Project Report Document for Understanding the Cost of Computing in the Cloud

Public Cloud Configuration Estimation:

- There are 3 configurations for the public cloud.
- We have divided the cost for compute server cost and additional storage server cost.
- For compute server cost we are referring to the Amazon's on demand pricing for the servers for Ohio location.
- For additional storage server cost we are referring to Amazon's S3 instance on demand pricing.
- All the prices are calculated in US dollars.
- Costs are estimated for the 5 years' period.

Compute server cost calculation:

Final cost = (Unit price for instance per hour) * (total number of instances) * (total number of hours in 5 years)

Storage server cost calculation:

Final cost: = (Unit price for instance per month) * (total number of instances) * (total number of months in 5 years)

Private cloud Configuration Estimation:

- There are 3 configurations for the public cloud.
- We have calculated the cost as cost for the each below component.
  I. Compute Servers
  II. Network Switches
  III. Network Cables
  IV. Racks
  V. Storage Servers
  VI. Electric Power
  VII. Cooling
  VIII. Administration

- The final cost is calculated as the total of cost of each component.
- We have assumed 1 system administrator is needed for every 1000 servers.
- Costs are estimated for the 5 years' period.
- All the prices are calculated in US dollars.

Cost for each component calculation: (Price for one unit) * (total number of component required)

Final cost = (sum of all cost for each component)

Configuration 1: 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.

1. Public Cloud Calculation:

A. Unit price for AWS instance:

Model	vCPU	Mem (GiB)	Storage (GB)	Networking Capacity	Price (Linux/Unix) per hour
d2.8xlarge	36	244	24 x 2000 HDD	10GB	$5.52

B. Number of instances for the Compute server:

Specification Name	For Single Instance	For Computer Server	Total Instances Required
No. of Cores	36 cores	32000 cores	889
Memory	244 GiB	256 TB	1050
HDD	24*2000 GB	50 PB	1042
		Total Number of instances required	**1050**

C. Total cost for Compute server:

Unit price for instance per hour	Total number of instances	Total number of hours in 5 years	Total cost
$5.52	1050	43800	**$ 253,864,800**

D. Total cost for Storage Server:

Unit price for per GB Storage per month	Total Storage for Server	Total number of months in 5 years	Total cost
$0.021	100,000,000 GB	60	**$ 126,000,000**

E. Final Cost for cluster:

Total Cost for Compute Server	Total Cost for Storage Server	Final Cost
$ 253,864,800	$ 126,000,000	**$ 379,864,800**

2. Private Cloud Calculation:

A. Compute Server instance required:

Specification Name	For Single Instance	For Computer Server	Total Instances Required
No. of Cores	32 cores	32000 cores	1000
Memory	256 GiB	256 TB	1000
HDD	48 GB	50 PB	1042
		Total Number of instances required	**1042**

B. Total Cost:

	Description	Price per Item	Quantity	Total Price
Compute Servers	1. CPU: Intel Xeon Gold 6142 16C 2.6GHz 22MB Cache 2.Memory:256GB DDR4 2666MHz ECC Reg (8*32GB) 3. HDD: HGST Ultra star HE 12 12TB 7200RPM SAS 12Gb/s * 4	13108.19	1042	**13,658,733.98**
Network Switches	NETGEAR 48-Port 10Gig Gigabit Ethernet Smart Managed Pro Switch, L2+/Layer 3 Lite, 10 SFP+, ProSAFE Lifetime Protection (XS748T)	3,642.72	25	**91,068.00**
	2. NETGEAR 8-Port 10Gig Gigabit Ethernet Smart Managed Pro Switch, L2+/Layer 3 Lite, 10 SFP+, ProSAFE Lifetime Protection (XS708T)	826.69	1	**826.69**
	3. Intel X550 Dual Port 10G Base-T Adapter	740.06	1150	**851,069.00**
Network Cables	Ethernet Cable, Vandesail CAT7 LAN Network Cable RJ45 High Speed Patch Cord STP Gigabit 10/100/1000Mbit/s Gold Plated Lead	6	1050	**6,300.00**
Racks	CRUXIAL-COOL-42u-10K | Rackmount Solutions | Air-Conditioned Racks	3199.98	25	**79,999.50**
Storage Servers	Storage Enclosure 4U 102 Bay 1020TB	53004	98	**5,194,392.00**
Electric Power	Electric power consumption cost calculated below	-	-	**2,155,993.79**

Cooling	Cooling cost calculated below	-	-	**230,680.37**
Administration	2 Administrators	138170	2	**276,340.00**
TOTAL	**NA**	**NA**	**NA**	**22,545,403.33**

C. Electric power cost:

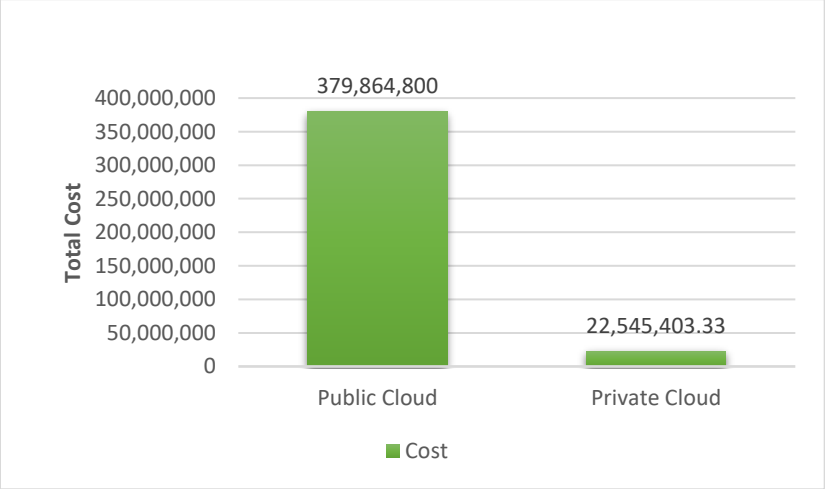
Name	Power supply in Watts	Electricity rate per KWatt	Number of Instances	5-year costing
Compute Server	500W	$0.0719	1042	1,640,743.62
Switches	262W	$0.0719	26	21,452.48
Storage Server	1600W	$0.0719	98	493,797.69
			Total Electric power cost	**2,155,993.79**

D. Cooling cost:

Cooling capacity	Total kWatt power consumption in 5 years	Chicago Electricity rate per KWatt	Number of Instances	Total cooling cost
10000BTU(2.93 Kwatt)	128334	$0.0719	25	**230680.365**

Public Vs Private Comparison for configuration 1:

Name	Public Cloud	Private Cloud
Cost	**379,864,800**	**22,545,403.33**



Conclusion:

We can see from the above graph the cost for public cloud is very much higher than the private cloud for 5 years duration. Private cloud option will be better if we are having the very high-end server requirement otherwise there will be the under utilization of the resources. If our requirement is not for the higher end servers then public cloud will be better. Also, we can scale the system easily on public cloud. But we haven't included the hardware failure cost and other infrastructure for private cloud which will increase the private cloud cost. Also, the startup cost for private cloud is higher as compared to public cloud. But as public cloud cost is very much higher private cloud cost will be lesser than it.

Configuration 2: 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.

1. Public Cloud Calculation:

A. Unit price for AWS instance:

Model	vCPU	Mem (GiB)	Storage (GB)	Price (Linux/Unix) per hour
r3.large	2	15	32	$0.18

B. Number of instances for the Compute server:

Number of instances for the Compute server
1000000

C. Total cost for Compute server:

Unit price for instance per hour	Total number of instances	Total number of hours in 5 years	Total cost
$0.18	1000000	43800	**$ 7,884,000,000**

D. Total cost for Storage Server:

Unit price for per GB Storage per month	Total Storage for Server	Total number of months in 5 years	Total cost
$0.021	10,000,000 GB	60	**$ 12,600,000**

E. Final Cost for cluster:

Total Cost for Compute Server	Total Cost for Storage Server	Final Cost
$ 7,884,000,000	$ 12,600,000	**$ 7,896,600,000**

2. Private Cloud Calculation:

A. Compute Server instance required:

Number of instances for the Compute server
1000000

B. Total Cost:

	Description	Price per Item	Quantity	Total Price
Compute Servers	1.NX236-S2HD - Intel Core i3-6100 3.70GHz 2Core/4Thread 3MB Cache CPU 2. Dogfish SSD 32GB SATA3 III 2.5 Inch Internal Solid-State Drive 7MM	845	1000000	**845,000,000.00**
Network Switches	NETGEAR 48-Port 10Gig Gigabit Ethernet Smart Managed Pro Switch, L2+/Layer 3 Lite, 10 SFP+, ProSAFE Lifetime Protection (XS748T)	3,642.72	20834	**75,892,428.48**
Network Cables	Ethernet Cable, Vandesail CAT7 LAN Network Cable RJ45 High Speed Patch Cord STP Gigabit 10/100/1000Mbit/s Gold Plated Lead	6	1020834	**6,125,004.00**
Racks	CRUXIAL-COOL-42u-10K | Rackmount Solutions | Air-Conditioned Racks	3199.98	23810	**76,191,523.80**
Storage Servers	Storage Enclosure 4U 102 Bay 1020TB	53004	9	**477,036.00**
Electric Power	Electric power consumption cost calculated below.	-	-	**1,172,323,938.56**
Cooling	Cooling cost calculated below.	-	-	**162,285,910.61**
Administration	2 Administrators	138170	1000	**138,170,000.00**
TOTAL	**NA**	**NA**	**NA**	**2,476,465,841.45**

C. Electric power cost:

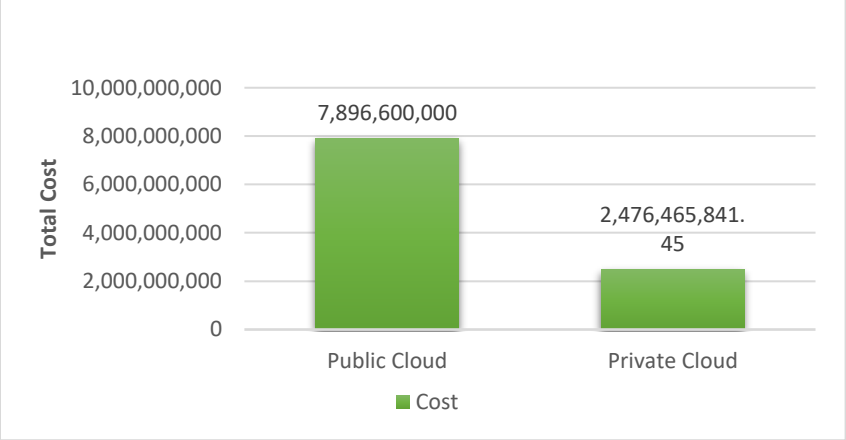
Name	Power supply in Watts	Chicago Electricity rate per kWatt	Number of Instances	5-year costing
Compute Server	350W	$0.0719	1000000	**944,766,000.00**
Switches	262W	$0.0719	220834	**182,209,170.56**
Storage Server	1600W	$0.0719	9	**45,348,768.00**
			Total Electric power cost	**1,172,323,938.56**

D. Cooling cost:

Cooling capacity	Total kWatt power consumption in 5 years	Chicago Electricity rate per KWatt	Number of Instances	Total cooling cost
10000BTU(2.93 Kwatt)	128334	$0.0719	23810	**162285910.61**

Public Vs Private Comparison for configuration 2:

Name	Public Cloud	Private Cloud
Cost	**7,896,600,000**	**2,476,465,841.45**



Conclusion:

From graphs we can see that the utilization for the private cloud is smaller than the public cloud. The price for private cloud is higher as we have used the 1 million smaller instances virtual machines. To reduce this cost, we could have used the higher configuration machine instead of one million virtual machines with 2-core, 15GB RAM, 32GB SSD storage. Also, for the public cloud we have calculated the estimation with the 100% utilization. So, we can use private cloud if we need the high-end server configurations with higher utilization whereas if we need the low server configuration with the less utilization then we can opt for the public cloud.

Configuration 3: 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

1. Public Cloud Calculation:

A. Unit price for AWS instance:

Model	vCPU	Mem (GiB)	Storage (GB)	Price (Linux/Unix) per hour
p3.16xlarge	64	488	128	$ 24.48

B. Number of instances for the Compute server:

Specification Name	GPU per instance	Mixed precision performance per instance	Performance required for cluster	Total number of instances
p3.16xlarge	8	125 TFLOPS	1 exaflop	1000

C. Total cost for Compute server:

Unit price for instance per hour	Total number of instances	Total number of hours in 5 years	Total cost
$24.48	1000	43800	**$ 1,072,224,000**

D. Total cost for Storage Server:

Unit price for per GB Storage per month	Total Storage for Server	Total number of months in 5 years	Total cost
$0.021	1,000,000 GB	60	**$ 1,260,000**

E. Final Cost for cluster:

Total Cost for Compute Server	Total Cost for Storage Server	Final Cost
$ 1,072,224,000	$ 1,260,000	**$ 1,073,484,000**

2. Private Cloud Calculation:

A. Compute Server instance required:

Name	GPU per node	Mixed precision flops	Total mixed precision flops required	Total number of instance required
NVIDIA DGX-1	8	1000TFLOPS	1 EXAFLOPS	**1000**

B. Total Cost:

	Description	Price per Item	Quantity	Total Price
Compute Servers	NVIDIA DGX-1	164,986.46	1000	**164,986,460.00**
Network Switches	Mellanox MSB7700-ES2F 36-port Non-Blocking Managed EDR 100Gb/s InfiniBand Switch Standard Depth	14,927	29	**432,883.00**
	Mellanox MCX515A-CCAT ConnectX-5 EN Network Interface Card	765	1001	**765,765.00**
Network Cables	Ipolex 100Gb/s QSFP28 for Mellanox MCP1600-C001, Direct-attach Copper Cable, 1-meter	69.99	1029	**72,019.71**
Racks	CRUXIAL-COOL-42u-10K | Rackmount Solutions | Air-Conditioned Racks	3199.98	24	**76,799.52**
Storage Servers	Storage Enclosure 4U 102 Bay 1020TB	53004	1	**53,004.00**
Electric Power	Electric power consumption cost calculated below.	-	-	**10,094,963.27**
Cooling	Cooling cost calculated below.	-	-	**9,227.21**
Administration	1 Administrators	69085	1	**69,085.00**
TOTAL	**NA**	**NA**	**NA**	**176,560,206.71**

C. Electric power cost:

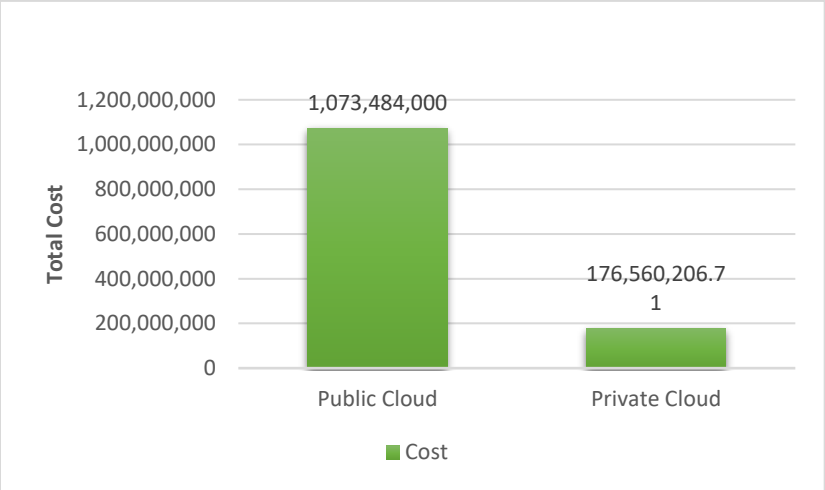
Name	Power supply in Watts	Chicago Electricity rate per kWatt	Number of Instances	5-year costing
Compute Server	3200W	$0.0719	1000	**10,077,504.00**
Switches	136W	$0.0719	29	**12,420.52**
Storage Server	1600W	$0.0719	1	**5,038.75**
			Total Electric power cost	**10,094,963.27**

D. Cooling cost:

Cooling capacity	Total kWatt power consumption in 5 years	Chicago Electricity rate per KWatt	Number of Instances	Total cooling cost
10000BTU(2.93 Kwatt)	128334	$0.0719	1	**9,227.21**

Public Vs Private Comparison for configuration 3:

Name	Public Cloud	Private Cloud
Cost	**1,073,484,000**	**176,560,206.71**



Conclusion:

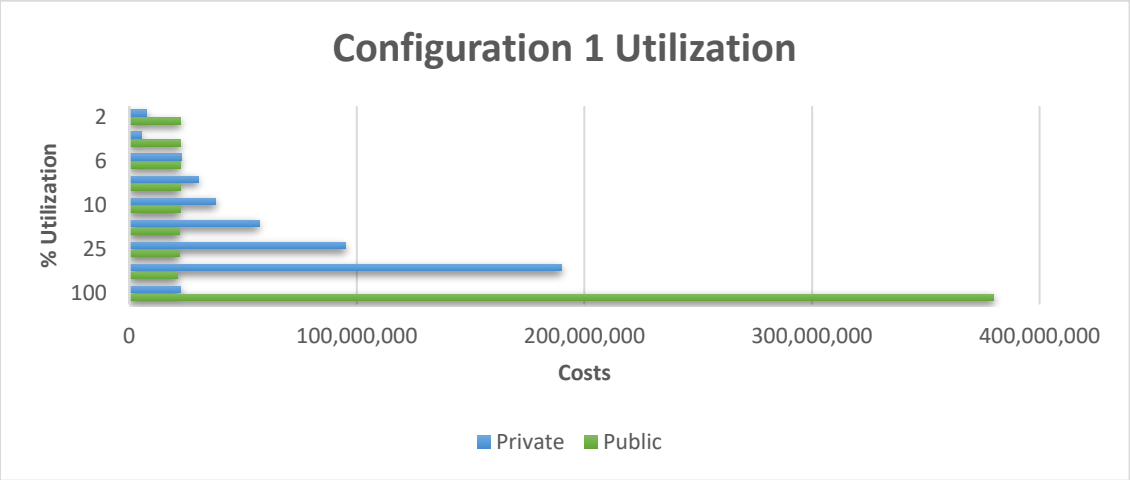
From the graph we can see that the public cloud cost estimation is higher than the private cloud estimation for 5 years of usage. In private cloud cost estimation, we have not considered the hardware failure cost. If we consider that cost, then private cloud cost would be equal or more than cost of public cloud as we are using the costly compute server. Also, for public cloud if reserve the instances for more than 3 years then Amazon will cost the around $10 per hours. So that will also reduce the cost estimation for the public cloud. In regards with the configuration 1 and 2, in configuration 3 we are having public cloud and private cloud cost difference higher than configuration 1 and lower than configuration 2 as we are using costly GPU servers in large quantity and for configuration 2 we are using the 1 million instances which reduces the gap between the private and public cloud.

Utilization:

The utilization rate is defined as the total extent to which cluster servers are being used and is usually recorded as a percentage. For public cloud the pricing is hourly basis, so we are considering the utilization for total cost. In private cloud the utilization will be affected only by cost of power, cooling, and administration should be to cover 5 years of costs, so we utilization for private cloud will be affected only by these factors.

Utilization for configuration 1:

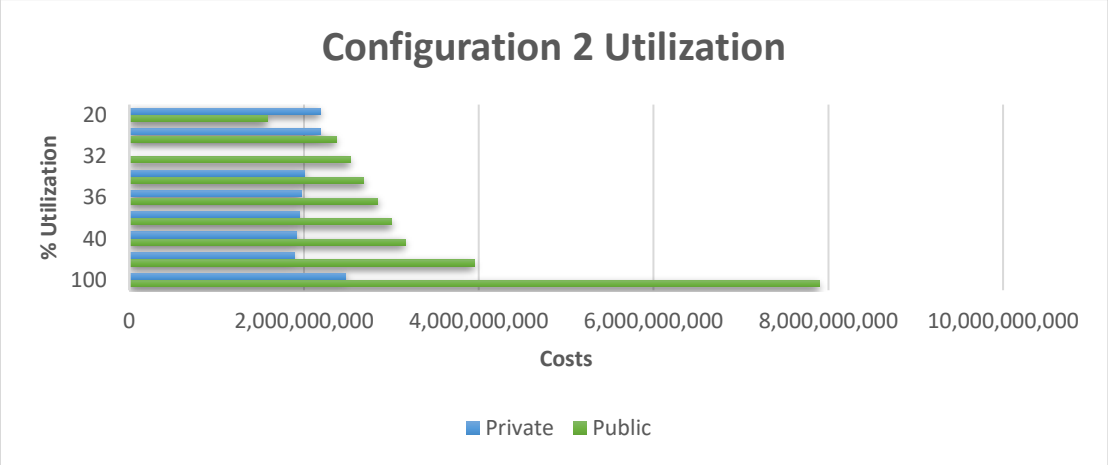
	100%	50%	25%	15%	10%	8%	6%	4%	2%
Public Cloud	379,864,800	21,213,896	21,879,649	22,145,951	22,279,101	22,332,362	22,385,622	22,438,882	22,492,143
Private Cloud	22,545,403	189,932,400	94,966,200	56,979,720	37,986,480	30,389,184	22,791,888	15,194,592	7,597,296



From above graph we can see that utilization is 6% which is very low due the huge difference between the private and public cost estimation.

Utilization for configuration 2:

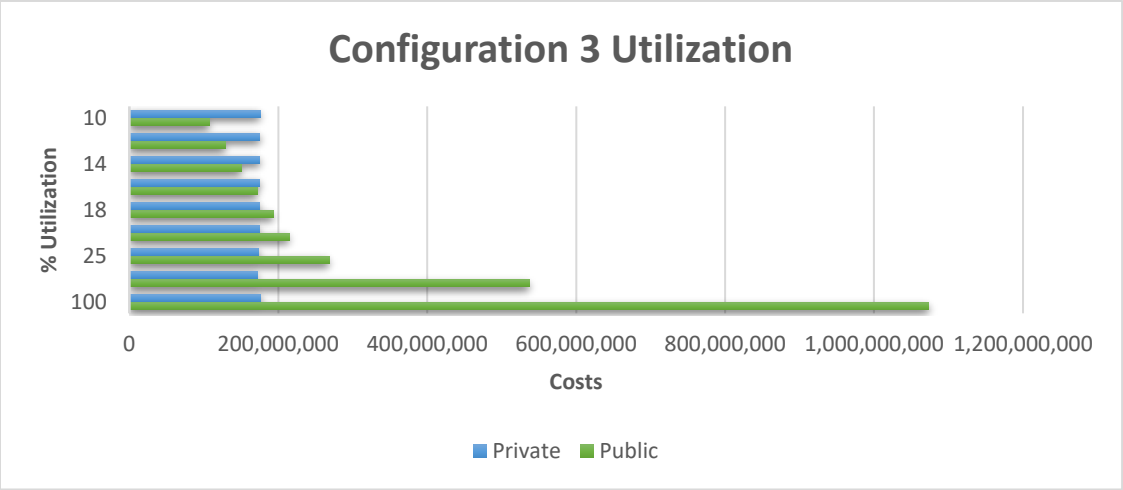
	100%	50%	40%	38%	36%	34%	32%	30%	20%
Public Cloud	7,896,600,000	3,948,300,000	3,158,640,000	3,000,708,000	2,842,776,000	2,684,844,000	2,526,912,000	2,368,980,000	1,579,320,000
Private Cloud	2,476,465,841	1,887,353,901	1,916,809,498	1,946,265,095	1,975,720,692	2,005,176,289	2,034,631,88	2,181,909,871	2,181,909,871



From above graph we can see that utilization is around 30% which is low due the difference between the private and public cost estimation.

Utilization for configuration 3:

	100%	50%	25%	20%	18%	16%	14%	12%	10%
Public Cloud	1,073,484,000	536,742,000	268,371,000	214,696,800	193,227,120	171,757,440	150,287,760	128,818,080	107,348,400
Private Cloud	176,560,206	171,473,568	174,016,887	174,525,551	174,729,017	174,932,482	175,135,948	175,339,413	175,542,879



From above graph we can see that utilization is around 16% which is very low due the difference between the private and public cost estimation.

Summary Table: Comparing the 3 Configurations between the Public and Private Cloud:

	Configuration 1	Configuration 2	Configuration 3
Public Cloud (including EC2 and S3) Cost over 5 years, 24/7 operation, with 100% usage	379,864,800	7,896,600,000	1,073,484,000
Private Cloud cost over 5 years, 24/7 operation, with 100% usage	22,545,403.33	2,476,465,841.45	176,560,206.71
What utilization must be achieved with the private cloud to make the private cloud option more attractive than the public cloud?	6%	30%	16%

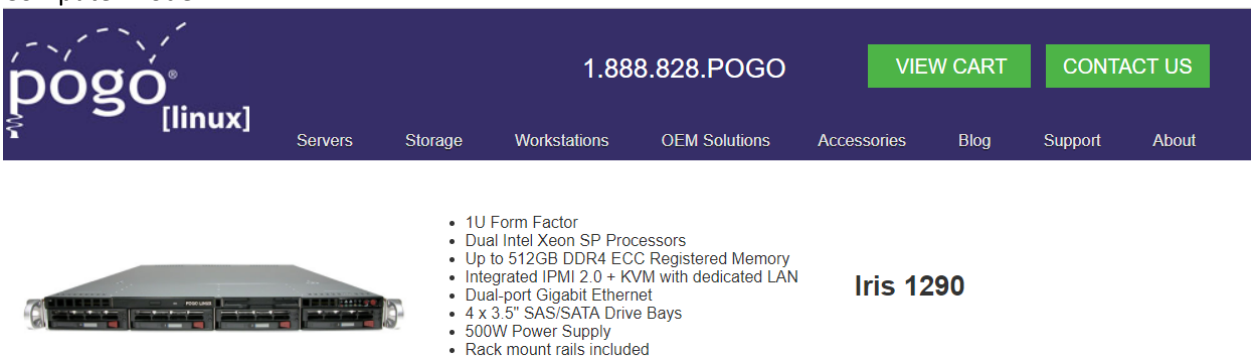
Conclusion:

From above table we can see that the configuration 2 has the highest utilization among the 3 configurations. So, we can conclude that if we need the small number of instances with low utilization then we can select the public cloud and if we require the higher number of instances with maximum utilization then we can go for the private cloud.

Screenshots:

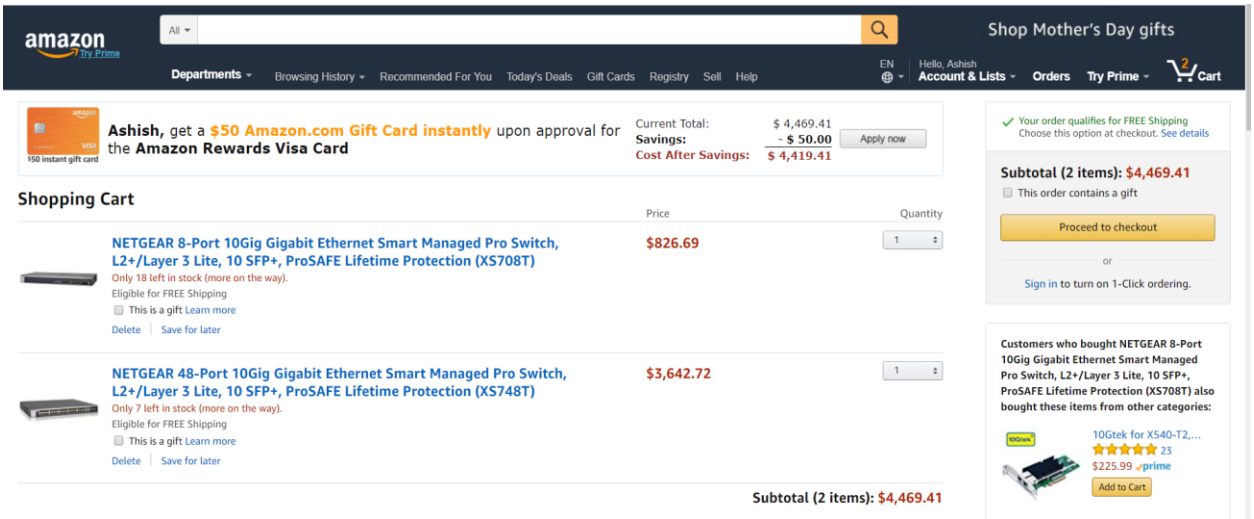
Configuration 1:

1. Computer Node:

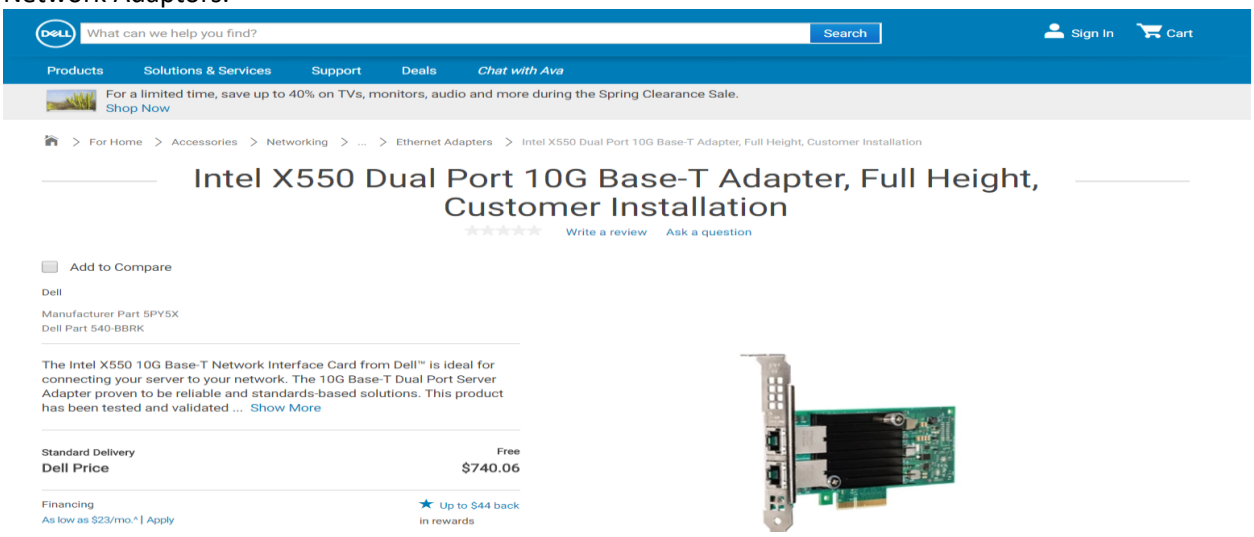


2. Compute Server:

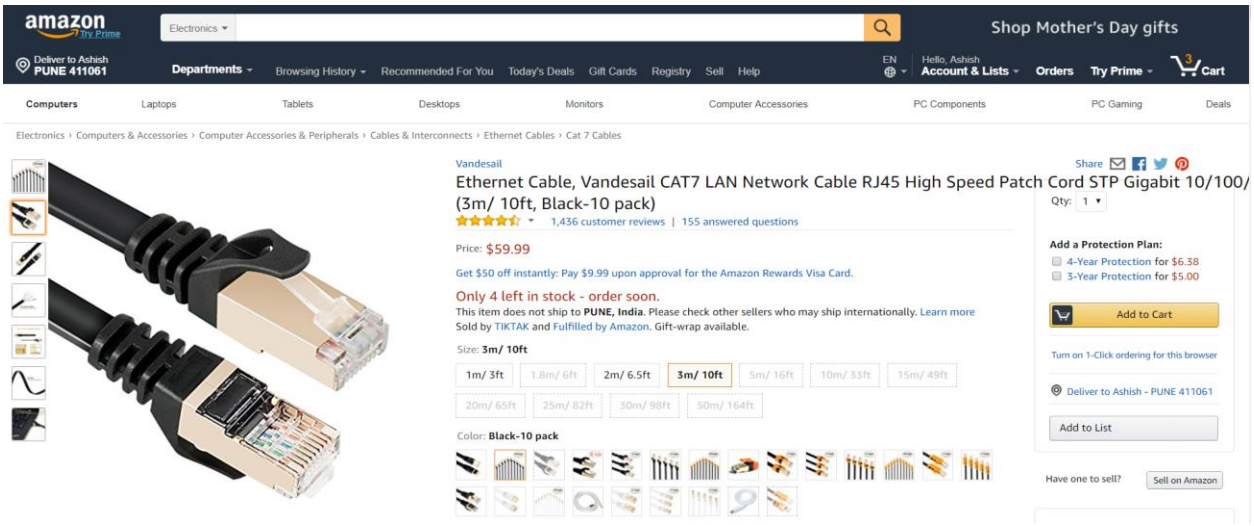
3. Network Switches:



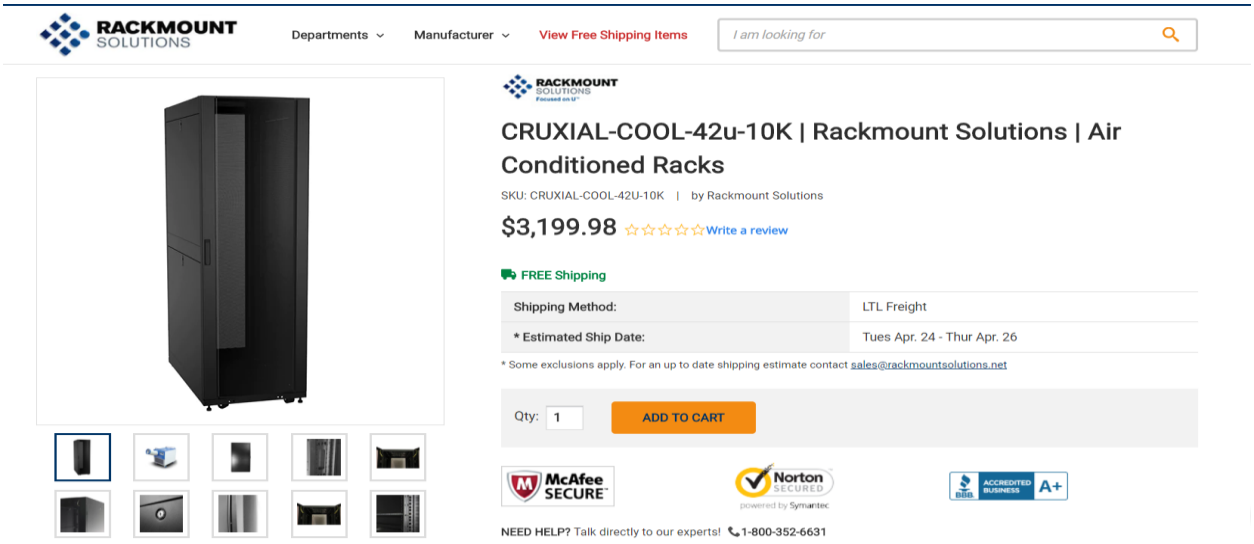
4. Network Adaptors:



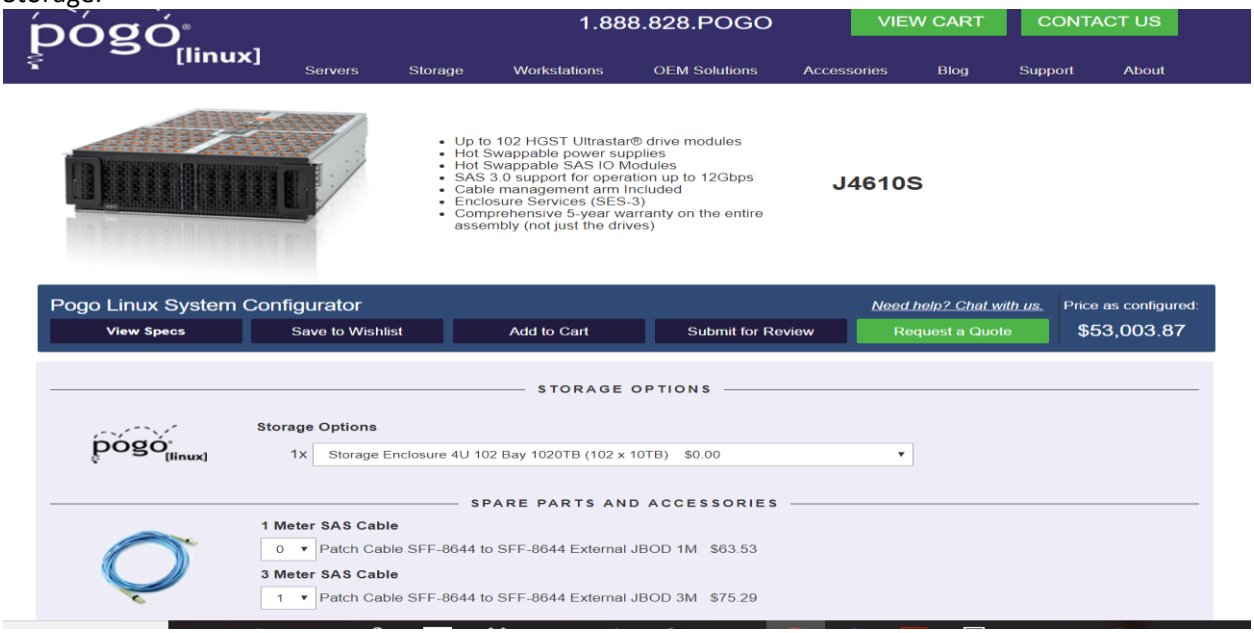
5. Network Cables:



6. Rack:

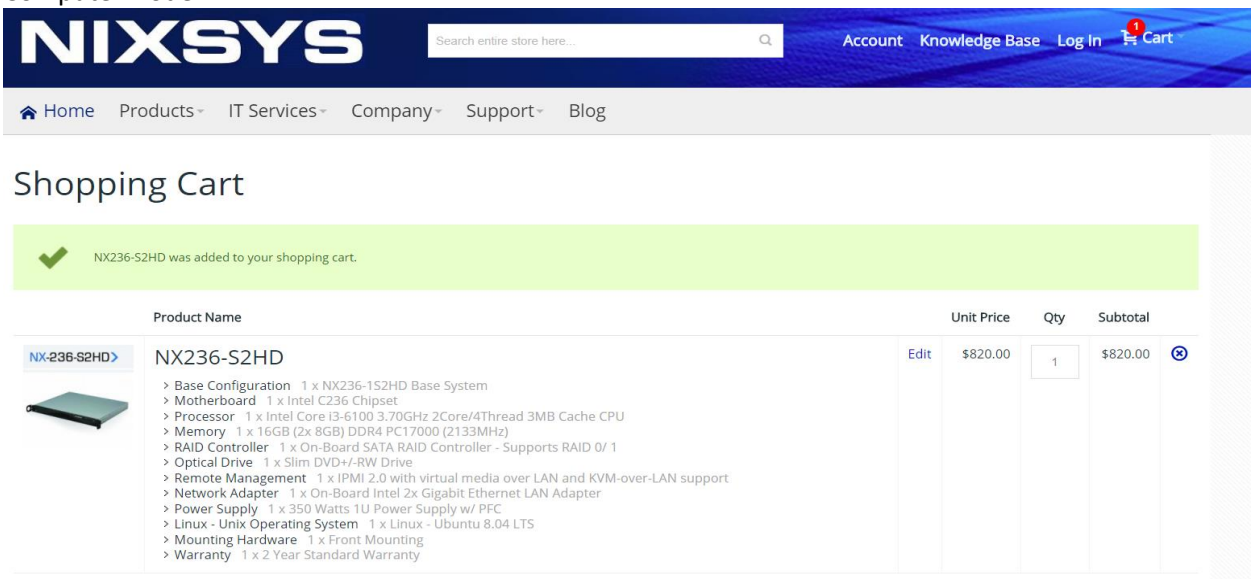


7. Storage:



Configuration 2:

1. Computer Node:

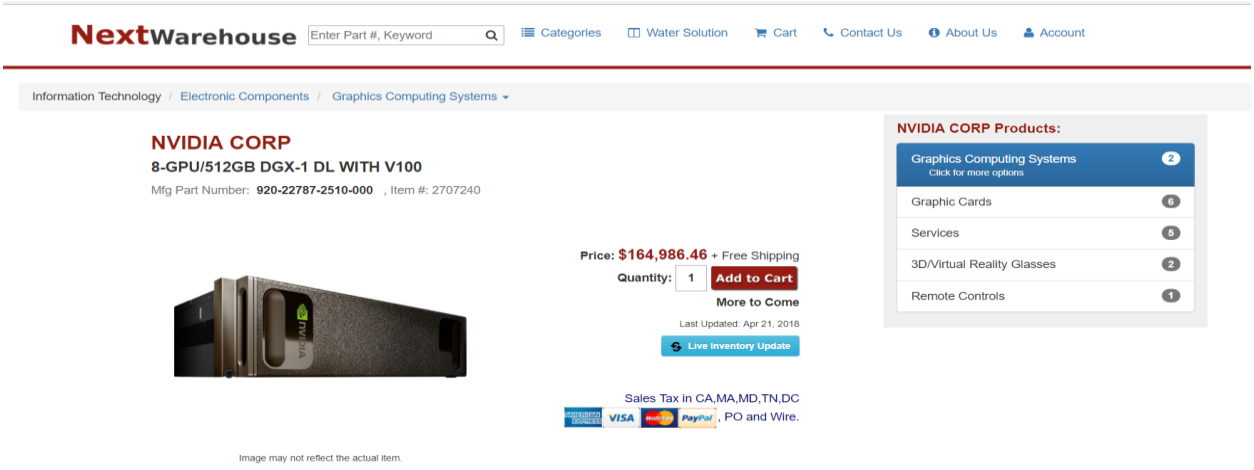


2. SSD:

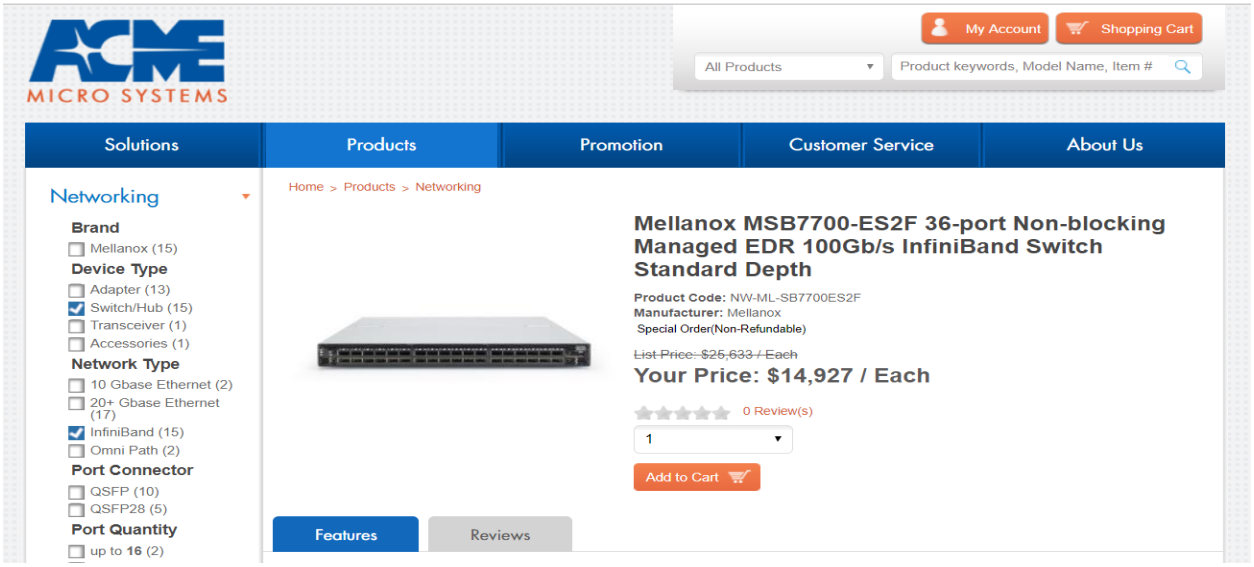
All other component for configuration 2 are same as configuration 1.

Configuration 3:

1. Computer Node:

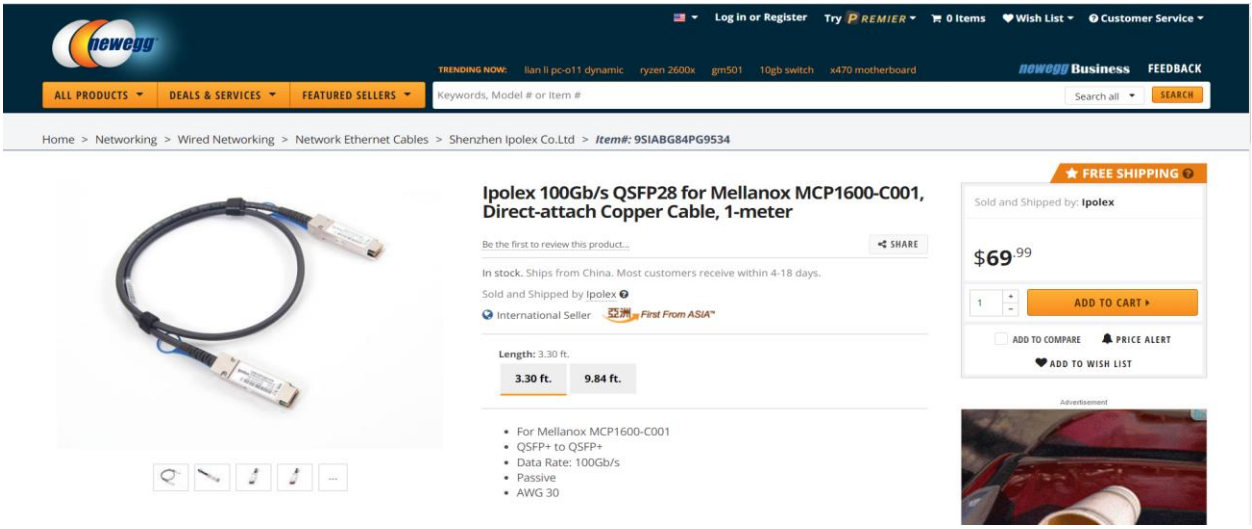


2. Network Switch:



3. Network Card:

4. Network Cable:



References:

Configuration 1:

1. http://www.pogolinux.com/quotes/editsys?sys_id=1117796
2. https://www.amazon.com/gp/product/B01ELW0QM4/ref=ox_sc_act_title_1?smid=ATVPDKIKX0DER&psc=1
3. https://www.amazon.com/gp/product/B01ELW0QRO/ref=ox_sc_act_title_3?smid=ATVPDKIKX0DER&psc=1
4. http://www.dell.com/en-us/shop/intel-x550-dual-port-10g-base-t-adapter-full-height-customer-installation/apd/540-bbrk/networking
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Configuration 2:

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