# Cloud Computing

# Understanding the cost of Computing in the Cloud

## Introduction:

➢ The main purpose of this project is to understand and compute the cost required for setting Private Cloud vs Cost required for Public Cloud.

➢ I have considered component cost, power cost, cooling cost and administration cost while evaluating the private cloud cost.

➢ Cost of private cloud is compared with the cost of public cloud and graphs are plotted. It helps us to decide which cloud system is better to own and when it is better to rent from public cloud.

➢ In this project 8 different systems are considered while setting up private cloud environment.

➢ Different Processor, RAM, Disk, GPU, Network Adapter, Switch, Chassis, Rack etc are considered for setting up different systems.

➢ Cost of different components are considered by searching all components from www.newegg.com

➢ Also while considering the cost of a private cloud, administration cost is also considered. Administration cost is considered for a period of 5 year.

➢ Average power consumption of different components are taken and power cost is calculated on basis of these consumption values.

# Component specification and costing estimates for 8 different instances in private cloud environment.

## m4.10xlarge

**Hardware Details:**

| Component | Details | Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|
| CPU | Matched PAIR INTEL XEON E5-2676 V3 2.40GHz SR1Y5 30Mb 12 Cores 24 Thread E5-2670 | 2 | 1800 | 3600 |
| Memory | Axiom 16GB 240-Pin DDR3 SDRAM ECC Registered DDR3 1333 (PC3 10600) Specific Memory Model MC730G/A-AX | 10 | 190 | 1900 |
| MotherBoard | Intel DBS2600CP2 SSI EEB Server Motherboard Dual LGA 2011 DDR3 1600 | 1 | 490 | 490 |
| HDD | SanDisk X300 2.5" 1TB SATA III Internal Solid State Drive (SSD) SD7SB7S-010T-1122 | 1 | 329 | 329 |
| Network Adaptor | Intel X540T2 Ethernet Converged Network Adapter 100Mbps/1Gbps/10Gbps PCI Express 2.1 x8 2 x RJ45 | 1 | 445 | 445 |
| Chassis | SUPERMICRO SuperChassis CSE-512L-200B Black 1U Rackmount Server Case 200W | 1 | 81 | 81 |
| Rack | StarTech.com 12U Server Rack | 1 | 108 | 108 |
| | StarTech.com 42U Adjustable Depth Open Frame 4 Post Server Rack Cabinet - Flat Pack w/ Casters, Levelers and Cable Management Hooks | 1 | 230 | 230 |
| Network Switch | Cisco Nexus 93128TX Layer 3 Switch - 96 port | 1 | 18465 | 18465 |
| | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty - 8 port | 1 | 850 | 850 |

**Cost Details:**

| GFLOPS | Instances Required | Cost of hardware | Rack Cost | Network Cost | Electricity /Power Cost | Network Power Cost | Cooling Cost | Administration Cost | Total Cost | Cost / Hour | Cost / Hour / GFLOP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 6845 | 108 | 850 | 1020 | 76.7 | 365.566667 | 500000 | 509265.267 | 11.6270609 | 0.01261617 |
| 10 | 1 | 6845 | 108 | 850 | 1020 | 76.7 | 365.566667 | 500000 | 509265.267 | 11.6270609 | 0.01261617 |
| 100 | 1 | 6845 | 108 | 850 | 1020 | 76.7 | 365.566667 | 500000 | 509265.267 | 11.6270609 | 0.01261617 |
| 1000 | 2 | 13690 | 108 | 850 | 2040 | 76.7 | 705.566667 | 500000 | 517470.267 | 11.8143896 | 0.00640972 |
| 10000 | 11 | 75295 | 108 | 850 | 11220 | 76.7 | 3765.56667 | 500000 | 591315.267 | 13.5003486 | 0.00133171 |
| 100000 | 109 | 746105 | 460 | 36930 | 111180 | 153.4 | 37111.1333 | 500000 | 1431939.53 | 32.6926834 | 0.00032545 |
| 1000000 | 1086 | 7433670 | 2760 | 221580 | 1107720 | 920.4 | 369546.8 | 1000000 | 10136197.2 | 231.420027 | 0.00023122 |

**Points Considered:**

➢ All the components for this instance are configured based on the specification given by Amazon for m4.10xlarge EC2 instance.

- GFLOPS are calculated based on CPU specification and on the basis of GDLOPS number of instances are calculated while scaling the private cloud.
- I have **considered Single precision Floating Point operations/sec** of CPU and GPU while Calculating the GFLOPS value for CPU and GPU.
- Below formula is used to calculate number of GFLOPS of an instance.

**Total number of GPLOFS of an Instance = Number of physical cores * Instruction per cycle**

**\* Clock speed**.

- Based on the CPU configuration, compatible mother board is selected.
- Based on mother board specification, Memory (RAM) configuration is selected.

## m3.large

**Hardware Details:**

| Component | Details | Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|
| CPU | Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz 25MB L3 Cache LGA 2011 115W BX80635E52670V2 Server Processor | 1 | 1560 | 1560 |
| Memory | Kingston ValueRAM 8GB 240-Pin DDR3 SDRAM DDR3 1333 (PC3 10600) Desktop Memory Model KVR1333D3N9H/8G | 1 | 35 | 35 |
| MotherBoard | Intel DBS2600CP2 SSI EEB Server Motherboard Dual LGA 2011 DDR3 1600 | 1 | 490 | 490 |
| HDD | SanDisk ReadyCache SDSSDRC-032G-G26 2.5" 32GB SATA III for Windows 7 and Windows 8 -based PCs | 1 | 50 | 50 |
| Network Adaptor | Intel EXPI9301CTBLK Network Adapter 10/ 100/ 1000Mbps PCI-Express 1 x RJ45 | 1 | 27 | 27 |
| Chassis | SUPERMICRO SuperChassis CSE-512L-200B Black 1U Rackmount Server Case 200W | 1 | 81 | 81 |
| Rack | StarTech.com 12U Server Rack | 1 | 108 | 108 |
|  | StarTech.com 42U Adjustable Depth Open Frame 4 Post Server Rack Cabinet - Flat Pack w/ Casters, Levelers and Cable Management Hooks | 1 | 230 | 230 |
| Network Switch | Cisco Nexus 93128TX Layer 3 Switch - 96 port | 1 | 18465 | 18465 |
|  | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty - 8 port | 1 | 850 | 850 |

**Cost Details:**

| GFlops | Instance Require | Cost of hardware | Rack Cost | Network Cost | Electricity /Power Cost | Network Power Cost | Cooling Cost | Administration Cost | Total Cost | Cost / Hour | Cost / Hour / GFLOP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2243 | 108 | 850 | 582.8 | 76.7 | 219.833333 | 500000 | 504080.333 | 11.5086834 | 0.05754342 |
| 10 | 1 | 2243 | 108 | 850 | 582.8 | 76.7 | 219.833333 | 500000 | 504080.333 | 11.5086834 | 0.05754342 |
| 100 | 1 | 2243 | 108 | 850 | 582.8 | 76.7 | 219.833333 | 500000 | 504080.333 | 11.5086834 | 0.05754342 |
| 1000 | 5 | 11215 | 108 | 850 | 2914 | 76.7 | 996.9 | 500000 | 516160.6 | 11.7844886 | 0.01178449 |
| 10000 | 50 | 112150 | 338 | 18465 | 29140 | 76.7 | 9738.9 | 500000 | 669908.6 | 15.2947169 | 0.00152947 |
| 100000 | 500 | 1121500 | 2760 | 110790 | 291400 | 460.2 | 97286.7333 | 500000 | 2124196.93 | 48.4976469 | 0.00048498 |
| 1000000 | 5000 | 11215000 | 27600 | 978645 | 2914000 | 4065.1 | 972688.367 | 2500000 | 18611998.5 | 424.931472 | 0.00042493 |

**Points Considered:**

- ➢ This instance is configured similar to the configuration given by Amazon EC2 for m3.large instance.
- ➢ Network cost is calculated based on the number of switches used for configuring the private cloud having various number of instances.
- ➢ Two different network switches are used while setting different environments. Their price is taken from www.newegg.com

## m3.2xlarge

**Hardware Details:**

| Component | Details | Quantity | Unit Cost | Total Cost |
|-----------|---------|----------|-----------|------------|
| CPU | Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5 GHz 25MB L3 Cache LGA 2011 115W BX80635E52670V2 Server Processor | 1 | 1560 | 1560 |
| Memory | Kingston 32GB (4 x 8GB) 240-Pin DDR3 SDRAM Unbuffered DDR3 1333 Server Memory STD Height 30mm Model KVR1333D3N9HK4/32G | 1 | 138 | 138 |
| MotherBoard | Intel DBS2600CP2 SSI EEB Server Motherboard Dual LGA 2011 DDR3 1600 | 1 | 490 | 490 |
| HDD | Intel DC S3500 Series 2.5" 160GB SATA III MLC Internal Solid State Drive (SSD) SSDSC2BB160G401 | 1 | 160 | 160 |
| Network Adaptor | StarTech ST1000SPEX2L 1-Port PCI Express PCIe Gigabit NIC Server Adapter Network Card - Low Profile | 1 | 28 | 28 |
| Chassis | SUPERMICRO SuperChassis CSE-512L-200B Black 1U Rackmount Server Case 200W | 1 | 81 | 81 |
| Rack | StarTech.com 12U Server Rack | 1 | 108 | 108 |
| | StarTech.com 42U Adjustable Depth Open Frame 4 Post Server Rack Cabinet - Flat Pack w/ Casters, Levelers and Cable Management Hooks | 1 | 230 | 230 |
| Network Switch | Cisco Nexus 93128TX Layer 3 Switch - 96 port | 1 | 18465 | 18465 |
| | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty - 8 port | 1 | 850 | 850 |

**Cost Details:**

| GFlops | Instance Require | Cost of hardware | Rack Cost | Network Cost | Electricity /Power Cost | Network Power Cost | Cooling Cost | Administration Cost | Total Cost | Cost / Hour | Cost / Hour / GFLOP |
|--------|------------------|------------------|-----------|--------------|-------------------------|--------------------|--------------|---------------------|------------|-------------|---------------------|
| 1 | 1 | 2457 | 108 | 850 | 582.8 | 76.7 | 219.833333 | 500000 | 504294.333 | 11.5135693 | 0.05756785 |
| 10 | 1 | 2457 | 108 | 850 | 582.8 | 76.7 | 219.833333 | 500000 | 504294.333 | 11.5135693 | 0.05756785 |
| 100 | 1 | 2457 | 108 | 850 | 582.8 | 76.7 | 219.833333 | 500000 | 504294.333 | 11.5135693 | 0.05756785 |
| 1000 | 5 | 12285 | 108 | 850 | 2914 | 76.7 | 996.9 | 500000 | 517230.6 | 11.8089178 | 0.01180892 |
| 10000 | 50 | 122850 | 460 | 18465 | 29140 | 76.7 | 9738.9 | 500000 | 680730.6 | 15.5417945 | 0.00155418 |
| 100000 | 500 | 1228500 | 2760 | 110790 | 291400 | 460.2 | 97286.7333 | 500000 | 2231196.93 | 50.9405693 | 0.00050941 |
| 1000000 | 5000 | 12285000 | 27600 | 978645 | 2914000 | 4065.1 | 972688.367 | 2500000 | 19681998.5 | 449.360696 | 0.00044936 |

**Points Considered:**

- This system has similar CPU and Disk specification as of m3.large instance.
- However it has four times the memory capacity from m3.large instance. And thus its hardware and electricity cost is bit more as compare to m3.large instance.

## c3.8xlarge
**Hardware Details:**

| Component | Details | Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|
| CPU | Intel Xeon E5-2680 v2 Ivy Bridge-EP 2.8 GHz 25MB L3 Cache LGA 2011 115W BX80635E52680V2 Server Processor | 2 | 1769 | 3538 |
| Memory | Axiom 16GB 240-Pin DDR3 SDRAM ECC Registered DDR3 1333 (PC3 10600) Specific Memory Model MC730G/A-AX | 4 | 190 | 1900 |
| MotherBoard | Intel DBS2600CP2 SSI EEB Server Motherboard Dual LGA 2011 DDR3 1600 | 1 | 760 | 760 |
| HDD | SanDisk Ultra II 2.5" 960GB SATA III Internal Solid State Drive (SSD) SDSSDHII-960G-G25 | 1 | 235 | 235 |
| Network Adaptor | Intel X540T2 Ethernet Converged Network Adapter 100Mbps/1Gbps/10Gbps PCI Express 2.1 x8 2 x RJ45 | 1 | 445 | 445 |
| Chassis | SUPERMICRO SuperChassis CSE-512L-200B Black 1U Rackmount Server Case 200W | 1 | 81 | 81 |
| Rack | StarTech.com 12U Server Rack | 1 | 108 | 108 |
| | StarTech.com 42U Adjustable Depth Open Frame 4 Post Server Rack Cabinet - Flat Pack w/ Casters, Levelers and Cable Management Hooks | 1 | 230 | 230 |
| Network Switch | Cisco Nexus 93128TX Layer 3 Switch - 96 port | 1 | 18465 | 18465 |
| | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty - 8 port | 1 | 850 | 850 |

**Cost Details:**

| GFlops | Instance Require | Cost of hardware | Rack Cost | Network Cost | Electricity /Power Cost | Network Power Cost | Cooling Cost | Administration Cost | Total Cost | Cost / Hour | Cost / Hour / GFLOP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 6959 | 108 | 850 | 963.35 | 76.7 | 346.683333 | 500000 | 509303.733 | 11.6279391 | 0.02595522 |
| 10 | 1 | 6959 | 108 | 850 | 963.35 | 76.7 | 346.683333 | 500000 | 509303.733 | 11.6279391 | 0.02595522 |
| 100 | 1 | 6959 | 108 | 850 | 963.35 | 76.7 | 346.683333 | 500000 | 509303.733 | 11.6279391 | 0.02595522 |
| 1000 | 3 | 20877 | 108 | 850 | 2890.05 | 76.7 | 988.916667 | 500000 | 525790.667 | 12.0043531 | 0.00893181 |
| 10000 | 23 | 160057 | 230 | 2550 | 22157.05 | 76.7 | 7411.25 | 500000 | 692482 | 15.8100913 | 0.00153436 |
| 100000 | 224 | 1558816 | 1380 | 55395 | 215790.4 | 690.3 | 72160.2333 | 500000 | 2404231.93 | 54.89114 | 0.00054699 |
| 1000000 | 2233 | 15539447 | 12420 | 424695 | 2151160.55 | 1764.1 | 717641.55 | 1500000 | 20347128.2 | 464.546306 | 0.00046437 |

**Points Considered:**

- ➢ All the components are selected based on the configuration given for Amazon c3.8xlarge EC2 instance.
- ➢ Admin cost is considered in all scenarios while calculating the total cost of a private cloud environment.
- ➢ I have consider admin cost as $100,000.00 per annum and thus for a period of 5 years it comes to $500,000.
- ➢ It is considered that one administrator can monitor over 1000 instances and accordingly cost is calculated.

## g2.2xlarge

**Hardware Details:**

| Component | Details | Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|
| CPU | Intel Xeon E5-2670 Sandy Bridge-EP 2.6 GHz 20MB L3 Cache LGA 2011 115W Server Processor 94Y6602 - OEM | 1 | 1349 | 1349 |
| Memory | Axiom 16GB 240-Pin DDR3 SDRAM ECC Registered DDR3 1333 (PC3 10600) Specific Memory Model MC730G/A-AX | 1 | 190 | 190 |
| MotherBoard | Intel DBS2600CP2 SSI EEB Server Motherboard Dual LGA 2011 DDR3 1600 | 1 | 490 | 490 |
| HDD | Kingston SSDNow V300 Series 2.5" 60GB SATA III Internal Solid State Drive (SSD) SV300S37A/60G | 1 | 43 | 43 |
| GPU | GIGABYTE GeForce GTX 960 4GB WINDFORCE 2X OC EDITION | 1 | 220 | 220 |
| Network Adaptor | StarTech ST1000SPEX2L 1-Port PCI Express PCIe Gigabit NIC Server Adapter Network Card - Low Profile | 1 | 28 | 28 |
| Chassis | SUPERMICRO SuperChassis CSE-512L-200B Black 1U Rackmount Server Case 200W | 1 | 81 | 81 |
| Rack | StarTech.com 12U Server Rack | 1 | 108 | 108 |
| | StarTech.com 42U Adjustable Depth Open Frame 4 Post Server Rack Cabinet - Flat Pack w/ Casters, Levelers and Cable Management Hooks | 1 | 230 | 230 |
| Network Switch | Cisco Nexus 93128TX Layer 3 Switch - 96 port | 1 | 18465 | 18465 |
| | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty - 8 port | 1 | 850 | 850 |

**Cost Details:**

| GFlops | Instance Require | Cost of hardware | Rack Cost | Network Cost | Electricity /Power Cost | Network Power Cost | Cooling Cost | Administration Cost | Total Cost | Cost / Hour | Cost / Hour / GFLOP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2401 | 108 | 850 | 966.45 | 76.7 | 347.716667 | 500000 | 504749.867 | 11.5239696 | 0.004255528 |
| 10 | 1 | 2401 | 108 | 850 | 966.45 | 76.7 | 347.716667 | 500000 | 504749.867 | 11.5239696 | 0.004255528 |
| 100 | 1 | 2401 | 108 | 850 | 966.45 | 76.7 | 347.716667 | 500000 | 504749.867 | 11.5239696 | 0.004255528 |
| 1000 | 1 | 2401 | 108 | 850 | 966.45 | 76.7 | 347.716667 | 500000 | 504749.867 | 11.5239696 | 0.004255528 |
| 10000 | 4 | 9604 | 108 | 18465 | 3865.8 | 76.7 | 1314.16667 | 500000 | 533433.667 | 12.1788508 | 0.00112434 |
| 100000 | 37 | 88837 | 230 | 18465 | 35758.65 | 76.7 | 11945.1167 | 500000 | 655312.467 | 14.9614718 | 0.000149322 |
| 1000000 | 370 | 888370 | 2070 | 73860 | 357586.5 | 306.8 | 119297.767 | 500000 | 1941491.07 | 44.3262801 | 4.42396E-05 |

**Points Considered:**

- ➢ G2.2xlarge has a GPU, and thus I have considered NVIDIA Graphics card while configuring this instance in private cloud environment.
- ➢ Thus the number of GFLOPS are increased accordingly. Also the Power consumption of an instance is increased thus increasing the total cost of an instance.
- ➢ GPU used for this instance gives up to 2542 GFFLOPS. This value is used while calculating cost/hour/GFLOP value.

## r3.4xlarge

**Hardware Details:**

| Component | Details | Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|
| CPU | Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5GHz 25MB L3 Cache LGA 2011 115W Server Processor CM8063501375000 - OEM | 1 | 1675 | 1675 |
| Memory | Axiom 16GB 240-Pin DDR3 SDRAM ECC Registered DDR3 1333 (PC3 10600) Specific Memory Model MC730G/A-AX | 8 | 190 | 1520 |
| MotherBoard | Intel DBS2600CP2 SSI EEB Server Motherboard Dual LGA 2011 DDR3 1600 | 1 | 490 | 490 |
| HDD | Micron M500 480GB 2.5-inch SATA III MLC (6.0Gb/s) Internal Solid State Drive (SSD) (MTFDDAK480MAV) - OEM | 1 | 120 | 120 |
| Network Adaptor | StarTech ST1000SPEX2L 1-Port PCI Express PCIe Gigabit NIC Server Adapter Network Card - Low Profile | 1 | 28 | 28 |
| Chassis | SUPERMICRO SuperChassis CSE-512L-200B Black 1U Rackmount Server Case 200W | 1 | 81 | 81 |
| Rack | StarTech.com 12U Server Rack | 1 | 108 | 108 |
| | StarTech.com 42U Adjustable Depth Open Frame 4 Post Server Rack Cabinet - Flat Pack w/ Casters, Levelers and Cable Management Hooks | 1 | 230 | 230 |
| Network Switch | Cisco Nexus 93128TX Layer 3 Switch - 96 port | 1 | 18465 | 18465 |
| | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty - 8 port | 1 | 850 | 850 |

**Cost Details:**

| GFlops | Instance Require | Cost of hardware | Rack Cost | Network Cost | Electricity /Power Cost | Network Power Cost | Cooling Cost | Administration Cost | Total Cost | Cost / Hour | Cost / Hour / GFLOP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 3914 | 108 | 850 | 650 | 76.7 | 242.233333 | 500000 | 505840.933 | 11.5488798 | 0.0577444 |
| 10 | 1 | 3914 | 108 | 850 | 650 | 76.7 | 242.233333 | 500000 | 505840.933 | 11.5488798 | 0.0577444 |
| 100 | 1 | 3914 | 108 | 850 | 650 | 76.7 | 242.233333 | 500000 | 505840.933 | 11.5488798 | 0.0577444 |
| 1000 | 5 | 19705 | 108 | 850 | 3250 | 76.7 | 1108.9 | 500000 | 525098.6 | 11.9885525 | 0.01198855 |
| 10000 | 50 | 197050 | 338 | 18465 | 32500 | 76.7 | 10858.9 | 500000 | 759288.6 | 17.3353562 | 0.00173354 |
| 100000 | 500 | 1970500 | 2760 | 110790 | 325000 | 460.2 | 108486.733 | 500000 | 3017996.93 | 68.9040396 | 0.00068904 |
| 1000000 | 5000 | 19705000 | 27600 | 978645 | 3250000 | 4065.1 | 1084688.37 | 2500000 | 27549998.5 | 628.995399 | 0.000629 |

**Points Considered:**

➢ R3.4xlarge is a high memory computing instance. Thus similar to Amazon r3.4xlarge instance all configuration is setup.
➢ 12U and 42U Racks are considered while setting the private cloud environment for multiple instances.
➢ So best suitable rack is considered and their appropriate cost is taken while calculating the total cost of an instance.

## i2.8xlarge

**Hardware Details:**

| Component | Details | Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|
| CPU | Intel Xeon E5-2670 v2 Ivy Bridge-EP 2.5GHz 25MB L3 Cache LGA 2011 115W Server Processor CM8063501375000 - OEM | 2 | 1675 | 3350 |
| Memory | Axiom 16GB 240-Pin DDR3 SDRAM ECC Registered DDR3 1333 (PC3 10600) Specific Memory Model MC730G/A-AX | 16 | 190 | 3040 |
| MotherBoard | Intel DBS2600CP2 SSI EEB Server Motherboard Dual LGA 2011 DDR3 1600 | 1 | 490 | 490 |
| HDD | SanDisk Ultra II 2.5" 960GB SATA III Internal Solid State Drive (SSD) SDSSDHII-960G-G25 | 8 | 235 | 1880 |
| Network Adaptor | Intel X540T2 Ethernet Converged Network Adapter 100Mbps/1Gbps/10Gbps PCI Express 2.1 x8 2 x RJ45 | 1 | 445 | 445 |
| Chassis | SUPERMICRO SuperChassis CSE-512L-200B Black 1U Rackmount Server Case 200W | 1 | 81 | 81 |
| Rack | StarTech.com 12U Server Rack | 1 | 108 | 108 |
| | StarTech.com 42U Adjustable Depth Open Frame 4 Post Server Rack Cabinet - Flat Pack w/ Casters, Levelers and Cable Management Hooks | 1 | 230 | 230 |
| Network Switch | Cisco Nexus 93128TX Layer 3 Switch - 96 port | 1 | 18465 | 18465 |
| | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty - 8 port | 1 | 850 | 850 |

**Cost Details:**

| GFlops | Instance Require | Cost of hardware | Rack Cost | Network Cost | Electricity /Power Cost | Network Power Cost | Cooling Cost | Administration Cost | Total Cost | Cost / Hour | Cost / Hour / GFLOP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 9286 | 108 | 850 | 1130 | 76.7 | 402.233333 | 500000 | 511852.933 | 11.68614 | 0.02921535 |
| 10 | 1 | 9286 | 108 | 850 | 1130 | 76.7 | 402.233333 | 500000 | 511852.933 | 11.68614 | 0.02921535 |
| 100 | 1 | 9286 | 108 | 850 | 1130 | 76.7 | 402.233333 | 500000 | 511852.933 | 11.68614 | 0.02921535 |
| 1000 | 2 | 18572 | 108 | 850 | 1130 | 76.7 | 402.233333 | 500000 | 521138.933 | 11.8981492 | 0.01487269 |
| 10000 | 13 | 120718 | 230 | 1700 | 14690 | 153.4 | 4947.8 | 500000 | 642439.2 | 14.6675616 | 0.00282068 |
| 100000 | 125 | 1160750 | 690 | 36930 | 141250 | 153.4 | 47134.4667 | 500000 | 1886907.87 | 43.0800883 | 0.0008616 |
| 1000000 | 1250 | 11607500 | 6900 | 258510 | 1412500 | 1073.8 | 471191.267 | 1000000 | 14757675.1 | 336.933221 | 0.00067387 |

**Points Considered:**

➢ It's a memory intensive system, having all similar specification same as that of Amazon i2.8xlarge instance.
➢ Cooling cost is considered as 1/3$^{rd}$ the total power cost required for an instance.

## d2.8xlarge

**Hardware Details:**

| Component | Details | Quantity | Unit Cost | Total Cost |
|---|---|---|---|---|
| CPU | Matched PAIR INTEL XEON E5-2676 V3 2.40GHz SR1Y5 30Mb 12 Cores 24 Thread E5-2670 | 2 | 1800 | 3600 |
| Memory | Axiom 16GB 240-Pin DDR3 SDRAM ECC Registered DDR3 1333 (PC3 10600) Specific Memory Model MC730G/A-AX | 16 | 190 | 3040 |
| MotherBoard | Intel DBS2600CP2 SSI EEB Server Motherboard Dual LGA 2011 DDR3 1600 | 1 | | 490 |
| HDD | SAMSUNG 850 EVO 2.5" 2 TB SATA III 3-D Vertical Internal Solid State Drive (SSD) MZ-75E2T0B/AM | 24 | 603 | 14472 |
| Network Adaptor | Intel X540T2 Ethernet Converged Network Adapter 100Mbps/1Gbps/10Gbps PCI Express 2.1 x8 2 x RJ45 | 1 | 445 | 445 |
| Chassis | SUPERMICRO SuperChassis CSE-512L-200B Black 1U Rackmount Server Case 200W | 1 | 81 | 81 |
| Rack | StarTech.com 12U Server Rack | 1 | 108 | 108 |
| | StarTech.com 42U Adjustable Depth Open Frame 4 Post Server Rack Cabinet - Flat Pack w/ Casters, Levelers and Cable Management Hooks | 1 | 230 | 230 |
| Network Switch | Cisco Nexus 93128TX Layer 3 Switch - 96 port | 1 | 18465 | 18465 |
| | NETGEAR ProSAFE 8-Port 10-Gigabit Plus Switch (XS708E) - Lifetime Warranty - 8 port | 1 | 850 | 850 |

**Cost Details:**

| GFlops | Instance Require | Cost of hardware | Rack Cost | Network Cost | Electricity /Power Cost | Network Power Cost | Cooling Cost | Administration Cost | Total Cost | Cost / Hour | Cost / Hour / GFLOP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 22128 | 108 | 850 | 1225 | 76.7 | 433.9 | 500000 | 524821.6 | 11.9822283 | 0.01300155 |
| 10 | 1 | 22128 | 108 | 850 | 1225 | 76.7 | 433.9 | 500000 | 524821.6 | 11.9822283 | 0.01300155 |
| 100 | 1 | 22128 | 108 | 850 | 1225 | 76.7 | 433.9 | 500000 | 524821.6 | 11.9822283 | 0.01300155 |
| 1000 | 1 | 22128 | 108 | 850 | 1225 | 76.7 | 433.9 | 500000 | 524821.6 | 11.9822283 | 0.01300155 |
| 10000 | 6 | 132768 | 108 | 850 | 7350 | 76.7 | 2475.56667 | 500000 | 643628.267 | 14.6947093 | 0.00265746 |
| 100000 | 55 | 1217040 | 460 | 18465 | 67375 | 76.7 | 22483.9 | 500000 | 1825900.6 | 41.6872283 | 0.00082243 |
| 1000000 | 543 | 12015504 | 2990 | 110790 | 665175 | 460.2 | 221878.4 | 500000 | 13516797.6 | 308.602685 | 0.00061668 |

**Points Considered:**

- This is data intensive system and has 48TB hardrive. All other specification is same as that of Amazon's d2.8xlarge system.
- Total cost of an instance is calculated by adding all the component/hardware cost, electricity cost, cooling cost and administration cost.
- Cost per hour of an instance is calculated by dividing the total cost of a system by 5 years * 365 days * 24 hours.
- (Cost/hour)/GFLOP is calculated by dividing above cost/hour value to total number of GFLOPS by that number of instances.

## Average Power consumption of different components in an instance

| Component | Average number of watts used per hour |
|---|---|
| CPU | 115 |
| Memory | 3 |
| Mother Board | 63 |
| HDD | 2 |
| Intel Network Adaptor- 10Gb | 10.8 |
| Intel Network Adaptor- 1Gb | 4.5 |
| StarTech Network Adaptor- 10Gb | 7.7 |
| StarTech Network Adaptor- 1Gb | 3.3 |
| Network Switch | 25 |

## Points Considered for Power Utilization:

- Depending on the number of component in particular instances watts used by that component is measured.
- Total power used by all component gives a power consumption of a single instance.
- Following sites are referred while calculating power usage.
  - http://www.buildcomputers.net/power-consumption-of-pc-components.html
  - https://www.startech.com/Networking-IO/Adapter-Cards/10gb-pcie-nic~ST10000SPEX

- Power cost is calculated using http://www.rapidtables.com/calc/electric/electricity-calculator.htm site.
- 7 cents per 1 kilowatt-hour is considered while estimating the power cost.

## Cost Comparison of Private and Public cloud.

**Cost per hour per GFLOP for different instances of Private Cloud environment.**

| GFLOPS | m4.10xlarge private | m3.large private | m3.2xlarge private | c3.8xlarge private | g2.2xlarge private | r3.4xlarge private | i2.8xlarge private | d2.8xlarge private |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.0126 | 0.0575 | 0.0575 | 0.0256 | 0.0692 | 0.0577 | 0.0291 | 0.013 |
| 10 | 0.0126 | 0.0575 | 0.0575 | 0.0256 | 0.0692 | 0.0577 | 0.0291 | 0.013 |
| 100 | 0.0126 | 0.0575 | 0.0575 | 0.0256 | 0.0692 | 0.0577 | 0.0291 | 0.013 |
| 1000 | 0.0064 | 0.0118 | 0.0117 | 0.0089 | 0.0692 | 0.0119 | 0.01484 | 0.013 |
| 10000 | 0.0013 | 0.0015 | 0.0015 | 0.0015 | 0.0183 | 0.0017 | 0.0028 | 0.0026 |
| 100000 | 0.0003 | 0.0004 | 0.0004 | 0.0005 | 0.0024 | 0.0006 | 0.0008 | 0.0008 |
| 1000000 | 0.0002 | 0.0003 | 0.0003 | 0.0004 | 0.0007 | 0.0005 | 0.0006 | 0.0005 |

**Cost per hour per GFLOP for different instances of Public Cloud environment.**

| GFLOPS | m4.10xlarge public | m3.large public | m3.2xlarge public | c3.8xlarge public | g2.2xlarge public | r3.4xlarge public | i2.8xlarge public | d2.8xlarge public |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.003117 | 0.00665 | 0.00665 | 0.004688 | 0.00029 | 0.008313 | 0.021313 | 0.007986 |
| 10 | 0.003117 | 0.00665 | 0.00665 | 0.004688 | 0.00029 | 0.008313 | 0.021313 | 0.007986 |
| 100 | 0.003117 | 0.00665 | 0.00665 | 0.004688 | 0.00029 | 0.008313 | 0.021313 | 0.007986 |
| 1000 | 0.003117 | 0.00665 | 0.00665 | 0.004688 | 0.00029 | 0.008313 | 0.021313 | 0.007986 |
| 10000 | 0.003117 | 0.00665 | 0.00665 | 0.004688 | 0.00029 | 0.008313 | 0.021313 | 0.007986 |
| 100000 | 0.003117 | 0.00665 | 0.00665 | 0.004688 | 0.00029 | 0.008313 | 0.021313 | 0.007986 |
| 1000000 | 0.003117 | 0.00665 | 0.00665 | 0.004688 | 0.00029 | 0.008313 | 0.021313 | 0.007986 |

**Point considered for Cost Calculation**

➢ For Public cloud instances GFLOP are calculated by using below formula:

**Total number of GFLOPS = (vCPU/2) * IPC * Clock Speed**

➢ For public cloud instances (cost/hour) /GFLOP is calculated by dividing per hour cost of an instance by number of GFLOPS by an instance.
➢ For Amazon g2.2xlarge instance, its GPU gives 2100 GPLOF which is used while calculating the cost/hour/GFLOP value.

Plot 1: Comparing Cost of Different Instances for Public and Private
Cloud.



**Public vs Private Cloud Cost Comparison for various Instances**
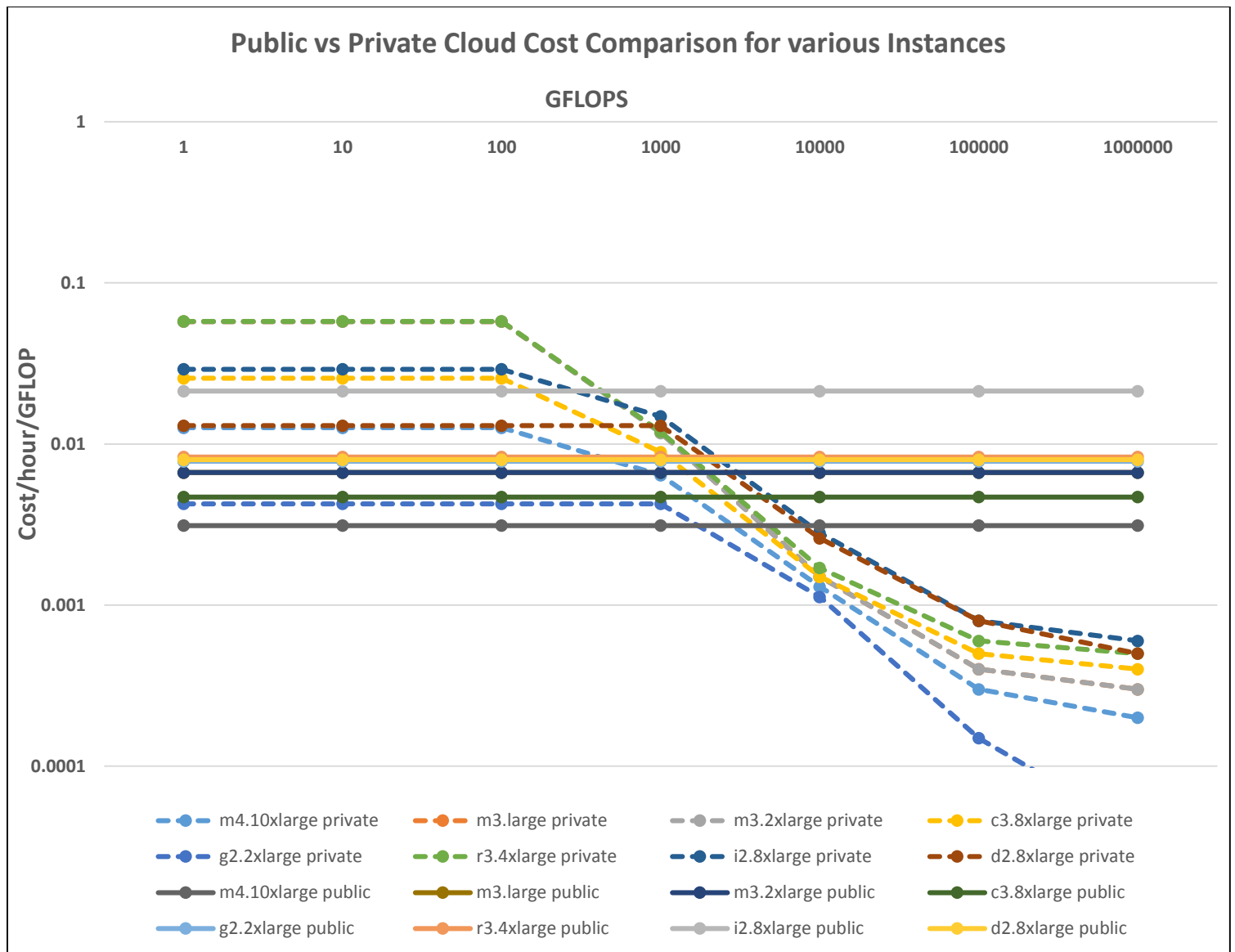
**Observations and Conclusion :**

➢ The above graph compare the cost per flop per hour value of an Amazon public cloud
instances to own created private cloud instances.

➢ X-axis has increasing number of GPLOPS, where Y-axis displays the Cost/hour/GFLOP value.

➢ From the above graph it is clearly observed that for small computation purpose private cloud
is more costly than public cloud.

➢ However as the computational power increases, private cloud becomes cheaper. It cost less
over an amortization period of 5 years.

➢ Cost for administration does not increase linearly, it remains constant for 1000 machines.
Thus it decrease the cost of private cloud when Computational power is increased for long
period of time.

➢ Cost/hour/GFLOP value is constant for public cloud, while Cost/hour/GFLOP value for private cloud decreases as the computational power increases.

## Plot 2: Needed utilization of private cloud from 1 GFLOP to 1 PFLOP for different instance type.

➢ Intersection point of public cloud cost/hour/GFLOP and Private cloud cost/hour/GFLOP is considered as a Break-even point.
➢ Percentage utilization on that intersection point is taken as a 100%.
➢ Percentage utilization for further points are calculated as the Cost/hour/GFLOP of Private Cloud to the Cost/hour/GFLOP of intersection point.

| GFLOPS | % Utilization of Different Instance type | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | m4.10xlarge private | m3.large private | m3.2xlarge private | c3.8xlarge private | g2.xlarge | r3.4xlarge private | i2.8xlarge private | d2.8xlarge private |
| 500 | | | | | | | 100 | |
| 1000 | | | | | | | 69.63 | |
| 2000 | | | | | | 100 | | |
| 3000 | | | | | | | | 100 |
| 5000 | | 100 | 100 | | | | | |
| 5500 | | | | 100 | | | | |
| 6000 | 100 | | | | | | | |
| 10000 | 41.7 | 22.56 | 22.56 | 32 | | 20.45 | 13.14 | 32.55 |
| 99000 | | | | | 100 | | | |
| 100000 | 9.62 | 6 | 6 | 10.67 | 50.16 | 7.21 | 3.75 | 10.02 |
| 1000000 | 6.41 | 4.51 | 4.51 | 8.53 | 14.86 | 6.02 | 2.81 | 6.26 |

## Percentage Utilization of Private Cloud Instances



**Legend:**
- m4.10xlarge private
- m3.large private
- m3.2xlarge private
- c3.8xlarge private
- g2.xlarge
- r3.4xlarge private
- i2.8xlarge private
- d2.8xlarge private
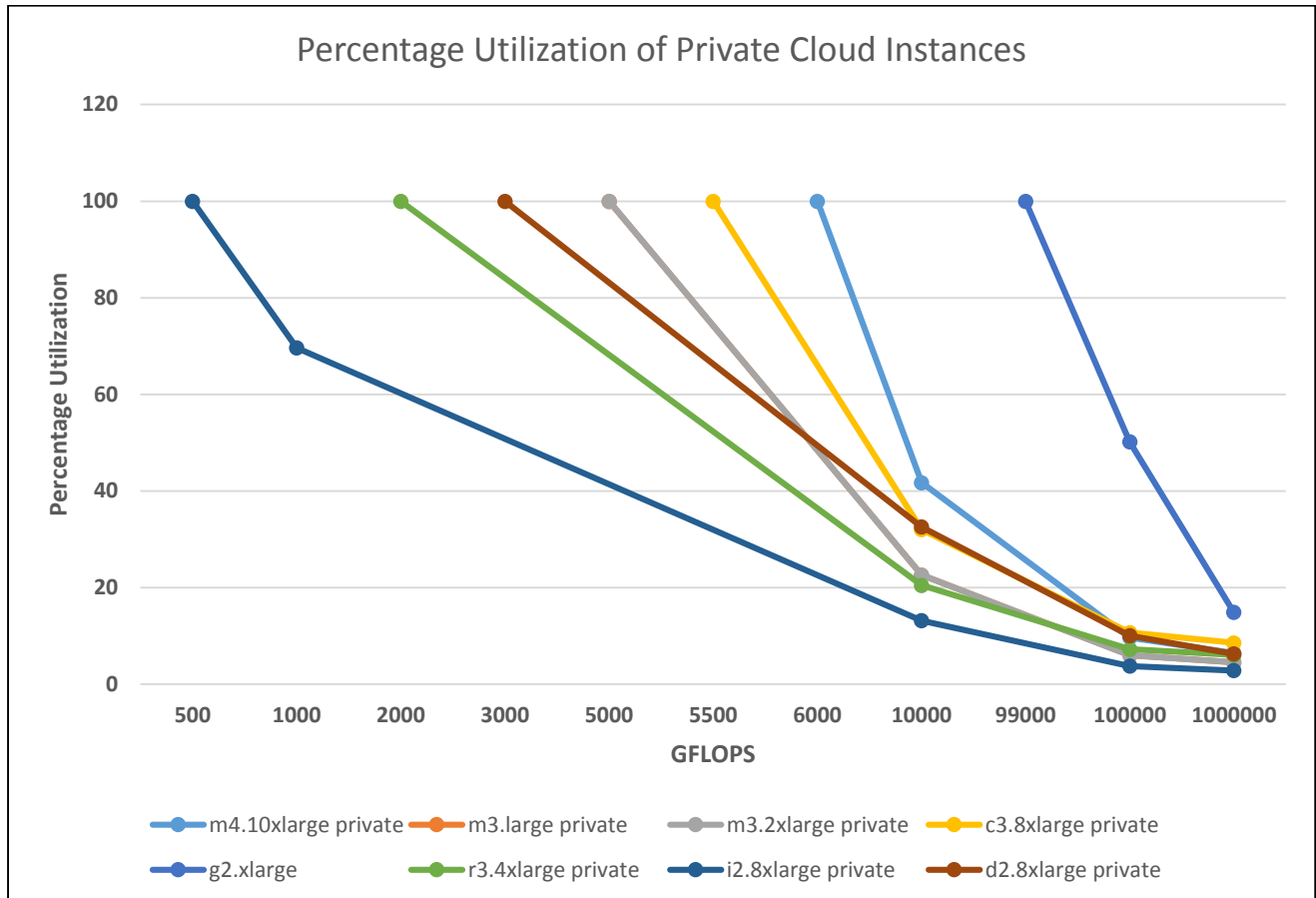
**Observation and Conclusion :**

➤ Above graph shows the utilization of private cloud at Break-even point as 100%.

➤ Percentage utilization of a private cloud instance decreases as the compute power is increased (For higher GFLOPS values).

➤ We can see that the cost of Private cloud instances decreases, as their percentage of utilization is decreased.

➤ Up to Break-even point Public cloud is better than the private cloud, while after the Break-even point Private Cloud becomes cheaper and cheaper as compared to public cloud over a large period of time.

➤ Thus for a large compute power over a long period of time we can say that private cloud is cheaper, and can be more beneficial than public cloud.

**Conclusion**

➤ When to use Private or Public cloud

|  | Small Computation, Short Period of Time | Small Computation, Long Period of Time | Large Computation, Short Period of Time | Large Computation, Long Period of Time |
|---|---|---|---|---|
| **Public Cloud** | Beneficial | Beneficial | Beneficial | Beneficial |
| **Private Cloud** | Not so Beneficial | Not so Beneficial | Not so Beneficial | Beneficial |

**References:**

- [www.newegg.com](www.newegg.com)
- [http://www.rapidtables.com/calc/electric/electricity-calculator.htm](http://www.rapidtables.com/calc/electric/electricity-calculator.htm)
- [http://www.buildcomputers.net/power-consumption-of-pc-components.html](http://www.buildcomputers.net/power-consumption-of-pc-components.html)
- [https://www.startech.com/Networking-IO/Adapter-Cards/10gb-pcie-nic~ST10000SPEX](https://www.startech.com/Networking-IO/Adapter-Cards/10gb-pcie-nic~ST10000SPEX)
- [https://www.techpowerup.com/gpudb/b3234/gigabyte-gtx-960-windforce-2x-oc-4-gb](https://www.techpowerup.com/gpudb/b3234/gigabyte-gtx-960-windforce-2x-oc-4-gb)
- [http://www.newegg.com/Product/Product.aspx?Item=N82E16814125778&cm_re=gigabyte-gtx-960-windforce-_-14-125-778-_-Product](http://www.newegg.com/Product/Product.aspx?Item=N82E16814125778&cm_re=gigabyte-gtx-960-windforce-_-14-125-778-_-Product)

# Screenshots

**M4.10xlarge**

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
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
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**M3.Large**

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**R3.4xlarge**

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**D2.8xlarge**



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