

# HW4

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4/15/2020

## 1 Assumptions

### 1.1 Network Switches and Cables

We calculate the number of switches and cables as follows [9]:

$k$  is the number of ports on a switch  
 $N$  is the number of computers  
 $N_s = k/2$  is the number of switches per pod  
 $N_p = \lceil N/(N_s * k/2) \rceil$  is the number of pods  
 $N_e = N_p * N_s$  is the number of edge switches  
 $N_a = N_e$  is the number of aggregate switches  
 $N_c = \lceil N_s * (k/2)/(k/N_p) \rceil$  is the number of core switches

Thus, the number of switches is:  $T_s = N_c + N_a + N_e$   
Thus, the number of links is:  $k * T_s$

We used [3] and [2] for the cost of network switches in the 25gbps and 10gbps cases respectively  
We used [1] (25gbps ethernet) for both the 25gbps and 10gbps cases.  
We create fat tree networks for both storage and compute servers.

### 1.2 Energy

According to [8], North Virginia has an hourly power rate of roughly .083 \$/KWH. We assume we are operating at full power 24hrs a day.

### 1.3 Cooling

According to [4] and [5], we can estimate the cooling cost by considering the cooling cost of the server equipment and the area of the room. According to [4], we can assume that it takes exactly as much power to cool the server equipment as the amount of power the server generates. Furthermore, we can assume that we need to use 20 BTU/hr of cooling energy per square foot of area [5]. In order to estimate the area of the room, we assume that the racks are placed side-by-side with no space in between. We multiply the area (width\*depth) of each rack by the number of racks in the configuration. We use the cabinets in [7] to house the server racks. Overall, we can calculate the cooling cost as follows:

[(Server Energy Consumption in KW) + (20 (BTU/hr)/sqft)\*( .000293 KW/(BTU/hr)\*(Server Room Area)\*(24\*365\*5 hours))\*(.083 \$/KWH)]

We assume the building has AC in the server room already. No additional hardware is purchased. Only the energy cost is considered.

### 1.4 Administration

According to [10], the average network administrator salary is \$59,323. We will assume that there needs to be one administrator for every 1000 server nodes.

### 1.5 Storage Throughput

When estimating the number of storage devices for storage servers, we use the following inequality to make sure that we meet the minimum throughput requirement:

(Minimum Throughput)\*(Bandwidth of HDD)\*(Number of HDDs)

We assume HDD has a bandwidth of 120 MB/s.

## 2 Configuration 1

COMPUTE:  
384GB \* 6400 = 2,457,600GB = 2.34PB of RAM  
4\*16TB \* 6400 = 400,600TB = 400PB of Storage  
40 cores \* 6400 = 256,000 cores

STORAGE:  
36\*16TB \* 1389 = 800,064TB = 800PB  
36\*120 MBPS \* 1389 = 6,000 GBPS

	Description	Price Per Item	Quantity	Total
Compute Servers	384GB RAM 4x 16TB HDD 2x 20-core CPU 420w 1U	\$10,359.00	6,400.00	\$66,297,600.00
	48-port, 25GB/s switch			
Network Switches		\$6,200.00	900	\$5,580,000.00
Network Cables	25GB/s 2m cable			
		\$78.00	43,200.00	\$3,369,600.00
Racks	42U Cabinet	\$992.99	307	\$303,949.51
Storage Servers	32GB RAM 36x 16TB HDD 783.5w 4U	\$24,414.00	1,389.00	\$33,911,046.00
	Energy cost of server (compute and storage) hardware in North Virginia	\$0.0830/kwh	161,160,028.2600 kwh	\$13,376,282.35
Electric Power	Energy cost of AC in North Virginia	\$0.0830/kwh	161,162,448.2197 kwh	\$13,376,483.20
Cooling	Those who manage the server.	\$59,323.00	8	\$462,066.85
Administration				
Total				\$136,676,827.05

Figure 1: Private Cloud Configuration-1

	Description	Price Per Item (Monthly)	Quantity (Monthly)	Total (Monthly)	Total (5 Years)
Compute Servers	62.8 Large Server CPU 16GB RAM 175GB NVMe	\$4,032.00	8,334.00	\$33,807,698.40	\$2,016,461,304.00
Storage Servers	800PB of S3 Storage	\$17,616,640.00	1.00	\$17,616,640.00	\$1,556,998,400.00
Total					\$3,073,459,704.00

Figure 2: Public Cloud Configuration-1

## 3 Configuration 2

COMPUTE:  
1TB \* 16,000 = 16,000TB = 16PB of RAM = 16GB RAM per VM  
(2TB + 2\*1.5TB) \* 16,000 = 80,000TB = 80PB of Storage = 80GB storage per VM  
2\*64 cores \* 16,000 = 2048000 cores = 2,048 cores per VM

STORAGE:  
36\*16TB \* 24 = 13,824TB = 13.824PB  
36\*120 MBPS \* 24 = 103.68 GBPS

	Description	Price Per Item	Quantity	Total
Compute Servers	1TB RAM 1x 2TB NVMe 2x 1.5TB NVMe 2x 64 core CPU 783.5 watt 1U	\$35,966.00	16,000.00	\$575,456,000.00
	48-port, 10GB/s switch			
Network Switches		\$3,600.00	1,740.00	\$6,264,000.00
Network Cables	25GB/s 2m cable			
		\$78.00	83,520.00	\$6,514,560.00
Racks	42U Cabinet	\$992.99	425	\$421,689.75
Storage Servers	32GB RAM 36x 16TB HDD 682.7 watt 4U	\$24,439.00	24	\$586,536.00
	Energy cost of server (compute and storage) hardware in North Virginia	\$0.0830/kwh	556,802,454.2400 kwh	\$46,214,603.70
Electric Power	Energy cost of AC in North Virginia	\$0.0830/kwh	556,804,874.1997 kwh	\$46,214,804.56
Cooling	Those who manage the server.	\$59,323.00	17	\$950,591.75
Administration				
Total				\$682,622,584.91

Figure 3: Private Cloud Configuration-1

	Description	Price Per Item (Monthly)	Quantity (Monthly)	Total (Monthly)	Total (5 Years)
Compute Servers	2vCPU 16GB RAM 175GB NVMe	\$108.12	1,000,000.00	\$108,120,000.00	\$6,487,200,000.00
Storage Servers	10PB of S3 Storage	\$220,764.16	1.00	\$220,764.16	\$1,355,849.80
Total					\$6,500,455,849.80

Figure 4: Public Cloud Configuration-1

## 4 Configuration 3

According to [6], the NVIDIA v100 GPU has 7tflops of double-precision performance.

COMPUTE:  
8\*7tflops \* 17,858 = 1,000,048tflops = 1 exaflop

STORAGE:  
36\*16TB \* 3 = 1,727TB = 1.7PB  
36\*120 MBPS \* 3 = 12.96 GBPS

	Description	Price Per Item	Quantity	Total
Compute Servers	512GB RAM 64 core CPU 8x NVIDIA V100 GPU 2310 watt 1TB HDD 2U	\$80,698.00	17,858.00	\$1,441,104,884.00
	48-port, 25GB/s switch			
Network Switches		\$6,200.00	1,980.00	\$12,276,000.00
Network Cables	25GB/s 2m cable			
		\$78.00	95,040.00	\$7,413,120.00
Racks	42U Cabinet	\$992.99	898	\$891,515.88
Storage Servers	32GB RAM 36x 16TB HDD 691.5 watt 4U	\$24,351.00	3	\$73,053.00
	Energy cost of server (compute and storage) hardware in North Virginia	\$0.0830/kwh	1,806,927,587.1000 kwh	\$149,974,989.73
Electric Power	Energy cost of AC in North Virginia	\$0.0830/kwh	1,806,930,007.0597 kwh	\$149,975,190.59
Cooling	Those who manage the server.	\$59,323.00	18	\$1,059,568.10
Administration				
Total				\$1,762,768,120.44

Figure 5: Private Cloud Configuration-1

	Description	Price Per Item (Monthly)	Quantity (Monthly)	Total (Monthly)	Total (5 Years)
Compute Servers	48GB RAM 64 core CPU 8x NVIDIA V100 GPU	\$17,873.40	17,858.00	\$319,183,177.20	\$19,150,990,632.00
Storage Servers	1PB of S3 Storage	\$22,583.30	1.00	\$22,583.30	\$1,353,998.00
Total					\$19,150,990,632.00

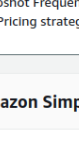
Figure 6: Public Cloud Configuration-1

## 5 Comparison

From this figure, it is apparent that purchasing is better than renting. It requires between 4% and 10.5% utilization in order to make it worth purchasing this equipment.

## 6 Appendix

### 6.1 Configuration 1



**RAXXS4-2151-10G (My System April 14th, 3:34 pm EDT)**  
Thinkmate Config ID 422538

Unit Price

\$10,359.00

Quantity

6400

Subtotal

\$66,297,600.00

Reconfigure

Add A Spares Kit

Intel® C622 Chipset - 14x SATA3 - 2x M.2 - Dual Intel® 1-Gigabit Ethernet (RJ45)  
2x Intel® Xeon® Gold 6230 Processor 20-Core 2.2GHz 28MB Cache (122W)  
2x Supremacy SMI-9620/9948 HeatSink  
12 x 32GB PC4-23400 2933MHz DDR4 ECC RDIMM  
Thinkmate® RAX-1304 1U Chassis - 4x Hot-Swap 3.5" SATA/SAS - 600W Single Power  
4x 16TB SATA 6.0Gb/s 7200RPM - 3.5" - Seagate Exos X10 Series FastFormat™ (512n/4K)  
Mellanox 25-Gigabit Ethernet Adapter ConnectX-4 Lx EN MCX4111A (1x SFP28)  
2x Supremacy RAX-0250-4 - 40x40x50 mm 13K 11K RPM Counter-rotating Fan/4xHS-REACH  
Thinkmate® 1U Riser Card - Left Side W/O - 2x PCIe 3.0 x16  
Thinkmate® 1U Riser Card - Right Side W/O - 1x PCIe 3.0 x8  
Thinkmate® Update Manager (QOB Management Package)  
No Operating System  
Thinkmate® ISO 9001 Certified Assembly, Testing, and Quality Control  
Thinkmate® System Badge - 1.75" x 0.4375"  
3 Year Advanced Parts Replacement Warranty

Reconfigure

Add A Spares Kit

STX-NS XE36-2451-10G (My System April 14th, 5:17 pm EDT)  
Thinkmate Config ID 422547

Unit Price

\$24,414.00

Quantity

1389

Subtotal

\$33,911,046.00

Reconfigure

Add A Spares Kit

Intel® C622 Chipset - 10x SATA3 - 2x M.2 - Dual Intel® 10-Gigabit Ethernet (RJ45) - IPMI 2.0 with LAN  
2x Intel® Xeon® Silver 4112 Processor 4-core 2.6GHz 8.25MB Cache (85W)  
2x Thinkmate® 2U Datacenter Class Passive HeatSink  
4x 8GB PC4-23400 2933MHz DDR4 ECC RDIMM  
Thinkmate® STX-4336 4U Chassis - 30x Hot-Swap 3.5" SAS - 12Gb/s SAS Single Expander - 1200W Redundant Power  
2x 240GB Intel® SSD D3-54010 Series 2.5" SATA 6.0Gb/s Solid State Drive  
36 x 16.0TB SATA 6.0Gb/s 7200RPM - 3.5" - Seagate Exos X10 Series FastFormat™ (512n/4K)  
Broadcom MegaRAID 9480 8-Bite SATA/SAS/NVMe 12Gb/s PCIe 3.1 8-Port RAID Controller with 4GB Cache  
CacheVault Flash Cache Protection Module for 9480/9480 Series (CVPM05)  
Mellanox 25-Gigabit Ethernet Adapter ConnectX-4 Lx EN MCX4111A (1x SFP28)  
Adaptec 2282500-R1 RA-HDMSAS-HDMSAS-0.3M  
Adaptec 2282100-R-CK1-HDMSAS-HDMSAS-1M  
LSI LOM SFF-8643 to 4x Discrete SATA w/ SideBand Cable  
2x Startech 12" 4-Pin Fan Power Extension Cable - M-F  
Supremacy MCP-220-82616-0N - Dual 2.5" Hot-Swap HDD tray  
Aberdeen Low Profile BBU Slot  
Remote Battery Mounting Bracket (LSIO0291)  
8GB USB EDC 3SE (SLC) (Vertical)  
Thinkmate® Update Manager (QOB Management Package)  
ThinkNAS™ DirectorProPlus v2.5 - 36-Drive License  
Thinkmate® ISO 9001 Certified Assembly, Testing, and Quality Control  
Thinkmate® System Badge - 1.75" x 0.4375"  
3 Year Advanced Parts Replacement Warranty

Reconfigure

Add A Spares Kit

Update

\$100,208,646.00

Figure 8: Private Cloud Configuration-1 Shopping Cart

Services (2)

Amazon EC2

Region: US East (N. Virginia)

Edit

Action

Advance estimate

Operating system (Linux), Storage for each EC2 instance (General Purpose SSD (gp2)), Storage amount (50 GB), Snapshot frequency (No snapshot storage), Data Transfer, Advance EC2 Instance (5d, Large), Data transfer cost (0), Pricing strategy (On-Demand)

Monthly Upfront

4,032.60 USD  
0.00 USD

Amazon Simple Storage Service (S3)

53 Standard storage (10240 TB per month)

Edit

Action

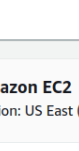
Data Transfer

Monthly

17,616.6400 USD

Figure 9: Public Cloud Configuration-1 AWS Estimation

### 6.2 Configuration 2



**RAXQS12-22F2 (My System April 14th, 10:23 pm EDT)**  
Thinkmate Config ID 422591

Unit Price

\$35,966.00

Quantity

16000

Subtotal

\$575,456,000.00

Reconfigure

Add A Spares Kit

AMD EPYC™ 7002 Series - 2U - 12x Hot-swap SATA/SAS - Dual 1-Gigabit Ethernet - 1200W Redundant Power Supply  
2x AMD EPYC™ 7742 Processor 64-core 2.25GHz 256MB Cache (225W)  
32 x 32GB PC4-23400 2933MHz DDR4 ECC RDIMM  
1.0TB SATA 6.0Gb/s 7200RPM - 3.5" - Ultrastar™ DC HA210 (512n)  
8x NVIDIA Tesla™ V100 GPU Computing Accelerator - 32GB HBM2 - PCIe 3.0 x16 - Passive Cooling  
Mellanox 25-Gigabit Ethernet Adapter ConnectX-4 Lx EN MCX4111A (1x SFP28)  
2x Intel® 10-Gigabit Ethernet Converged Network Adapter X550-SR2 (2x Lx)  
2x Intel® Optane™ SSD DC P4600X Series 1.5TB PCIe 3.0 w/ NVMe Solid State Addon Card  
2x EC60320 C13 to C14 Power Cable, 16 AWG, 240V/15A, Black - 6'  
No-Operating System  
Thinkmate® ISO 9001 Certified Assembly, Testing, and Quality Control  
Thinkmate® System Badge - 1.75" x 0.4375"  
3 Year Advanced Parts Replacement Warranty

Reconfigure

Add A Spares Kit

STX-NS XE36-2451-10G (My System April 14th, 10:38 pm EDT)  
Thinkmate Config ID 422592

Unit Price

\$24,439.00

Quantity

24

Subtotal

\$586,536.00

Reconfigure

Add A Spares Kit

Intel® C622 Chipset - 10x SATA3 - 2x M.2 - Dual Intel® 10-Gigabit Ethernet (RJ45) - IPMI 2.0 with LAN  
2x Intel® Xeon® Silver 4112 Processor 4-core 2.6GHz 8.25MB Cache (85W)  
2x Thinkmate® 2U Datacenter Class Passive HeatSink  
4x 8GB PC4-23400 2933MHz DDR4 ECC RDIMM  
Thinkmate® STX-4336 4U Chassis - 30x Hot-Swap 3.5" SAS - 12Gb/s SAS Single Expander - 1200W Redundant Power  
2x 240GB Intel® SSD D3-54010 Series 2.5" SATA 6.0Gb/s Solid State Drive  
36 x 16.0TB SATA 6.0Gb/s 7200RPM - 3.5" - Seagate Exos X10 Series FastFormat™ (512n/4K)  
Broadcom MegaRAID 9480 8-Bite SATA/SAS/NVMe 12Gb/s PCIe 3.1 8-Port RAID Controller with 4GB Cache  
CacheVault Flash Cache Protection Module for 9480/9480 Series (CVPM05)  
Intel® 10-Gigabit Ethernet Converged Network Adapter X550-T1 (1x RJ-45)  
Adaptec 2282500-R1 RA-HDMSAS-HDMSAS-0.3M  
Adaptec 2282100-R-CK1-HDMSAS-HDMSAS-1M  
LSI LOM SFF-8643 to 4x Discrete SATA w/ SideBand Cable  
2x Startech 12" 4-Pin Fan Power Extension Cable - M-F  
Supremacy MCP-220-82616-0N - Dual 2.5" Hot-swap HDD tray  
Aberdeen Low Profile BBU Slot  
Remote Battery Mounting Bracket (LSIO0291)  
8GB USB EDC 3SE (SLC) (Vertical)  
Thinkmate® Update Manager (QOB Management Package)  
ThinkNAS™ DirectorProPlus v2.5 - 36-Drive License  
Thinkmate® ISO 9001 Certified Assembly, Testing, and Quality Control  
Thinkmate® System Badge - 1.75" x 0.4375"  
3 Year Advanced Parts Replacement Warranty

Reconfigure

Add A Spares Kit

Update

\$576,042,536.00

Figure 10: Private Cloud Configuration-2 Shopping Cart

Services (2)

Amazon Simple Storage Service (S3)

53 Standard storage (10240 TB per month)

Edit

Action

Data Transfer

Monthly

22,583.30 USD

Amazon EC2

Region: US East (N. Virginia)

Edit

Action

Advance estimate

Operating system (Linux), Storage for each EC2 instance (General Purpose SSD (gp2)), Storage amount (50 GB), Snapshot frequency (No snapshot storage), Data Transfer, Advance EC2 Instance (5d, Large), Data transfer cost (0), Pricing strategy (On-Demand)

Monthly Upfront

17,873.40 USD  
0.00 USD

Figure 13: Public Cloud Configuration-3 AWS Estimation

## References

- 25gbps ethernet cable. URL: [https://www.fs.com/products/50510.html?currency=USD&paid=google\\_shopping&gclid=CjwKCAjwvtX0BRAFEEiWAGWJyZGZq\\_XUkTuxqlfBmZHyRLVqemngT9rXBPlv4f5KwnSB1zLUACqgBoCEWoQvD\\_BwE](https://www.fs.com/products/50510.html?currency=USD&paid=google_shopping&gclid=CjwKCAjwvtX0BRAFEEiWAGWJyZGZq_XUkTuxqlfBmZHyRLVqemngT9rXBPlv4f5KwnSB1zLUACqgBoCEWoQvD_BwE).
- 48 port 10gbps switch. URL: [https://www.fs.com/products/29123.html?currency=USD&paid=google\\_shopping&gclid=CjwKCAjwvtX0BRAFEEiWAGWJyZGZq\\_XUkTuxqlfBmZHyRLVqemngT9rXBPlv4f5KwnSB1zLUACqgBoCEWoQvD\\_BwE](https://www.fs.com/products/29123.html?currency=USD&paid=google_shopping&gclid=CjwKCAjwvtX0BRAFEEiWAGWJyZGZq_XUkTuxqlfBmZHyRLVqemngT9rXBPlv4f5KwnSB1zLUACqgBoCEWoQvD_BwE).
- 48 port 25gbps switch. URL: <https://www.fs.com/products/97291.html>.
- Calculate cooling requirements. URL: <https://www.dataspan.com/blog/how-to-calculate-cooling-requirements-for-server-room/>.
- Cost of cooling a room. URL: <https://www.portablefireplace.com/blog/calculating-btu-per-square-foot/>.
- Nvidia v100 specifications. URL: <https://www.nvidia.com/en-us/data-center/v100/>.
- Server cabinet. URL: [https://www.cdw.com/product/APC-NetShelter-SV-42U-Rack-Enclosure-2210-lbs/3036239?cm\\_cat=google&cm\\_cite=3036239&cm\\_pla=NA-NA-APC\\_RQ&cm\\_ven=acquirgy&ef\\_id=CjwKCAjwvtX0BRAFEEiWAGWJyZDJSHSXdz1T4xT5dEs1LoTXZF80UTZ9nHZHjWJNjCL-k6mKY6qYbJhoCIuWQvD\\_BwE:G:s&gclid=CjwKCAjwvtX0BRAFEEiWAGWJyZDJSHSXdz1T4xT5dEs1LoTXZF80UTZ9nHZHjWJNjCL-k6mKY6qYbJhoCIuWQvD\\_BwE&as\\_kwcid=AL14223131479816533391!g1!2999372841361](https://www.cdw.com/product/APC-NetShelter-SV-42U-Rack-Enclosure-2210-lbs/3036239?cm_cat=google&cm_cite=3036239&cm_pla=NA-NA-APC_RQ&cm_ven=acquirgy&ef_id=CjwKCAjwvtX0BRAFEEiWAGWJyZDJSHSXdz1T4xT5dEs1LoTXZF80UTZ9nHZHjWJNjCL-k6mKY6qYbJhoCIuWQvD_BwE:G:s&gclid=CjwKCAjwvtX0BRAFEEiWAGWJyZDJSHSXdz1T4xT5dEs1LoTXZF80UTZ9nHZHjWJNjCL-k6mKY6qYbJhoCIuWQvD_BwE&as_kwcid=AL14223131479816533391!g1!2999372841361).
- US Energy Information Administration. 2018 average monthly bill- industrial. URL: [https://www.eia.gov/electricity/monthly/epm\\_table\\_grapher.php?t=emnt\\_5\\_6.a](https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=emnt_5_6.a).
- Argonne National Laboratory. Codes. URL: <https://github.com/codes-org/codes/wiki/codes-fattree>.
- PayScale. Network administrator salary. URL: [https://www.payscale.com/research/US/Job=Network\\_Administrator/Salary](https://www.payscale.com/research/US/Job=Network_Administrator/Salary).

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