NVA-1173 NetApp AIPod with NVIDIA DGX Systems

NetApp Solutions

NetApp
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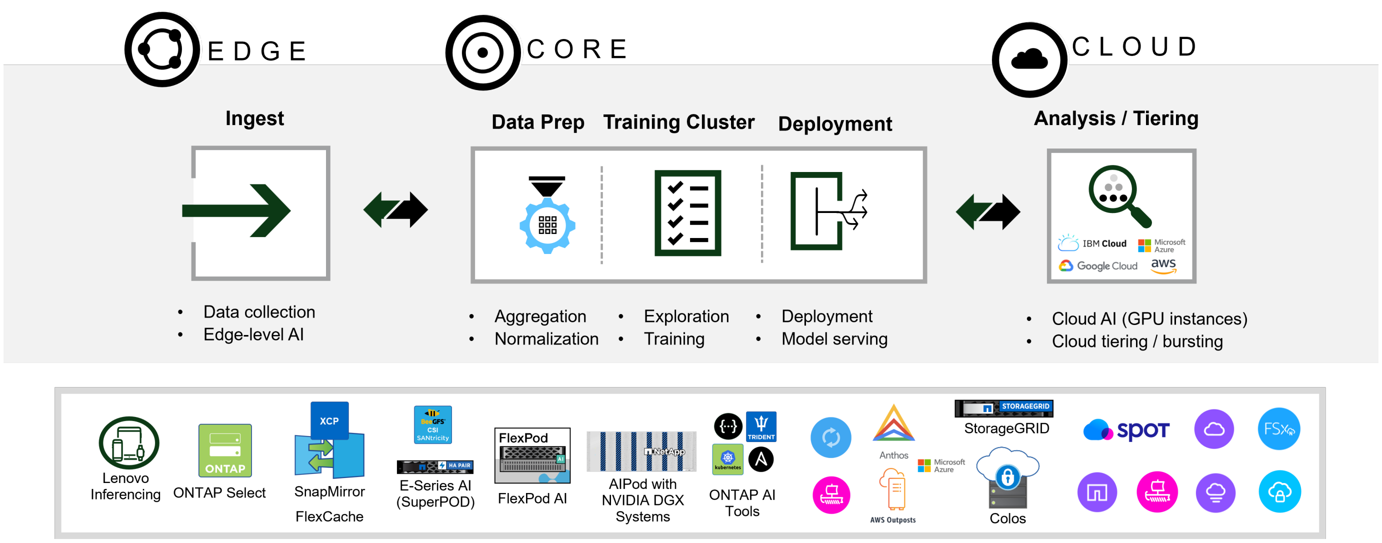
NetApp AI Solutions Portfolio



This document describes the key components of the AIPod reference architecture, system connectivity and configuration information, validation testing results and solution sizing guidance. This document is intended for NetApp and partner solutions engineers and customer strategic decision makers interested in deploying a high-performance infrastructure for ML/DL and analytics workloads.

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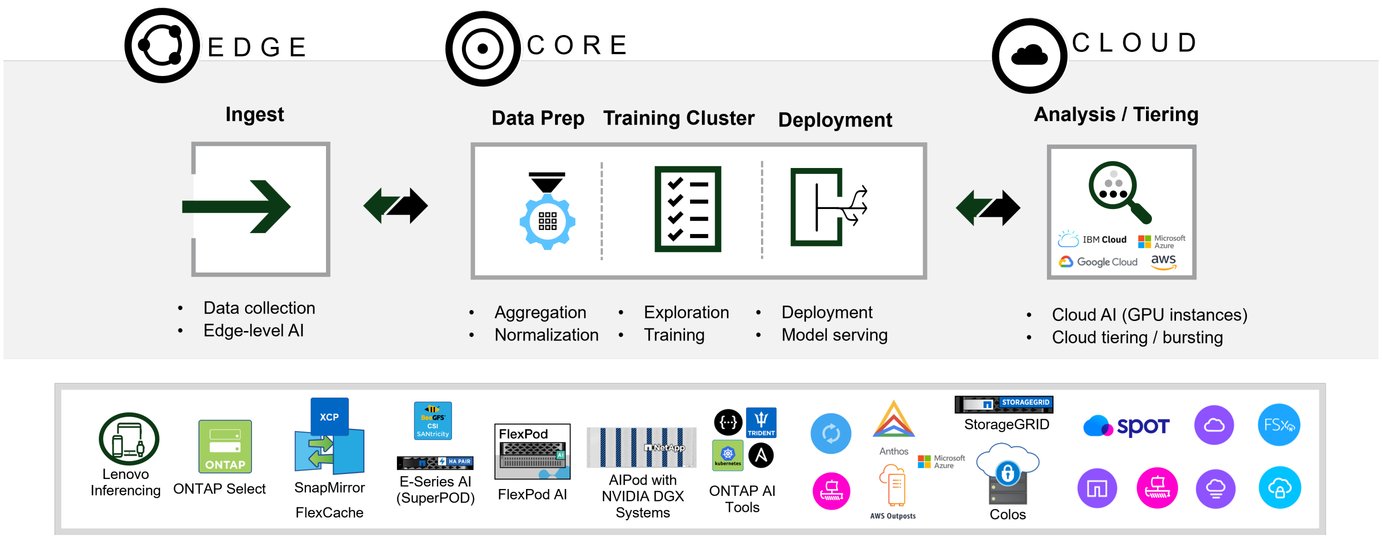

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NVA-1173 NetApp AIPod with NVIDIA DGX Systems - Hardware Components

This section focuses on the hardware components for the NetApp AIPod with NVIDIA DGX systems.

NetApp AFF Storage Systems

NetApp AFF state-of-the-art storage systems enable IT departments to meet enterprise storage requirements with industry-leading performance, superior flexibility, cloud integration, and best-in-class data management. Designed specifically for flash, AFF systems help accelerate, manage, and protect business-critical data.

AFF A90 storage systems

The NetApp AFF A90 powered by NetApp ONTAP data management software provides built-in data protection, optional anti-ransomware capabilities, and the high performance and resiliency required to support the most critical business workloads. It eliminates disruptions to mission-critical operations, minimizes performance

tuning, and safeguards your data from ransomware attacks. It delivers:
• Industry-leading performance
• Uncompromised data security
• Simplified non-disruptive upgrades

NetApp AFF A90 storage system

Industry-leading Performance

The AFF A90 easily manages next-generation workloads like deep learning, AI, and high-speed analytics as well as traditional enterprise databases like Oracle, SAP HANA, Microsoft SQL Server, and virtualized applications. It keeps business-critical applications running at top speed with up to 2.4M IOPS per HA pair and latency as low as 100µs—and increases performance by up to 50% over previous NetApp models. With NFS over RDMA, pNFS and Session Trunking, customers can achieve the high level of network performance required for next-generation applications using existing data center networking infrastructure.
Customers can also scale and grow with unified multi-protocol support for SAN, NAS, and Object storage and deliver maximum flexibility with unified and single ONTAP data management software, for data on-premises or in the cloud. In addition, system health can be optimized with AI-based predictive analytics delivered by Active IQ and Cloud Insights.

Uncompromised Data Security

AFF A90 systems contain a full suite of NetApp integrated and application-consistent data protection software. It provides built-in data protection and cutting-edge anti-ransomware solutions for pre-emption and post-attack recovery. Malicious files can be blocked from ever being written to disk, and storage abnormalities are easily monitored to gain insights.

Simplified Non-Disruptive Upgrades

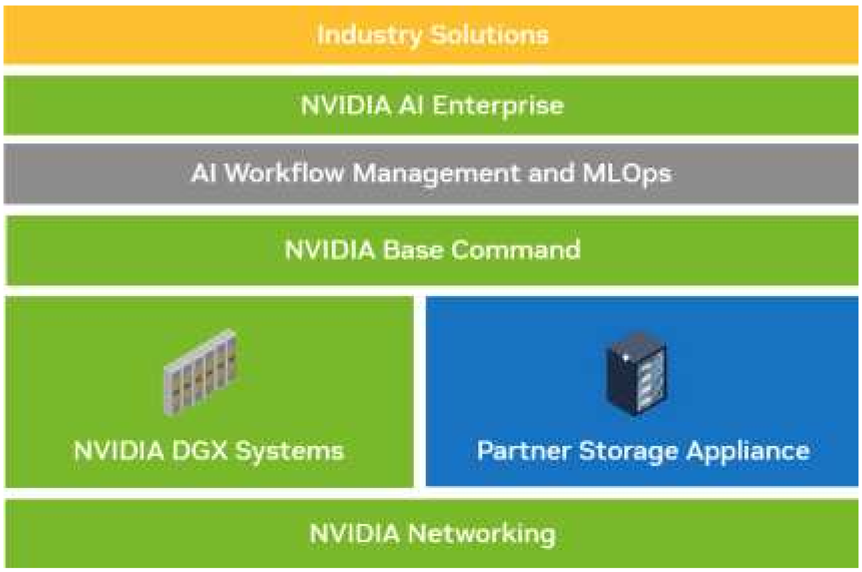
The AFF A90 is available as a non-disruptive in-chassis upgrade to existing A800 customers. NetApp makes it simple to refresh and eliminate disruptions to mission-critical operations through our advanced reliability, availability, serviceability, and manageability (RASM) capabilities. In addition, NetApp further increases operational efficiency and simplifies day-to-day activities for IT teams because ONTAP software automatically applies firmware updates for all system components.

For the largest deployments, AFF A1K systems offer the highest performance and capacity options while other NetApp storage systems, such as the AFF A70, and AFF C800 offer options for smaller deployments at lower cost points.

NVIDIA DGX BasePOD

NVIDIA DGX BasePOD is an integrated solution consisting of NVIDIA hardware and software components, MLOps solutions, and third-party storage. Leveraging best practices of scale-out system design with NVIDIA products and validated partner solutions, customers can implement an efficient and manageable platform for AI development. Figure 1 highlights the various components of NVIDIA DGX BasePOD.

NVIDIA DGX BasePOD solution



NVIDIA DGX H100 Systems

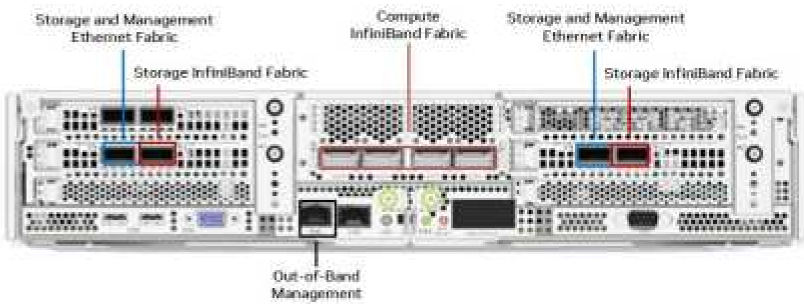
The NVIDIA DGX H100™ system is the AI powerhouse that is accelerated by the groundbreaking performance of the NVIDIA H100 Tensor Core GPU.

NVIDIA DGX H100 system

Key specifications of the DGX H100 system are:
• Eight NVIDIA H100 GPUs.
• 80 GB GPU memory per GPU, for a total of 640GB.
• Four NVIDIA NVSwitch™ chips.
• Dual 56-core Intel® Xeon® Platinum 8480 processors with PCIe 5.0 support.
• 2 TB of DDR5 system memory.
• Four OSFP ports serving eight single-port NVIDIA ConnectX®-7 (InfiniBand/Ethernet) adapters, and two

dual-port NVIDIA ConnectX-7 (InfiniBand/Ethernet) adapters.
• Two 1.92 TB M.2 NVMe drives for DGX OS, eight 3.84 TB U.2 NVMe drives for storage/cache.
• 10.2 kW max power.
The rear ports of the DGX H100 CPU tray are shown below. Four of the OSFP ports serve eight ConnectX-7 adapters for the InfiniBand compute fabric. Each pair of dual-port ConnectX-7 adapters provide parallel pathways to the storage and management fabrics. The out-of-band port is used for BMC access.

NVIDIA DGX H100 rear panel



NVIDIA Networking

NVIDIA Quantum-2 QM9700 Switch

NVIDIA Quantum-2 QM9700 InfiniBand switch

NVIDIA Quantum-2 QM9700 switches with 400Gb/s InfiniBand connectivity power the compute fabric in NVIDIA Quantum-2 InfiniBand BasePOD configurations. ConnectX-7 single-port adapters are used for the InfiniBand compute fabric. Each NVIDIA DGX system has dual connections to each QM9700 switch, providing multiple high-bandwidth, low-latency paths between the systems.

NVIDIA Spectrum-3 SN4600 Switch

NVIDIA Spectrum-3 SN4600 switch

NVIDIA Spectrum™-3 SN4600 switches offer 128 total ports (64 per switch) to provide redundant connectivity for in-band management of the DGX BasePOD. The NVIDIA SN4600 switch can provide for speeds between 1 GbE and 200 GbE. For storage appliances connected over Ethernet, the NVIDIA SN4600 switches are also used. The ports on the NVIDIA DGX dual-port ConnectX-7 adapters are used for both in-band management and storage connectivity.

NVIDIA Spectrum SN2201 Switch

NVIDIA Spectrum SN2201 switch

NVIDIA Spectrum SN2201 switches offer 48 ports to provide connectivity for out-of-band management. Out-of-band management provides consolidated management connectivity for all components in DGX BasePOD.

NVIDIA ConnectX-7 Adapter

NVIDIA ConnectX-7 adapter

The NVIDIA ConnectX-7 adapter can provide 25/50/100/200/400G of throughput. NVIDIA DGX systems use both the single and dual-port ConnectX-7 adapters to provide flexibility in DGX BasePOD deployments with 400Gb/s InfiniBand and Ethernet.

NVA-1173 NetApp AIPod with NVIDIA DGX Systems - Software Components

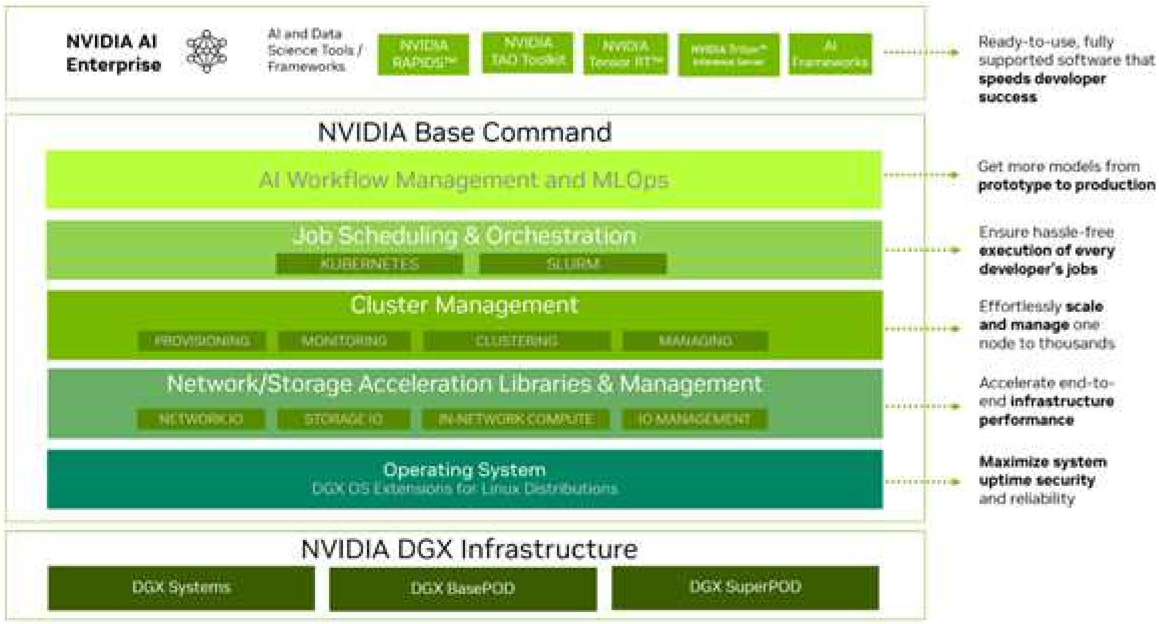
This section focuses on the software components of the NetApp AIPod with NVIDIA DGX systems.

NVIDIA Software

NVIDIA Base Command

NVIDIA Base Command™ powers every DGX BasePOD, enabling organizations to leverage the best of NVIDIA software innovation. Enterprises can unleash the full potential of their investment with a proven platform that includes enterprise-grade orchestration and cluster management, libraries that accelerate compute, storage and network infrastructure, and an operating system (OS) optimized for AI workloads.

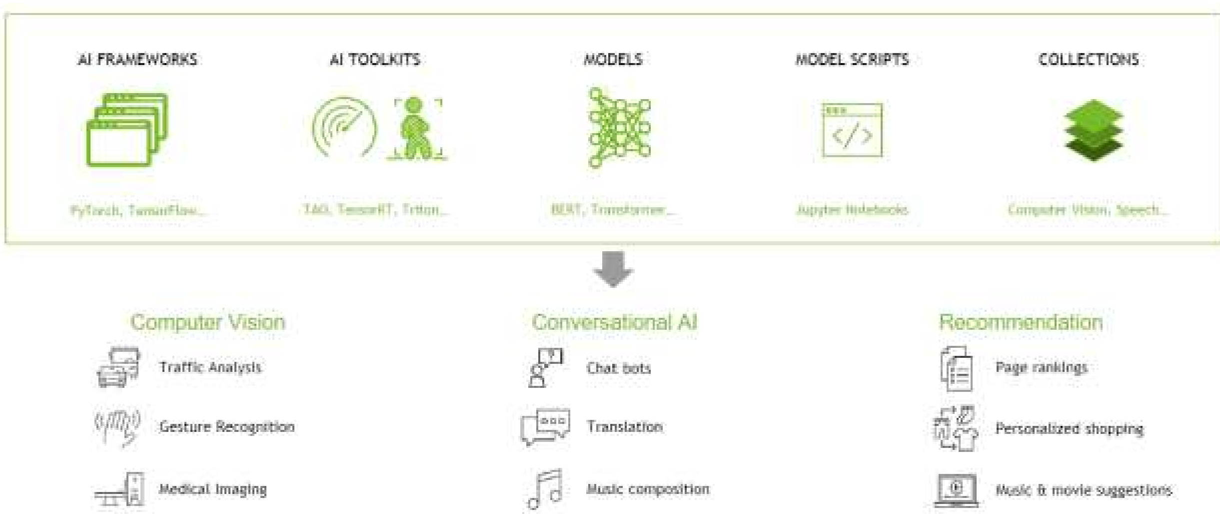
NVIDIA BaseCommand solution



NVIDIA GPU Cloud (NGC)

NVIDIA NGC™ provides software to meet the needs of data scientists, developers, and researchers with various levels of AI expertise. Software hosted on NGC undergoes scans against an aggregated set of common vulnerabilities and exposures (CVEs), crypto, and private keys. It is tested and designed to scale to multiple GPUs and in many cases, to multi-node, ensuring users maximize their investment in DGX systems.

NVIDIA GPU Cloud



NVIDIA AI Enterprise

NVIDIA AI Enterprise is the end-to-end software platform that brings generative AI into reach for every enterprise, providing the fastest and most efficient runtime for generative AI foundation models optimized to run on the NVIDIA DGX platform. With production-grade security, stability, and manageability, it streamlines the development of generative AI solutions. NVIDIA AI Enterprise is included with DGX BasePOD for enterprise developers to access pretrained models, optimized frameworks, microservices, accelerated libraries, and enterprise support.

NetApp Software

NetApp ONTAP

ONTAP 9, the latest generation of storage management software from NetApp, enables businesses to modernize infrastructure and transition to a cloud-ready data center. Leveraging industry-leading data management capabilities, ONTAP enables the management and protection of data with a single set of tools, regardless of where that data resides. You can also move data freely to wherever it is needed: the edge, the core, or the cloud. ONTAP 9 includes numerous features that simplify data management, accelerate, and protect critical data, and enable next generation infrastructure capabilities across hybrid cloud architectures.

Accelerate and protect data

ONTAP delivers superior levels of performance and data protection and extends these capabilities in the following ways:

- Performance and lower latency. ONTAP offers the highest possible throughput at the lowest possible latency, including support for NVIDIA GPUDirect Storage (GDS) using NFS over RDMA, parallel NFS (pNFS), and NFS session trunking.
- Data protection. ONTAP provides built-in data protection capabilities and the industry's strongest anti-ransomware guarantee with common management across all platforms.
- NetApp Volume Encryption (NVE). ONTAP offers native volume-level encryption with both onboard and External Key Management support.
- Storage multitenancy and multifactor authentication. ONTAP enables sharing of infrastructure resources with the highest levels of security.

Simplify data management

Data management is crucial to enterprise IT operations and data scientists so that appropriate resources are used for AI applications and training AI/ML datasets. The following additional information about NetApp technologies is out of scope for this validation but might be relevant depending on your deployment.

ONTAP data management software includes the following features to streamline and simplify operations and reduce your total cost of operation:

- Snapshots and clones enable collaboration, parallel experimentation and enhanced data governance for ML/DL workflows.
- SnapMirror enables seamless data movement in hybrid cloud and multi-site environments, delivering data where and when it's needed.
- Inline data compaction and expanded deduplication. Data compaction reduces wasted space inside storage blocks, and deduplication significantly increases effective capacity. This applies to data stored locally and data tiered to the cloud.
- Minimum, maximum, and adaptive quality of service (AQoS). Granular quality of service (QoS) controls help maintain performance levels for critical applications in highly shared environments.
- NetApp FlexGroups enable distribution of data across all nodes in the storage cluster providing massive capacity and higher performance for extremely large datasets.
- NetApp FabricPool. Provides automatic tiering of cold data to public and private cloud storage options, including Amazon Web Services (AWS), Azure, and NetApp StorageGRID storage solution. For more information about FabricPool, see TR-4598: FabricPool best practices.
- NetApp FlexCache. Provides remote volume caching capabilities that simplify file distribution, reduces WAN latency, and lowers WAN bandwidth costs. FlexCache enables distributed product development

across multiple sites, as well as accelerated access to corporate datasets from remote locations.

Future-proof infrastructure

ONTAP helps meet demanding and constantly changing business needs with the following features:

- Seamless scaling and non disruptive operations. ONTAP supports the online addition of capacity to existing controllers and to scale-out clusters. Customers can upgrade to the latest technologies, such as NVMe and 32Gb FC, without costly data migrations or outages.
- Cloud connection. ONTAP is the most cloud-connected storage management software, with options for software-defined storage (ONTAP Select) and cloud-native instances (NetApp Cloud Volumes Service) in all public clouds.
- Integration with emerging applications. ONTAP offers enterprise-grade data services for next generation platforms and applications, such as autonomous vehicles, smart cities, and Industry 4.0, by using the same infrastructure that supports existing enterprise apps.

NetApp DataOps Toolkit

The NetApp DataOps Toolkit is a Python-based tool that simplifies the management of development/training workspaces and inference servers that are backed by high-performance, scale-out NetApp storage. The DataOps Toolkit can operate as a stand-alone utility, and is even more effective in Kubernetes environments leveraging NetApp Astra Trident to automate storage operations. Key capabilities include:

- Rapidly provision new high-capacity JupyterLab workspaces that are backed by high-performance, scale-out NetApp storage.
- Rapidly provision new NVIDIA Triton Inference Server instances that are backed by enterprise-class NetApp storage.
- Near-instantaneous cloning of high-capacity JupyterLab workspaces in order to enable experimentation or rapid iteration.
- Near-instantaneous snapshots of high-capacity JupyterLab workspaces for backup and/or traceability/baselining.
- Near-instantaneous provisioning, cloning, and snapshots of high-capacity, high-performance data volumes.

NetApp Astra Trident

Astra Trident is a fully supported, open-source storage orchestrator for containers and Kubernetes distributions, including Anthos. Trident works with the entire NetApp storage portfolio, including NetApp ONTAP, and it also supports NFS, NVMe/TCP, and iSCSI connections. Trident accelerates the DevOps workflow by allowing end users to provision and manage storage from their NetApp storage systems without requiring intervention from a storage administrator.

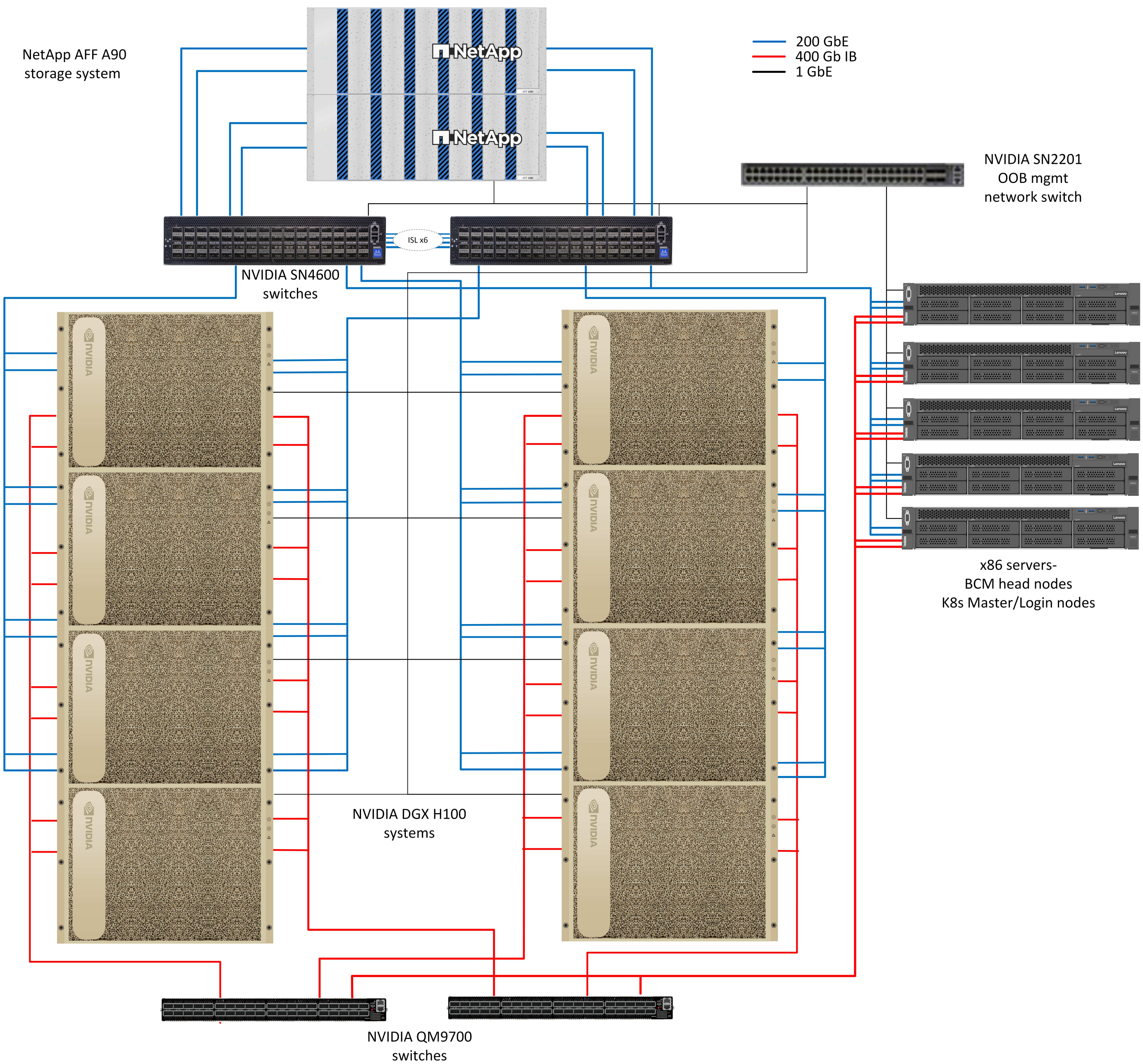
NVA-1173 NetApp AIPod with NVIDIA DGX H100 Systems - Solution Architecture

This section focuses on the architecture for the NetApp AIPod with NVIDIA DGX systems.

NetApp AIPod with DGX systems

This reference architecture leverages separate fabrics for compute cluster interconnect and storage access, with 400Gb/s InfiniBand (IB) connectivity between compute nodes. The drawing below shows the overall solution topology of NetApp AIPod with DGX H100 systems.

NetApp AIpod solution topology



Network design

In this configuration the compute cluster fabric uses a pair of QM9700 400Gb/s IB switches, which are connected together for high availability. Each DGX H100 system is connected to the switches using eight connections, with even-numbered ports connected to one switch and odd-numbered ports connected to the other switch.

For storage system access, in-band management and client access, a pair of SN4600 Ethernet switches is used. The switches are connected with inter-switch links and configured with multiple VLANs to isolate the various traffic types. Basic L3 routing is enabled between specific VLANs to enable multiple paths between client and storage interfaces on the same switch as well as between switches for high availability. For larger deployments the Ethernet network can be expanded to a leaf-spine configuration by adding additional switch pairs for spine switches and additional leaves as needed.

In addition to the compute interconnect and high-speed Ethernet networks, all of the physical devices are also connected to one or more SN2201 Ethernet switches for out of band management. Please see the deployment details page for more information on network configuration.

Storage access overview for DGX H100 systems

Each DGX H100 system is provisioned with two dual-ported ConnectX-7 adapters for management and storage traffic, and for this solution both ports on each card are connected to the same switch. One port from each card is then configured into a LACP MLAG bond with one port connected to each switch, and VLANs for in-band management, client access, and user-level storage access are hosted on this bond.

The other port on each card is used for connectivity to the AFF A90 storage systems, and can be used in several configurations depending on workload requirements. For configurations using NFS over RDMA to support NVIDIA Magnum IO GPUDirect Storage, the ports are used individually with IP addresses in separate VLANs. For deployments that do not require RDMA, the storage interfaces can also be configured with LACP bonding to deliver high availability and additional bandwidth. With or without RDMA, clients can mount the storage system using NFS v4.1 pNFS and Session trunking to enable parallel access to all storage nodes in the cluster. Please see the deployment details page for more information on client configuration.

For more details on DGX H100 system connectivity please refer to the NVIDIA BasePOD documentation.

Storage system design

Each AFF A90 storage system is connected using six 200 GbE ports from each controller. Four ports from each controller are used for workload data access from the DGX systems, and two ports from each controller are configured as an LACP interface group to support access from the management plane servers for cluster management artifacts and user home directories. All data access from the storage system is provided through NFS, with a storage virtual machine (SVM) dedicated to AI workload access and a separate SVM dedicated to cluster management uses.

Please see the deployment details page for more information on storage system configuration.

Management plane servers

This reference architecture also includes five CPU-based servers for management plane uses. Two of these systems are used as the head nodes for NVIDIA Base Command Manager for cluster deployment and management. The other three systems are used to provide additional cluster services such as Kubernetes master nodes or login nodes for deployments utilizing Slurm for job scheduling. Deployments utilizing Kubernetes can leverage the NetApp Astra Trident CSI driver to provide automated provisioning and data services with persistent storage for both management and AI workloads on the AFF A900 storage system.

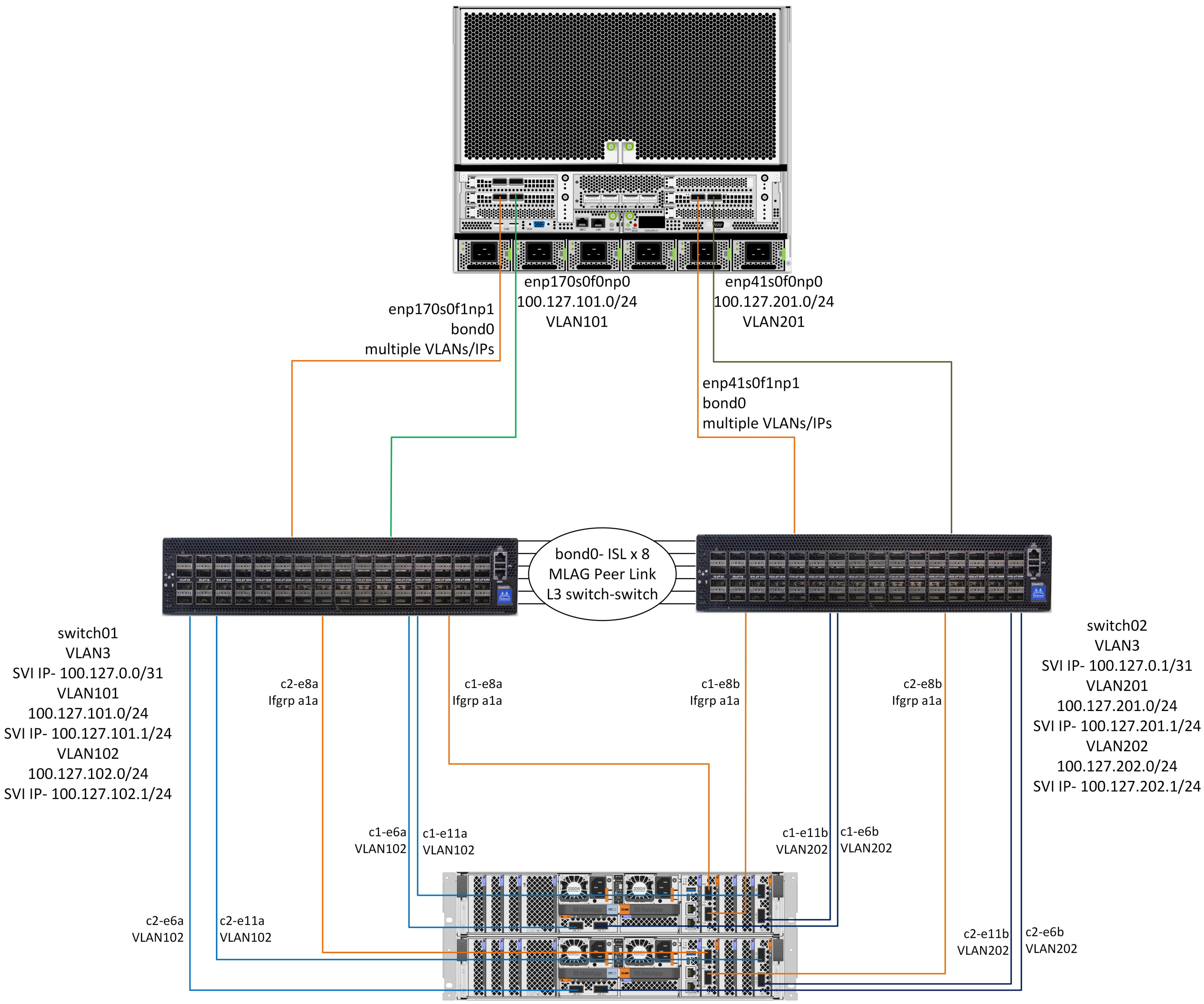
Each server is physically connected to both the IB switches and Ethernet switches to enable cluster deployment and management, and configured with NFS mounts to the storage system via the management SVM for storage of cluster management artifacts as described earlier.

NVA-1173 NetApp AIPod with NVIDIA DGX Systems - Deployment Details

This section describes the deployment details used during validation of this solution. The IP addresses used are examples and should be modified based on the deployment environment. For more information on specific commands used in the implementation of this configuration please refer to the appropriate product documentation.

The diagram below show detailed network and connectivity information for 1 DGX H100 system and 1 HA pair of AFF A90 controllers. The deployment guidance in the following sections is based on the details in this diagram.

NetApp AIpod network configuration



The following table shows example cabling assignments for up to 16 DGX systems and 2 AFF A90 HA pairs.

Table 1. Cabling example

Switch & port	Device	Device port
switch1 ports 1-16	DGX-H100-01 through -16	enp170s0f0np0, slot1 port 1
switch1 ports 17-32	DGX-H100-01 through -16	enp170s0f1np1, slot1 port 2
switch1 ports 33-36	AFF-A90-01 through -04	port e6a
switch1 ports 37-40	AFF-A90-01 through -04	port e11a

Switch & port	Device	Device port
switch1 ports 41-44	AFF-A90-01 through -04	port e8a
switch1 ports 57-64	ISL to switch2	ports 57-64
switch2 ports 1-16	DGX-H100-01 through -16	enp41s0f0np0, slot 2 port 1
switch2 ports 17-32	DGX-H100-01 through -16	enp41s0f1np1, slot 2 port 2
switch2 ports 33-36	AFF-A90-01 through -04	port e6b
switch2 ports 37-40	AFF-A90-01 through -04	port e11b
switch2 ports 41-44	AFF-A90-01 through -04	port e8b
switch2 ports 57-64	ISL to switch1	ports 57-64

The following table shows the software versions for the various components used in this validation.

Table 2. Software versions

Device	Software version
NVIDIA SN4600 switches	Cumulus Linux v5.9.1
NVIDIA DGX system	DGX OS v6.2.1 (Ubuntu 22.04 LTS)
Mellanox OFED	24.01
NetApp AFF A90	NetApp ONTAP 9.14.1

Storage network configuration

This section outlines key details for configuration of the Ethernet storage network. For information on configuring the InfiniBand compute network please see the NVIDIA BasePOD documentation. For more details about switch configuration please refer to the NVIDIA Cumulus Linux documentation.

The basic steps used to configure the SN4600 switches are outlined below. This process assumes that cabling and basic switch setup (mgmt IP address, licensing, etc) is complete.

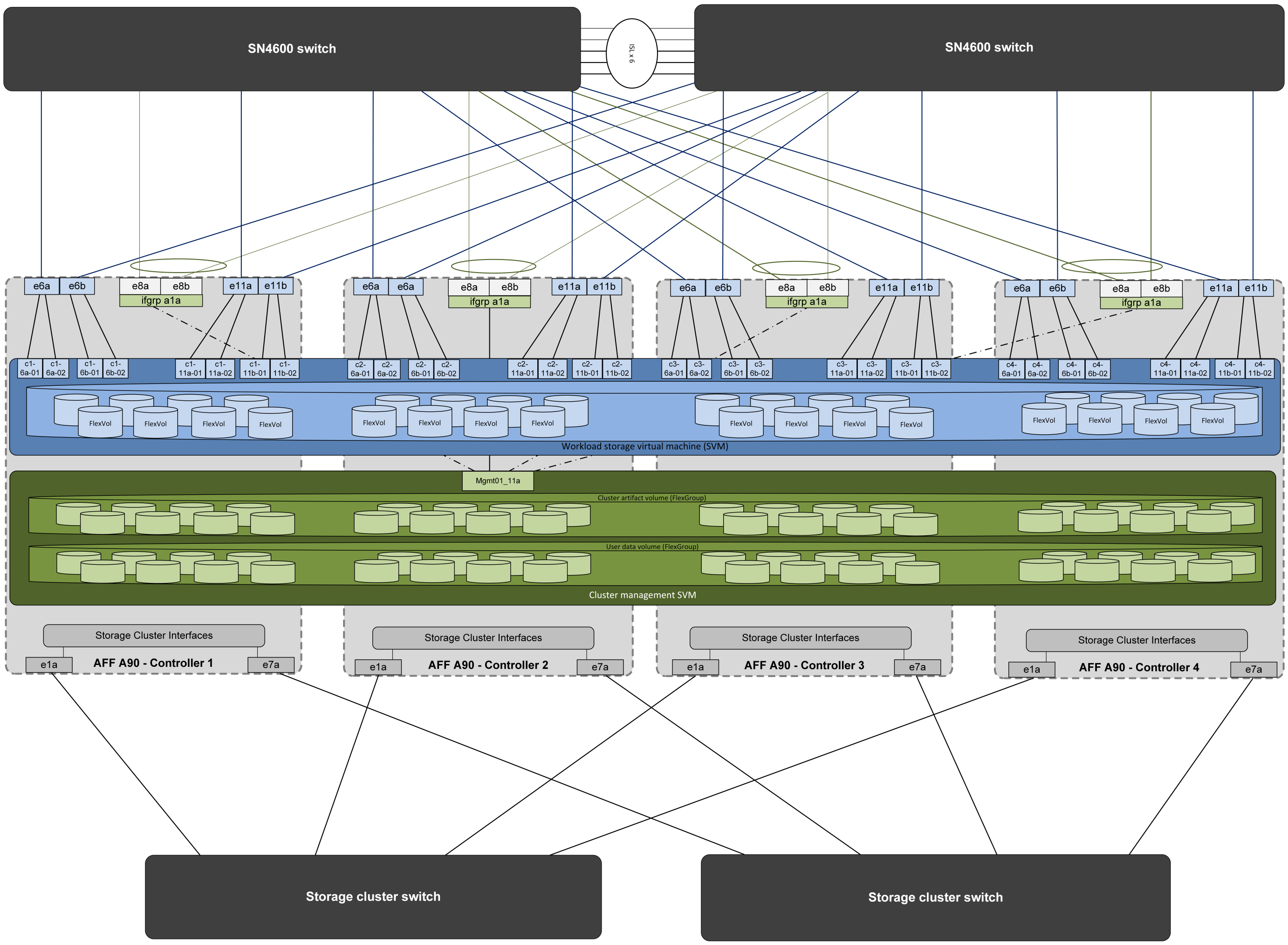
1. Configure the ISL bond between the switches to enable multi-link aggregation (MLAG) and failover traffic
   - This validation used 8 links to provide more than enough bandwidth for the storage configuration under test
   - For specific instructions on enabling MLAG please refer to the Cumulus Linux documentation.
2. Configure LACP MLAG for each pair of client ports and storage ports on both switches
   - port swp17 on each switch for DGX-H100-01 (enp170s0f1np1 and enp41s0f1np1), port swp18 for DGX-H100-02, etc (bond1-16)
   - port swp41 on each switch for AFF-A90-01 (e8a and e8b), port swp42 for AFF-A90-02, etc (bond17-20)
   - nv set interface bondX bond member swpX
   - nv set interface bondx bond mlag id X
3. Add all ports and MLAG bonds to the default bridge domain
   - nv set int swp1-16,33-40 bridge domain br_default

    - nv set int bond1-20 bridge domain br_default
4. Enable RoCE on each switch
    - nv set roce mode lossless
5. Configure VLANs- 2 for client ports, 2 for storage ports, 1 for management, 1 for L3 switch to switch
    - switch 1-
        - VLAN 3 for L3 switch to switch routing in the event of client NIC failure
        - VLAN 101 for storage port 1 on each DGX system (enp170s0f0np0, slot1 port 1)
        - VLAN 102 for port e6a & e11a on each AFF A90 storage controller
        - VLAN 301 for management using the MLAG interfaces to each DGX system and storage controller
    - switch 2-
        - VLAN 3 for L3 switch to switch routing in the event of client NIC failure
        - VLAN 201 for storage port 2 on each DGX system (enp41s0f0np0, slot2 port 1)
        - VLAN 202 for port e6b & e11b on each AFF A90 storage controller
        - VLAN 301 for management using the MLAG interfaces to each DGX system and storage controller
6. Assign physical ports to each VLAN as appropriate, e.g. client ports in client VLANs and storage ports in storage VLANs
    - nv set int <swpX> bridge domain br_default access <vlan id>
    - MLAG ports should remain as trunk ports to enable multiple VLANs over the bonded interfaces as needed.
7. Configure switch virtual interfaces (SVI) on each VLAN to act as a gateway & enable L3 routing
    - switch 1-
        - nv set int vlan3 ip address 100.127.0.0/31
        - nv set int vlan101 ip address 100.127.101.1/24
        - nv set int vlan102 ip address 100.127.102.1/24
    - switch 2-
        - nv set int vlan3 ip address 100.127.0.1/31
        - nv set int vlan201 ip address 100.127.201.1/24
        - nv set int vlan202 ip address 100.127.202.1/24
8. Create static routes
    - Static routes are automatically created for subnets on the same switch
    - Additional static routes are required for switch to switch routing in the event of a client link failure
        - switch 1-
            - nv set vrf default router static 100.127.128.0/17 via 100.127.0.1
        - switch 2-
            - nv set vrf default router static 100.127.0.0/17 via 100.127.0.0

Storage system configuration

This section describes key details for configuration of the A90 storage system for this solution. For more details about configuration of ONTAP systems please refer to the [ONTAP documentation]. The diagram below shows the logical configuration of the storage system.

NetApp A90 storage cluster logical configuration



The basic steps used to configure the storage system are outlined below. This process assumes that basic storage cluster installation has been completed.

1. Configure 1 aggregate on each controller with all available partitions minus 1 spare
    - aggr create -node <node> -aggregate <node>_data01 -diskcount <47>
2. Configure ifgrps on each controller
    - net port ifgrp create -node <node> -ifgrp a1a -mode multimode_lacp -distr-function port
    - net port ifgrp add-port -node <node> -ifgrp <ifgrp> -ports <node>:e8a,<node>:e8b
3. Configure mgmt vlan port on ifgrp on each controller
    - net port vlan create -node aff-a90-01 -port a1a -vlan-id 31
    - net port vlan create -node aff-a90-02 -port a1a -vlan-id 31
    - net port vlan create -node aff-a90-03 -port a1a -vlan-id 31
    - net port vlan create -node aff-a90-04 -port a1a -vlan-id 31
4. Create broadcast domains

- broadcast-domain create -broadcast-domain vlan21 -mtu 9000 -ports aff-a90-01:e6a,aff-a90-01:e11a,aff-a90-02:e6a,aff-a90-02:e11a,aff-a90-03:e6a,aff-a90-03:e11a,aff-a90-04:e6a,aff-a90-04:e11a
- broadcast-domain create -broadcast-domain vlan22 -mtu 9000 -ports aaff-a90-01:e6b,aff-a90-01:e11b,aff-a90-02:e6b,aff-a90-02:e11b,aff-a90-03:e6b,aff-a90-03:e11b,aff-a90-04:e6b,aff-a90-04:e11b
- broadcast-domain create -broadcast-domain vlan31 -mtu 9000 -ports aff-a90-01:a1a-31,aff-a90-02:a1a-31,aff-a90-03:a1a-31,aff-a90-04:a1a-31

5. Create management SVM
   *
6. Configure management SVM
   - create LIF
     - net int create -vserver basepod-mgmt -lif vlan31-01 -home-node aff-a90-01 -home-port a1a-31 -address 192.168.31.X -netmask 255.255.255.0
   - create FlexGroup volumes-
     - vol create -vserver basepod-mgmt -volume home -size 10T -auto-provision-as flexgroup -junction -path /home
     - vol create -vserver basepod-mgmt -volume cm -size 10T -auto-provision-as flexgroup -junction -path /cm
   - create export policy
     - export-policy rule create -vserver basepod-mgmt -policy default -client-match 192.168.31.0/24 -rorule sys -rwrule sys -superuser sys
7. Create data SVM
   *
8. Configure data SVM
   - configure SVM for RDMA support
     - vserver modify -vserver basepod-data -rdma enabled
   - create LIFs
     - net int create -vserver basepod-data -lif c1-6a-lif1 -home-node aff-a90-01 -home-port e6a -address 100.127.102.101 -netmask 255.255.255.0
     - net int create -vserver basepod-data -lif c1-6a-lif2 -home-node aff-a90-01 -home-port e6a -address 100.127.102.102 -netmask 255.255.255.0
     - net int create -vserver basepod-data -lif c1-6b-lif1 -home-node aff-a90-01 -home-port e6b -address 100.127.202.101 -netmask 255.255.255.0
     - net int create -vserver basepod-data -lif c1-6b-lif2 -home-node aff-a90-01 -home-port e6b -address 100.127.202.102 -netmask 255.255.255.0
     - net int create -vserver basepod-data -lif c1-11a-lif1 -home-node aff-a90-01 -home-port e11a -address 100.127.102.103 -netmask 255.255.255.0
     - net int create -vserver basepod-data -lif c1-11a-lif2 -home-node aff-a90-01 -home-port e11a -address 100.127.102.104 -netmask 255.255.255.0
     - net int create -vserver basepod-data -lif c1-11b-lif1 -home-node aff-a90-01 -home-port e11b -address 100.127.202.103 -netmask 255.255.255.0
     - net int create -vserver basepod-data -lif c1-11b-lif2 -home-node aff-a90-01 -home-port e11b -address 100.127.202.104 -netmask 255.255.255.0

- net int create -vserver basepod-data -lif c2-6a-lif1 -home-node aff-a90-02 -home-port e6a -address 100.127.102.105 -netmask 255.255.255.0
- net int create -vserver basepod-data -lif c2-6a-lif2 -home-node aff-a90-02 -home-port e6a -address 100.127.102.106 -netmask 255.255.255.0
- net int create -vserver basepod-data -lif c2-6b-lif1 -home-node aff-a90-02 -home-port e6b -address 100.127.202.105 -netmask 255.255.255.0
- net int create -vserver basepod-data -lif c2-6b-lif2 -home-node aff-a90-02 -home-port e6b -address 100.127.202.106 -netmask 255.255.255.0
- net int create -vserver basepod-data -lif c2-11a-lif1 -home-node aff-a90-02 -home-port e11a -address 100.127.102.107 -netmask 255.255.255.0
- net int create -vserver basepod-data -lif c2-11a-lif2 -home-node aff-a90-02 -home-port e11a -address 100.127.102.108 -netmask 255.255.255.0
- net int create -vserver basepod-data -lif c2-11b-lif1 -home-node aff-a90-02 -home-port e11b -address 100.127.202.107 -netmask 255.255.255.0
- net int create -vserver basepod-data -lif c2-11b-lif2 -home-node aff-a90-02 -home-port e11b -address 100.127.202.108 -netmask 255.255.255.0

9. Configure LIFs for RDMA access
   - For deployments with ONTAP 9.15.1, RoCE QoS configuration for physical information requires os-level commands that are not available in the ONTAP CLI. Please contact NetApp Support for assistance with configuration of ports for RoCE support. NFS over RDMA functions without issue
   - Beginning with ONTAP 9.16.1, physical interfaces will automatically be configured with appropriate settings for end-to-end RoCE support.
   - net int modify -vserver basepod-data -lif * -rdma-protocols roce
10. Configure NFS parameters on the data SVM
    - nfs modify -vserver basepod-data -v4.1 enabled -v4.1-pnfs enabled -v4.1-trunking enabled -tcp-max -transfer-size 262144
11. Create FlexGroup volumes-
    - vol create -vserver basepod-data -volume data -size 100T -auto-provision-as flexgroup -junction-path /data
12. Create export policy
    - export-policy rule create -vserver basepod-data -policy default -client-match 100.127.101.0/24 -rorule sys -rwrule sys -superuser sys
    - export-policy rule create -vserver basepod-data -policy default -client-match 100.127.201.0/24 -rorule sys -rwrule sys -superuser sys
13. create routes
    - route add -vserver basepod_data -destination 100.127.0.0/17 -gateway 100.127.102.1 metric 20
    - route add -vserver basepod_data -destination 100.127.0.0/17 -gateway 100.127.202.1 metric 30
    - route add -vserver basepod_data -destination 100.127.128.0/17 -gateway 100.127.202.1 metric 20
    - route add -vserver basepod_data -destination 100.127.128.0/17 -gateway 100.127.102.1 metric 30

DGX H100 configuration for RoCE storage access

This section describes key details for configuration of the DGX H100 systems. Many of these configuration items can be included in the OS image deployed to the DGX systems or implemented by Base Command

Manager at boot time. They are listed here for reference, for more information on configuring nodes and software images in BCM please see the BCM documentation.

1. Install additional packages
   - ipmitool
   - python3-pip
2. Install Python packages
   - paramiko
   - matplotlib
3. Reconfigure dpkg after package installation
   - dpkg --configure -a
4. Install MOFED
5. Set mst values for performance tuning
   - mstconfig -y -d <aa:00.0,29:00.0> set ADVANCED_PCI_SETTINGS=1 NUM_OF_VFS=0 MAX_ACC_OUT_READ=44
6. Reset the adapters after modifying settings
   - mlxfwreset -d <aa:00.0,29:00.0> -y reset
7. Set MaxReadReq on PCI devices
   - setpci -s <aa:00.0,29:00.0> 68.W=5957
8. Set RX and TX ring buffer size
   - ethtool -G <enp170s0f0np0,enp41s0f0np0> rx 8192 tx 8192
9. Set PFC and DSCP using mlnx_qos
   - mlnx_qos -i <enp170s0f0np0,enp41s0f0np0> --pfc 0,0,0,1,0,0,0,0 --trust=dscp --cable_len=3
10. Set ToS for RoCE traffic on network ports
    - echo 106 > /sys/class/infiniband/<mlx5_7,mlx5_1>/tc/1/traffic_class
11. Configure each storage NIC with an IP address on appropriate subnet
    - 100.127.101.0/24 for storage NIC 1
    - 100.127.201.0/24 for storage NIC 2
12. Configure in-band network ports for LACP bonding (enp170s0f1np1,enp41s0f1np1)
13. configure static routes for primary & secondary paths to each storage subnet
    - route add –net 100.127.0.0/17 gw 100.127.101.1 metric 20
    - route add –net 100.127.0.0/17 gw 100.127.201.1 metric 30
    - route add –net 100.127.128.0/17 gw 100.127.201.1 metric 20
    - route add –net 100.127.128.0/17 gw 100.127.101.1 metric 30
14. Mount /home volume
    - mount -o vers=3,nconnect=16,rsize=262144,wsize=262144 192.168.31.X:/home /home
15. Mount /data volume
    - The following mount options were used when mounting the data volume-
      - vers=4.1 # enables pNFS for parallel access to multiple storage nodes

- proto=rdma # sets the transfer protocol to RDMA instead of the default TCP
- max_connect=16 # enables NFS session trunking to aggregate storage port bandwidth
- write=eager # improves write performance of buffered writes
- rsize=262144,wsize=262144 # sets the I/O transfer size to 256k

NVA-1173 NetApp AIPod with NVIDIA DGX Systems - Solution Validation and Sizing Guidance

This section focuses on the solution validation and sizing guidance for the NetApp AIPod with NVIDIA DGX systems.

Solution Validation

The storage configuration in this solution was validated using a series of synthetic workloads using the open-source tool FIO. These tests include read and write I/O patterns intended to simulate the storage workload generated by DGX systems performing deep learning training jobs. The storage configuration was validated using a cluster of 2-socket CPU servers running the FIO workloads concurrently to simulate a cluster of DGX systems. Each client was configured with the same network configuration described previously, with the addition of the following details.

The following mount options were used for this validation:

vers=4.1	enables pNFS for parallel access to multiple storage nodes
proto=rdma	sets the transfer protocol to RDMA instead of the default TCP
port=20049	specify the correct port for the RDMA NFS service
max_connect=16	enables NFS session trunking to aggregate storage port bandwidth
write=eager	improves write performance of buffered writes
rsize=262144,wsize=262144	sets the I/O transfer size to 256k

In addition the clients were configured with an NFS max_session_slots value of 1024. As the solution was tested using NFS over RDMA, the storage networks ports were configured with an active/passive bond. The following bond parameters were used for this validation:

mode=active-backup	sets the bond to active/passive mode
primary=<interface name>	primary interfaces for all clients were distributed across the switches
mii-monitor-interval=100	specifies monitoring interval of 100ms
fail-over-mac-policy=active	specifies that the MAC address of the active link is the MAC of the bond. This is required for proper operation of RDMA over the bonded interface.

The storage system was configured as described with two A900 HA pairs (4 controllers) with two NS224 disk shelves of 24 1.9TB NVMe disk drives attached to each HA pair. As noted in the architecture section, storage capacity from all controllers was combined using a FlexGroup volume, and data from all clients was distributed across all the controllers in the cluster.

Storage System Sizing Guidance

NetApp has successfully completed the DGX BasePOD certification, and the two A90 HA pairs as tested can easily support a cluster of sixteen DGX H100 systems. For larger deployments with higher storage performance requirements, additional AFF systems can be added to the NetApp ONTAP cluster up to 12 HA pairs (24 nodes) in a single cluster. Using the FlexGroup technology described in this solution, a 24-node cluster can provide over 40 PB and up to 300 GBps throughput in a single namespace. Other NetApp storage systems such as the AFF A400, A250 and C800 offer lower performance and/or higher capacity options for smaller deployments at lower cost points. Because ONTAP 9 supports mixed-model clusters, customers can start with a smaller initial footprint and add more or larger storage systems to the cluster as capacity and performance requirements grow. The table below shows a rough estimate of the number of A100 and H100 GPUs supported on each AFF model.

NetApp storage system sizing guidance

		Throughput[2]	Raw capacity *(typical / max)*	Connectivity	# NVIDIA A100 GPUs supported[3]	# NVIDIA H100 GPUs supported[4]
NetApp® AFF A900	**1 HA pair[1]**	28GB/s	182TB / 14.7PB	**100 GbE**	1 - 64	1-32
	12 HA pairs	336GB/s	2.1PB / **176.4PB**		**768**	**384**
AFF A800	**1 HA pair**	25GB/s	368TB / 3.6PB	**100 GbE**	1 - 64	1-32
	12 HA pairs	300GB/s	4.4PB / **43.2PB**		**768**	**384**
AFF C800	**1 HA pair**	21GB/s	368TB / 3.6PB	**100 GbE**	1-48	1-24
	12 HA pairs	252GB/s	4.4PB / **43.2PB**		**576**	**288**
AFF A400	**1 HA pair**	11GB/s	182TB / 14.7PB	**40/100 GbE**	1 - 32	1-16
	12 HA pairs	132GB/s	2.1PB / **176.4PB**		**384**	**192**
AFF C400	**1 HA pair**	8GB/s	182TB / 14.7PB	**40/100 GbE**	1 - 16	1-8
	12 HA pairs	128GB/s	2.1PB / **176.4PB**		**192**	**96**
AFF A250	**1 HA pair**	7.4GB/s	91.2TB / 4.4PB	**25 GbE 40/100GbE**	1 - 16	1-8
	4 HA pairs	29.6GB/s	364.8TB / 17.6PB		64	32
AFF C250	**1 HA pair**	5 GB/s	91.2TB / 4.4PB	**25 GbE 40/100GbE**	1-8	1-4
	4 HA pairs	20 GB/s	364.8TB / 17.6PB		32	8

1 – 1 AFF = 1 HA pair = 2 Nodes. 12 HA pairs = 24 nodes
2 – 100% sequential read
3 – Based on workload testing in NVA-1153
4 – Based on BasePOD validation test results

NVA-1173 NetApp AIPod with NVIDIA DGX Systems - Conclusion and Additional Information

This section includes references for additional information for the NetApp AIPod with NVIDIA DGX systems.

Conclusion

The DGX BasePOD architecture is a next-generation deep learning platform that requires equally advanced storage and data management capabilities. By combining DGX BasePOD with NetApp AFF systems, the NetApp AIPod with DGX systems architecture can be implemented at almost any scale. Combined with the superior cloud integration and software-defined capabilities of NetApp ONTAP, AFF enables a full range of data pipelines that spans the edge, the core, and the cloud for successful DL projects.

Additional Information

To learn more about the information described in this document, please refer to the following documents and/or websites:

- NetApp ONTAP data management software — ONTAP information library

  https://docs.netapp.com/us-en/ontap-family/

- NetApp AFF A900 storage systems-

  https://www.netapp.com/data-storage/aff-a-series/aff-a900/

- NetApp ONTAP RDMA information-

  https://docs.netapp.com/us-en/ontap/nfs-rdma/index.html

- NetApp DataOps Toolkit

  https://github.com/NetApp/netapp-dataops-toolkit

- NetApp Astra Trident

  Overview

- NetApp GPUDirect Storage Blog-

  https://www.netapp.com/blog/ontap-reaches-171-gpudirect-storage/

- NVIDIA DGX BasePOD

  https://www.nvidia.com/en-us/data-center/dgx-basepod/

- NVIDIA DGX H100 systems

  https://www.nvidia.com/en-us/data-center/dgx-h100/

- NVIDIA Networking

  https://www.nvidia.com/en-us/networking/

- NVIDIA Magnum IO™ GPUDirect® Storage

  https://docs.nvidia.com/gpudirect-storage

- NVIDIA Base Command

  https://www.nvidia.com/en-us/data-center/base-command/

- NVIDIA Base Command Manager

  https://www.nvidia.com/en-us/data-center/base-command/manager

- NVIDIA AI Enterprise

  https://www.nvidia.com/en-us/data-center/products/ai-enterprise/

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