Reference Architecture

Pre-Defined Appliances Based on Dell Server Hardware

REFERENCE ARCHITECTURE

Introduction

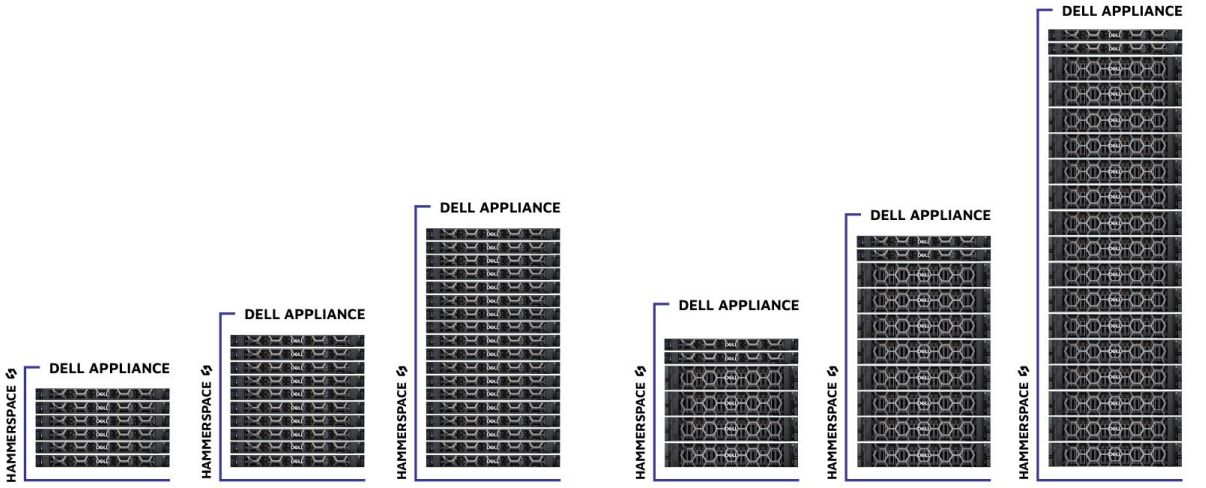
Hammerspace has partnered with Dell and Arrow Electronics to deliver the Global Data Platform software as a series of appliances based on Dell server hardware.

In order to provide sample configurations that span various performance requirements and capacity points, Hammerspace has defined two types of appliances that combine specific metadata servers and data servers:

- **Throughput-Optimized Appliances** are based on a 1U, 10-drive (1U10) server form factor, and are designed to maximize throughput per rack unit.
- **Flash-Capacity-Optimized Appliances** are based on a 2U, 24-drive (2U24) server form factor, and are designed to maximize flash capacity per rack unit.

For each of these types of appliances, a small, medium, and large configuration was defined, resulting in the six configurations shown below.

This Reference Architecture document provides more detail on these pre-defined appliances, including how they were selected, additional details on capacity, networking, and performance, and the Bills of Material (BOMs) for each appliance.



	THROUGHPUT OPTIMIZED Best Throughput per Rack Unit			FLASH CAPACITY OPTIMIZED Best Flash $ per TB		
Configuration	Small	Medium	Large	Small	Medium	Large
Rack Units	6U	10U	18U	10U	18U	34U
Raw Capacity	307.2 TB	1228.8 TB	4915.2 TB	2949.2 TB	5898.24 TB	11796.48 TB
Max Throughput*	90 GB/sec	180 GB/sec	360 GB/sec	90 GB/sec	180 GB/sec	360 GB/sec

**Maximum throughput is shown based on 200GbE networking. Performance will vary based on a number of factors, most notably network speeds.*

Building the Appliances Based on Specific Metadata and Data Servers

Hammerspace can be configured to address a broad range of performance and capacity needs, including the extreme levels of performance required in AI and HPC workloads. Metadata and data servers are scaled independently using the server types shown below.

Server Types	Metadata Servers	Data Servers	
Description	Anvil Metadata Servers	Data Services (DSX) Nodes	Linux Storage Servers
Function	Runs Hammerspace Anvil metadata services	Used to scale out client access, scale performance, provide cross-platform data services, and provide multi-protocol access via NFSv3, SMB, and S3 protocols	Used to scale performance and capacity when clients access storage directly using the Parallel NFSv4.2 protocol, or scale capacity when building storage clusters based on commodity servers
Form Factor	1U 10-Drive	1U 10-Drive 2U 24-Drive	1U 10-Drive 2U 24-Drive
Processor Options	Intel or AMD		

See the Dell Servers Datasheet for the specifications of all of these servers. As noted above, each of these server models is available with either Intel or AMD CPUs. All of these appliances have been designed with the Intel CPU server models.

Each appliance is comprised of (2) Anvil Metadata Servers, plus some number of data servers, as summarized in the tables below:

Throughput Optimized Appliances

Configuration	Small	Medium	Large
Metadata Servers	Intel 1U Small Anvil Metadata Server 2x 1.6TB	Intel 1U Med Anvil Metadata Server 4x 1.6TB	Intel 1U Large Anvil Metadata Server 4x 3.2TB
Data Servers	Intel 1U Small DSX 10 Bay Server	Intel 1U Medium DSX 10 Bay Server	Intel 1U Large DSX 10 Bay Server
Metadata Server QTY	2	2	2
Data Server QTY	4	8	16
SSDs per server	10	10	10
Total Rack Units	6	10	18

Flash-Capacity-Optimized Appliances

Configuration	Small	Medium	Large
Metadata Servers	Intel 1U Small Anvil Metadata Server 2x 1.6TB	Intel 1U Med Anvil Metadata Server 4x 1.6TB	Intel 1U XLarge Anvil Metadata Server 512GB RAM 4x 6.4TB
Data Servers	Intel 2U Small DSX 24 Bay Server	Intel 2U Medium DSX 24 Bay Server	Intel 2U Large DSX 24 Bay Server
Metadata Server QTY	2	2	2
Data Server QTY	4	8	16
SSDs per server	24	24	24
Total Rack Units	10	18	34

Capacity Options and NVMe Drive Selection

The data servers are either a 1U10 drive server model, or a 2U24 drive server model. For each of these models, Dell offers a variety of NVMe SSDs – both Mixed Use SSDs and Read Intensive SSDs across a variety of capacity points, displayed in the matrix below.

	Throughput Optimized			Flash Capacity Optimized		
Configuration	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
Data Server QTY	4	8	16	4	8	16
SSDs per server	10	10	10	24	24	24
Total Rack Units	6	10	18	10	18	34
Capacity Options						
Mixed Use SSDs						
1.6	64	128	256	153.6	307.2	614.4
3.2	128	256	512	307.2	614.4	1228.8
6.4	256	512	1024	614.4	1228.8	2457.6
Read Intensive SSDs						
1.92	76.8	153.6	307.2	184.32	368.64	737.28
3.84	153.6	307.2	614.4	368.64	737.28	1474.56
7.68	**307.2**	614.4	1228.8	737.28	1474.56	2949.12
15.36	614.4	**1228.8**	2457.6	1474.56	2949.12	5898.24
30.72	1228.8	2457.6	**4915.2**	**2949.12**	**5898.24**	**11796.48**
61.44	2457.6	4915.2	9830.4	5898.24	11796.48	23592.96

Drives Chosen for These Appliances

For these appliances, we selected Read-Intensive SSDs at the capacity points highlighted in green in the table above. The factors that went into making these selections include:

- Read-intensive SSDs are generally more widely used and deployed in enterprise storage systems
- The capacities selected were influenced both by overall mix and adoption, considerations for best $ per TB, and selecting appliances to represent a typical range of capacity points requested by our customers.

> ***Important: Note the largest appliance defined here is 16 data servers with 24x 30.72TB NVMe SSDs, which equates to just under 12 PBs of raw capacity. Hammerspace software can scale to 1000s of nodes in a single storage cluster, and can scale to Exabytes of data, with linear performance scalability.***

If you are configuring a Hammerspace storage cluster using Dell servers, our teams can help to select any of the drive options above to suit your specific performance and capacity needs.

Networking Options and Considerations

Each of the Dell servers specified for both Anvil Metadata servers and the DSX/LSS Data Servers can be configured with 25GbE, 100GbE, 200GbE, or 400GbE network cards.

The choice of networking has a big impact on the overall throughput of the system, as discussed next the Performance Considerations section of this document.

Performance Considerations

The table below shows the maximum read and write throughput of each data server, and each appliance, for each of the four networking options.

	Throughput Optimized			Flash Capacity Optimized		
Configuration	**Small**	**Medium**	**Large**	**Small**	**Medium**	**Large**
Data Server QTY	4	8	16	4	8	16
SSDs per server	10	10	10	24	24	24
Networking (GbE)	Max Write Throughput per Server (GB/sec)			Max Write Throughput per Server (GB/sec)		
25 GbE	2.8	2.8	2.8	2.8	2.8	2.8
100 GbE	11.3	11.3	11.3	11.3	11.3	11.3
200 GbE	22.5	22.5	22.5	22.5	22.5	22.5
400 GbE	45	45	45	45	45	45
Networking	Max Read Throughput per Server (GB/sec)			Max Read Throughput per Server (GB/sec)		
25 GbE	2.8	2.8	2.8	2.8	2.8	2.8
100 GbE	11.3	11.3	11.3	11.3	11.3	11.3
200 GbE	22.5	22.5	22.5	22.5	22.5	22.5
400 GbE	45	45	45	45	45	45
Networking	Max Write Throughput per Appliance (GB/sec)			Max Write Throughput per Appliance (GB/sec)		
25 GbE	11.3	22.5	45.0	11.3	22.5	45.0
100 GbE	45.0	90.0	180.0	45.0	90.0	180.0
200 GbE	90.0	180.0	360.0	90.0	180.0	360.0
400 GbE	180.0	360.0	720.0	180.0	360.0	720.0
Networking	Max Read Throughput per Appliance (GB/sec)			Max Read Throughput per Appliance (GB/sec)		
25 GbE	11.3	22.5	45.0	11.3	22.5	45.0
100 GbE	45.0	90.0	180.0	45.0	90.0	180.0
200 GbE	90.0	180.0	360.0	90.0	180.0	360.0
400 GbE	180.0	360.0	720.0	180.0	360.0	720.0

Performance Discussion and Considerations

- These numbers are based on the assumption that clients have a direct I/O path to the data servers using NFSv4.2, with Parallel NFS, which provides for a direct data path between client and storage.
- Writes go directly to disk. Reads typically come from memory, though if reads come from NVMe there should be sufficient performance to saturate the network. The servers have been specified with sufficient memory so that if your working set fits within the Linux Storage Server memory or DSX server memory in the cluster, then there is a high likelihood that most reads will come from the memory of the backend server(s).
- Each 'per server' throughput reflects the measured and observed maximum throughput for each networking choice. For example, 11.8 GB/sec is the maximum throughput achieved on a 100GbE network, when the drives are not the bottleneck.
- Importantly – these read and write throughput per server numbers are based on selecting NVMe SSDs with the best throughput – for example Kioxia TLC drives.
    - In the 1U 10-drive servers, aggregate drive throughput may be a bottleneck if the individual drives do not have enough throughput – for example if a Solidigm drive only provides 3 GB/sec of throughput per drive, that would equate to 30 GB/sec of aggregate drive throughput for the server, in which case the full 47.2GB/sec of throughput would not be achieved on a 400GbE network.
    - In the 2U 24-drive servers, the aggregate drive throughput greatly exceeds the network port throughput, so for these configurations the network ports are the bottleneck.

Bill of Material (BOMs)

This section lists the specific SKUs and QTYs included in each of these appliance configurations.

Throughput-Optimized Appliance - Small

SKU	Description	QTY
HS-1U SM-ANVIL-128G- 2x 1.6TBTB INTEL	Intel 1U Small Hammerspace Anvil Metadata Server 2x 1.6TB	2
HS-1U SM-DSX 10BS R660XS INTEL	Intel 1U Small Hammerspace DSX 10 Bay Server with 10x 7.68 TB NVMe SSDs	4
HS-GDP-C-300-1	Hammerspace Global Data Platform - Band C - 300TBs	1

Throughput-Optimized Appliance – Medium

SKU	Description	QTY
HS-1U MED-ANVIL-256G- 4x 1.6TBTB INTEL	Intel 1U Med Hammerspace Anvil Metadata Server 4x 1.6TB	2
HS-1U MED-DSX 10BS R660XS INTEL	Intel 1U Medium Hammerspace DSX 10 Bay Server with 10x 15.36 TB NVMe SSDs	8
HS-GDP-E-1200-1	Hammerspace Global Data Platform - Band E - 1.2PBs	1

Throughput-Optimized Appliance – Large

SKU	Description	QTY
HS-1U LRG-ANVIL-512G- 4x 3.2TB INTEL	Intel 1U Large Hammerspace Anvil Metadata Server 4x 3.2TB	2
HS-1U LRG-DSX 10BS R660 INTEL	Intel 1U Large Hammerspace DSX 10 Bay Server with 10x 30.72 TB NVMe SSDs	16
HS-GDP-G-5000-1	Hammerspace Global Data Platform - Band G -5PB	1

Flash-Capacity-Optimized Appliance - Small

SKU	Description	QTY
HS-1U SM-ANVIL-128G- 2x 1.6TBTB INTEL	Intel 1U Small Hammerspace Anvil Metadata Server 2x 1.6TB	2
HS-2U SM-DSX 24BS R760 INTEL	Intel 2U Small Hammerspace DSX 24 Bay Server with 24x 30.72 TB NVMe SSDs	4
HS-GDP-F-3000-1	Hammerspace Global Data Platform - Band F - 3PB	1

Flash-Capacity-Optimized Appliance – Medium

SKU	Description	QTY
HS-1U MED-ANVIL-256G- 4x 1.6TBTB INTEL	Intel 1U Med Hammerspace Anvil Metadata Server 4x 1.6TB	2
HS-2U MED-DSX 24BS R760 INTEL	Intel 2U Medium Hammerspace DSX 24 Bay Server with 24x 30.72 TB NVMe SSDs	8
Custom SKU	Hammerspace Global Data Platform - 6 PB	1

Flash-Capacity-Optimized Appliance – Large

SKU	Description	QTY
HS-1U XLRG-ANVIL-512G- 4x 6.4TB INTEL	Intel 1U XLarge Hammerspace Anvil Metadata Server 512GB RAM 4x 6.4TB	2
HS-2U LRG-DSX 24BS R760 INTEL	Intel 2U Large Hammerspace DSX 24 Bay Server with 24x 30.72 TB NVMe SSDs	16
Custom SKU	Hammerspace Global Data Platform - 12 PB	1