CS 553 - CLOUD COMPUTING

Project Report

TEAM MEMBERS:
1] VAISHNAVI GUDUR (A20384900)
2] SATYA SUVEEN REDDY MEKALA (A20379568)

Introduction:

In this report we compare the cost of building a private cloud equivalent to Public cloud (Amazon AWS).

Using a public cloud is very comfortable since there is no need of thinking about the hardware and maintenance of the hardware.

On the other hand private cloud takes time to set it up and there are many overheads like maintenance, upgrades, electricity and management charges.

Thus the main goal of this project is to check if it is feasible to set up a private cloud or use a public cloud over a time of 5 Years. And If it is better to buy, what utilization should we maintain over the 5 year lifetime of the private cloud in order to break even on the investment.

Method:

We are given 3 EC2 instances in AWS to create our own configuration based on the requirements given.

The cost of amazon EC2 instances were calculated using the pricing given in the AWS website. It can be obtained from https://aws.amazon.com/ec2/pricing/on-demand/ .

The steps briefly followed to build a private cloud system are as follows:

1. Selection of the Processor, Memory, Disk, Mother board and Fan.
2. Calculation of the number of nodes required.
3. Design the fat tree for compute nodes
4. Get the network switches and network adaptor to achieve the speeds given in the question.
5. Deciding on the Fast HDD capacity for the distributed storage.
6. Design the fat tree for storage nodes
7. Calculation of number of HDD's required.
8. Calculation of number of cables and storage boxes.
9. Get the racks based on the no. of compute nodes required.

After all the hardware components are obtained and the design is completed, other factors like cooling, power and administration costs are calculated.

Results:

Configuration 1:

Cost for a Public cloud :

Number of hours in a year = 365 days * 24 hours = 8760 hours
Number of hours in 5 years = 8760 * 5 = 43800 hours

Number of nodes as per requirement = 32000/36 = ~889 nodes, where 36 is the number of CPU cores in the instance. Each node is equivalent to the d2.8xlarge instance.

For EC2 instance **d2.8xlarge**, the price is $5.52 per hour for a single instance.

Number of Instances	Cost per 5 years
1	$ 241776
889	$ 214938864

For S3, the pricing is calculated based on the values given at https://aws.amazon.com/s3/pricing/ and it is calculated using the price estimation tool of AWS.

We are to procure a 100PB distributed storage shared across the entire cloud (AWS S3 in public cloud)

Cost estimation which includes AWS support cost is given in the table below.

Time	Cost
1 month	$ 2275549.87
5 Years	$ 136532992.2

Thus the total cost of using AWS for this configuration for a period of 5 years is :

Service	Cost
EC2	$ 214938864
S3	$ 136532992.2
TOTAL	$ **351471856.2**

Cost for a Private cloud :

	Description	Price per Item	Quantity	Total Price
Compute Servers	CPU + Mem + Disk + etc	$ 12267	889	$ 10905363
Network Switches	1* 24 port + 22 * 44 port	$ 3329; $5109	23	$ 110618
Network Cables	**[*RJ45*]** + **[*QSFP+*]***	$ 10.70	910+43	$ 10197.1
Racks	25U Adjustable racks	$ 247	36	$ 8783.32
Storage Servers	4U60 from HGST + server	$ 161335.1	42	$ 6776074.2
Electric Power	Chicago industrial rate	$ 0.0139/kWh	341717 W	$ 10408.54
Cooling	Daikin	$ 2480	4	$ 9920
Administration	Server Administrator	$ 37.15/hr	1	$ 77271
TOTAL	N/A	N/A	N/A	$ **17908635.2**

* Included in the storage server module

Electricity and Cooling Calculation

Type of Node	No.of nodes	Watts Consumed per node	Cost for 5 years
Compute	889	305	$ 8253.92
Storage	42	1650	$ 2115.9
Cooling	4	318 W for 24000BTU*	$ 38.72

* 1 W = 3.412 BTU/hr

** Power cost in $ = (operating hours *kiloWatt Usage * Electricity Costs) /100

*** Cooling cost in $ = (operating hours *BT/hr * 0.293 * Electricity Costs) /100

Configuration 2:

Cost for a Public cloud :

Number of hours in a year = 365 days * 24 hours = 8760 hours
Number of hours in 5 years = 8760 * 5 = 43800 hours

We are given that we have 1 million VM's.
Number of nodes as per requirement = 1000000/10 = 100000 nodes
Here, each node is equivalent to 10 VM's.

For EC2 instance **r3.large**, the price is $ 0.166 per hour for a single instance(VM).

Number of Instances	Cost per 5 years
1	$ 7270.8
1000000	$ 7270800000

For S3, the pricing is calculated based on the values given at https://aws.amazon.com/s3/pricing/ and it is calculated using the price estimation tool of AWS.

Since we are to procure a 10PB distributed storage shared across the entire cloud (AWS S3 in public cloud)

Cost estimation which includes AWS support cost is given in the table below.

Time	Cost
1 month	$ 233702.25
5 Years	$ 14022135

Thus the total cost of using AWS for this configuration for a period of 5 years is :

Service	Cost
EC2	$ 7270800000
S3	$ 14022135
TOTAL	$ **7,284,822,135**

Cost for a Private cloud :

	Description	Price per Item	Quantity	Total Price
Compute Servers	CPU + Mem + Disk + etc	$ 6775	100000	$ 677500000
Network Switches	[102257 *48 port] + [1* 8port]	$ 2249.99;$659.99	102257;1	$ 230077887
Network Cables	**[*RJ45*]** + **[*QSFP+*]***	$ 10.70	102256	$ 10197.1
Racks	25U Adjustable racks	$ 247	4091	$ 1010477
Storage Servers	4U60 from HGST + server	$ 161335.1	5	$ 806675.5
Electric Power	Chicago industrial rate	$ 0.0139/kWh	15e+6 W	$ 16284055.3
Cooling	Daikin	$ 2480	1635	$ 4054800
Administration	Server Administrator	$ 37.15/hr	100	$ 7727100
TOTAL	N/A	N/A	N/A	$ 937471192

* Price is Included in the storage server module

Electricity and Cooling Calculation

Type of Node	No.of nodes	Watts Consumed per node	Cost for 5 years
Compute	100000	150	$ 456615
Storage	5	1650	$ 251.138
Cooling	1635	318 W for 24000BTU*	$ 15827189.1

* 1 W = 3.412 BTU/hr

** Power cost in $ = (operating hours *kiloWatt Usage * Electricity Costs) /100

*** Cooling cost in $ = (operating hours *BT/hr * 0.293 * Electricity Costs) /100

Configuration 3:

Cost for a Public cloud :

Number of hours in a year = 365 days * 24 hours = 8760 hours
Number of hours in 5 years = 8760 * 5 = 43800 hours

We are given that we have 1 exaflop of mixed precision performance
Since,
1 ExaFlop = 10^{18} Flops
1 TeraFlop = 10^{12} Flops
And 1 GPU(Nvidia Tesla V100) can deliver up to 125 TFLOPS of mixed-precision floating point and we have 8 GPUs per node and 125 * 8 TFLops= 1000 TFlops. This is per node equivalent to the **p3.16xlarge** instance.
And since 1 ExaFlop = 10^{6} TeraFlops , we need to have 1000 of the p3.16xlarge instances i.e., 1000 nodes to support deep learning capability of a 1 exaFlop of Mixed precision performance.

Therefore number of nodes as per requirement = 1000 nodes

For EC2 instance p3.16xlarge, the price is $ 24.48 per hour for a single instance(VM). This type of instance is available in US East(North virginia) region.

Number of Instances	Cost per 5 years
1	$ 1072224
1000	$ 1072224000

For S3, the pricing is calculated based on the values given at https://aws.amazon.com/s3/pricing/ and it is calculated using the price estimation tool of AWS. Since we are to procure a 10PB distributed storage shared across the entire cloud (AWS S3 in public cloud)

Cost estimation which includes AWS support cost is given in the table below.

Time	Cost
1 month	$ 24464.01
5 Years	$ 1467840.6

Thus the total cost of using AWS for this configuration for a period of 5 years is :

Service	Cost
EC2	$ 1072224000
S3	$ 1467840.6
TOTAL	$ **1073691840.6**

Cost for a Private cloud :

	Description	Price per Item	Quantity	Total Price
Compute Servers	CPU + Mem + Disk + GPU^	$ 152738	1000	$ 152738000
Network Switches	1037 * 24 port+ 1* 24 port	$ 5499	1037+1	$ 5707962
Network Cables	**[*RJ45*]** + **[*QSFP+*]***	$ 10.70	1036	$ 11085.2
Racks	25U Adjustable racks	$ 247	40	$ 9880
Storage Servers	500TB Iris 428-60 storage server	$ 41005.16	2	$ 82010.32
Electric Power	Chicago industrial rate	$ 0.0139/kWh	3204000 W	$ 97920.55
Cooling	Daikin	$ 2480	40	$ 99200
Administration	Server Administrator	$ 37.15/hr	1	$ 77271
TOTAL	N/A	N/A	N/A	$ 158823329

^ GPU price is calculated using:
Price of DGX-1 module - price of (CPU+Memory+SSD+N/w Adaptor) and dividing it by 8.
* Price is Included in the storage server module

Electricity and Cooling Calculation

Type of Node	No.of nodes	Watts Consumed per node	Cost for 5 years
Compute	1000	3200	$ 97411.2
Storage	2	2000	$ 121.764
Cooling	40	318 W for 24000BTU*	$ 387.59

* 1 W = 3.412 BTU/hr

** Power cost in $ = (operating hours *kiloWatt Usage * Electricity Costs) /100
*** Cooling cost in $ = (operating hours *BT/hr * 0.293 * Electricity Costs) /100

Discussion:

	Configuration 1*	Configuration 2	Configuration 3
Public Cloud (including EC2 and S3) Cost over 5 years, 24/7 operation, with 100% usage	**$ 351,471,856.2**	**$ 7,284,822,135.0**	**$ 1,073,691,840.6**
Private Cloud cost over 5 years, 24/7 operation, with 100% usage	**$ 17,908,635.2**	**$ 937,471,192.0**	**$ 158,823,329.0**
What utilization must be achieved with the private cloud to make the private cloud option more attractive than the public cloud?	**5.0689%**	**12.532%**	**14.770%**

*Example calculation for Config 1:

Utilization	Private	Public
100%	**$ 17,908,635.2**	**$ 351,471,856.2**
75%	$ 17,884,235.3	$ 263,603,892.15
50%	$ 17,859,835.4	$ 175,735,928.1
10%	$ 17,820,795.6	$ 35,147,185.62
5.069%	**$ 17,815,982.9**	**$ 17,816,108.39**

Hardware cost: $ 17811035.6
Electricity and admin cost: $ 97599.58

Conclusion:

- The main difference between a private cloud and the public cloud is the cost of ownership.

- Private cloud needs a lot of time and resources to build the infrastructure before it can be used for computation purposes. On the other hand, Public clouds are already setup and it can be used whenever the need be.

- Also the important factor to consider while building a private cloud is scalability issue. Private cloud needs a lot of intricate planning and huge amounts of manpower to scale it up on a short notice. Whereas the public cloud takes little or no time to scale up in the case of increased number of requirement for computation.

- It's a bad idea to build a private cloud if the computation requirement is less. In this case(less computation requirement), it is better to rent a public cloud.

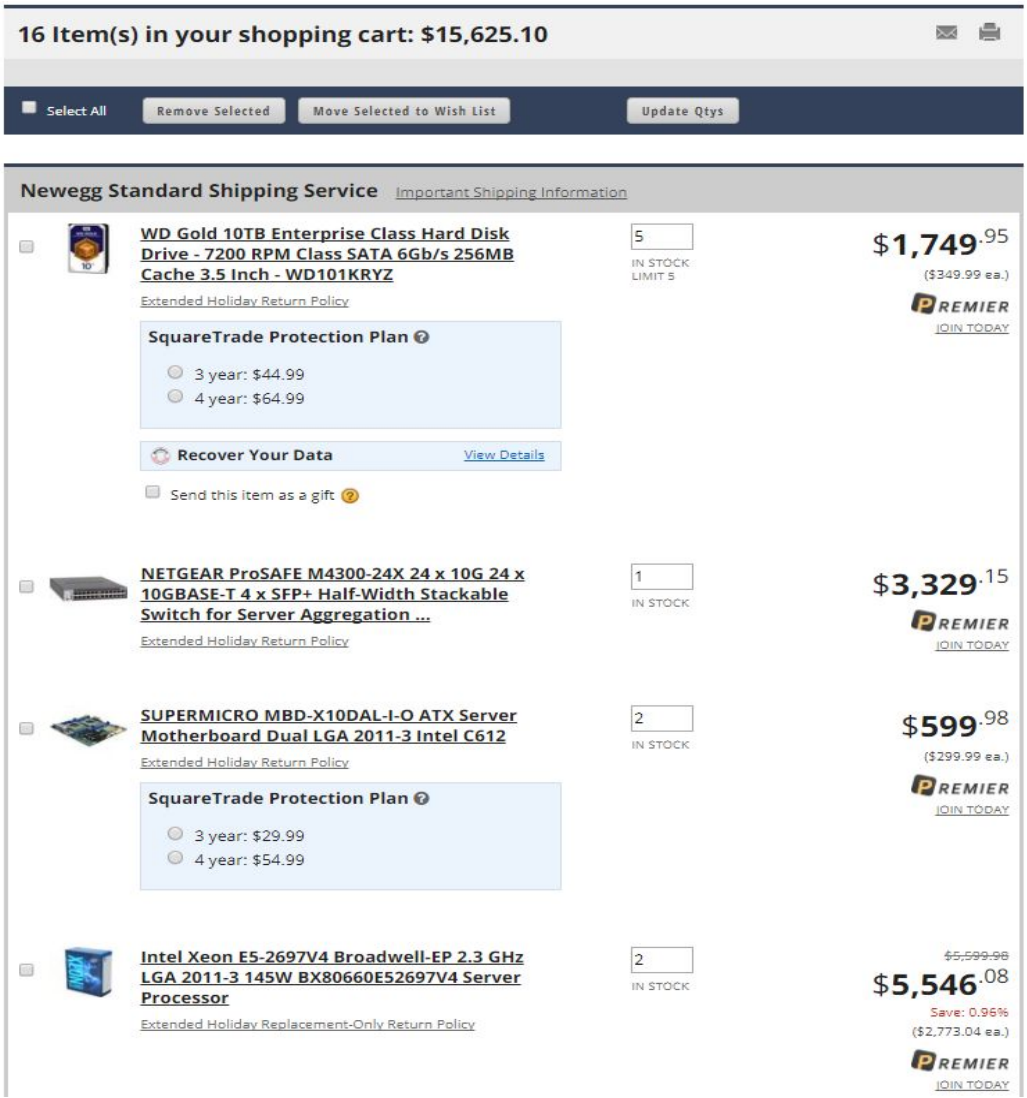
- From the percentage of utilization calculated in the table, we know that if the usage is up to around 15% the cost of infrastructure is more if a private cloud is built and it takes many years to break even. Hence renting a public cloud makes sense.

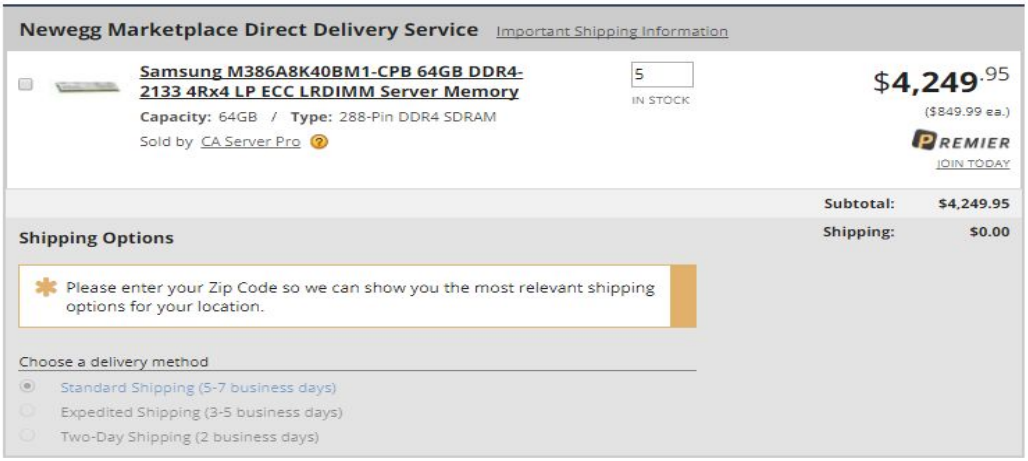
- If the usage is above the range, it is good to get a private cloud.

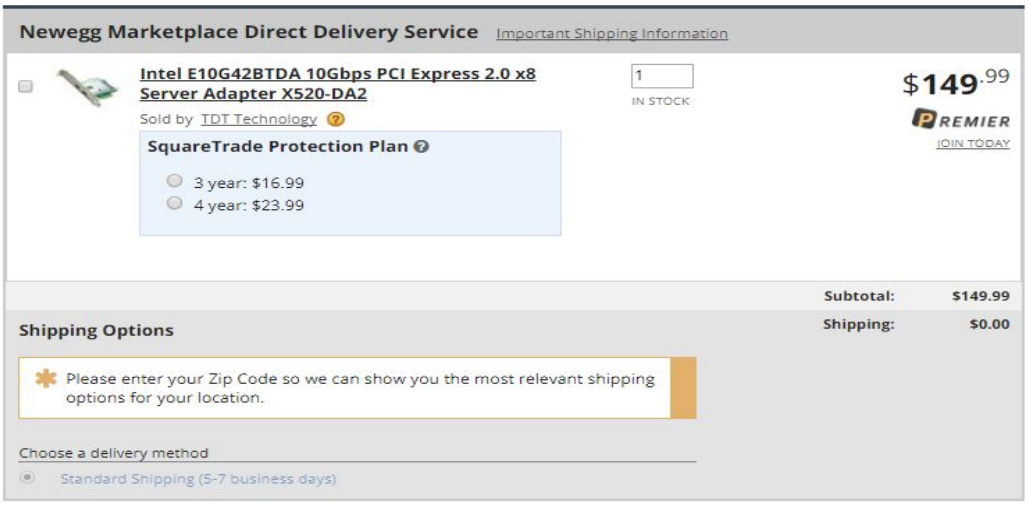
Appendices:

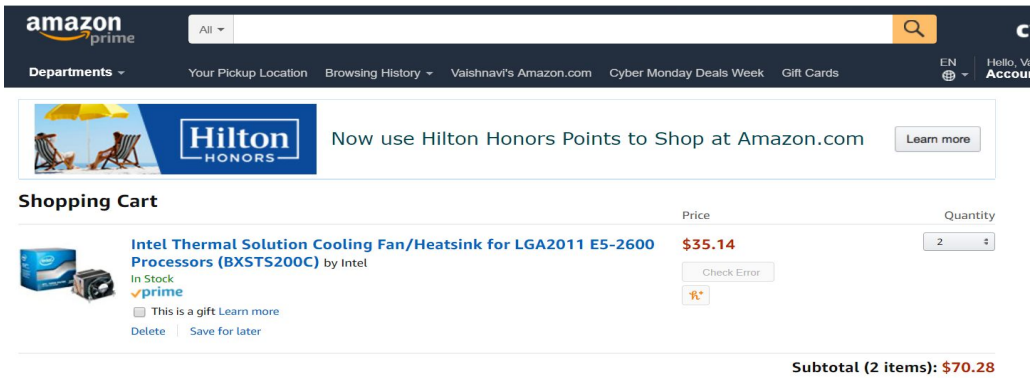
Shopping Cart:

Configuration 1:




Newegg Marketplace Direct Delivery Service
Important Shipping Information
Samsung M386A8K40BM1-CPB 64GB DDR4-2133 4Rx4 LP ECC LRDIMM Server Memory
Capacity: 64GB / Type: 288-Pin DDR4 SDRAM
Sold by CA Server Pro
5
IN STOCK
$4,249.95
($849.99 ea.)
PREMIER
JOIN TODAY
Subtotal: $4,249.95
Shipping: $0.00
Shipping Options
Please enter your Zip Code so we can show you the most relevant shipping options for your location.
Choose a delivery method
Standard Shipping (5-7 business days)
Expedited Shipping (3-5 business days)
Two-Day Shipping (2 business days)


Newegg Marketplace Direct Delivery Service
Important Shipping Information
Intel E10G42BTDA 10Gbps PCI Express 2.0 x8 Server Adapter X520-DA2
Sold by TDT Technology
1
IN STOCK
$149.99
PREMIER
JOIN TODAY
SquareTrade Protection Plan
3 year: $16.99
4 year: $23.99
Subtotal: $149.99
Shipping: $0.00
Shipping Options
Please enter your Zip Code so we can show you the most relevant shipping options for your location.
Choose a delivery method
Standard Shipping (5-7 business days)


amazon prime
All
Departments
Your Pickup Location
Browsing History
Vaishnavi's Amazon.com
Cyber Monday Deals Week
Gift Cards
EN
Hilton HONORS
Now use Hilton Honors Points to Shop at Amazon.com
Learn more
Shopping Cart
Price
Quantity
Intel Thermal Solution Cooling Fan/Heatsink for LGA2011 E5-2600 Processors (BXSTS200C) by Intel
$35.14
2
In Stock
prime
This is a gift Learn more
Delete
Save for later
Subtotal (2 items): $70.28

Home > My Cart

My Shopping Cart

Product	Product Code	Unit Price	Quantity	Sub Total
Netgear XS748T-100NES ProSafe 44-Port 10GbE RJ45 Smart managed Switch with 4 SFP+ ports Retail 	NW-NG-XS748T-N	$5,109	1	$5,109

Storage Server :

Motherboard Supermicro MBD-X9SRH-7TF-O (MicroATX)	1	$539.50	$539.50
CPU Fan DYNATRON R13 1U Server CPU FAN	1	$45.71	$45.71
CPU Intel XEON E5 -1620 V2 (Quad Core)	1	$343.94	$343.94
8GB RAM PC3-12800 DDR3-1600MHz 240-Pin	4	$89.49	$357.96

Network Adaptor :

Your Shopping Cart

Secure Checkout

Cart Items	Qty	Item Price	Item Total
 Mellanox MCX313A-BCCT ConnectX-3 Pro EN Network Interface Card 40/56GbE Single-Port QSFP PCIe3.0 x8 8GT/s RoHS R6 Change Ships same day	1 Remove	$400.00	*$400.00*

Subtotal: ***$400.00***

Estimate Shipping & Tax

Grand Total: **$400.00**

Storage Box + HDD's :

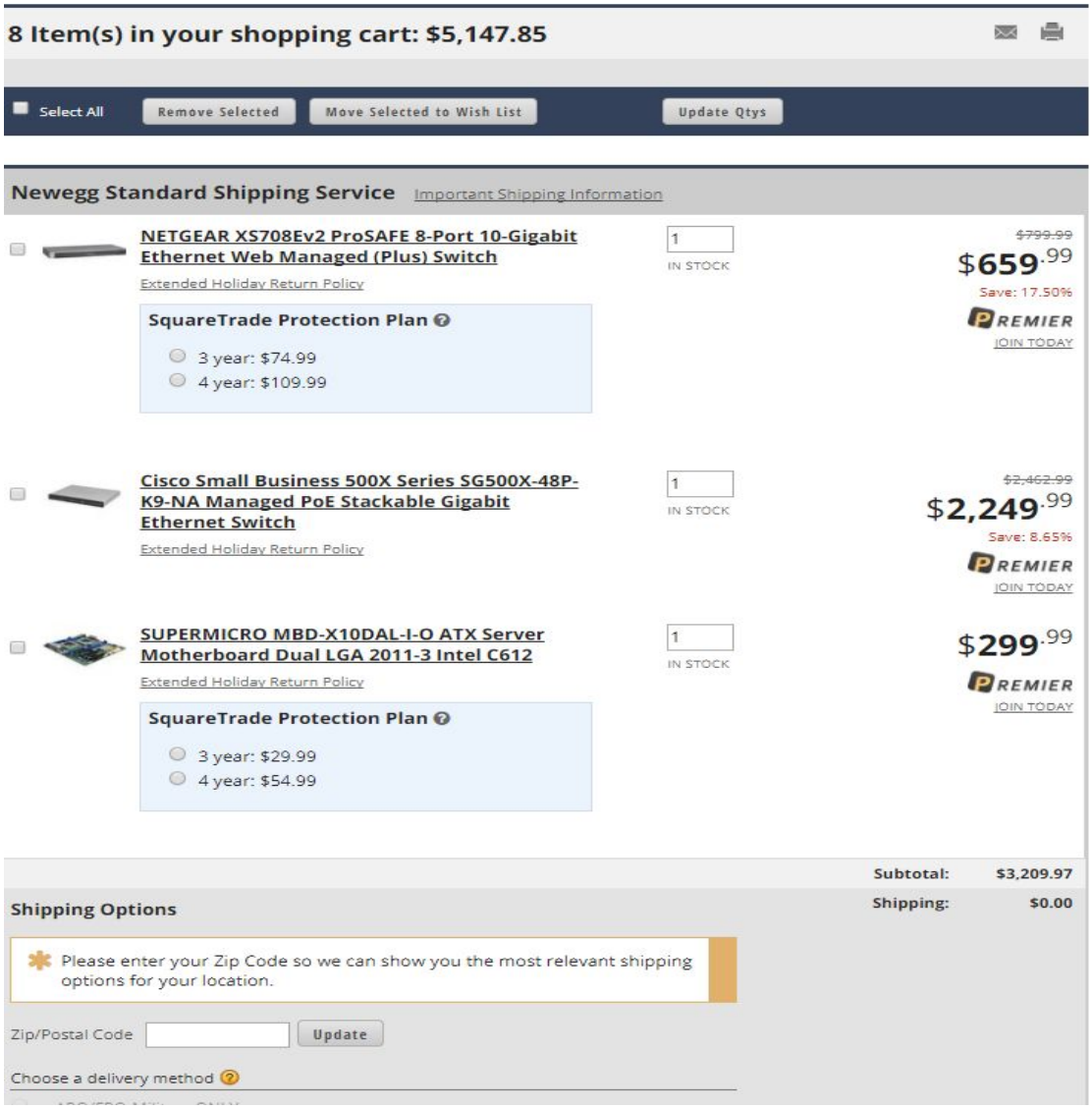
Quote #8235728181

pogo [linux]™	Pogo Linux, Inc. 15233 NE 90th ST Redmond, WA 98052 Tel: (888) 828 7646 Fax: (425) 898 2299 www.pogolinux.com

Quote #	Issue Date:	Issue Type:	
8235728181	Nov 26th, 2017	Website	

Qty	Description	Unit Amount	Extended Amount
1	**Iris 428-60**	$41,005.16	$41,005.16
	• 4U 60bay Storage Server • Dual Xeon E5-2600v4 Series CPU • Up to 1536GB DDR4 ECC Reg • Flexible Networking Options • Integrated IPMI 2.0 with Dedicated LAN • 2000W Redundant Power Supply		
2	Intel Xeon E5-2603v4 6C 1.7GHz 15MB Cache		
1	16GB DDR4 ECC Reg 2400MHz (2 x 8GB)		
2	Micron M510DC 480GB 2.5â• Enterprise SSD		
50	HGST Ultrastar HE10 10TB 7200RPM SATA 6Gb/s		
1	Dual Port 10G SFP+ Ethernet Module X520		
1	No Operating System. Include testing and customer OS preference in notes.		
1	Return to Depot Warranty (3 Year Hardware Warranty with Standard Advance Parts Replacement)		
Notes:	*none*		

Configuration 2:



Newegg Marketplace Direct Delivery Service Important Shipping Information

NETGEAR ProSAFE 12-Port Gigabit Managed Switch Layer 2+ With Static L3 Routing (GSM5212)

Model: GSM5212-100NES

Sold by BuyVPC.com

1 IN STOCK

~~$310.00~~
$198.90
Save: 35.84%

SquareTrade Protection Plan

- 3 year: $24.99
- 4 year: $33.99

Subtotal: $198.90

Newegg Marketplace Direct Delivery Service Important Shipping Information

Transcend 32 GB SATA III 6Gb/s MTS400 42 mm M.2 SSD Solid State Drive TS32GMTS400

Form Factor: M.2 / **Capacity:** 32GB

Sold by CH-Apple

1 IN STOCK

$89.99

SquareTrade Protection Plan

- 3 year: $6.99
- 4 year: $9.99

Recover Your Data View Details

Subtotal: $89.99

Shipping Options

Shipping: $0.00

Please enter your Zip Code so we can show you the most relevant shipping

Newegg Marketplace Direct Delivery Service Important Shipping Information

Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz LGA 2011 115W BX80635E52670V2 Server Processor

# of Cores: 10-Core / **Operating Frequency:** 2.5 GHz

Sold by E.O.L. Tech Inc.,.

1 IN STOCK

$1,550.00

Subtotal:	$1,550.00
Shipping Options	**Shipping:** $0.00

Newegg Marketplace Direct Delivery Service Important Shipping Information

Black Diamond Memory 16GB (2 x 8GB) 240-Pin DDR3 SDRAM ECC Registered DDR3 1333 (PC3 10600) Server Memory Model ...

Sold by MemoryUp

1 IN STOCK

$72.00

Subtotal:	$72.00
Shipping Options	**Shipping:** $0.00

Newegg Marketplace Direct Delivery Service Important Shipping Information

Intel EXPI9301CTBLK 10/100/1000Mbps PCI-Express Network Adapter

Sold by TDT Technology

SquareTrade Protection Plan

- 3 year: $6.99
- 4 year: $8.99

1 IN STOCK

$26.99

PREMIER JOIN TODAY

Subtotal:	$26.99
Shipping Options	**Shipping:** $0.00

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Shopping Cart

	Price	Quantity
Intel Thermal Solution Cooling Fan/Heatsink for LGA2011 E5-2600 Processors (BXSTS200C) by Intel In Stock prime This is a gift Learn more Delete | Save for later	$35.14 Save $1.79	1

Subtotal (1 item): $35.14

Storage Server:

Motherboard Supermicro MBD-X9SRH-7TF-O (MicroATX)	1	$539.50	$539.50
CPU Fan DYNATRON R13 1U Server CPU FAN	1	$45.71	$45.71
CPU Intel XEON E5 -1620 V2 (Quad Core)	1	$343.94	$343.94
8GB RAM PC3-12800 DDR3-1600MHz 240-Pin	4	$89.49	$357.96

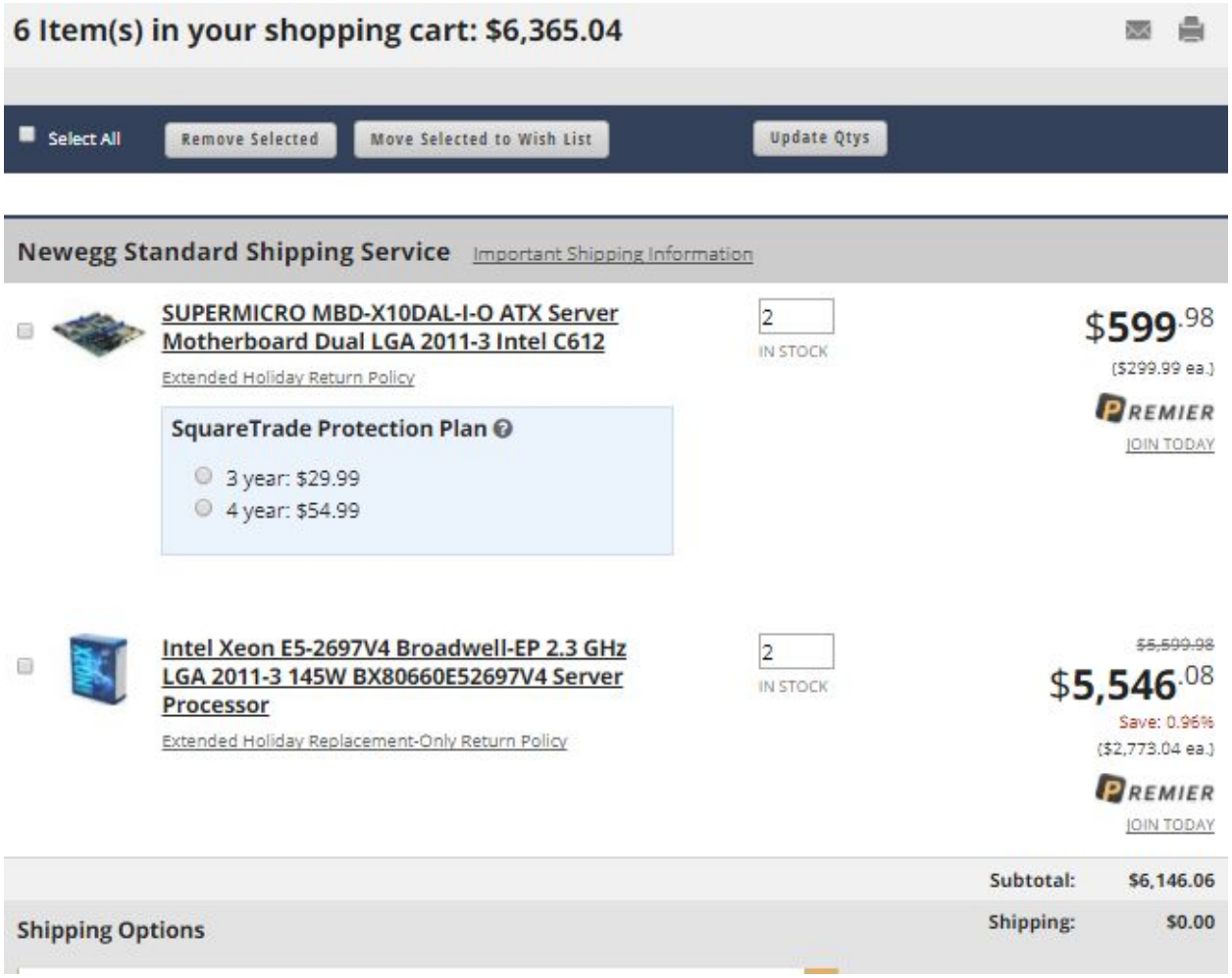
Storage Box + HDD's

Quote #8235728181

pogo [linux]™			Pogo Linux, Inc. 15233 NE 90th ST Redmond, WA 98052 Tel: (888) 828 7646 Fax: (425) 898 2299 www.pogolinux.com
Quote #	**Issue Date:**	**Issue Type:**	
8235728181	Nov 26th, 2017	Website	

Qty	Description	Unit Amount	Extended Amount
1	**Iris 428-60**	**$41,005.16**	**$41,005.16**
	• 4U 60bay Storage Server • Dual Xeon E5-2600v4 Series CPU • Up to 1536GB DDR4 ECC Reg • Flexible Networking Options • Integrated IPMI 2.0 with Dedicated LAN • 2000W Redundant Power Supply		
2	Intel Xeon E5-2603v4 6C 1.7GHz 15MB Cache		
1	16GB DDR4 ECC Reg 2400MHz (2 x 8GB)		
2	Micron M510DC 480GB 2.5â• Enterprise SSD		
50	HGST Ultrastar HE10 10TB 7200RPM SATA 6Gb/s		
1	Dual Port 10G SFP+ Ethernet Module X520		
1	No Operating System. Include testing and customer OS preference in notes.		
1	Return to Depot Warranty (3 Year Hardware Warranty with Standard Advance Parts Replacement)		
Notes:	*none*		

Configuration 3:



Newegg Marketplace Direct Delivery Service Important Shipping Information

Mellanox MHQH19B-XTR 40Gbps PCI Express 2.0 x8 ConnectX 2 VPI - Network adapter

1 IN STOCK

$199.99

Sold by IT WHOLESALERS

SquareTrade Protection Plan

- 3 year: $24.99
- 4 year: $33.99

Subtotal:	**$199.99**
Shipping:	**$0.00**

Shipping Options

Please enter your Zip Code so we can show you the most relevant shipping options for your location.

Choose a delivery method

Standard Shipping (5-7 business days)

Newegg Marketplace Direct Delivery Service Important Shipping Information

KingDian 8GB 16GB 32GB 2.5' SATAII 3Gb/S Internal Solid State Drive SSD (S100 8GB)

1 IN STOCK

$18.99

Form Factor: 2.5" / **Capacity:** 8GB / **Memory Components:** MLC / **Option:** N/A

Sold by KingDian SSD

SquareTrade Protection Plan

- 3 year: $4.99
- 4 year: $6.99

Recover Your Data View Details

Subtotal:	**$18.99**
Shipping:	**$0.00**

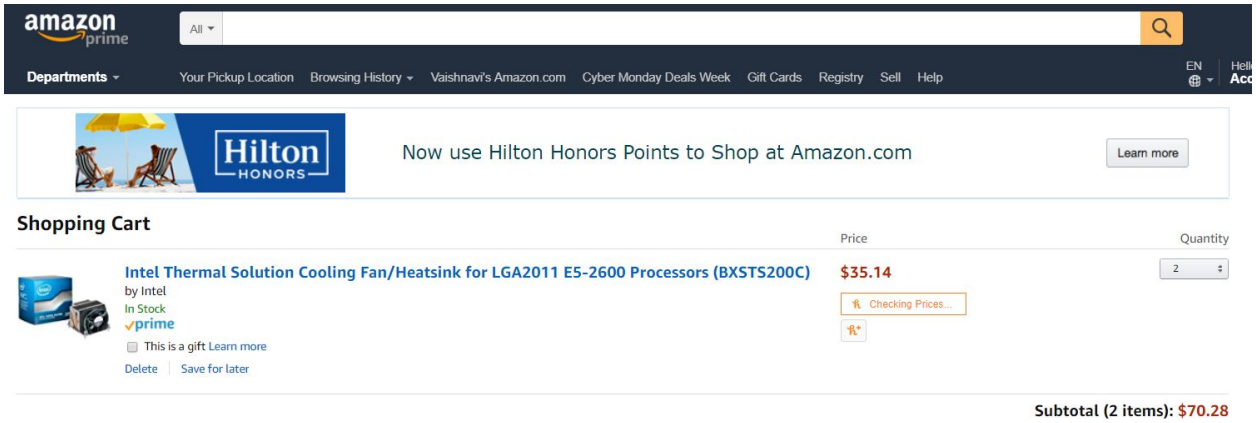
Shipping Options

Shopping Cart

Save Share Print

	Your item	Unit Price	Qty	Weight	Total
	S8050-20Q4C (20*40GE+4*100GE) 40GbE IP Storage and Spine/Aggregation Layer Switch #29126 - 9 pcs in stock, Ready to ship Save for later | Remove	US$ 5,499.00	1	8.3 kg	US$ 5,499.00

Subtotal (Shipping and taxes excluded) : **US$ 5,499.00**



Storage server and HDD's:

Quote #9143785813

pogo [linux]	Pogo Linux, Inc. 15233 NE 90th ST Redmond, WA 98052 Tel: (888) 828 7646 Fax: (425) 898 2299 www.pogolinux.com

Quote #	Issue Date:	Issue Type:	
9143785813	Nov 25th, 2017	Website	

Qty	Description	Unit Amount	Extended Amount
1	**J4601S**	**$39,244.15**	**$39,244.15**
	• 4U 60 Bay JBOD • Up to 600TB Raw Capacity • Dual Expander Modules • Redundant Power Supplies • Rack Mount Rails Included		
1	HGST 4U 60 Bay JBOD with 60 x 10TB Helium SAS HDD (Kepler)		
4	Patch Cable SFF-8644 to SFF-8644 External JBOD 3M		
1	Return to Depot Warranty (5 Year Hardware Warranty with Standard Advance Parts Replacement)		
Notes:	*none*		

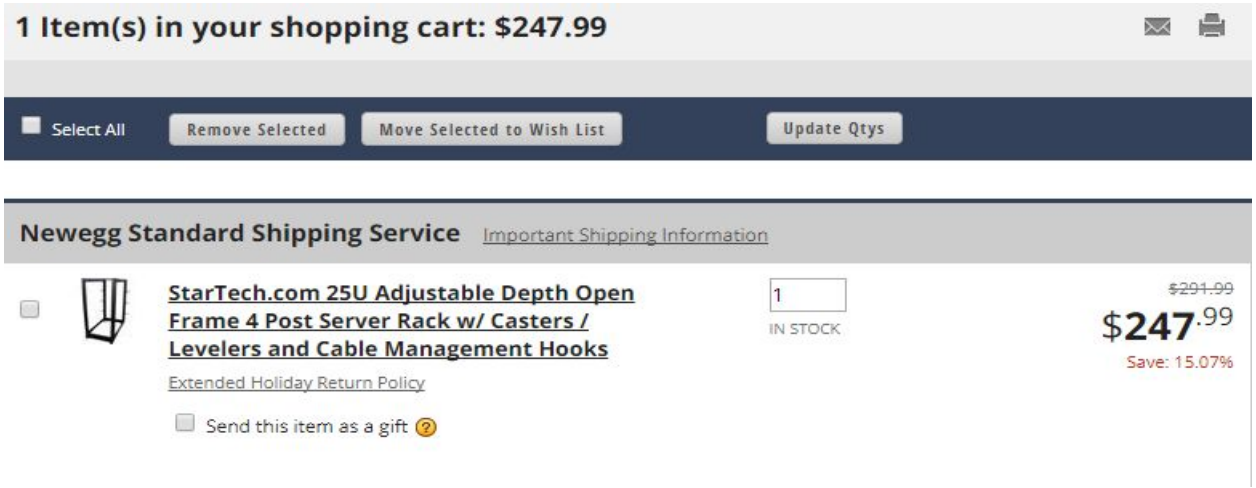
Total		
Suveen	**Subtotal:**	$39,244.15
	Tax:	TBD
	Shipping:	TBD
	Total:	$39,244.15

Standard lead time on new orders is two weeks from credit approval. Due to changing market conditions, pricing is subject to change without notice. If shipping is not included on the quote, actual shipping costs will be added to the final invoice.

For details on the Terms and Conditions of this transaction, please visit: http://www.pogolinux.com/support/terms-and-conditions.php (the "Terms and Conditions"). For details on our Standard Warranty, please visit: http://www.pogolinux.com/support/standard-warranty.php (the "Standard Warranty"). The terms and provisions of our Terms and Conditions and Standard Warranty are incorporated by reference to this quote. By accepting this quote, you agree to the terms of our Terms and Conditions and Standard Warranty.

Common stuff:

Racks:



Cables:

L-com Item # TRD695SCR-5

List Price	$11.39
Your Price 1-9	**$11.39**
10-24	$11.05
25-99	$10.70
100 +	Call Us

Availability: In Stock
Available for Same Day Shipping
Quantity ADD TO CART
Added to Cart. Proceed to Checkout
Email This Page

References:

1] https://aws.amazon.com/blogs/aws/next-generation-of-dense-storage-instances-for-ec2/
2] https://aws.amazon.com/s3/pricing/
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