

**CS 553: CLOUD COMPUTING**

**Understanding the Cost of Computing in Cloud**

**By**

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## Problem Statement

You are hired by a startup company who is considering using cloud computing instead of building its own infrastructure. There is consensus that a cloud computing software stack at the layer of IaaS will be used, but it's not clear whether the computing resources should be rented from a public cloud on-demand, or whether a private cloud should be purchased. You are tasked to find the cost breakdown of a private cloud, and compare that to what Amazon would charge.

You are to estimate the cost of different configurations for 3 different set of requirements:

- 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 (for pricing comparison, see S3)
- 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 (for pricing comparison, see S3)
- 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 (for pricing comparison, see S3)

## Amazon Instance Types

Amazon EC2 provides wide selection of instance types optimized to fit different use cases. Instance type compromises varying combinations of CPU, Memory, Storage and networking capacity and gives you the flexibility to choose the appropriate mix of resources for your applications. Each instance type includes one or more instance sizes, allowing you to scale your resources to the requirements of your target workload

AWS Cost for making Configuration 1 (5 Years) = \$396,482,700

AWS Cost for making Configuration 2 (5 Years) = \$7,523,993,158.2

AWS Cost for making Configuration 3 (5 Years) = \$208,093,080

### 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.

We need 1041 instances to setup this configuration in AWS along with 100PB S3 Storage. So (d2.8xlarge \* 1041) = \$396,482,700 for 5 years on demand pricing.

### Private Cloud

	Description	Price Per Item	Quantity	Total Price
<b>Computer Servers</b>	AMD EPYC 7601 Processor PS7601BDVIHAF 32Cores 64Threads 2.20GHz 64MB L3 Cache 341GB/s 180W 2P/1P + A+ H11DSi-NT Motherboard Dual AMD EPYC 7000-Series DDR4 SATA3 M.2 PCIe NVMe Dual 10GBase-T IPMI E-ATX	\$4830 + \$610 + \$899.99 + \$460.99 = \$6800.98	1,000 + 1000 + 4000 + 5,000	\$4,830,000 + \$610,000 + \$3,600,000 + \$2,305,000 = \$11,345,000

	+ 64GB PC4-21300 DDR4-2666Mhz Load Reduced ECC Quad Ranked 1.2V Major Brand + 10TB HGST 0F27454 / HUH721010ALE604 - Ultrastar He10 512E SE Enterprise SATA 6.0 Gb/s 7200rpm 256MB 3.5-inch HDD Bulk			
<b>Network Switches</b>	CISCO Catalyst 3750-X Series WS- C3750X-48P-S Switch	\$7,347	48	\$352,656
<b>Network Cables</b>	Supermicro CBL- NTWK-0719 QSFP+ (40GbE) to 4 SFP+ (10GbE) split cable 1m long	\$185	2250	\$416,250
<b>Racks</b>	Rosewill RSWM- 12U001 12U 450mm Deep Single Section Wall Cabinet, Toughened Front Glass Door and Solid Side Panels with Lock	\$953	84	\$80,052
<b>Storage Servers</b>	Promise VTrak J830s-Dual JBOD Storage J830SDNX 4U SAS-to-SAS Dual-Ctrl 4xMiniSAS 24x3.5in SAS2/SATA3 6Gb/s HotSwap R750W + 10TB HGST 0F27454 / HUH721010ALE604 - Ultrastar He10 512E SE Enterprise SATA 6.0 Gb/s	\$5,739 + \$460.99	1,250 + 10,000	\$7,173,750 + \$4,610,000 = \$11,783,450

	7200rpm 256MB 3.5-inch HDD Bulk			
<b>Electric Power</b>	-	-	-	\$946,080
<b>Cooling</b>	Hyper 212 LED Turbo- Red Top Cover is equipped with dual 120mm PWM Fans with red LEDs by Cooler Master	\$44.99	1000	\$7,877,140.92 + \$45000
<b>Administration</b>	-	\$80,000	1	\$4,800,000
<b>Total</b>	-	-	-	\$37,645,628.90

## 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.

We need to support 1 million Virtual Machines. So, the AWS cost for making the above system will be \$7,523,993,158.2 for 5 years on demand pricing.

## Private Cloud

	Description	Price Per Item	Quantity	Total Price
Computer Servers	Velocity P58 (See Attached Image)	\$10,291.76	27,778	\$285,884,509.20
Network Switches	Cisco - SG350X-48P-K9-NA - Cisco SG350X-48P Layer 3 Switch - 48 x Gigabit Ethernet Network, 2 x 10 Gigabit Ethernet	\$1729.99	30,974	\$53,584,710.26
Network Cables	Intel X557T2OCPG1P5/OCPC X557-T2 Dual Port 10GBASE-T (RJ45) Ethernet Network Connection	\$230	58,766	\$13,516,180
Racks	StarTech.com 45U 3300lb High Capacity 4 Post Open Server Equipment Rack - Flat Pack + Tripp Lite 18U Wall-Mount Rack Enclosure Cabinet, Hinged Back, Switch-Depth (SRW18US)	\$897.47 + \$529.99	617 + 1720	\$553,738.99 + \$911,582.8 = \$1,465,321.79
Storage Servers	Iris 428-60 (See Attached Image)	\$57,761.40	14	\$808,659.6
Electric Power	-	-	-	\$109,648,044
Cooling	-	-	-	\$36,549,348
Administration	-	\$80,000	1	\$4,800,000
Total	-	-	-	\$506,256,772.85

### 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.

We need to perform 1 exaflop of mixed precision performance. Here we have taken g3.16x large instances as p3 instance pricing is not yet available along with 1 PB S3 storage. So, the AWS cost for making the above system will be \$208,093,080 for 5 years on demand pricing.

### Private Cloud

	Description	Price Per Item	Quantity	Total Price
<b>Computer Servers</b>	NVIDIA CORP 8-GPU/512GB DGX-1 DL WITH V100 + AMD EPYC 7601 Processor PS7601BDVIHAF 32Cores 64Threads 2.20GHz 64MB L3 Cache 341GB/s 180W 2P/1P	\$154,766.06 + \$4866	1042 + 1	\$161,266,235 + \$4866 = \$161,277,101
<b>Network Switches</b>	CISCO Catalyst 3750-X Series WS-C3750X-48P-S Switch	\$7,347	23	\$168,981
<b>Network Cables</b>	Supermicro CBL-NTWK-0719 QSFP+ (40GbE) to 4 SFP+ (10GbE) split cable 1m long	\$185	1,066	\$197,210
<b>Racks</b>	Rosewill RSWM-12U001 12U 450mm Deep Single Section Wall Cabinet, Toughened Front Glass Door and Solid Side Panels with Lock	\$953	87	\$82,911

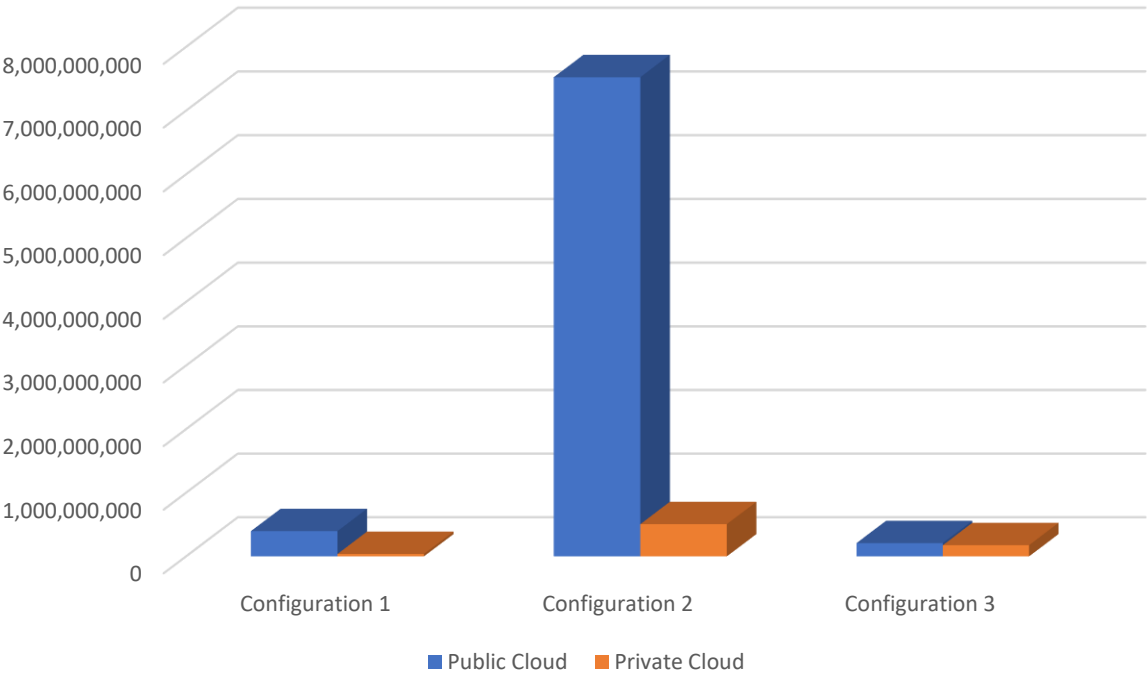
<b>Storage Servers</b>	Promise VTrak J830s-Dual JBOD Storage J830SDNX 4U SAS-to-SAS Dual-Ctrl 4xMiniSAS 24x3.5in SAS2/SATA3 6Gb/s HotSwap R750W + 10TB HGST 0F27454 / HUH721010ALE604 - Ultrastar He10 512E SE Enterprise SATA 6.0 Gb/s 7200rpm 256MB 3.5-inch HDD Bulk	\$5739 + 460	25 + 100	\$143,475 + \$46000 = \$189,475
<b>Electric Power</b>	-	-	-	\$946,080
<b>Cooling</b>	Hyper 212 LED Turbo-Red Top Cover is equipped with dual 120mm PWM Fans with red LEDs by Cooler Master	\$44.99	1000	\$7,977,140.92 + \$45,000
<b>Administration</b>	-	\$80,000	1	\$4,800,000
<b>Total</b>	-	-	-	\$175,593,899



## Conclusion

	Configuration 1	Configuration 2	Configuration 3
<b>Public Cloud (including EC2 and S3) Cost over 5 years, 24/7 operation, with 100% usage</b>	\$396,482,700	\$7,523,993,158.2	\$208,093,080
<b>Private Cloud cost over 5 years, 24/7 operation, with 100% usage</b>	\$37,645,628.90	\$506,256,772.85	\$175,593,899
<b>What utilization must be achieved with the private cloud to make the private cloud option more attractive than the public cloud?</b>	<p>Here, the private cloud is working cheaper than public cloud because we have a Private cloud on large scale. After understanding the concepts of cloud costs, we can say for small loads public cloud is better than private clouds.</p> <p>We see for 100 % Virtual Machine Utilization, in this case private cloud is a much more attractive option in the long run.</p> <p>There are another factor also which effects on choosing a cloud which is Location, Human Resource, Climate, Infrastructure etc.</p>	<p>Here, the private cloud is working cheaper than public cloud because we have a Private cloud on large scale. After understanding the concepts of cloud costs, we can say for small loads public cloud is better than private clouds.</p> <p>We see for 100 % Virtual Machine Utilization, in this case private cloud is a much more attractive option in the long run.</p> <p>There are another factor also which effects on choosing a cloud which is Location, Human Resource, Climate, Infrastructure etc.</p>	<p>Here, the private cloud is working cheaper than public cloud because we have a Private cloud on large scale. After understanding the concepts of cloud costs, we can say for small loads public cloud is better than private clouds.</p> <p>We see for 100 % Virtual Machine Utilization, in this case private cloud is a much more attractive option in the long run.</p> <p>There are another factor also which effects on choosing a cloud which is Location, Human Resource, Climate, Infrastructure etc.</p>

Understanding the Cost of Computing in Cloud



## Assumptions

- No Data Security Concerns are considered.
- Each System Administrator handles 1000 machines
- Electricity Cost Rate is taken of all around USA area which is \$0.12 per kWh.
- Electricity = ((Operating Hours \* Watt Usage Per hour) / 1000) = kWh \* Electricity cost per kWh
- Rent for Land and Infrastructure is not considered.
- We have used no electricity other than powering and Cooling the system.
- <https://www.vmguru.com/2011/06/how-to-calculate-electrical-costs-for-cooling-and-power-consumption/>

## References

- <http://www.acmemicro.com/>
- <http://www.pogolinux.com/>
- <http://calculator.s3.amazonaws.com/index.html?key=calc-66EED67E-8369-42F2-A19F-495BE8840EE6>
- <https://aws.amazon.com/ec2/instance-types/>
- <https://aws.amazon.com/ec2/pricing/>
- <https://www.vmguru.com/2011/06/how-to-calculate-electrical-costs-for-cooling-and-power-consumption/>
- <https://www.newegg.com/>
- <http://nextwarehouse.com/>

Appendix

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64GB PC4-21300 DDR4-2666Mhz Load Reduced ECC Quad  
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HDD Bulk



Supermicro CBL-NTWK-0719 QSFP+ (40GbE) to 4 SFP+  
(10GbE) split cable 1m long



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AMD EPYC 7601 Processor PS7601BDVIHAF 32Cores  
64Threads 2.20GHz 64MB L3 Cache 341GB/s 180W 2P/1P



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MB-SM-H11DSINT	\$610	<input type="text" value="1"/>	\$610
DR4-64G-LR21300E	\$899.99	<input type="text" value="1"/>	\$899.99
HD-HI-0F27454	\$460.99	<input type="text" value="1"/>	\$460.99
CAB-SM-0719	\$185	<input type="text" value="1000"/>	\$185,000
CP-AD-PS7601BDVIHAF	\$4,830	<input type="text" value="1"/>	\$4,830

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Part Number: 920-22787-2510-000, Item #: 2707240





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<input type="checkbox"/>	 <b><u>Rosewill RSWM-12U001 12U 450mm Deep Single Section Wall Cabinet, Toughened Front Glass Door and Solid Side Panels with ...</u></b> <a href="#">Extended Holiday Return Policy</a>	<input type="text" value="1"/> IN STOCK	<del>\$299.99</del> <b>\$209.99</b> Save: 30.00%
<input type="checkbox"/>	 <b><u>iStarUSA WA-SF96B-1U 1U Heavy Duty Rackmount Shelf</u></b> <a href="#">Extended Holiday Return Policy</a>	<input type="text" value="1"/> IN STOCK	<del>\$88.99</del> <b>\$62.99</b> Save: 29.22% <b>PREMIER</b> <a href="#">JOIN TODAY</a>

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1	Velocity P58	view components	\$10,291.76	\$10,291.76	<a href="#">Edit System</a> <a href="#">Delete System</a>
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**Memory**  
1x 16GB DDR4 ECC Reg 2400MHz (2 x 8GB) \$0.00

### HARD DISK DRIVES

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1x HGST Ultrastar 2TB 7200RPM SATA 6Gb/s \$0.00

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<p><b>Specs:</b></p> <ul style="list-style-type: none"><li><b>CPU:</b> 2x Intel Xeon E5-2603v4 6C 1.7GHz 10MB Cache</li><li><b>Memory:</b> 1x 16GB DDR4 ECC Reg 2400MHz (2 x 8GB)</li><li><b>Storage:</b> 2x Micron M2100C 480GB 2.5" Enterprise SSD</li><li><b>Enterprise HDD:</b> 5x HGST Ultrastar HE12 15TB 7200RPM SAS 12Gb/s</li><li><b>Networking Options:</b> 1x Dual Port Gigabit Ethernet Module</li><li><b>OS:</b> 1x Red Hat Enterprise Linux 7.5 (64-bit) with customer OS preference in notes.</li><li><b>Warranty:</b> 1x Return to Depot Warranty (3 Year Hardware Warranty with Standard Advance Parts Replacement)</li></ul> <p>close</p>					
1	Velocity P58	view components	\$10,291.76	\$10,291.76	<a href="#">Edit System</a> <a href="#">Delete System</a>
<p><b>Specs:</b></p> <ul style="list-style-type: none"><li><b>CPU:</b> 1x Intel Xeon Phi Processor 7290 72C 1.5GHz</li><li><b>Memory:</b> 1x 16GB DDR4 ECC Reg 2400MHz (2 x 8GB)</li><li><b>HDD 1:</b> 1x HGST Ultrastar 2TB 7200RPM SATA 6Gb/s</li><li><b>Graphics Card:</b> 1x NVIDIA G770 2GB PCI-E 1x DVI-D 1x HDMI 1x VGA</li><li><b>Operating System:</b> 1x CentOS 7 64bit</li><li><b>Warranty and Support:</b> 1x Return to Depot Warranty (3 Year Hardware Warranty with Standard Advance Parts Replacement)</li></ul> <p>close</p>					
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