz)	2.4 Ghz

Below is the hardware configuration used to build the same instance Amazon cloud using the hardware items and installing them.

EQUIPMENTS NEEDED			
PRODUCT	DETAILS	QUANTITY	PRICE

CPU Used	Intel Xeon E5 2676 v3 12 core 2.4 GHz L3 Processor 30 MB	~2667	$\$2197 \times 2 = \5859400
Case/Chassis	Rackmount Server Case RPC-230 2U	~1334	$\$39.99 \times 1334 = \53346.66
Memory Used	256 GB - NEMIX RAM 64GB for 244 GB equivalent	~1334	$\$650 \times 1334 = \867100
Motherboard	ASUS ROG Intel X99 SATA 6 Gb/s 3.1 ATX	~1334	$\$279.99 \times 1334 = \373507
Storage Servers	10 TB HDD - Seagate Enterprise Power Vault	5000	$\$410 \times 5000 = \2049950
Network Adapter	48 Port 10 Gigabit NetGear Edge M4300 10 Gigabit 48 port managed Switch	76	$\$4500 \times 76 = \337500
Network Swtiches/Cables	Startech Cisco Meraki Ma 10 Gb/s	3525 (3 layer)	$\$3525$
Racks	24U – Hoffman Enclosures 24u Black Steel	134	$\$364.92 \times 134 = \48899.28
	Navepoint 2U Universal Rack Mount Server Cabinet Shelf	1340	$\$28.79 \times 1340 = \38578.6
Component Total			\$9,631,806.54
MAINTENANCE AND COOLING COSTS (5 year estimate)			
Electric Power Usage	\$858.84/year		\$4624.2
Cooling	One-third of Power used		\$1421.4
Administration	\$100,000/year		\$3200000
TOTAL			\$12,827,852.14

Now considering we need to add 100PB of shared resources along the cloud instance to the data center with the throughput of 100GB/sec, then we need to add the storage across the servers.

Seagate ronwolf 10TB NAS hard Drive 7200 RPM 256MB 6.0 Gb/s	~10,000	$\$409.99 \times 1000 = \4099900
TOTAL		\$16,937,752.14

The cost of the private cloud established would comes upto to be \$453.00

Now, we will check for the next configuration with respect to r3.large and what hardware components are needed to build the equivalent Amazon instance.

2.2 Configuration 2 - r3.large

The following is the d2.8xlarge configuration information obtained for Amazon instance with respect to the memory storage and network performance and clock speed.

REQUIREMENT - Support 1 million virtual machines (VM) where each VM requires 2-core, 15GB RAM, 32GB SSD storage, and 1Gb/s Fat-Tree network (each VM should be equivalent to the r3.large instances); in addition to the compute resources, a 10PB distributed storage shared across the entire cloud should be procured, with enough capacity for 10GB/sec throughput.

vCPUs	2
Memory (GiB)	15.25
Storage(GB)	1 x 32 HDD
Network performance	Enhanced Networking
Processor used	Intel Xeon E5-2670 v2 (Ivy Bridge) Processors
Clock Speed(GHz)	2.5 Ghz

Below is the hardware configuration used to build the same instance Amazon cloud using the hardware items and installing them.

EQUIPMENTS NEEDED			
PRODUCT	DETAILS	QUANTITY	PRICE
CPU Used	Intel Xeon E5-2670 v2 Ivy Bridge Processor	1000000	\$1550 x 1000000 = \$1550000000
Case/Chassis	Norco Rackmount Server Case RPC-230 2U	1000000	\$59.99 x 1000000 = \$59990000
Memory Used	16 GB - Sandis 16GB Low Voltage PC3	1000000	\$87.19 x 1000000 = \$87190000
	Kingston 16 GB SDRAM Memory DDR2	1000000	\$69.00 x 1000000 = \$69000000
Motherboard	Asus H110M-K 6Gb/s USB 3.1 Micro ATX for Intel Motherboard	1000000	\$62.99 x 1000000 = \$62990000
Storage Servers	Sandisk 32GB DDR4 SATA SSD 1.5 Gb/s	1000000	\$31.65 x 1000000 = \$31650000
Network Adapter	Intel E10G42BT X520-T2 10Gigabit Ethernet Card	1000000	\$399.99 x 1000000 = \$399990000
Network Switches	48 Port 10 Gigabit NetGear Edge M4300	~21300 (since we need to make 1	\$4460 x 21300 = \$94998000

	10 Gigabit 48 port managed Switch	million instances of the cloud instance to run these virtual machine)	
Network Cables	C2G 10m Duplex Fiber Optic Cable	21000 (to run 1 million virtual machine instances)	$\$36.49 \times 1022019 = \37293473.31
Racks	24U – Hoffman Enclosures 24u Black Steel Navepoint 2U Universal Rack Mount Server Cabinet Shelf Post Open Frame Rack	25000 (to run 1 million instances)	$\$364.92 \times 102189 = \37290809.88 $\$27.78 \times 1022019 = \28391687.82
Component Total			\$2458783971.01
MAINTENANCE AND COOLING COSTS (5 year estimate)			
Electric Power Usage	\$858.84/year	\$4624.2	
Cooling	One-third of Power used	\$1421.4	
Administration	\$100,000/year	\$500000	
TOTAL			\$2459290016.61

Now considering we need to add 10PB of shared resources along the cloud instance to the data center with the throughput of 10GB/sec, then we need to add the storage across the servers.

Seagate ironwolf 10TB NAS hard Drive 7200 RPM 256MB 6.0 Gb/s	1000	$\$409.99 \times 1000 = \409990
TOTAL		\$2459700006.61

Even after adding this amount to the total cost of the Amazon Instance assembling using hardware installment, it doesn't do much high percentage of the cost increment. So now if we calculate the total after adding the 10PB distributed storage shared across entire cloud it is equivalent to the amount summed up.

The cost per month cost of the private cloud would come up to be \$5615.53

Now, we will check for the next configuration with respect to p3.16xlarge and what hardware components are needed to build the equivalent Amazon instance.

2.3 Configuration 3 - p3.16xlarge

The following is the p3.16xlarge configuration information obtained for Amazon instance with respect to the memory storage and network performance and clock speed.

REQUIREMENTS - Support deep learning with 1 exaflop of mixed precision performance (hint: each VM should be equivalent to p3.16xlarge instances; you will want to use the NVIDIA V100 GPUs (8 GPUs per node), and allocate 8-cores per GPU (64-cores per node) with 8GB of memory per core (512GB per node); the network to use is at least 10Gb/s per GPU (100Gb/s should work), and should be organized in a Fat-Tree network; in addition to the compute resources, a 1PB distributed storage shared across the entire cloud should be procured, with enough capacity for 10GB/sec throughput.

Tesla V100 delivers industry-leading floating-point and integer performance. Peak computation rates (based on GPU Boost clock rate) are

- 7.8 TFLOP/s of double precision floating-point (FP64) performance;
- 15.7 TFLOP/s of single precision (FP32) performance;
- 125 Tensor TFLOP/s of mixed-precision matrix-multiply-and-accumulate.

Therefore, 8 GPUs would have performance = 125×8 TFLOP/s (for mixed-precision).

To get 1 exaflop performance we would require, $(10^{18}) / (125 \text{ TFLOPS} \times 8) = 1000$ VMs (each equivalent to p3.16xlarge instance). All these information is referred from an article listed below

Note - Referred from <https://devblogs.nvidia.com/parallelforall/inside-volta/>

GPUs	8
vCPUs	64
Memory (GiB)	488
GPU Mem (GiB)	128
Network performance	25 GigaBit
Processor used	Intel Xeon E5-2686 v4 (Broadwell) processors
Clock Speed(GHz)	2.3 Ghz (Base) / 2.7 GHz (Turbo)

Below is the hardware configuration used to build the same instance Amazon cloud using the hardware items and installing them.

EQUIPMENTS NEEDED			
PRODUCT	DETAILS	QUANTITY	PRICE
GPU Used	NVIDIA Tesla GPU 8GB Active Accelerator	1000	$\$154766.06 \times 1000 = \154766060
CPU Used	Intel Xeon E5-2686 v4 (Broadwell) processors 2.3GHz 18 Core 45 MB	1000	$\$1319 \times 1000 = \1319000

Case/Chassis	Norco Rackmount Server Case RPC-230 2U	1000	\$59.99 x 1000 = \$59990
Memory Used	Trident Series SDRAM DDR4 3200 Intel Platform	32 x 1000 (total for 1000 nodes calculated)	\$299.99 x 32000 = \$9599680
Motherboard	Asus H110M-K 6Gb/s USB 3.1 Micro ATX for Intel Motherboard	1000	\$62.99 x 1000 = \$62990
Storage Servers	Intel Optane SSD 900P	1000	\$369.99 x 1000 = \$369990
Network Adapter	Intel E10G42BT X520-T2 10Gigabit Ethernet Card	1000	\$399.99 x 1000 = \$399990
Network Switches	Cisco 48 Port Gigabit 370W Switch	24 (as per the design requirement)	\$369.99 x 24 = \$8879.76
Network Cables	C2G 10m Duplex Fiber Optic Cable	1048	\$36.49 x 1048 = \$38241.52
Racks	24U – Hoffman Enclosures 24u Black Steel Navepoint 2U Universal Rack Mount Server Cabinet Shelf Post Open Frame Rack	~104 ~1050	\$364.92 x 104 = \$37951.68 \$27.78 x 1050 = \$29169
Component Total			\$164,848,996.56
MAINTENANCE AND COOLING COSTS (5 year estimate)			
Electric Power Usage	\$858.84/year		\$4624.2
Cooling	One-third of Power used		\$1421.4
Administration	\$100,000/year		\$500000
TOTAL			\$165,355,042.16

Now considering we need to add 1PB of shared resources along the cloud instance to the data center with the throughput of 10GB/sec, then we need to add the storage across the servers.

Seagate ironwolf 10TB NAS hard Drive 7200 RPM 256MB 6.0 Gb/s	100	\$409.99 x 100 = \$40999
TOTAL		\$165,396,041.16

Even after adding this amount to the total cost of the Amazon Instance assembling using hardware installment, it doesn't do much high percentage of the cost increment. So now if we

calculate the total after adding the 1PB distributed storage shared across entire cloud it is equivalent to the amount summed up.

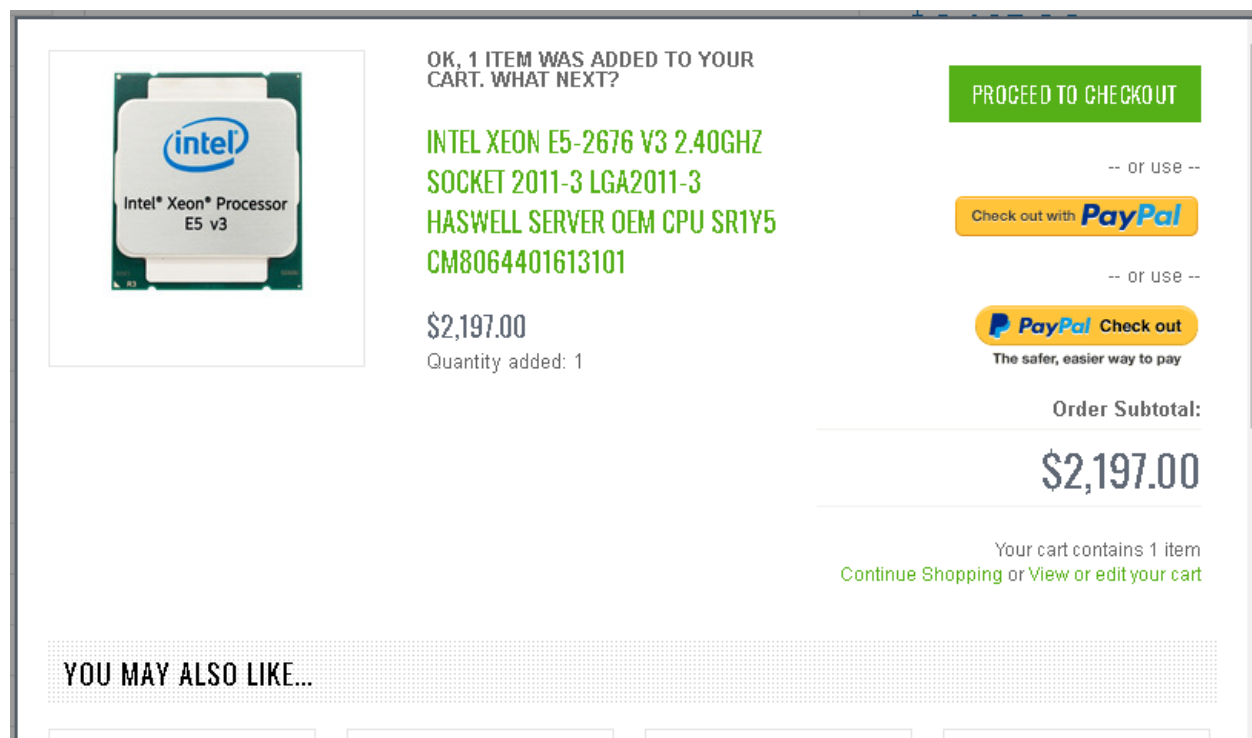
The cost of the private cloud would come upto \$3776.16

Now if we see the comparison from the public and private cost all together we see that the private seems to be the best option (considering the requirements). The public is considered on the fact of the full utilization. But, the cost may go down if the public cloud setup isn't used fully at entire 5 year duration which is one factor to care into (hypothetical situation considered).

Configuration	Private	Public
Config 1	\$16,937,752.14	\$630,253,297.2
Config 2	\$2,459,700,006.61	\$9,070,992,499.8
Config 3	\$165,396,041.16	\$1,057,536,000
What utilization must be achieved with the private cloud to make the private cloud option more attractive than the public cloud?	Here we see the Public is 3 times the private in Config 1, public is 10 times almost the private setup in Config 2 and in the 3 rd Config the cost is almost higher than the public setup. This concludes that in this following config the private seems to be the best option no matter what including the advantage of security and other factors.	

Snapshots of the Components of cart purchased for specific Amazon instance equivalent cloud generation.

d2.8xlarge



OK, 1 ITEM WAS ADDED TO YOUR CART. WHAT NEXT?

**INTEL XEON E5-2676 V3 2.40GHZ
SOCKET 2011-3 LGA2011-3
HASWELL SERVER OEM CPU SR1Y5
CM8064401613101**

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Intel X540-T1BLK 10-Gigabit Ethernet Converged Server Adapter PCIe 1-Port 1xRJ45 Copper 10GBASE-T IPv6 Low-Profile  Remove Item	HW-IT-X540T1B	\$382.78	1	\$382.78

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<div style="border: 1px solid #ccc; padding: 5px; background-color: #f0f8ff;"> SquareTrade Protection Plan ⓘ <div style="display: flex; justify-content: space-between; margin-top: 5px;"> <input type="radio"/> 3 year: \$34.99 <input type="radio"/> 4 year: \$54.99 </div> </div>				
<input type="checkbox"/>		Athena Power RM-2UC238 Black 1.0mm SECC 2U Rackmount Server Case - OEM Extended Holiday Return Policy	<input type="text" value="1"/> IN STOCK	\$39.99 JOIN TODAY
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Shipping Options				Subtotal: \$364.92 Shipping: \$0.00
Please enter your Zip Code so we can show you the most relevant shipping options for your location.				
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of Cores: 10-Core / Operating Frequency: 2.5 GHz

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p3.16xlarge

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Qty: 1

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