UNDERSTANDING THE COST OF CLOUD COMPUTING

CS553 PROJECT

under the guidance of : PROFESSOR IOAN RAICU

Team:

Abhay Nagaraj B R A20382006

Indranil Thakur A20377114

CLOUD COMPUTING PROJECT

Public Cloud:

Configuration 1:

Name	vCPUs	Cores	ECU	Memory(GiB)	Storage(GB)	Linux/UNIX Usage
d2.8xlarge	36	18	116	244	24*2000HDD	$5.52 per hour

Calculations of the number of instances we need of d2.8xlarge to get the total public cloud cost.

1) With respect to the number of cores:
   As mentioned in the question, we want 32K cores.
   Total number of d2.8xlarge instances = 32,000 / 18
   = 1777.77
   = 1778 approx.
2) With respect to the memory:
   As mentioned in the question, we want 256 TB of memory.
   As we know, 1 GiB = 1.07374 GB
   Therefore 244 GiB = 261.993 GB = 262 GB
   Total number of d2.8xlarge instances = 256,000/262
   = 977.09
   = 977 approx.
3) With respect to the storage:
   As mentioned in the question, we want 50PB HDD of storage.
   Total number of d2.8xlarge instances = 50,000 / 48
   = 1041.667
   = 1042 approx.

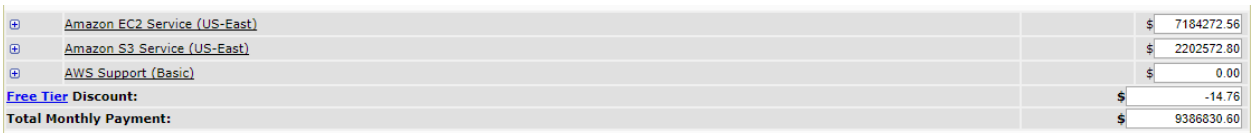
As the number of instance is highest when calculated using the number of cores, we would consider 1778 instances of d2.8xlarge for the calculations of public and private cloud.

Total cost of public cloud:
Cost of 1778 d2.8xlarge instances monthly cost is as follows:

Compute: Amazon EC2 Instances:

	Description	Instances	Usage	Type	Billing Option	Monthly Cost
⊖		1778	100 % Utilized/Mo ▾	Linux on d2.8xlarge	On-Demand (No Cor	$ 7184257.92
⊕	Add New Row					

Cost of 1778 d2.8xlarge instances yearly cost is as follows = 7184257.92 * 12
= $86,211,095.04
Cost of 1778 d2.8xlarge instance for 5 years = 86211095.04 * 5
= $431,055,475.2
Cost of 100 PB distributed storage for one month is = $2202572.8
Cost of 100 PB distributed storage for 5 years is = $2202572.8 * 12 * 5
= $132,154,368



⊞	Amazon EC2 Service (US-East)	$ 7184272.56
⊞	Amazon S3 Service (US-East)	$ 2202572.80
⊞	AWS Support (Basic)	$ 0.00
Free Tier Discount:		$ -14.76
Total Monthly Payment:		$ 9386830.60

Therefore, the total cost of 1778 d2.8xlarge instances for 5 years is as follows:

= 9386830.6 * 12 * 5

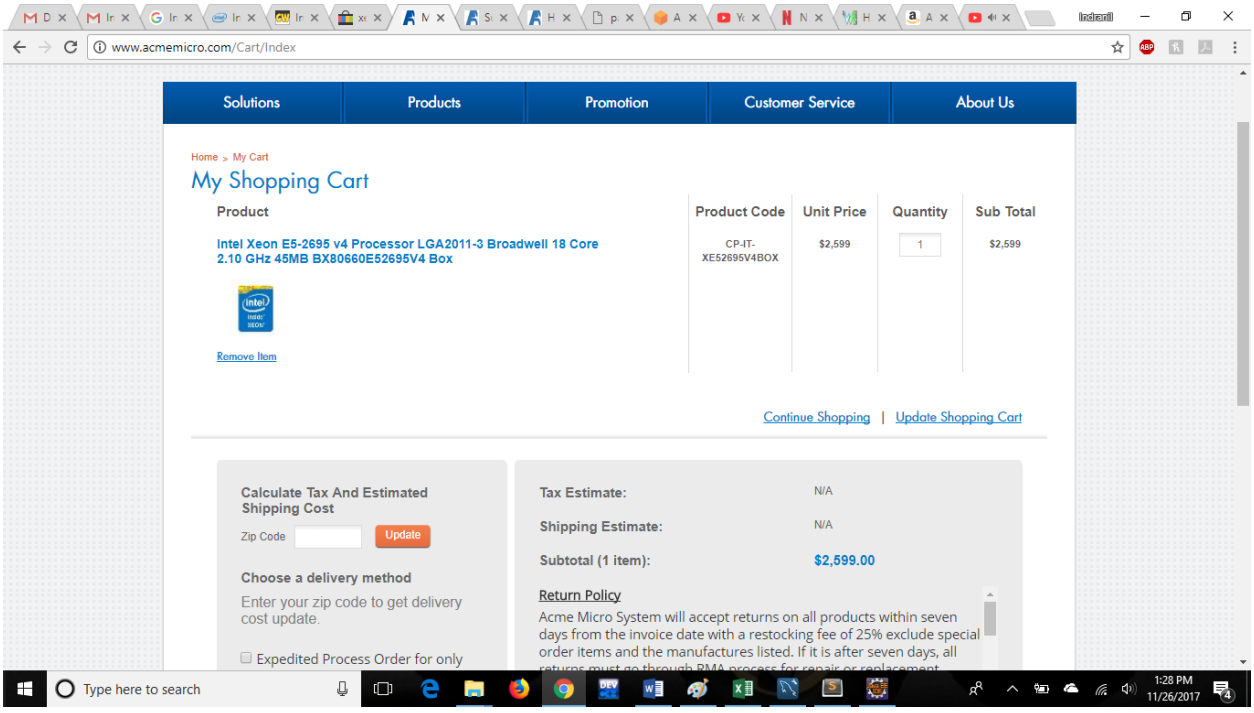
= $563,209,836

Private Cloud for Configuration 1:

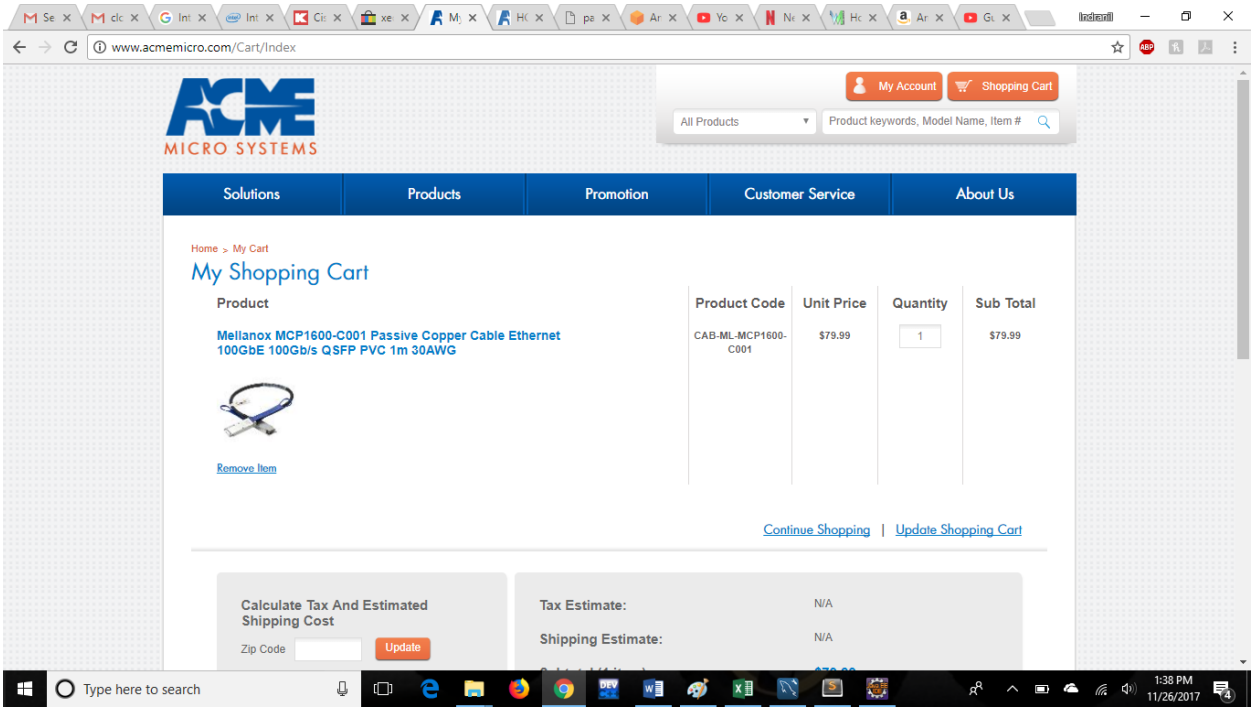
		Description	Price per Item (USD)	Quantity	Total Price (USD)
1.	**Computer Servers**				
1.1	**Processor & Memory**	Intel Xeon E5-2695 v4 Processor LGA2011-3 Broadwell 18 Core with 1.5TB Memory	2,599	1778	4,621,022 = 4.6M
1.2	**Motherboard**	Intel Server Board S2600BPB DP Xeon Socket P LGA-3647 C621 chipset DDR4 16x DIMM SATA3 RAID PCIe 2x 10GbE Custom 6.8" x 19.1"	950	889	946,550
1.3	**Network Adopter**	Supermicro Superserver 2028BT-HTR+ 2U 4-node DP Xeon LGA2011-R3 DDR4X24 SATA3 drive HotSwap 1 NIC or SIOM card R2200W	3908	889	3,474,212=3.47M
2.	**Network Switches**	Cisco Catalyst 4500-X -Switch - 32 x 1 Gigabit SFP/ 10 Gigabit SFP+ - rack-mountable	7475	39	291525
3.	**Network Cables**	Mellanox MCP1600-C001 Passive Copper Cable Ethernet 100GbE 100Gb/s QSFP PVC 1m 30AWG	79.99	1834	146701.66
4.	**Racks**	APC AR3357 48U NetShelter SX 750mm Wide x 1200mm Deep Enclosure	2432.24	38	92425.12
5.	**Storage Servers**	HGST 4U60 1ES0094 600TB 60 x 10TB drives SAS3 12Gbps JBOD storage subsystem 2x 1650W power supply	48,999	246	12,053,754 = 12 M
6.	**Electric Power**	1685W @ 12 cents per KWH in IL (246*1.6*0.12) + (1777*0.12*0.12)+(39*0.75*0.12)+(2*.12*889)	2,608,598/yr	5 years	13.04M
7.	**Cooling**	N+1 redundant fans (fans integrated in PSU)	1,217,124.16/yr	5 years	5.23M
8.	**Administration**	(Maintenance, Security, Deployment) per 500 nodes	120,000 * (1778/500)	5	2,133,600 = 2.13M
	TOTAL	N/A	N/A	N/A	46.53M

Screenshots:

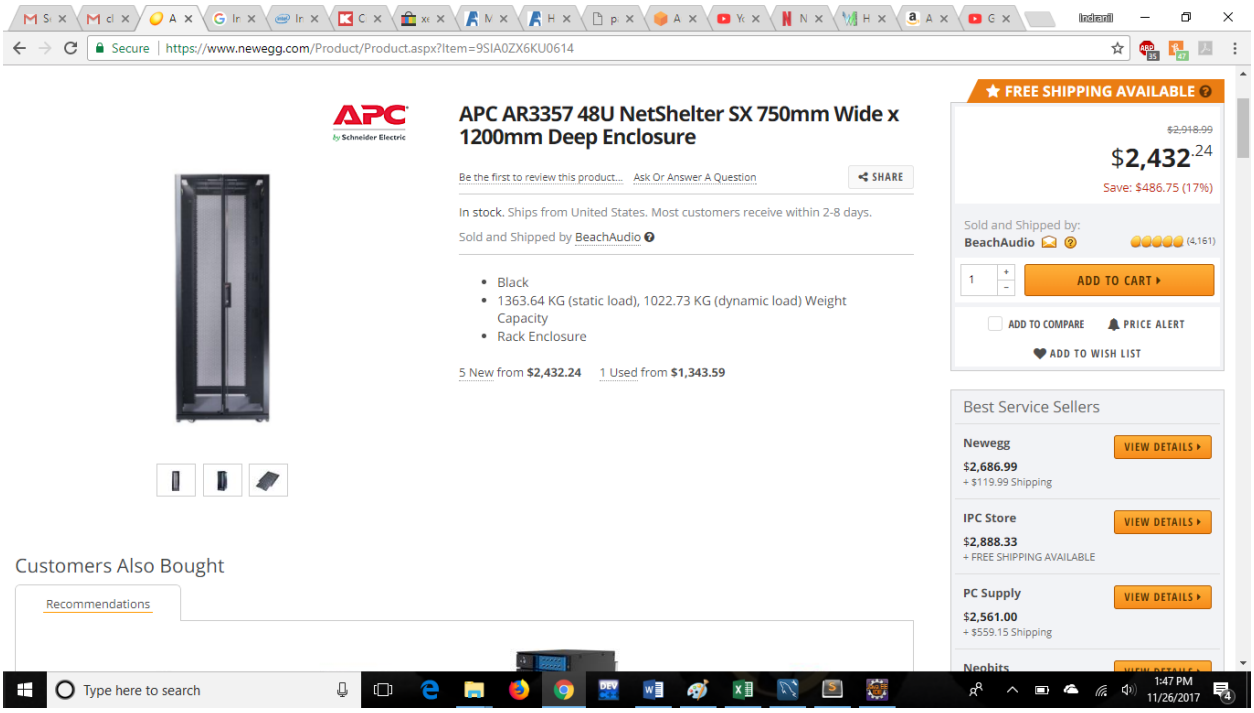
CPU



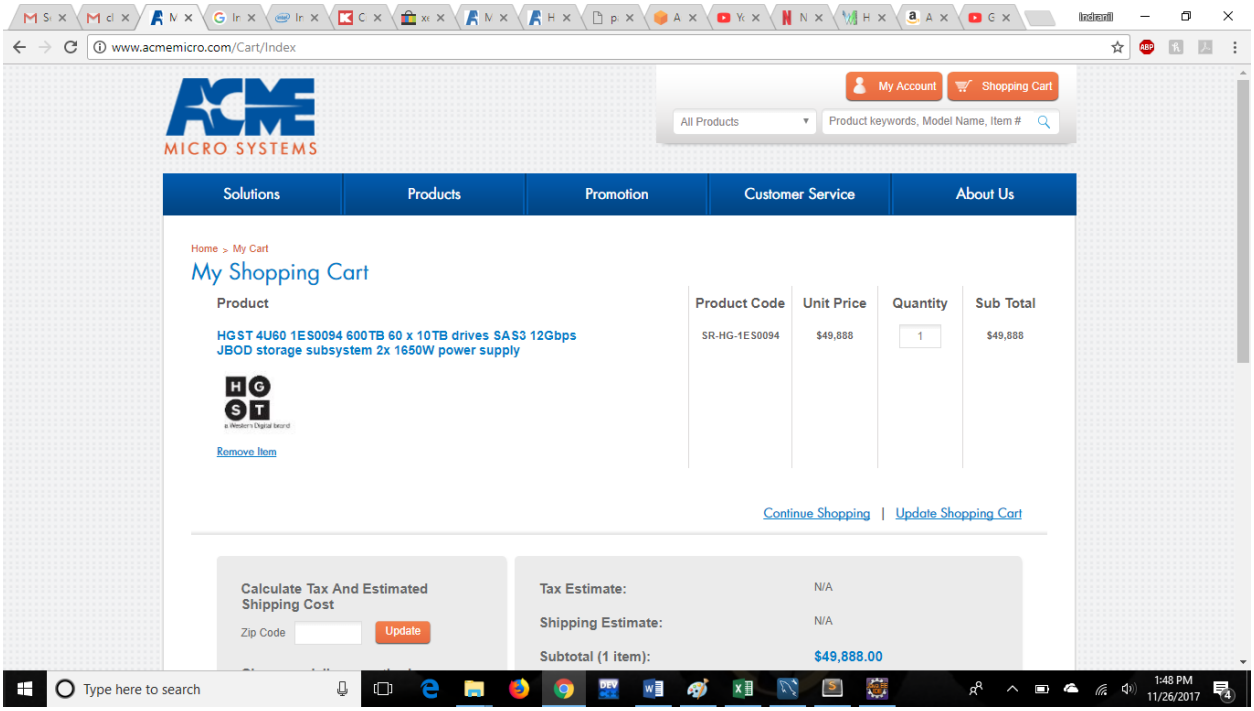
Network Cable:



Racks:



Storage Servers:



Configuration 2:

Name	vCPUs	ECU	Memory(GiB)	Storage(GB)	Linux/UNIX Usage
r3.large	2	6.5	15	1*32 SSD	$0.166 per hour

		Description	Price per Item (USD)	Quantity	Total Price (USD)
1.	**Computer Servers**				
1.1	**Processor**	Intel Xeon E5-2670 v2 (Ivy Bridge	1527.50	200,000	305.5M
1.2	**MotherBoard**	Intel Server Board S2600BPB DP Xeon Socket P LGA-3647 C621 chipset DDR4 16x DIMM SATA3 RAID PCIe 2x 10GbE Custom 6.8" x 19.1"	950	100,000	95M
1.3	**Network Adopter**	Supermicro Superserver 2028BT-HTR+ 2U 4-node DP Xeon LGA2011-R3 DDR4X24 SATA3 drive HotSwap 1 NIC or SIOM card R2200W	3908	100,000	390.8M
1.4	**Memory**	16GB PC4-19200 DDR4-2400Mhz Registered ECC DIMM 1.2V Major Brand	199.99	1M	199.99M
2.	**Network Switches**	Cisco Catalyst 4500-X -Switch - 32 x 1 Gigabit SFP/ 10 Gigabit SFP+ - rack-mountable	7475	221,38	165,481,550 = 165.5M
3.	**Network Cables**	Mellanox MCP1600-C001 Passive Copper Cable Ethernet 100GbE 100Gb/s QSFP PVC 1m 30AWG	79.99	1,040,443	83,225,035.57 = 83.22M
4.	**Racks**	APC AR3357 48U NetShelter SX 750mm Wide x 1200mm Deep Enclosure	2432.24	21295	51,793,436.02= 51.8M
5.	**Storage Servers**	HGST 4U60 1ES0094 600TB 60 x 10TB drives SAS3 12Gbps JBOD storage subsystem 2x 1650W power supply	49,888	17	848,096
6.	**SSD**	Intel 32GB MEMPEK1W032GAXT Optane Memory Series NVMe PCIe M.2 2280 1350MB/sec Read 20nm 3D Xpoint, Retail	96.99	1M	96.99M
7.	**Electric Power**	1685W @ 12 cents per KWH in IL (17*1.6*0.12) + (1M*0.035*0.12)+(100000*2*0.12) + (100000*2*0.12)	475,139,351.2/yr	5 years	2,375,696,756=2.375Billion
8.	**Cooling**	N+1 redundant fans (fans integrated in PSU)	158.379M/yr	5 years	791.898M
9.	**Administration**	Maintenance, Security, Deployment per 500 nodes	120,000*(1M/500)	5	240M
	TOTAL	N/A	N/A	N/A	5.036 Billion

Calculations of the number of instances we need of r3.large to get the total public cloud cost.

Cost of 1 million r3.large instances monthly cost is as follows:

Compute: Amazon EC2 Instances:

	Description	Instances	Usage	Type	Billing Option	Monthly Cost
⊖		1000000	100 % Utilized/Mo	Linux on r3.large	On-Demand (No Cor	$ 121520000.00
⊕	Add New Row					

Cost of 1 million r3.large instances for 5 years is as follows:

= 121520000 * 12 * 5

= $7,291,200,000

Cost of 10 PB distributed storage for one month is = $220764.16

The total cost of 1million r3.large instances for 1 month is as follows:

⊕	Amazon EC2 Service (US-East)	$ 121520000.00
⊕	Amazon S3 Service (US-East)	$ 220764.16
⊕	AWS Support (Basic)	$ 0.00
Free Tier Discount:		$ -0.12
Total Monthly Payment:		$ 121740764.04

Therefore, the total cost of 1million r3.large instances for 5 years is as follows:

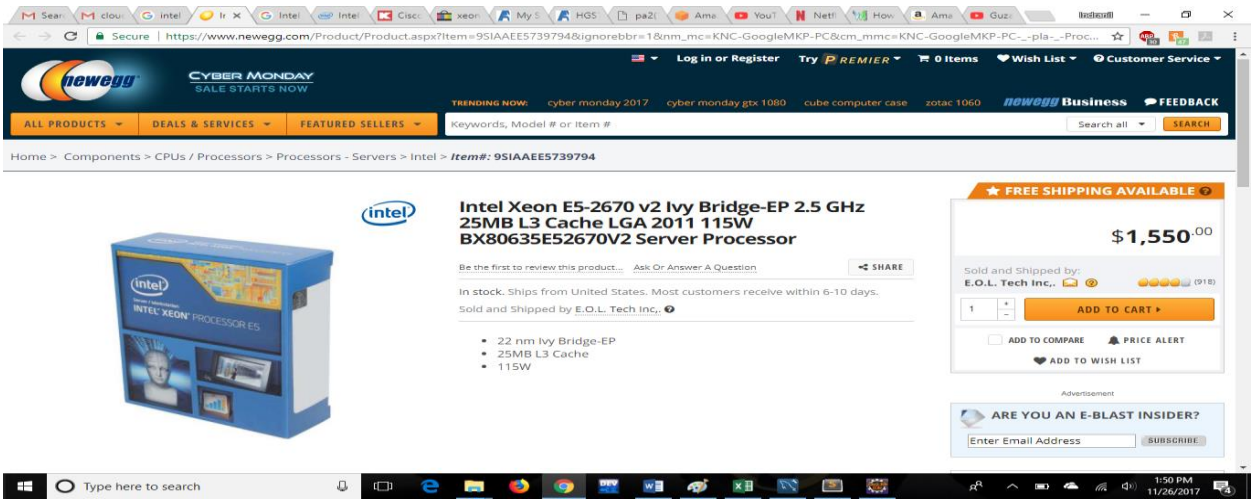
= 121740764.04 * 12 * 5

= $7,304,445,840

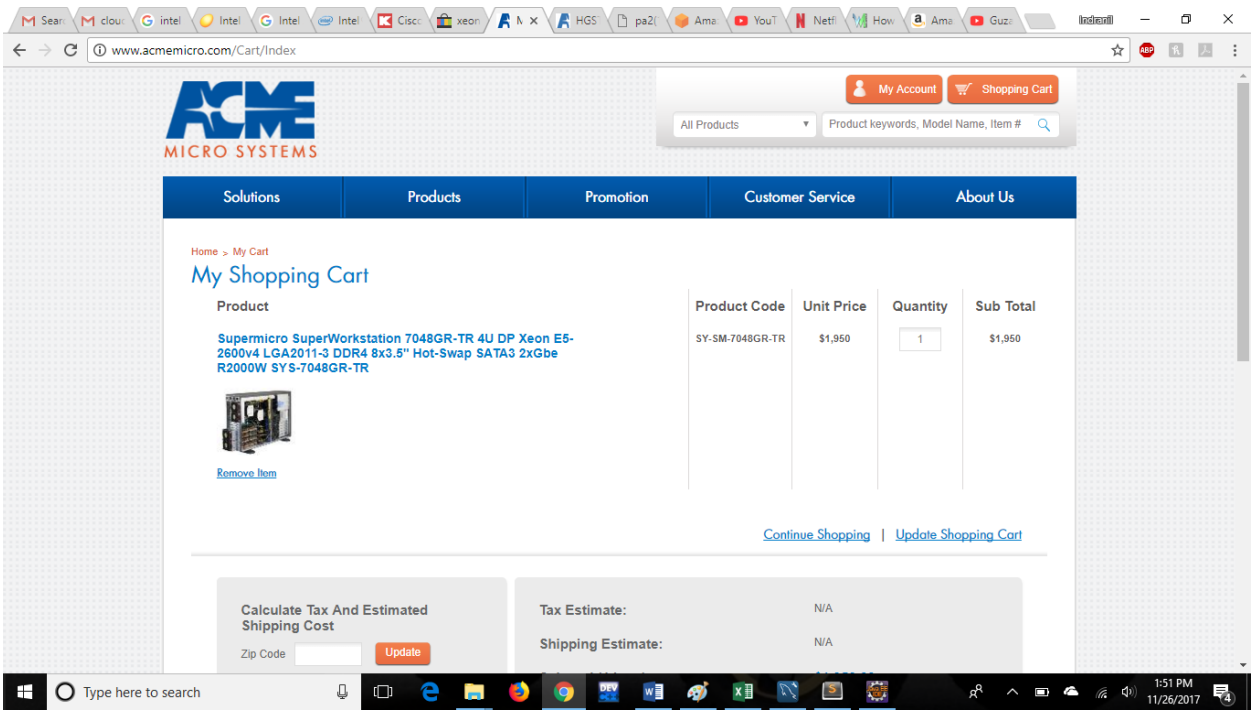
Private Cloud for Configuration 2:

Screenshots:

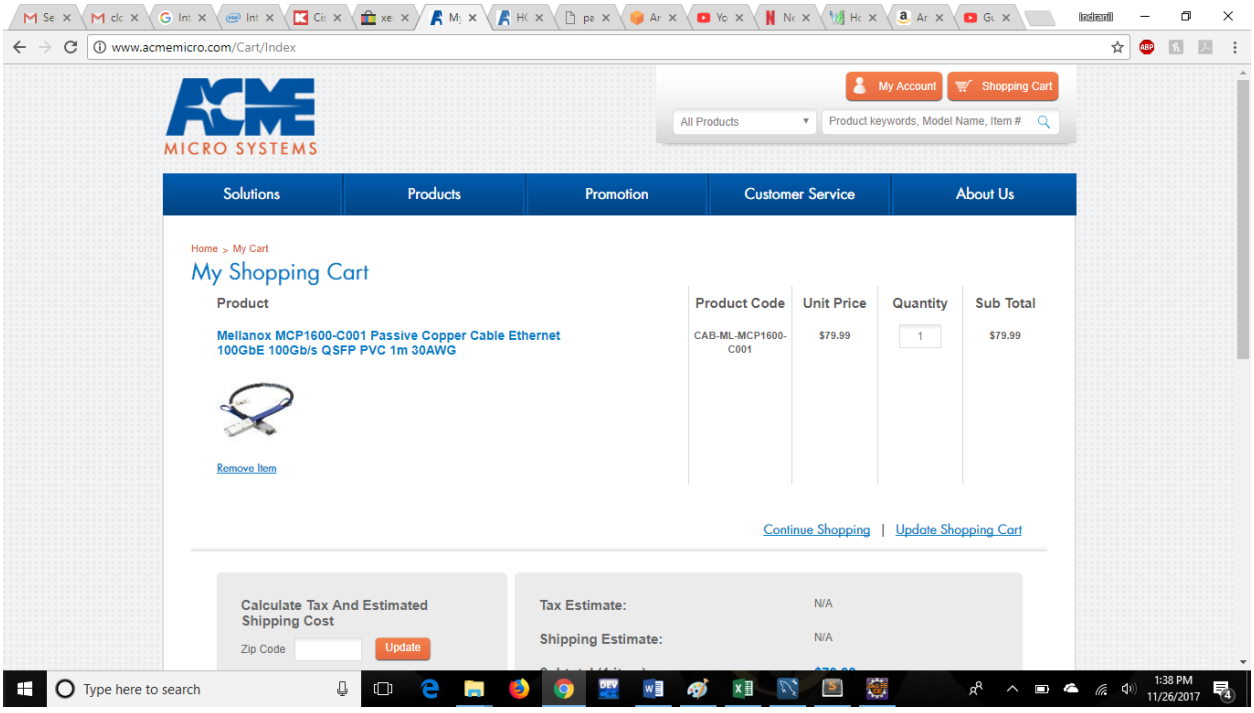
Processor:



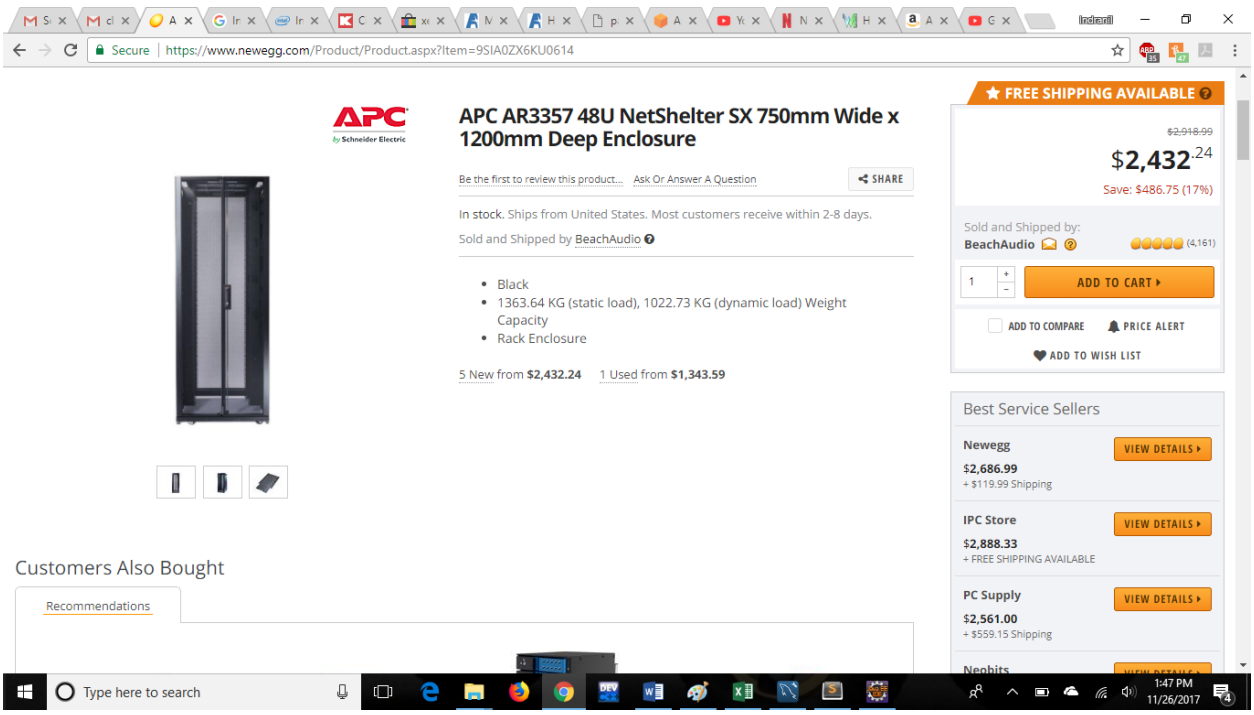
Motherboard:



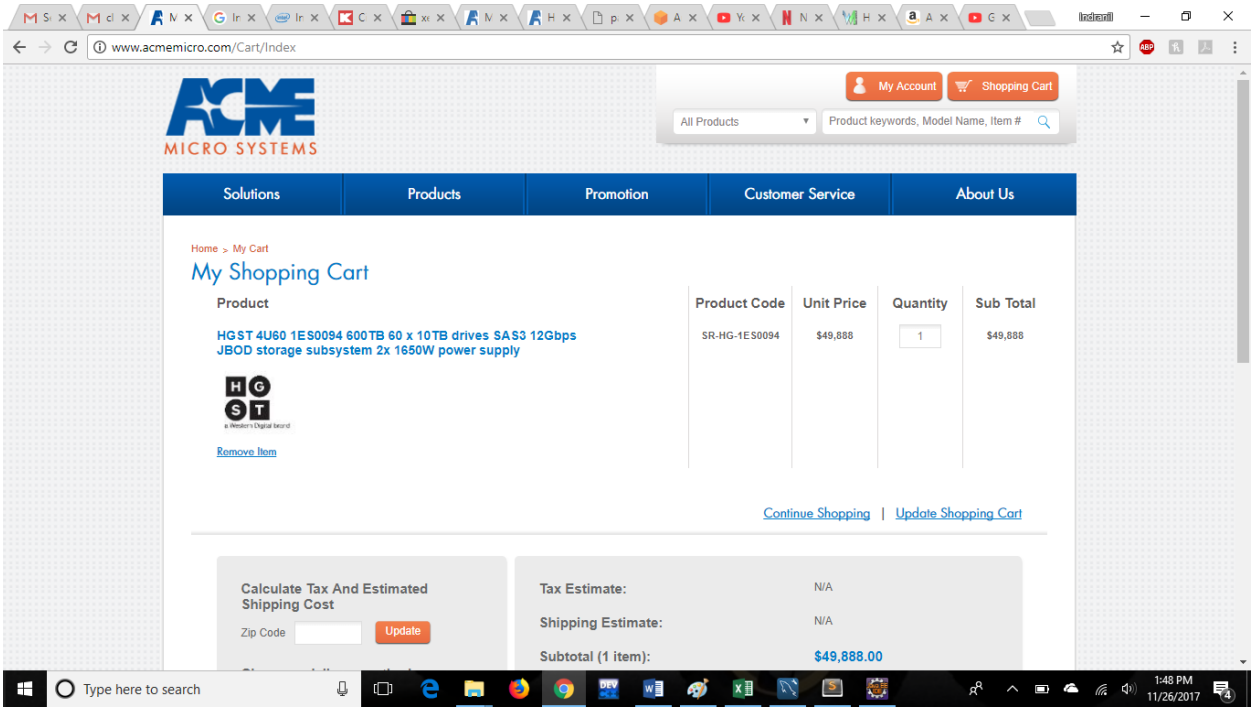
Network Cable:



Racks:



Storage Servers:



Configuration 3:

Name	vCPUs	GPU	Memory(GiB)	GPU Memory(GiB)	GPU P2P
p3.16xlarge	64	8	488	128	NV Link

The performance expected = 1 exaflop (10^18)

Performance of p3.16xlarge instance = 960 Teraflops

Therefore, number of p3.16xlarge instances needed = 1 exaflop / 960 teraflops

= 1041.66

= 1042 approx.

Cost of 1 p3.16xlarge instance for one hour = $24.48

Cost of 8333 p3.16xlarge instances for 5 years = 1042*24.48*24*365*5

= $1,117,257,408

Cost of 1PB of storage for one month :

⊞	Amazon S3 Service (US-East)	$ 22583.30
⊞	AWS Support (Basic)	$ 0.00
Free Tier Discount:		$ -0.12
Total Monthly Payment:		$ 22583.18

Cost of 1PB of storage for 5 years:

= 22583.18*12*5

= $ 1,354,990.8

Total cost of 1042 p3.16xlarge instances for 5 years for public cloud:

= $1,117,257,408 + $ 1,354,990.8

= $ 1,118,612,398.8

Private Cloud for Configuration 3:

The performance expected = 1 exaflop (10^18)

Performance of NVIDIA DGX-1 with TESLA V100 instance = 960 Teraflops

Therefore, number of NVIDIA DGX-1 with TESLA V100 instances needed = 1 exaflop / 960 teraflops

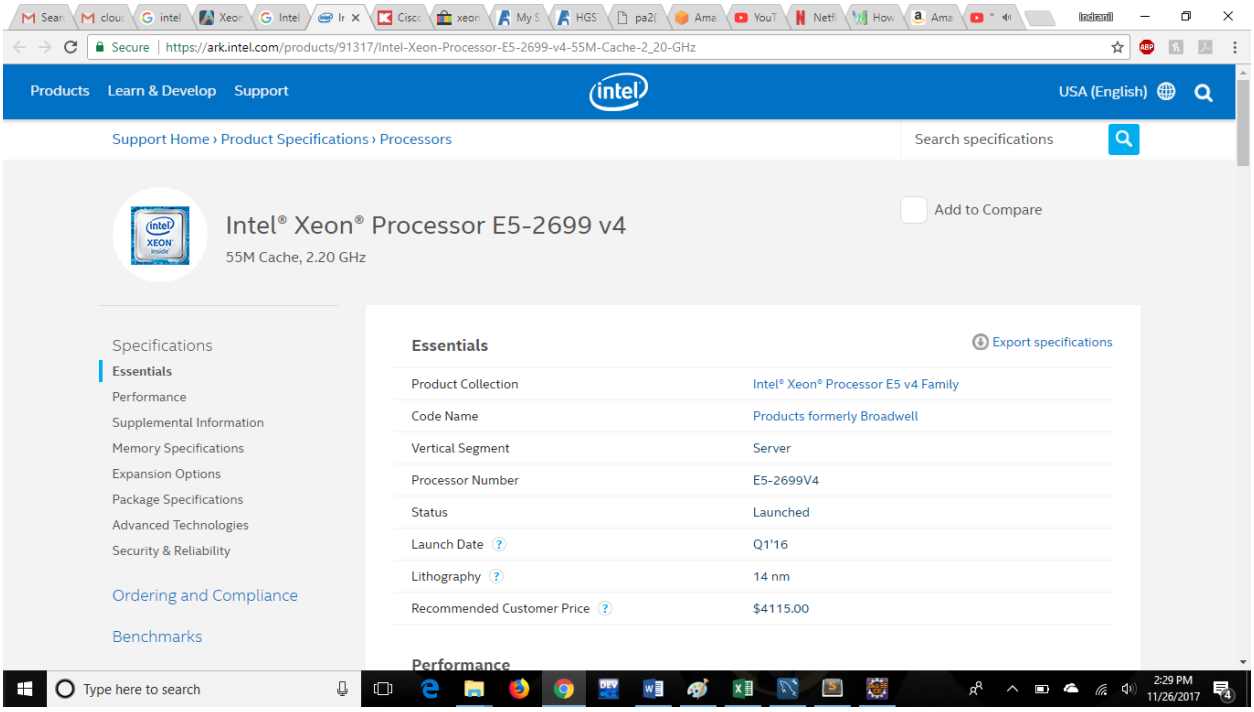
= 1041.66

= 1042 approx.

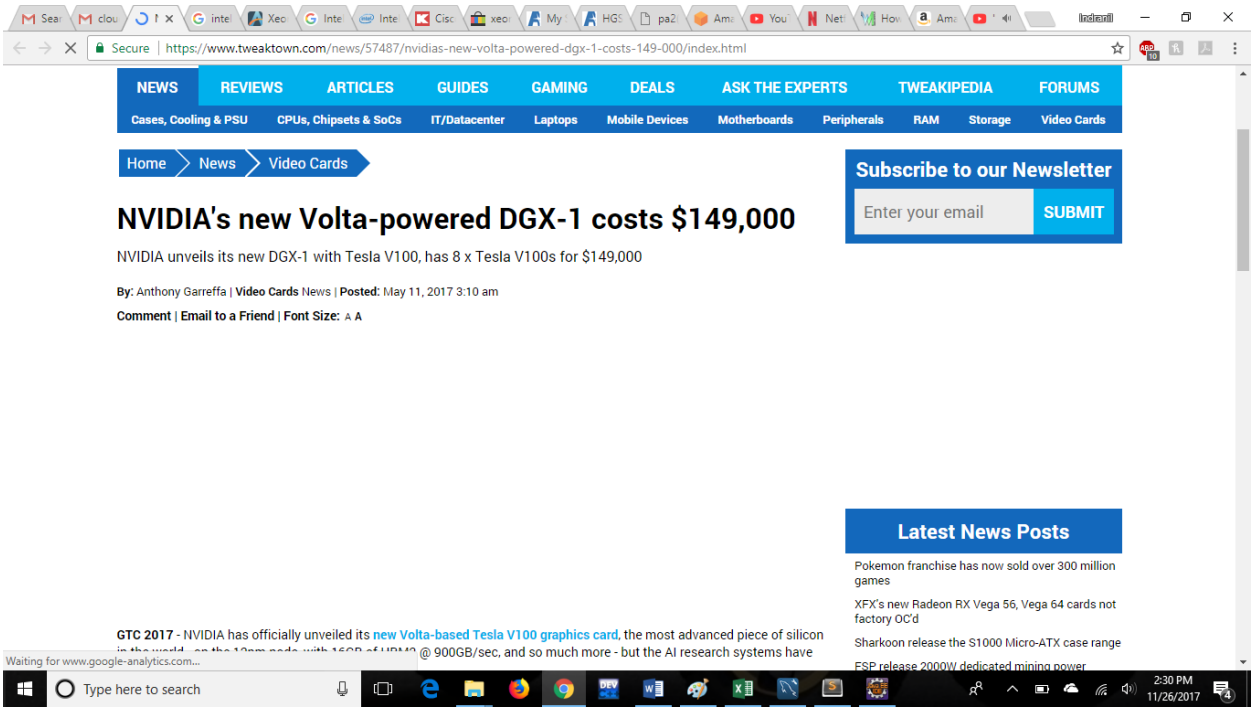
		Description	Price per Item(USD)	Quantity	Total Price(USD)
1.	**Computer Servers**				
1.1	**CPU**	**INTEL® XEON® PROCESSOR E5-2699 V4**	4115	1042	4,863,490=4.8M
1.2	**GPU & Memory**	NVIDIA DGX-1 with TESLA V100 with 128GB per GPU.	1,49,000	1042	155,258,000 = 155M
2.	**Network Switches**	Cisco Catalyst 4500-X -Switch - 32 x 1 Gigabit SFP/ 10 Gigabit SFP+ - rack-mountable	7475	34	254,150
3.	**Network Cables**	Mellanox MCP1600-C001 Passive Copper Cable Ethernet 100GbE 100Gb/s QSFP PVC 1m 30AWG	79.99	1043	83,429.57
4.	**Racks**	APC AR3357 48U NetShelter SX 750mm Wide x 1200mm Deep Enclosure	2432.24	23	55,941
5.	**Storage Servers**	HGST 4U60 1ES0094 600TB 60 x 10TB drives SAS3 12Gbps JBOD storage subsystem 2x 1650W power supply	49,888	2	99,776
6.	**Electric Power**	1650W @ 12 cents per KWH in IL (246*1.6*0.12) + (1042*3.2*0.12)	3,918,873.6/yr	5 years	19,594,368= 19.5M
7.	**Cooling**	N+1 redundant fans (fans integrated in PSU)	1,268,929.84/yr	5 years	6,744,649.22= 6.7M
8.	**Administration**	Maintenance, Security, Deployment	200,000 per year	5	1M
9.	**CPU Admin**	100 processor per person	Number of people = 32		32M
10.	**GPU Admin**	50 NVIDIA processor per person	Number of people = 21		21M
	TOTAL	N/A	N/A	N/A	246.29M

Screenshots:

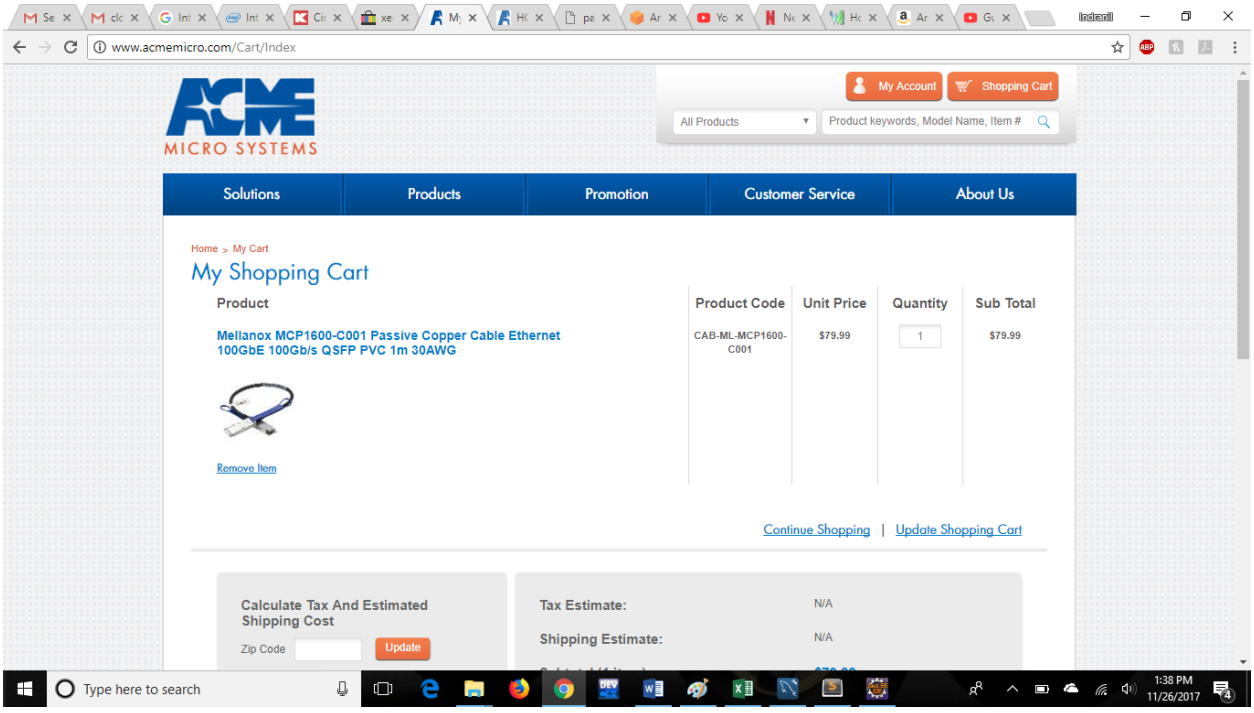
CPU:



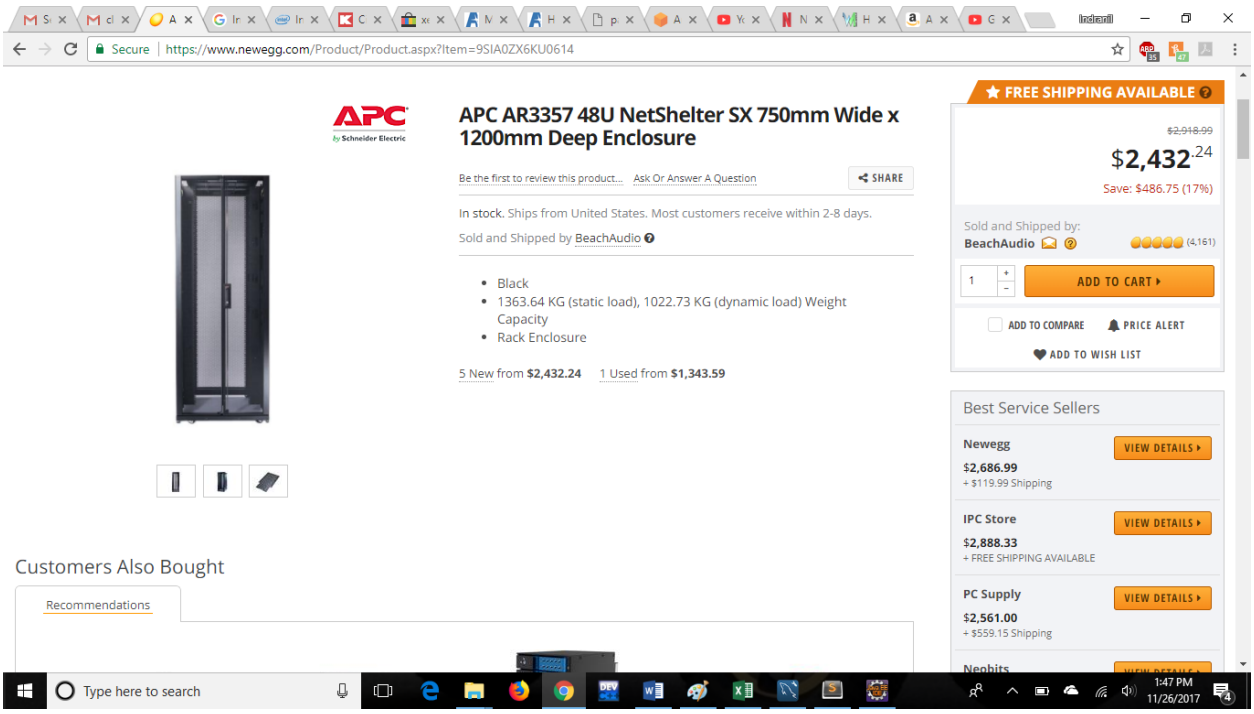
GPU:



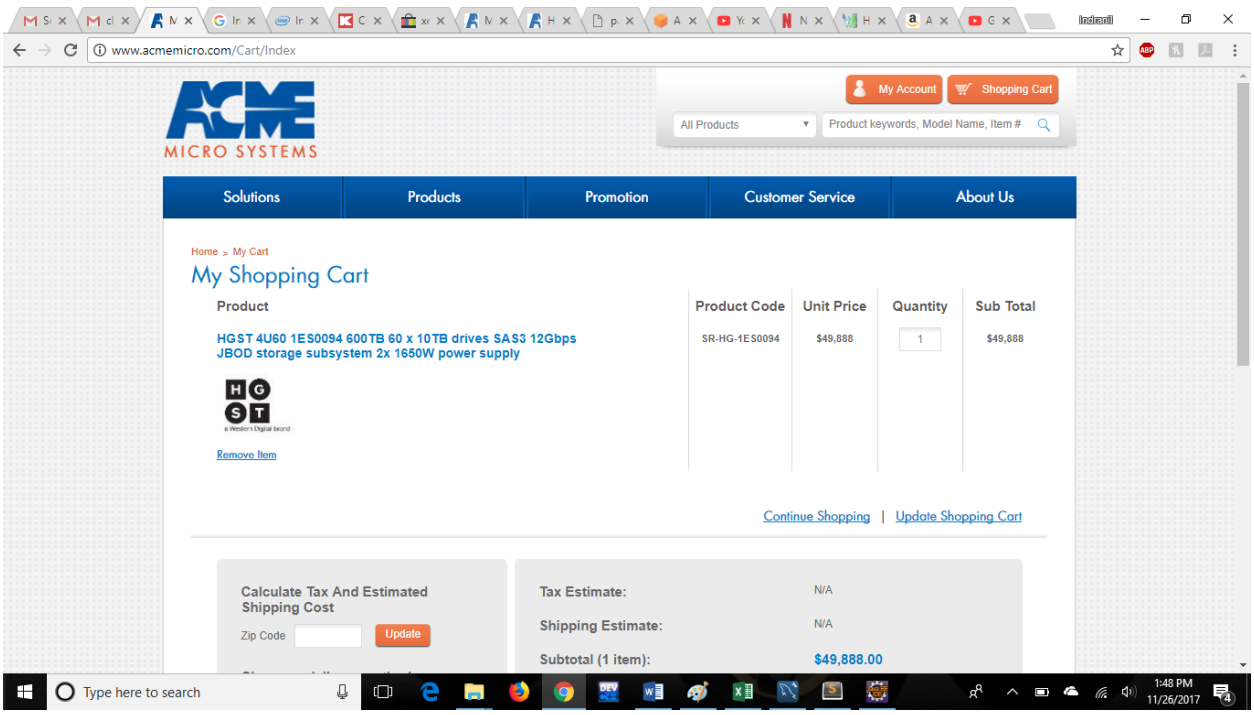
Network Cable:



Racks:



Storage Servers:



	Configuration 1	Configuration 2	Configuration 3
Public Cloud (including EC2 and S3) Cost over 5 years, 24/7 operation, with 100% usage	$563,209,836	$7,304,445,840	$ 1.1B
Private Cloud cost over 5 years, 24/7 operation, with 100% usage	46.53M	5.036Billion	246.9M
What utilization must be achieved with the private cloud to make the private cloud option more attractive than the public cloud?	**>= 4.8%** private cloud remains an attractive option. (Explained in detail in the break-even section below)	**>= 45%** private cloud remains an attractive option. (Explained in detail in the break-even section below)	**>=16%** private cloud remains an attractive option. (Explained in detail in the break-even section below)

Explain in words if it is better to rent or buy. If it is better to buy, what utilization must you maintain over the 5-year lifetime of the private cloud in order to break even on the investment?

I would like to place an analogy here to discuss the break even and make the appropriate choice between private and public cloud.
For instance, if we ought to travel everyday and we chose Uber/Lyft as our mode of commute, then we would of course end up paying a huge amount in just an year's span. Had we rather chosen to buy our own car, we could've hired a driver and still ended up paying way lesser than the we did for renting the car.
But however, car-pooling would be the best fit if we did just travel to and from the work place and needed a private vehicle for nothing else.
So, this is where the cloud kicks in. "**Pay per usage".**

Therefore, if we are having a requirement which demands a 100 % utilization of the resources all through the 5-year period, then buying our own resources would pay up better than using cloud. Whereas, If we know for sure that the utilization of the resources would not be anywhere close to 100% all through 5 years, which is the case in most of our requirements in practice, then it is a better option to go with cloud. We should also keep in mind the "Durability of the hardware". Because, if we do not tend to use the resources close to 100% and also that if our utilization period (not the percentage of utilization), for example, our project would go on for more than 5 years but not using the resources to their fullest, then we would have a penalty of replacing the resources all together post the 5 year period as their performance to power consumption ratio would have gone really low and bad by then with time. Even in this case, public cloud would prove worthier than the private.

- In addition to the points above, public cloud establishment even waives us off the burden of maintenance and upgradation processes which would happen so seamlessly with public cloud like AWS.
- Furthermore, we cannot ignore the fact that private cloud has a bottle neck of scalability as it cannot scale horizontally with load increase as flexibly as the public cloud assures us with the high availability.
- Locality awareness and replication factors are the other valuable factors of the public cloud implementation which is an inherent advantage of the wide spread network of public cloud giants like AWS, Azure, Bluemix etc.

Finally, when it comes to the ***break-even*** points between the private and the public cloud for the 3 configurations then, the following is the substantiations with the current market rates for both public cloud and private cloud resources in context.

We have the **constant** and the **variable** parts for all the configurations of the private cloud.

Power consumption, Cooling and Administration costs vary with their utilization.

Whereas, the rest of the investment stays invariable which is the cost of buying the required hardware.

Configuration 1:

This configuration makes the private cloud play a very clear winner role with a pretty low percentage of utilization sufficing its usage being more attractive than the public cloud for a vast range of utilization.

Private Cloud				Public Cloud
% Utilization	Constant Part (USD)	Variable Part (USD)	Total cost (USD)	Variable Part (USD)
4.7	26.1M	0.95M	27.05M	26.45M
>= 4.8	26.1M	0.97M	27.07M	27.068M
4.9	26.1M	0.99M	27.09M	27.587M

Configuration 2:

Private Cloud				Public Cloud
% Utilization (USD)	Constant Part (USD)	Variable Part (USD)	Total cost (USD)	Variable Part (USD)
40	1.63B	1.36B	3.071B	2.921B
>=45	1.63B	1.53B	3.251B	3.258B
47	1.63B	1.60B	3.321B	3.432B

Configuration 3:

Private Cloud				Public Cloud
% Utilization	Constant Part (USD)	Variable Part (USD)	Total cost (USD)	Variable Part (USD)
15	166M	12.03M	178.03M	167.7M
16	166M	12.83M	178.83M	178.9M
17	166M	13.63M	179.63M	190M

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