**CS 553**
**CLOUD COMPUTING**
**PROJECT**
**"UNDERSTANDING THE COST OF COMPUTING IN THE CLOUD"**

**SUBMITTED BY :**
**SACHIN KRISHNA MURTHY**
**CWID : A20354077**

# UNDERSTANDING THE COST OF COMPUTING IN THE CLOUD

Basically cloud storage is required for saving the data in large scales but the cost of these cloud storage is a big issue. Mainly there is a need for a lower cost cloud storage systems that can be used by the individual users.

Usually cloud storage is beneficial for the users for having back up of their data, since they do not need to access their data often nor they do not need to have a parallel access to their data from different locations at the same time. Hence a storage system that provides services to this type of users can make assumptions on lower availability rate and lower bandwidth.

On the other hand reliability and fault tolerance are the two main challenges in online storage systems. Therefore in order to provide a reliable system, the storage providers need to use more than 3 times the size of the data. But the usage of dispersed storage systems helps the storage providers to save their resources by the usage of only 1.2 times the size of the data through which they can provide a reliable system.

Hence, we can say that the design, price and performance of the components plays a vital role in systems reliability. Here we are trying to build the storage systems by making use of the components with the least cost as possible. As a result these systems will be in turn beneficial for the individual users.

> **Tables:**

For the below calculations and experiments performed double precision FLOPS per clock is considered.

> **Public Cloud:**

The below table gives the details of the cost computed per hour and per GFLOP for Amazon EC2 instances.

Formula used for calculation:

GFLOP = Number of Cores * IPC * Clock Speed

Cost per GFLOP per hour = Instance Cost per hour / GFLOP

| Instance Type | No. of Cores | IPC | Clock Speed(GHz) | GFLOPS | Instance Cost per hour | Cost per GFLOP per hour-Computation in GFLOP | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 1 | 10 | 100 | 1000 | 10000 | 100000 | 1000000 |
| m4.10xlarge | 20 | 16 | 2.4 | 768 | 2.394 | 0.003117 | 0.003117 | 0.003117 | 0.003117 | 0.003117 | 0.003117 | 0.003117 |
| m3.large | 1 | 8 | 2.5 | 20 | 0.133 | 0.0065 | 0.0065 | 0.0065 | 0.0065 | 0.0065 | 0.0065 | 0.0065 |
| m3.2xlarge | 4 | 8 | 2.5 | 80 | 0.532 | 0.00665 | 0.00665 | 0.00665 | 0.00665 | 0.00665 | 0.00665 | 0.00665 |
| c3.8xlarge | 16 | 8 | 2.8 | 358.4 | 1.68 | 0.004688 | 0.004688 | 0.004688 | 0.004688 | 0.004688 | 0.004688 | 0.004688 |
| g2.2xlarge | 4 | 16 | 2.6 | 166.4 | 0.65 | 0.003906 | 0.003906 | 0.003906 | 0.003906 | 0.003906 | 0.003906 | 0.003906 |
| r3.4xlarge | 8 | 8 | 2.5 | 160 | 1.33 | 0.008313 | 0.008313 | 0.008313 | 0.008313 | 0.008313 | 0.008313 | 0.008313 |
| i2.8xlarge | 16 | 8 | 2.5 | 320 | 6.82 | 0.021313 | 0.021313 | 0.021313 | 0.021313 | 0.021313 | 0.021313 | 0.021313 |
| d2.8xlarge | 18 | 16 | 2.4 | 691.2 | 5.52 | 0.007986 | 0.007986 | 0.007986 | 0.007986 | 0.007986 | 0.007986 | 0.007986 |

> ➤ **Private Cloud:**

Here we compute the cost of the private cloud on the specified instances which enables us to compare the cost of the private and the cost of the public cloud.

The following factors are considered while building our private cloud:

- CPU
- Memory
- Motherboard
- Case
- Disk
- Network card ( Network Adapter and Network Switch )
- Administration
- Racks
- Power supply
- Cooling Power

The below tables shows the components and the cost calculation for 8 different types of instances: m4.10xlarge, m3.large, m3.2xlarge, c3.8xlarge, g2.2xlarge, r3.4xlarge, i2.8xlarge and d2.8xlarge.

The components to build the cloud are considered in order to obtain the least cost.

The administration cost is considered as 100000$ per year for 1000 instances and the cost of the power supply is considered as 6.78 cents per kWH.

Formula used for calculation of cost per hour per GFLOP :

Total Cost / (5*24*365*Number of GFLOPS)

➤ **m4.10xlarge**

| m4.10xlarge | |
|---|---|
| CPU | Intel Xeon E5-2640 V4 2.4 GHz LGA 2011 90W BX80660E52640V4 Server Processor |
| Memory | Black Diamond Memory 64GB 288-Pin DDR4 SDRAM ECC Registered DDR4 2133 (PC4 17000) Server Memory Model BD64G2133MQR96 |
| Motherboard | SUPERMICRO MBD-X10DRI-LN4+-O Enhanced Extended ATX Xeon Server Motherboard Dual LGA 2011 Intel C612 |
| Case | ARK 4U-500-CA Black 4U Rackmount Case |
| Disk | TOSHIBA DT01ACA050 500GB 7200 RPM 32MB Cache SATA 6.0Gb/s 3.5" Internal Hard Drive Bare Drive |
| Network Card | Network Adapter | AddOn - Network Upgrades 49Y7970-AOK 10Gbps PCI-Express Network Adapter |
| | Network Switch | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty |
| Administration | |
| Racks | iStarUSA WM1260B 12U 600mm Depth Wallmount Server Cabinet |
| Power Supply | 720W |
| Cooling Power | 360W |

| | | | 1G | 1 | 10G | 1 | 100G | 1 | 1T | 2 | 10T | 13 | 100T | 131 | 1P | 1303 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| m4.10xlarge | | | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost |
| CPU | | 989.99 | 2 | 1979.98 | | | | | | | | | | | | |
| Memory | | 899.99 | 3 | 2699.97 | | | | | | | | | | | | |
| Motherboard | | 548.99 | 1 | 548.99 | | | | | | | | | | | | |
| Case | | 89.99 | 1 | 89.99 | | | | | | | | | | | | |
| Disk | | 44.99 | 1 | 44.99 | | | | | | | | | | | | |
| Network Card | Network Adapter | 361.99 | | 361.99 | | | | | | | | | | | | |
| | | | | 5725.91 | | 5725.91 | | 5725.91 | | 11451.82 | | 74436.83 | | 750094.21 | | 7460860.73 |
| | Network Switch | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 | 849.99 | 2 | 1699.98 | 3 (52-port) | 6149.97 | 26 | 22099.74 |
| Administration | | 100000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 2 | 1000000 |
| Racks | | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 2 | 299.98 | 11 | 1649.89 | 109 | 16348.91 |
| Power Supply | | | | 2138.14 | | 2138.14 | | 2138.14 | | 4276.28 | | 27795.82 | | 280096.34 | | 2785996.42 |
| Cooling Power | | | | 1069.07 | | 1069.07 | | 1069.07 | | 2138.14 | | 13897.91 | | 140048.17 | | 1392998.21 |
| | | | | 509933.1 | | 509933.1 | | 509933.1 | | 518866.22 | | 618130.52 | | 1678038.58 | | 12678304.01 |
| 5 Years Amortized Cost | | | 1 | 11.6423082 | 10 | 1.164231 | 100 | 0.116423082 | 1000 | 0.011846261 | 10000 | 0.001411257 | 100000 | 0.000383114 | 1000000 | 0.000289459 |

➤ **m3.large**

| m3.large | |
|---|---|
| CPU | Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz LGA 2011 115W BX80635E52670V2 Server Processor |
| Memory | Axiom 8GB (2 x 4GB) 240-Pin DDR2 SDRAM ECC ECC Chipkill Fully Buffered DDR2 667 (PC2 5300) Server Memory Model 39M5797-AX |
| Motherboard | SUPERMICRO MBD-X10DRI-LN4+-O Enhanced Extended ATX Xeon Server Motherboard Dual LGA 2011 Intel C612 |
| Case | ARK 4U-500-CA Black 4U Rackmount Case |
| Disk | Transcend MTS600 M.2 32GB SATA III MLC Internal Solid State Drive (SSD) TS32GMTS600 |
| Network Card | Network Adapter | TP-LINK TG-3468 10/ 100/ 1000Mbps PCI-Express Network Adapter |
| | Network Switch | TP-LINK TL-SG1005D 10/100/1000Mbps Unmanaged 5-Port Gigabit Desktop Switch, Power-Saving |
| Administration | |
| Racks | iStarUSA WM1260B 12U 600mm Depth Wallmount Server Cabinet |
| Power Consumption | 300W |
| Cooling Power Consumption | 150W |

| m3.large | | | 1G | 1 | 10G | 1 | 100G | 5 | 1T | 50 | 10T | 500 | 100T | 5000 | 1P | 50000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost |
| CPU | | 1559.99 | | | | | | | | | | | | | | |
| Memory | | 194.99 | | | | | | | | | | | | | | |
| Motherboard | | 548.99 | | | | | | | | | | | | | | |
| Case | | 89.99 | | | | | | | | | | | | | | |
| Disk | | 30.67 | | | | | | | | | | | | | | |
| Network Card | Network Adapter | 11.99 | | | | | | | | | | | | | | |
| | | 2436.62 | | 2436.62 | | 2436.62 | | 12183.1 | | 121831 | | 1218310 | | 12183100 | | 121831000 |
| | Network Switch | 15.99 | 1 | 15.99 | 1 | 15.99 | 1 | 15.99 | 10 | 159.9 | 100 | 1599 | 1000 | 15990 | 10000 | 159900 |
| Administration | | 100000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 5 | 2500000 | 50 | 25000000 |
| Racks | | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 5 | 749.95 | 42 | 6299.58 | 417 | 62545.83 | 4167 | 625008.33 |
| Power Consumption | | | | 890.892 | | 890.892 | | 4454.46 | | 44544.6 | | 445446 | | 4454460 | | 44544600 |
| Cooling Power Consumption | | | | 445.556 | | 445.556 | | 2227.78 | | 22277.8 | | 222778 | | 2227780 | | 22277800 |
| | | | | 503939.048 | | 503939 | | 519031.32 | | 689563.25 | | 2394432.58 | | 21443875.83 | | 214438308.3 |
| | | | | 11.5054577 | | 11.50546 | | 11.85003014 | | 15.7434532 | | 54.6674105 | | 489.5862062 | | 4895.851788 |
| 5 Years Amortized Cost | | | | 11.5054577 | | 1.150546 | | 0.118500301 | | 0.015743453 | | 0.005466741 | | 0.004895862 | | 0.004895852 |

> ## m3.2xlarge

| m3.2xlarge | | |
|---|---|---|
| CPU | | Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz LGA 2011 115W BX80635E52670V2 Server Processor |
| Memory | | SAMSUNG 32GB 288-Pin DDR4 SDRAM DDR4 2133 (PC4 17000) Server Memory Model M386A4G40DM0-CPB |
| Motherboard | | SUPERMICRO MBD-X10DRI-LN4+-O Enhanced Extended ATX Xeon Server Motherboard Dual LGA 2011 Intel C612 |
| Case | | ARK 4U-500-CA Black 4U Rackmount Case |
| Disk | | Intel X25-M 160GB 2.5 SATA II MLC Internal Solid State Drive 43N3435 for Lenovo ThinkPad |
| Network Card | Network Adapter | TP-LINK TG-3468 10/ 100/ 1000Mbps PCI-Express Network Adapter |
| | Network Switch | TP-LINK TL-SG1005D 10/100/1000Mbps Unmanaged 5-Port Gigabit Desktop Switch, Power-Saving |
| Administration | | |
| Racks | | iStarUSA WM1260B 12U 600mm Depth Wallmount Server Cabinet |
| Power Supply | | 300W |
| Cooling Power | | 150W |

| m3.2xlarge | | | 1G | 1 | 10G | 1 | 100G | 3 | 1T | 13 | 10T | 125 | 100T | 1250 | 1P | 12500 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost |
| CPU | | 1559.99 | | | | | | | | | | | | | | |
| Memory | | 222.99 | | | | | | | | | | | | | | |
| Motherboard | | 548.99 | | | | | | | | | | | | | | |
| Case | | 89.99 | | | | | | | | | | | | | | |
| Disk | | 119.89 | | | | | | | | | | | | | | |
| Network Card | Network Adapter | 11.99 | | | | | | | | | | | | | | |
| | | 2553.84 | | 2553.84 | | 2553.84 | | 7661.52 | | 33199.92 | | 319230 | | 3192300 | | 31923000 |
| | Network Switch | 15.99 | 1 | 15.99 | 1 | 15.99 | 1 | 15.99 | 3 | 47.97 | 25 | 399.75 | 250 | 3997.5 | | 39975 |
| Administration | | 100000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 2 | 1000000 | 13 | 6500000 |
| Racks | | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 2 | 299.98 | 11 | 1649.89 | 105 | 15748.95 | 1042 | 156289.58 |
| Power Supply | | | | 890.892 | | 890.892 | | 2672.676 | | 11581.596 | | 111361.5 | | 1113615 | | 11136150 |
| Cooling Power | | | | 445.556 | | 445.556 | | 1336.668 | | 5792.228 | | 55694.5 | | 556945 | | 5569450 |
| | | | | 504056.268 | | 504056.3 | | 511836.844 | | 550921.694 | | 988335.64 | | 5882606.45 | | 55324864.58 |
| | | | | 11.508134 | | 11.50813 | | 11.68577269 | | 12.57812087 | | 22.56474064 | | 134.3060833 | | 1263.124762 |
| 5 Years Amortized Cost | | | | 11.508134 | | 1.150813 | | 0.116857727 | | 0.012578121 | | 0.002256474 | | 0.001343061 | | 0.001263125 |

| c3.8xlarge | | |
|---|---|---|
| CPU | | Intel Xeon E5-2680 v2 Ivy Bridge-EP 2.8 GHz LGA 2011 115W BX80635E52680V2 Server Processor |
| Memory | | Black Diamond Memory 64GB 288-Pin DDR4 SDRAM ECC Registered DDR4 2133 (PC4 17000) Server Memory Model BD64G2133MQR96 |
| Motherboard | | SUPERMICRO MBD-X10DRI-LN4+-O Enhanced Extended ATX Xeon Server Motherboard Dual LGA 2011 Intel C612 |
| Case | | ARK 4U-500-CA Black 4U Rackmount Case |
| Disk | | Intel 535 Series 2.5" 360GB SATA III MLC Internal Solid State Drive (SSD) SSDSC2BW360H601 |
| Network Card | Network Adapter | AddOn - Network Upgrades 49Y7970-AOK 10Gbps PCI-Express Network Adapter |
| | Network Switch | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty |
| Administration | | |
| Racks | | iStarUSA WM1260B 12U 600mm Depth Wallmount Server Cabinet |
| Power Supply | | 720W |
| Cooling Power | | 360W |

| | | | 1G | 1 | 10G | 1 | 100G | 1 | 1T | 3 | 10T | 28 | 100T | 280 | 1P | 2791 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| c3.8xlarge | | | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost |
| CPU | | 1769.99 | 2 | 3539.98 | | | | | | | | | | | | |
| Memory | | 899.99 | 1 | 899.99 | | | | | | | | | | | | |
| Motherboard | | 548.99 | 1 | 548.99 | | | | | | | | | | | | |
| Case | | 89.99 | 1 | 89.99 | | | | | | | | | | | | |
| Disk | | 183 | 2 | 366 | | | | | | | | | | | | |
| Network Card | Network Adapter | 361.99 | 1 | 361.99 | | | | | | | | | | | | |
| | | | | 5806.94 | | 5806.94 | | 5806.94 | | 17420.82 | | 162594.32 | | 1625943.2 | | 16207169.54 |
| | Network Switch | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 (52-p | 2049.99 | 6 | 12299.94 | 54 | 110699.46 |
| Administration | | 100000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 3 | 1500000 |
| Racks | | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 3 | 449.97 | 24 | 3599.76 | 233 | 34947.67 |
| Power Supply | | | | 2138.14 | | 2138.14 | | 2138.14 | | 6414.42 | | 59867.92 | | 598679.2 | | 5967548.74 |
| Cooling Power | | | | 1069.07 | | 1069.07 | | 1069.07 | | 3207.21 | | 29933.96 | | 299339.6 | | 2983774.37 |
| | | | | 510014.13 | | 510014.1 | | 510014.13 | | 528042.43 | | 754896.16 | | 3039861.7 | | 26804139.78 |
| 5 Years Amortized Cost | | | 1 | 11.6441582 | 10 | 1.164416 | 100 | 0.116441582 | 1000 | 0.012055763 | 10000 | 0.001723507 | 100000 | 0.000694032 | 1000000 | 0.000611967 |

➢ **g2.2xlarge**

| g2.2xlarge | | |
|---|---|---|
| CPU | | Intel Xeon E5-2670 Sandy Bridge-EP 2.6GHz (3.3GHz Turbo Boost) LGA 2011 115W BX80621E52670 Server Processor |
| Memory | | SAMSUNG 16GB 288-Pin DDR4 SDRAM ECC Registered DDR4 2133 (PC4 17000) Server Memory Model M393A2G40DB0-CPB |
| Motherboard | | SUPERMICRO MBD-X10DRI-LN4+-O Enhanced Extended ATX Xeon Server Motherboard Dual LGA 2011 Intel C612 |
| Case | | ARK 4U-500-CA Black 4U Rackmount Case |
| Disk | | Netac N5m mSATA Interface SSD Disk 60GB Internal Solid State Drive Disc MLC Flash Storage Devices for Desktoo Laptop |
| Network Card | Network Adapter | TP-LINK TG-3468 10/ 100/ 1000Mbps PCI-Express Network Adapter |
| | Network Switch | TP-LINK TL-SG1005D 10/100/1000Mbps Unmanaged 5-Port Gigabit Desktop Switch, Power-Saving |
| Administration | | |
| Racks | | iStarUSA WM1260B 12U 600mm Depth Wallmount Server Cabinet |
| Power Supply | | 300W |
| Cooling Power | | 150W |

| g2.2xlarge | | | 1G | 1 | 10G | 1 | 100G | 1 | 1T | 6 | 10T | 61 | 100T | 601 | 1P | 6010 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost |
| CPU | | 575 | | | | | | | | | | | | | | |
| Memory | | 109.99 | | | | | | | | | | | | | | |
| Motherboard | | 548.99 | | | | | | | | | | | | | | |
| Case | | 89.99 | | | | | | | | | | | | | | |
| Disk | | 43.99 | | | | | | | | | | | | | | |
| Network Card | Network Adapter | 11.99 | | | | | | | | | | | | | | |
| | | 1379.95 | | 1379.95 | | 1379.95 | | 1379.95 | | 8279.7 | | 84176.95 | | 829349.95 | | 8293499.5 |
| | Network Switch | 15.99 | 1 | 15.99 | 1 | 15.99 | 1 | 15.99 | 2 | 31.98 | 13 | 207.87 | 121 | 1934.79 | 1202 | 19219.98 |
| Administration | | 100000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 7 | 3500000 |
| Racks | | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 6 | 899.94 | 51 | 7649.49 | 501 | 75144.99 |
| Power Supply | | | | 890.892 | | 890.892 | | 890.892 | | 5345.352 | | 54344.412 | | 535426.092 | | 5354260.92 |
| Cooling Power | | | | 445.556 | | 445.556 | | 445.556 | | 2673.336 | | 27178.916 | | 267779.156 | | 2677791.56 |
| | | | | 502882.378 | | 502882.4 | | 502882.378 | | 516480.358 | | 666808.088 | | 2142139.478 | | 19919916.95 |
| 5 Years Amortized Cost | | | 1 | 11.4813328 | 10 | 1.148133 | 100 | 0.114813328 | 1000 | 0.011791789 | 10000 | 0.001522393 | 100000 | 0.000489073 | 1000000 | 0.000454793 |

➢ **r3.4xlarge**

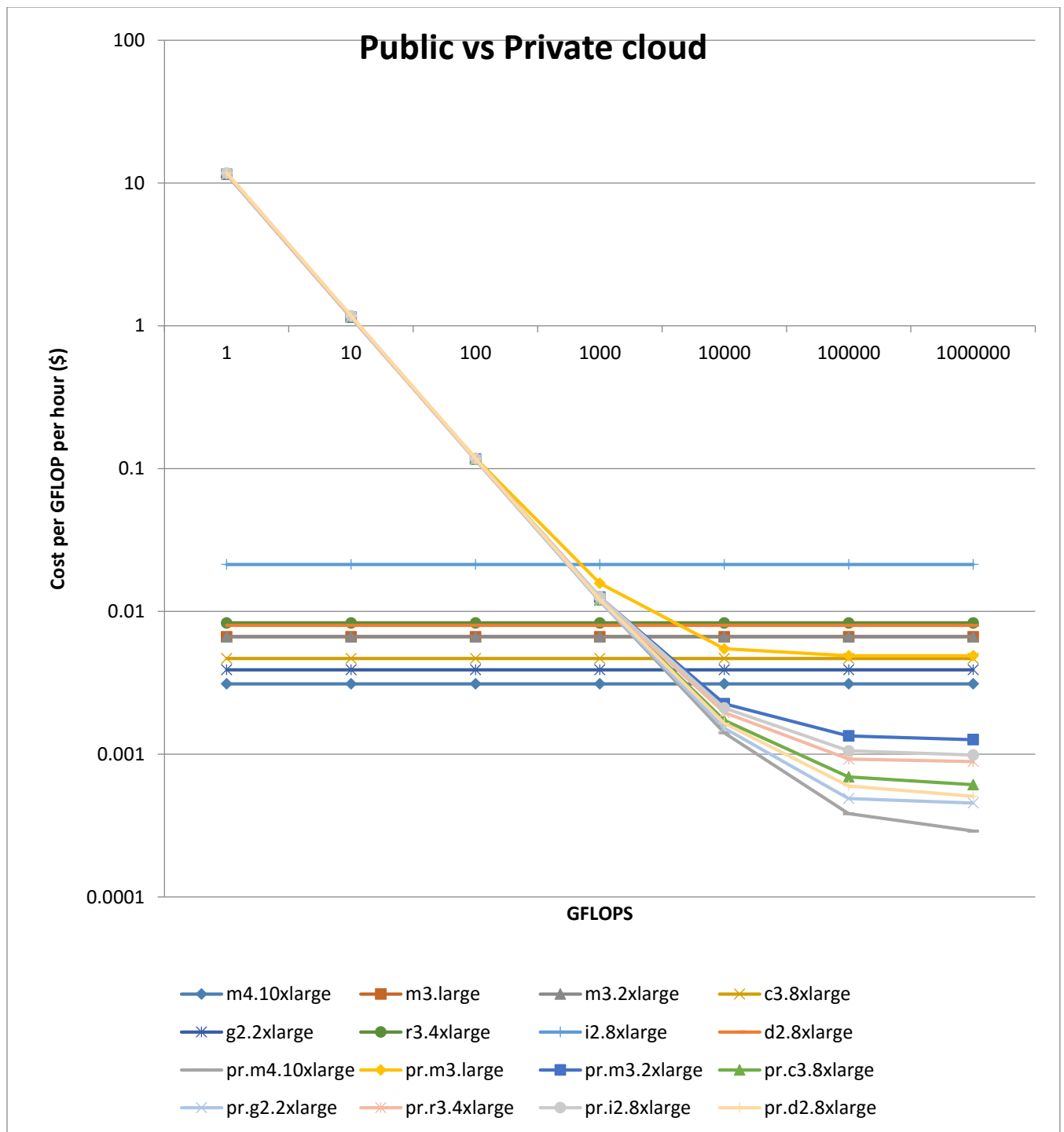| r3.4xlarge | | |
|---|---|---|
| CPU | | Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz LGA 2011 115W BX80635E52670V2 Server Processor |
| Memory | | Black Diamond Memory 128GB (2 x 64GB) 288-Pin DDR4 SDRAM ECC Registered DDR4 2133 (PC4 17000) Server Memory Model BD64GX22133MQR96 |
| Motherboard | | SUPERMICRO MBD-X10DRI-LN4+-O Enhanced Extended ATX Xeon Server Motherboard Dual LGA 2011 Intel C612 |
| Case | | ARK 4U-500-CA Black 4U Rackmount Case |
| Disk | | Intel 535 Series 2.5" 360GB SATA III MLC Internal Solid State Drive (SSD) SSDSC2BW360H601 |
| Network Card | Network Adapter | TP-LINK TG-3468 10/ 100/ 1000Mbps PCI-Express Network Adapter |
| | Network Switch | TP-LINK TL-SG1005D 10/100/1000Mbps Unmanaged 5-Port Gigabit Desktop Switch, Power-Saving |
| Administration | | |
| Racks | | iStarUSA WM1260B 12U 600mm Depth Wallmount Server Cabinet |
| Power Supply | | 300W |
| Cooling Power | | 150W |

| r3.4xlarge | | | 1G | 1 | 10G | 1 | 100G | 1 | 1T | 7 | 10T | 63 | 100T | 625 | 1P | 6250 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost |
| CPU | | 1559.99 | | | | | | | | | | | | | | |
| Memory | | 1899.99 | | | | | | | | | | | | | | |
| Motherboard | | 548.99 | | | | | | | | | | | | | | |
| Case | | 89.99 | | | | | | | | | | | | | | |
| Disk | | 199.99 | | | | | | | | | | | | | | |
| Network Card | Network Adapter | 11.99 | | | | | | | | | | | | | | |
| | | 4310.94 | | 4310.94 | | 4310.94 | | 4310.94 | | 30176.58 | | 271589.22 | | 2694337.5 | | 26943375 |
| | Network Switch | 15.99 | 1 | 15.99 | 1 | 15.99 | 1 | 15.99 | 2 | 31.98 | 13 | 207.87 | 125 | 1998.75 | 1250 | 19987.5 |
| Administration | | 100000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 7 | 3500000 |
| Racks | | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 6 | 899.94 | 53 | 7949.47 | 521 | 78144.79 |
| Power Supply | | | | 890.892 | | 890.892 | | 890.892 | | 6236.244 | | 56126.196 | | 556807.5 | | 5568075 |
| Cooling Power | | | | 445.556 | | 445.556 | | 445.556 | | 3118.892 | | 28070.028 | | 278472.5 | | 2784725 |
| | | | | 505813.368 | | 505813.4 | | 505813.368 | | 539713.686 | | 856893.254 | | 4039565.72 | | 38894307.29 |
| | | | | 11.5482504 | | 11.54825 | | 11.54825041 | | 12.32223027 | | 19.56377292 | | 92.22752785 | | 887.9978833 |
| 5 Years Amortized Cost | | | | 11.5482504 | | 1.154825 | | 0.115482504 | | 0.01232223 | | 0.001956377 | | 0.000922275 | | 0.000887998 |

➢ **i2.8xlarge**

| i2.8xlarge | | |
|---|---|---|
| CPU | | Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz LGA 2011 115W BX80635E52670V2 Server Processor |
| Memory | | Black Diamond Memory 128GB (2 x 64GB) 288-Pin DDR4 SDRAM ECC Registered DDR4 2133 (PC4 17000) Server Memory Model BD64GX22133MQR96 |
| Motherboard | | SUPERMICRO MBD-X10DRI-LN4+-O Enhanced Extended ATX Xeon Server Motherboard Dual LGA 2011 Intel C612 |
| Case | | ARK 4U-500-CA Black 4U Rackmount Case |
| Disk | | CUK Cyclone 2TB 7mm 2.5-Inch SATA III Internal Solid State Drive (SSD) |
| Network Card | Network Adapter | AddOn - Network Upgrades 49Y7970-AOK 10Gbps PCI-Express Network Adapter |
| | Network Switch | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty |
| Administration | | |
| Racks | | iStarUSA WM1260B 12U 600mm Depth Wallmount Server Cabinet |
| Power Supply | | 720W |
| Cooling Power | | 360W |

| | | | 1G | 1 | 10G | 1 | 100G | 1 | 1T | 4 | 10T | 32 | 100T | 313 | 1P | 3125 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| i2.8xlarge | | | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost |
| CPU | | 1559.99 | 2 | 3119.98 | | | | | | | | | | | | |
| Memory | | 1899.99 | 2 | 3799.98 | | | | | | | | | | | | |
| Motherboard | | 548.99 | 1 | 548.99 | | | | | | | | | | | | |
| Case | | 89.99 | 1 | 89.99 | | | | | | | | | | | | |
| Disk | | 499.99 | 4 | 1999.96 | | | | | | | | | | | | |
| Network Card | Network Adapter | 361.99 | | 361.99 | | | | | | | | | | | | |
| | | | | 9920.89 | | 9920.89 | | 9920.89 | | 39683.56 | | 317468.48 | | 3105238.57 | | 31002781.25 |
| | Network Switch | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 (52-p | 2049.99 | 6 | 12299.94 | 60 | 122999.4 |
| Administration | | 100000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 4 | 2000000 |
| Racks | | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 3 | 449.97 | 27 | 4049.73 | 261 | 39147.39 |
| Power Supply | | | | 2138.14 | | 2138.14 | | 2138.14 | | 8552.56 | | 68420.48 | | 669237.82 | | 6681687.5 |
| Cooling Power | | | | 1069.07 | | 1069.07 | | 1069.07 | | 4276.28 | | 34210.24 | | 334618.91 | | 3340843.75 |
| | | | | 514128.08 | | 514128.1 | | 514128.08 | | 553512.38 | | 922599.16 | | 4625444.97 | | 43187459.29 |
| | | | | 11.738084 | | 11.73808 | | 11.73808402 | | 12.63726895 | | 21.06390776 | | 105.6037664 | | 986.0150523 |
| 5 Years Amortized Cost | | | | 11.738084 | | 1.173808 | | 0.11738084 | | 0.012637269 | | 0.002106391 | | 0.001056038 | | 0.000986015 |

➢ **d2.8xlarge**

| d2.8xlarge | | |
|---|---|---|
| CPU | | Intel Xeon E5-2640 V4 2.4 GHz LGA 2011 90W BX80660E52640V4 Server Processor |
| Memory | | Black Diamond Memory 128GB (2 x 64GB) 288-Pin DDR4 SDRAM ECC Registered DDR4 2133 (PC4 17000) Server Memory Model BD64GX22133MQR96 |
| Motherboard | | SUPERMICRO MBD-X10DRI-LN4+-O Enhanced Extended ATX Xeon Server Motherboard Dual LGA 2011 Intel C612 |
| Case | | ARK 4U-500-CA Black 4U Rackmount Case |
| Disk | | LaCie 8big Rack Thunderbolt 2 48TB (8 x 6TB) 2 x Thunderbolt 2 8-bay 1U Rackmount Hardware RAID LAC9000476U |
| Network Card | Network Adapter | AddOn - Network Upgrades 49Y7970-AOK 10Gbps PCI-Express Network Adapter |
| | Network Switch | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty |
| Administration | | |
| Racks | | iStarUSA WM1260B 12U 600mm Depth Wallmount Server Cabinet |
| Power Supply | | 720W |
| Cooling Power | | 360W |

| | | | 1G | 1 | 10G | 1 | 100G | 1 | 1T | 2 | 10T | 15 | 100T | 145 | 1P | 1447 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **d2.8xlarge** | | | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost | Qty | Cost |
| CPU | | 989.99 | 2 | 1979.98 | | | | | | | | | | | | |
| Memory | | 1899.99 | 2 | 3799.98 | | | | | | | | | | | | |
| Motherboard | | 548.99 | 1 | 548.99 | | | | | | | | | | | | |
| Case | | 89.99 | 1 | 89.99 | | | | | | | | | | | | |
| Disk | | 4599 | 1 | 4599 | | | | | | | | | | | | |
| Network Card | Network Adapter | 361.99 | | 361.99 | | | | | | | | | | | | |
| | | | | 11379.93 | | 11379.93 | | 11379.93 | | 22759.86 | | 170698.95 | | 1650089.85 | | 16466758.71 |
| | Network Switch | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 | 849.99 | 1 | 849.99 | 2 | 1699.98 | 3 (52-port) | 6149.97 | 28 | 57399.72 |
| Administration | | 100000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 1 | 500000 | 2 | 1000000 |
| Racks | | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 1 | 149.99 | 2 | 299.98 | 13 | 1949.87 | 121 | 18148.79 |
| Power Supply | | | | 2138.14 | | 2138.14 | | 2138.14 | | 4276.28 | | 32072.1 | | 310030.3 | | 3093888.58 |
| Cooling Power | | | | 1069.07 | | 1069.07 | | 1069.07 | | 2138.14 | | 16036.05 | | 155015.15 | | 1546944.29 |
| | | | | 515587.12 | | 515587.1 | | 515587.12 | | 530174.26 | | 720807.06 | | 2623235.14 | | 22183140.09 |
| **5 Years Amortized Cost** | | | 1 | 11.7713954 | 10 | 1.17714 | 100 | 0.117713954 | 1000 | 0.012104435 | 10000 | 0.001645678 | 100000 | 0.000598912 | 1000000 | 0.000506464 |

➢ **Graphs :**

➢ **Plot 1: Public vs Private**

**Public vs Private cloud**

*Cost per GFLOP per hour ($)* vs *GFLOPS*

Legend:
- m4.10xlarge
- m3.large
- m3.2xlarge
- c3.8xlarge
- g2.2xlarge
- r3.4xlarge
- i2.8xlarge
- d2.8xlarge
- pr.m4.10xlarge
- pr.m3.large
- pr.m3.2xlarge
- pr.c3.8xlarge
- pr.g2.2xlarge
- pr.r3.4xlarge
- pr.i2.8xlarge
- pr.d2.8xlarge

From the above plot, we can notice that the cost of the public cloud per flop per hour is linear from 1GFLOP to 1PFLOP whereas considering private cloud, we can say that the cost of private cloud decreases from 1GFLOP to 1PFLOP. Also we can observe that the private cloud instances intersect the public cloud instances at a certain point as shown in the above plot.

➢ **Comparison between Public Cloud and Private Cloud :**

| Public Cloud | Private Cloud |
|---|---|
| Cost Effective for Smaller Sizes | Cost Effective for larger sizes |
| Cost is linear from 1GFLOP to 1PFLOP | Cost decreases from 1GFLOP to 1PFLOP |
| Suitable for smaller workloads | Suitable for larger workloads |

➢ **Plot 2 : Utilization of Private vs Public cloud**
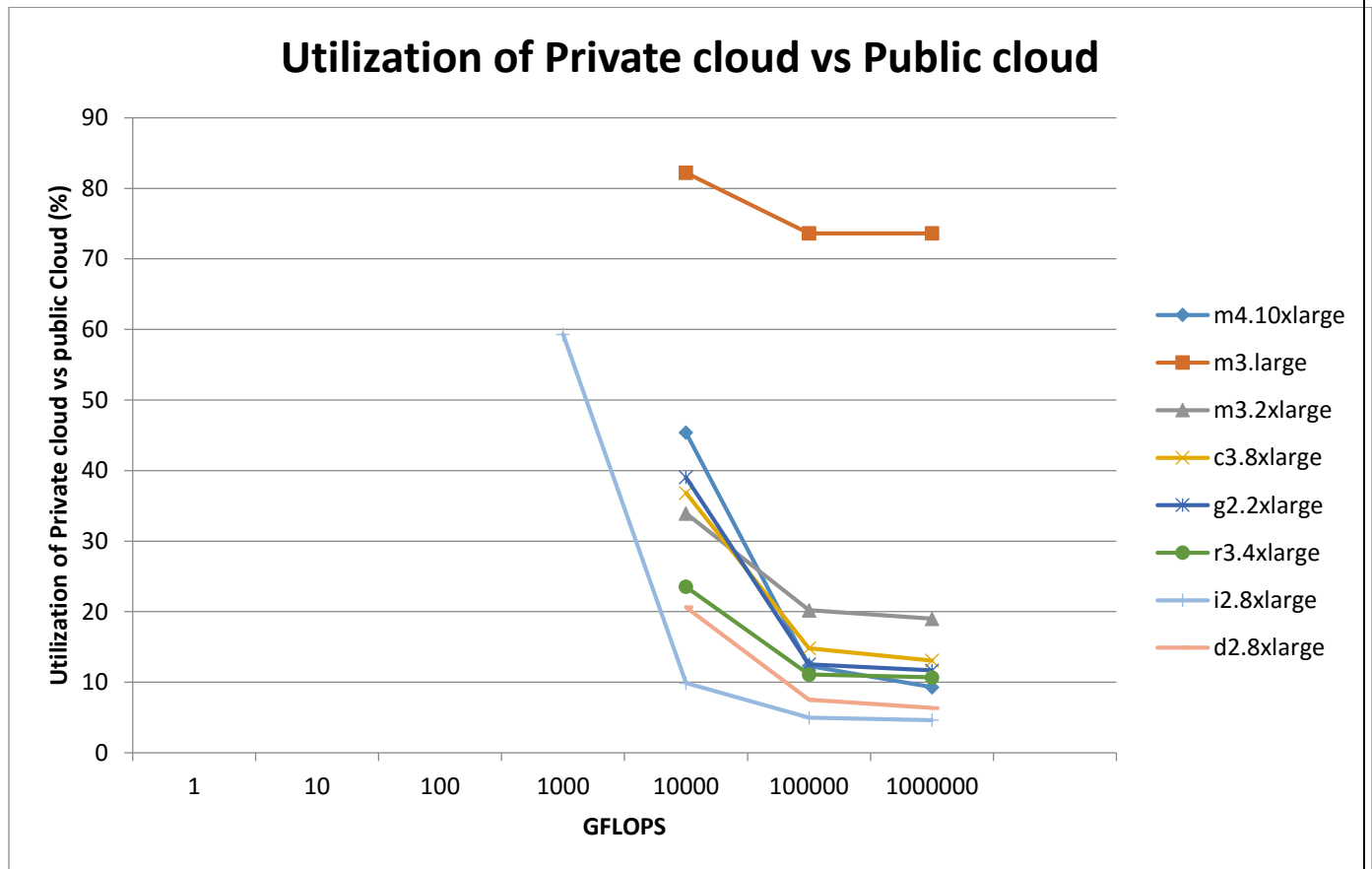


The above gives us the utilization percentage of private/public cloud.

We noticed that, the utilization percentage was more than 100% for the computations lesser than 1000 GFLOPS and the utilization percentage is less than 100% for the computations more than 1000 GFLOPS. Also from the above plot we can observe the decrease in percentage of utilization from 1000 GFLOPS to 1PFLOPS. Hence we can say that the private instances are cheaper for the larger workloads and public instances are cheaper for smaller workloads.

> ## **Conclusion :**

The first plot gives us the comparison between public and the private cloud and the second plot gives us the information regarding the utilization of private and public clouds.

From the above tables and plots we can observe that the public amazon instances are cost effective on smaller sizes. On the other hand we can say that the private cloud instances are cost effective on larger sizes since we saw that the cost decreases from 1GFLOPS to 1PFLOPS, as they have some constant cost up to a certain scale and these costs break down for larger sizes.

Hence, we can conclude that private cloud instances are beneficial for larger sizes and amazon cloud instances is a better choice for smaller sizes. Also, public instances are suitable for smaller workloads and private instances are suitable for larger workloads.