Scaling FlexPod for GPU Intensive Applications

Model Simulations and Complex Data Analysis

Published: December 2023

CISCO
Validated
Design

FlexPod
A Cisco and NetApp Solution

In partnership with:

NetApp®

About the Cisco Validated Design Program

The Cisco Validated Design (CVD) program consists of systems and solutions designed, tested, and documented to facilitate faster, more reliable, and more predictable customer deployments. For more information, go to: http://www.cisco.com/go/designzone.

Executive Summary

Organizations across various industries are facing challenges in overcoming competitive pressures, improve quality, boost productivity, accelerate digital transformation and decrease time to market, costs, and risks. The exponential growth in data is propelling the adoption of GPU Intensive Applications, HPC and AI technologies across multiple domains, as organizations seek to harness the power of these tools to extract meaningful insights, drive innovation, and make data-driven decisions in an increasingly data-rich world.

The definition of HPC (High-Performance Computing) is constantly changing, traditionally focused on transports that are sensitive to latency and the highest level of parallelization. GPUs take this evolution a step further. These advancements are enhanced by the amalgamation of GPU-accelerated applications and AI, leading to significant breakthroughs in various fields such as healthcare, finance, materials science, and climate research. This fusion allows researchers to delve into more complex models, simulate real-world scenarios, and analyze large datasets for data-driven discoveries. To fully leverage these capabilities and reap maximum benefits, a well-balanced and high-performing infrastructure encompassing compute, network, and storage is necessary. FlexPod facilitates this comprehensive approach.

AI has made a significant impact by transforming how the IT systems and services are developed, managed, and utilized. Adoption of AI-native infrastructure includes hardware accelerators such as GPU (Graphics Processing Unit), FPGA (Field Programmable Gate Arrays) and Tensor Processing Units (TPU) to handle AI computation effectively at scale. capable of extracting insights, learning from data patterns, and generating predictions, and making intelligent decisions, all at a scale and speed previously unattainable. Convergence of HPC and AI are reshaping the future datacenter design paradigm.

The convergence of GPU Intensive Applications, High-Performance Computing (HPC) and Artificial Intelligence (AI) technologies in a unified architecture brings about enhanced performance, scalability, and versatility for data-intensive tasks. This integration seamlessly incorporates popular AI development frameworks like TensorFlow and PyTorch, allowing data scientists and researchers to develop, train, and deploy AI models within the HPC environment. The fusion of custom solutions, hyperparameter optimization, and cross-validation enables the fine-tuning of models, empowering the exploration of complex scenarios and analysis of vast datasets in fields such as healthcare, finance, materials science, and climate research. Groundbreaking advancements are evident in applications like climate modeling, weather prediction, finance (risk analysis and fraud detection), energy exploration, material science, and healthcare (drug discovery and patient care).

While challenges exist, addressing them through strategic approaches involving talent development, best practices, robust data governance, and awareness of evolving technologies and regulations can unlock the transformative benefits of HPC and AI integration. This collaborative approach fosters improved decision-making, scientific advancements, and innovation across diverse industries and research domains.

This document summarizes SpecHPC 2021 based benchmark applications targeted for real-life model simulation in the fields of but not limited to; linear scalability when executing various size of dataset on HPC cluster consisting of eight node Cisco UCS C240 M7 Rack Server hosting NVIDIA A100-80G GPUs in FlexPod architecture.

- Weather simulation – Weather forecasting and climate modeling, agriculture, aviation, natural disaster prediction and prevention, renewable energy.
- Nuclear engineering (radiation transport) – Nuclear energy, radiation shielding, nuclear security and safeguards, medical imaging, and treatment.
- High performance geometric multigrid – Biomedical simulation, oil and gas reservoir simulation, Fluid Dynamics and Aerodynamics, structural mechanics.

FlexPod is designed to meet the demands of AI workloads. It offers:

- Simplified deployment and operation of general-purpose AI workloads.
- Seamless integration into AI eco systems.
- Gain operational simplicity and efficiency.
- Accelerate time to value and speed up AI implementation.
- Protect AI infra to safeguard systems, management, data, and applications.
- Linear Scalability: Demonstrated through benchmark tests, showcasing consistent performance even with varying dataset sizes.
- Centralized Management and Automation: Powered by Cisco Intersight, FlexPod reduces deployment times, optimizes resource utilization, minimizes energy consumption, and streamlines operations.
- NVIDIA HPC-X Software Toolkit Setup and Configuration: We've validated FlexPod using the NVIDIA HPC-X software toolkit, ensuring seamless integration and optimal performance. This toolkit harnesses the power of technologies like MPI (Message Passing Interface), OpenACC (Open Accelerators), and UCX (Unified Communication X) to enhance the capabilities of our solution.
- NetApp Tools: NetApp DataOps Toolkit is a Python library that makes it easy for developers, data scientists, and data engineers to perform numerous data management tasks.
- Comprehensive Testing for Real-World Workloads: Our rigorous testing process evaluates the scalability of FlexPod across different dataset sizes and application areas. We compare CPU-only performance with GPU-equipped systems, providing valuable insights into the capabilities of our solution.

The pre-validated design of FlexPod with centralized management and automation capabilities of Cisco Intersight reduces deployment times, optimize resource utilization, minimize energy consumption, and streamlining operations leading to better TCO (Total Cost of Ownership) and improved ROI (Return on Investment).

Solution Overview

This chapter contains the following:

- Audience
- Purpose of this Document
- What's New in this Release?
- Solution Summary

The FlexPod AI (Artificial Intelligence) solution for HPC and AI workloads aims to deliver a seamless integration of the current FlexPod portfolio to enable single architecture which can be sized and optimized for GPU acceleration and faster access to data through high-speed data-fabric.

This document describes steps to install and configure the Cisco UCS C240 M7 Rack Server with NVIDIA GPU in FlexPod AI. The deployment details can be extended on the Cisco UCS server with supported NVIDIA GPUs such as Cisco UCS C22X M7, C24X M7 and Cisco UCS X210c compute nodes with X440p PCIe node within the FlexPod AI.

Audience

The intended audience for this document includes, but is not limited to, sales engineers, field consultants, professional services, IT managers, IT engineers, partners, and customers who wants to take advantage of an infrastructure catering diverse workload HPC, AI/ML and analytics in a single architecture and be able to deliver IT efficiency and enable IT innovation.

Purpose of this Document

This document serves as a comprehensive guide for integrating the Cisco Intersight-managed Cisco UCS M7 servers into the FlexPod AI infrastructure. It provides essential design guidance, covering various elements and considerations necessary for a successful deployment. This document highlights the significant value of horizontal scaling in accelerating applications through the addition of GPU and CPU resources. Horizontal scaling enables organizations to harness the power of multiple GPUs and CPUs, unlocking enhanced processing capabilities and improved performance for AI/ML workloads. By leveraging the scalability of the Cisco UCS M7 servers, businesses can achieve optimal utilization of computational resources and drive breakthroughs in fields that demand intensive computing power. Additionally, this document emphasizes the design and product requirements for incorporating scalable AI/ML solutions to address high-performance computing use cases, including weather modeling, high energy physics, scientific experiment simulation, and life sciences.

Furthermore, through the integration of Cisco Intersight management and the FlexPod AI infrastructure, this document provides valuable insights into the best practices and considerations for deploying a scalable and high-performing solution. It empowers organizations to leverage advanced technologies and accelerate their AI/ML initiatives, ultimately driving innovation and achieving transformative results in their respective industries.

What's New in this Release?

The following design elements distinguish this version of FlexPod from previous models:

- Optimized integration of Cisco UCS C240 M7 servers with NVIDIA A100 GPU into the platform design.
- Scalable HPC cluster with GPU (Nvidia A100) and CPU (Intel 4th gen scalable processors) based practices.
- Support for 4th Gen Intel Xeon Scalable Processors (Sapphire Rapids) with up to 60 cores per processor and up to 8TB memory with 32 x 256GB DDR5-4800 DIMMs.

- Integration of NetApp A400 NVMe based all flash storage system to support AI/ML dataset.
- NetApp ONTAP 9.12.1.
- FlexPod AI architecture with end-to-end 100Gbps.
- Cisco Intersight managed stand-alone UCS C-Series rack server connected to Cisco Nexus switch.
- Cisco Intersight automated operating system installation.
- Ansible for post-OS configuration of HPC-AI cluster on bare metal.

Solution Summary

The FlexPod AI solution offers the following key benefits:

- **Converged Infrastructure:** FlexPod provides a pre-validated and integrated solution that combines compute, storage, and networking components, streamlining deployment and management.
- **Modular Scalability:** With its modular architecture, FlexPod allows for the independent scaling of resources, enabling organizations to adapt to changing workload demands.
- **Simplified Management:** FlexPod includes management and orchestration tools that automate provisioning and ensure consistent and compliant infrastructure management.
- **Multitenancy Support:** It offers multitenancy capabilities, allowing multiple workloads or applications to run concurrently while maintaining isolation and security.
- **Compatibility Assurance:** Cisco and NetApp certification processes ensure that all components are compatible and reliable, reducing the risk of integration issues and providing stable and supported infrastructure.
- **Investment protection:** as technology evolves, businesses can add new components or upgrade existing ones to adapt to changing workload demands while maintaining the integrity of their initial investment in FlexPod.

Technology Overview

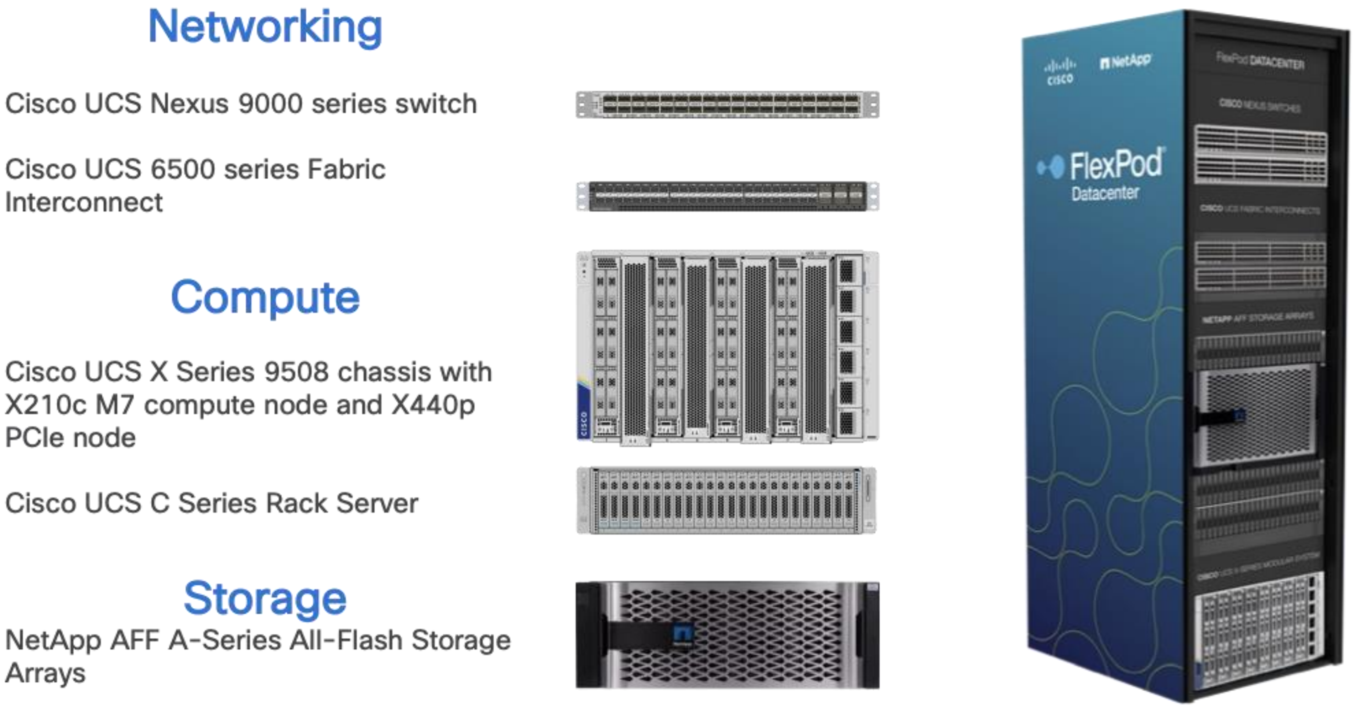
This chapter contains the following:

- FlexPod AI
- Cisco Unified Computing System
- Cisco UCS C-Series Rack Server
- Cisco Nexus 93600CD-GX
- NetApp AFF A-Series Storage

FlexPod AI

FlexPod is an integrated data center solution that combines compute, storage, and networking components, simplifying deployment, and offering scalability. It ensures compatibility and supports multiple workloads, making it an efficient and adaptable choice for modern data centers.

Figure 1. FlexPod AI components


Networking
Cisco UCS Nexus 9000 series switch
Cisco UCS 6500 series Fabric Interconnect
Compute
Cisco UCS X Series 9508 chassis with X210c M7 compute node and X440p PCIe node
Cisco UCS C Series Rack Server
Storage
NetApp AFF A-Series All-Flash Storage Arrays
cisco
NetApp
FlexPod
Datacenter

Go to the Cisco Design Zone for pre-validated FlexPod Design Guides containing a wide variety of enterprise applications.

Cisco Unified Computing System

Cisco Unified Computing System (Cisco UCS) is a next-generation data center platform that integrates compute, network, storage, and virtualization resources into a single cohesive architecture simplifying data center management, improved operational efficiency, reduce total cost of ownership, and increase business agility.

Cisco UCS Manager is the central management software that provides a unified interface for configuring, monitoring, and automating the entire UCS infrastructure, streamlining operations and enabling rapid resource provisioning. Cisco Intersight is a cloud-based management platform that offers enhanced visibility, analytics, and automation for Cisco UCS and other Cisco infrastructure, providing a scalable and intelligent solution for optimizing data center operations and achieving agility in the modern IT landscape.

Cisco UCS Differentiators

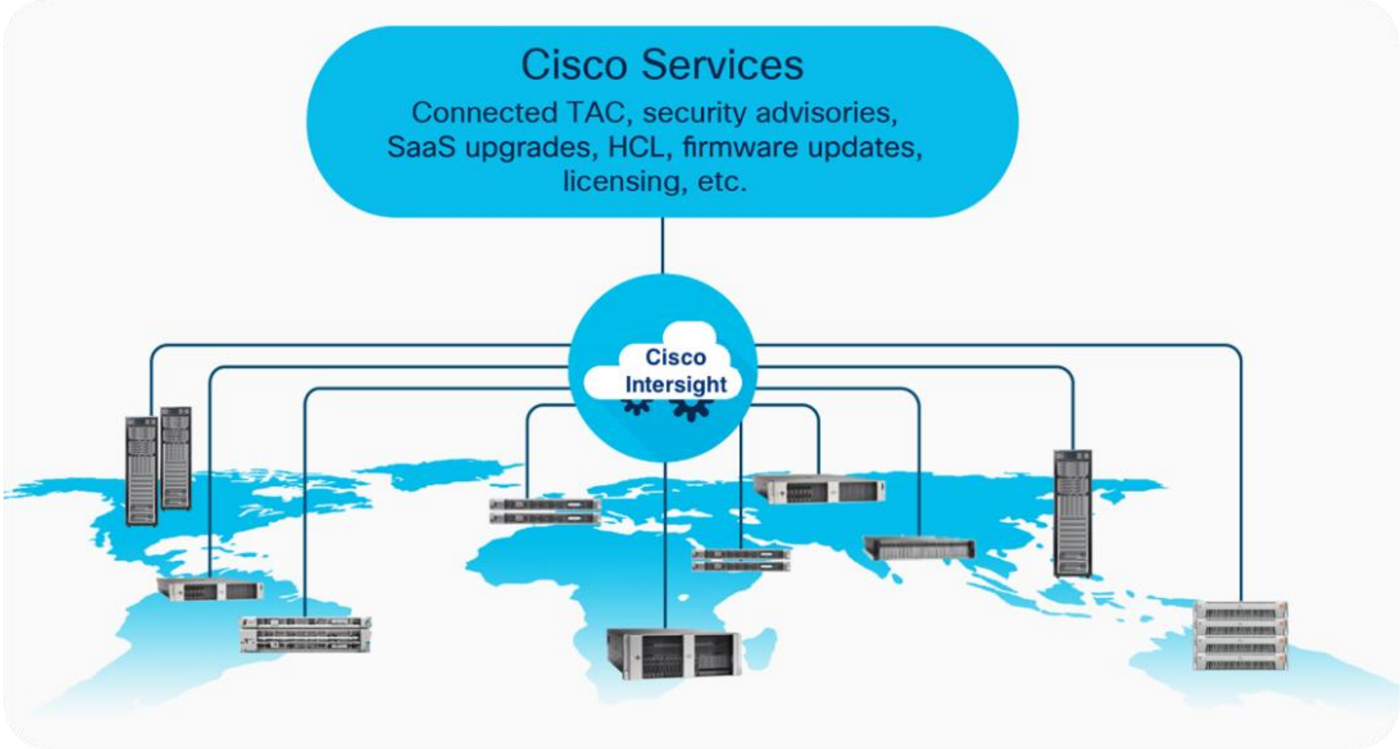
Cisco Unified Computing System is revolutionizing the way servers are managed in the datacenter. The following are the unique differentiators of Cisco Unified Computing System and Cisco UCS Manager:

- Embedded Management—In Cisco UCS, the servers are managed by the embedded firmware in the Fabric Inter-connects, eliminating the need for any external physical or virtual devices to manage the servers.
- Unified Fabric—In Cisco UCS, from blade server chassis or rack servers to FI, there is a single Ethernet cable used for LAN, SAN, and management traffic. This converged I/O results in reduced cables, SFPs and adapters – reducing capital and operational expenses of the overall solution.
- Auto Discovery—By simply inserting the blade server in the chassis or connecting the rack server to the fabric interconnect, discovery and inventory of compute resources occurs automatically without any management intervention. The combination of unified fabric and auto-discovery enables the wire-once architecture of Cisco UCS, where compute capability of Cisco UCS can be extended easily while keeping the existing external connectivity to LAN, SAN, and management networks.

Cisco Intersight

Cisco Intersight is a lifecycle management platform for your infrastructure, regardless of where it resides. In your enterprise data center, at the edge, in remote and branch offices, at retail and industrial sites—all these locations present unique management challenges and have typically required separate tools. Cisco Intersight Software as a Service (SaaS) unifies and simplifies your experience of the Cisco Unified Computing System (Cisco UCS). See Figure 2.

Figure 2. Cisco Intersight


Cisco Services
Connected TAC, security advisories, SaaS upgrades, HCL, firmware updates, licensing, etc.
Cisco Intersight

Cisco UCS C-Series Rack Server

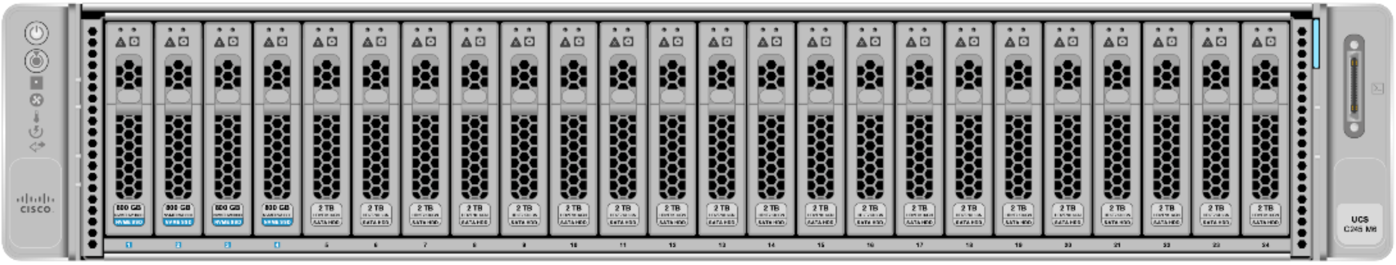
Cisco UCS C-Series Rack-Mount Servers keep pace with Intel Xeon and AMD EPYC processor innovation by offering the latest processors with increased processor frequency and improved security and availability features. Cisco UCS C-Series servers offer an improved price-to-performance ratio. They also extend Cisco UCS innovations to an industry-standard rack-mount form factor, including a standards-based unified network fabric, Cisco VN-Link virtualization support, and Cisco Extended Memory Technology.

It is designed to operate both in standalone environments and as part of Cisco UCS managed by Cisco Intersight or Cisco UCS Manager. Cisco UCS C-Series servers enable organizations to deploy systems incrementally—using as many or as few servers as needed—on a schedule that best meets the organization’s timing and budget.

Cisco UCS C240 M7 Rack Server

The Cisco UCS C240 M7 Rack Server extends the capabilities of the Cisco UCS rack server portfolio with up to two 4th Gen Intel Xeon Scalable CPUs, with up to 60 cores per socket. The maximum memory capacity for 2 CPUs is 8 TB (for 32 x 256 GB DDR5 4800 MT/s DIMMs). The Cisco UCS C240 M7 has a 2-Rack-Unit (RU) form and supports up to 8 PCIe 4.0 slots or up to 4 PCIe 5.0 slots plus a modular LAN on motherboard (mLOM) slot. Up to five GPUs are supported. The server delivers significant performance and efficiency gains that will improve your application performance.

Figure 3. Cisco UCS C240 M7 Rack Server - front and rear image



For more details, go to: Cisco UCS C240 M7 Rack Server Data Sheet.

Cisco Nexus 93600CD-GX

Based on Cisco Cloud Scale technology, the Cisco Nexus 9300-GX switches are the next generation of fixed Cisco Nexus 9000 Series Switches capable of supporting 400 Gigabit Ethernet (GE). With the increase in use cases for applications requiring Artificial Intelligence (AI) and Machine Learning (ML), the platform addresses the need for high-performance, power-efficient, compact switches in the networking infrastructure. These switches are designed to support 100G and 400G fabrics for mobile service provider environments, including the network edge, 5G, IoT, Professional Media Networking platform (PMN), and Network Functions Virtualization (NFV).

The Cisco Nexus 93600CD-GX Switch (Figure 2) is a 1RU switch that supports 12 Tbps of bandwidth and 4.0 bpps across 28 fixed 40/100G QSFP-28 ports and 8 fixed 10/25/40/50/100/200/400G QSFP-DD ports.

Cisco provides two modes of operation for Cisco Nexus 9000 Series Switches. Organizations can deploy Cisco Application Centric Infrastructure (Cisco ACI) or Cisco NX-OS mode.

Figure 4. Cisco UCS Nexus 93600CD-GX Switch

For more details, see https://www.cisco.com/c/en/us/products/collateral/switches/nexus-9000-series-switches/nexus-9300-gx-series-switches-ds.html

NetApp AFF A-Series Storage

NetApp AFF A-Series controller lineup provides industry leading performance while continuing to provide a full suite of enterprise-grade data management and data protection features. NetApp AFF A-Series systems support end-to-end NVMe technologies, from NVMe-attached SSDs to frontend NVMe over Fibre Channel (NVMe/FC) host connectivity. These systems deliver enterprise class performance, making them a superior choice for driving the most demanding workloads and applications. With a simple software upgrade to the modern NVMe/FC SAN infrastructure, you can drive more workloads with faster response times, without disruption or data migration. Additionally, more organizations are adopting a “cloud first” strategy, driving the need for enterprise-grade data services for a shared environment across on-premises data centers and the cloud. As a result, modern all-flash arrays must provide robust data services, integrated data protection, seamless scalability, and new levels of performance — plus deep application and cloud integration. These new workloads demand performance that first-generation flash systems cannot deliver.

For more information about the NetApp AFF A-series controllers, see the AFF product page: https://www.netapp.com/us/products/storage-systems/all-flash-array/aff-a-series.aspx.

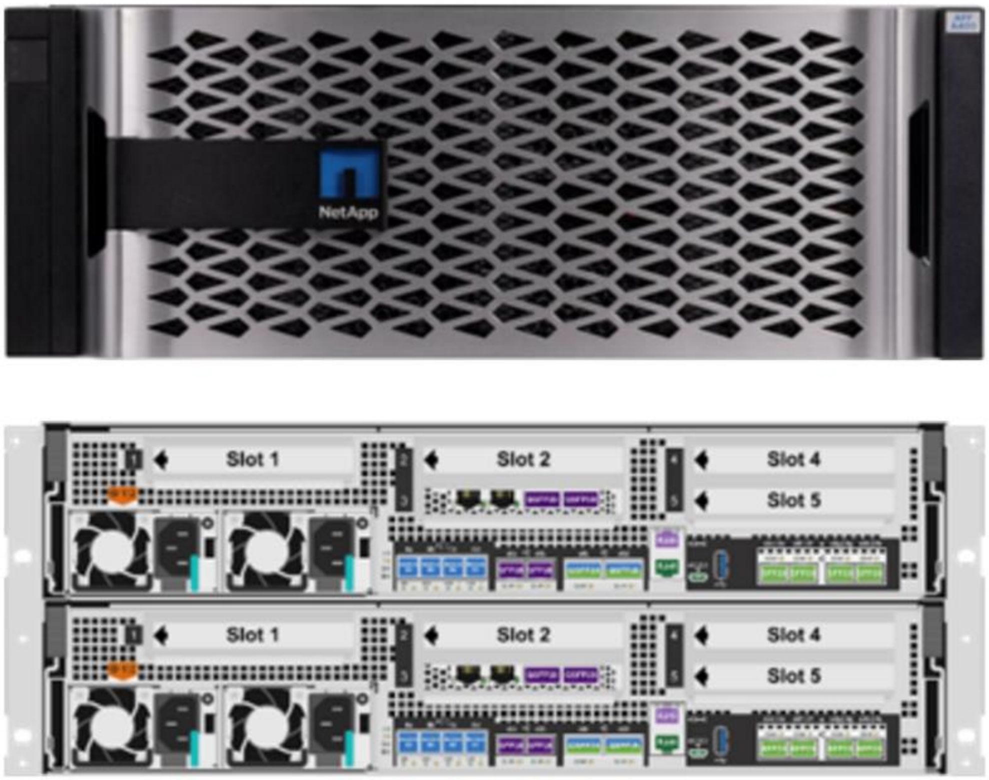
You can view or download more technical specifications of the NetApp AFF A-series controllers here: https://www.netapp.com/us/media/ds-3582.pdf

NetApp AFF A400

The NetApp AFF A400 offers full end-to-end NVMe support. The frontend NVMe/FC connectivity makes it possible to achieve optimal performance from an all-flash array for workloads that include artificial intelligence, machine learning, and real-time analytics as well as business-critical databases. On the back end, the A400 supports both serial-attached SCSI (SAS) and NVMe-attached SSDs, offering the versatility for current customers to move up from their legacy A-Series systems and satisfying the increasing interest that all customers have in NVMe-based storage.

The NetApp AFF A400 offers greater port availability, network connectivity, and expandability. The NetApp AFF A400 has 10 PCIe Gen3 slots per high availability pair. The NetApp AFF A400 offers 25GbE or 100GbE, as well as 32Gb/FC and NVMe/FC network connectivity. This model was created to keep up with changing business needs and performance and workload requirements by merging the latest technology for data acceleration and ultra-low latency in an end-to-end NVMe storage system.

Figure 5. NetApp AFF A400 Storage - front and rear image



NetApp ONTAP 9

NetApp storage systems harness the power of ONTAP to simplify the data infrastructure from edge, core, and cloud with a common set of data services and 99.9999 percent availability. NetApp ONTAP 9 data management software from NetApp enables customers to modernize their infrastructure and transition to a cloud-ready data center. ONTAP 9 has a host of features to simplify deployment and data management, accelerate and protect critical data, and make infrastructure future-ready across hybrid-cloud architectures.

NetApp ONTAP 9 is the data management software that is used with the NetApp AFF A400 all-flash storage system in this solution design. ONTAP software offers secure unified storage for applications that read and write data over block- or file-access protocol storage configurations. These storage configurations range from high-speed flash to lower-priced spinning media or cloud-based object storage. ONTAP implementations can run on NetApp engineered FAS or AFF series arrays and in private, public, or hybrid clouds (NetApp Private Storage and NetApp Cloud Volumes ONTAP). Specialized implementations offer best-in-class converged infrastructure, featured here as part of the FlexPod AI solution or with access to third-party storage arrays (NetApp FlexArray virtualization). Together these implementations form the basic framework of the NetApp Data Fabric, with a common software-defined approach to data management, and fast efficient replication across systems. FlexPod and ONTAP architectures can serve as the foundation for both hybrid cloud and private cloud designs.

Read more about all the capabilities of ONTAP data management software here: https://www.netapp.com/us/products/data-management-software/ontap.aspx

ONTAP 9.12 brings additional enhancements in manageability, data protection, networking and security protocols, and SAN and object storage. It also includes updated hardware support, increased MetroCluster IP solution scale, and supports IP-routed MetroCluster IP backend connections. See the ONTAP 9.12.1 release note below for more details: https://docs.netapp.com/us-en/cloud-volumes-ontap-9121-relnotes/

FlexClone

NetApp FlexClone technology enables instantaneous point-in-time copies of a FlexVol volume without consuming any additional storage until the cloned data changes from the original. FlexClone volumes add extra agility and efficiency to storage operations. They take only a few seconds to create and do not interrupt access to the parent FlexVol volume. FlexClone volumes use space efficiently, applying the ONTAP architecture to store only data that changes between the parent and clone. FlexClone volumes are suitable for testing or development environments, or any environment where progress is made by locking-in incremental improvements. FlexClone volumes also benefit any business process where you must distribute data in a changeable form without endangering the integrity of the original.

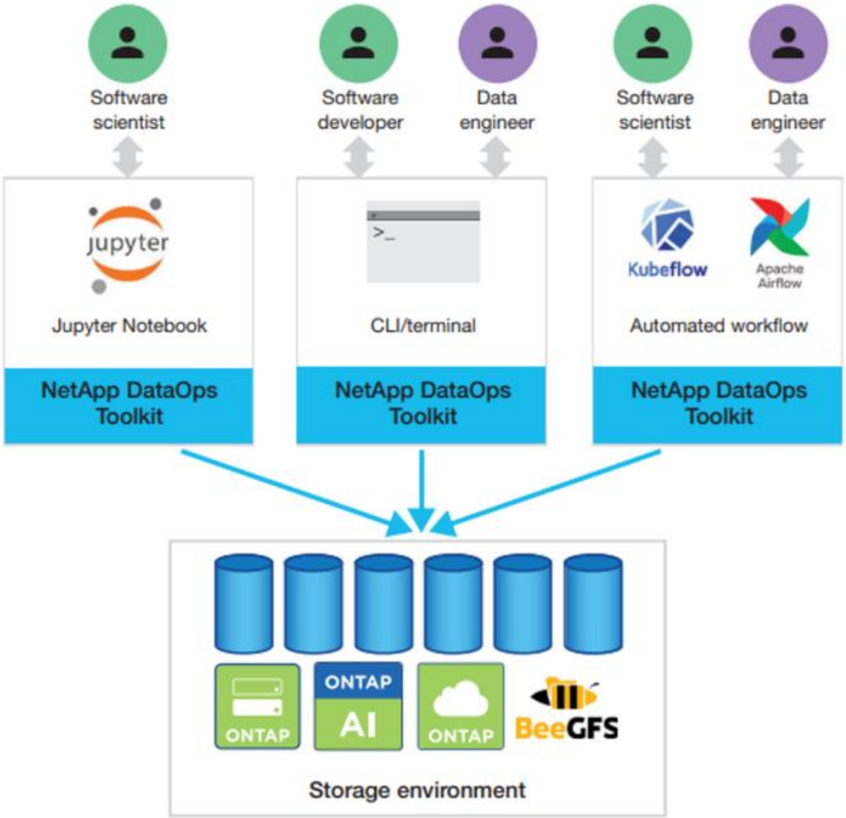
NetApp DataOps Toolkit

The NetApp DataOps Toolkit is a Python library that makes it easy for developers, data scientists, and data engineers to perform numerous data management tasks. These tasks include provisioning a new data volume or development workspace, cloning a data volume or development workspace almost instantaneously, and creating a NetApp Snapshot copy of a data volume or development workspace for traceability and baselining. This Python library can function as either a command-line utility or a library of functions that can be imported into any Python program or Jupyter Notebook.

The DataOps Toolkit supports Linux and macOS hosts. The toolkit must be used in conjunction with a NetApp data storage system or service. It simplifies various data management tasks that are executed by the data storage system or service. To facilitate this simplification, the toolkit communicates with the data storage system or service through an API.

The NetApp DataOps Toolkit for Kubernetes abstracts storage resources and Kubernetes workloads up to the data-science workspace level. These capabilities are packaged in a simple, easy-to-use interface that is designed for data scientists and data engineers. Using the familiar form of a Python program, the Toolkit enables data scientists and engineers to provision and destroy JupyterLab workspaces in just seconds. These workspaces can contain terabytes, or even petabytes, of storage capacity, enabling data scientists to store all their training datasets directly in their project workspaces. Gone are the days of separately managing workspaces and data volumes.

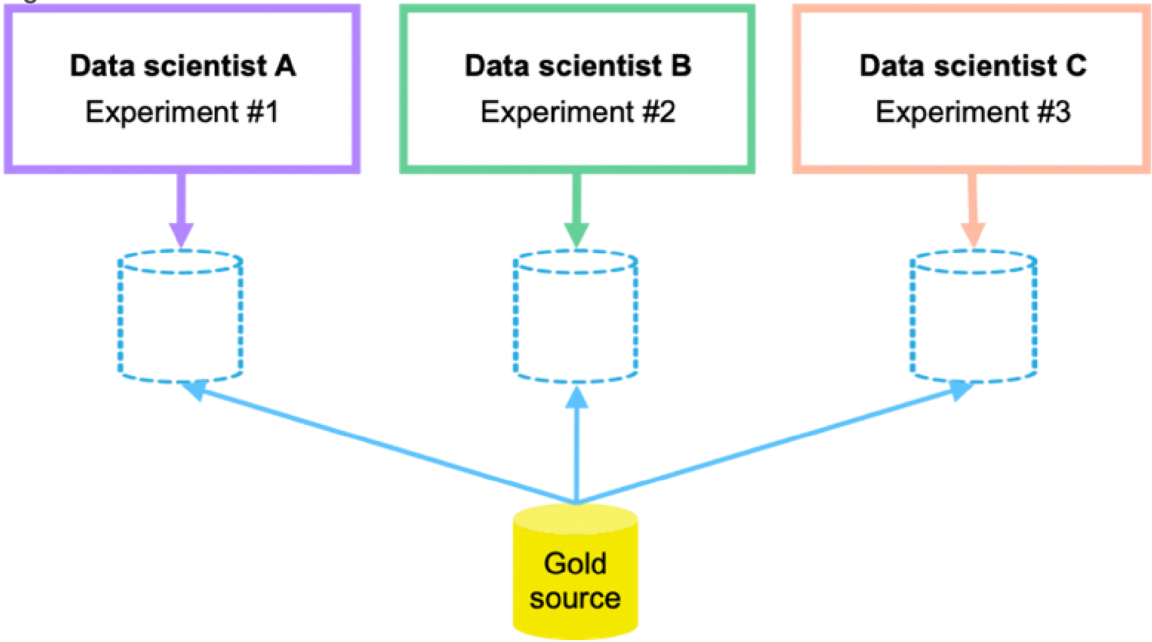
Figure 6. NetApp Data Science Toolkit



AI/ML Use Cases – DataOps for Data Scientist

With the NetApp DataOps Toolkit, a data scientist can almost instantaneously create a space-efficient data volume that's an exact copy of an existing volume regardless of the size of the dataset. Data scientists can quickly create clones of datasets that they can reformat, normalize, and manipulate, while preserving the original "gold-source" dataset. Under the hood, these operations use highly efficient and battle-tested NetApp FlexClone feature, but they can be performed by a data scientist without storage expertise. What used to take days or weeks (and the assistance of a storage administrator) now takes seconds.

Figure 7. Clone of dataset



Data scientists can also save a space-efficient, read-only copy of an existing data volume. Based on the famed NetApp Snapshot technology, this functionality can be used to version datasets and implement dataset-to-model traceability. In regulated industries, traceability is a baseline requirement, and implementing it is extremely complicated with most other tools. With the NetApp DataOps Toolkit, it's quick and easy.

More operations and capabilities are available and documented here: https://github.com/NetApp/netapp-data-science-toolkit

Solution Design

This chapter contains the following:

- Requirements
- Considerations

Requirements

The FlexPod AI with Cisco UCS and NetApp storage meets the following general design requirements:

- Resilient design across all layers of the infrastructure with no single point of failure.
- Scalable design with the flexibility to add compute capacity, storage, or network bandwidth as needed.
- Modular design that can be replicated to expand and grow as the needs of the business grow.
- Flexible design that can support different models of various components with ease.
- Simplified design with ability to integrate and automate with external automation tools.
- Cloud-enabled design which can be configured, managed, and orchestrated from the cloud using GUI or APIs.

To deliver a solution which meets all these design requirements, various solution components are connected and configured as explained in the following sections.

Physical Components

Table 1 lists the required physical components and hardware for FlexPod AI.

Table 1. FlexPod AI Hardware Components

Component	Hardware
Servers	Eight (8) Cisco UCS C240 M7 rack server
Storage	NetApp AFF A400
Network	Two (2) Cisco Nexus 93600CD-GX

Table 2. Cisco UCS C240 M7 Hardware Components

Component	Hardware
Processor	Two (2) 4th Gen Intel® Xeon® Scalable Processor 6454S 32C/2.2GHz/270W
Memory	Sixteen (16) 64GB DDR5-4800 RDIMM
NIC (Network Interface Card)	Mellanox ConnectX-6 DX 2 x 100Gb Ethernet
GPU (Graphics Processing Unit)	NVIDIA Tesla A100-80GB GPU

Table 3. NetApp AFF A400 Components

Component	Hardware
AFF Flash Array	NetApp All Flash AFF A400 Storage Array (4RU)

Component	Hardware
Capacity	27.8TB (12 x 3.49TB NVMe SSD Drives)
Connectivity	4 x 100Gb/s (2 x 100Gb per controller) Data Rate: 100 Gb/s Ethernet, PCI Express Gen3: SERDES @ 8.0GT/s, 16 lanes) (MCX516A-CCAT) 1 Gb/s redundant Ethernet (Management port)

Software Components

Table 4 lists the software components and the versions required for FlexPod AI as tested and validated in this document.

Table 4. FlexPod AI Software Components

Component	Software version
Cisco Intersight	SaaS platform
Cisco UCS Server Firmware	4.3(2.230207)
Host OS	Ubuntu 22.04 LTS
Mellanox ConnectX-6 NIC	22.36.1010
	MLNX OFED 5.8-1.1.2.1
NVIDIA Tesla A100-80GB GPU	NVIDIA CUDA 12.2.2
	NVIDIA Driver 535.104.05
NetApp AFF A400	ONTAP 9.12.1
Cisco Nexus 93600CD-GX	NX-OS 10.3.3

Note: See the Bill of Materials section for a complete list and corresponding PID.

Required VLANs

Table 5 lists various VLANs configured for setting up the FlexPod environment including their specific usage.

Table 5. FlexPod AI – VLAN Usage

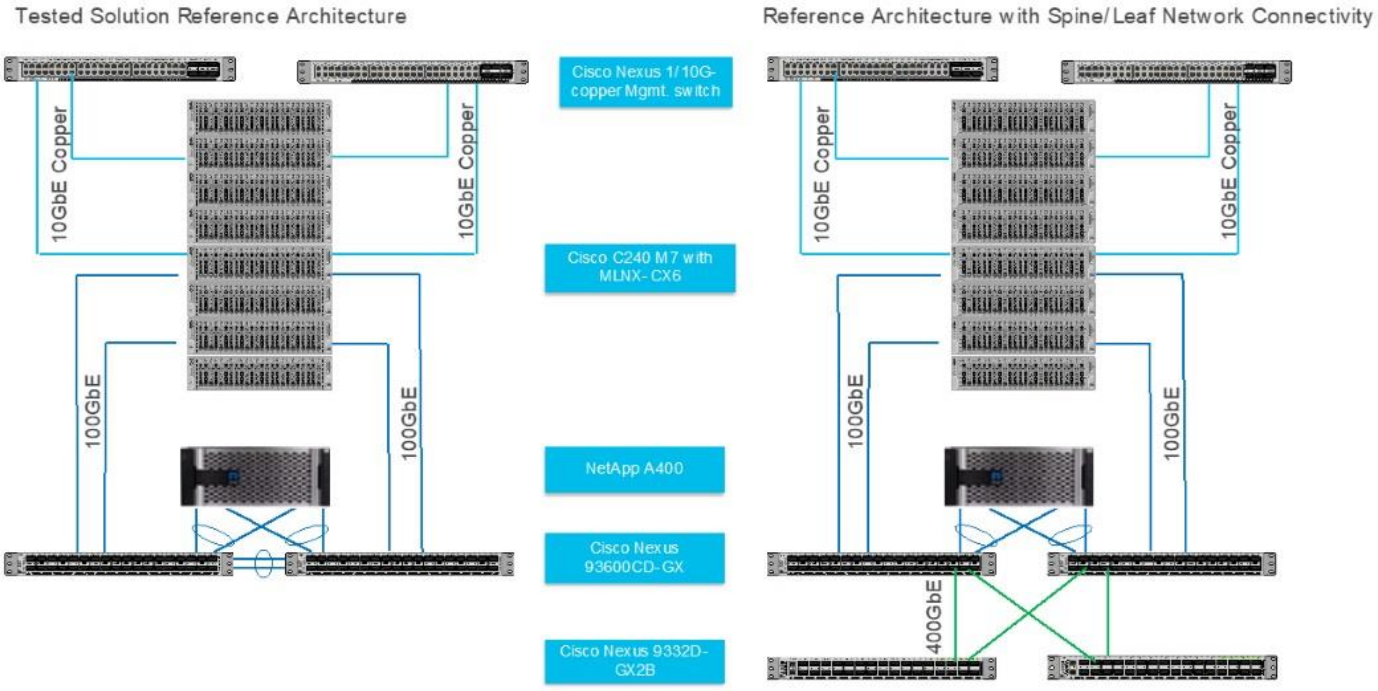
VLAN ID	Name	Usage
2	Native-VLAN	Use VLAN 2 as Native VLAN instead of default VLAN (1)
248	OOB-MGMT-VLAN	Management VLAN to access and manage the servers
110	AI-ML-NFS_1	NFS VLAN to access AI/ML NFS volume hosting HPC data
160	AI-ML-NFS_2	NFS VLAN to access AI/ML NFS volume hosting HPC data

Some of the key highlights of VLAN usage are as follows:

- Bare-metal servers are managed using same management in-band VLAN: IB-MGMT-VLAN (248).
- Utilizing dedicated NFS VLANs for HPC and AI; hosts provide path selection flexibility and the ability to configure specific QoS policies. You are encouraged to use separate, dedicated VLANs for NFS traffic.

Physical Topology

Figure 8. FlexPod AI Physical Topology


Tested Solution Reference Architecture
Reference Architecture with Spine/Leaf Network Connectivity
10GbE Copper
10GbE Copper
100GbE
100GbE
Cisco Nexus 1/10G-copper Mgmt. switch
Cisco C240 M7 with MLNX-CX6
NetApp A400
Cisco Nexus 93600CD-GX
Cisco Nexus 9332D-GX2B
10GbE Copper
10GbE Copper
100GbE
100GbE
400GbE

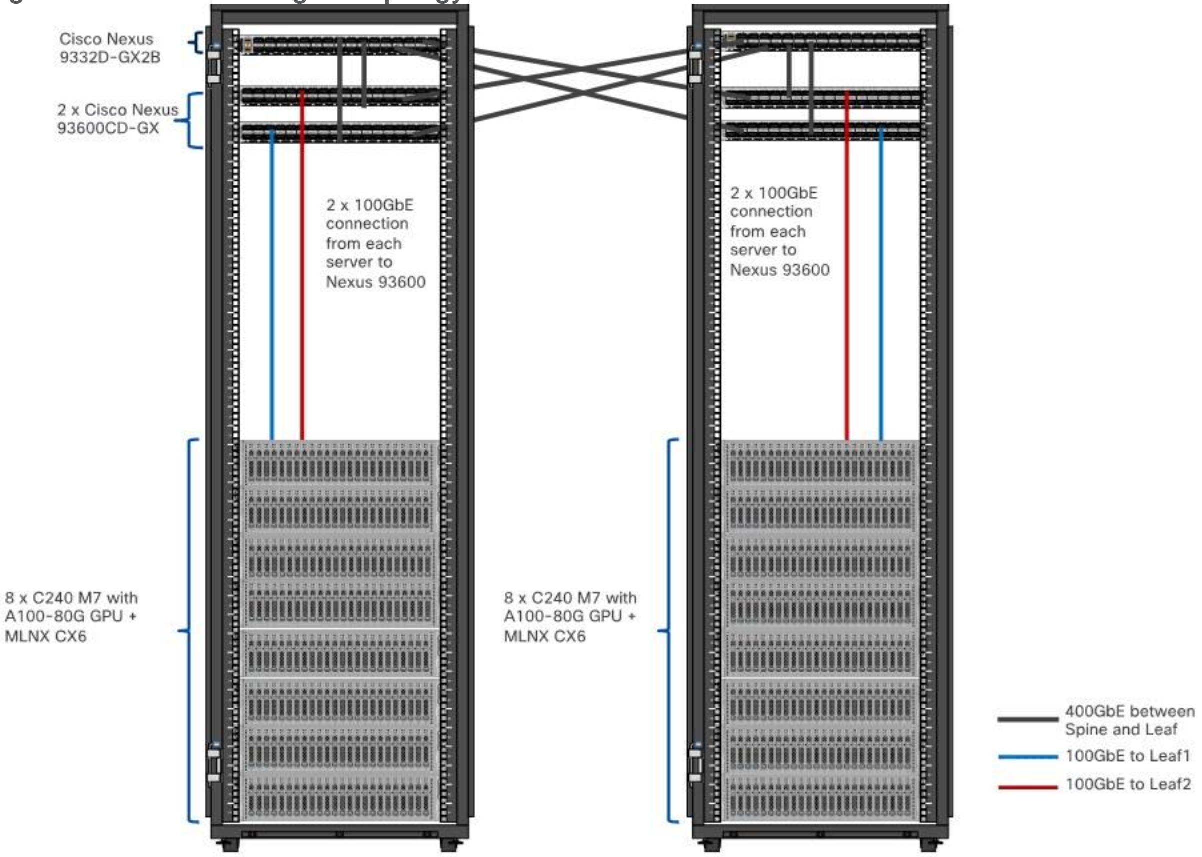
For this solution, we tested left side configuration as shown in Figure 8 with Cisco UCS C-Series Rack Server and NetApp AFF A400 storage array connected to Cisco Nexus 93600CD-GX leaf switch with layer 2 configuration for a single rack testing. For large cluster spanning across multiple racks and Spine/Leaf networking best practices, please refer to Cisco Data Center Networking Blueprint for AI/ML Applications.

Note: This solution is tested with Cisco VIC 15428 (4x 10/25/50G mLOM C-Series) for 10GbE connection with ToR switch and utilized for separate OS management from data traffic on Mellanox ConnectX6-DX Ethernet NIC.

Logical Topology

The single rack topology of the FlexPod AI architecture highlighted in this CVD can be easily expanded to a larger size cluster connecting hundreds of servers with Spine-Leaf network design where congestion management enabled on leaf layer and spine later with PFC and ECN as shown in Figure 9.

Figure 9. FlexPod AI Logical Topology


Cisco Nexus 9332D-GX2B
2 x Cisco Nexus 93600CD-GX
2 x 100GbE connection from each server to Nexus 93600
2 x 100GbE connection from each server to Nexus 93600
8 x C240 M7 with A100-80G GPU + MLNX CX6
8 x C240 M7 with A100-80G GPU + MLNX CX6
400GbE between Spine and Leaf
100GbE to Leaf1
100GbE to Leaf2

Considerations

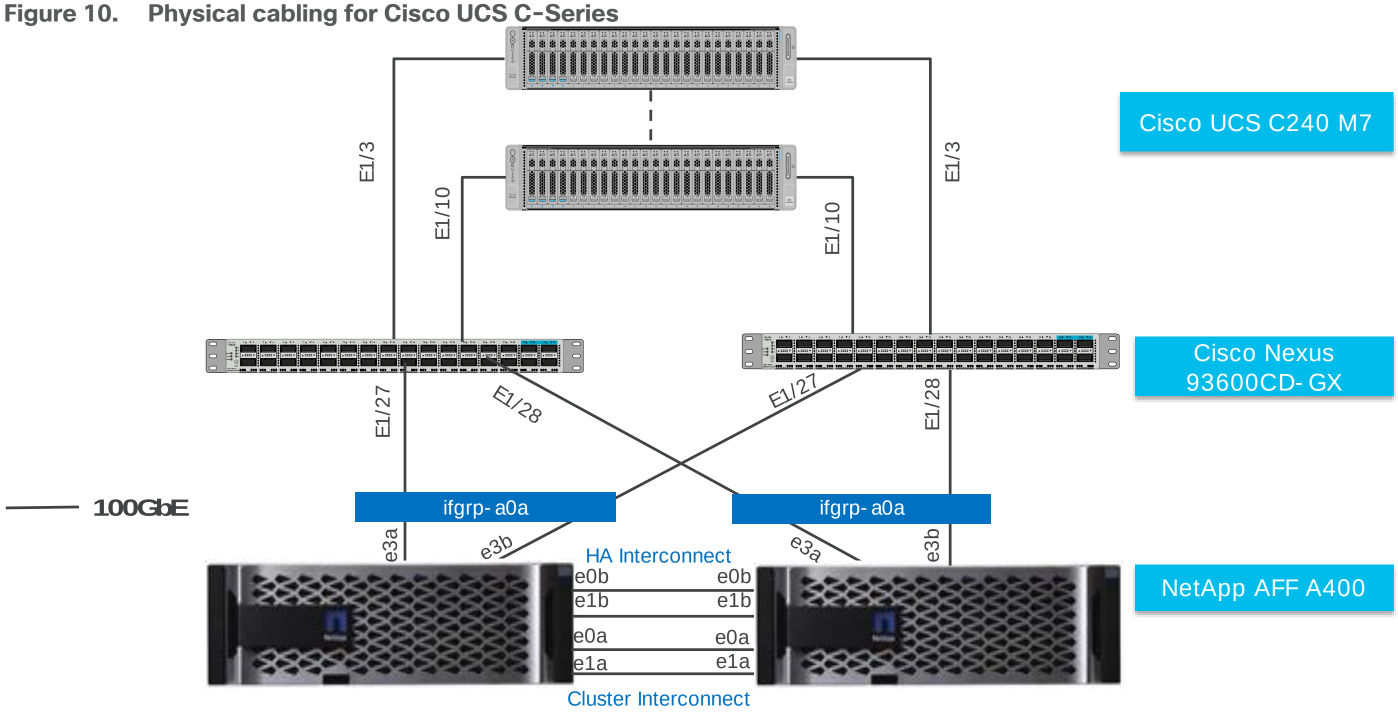
The information in this section is provided as a reference for cabling the physical equipment in a FlexPod environment. To simplify cabling requirements, a cabling diagram was used.

The cabling diagram in this section contains the details for the prescribed and supported configuration of the NetApp AFF 400 running NetApp ONTAP 9.12.1.

Tech tip
For any modifications of this prescribed architecture, consult the NetApp Interoperability Matrix Tool (IMT). This document assumes that out-of-band management ports are plugged into an existing management infrastructure at the deployment site. These interfaces will be used in various configuration steps. Be sure to use the cabling directions in this section as a guide. The NetApp storage controller and disk shelves should be connected according to best practices for the specific storage controller and disk shelves. For disk shelf cabling, refer to NetApp Support.

Figure 10 details the cable connections used in the validation lab for the FlexPod topology based on the Cisco UCS C240 M7 stand-alone server managed via Intersight and NetApp AFF A400 storage array. Two 100Gb uplinks connect as port-channels from each Cisco UCS Nexus 93600CD-GX switches to the NetApp AFF controllers. Additional 1Gb management connections will be needed for an out-of-band network switch that sits apart from the FlexPod infrastructure. Each Cisco UCS C240 M7 rack server and Cisco Nexus switch is connected to the out-of-band network switch, and each AFF controller has a connection to the out-of-band network switch. Layer 3 network connectivity is required between the Out-of-Band (OOB) and In-Band (IB) Management Subnets.

Figure 10. **Physical cabling for Cisco UCS C-Series**



Install and Configure

This chapter contains the following:

- Network Switch Configuration
- NetApp ONTAP Storage Configuration
- Install Cisco UCS
- Cisco Intersight Configuration
- Post-OS Configuration
- Mellanox ConnectX-6 NIC Best Practice
- NVIDIA GPU Configuration for HPC Workload

Network Switch Configuration

Designing a network infrastructure for an HPC and AI cluster requires careful consideration to ensure efficient data transfer, low latency, and scalability. The network configuration tuned to match the specific requirements of your HPC and AI workloads via implementation of QoS (Quality of Service) to ensure efficient utilization and monitoring of the network resources available.

Please refer to Cisco Data Center Networking Blueprint for AI/ML Applications for more detailed documentation on best practices for lossless network design and configuration required for HPC and AI workload.

This section provides a detailed procedure for configuring the Cisco Nexus 93600CD-GX switches for use in a FlexPod AI/ML environment. The Cisco Nexus 93600CD-GX will be used for LAN switching in this solution. This configuration allows deployment of Cisco AI/ML platforms in bare-metal server configuration.

Tech tip

The following procedures describe how to configure the Cisco Nexus switches for use in a base FlexPod environment. This procedure assumes the use of Cisco Nexus 9000 NX-OS 10.3.3F.

The following procedure includes the setup of NTP distribution on both the mgmt0 port and the in-band management VLAN. The interface-vlan feature and ntp commands are used to set this up. This procedure also assumes that the default VRF is used to route the in-band management VLAN.

This procedure sets up and uplink virtual port channel (vPC) with the IB-MGMT and OOB-MGMT VLANs allowed.

This validation assumes that both switches have been reset to factory defaults by using the “write erase” command followed by the “reload” command.

Physical Connectivity

Follow the physical connectivity guidelines for FlexPod as explained in the Physical Topology section.

Initial Configuration

The following procedures describe this basic configuration of the Cisco Nexus switches for use in the FlexPod environment. This procedure assumes the use of Cisco Nexus 9000 10.2(5)M, the Cisco suggested Nexus switch release at the time of this validation.

Procedure 1. Set Up Initial Configuration from a serial console

Step 1. Set up the initial configuration for the Cisco Nexus 93600CD-GX switch.

Procedure 2. Configure Global Settings on both Cisco Nexus Switches

Tech tip

Remote Direct Memory Access (RDMA) over Converged Ethernet (RoCE); for RoCEv2 transport, the network must provide high throughput and low latency while avoiding traffic drops in situations where congestion occurs.

The following procedures describe how to configure the Cisco Nexus switches global configuration highlighting for RoCE V2 and QoS, no-drop shown. Please refer Appendix for full configuration.

Step 1. Login as admin user into the Cisco Nexus switch A and run the following commands to set the global configuration on switch:

```
configure terminal

policy-map type network-qos qos_network

  class type network-qos c-8q-nq3

    mtu 9216

    pause pfc-cos 3

  class type network-qos c-8q-nq-default

    mtu 9216

class-map type qos match-any CNP

  match dscp 48

class-map type qos match-all ROCEv2

  match dscp 24,26

policy-map type qos QOS_MARKING

  class ROCEv2

    set qos-group 3

  class CNP

    set qos-group 7

  class class-default

    set qos-group 0

policy-map type queuing QOS_EGRESS_PORT

  class type queuing c-out-8q-q6

    bandwidth remaining percent 0

  class type queuing c-out-8q-q5

    bandwidth remaining percent 0
  class type queuing c-out-8q-q4
    bandwidth remaining percent 0
  class type queuing c-out-8q-q3
    bandwidth remaining percent 50
    random-detect minimum-threshold 150 kbytes maximum-threshold 3000 kbytes drop-probability 7 weight 0 ecn
  class type queuing c-out-8q-q2
    bandwidth remaining percent 0
  class type queuing c-out-8q-q1
    bandwidth remaining percent 0
  class type queuing c-out-8q-q-default
    bandwidth remaining percent 50
  class type queuing c-out-8q-q7
    priority level 1
system qos
  service-policy type network-qos qos_network
  service-policy type queuing output QOS_EGRESS_PORT
copy running-config startup-config
```

Step 2. Login as admin user into Cisco Nexus Switch B; repeat steps 1 and 2 above to set up the global configuration.

Tech tip
Make sure to run copy run start to save the configuration on each switch after the configuration is completed.

NetApp ONTAP Storage Configuration

NetApp AFF A-Series Storage System

NetApp AFF A-Series is a family of all-flash storage systems by NetApp. The systems are designed to provide high-performance, low-latency and highly available storage solution suitable for a wide range of enterprise applications such as AI/ML, databases, and virtualization.

NetApp storage systems support a wide variety of disk shelves and disk drives. The complete list of disk shelves that are supported by the AFF A400 is available at the NetApp Support site.

Follow the physical installation procedures for the controllers found here: https://docs.netapp.com/us-en/ontap-systems/index.html.

When using SAS disk shelves with NetApp storage controllers, refer to: https://docs.netapp.com/us-en/ontap-systems/sas3/install-new-system.html for proper cabling guidelines.

When using NVMe drive shelves with NetApp storage controllers, refer to: https://docs.netapp.com/us-en/ontap-systems/ns224/hot-add-shelf.html for installation and servicing guidelines.

For more information about the setup and configuration of the NetApp AFF A-Series storage system setup and deployment FlexPod solution, go to:

https://www.cisco.com/c/en/us/solutions/design-zone/data-center-design-guides/flexpod-design-guides.html

https://www.netapp.com/data-storage/flexpod/validated-designs/

Install Cisco UCS

This section contains the following:

- Physical Connectivity

Tech tip

Please visit Cisco UCS C240 M7 Server Installation and Service Guide: https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/c/hw/C240M7/install/b-cisco-c240-m7-install/m-installing.html

Please visit GPU card installation on C240 M7: https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/c/hw/C240M7/install/b-cisco-c240-m7-install/m-gpu-install.html

Please visit Cisco UCS C-Series Integrated Management Controller GUI Configuration Guide: https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/c/sw/gui/config/guide/4_3/b_cisco_ucs_c-series_gui_configuration_guide_43.html

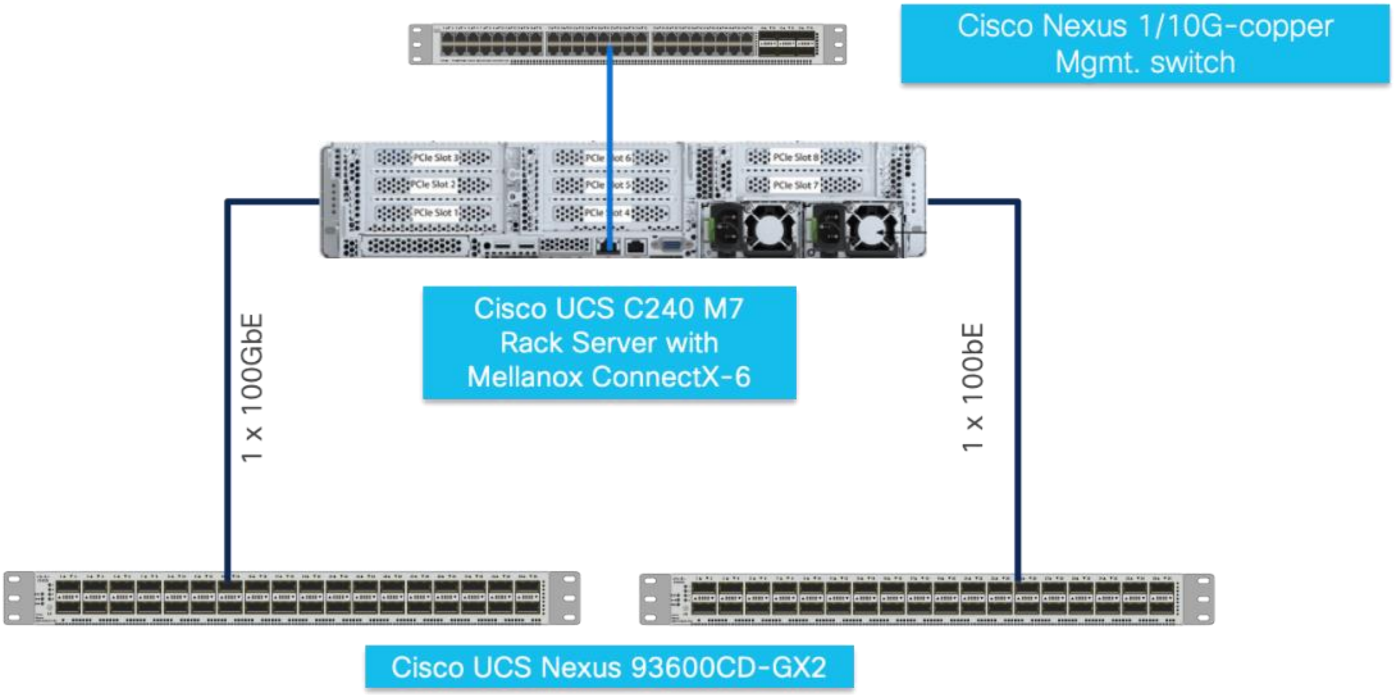
Physical Connectivity

To manage Cisco UCS C240 M7 Rack Server connected to Cisco Nexus switch directly; connect and configure Cisco Integrated Management Controller connect CIMC port to ToR (top of rack) switch as shown in Figure 11.

Tech tip

The Cisco IMC management service is used only when the server is operating in Standalone Mode. If your C-Series server is integrated into a UCS system, you must manage it using a Cisco UCS Fabric Interconnect running in either CSM or IMM. For information about using UCS Manager, see the configuration guides listed in the Cisco UCS B-Series Servers Documentation Roadmap at http://www.cisco.com/go/unifiedcomputing/b-series-doc.

Figure 11. Cisco UCS C240 M7 stand-alone rack server connectivity with Cisco Nexus Switches


Cisco Nexus 1/10G-copper Mgmt. switch
Cisco UCS C240 M7 Rack Server with Mellanox ConnectX-6
1 x 100GbE
1 x 100bE
Cisco UCS Nexus 93600CD-GX2

Cisco Intersight Configuration

This section contains the following:

- Claim Target
- Pool Configuration
- Policy Configuration
- Template and Profile Configuration
- Install Operating System using Cisco Intersight

Cisco Intersight Infrastructure Service allows policy managed infrastructure configuration for ease of management, monitoring and Remediate issues and stay ahead with proactive awareness of Cisco UCS Infrastructure.

Tech tip
Please visit Intersight Help Center for more details: https://us-east-1.intersight.com/help/saas/home

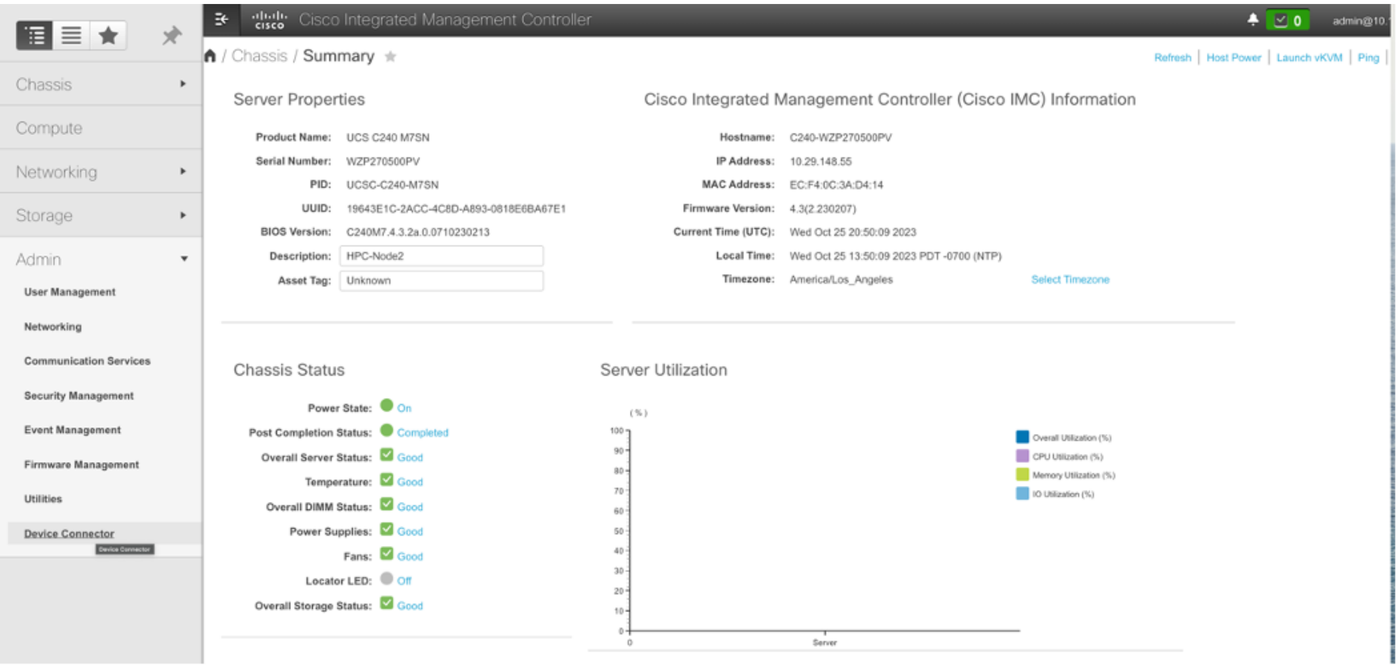
This section highlights initial configuration required to claim a target in a new or existing Cisco Intersight account. Based on the requirement and intended configuration for Cisco Intersight managed Infrastructure either create new pools, policies, template, and profiles or leverage existing configuration for faster deployment. Github repositories for automated FlexPod deployment and configuration can be found here: https://github.com/orgs/ucs-compute-solutions/repositories

Claim Target

This procedure details how to claim a Cisco UCS standalone server using Cisco Intersight.

Step 1. Log into CIMC web UI https://<cimc_mgmt_ip> and enter your username and password.

Step 2. Go to Admin > Device Connector.



/ Chassis / Summary

Server Properties

Product Name: UCS C240 M7SN
Serial Number: WZP270500PV
PID: UCSC-C240-M7SN
UUID: 19643E1C-2ACC-4C8D-A893-0818E6BA67E1
BIOS Version: C240M7.4.3.2a.0.0710230213
Description: HPC-Node2
Asset Tag: Unknown

Cisco Integrated Management Controller (Cisco IMC) Information

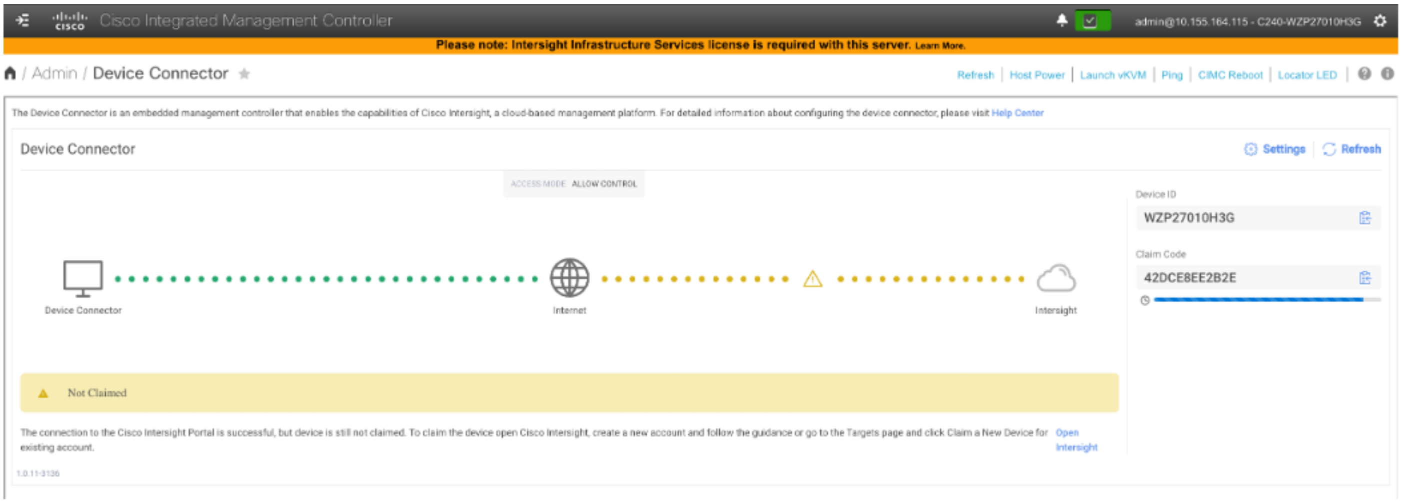
Hostname: C240-WZP270500PV
IP Address: 10.29.148.55
MAC Address: EC:F4:0C:3A:D4:14
Firmware Version: 4.3(2.230207)
Current Time (UTC): Wed Oct 25 20:50:09 2023
Local Time: Wed Oct 25 13:50:09 2023 PDT -0700 (NTP)
Timezone: America/Los_Angeles Select Timezone

Chassis Status

Power State: ● On
Post Completion Status: ● Completed
Overall Server Status: ✓ Good
Temperature: ✓ Good
Overall DIMM Status: ✓ Good
Power Supplies: ✓ Good
Fans: ✓ Good
Locator LED: ● Off
Overall Storage Status: ✓ Good

Server Utilization

Note: This is the first step. In general, processes should have multiple procedures, and procedures should have multiple steps.


Cisco Integrated Management Controller
admin@10.155.164.115 - C240-WZP27010H3G
Refresh | Host Power | Launch vKVM | Ping | CIMC Reboot | Locator LED
Settings
Refresh
ACCESS MODE ALLOW CONTROL
Device Connector
Internet
Intersight

Please note: Intersight Infrastructure Services license is required with this server. Learn More.

/ Admin / Device Connector

The Device Connector is an embedded management controller that enables the capabilities of Cisco Intersight, a cloud-based management platform. For detailed information about configuring the device connector, please visit Help Center

Device Connector

Device ID
WZP27010H3G

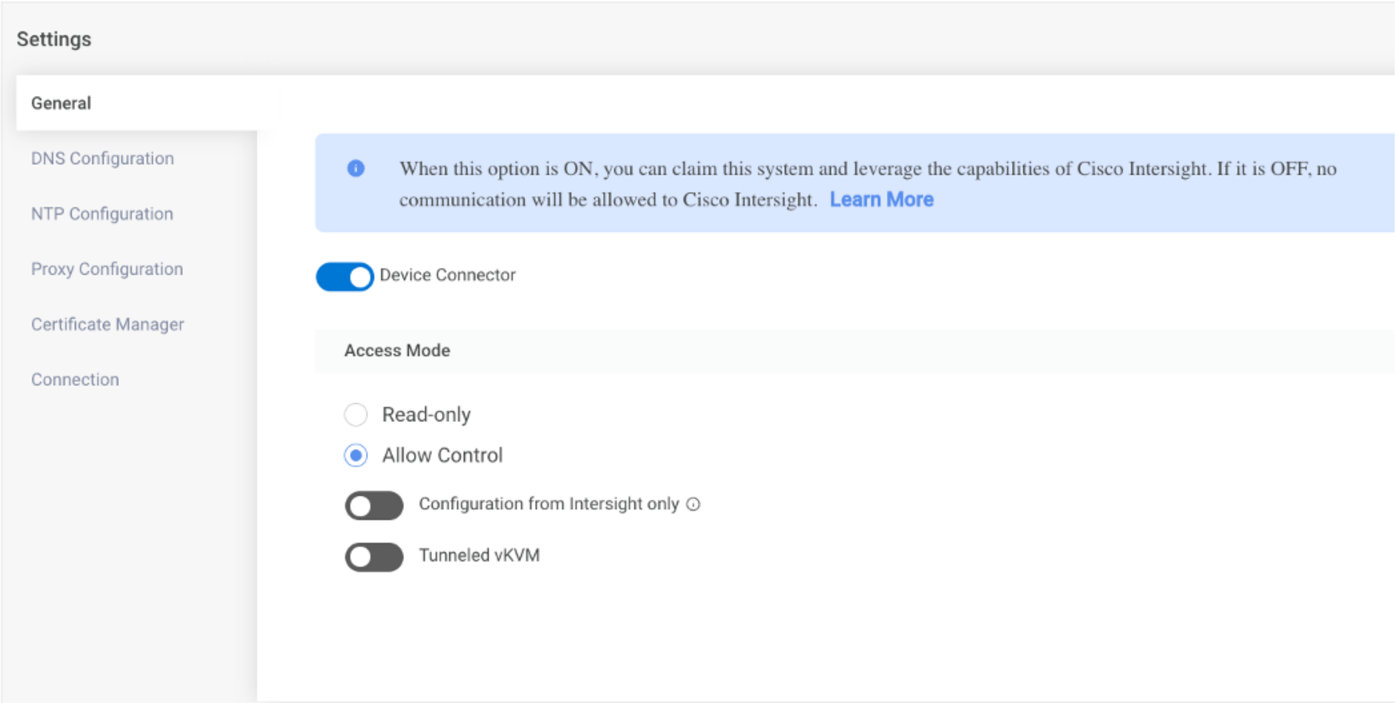
Claim Code
42DCE8EE2B2E

⚠ Not Claimed

The connection to the Cisco Intersight Portal is successful, but device is still not claimed. To claim the device open Cisco Intersight, create a new account and follow the guidance or go to the Targets page and click Claim a New Device for existing account. Open Intersight

1.0.11-3136

Step 3. Update settings input as appropriate and click Save.



When this option is ON, you can claim this system and leverage the capabilities of Cisco Intersight. If it is OFF, no communication will be allowed to Cisco Intersight. Learn More

Device Connector: ON

Access Mode

○ Read-only

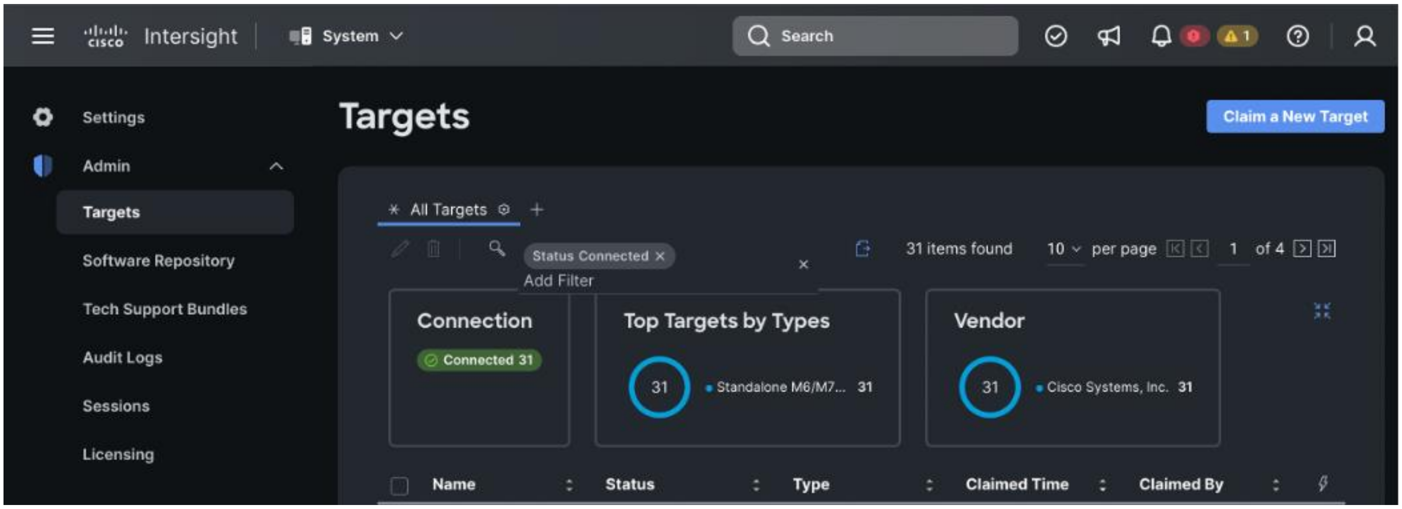
● Allow Control

Configuration from Intersight only: OFF

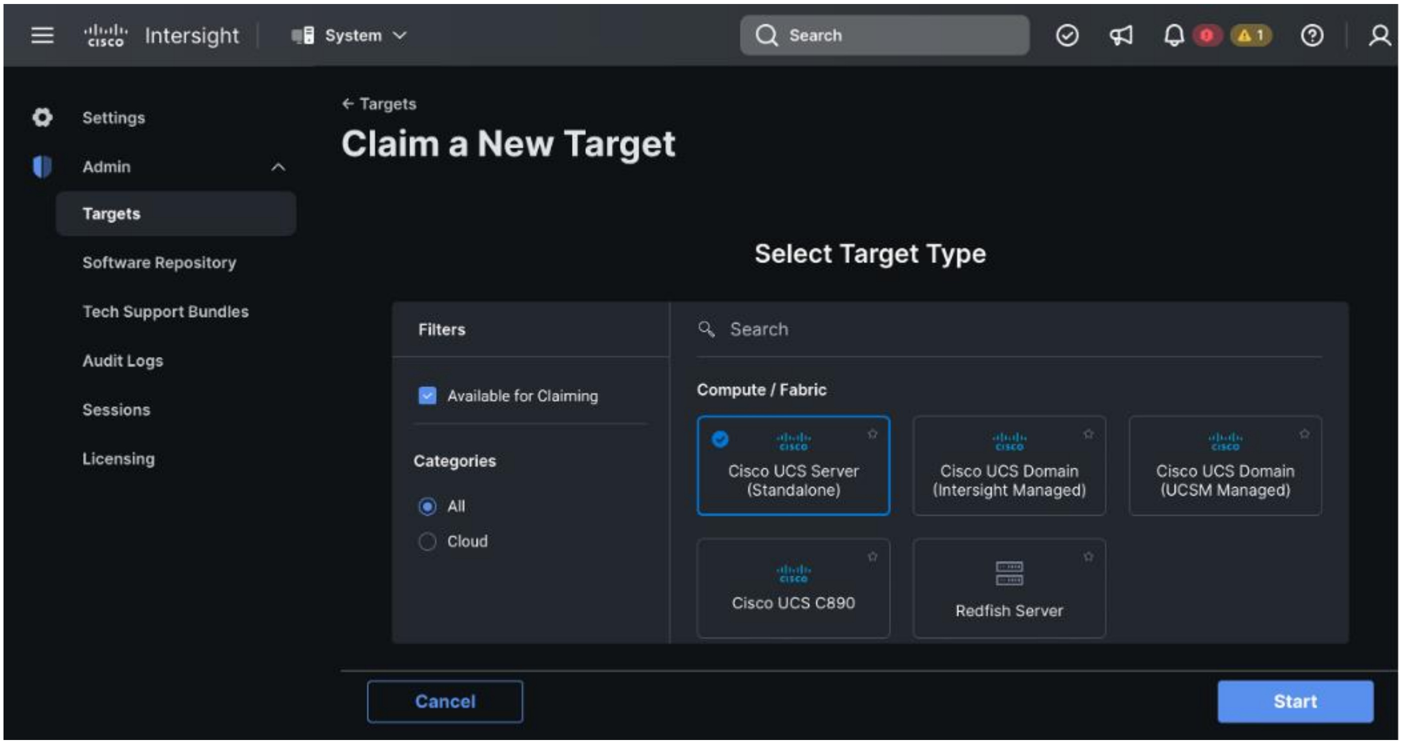
Tunneled vKVM: OFF

Step 4. Copy Device ID and Claim code to be entered while claiming a target in Cisco Intersight.

Step 5. Log into Cisco Intersight; go to System > Targets. Click Claim a new Target.



Step 6. Select Cisco UCS Server (standalone) in Compute/Fabric section. Click Start.

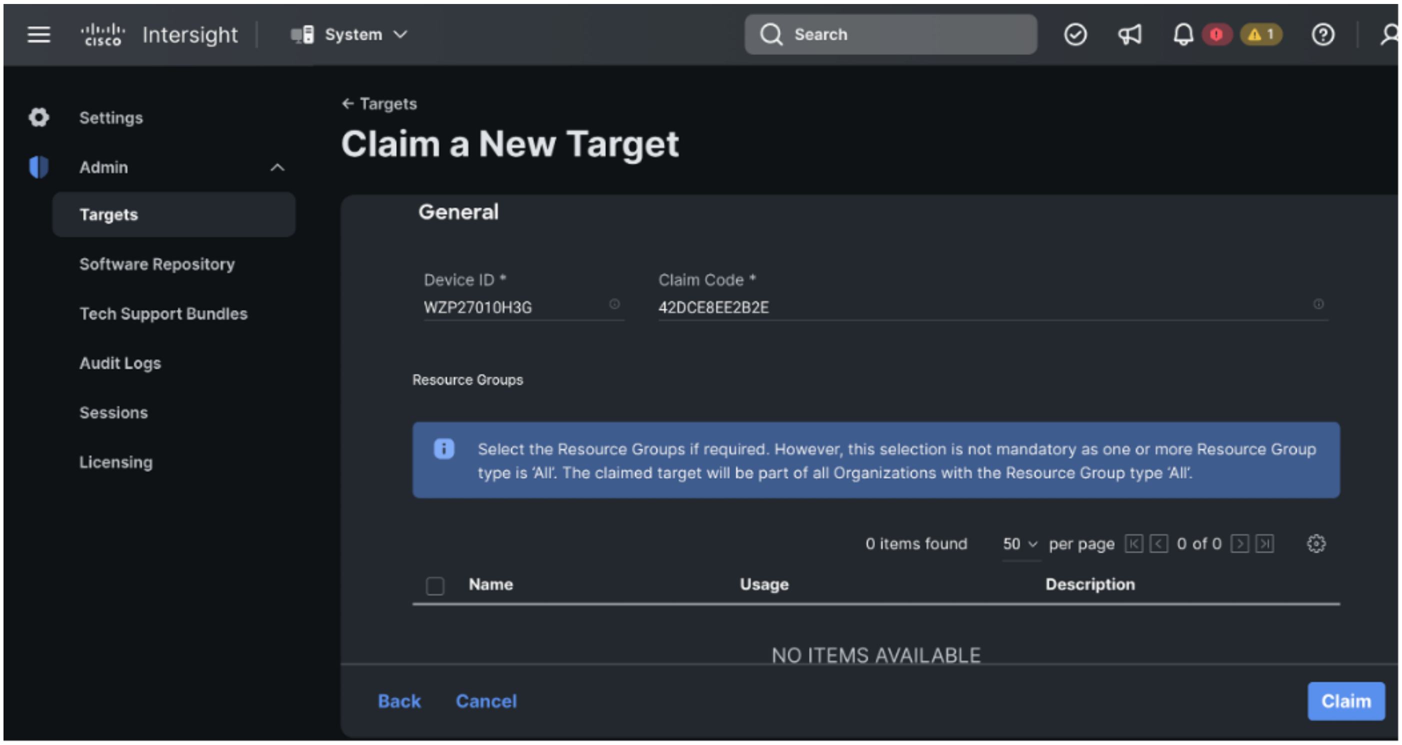


☑ Available for Claiming

● All
○ Cloud

● Cisco UCS Server (Standalone)

Step 7. Enter Device ID and Claim Code copied from Cisco CIMC for the standalone server to claim in the Cisco Intersight.

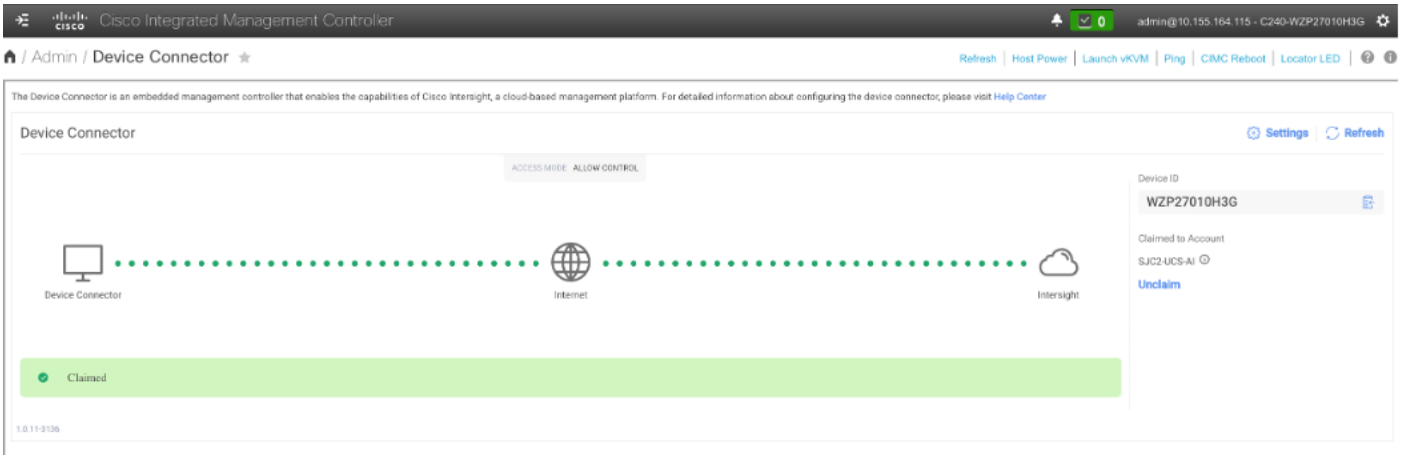


Device ID * WZP27010H3G

Claim Code * 42DCE8EE2B2E

Select the Resource Groups if required. However, this selection is not mandatory as one or more Resource Group type is 'All'. The claimed target will be part of all Organizations with the Resource Group type 'All'.

Cisco CIMC and Cisco Intersight WebUI reporting Cisco UCS Rack Server claimed and connected is shown below:


Cisco Integrated Management Controller
admin@10.155.164.115 - C240-WZP27010H3G
Admin / Device Connector
Refresh | Host Power | Launch vKVM | Ping | CIMC Reboot | Locator LED
Settings
Refresh
Device Connector
Internet
Intersight
Unclaim

The Device Connector is an embedded management controller that enables the capabilities of Cisco Intersight, a cloud-based management platform. For detailed information about configuring the device connector, please visit Help Center

Device Connector

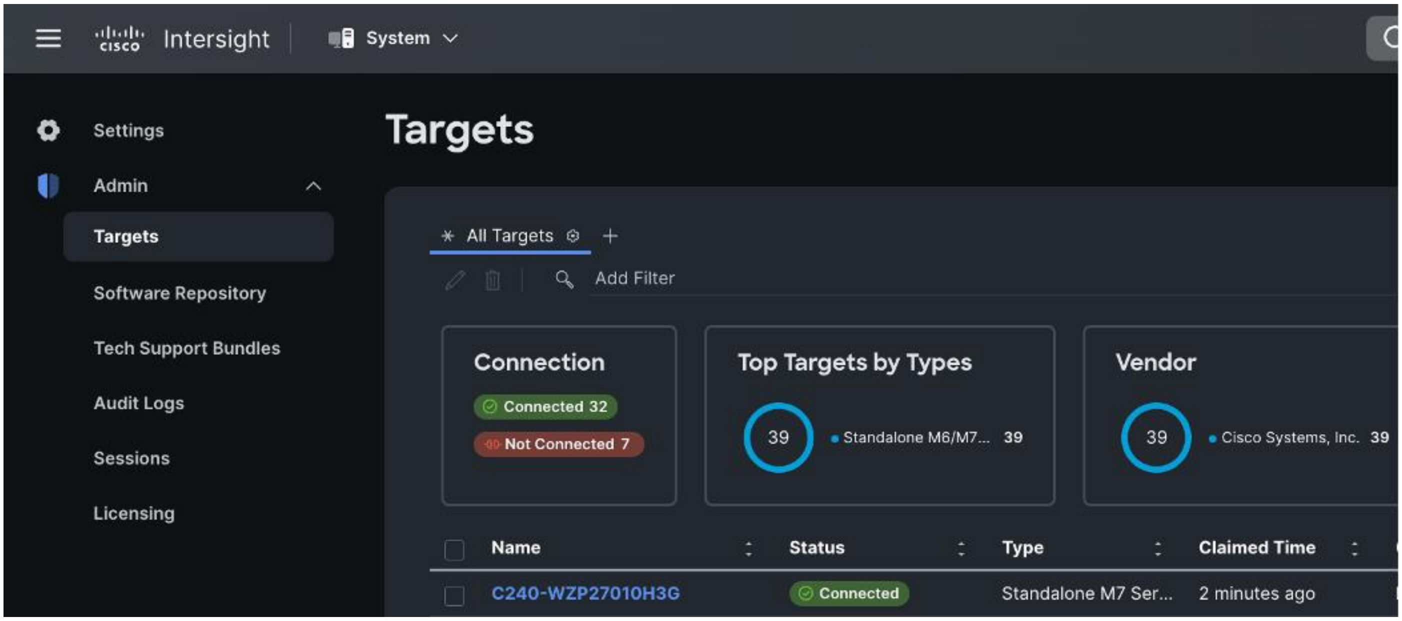
ACCESS MODE ALLOW CONTROL

Device ID: WZP27010H3G

Claimed to Account: SJC2-UCS-AI

Claimed

1.0.11-3136



Targets

Connection	Top Targets by Types	Vendor
Connected 32 Not Connected 7	39 Standalone M6/M7... 39	39 Cisco Systems, Inc. 39

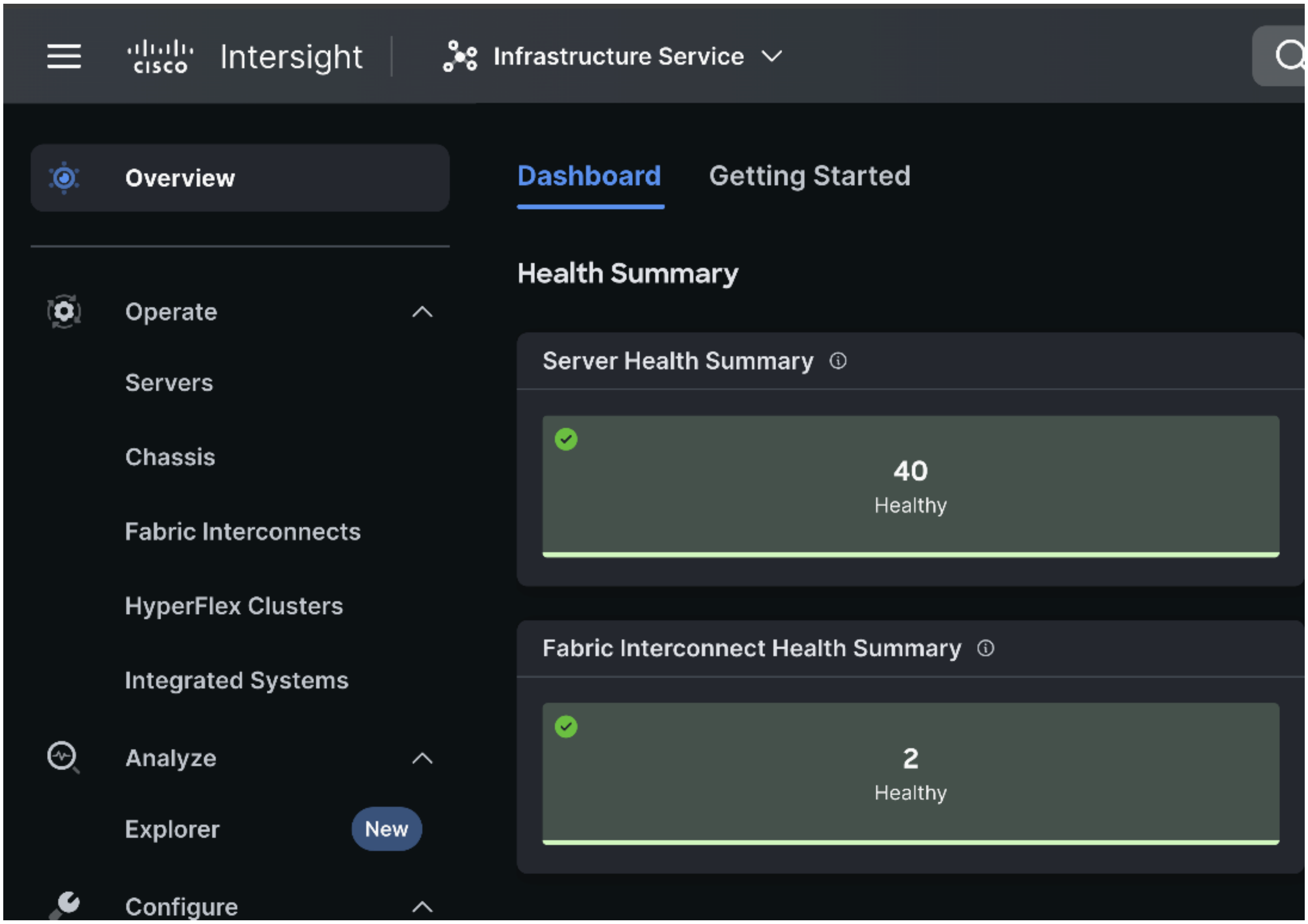
Name	Status	Type	Claimed Time
C240-WZP27010H3G	Connected	Standalone M7 Ser...	2 minutes ago

Pool Configuration

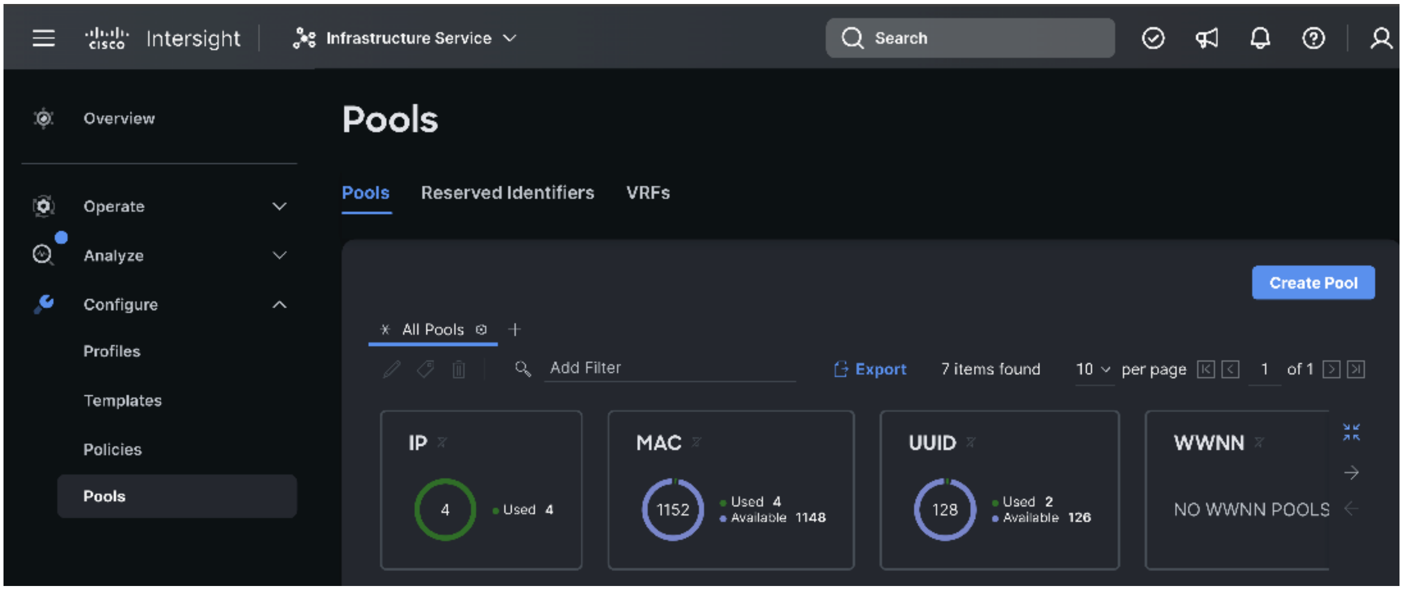
Tech tip
For more information on licensing requirements for Infrastructure Services, see Infrastructure Services License.

You can either create the required pools and policies to attach to a server profile or create them as progressing through the server profile/template creation.

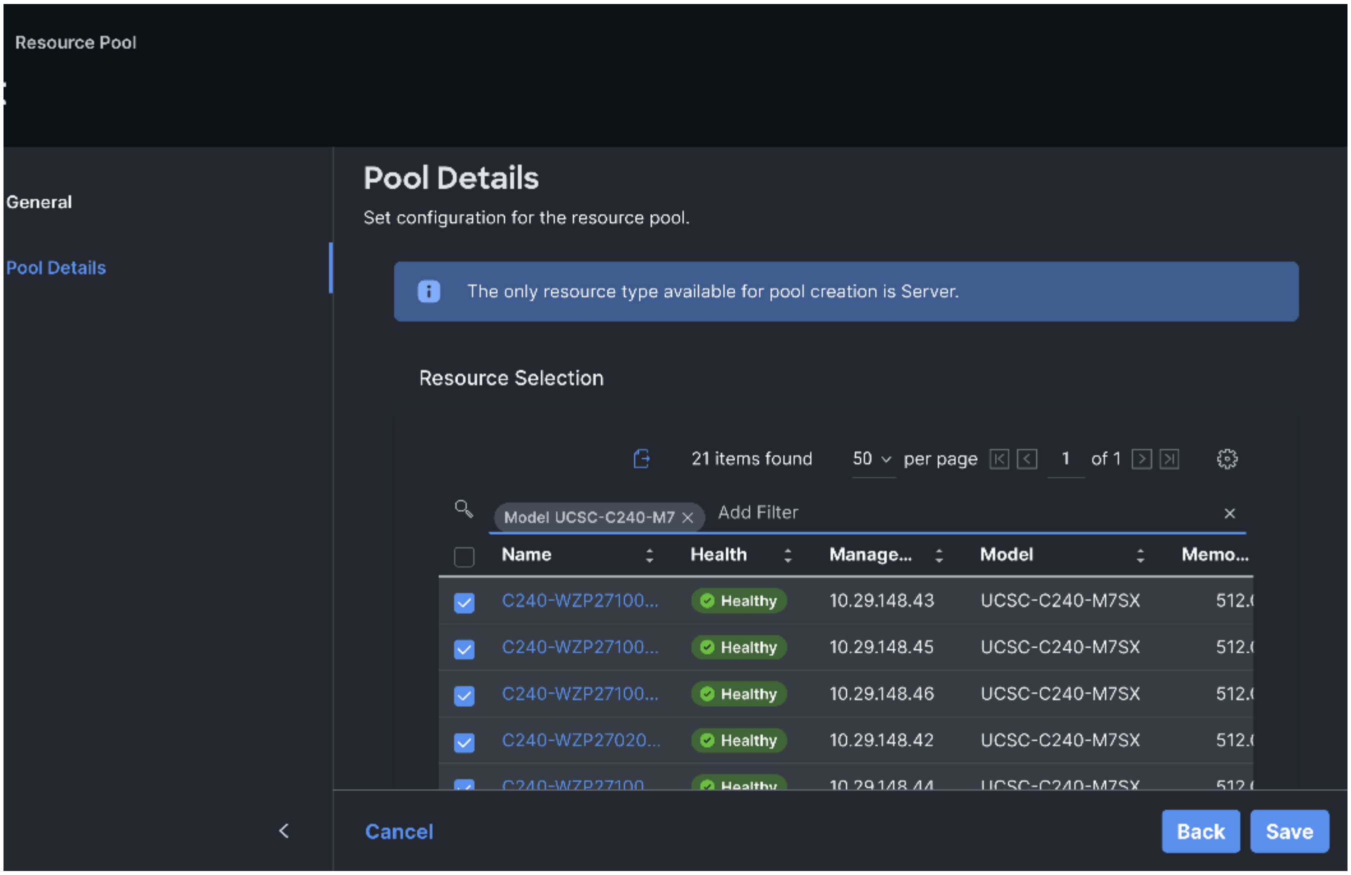
Step 1. Log into Cisco Intersight. Go to Infrastructure Service.



Step 2. Select Pools and click Create Pool.



Step 3. Select Resources. Click Start. Enter a name for the new Resource Pool. Select the Target Platform to add in the resource pool. Select by filtering the set of nodes to be part of the resource pool. For example, UCSC-C240-M7 as shown below:



Resource Pool

General

Pool Details

Pool Details

Set configuration for the resource pool.

The only resource type available for pool creation is Server.

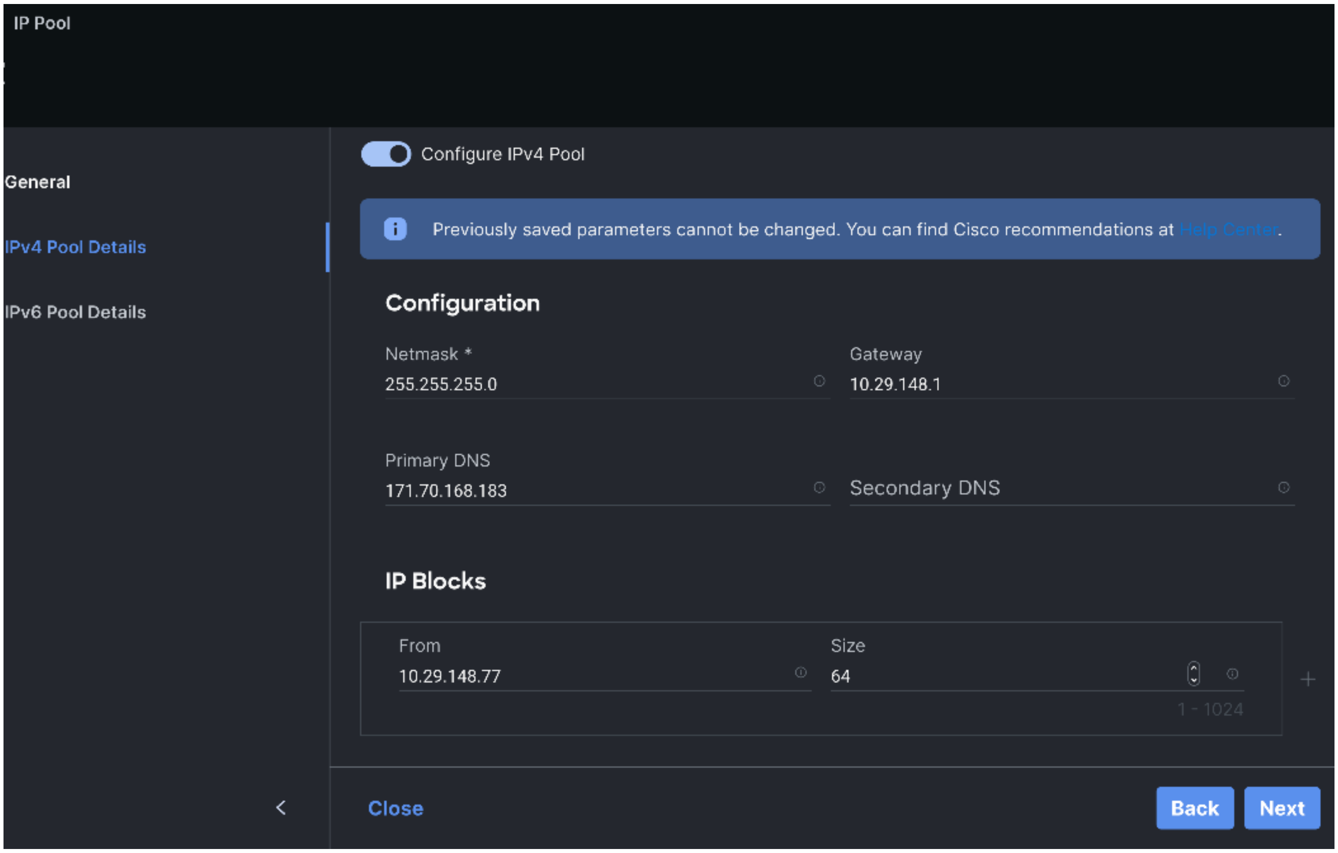
Resource Selection

21 items found 50 per page 1 of 1

Model UCSC-C240-M7 × Add Filter

□	Name	Health	Manage...	Model	Memo...
☑	C240-WZP27100...	Healthy	10.29.148.43	UCSC-C240-M7SX	512.(
☑	C240-WZP27100...	Healthy	10.29.148.45	UCSC-C240-M7SX	512.(
☑	C240-WZP27100...	Healthy	10.29.148.46	UCSC-C240-M7SX	512.(
☑	C240-WZP27020...	Healthy	10.29.148.42	UCSC-C240-M7SX	512.(
☑	C240-WZP27100	Healthy	10.29.148.44	UCSC-C240-M7SX	512.(

Step 4. Create the IP Pool for KVM access as shown below:



IP Pool

General

IPv4 Pool Details

IPv6 Pool Details

Configure IPv4 Pool

Previously saved parameters cannot be changed. You can find Cisco recommendations at Help Center.

Configuration

Netmask * 255.255.255.0

Gateway 10.29.148.1

Primary DNS 171.70.168.183

Secondary DNS

IP Blocks

From 10.29.148.77

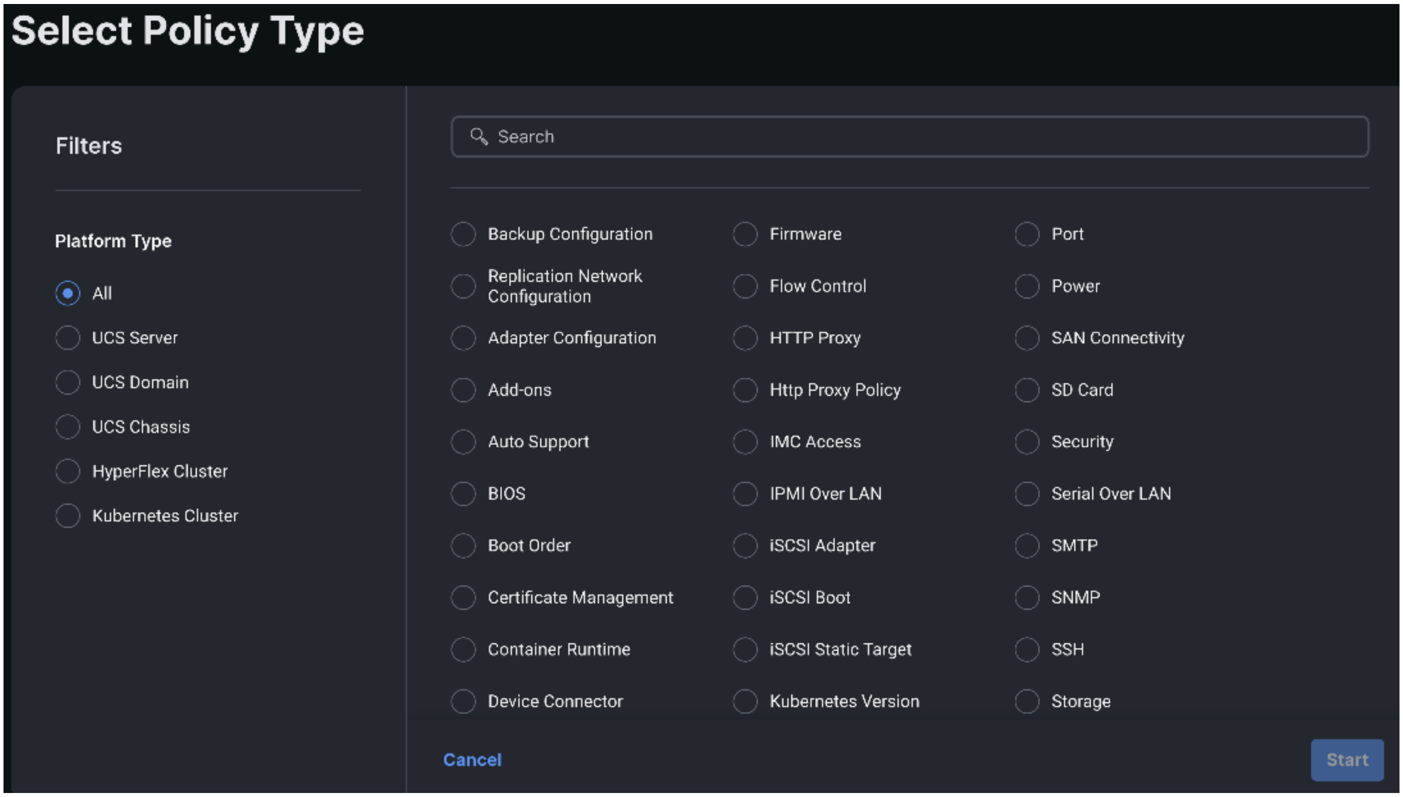
Size 64

1 - 1024

Policy Configuration

This section provides the screenshots where input is required to complete the policy creation. The process remains the same, such as selection of organization, entering name for the policy, tags, and description.

Step 1. Go to Policies. Select type of policy to create.



Step 2. Select BIOS and click Start.

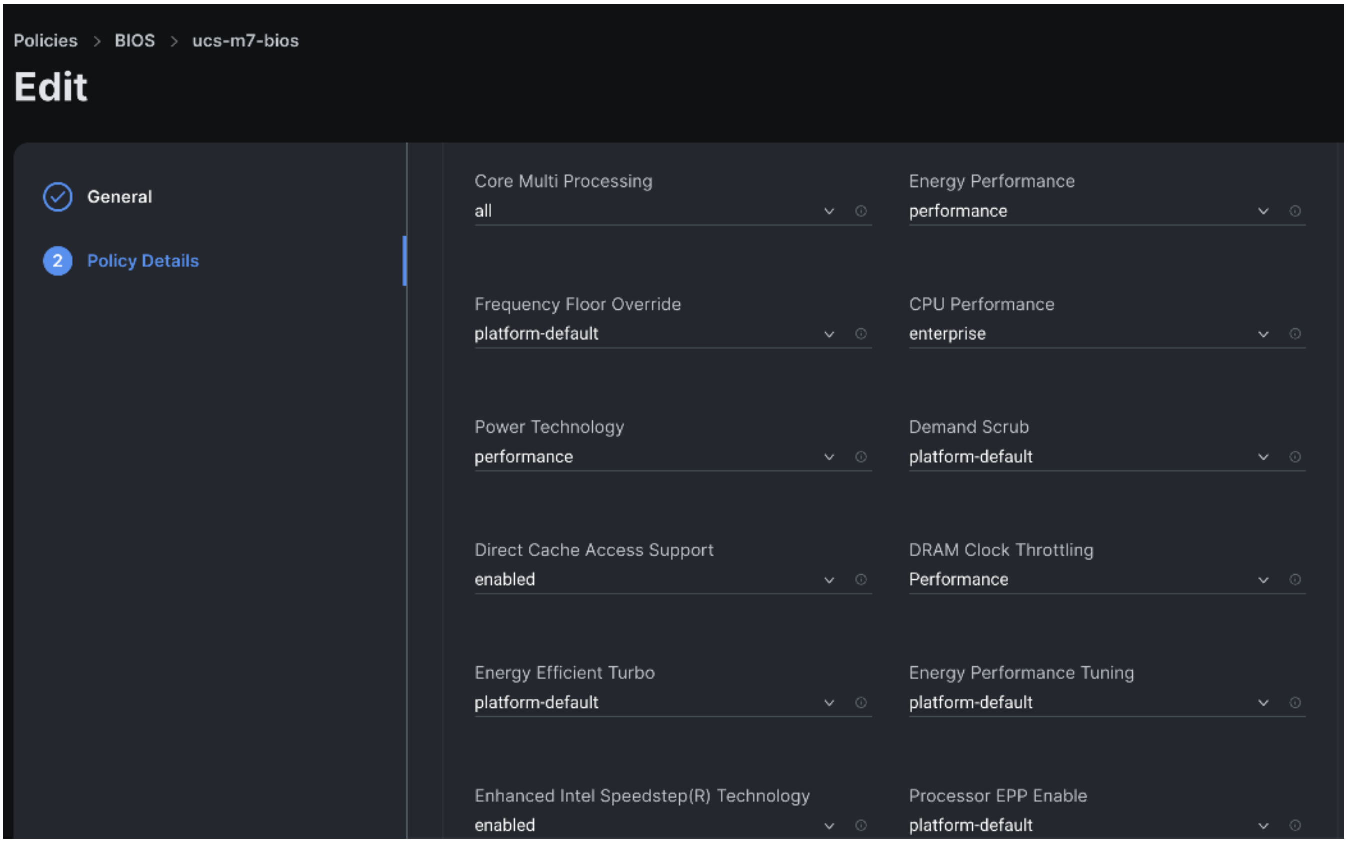
Step 3. We kept all settings as platform-default, except for the following parameters changes in the BIOS policy:

- LLC dead line – Disabled
- Intel Virtualization Technology – Disabled
- LLC prefetch – Disabled
- Workload configuration – Balanced

Tech tip

Selection of BIOS parameters determines the cluster optimization for performance or power saving or balanced of performance and power savings goal.

Please review Performance Tuning Best Practices Guide for Cisco UCS M7 Platforms: https://www.cisco.com/c/en/us/products/collateral/servers-unified-computing/ucs-b-series-blade-servers/ucs-m7-platforms-wp.html



Core Multi Processing
all

Energy Performance
performance

Frequency Floor Override
platform-default

CPU Performance
enterprise

Power Technology
performance

Demand Scrub
platform-default

Direct Cache Access Support
enabled

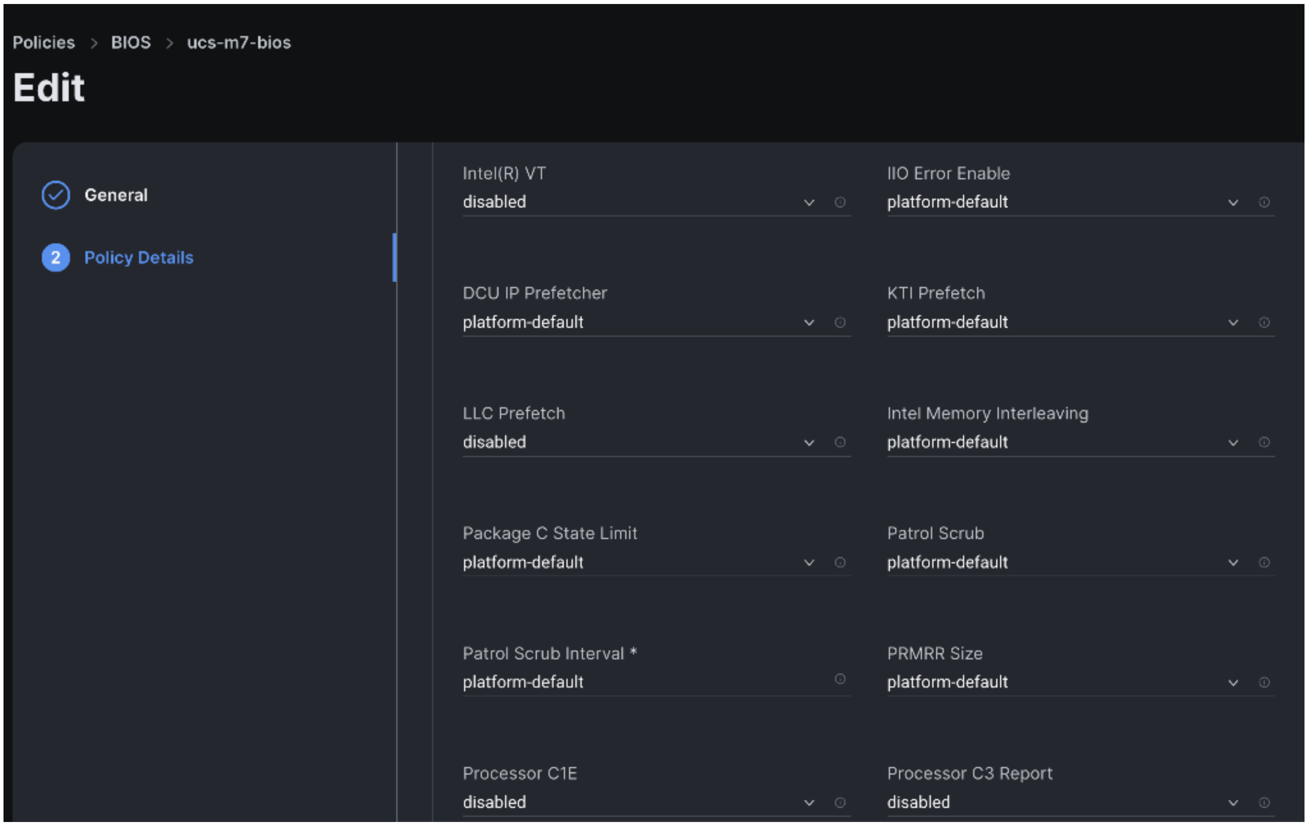
DRAM Clock Throttling
Performance

Energy Efficient Turbo
platform-default

Energy Performance Tuning
platform-default

Enhanced Intel Speedstep(R) Technology
enabled

Processor EPP Enable
platform-default



Intel(R) VT
disabled

IIO Error Enable
platform-default

DCU IP Prefetcher
platform-default

KTI Prefetch
platform-default

LLC Prefetch
disabled

Intel Memory Interleaving
platform-default

Package C State Limit
platform-default

Patrol Scrub
platform-default

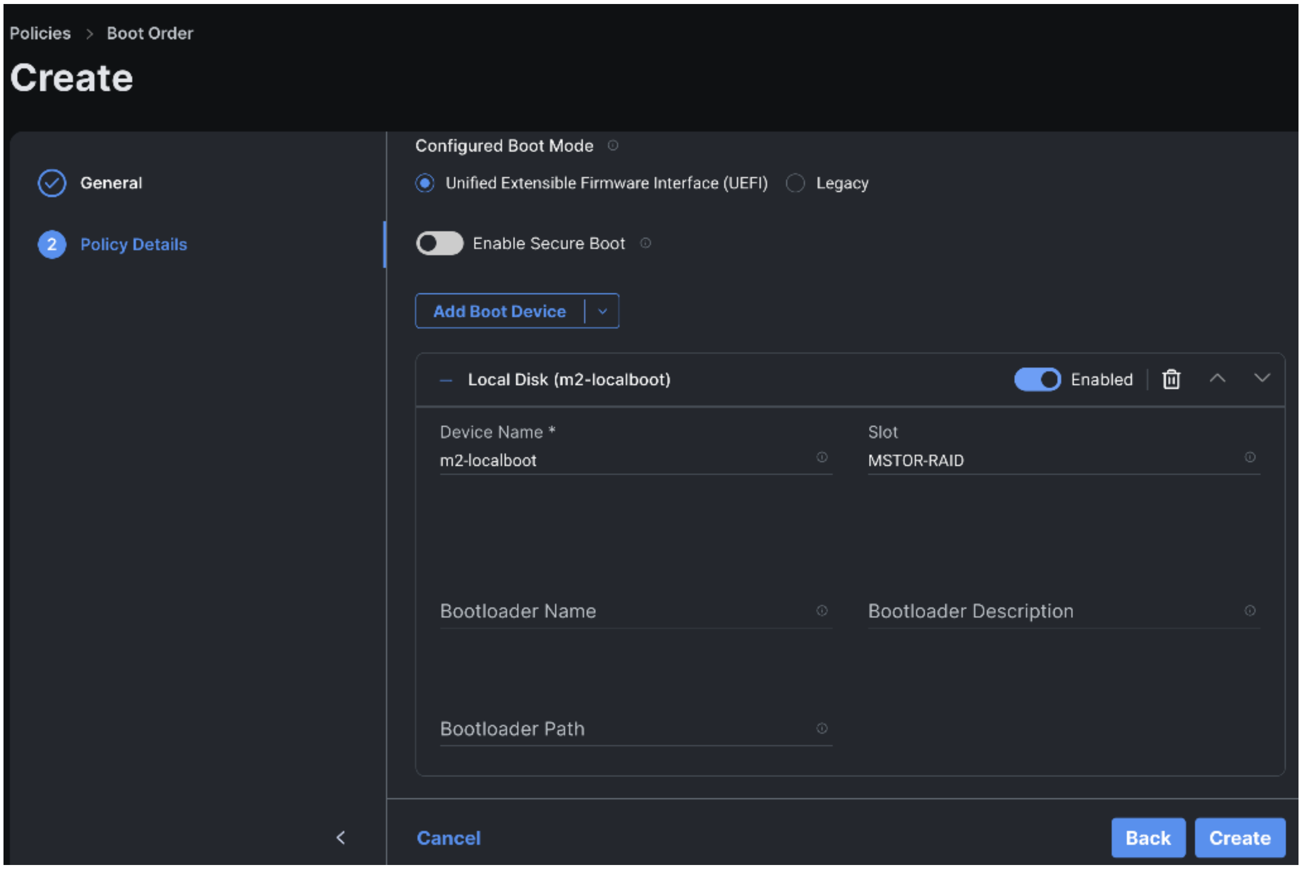
Patrol Scrub Interval *
platform-default

PRMRR Size
platform-default

Processor C1E
disabled

Processor C3 Report
disabled

Step 4. Create Boot order policy. Select UCS Standalone Server. Select Boot Mode. Click Add Boot Device. Select LocalDisk from the drop-down list for “Add Boot Device.” For the device name and Slot enter “MSTOR-RAID.”


Policies > Boot Order

Create

General

2 Policy Details

Configured Boot Mode

● Unified Extensible Firmware Interface (UEFI) ○ Legacy

Enable Secure Boot

Local Disk (m2-localboot) Enabled

Device Name *: m2-localboot

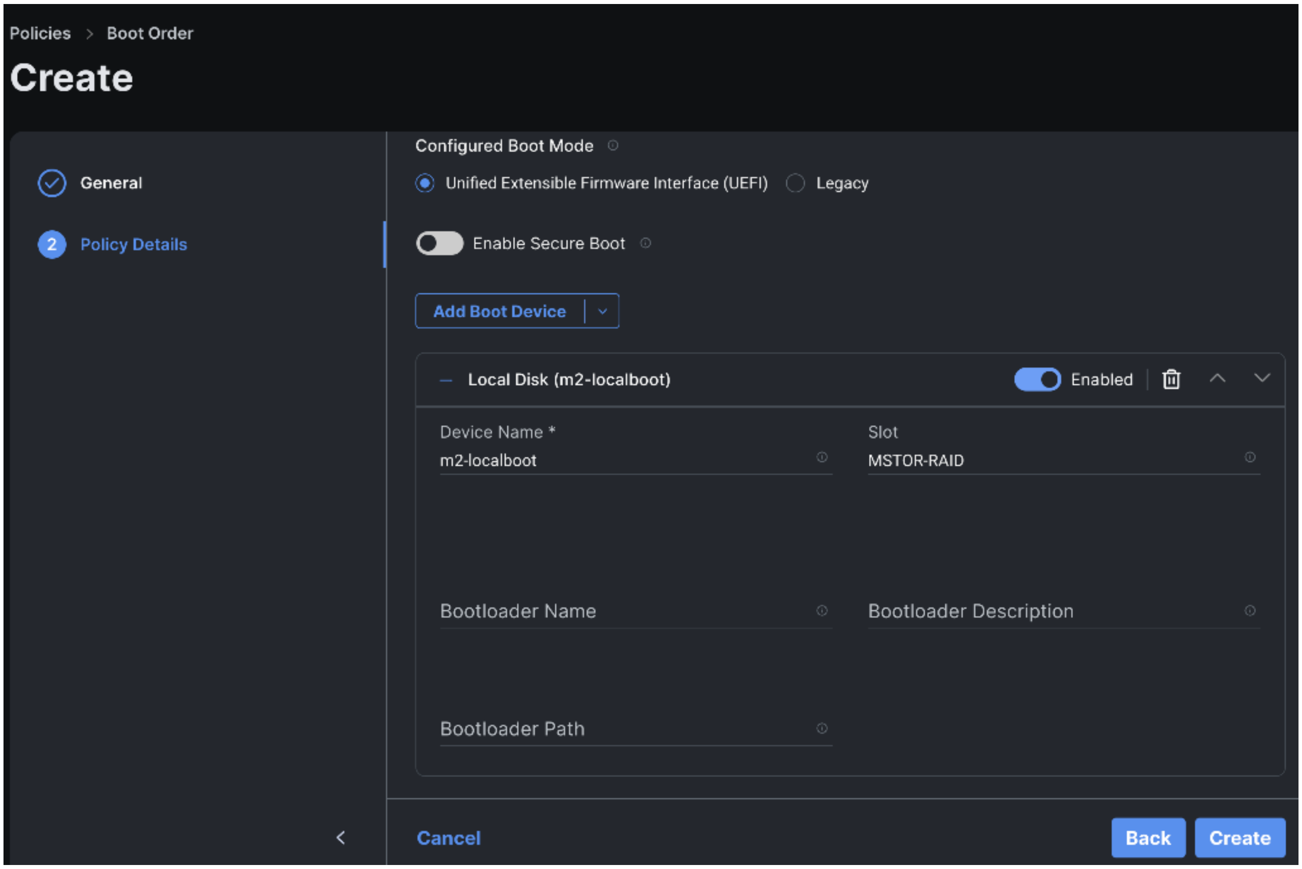
Slot: MSTOR-RAID

Bootloader Name

Bootloader Description

Bootloader Path

Note: Additional boot devices can be added as per the requirement.



Configured Boot Mode

● Unified Extensible Firmware Interface (UEFI) ○ Legacy

Enable Secure Boot: off

Local Disk (m2-localboot): Enabled

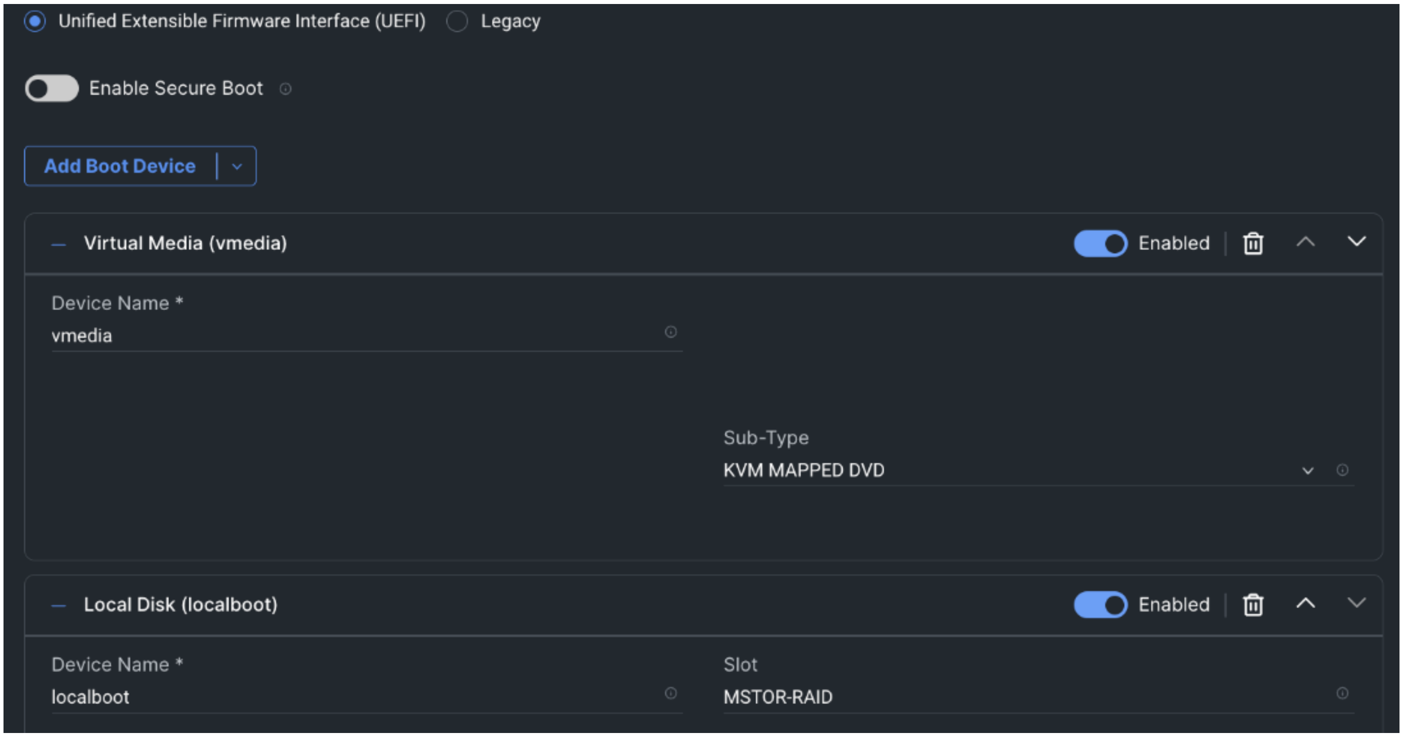
Device Name *: m2-localboot

Slot: MSTOR-RAID

Bootloader Name

Bootloader Description

Bootloader Path



● Unified Extensible Firmware Interface (UEFI) ○ Legacy

Enable Secure Boot: off

Virtual Media (vmedia): Enabled

Device Name *: vmedia

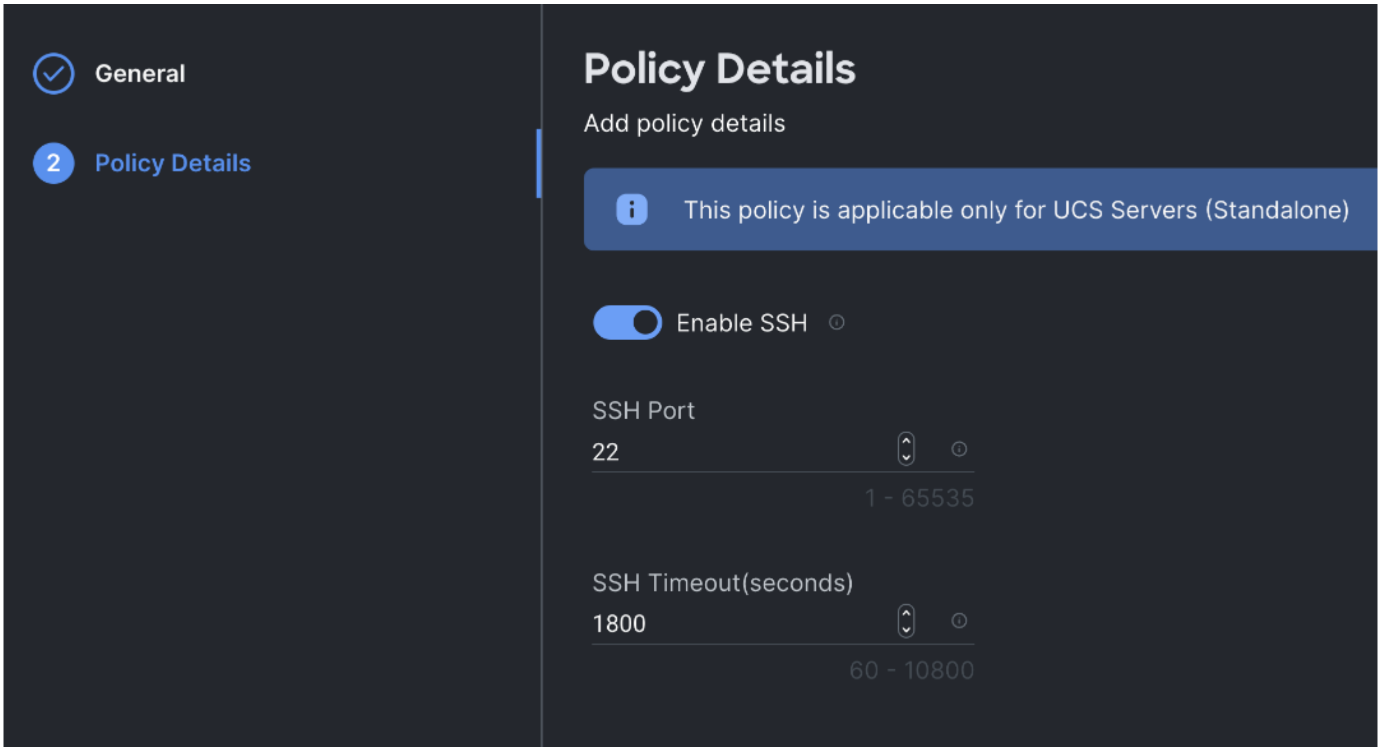
Sub-Type: KVM MAPPED DVD

Local Disk (localboot): Enabled

Device Name *: localboot

Slot: MSTOR-RAID

Step 5. Create the SSH policy.



Policy Details

Add policy details

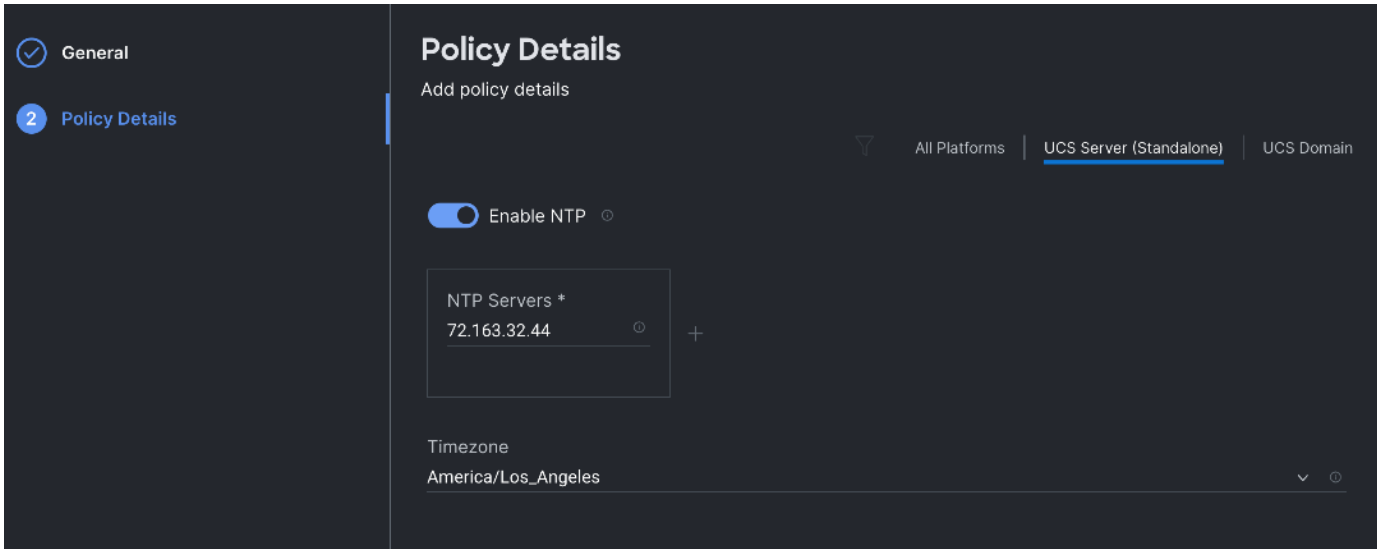
This policy is applicable only for UCS Servers (Standalone)

Enable SSH

SSH Port: 22 (1 - 65535)

SSH Timeout(seconds): 1800 (60 - 10800)

Step 6. Create the NTP policy.



Policy Details

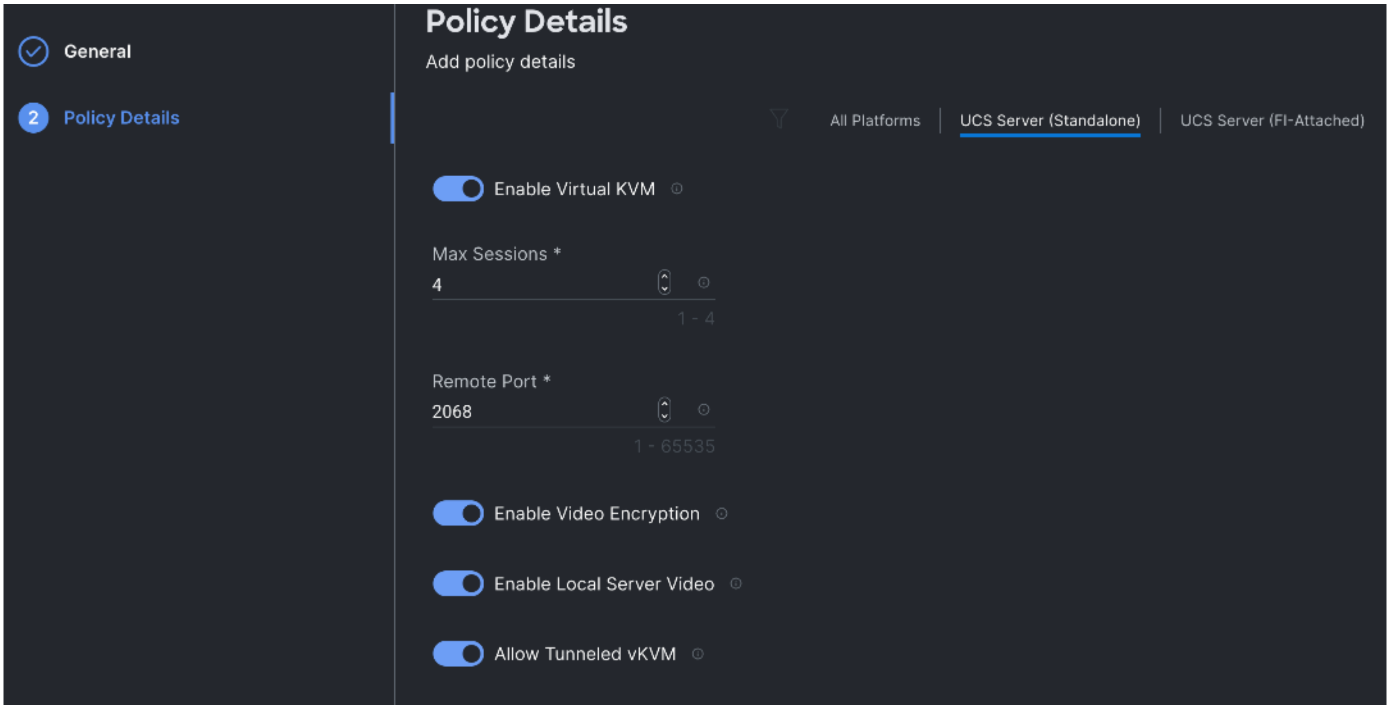
Add policy details

Enable NTP

NTP Servers *: 72.163.32.44

Timezone: America/Los_Angeles

Step 7. Create the Virtual KVM policy.



General

2 Policy Details

Policy Details

Add policy details

All Platforms | UCS Server (Standalone) | UCS Server (FI-Attached)

Enable Virtual KVM

Max Sessions *
4
1 - 4

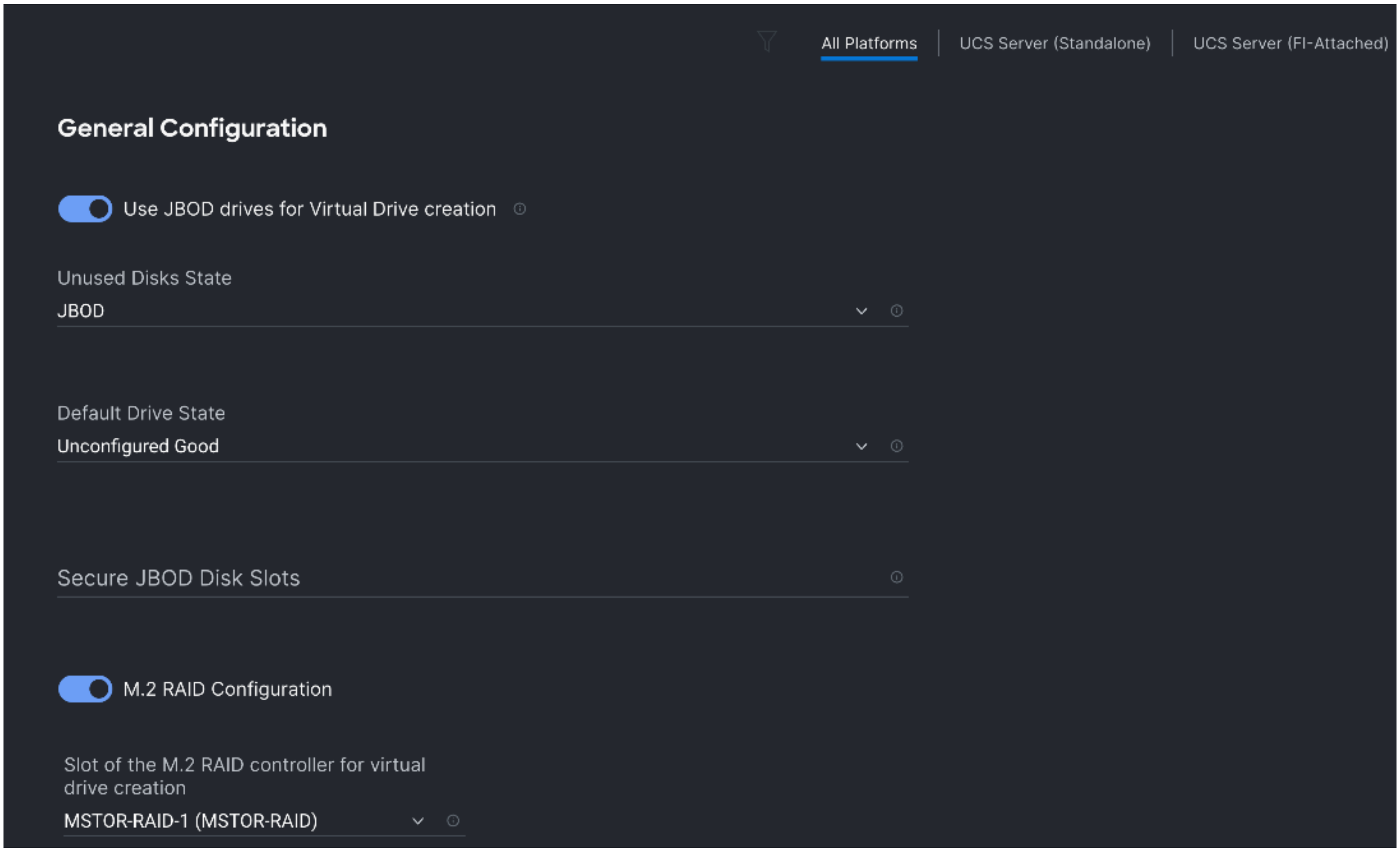
Remote Port *
2068
1 - 65535

Enable Video Encryption

Enable Local Server Video

Allow Tunneled vKVM

Step 8. Create the Storage policy to create RAID 1 on two M.2 SATA SSD with boot optimized RAID controller. Select M.2 RAID configuration. From the drop-down list select MSTOR-RAID-1(MSTOR-RAID).



All Platforms | UCS Server (Standalone) | UCS Server (FI-Attached)

General Configuration

Use JBOD drives for Virtual Drive creation

Unused Disks State
JBOD

Default Drive State
Unconfigured Good

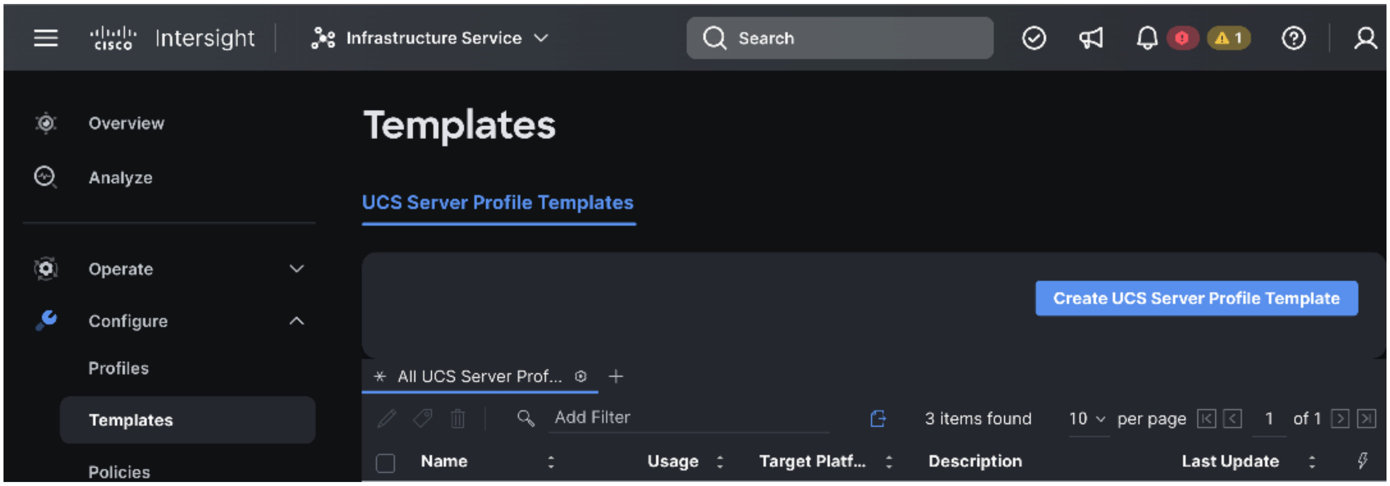
Secure JBOD Disk Slots

M.2 RAID Configuration

Slot of the M.2 RAID controller for virtual drive creation
MSTOR-RAID-1 (MSTOR-RAID)

Template and Profile Configuration

Step 1. In Cisco UCS Infrastructure Services page, go to Templates. Click Create UCS Server Profile Template.

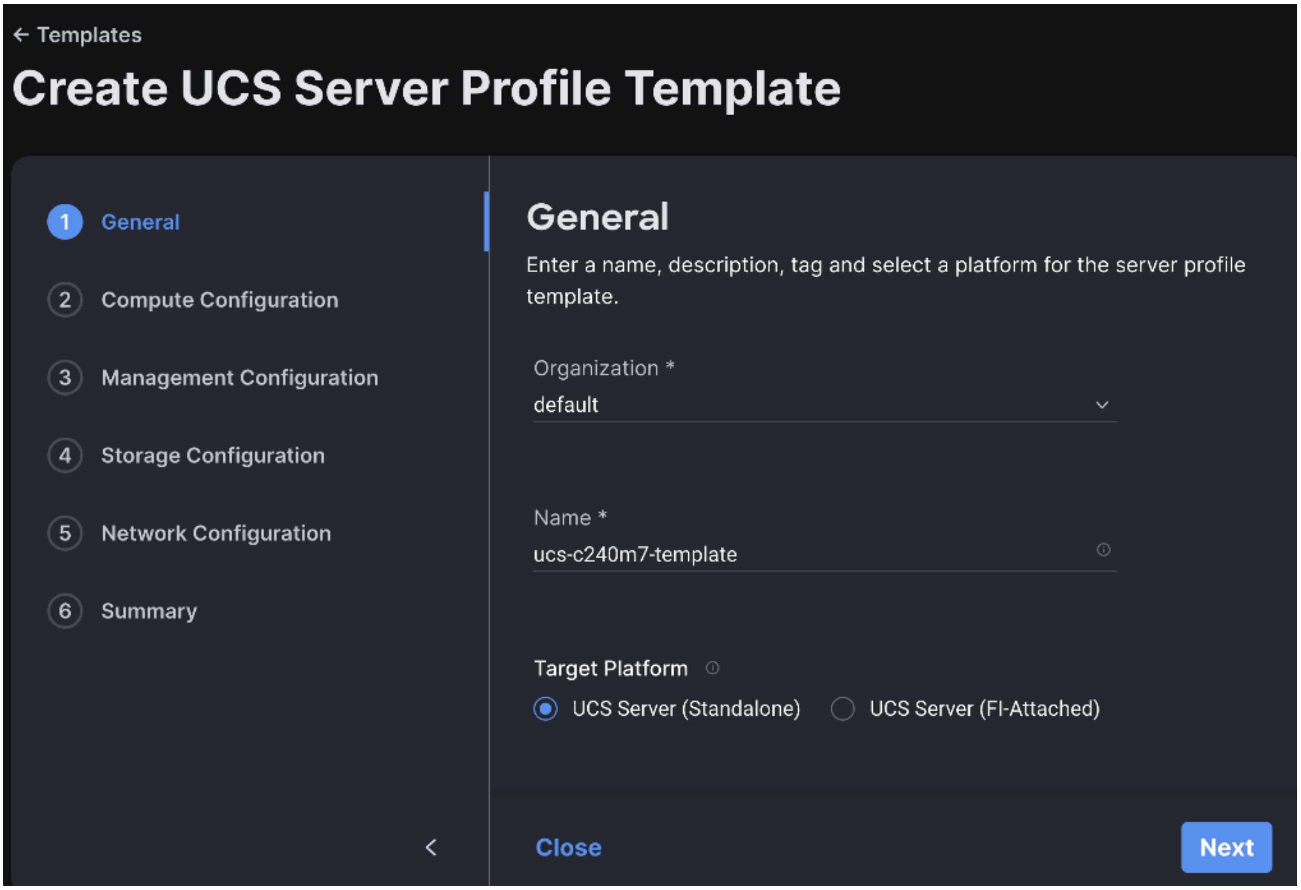


Templates

UCS Server Profile Templates

3 items found · 10 per page · 1 of 1

Step 2. Enter a name for the Server Profile Template and select the Target Platform.



Create UCS Server Profile Template

General

Enter a name, description, tag and select a platform for the server profile template.

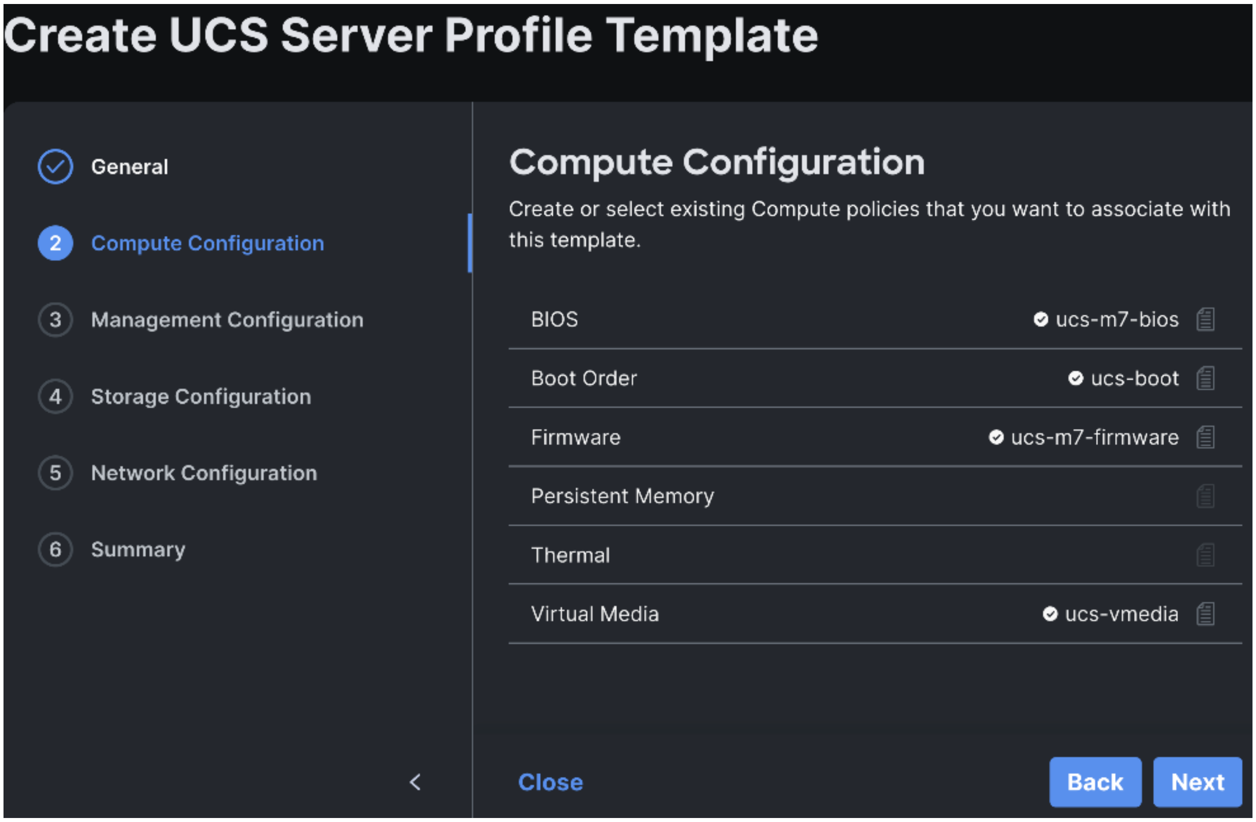
Organization * : default

Name * : ucs-c240m7-template

Target Platform

● UCS Server (Standalone) ○ UCS Server (FI-Attached)

Step 3. Select policies or create new to associate with the server profile template.

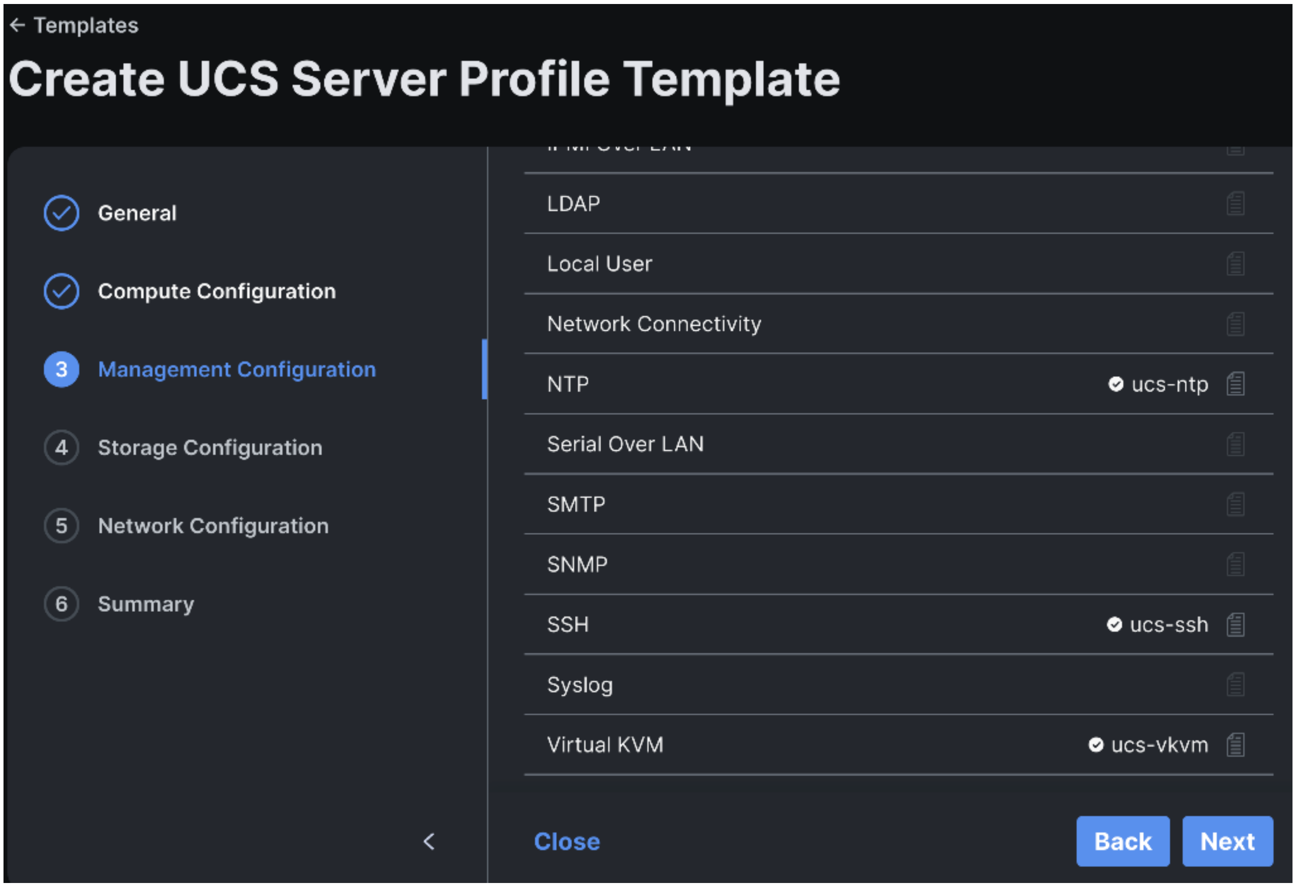


Create UCS Server Profile Template

Compute Configuration

Create or select existing Compute policies that you want to associate with this template.

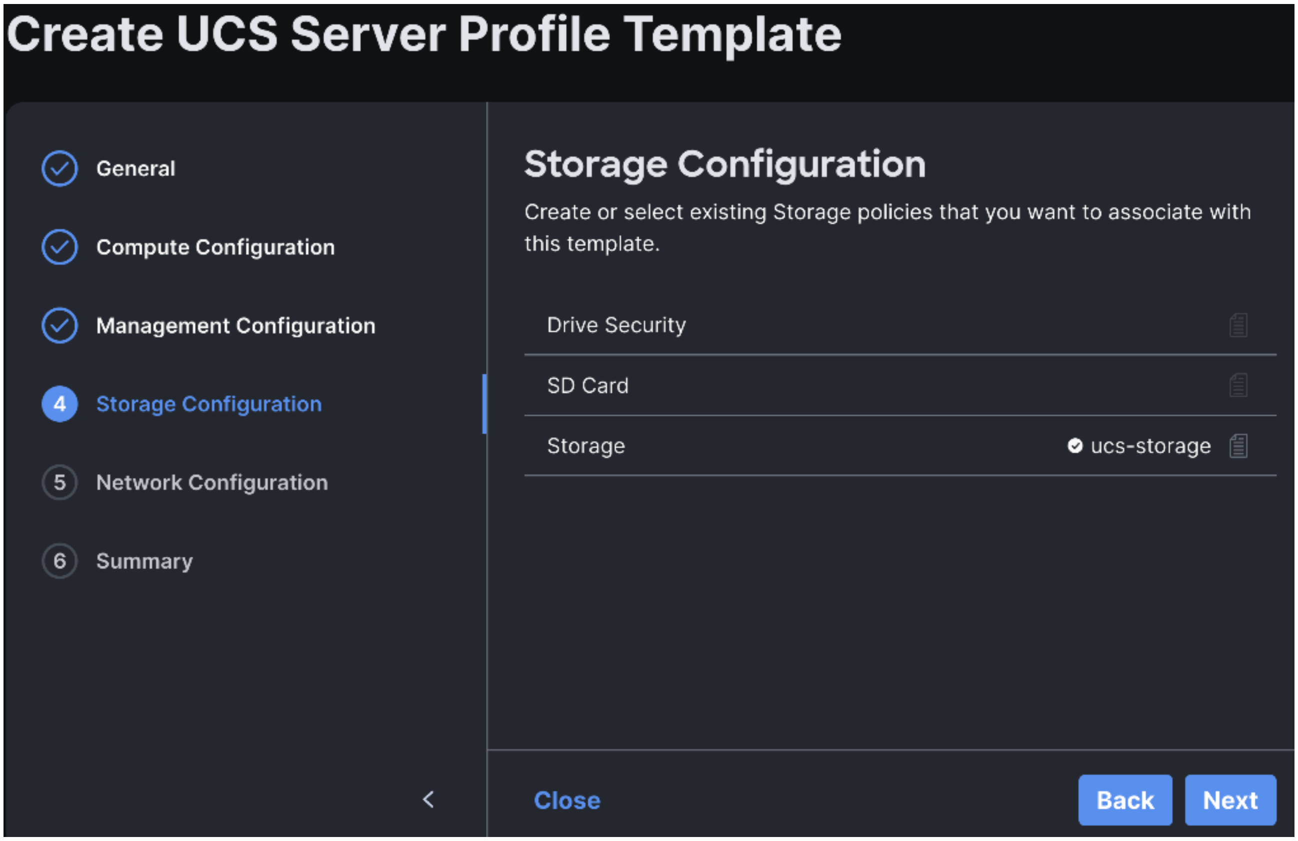
BIOS	ucs-m7-bios
Boot Order	ucs-boot
Firmware	ucs-m7-firmware
Persistent Memory	
Thermal	
Virtual Media	ucs-vmedia



← Templates

Create UCS Server Profile Template

IPMI Over LAN	
LDAP	
Local User	
Network Connectivity	
NTP	ucs-ntp
Serial Over LAN	
SMTP	
SNMP	
SSH	ucs-ssh
Syslog	
Virtual KVM	ucs-vkvm



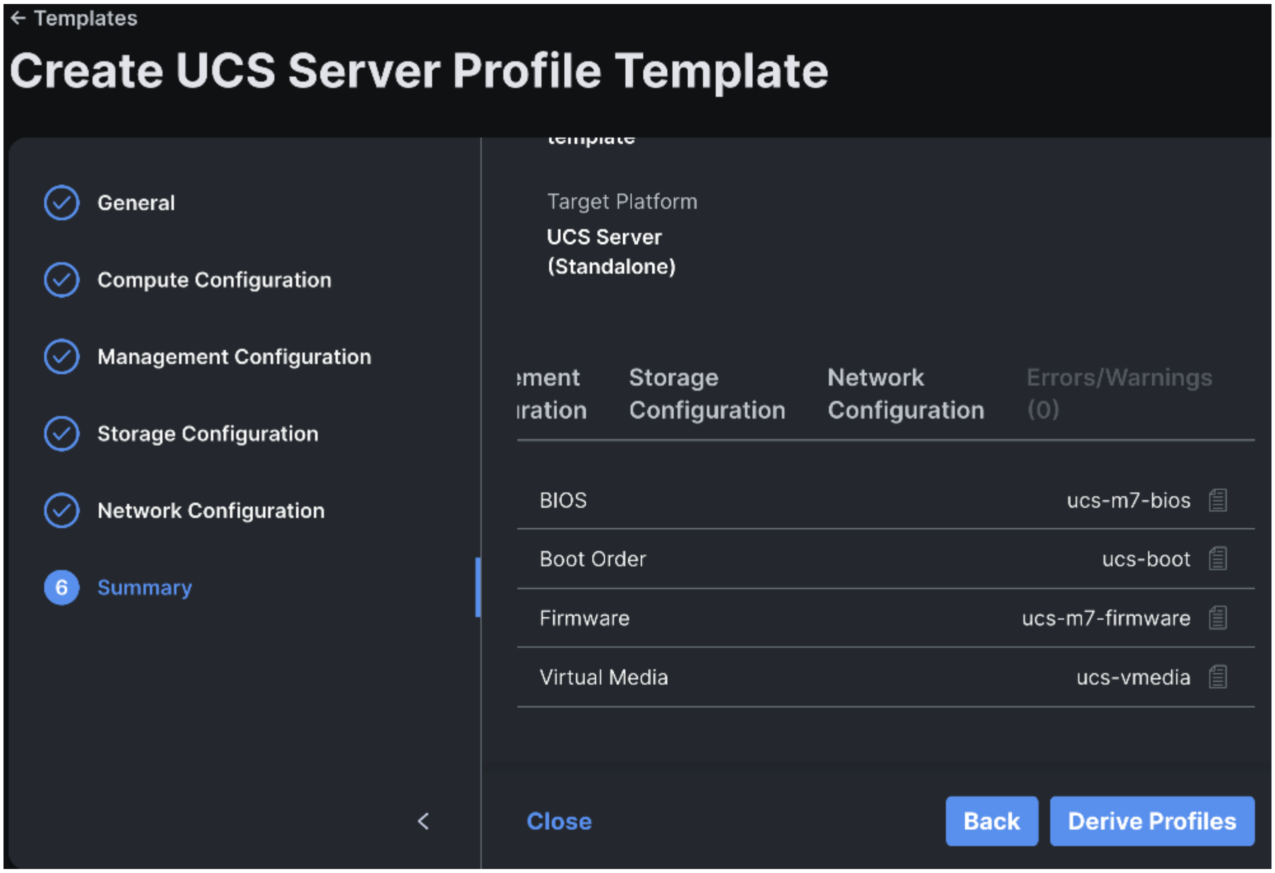
Create UCS Server Profile Template

Storage Configuration

Create or select existing Storage policies that you want to associate with this template.

Drive Security	
SD Card	
Storage	ucs-storage

Step 4. Review and click Derive Profiles.



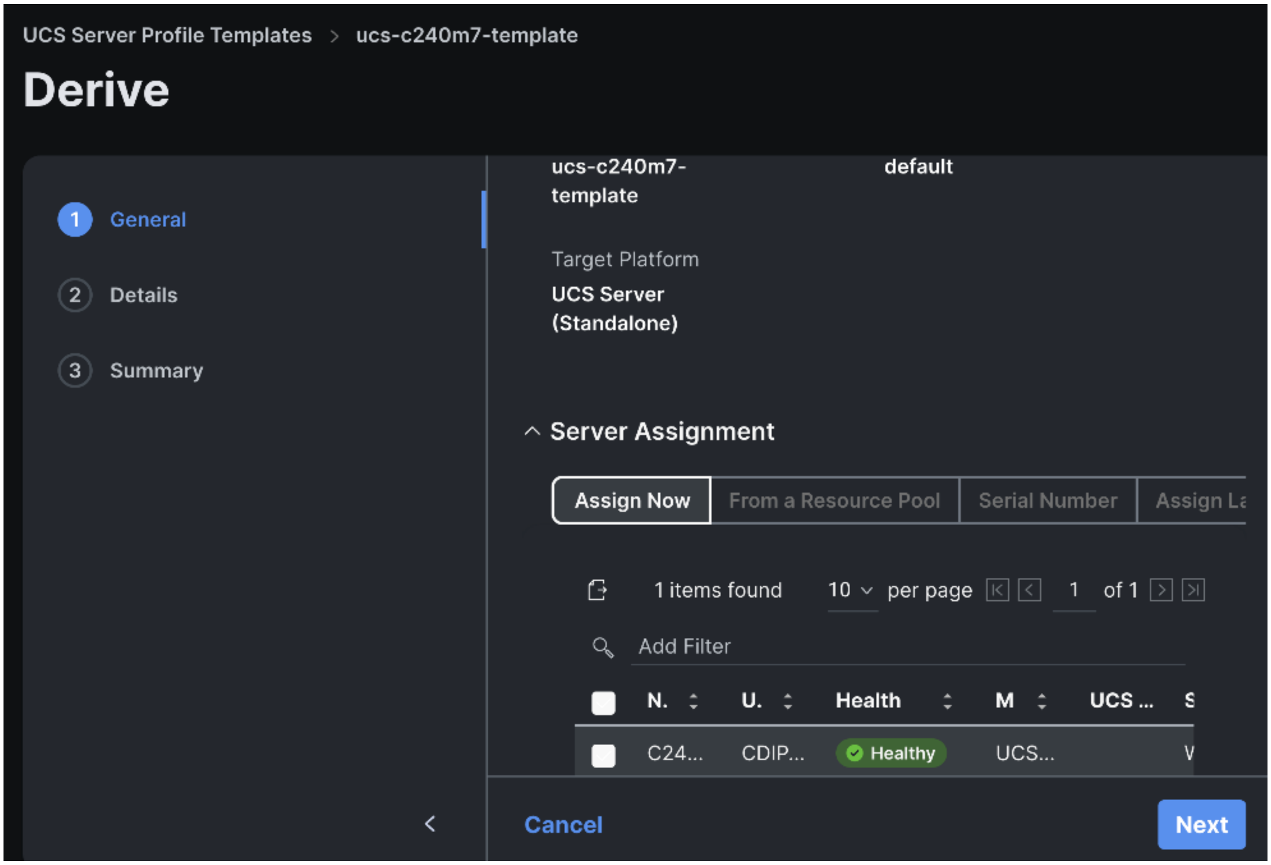
Create UCS Server Profile Template

Target Platform

UCS Server (Standalone)

BIOS	ucs-m7-bios
Boot Order	ucs-boot
Firmware	ucs-m7-firmware
Virtual Media	ucs-vmedia

Step 5. Select the Server Assignment.



UCS Server Profile Templates > ucs-c240m7-template

Derive

ucs-c240m7-template default

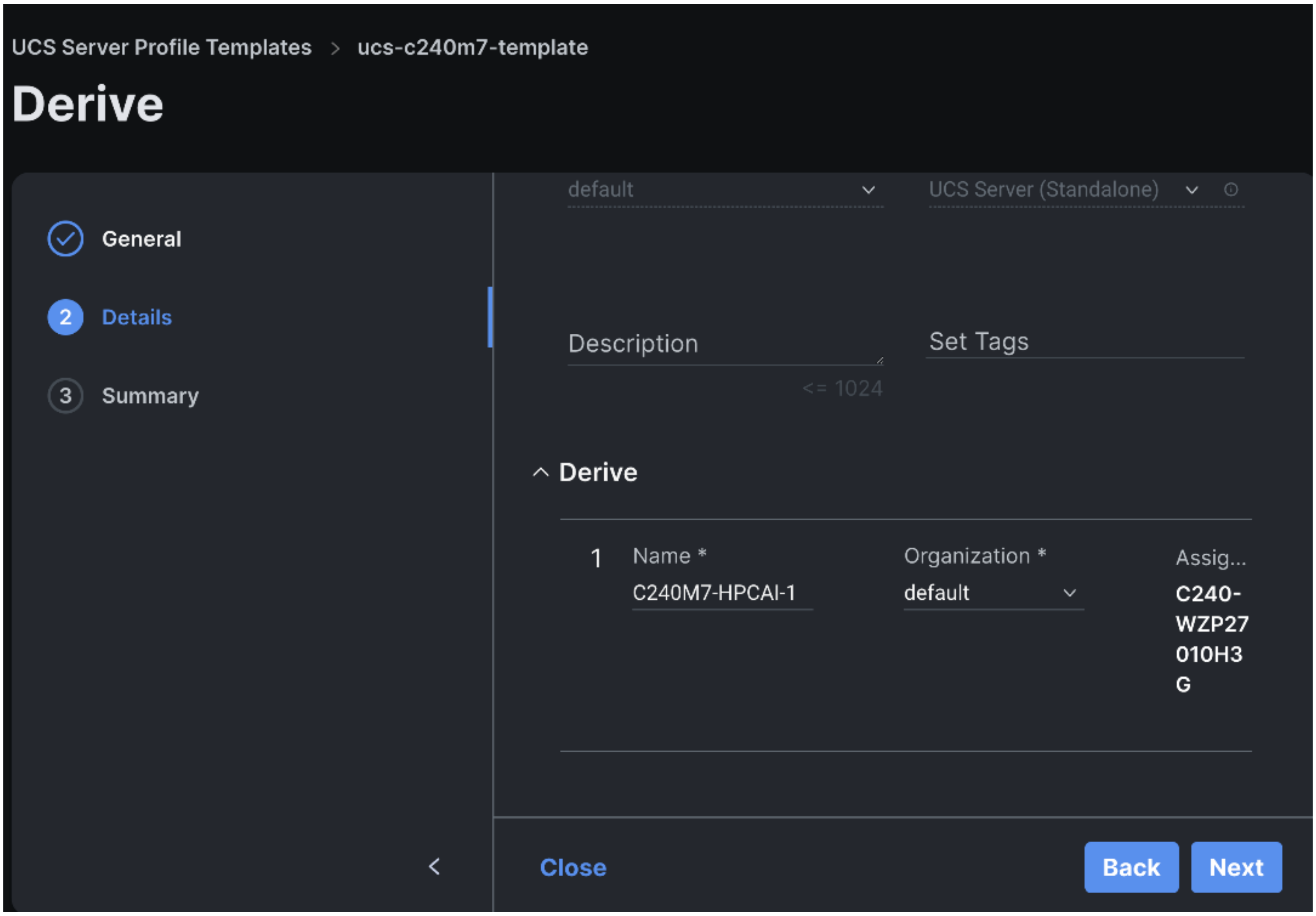
Target Platform
UCS Server (Standalone)

Server Assignment

1 items found 10 per page 1 of 1

	N.	U.	Health	M	UCS ...	S
□	C24...	CDIP...	Healthy	UCS...		V

Step 6. Edit the name for the server profile(s) to be derived from the template.



default
UCS Server (Standalone)

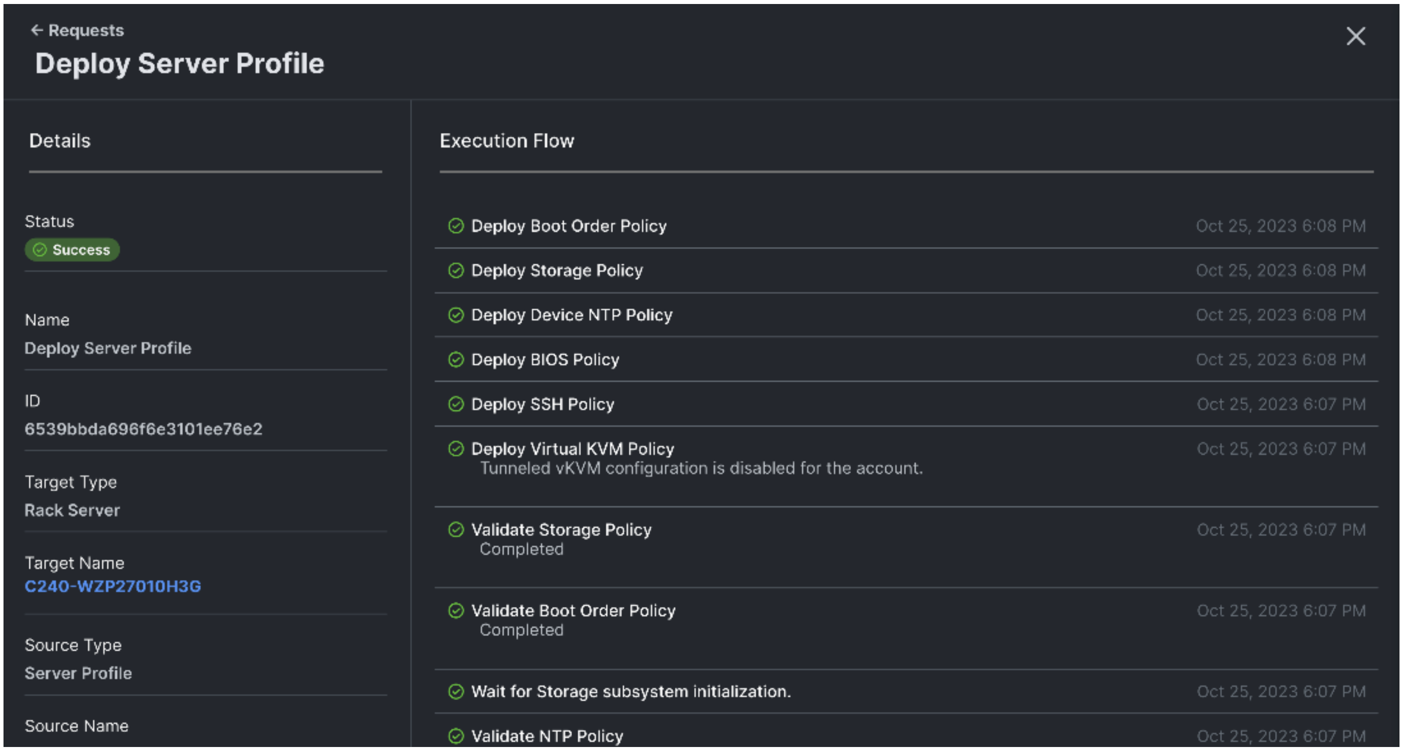
Description
<= 1024

Set Tags

Derive

	Name *	Organization *	Assig...
1	C240M7-HPCAI-1	default	C240-WZP27010H3G

Step 7. Click Deploy Server Profile. Monitor the Server profile deployment task.



Status
Success

Name
Deploy Server Profile

ID
6539bbda696f6e3101ee76e2

Target Type
Rack Server

Target Name
C240-WZP27010H3G

Source Type
Server Profile

Source Name

✓ Deploy Boot Order Policy	Oct 25, 2023 6:08 PM
✓ Deploy Storage Policy	Oct 25, 2023 6:08 PM
✓ Deploy Device NTP Policy	Oct 25, 2023 6:08 PM
✓ Deploy BIOS Policy	Oct 25, 2023 6:08 PM
✓ Deploy SSH Policy	Oct 25, 2023 6:07 PM
✓ Deploy Virtual KVM Policy Tunneled vKVM configuration is disabled for the account.	Oct 25, 2023 6:07 PM
✓ Validate Storage Policy Completed	Oct 25, 2023 6:07 PM
✓ Validate Boot Order Policy Completed	Oct 25, 2023 6:07 PM
✓ Wait for Storage subsystem initialization.	Oct 25, 2023 6:07 PM
✓ Validate NTP Policy	Oct 25, 2023 6:07 PM

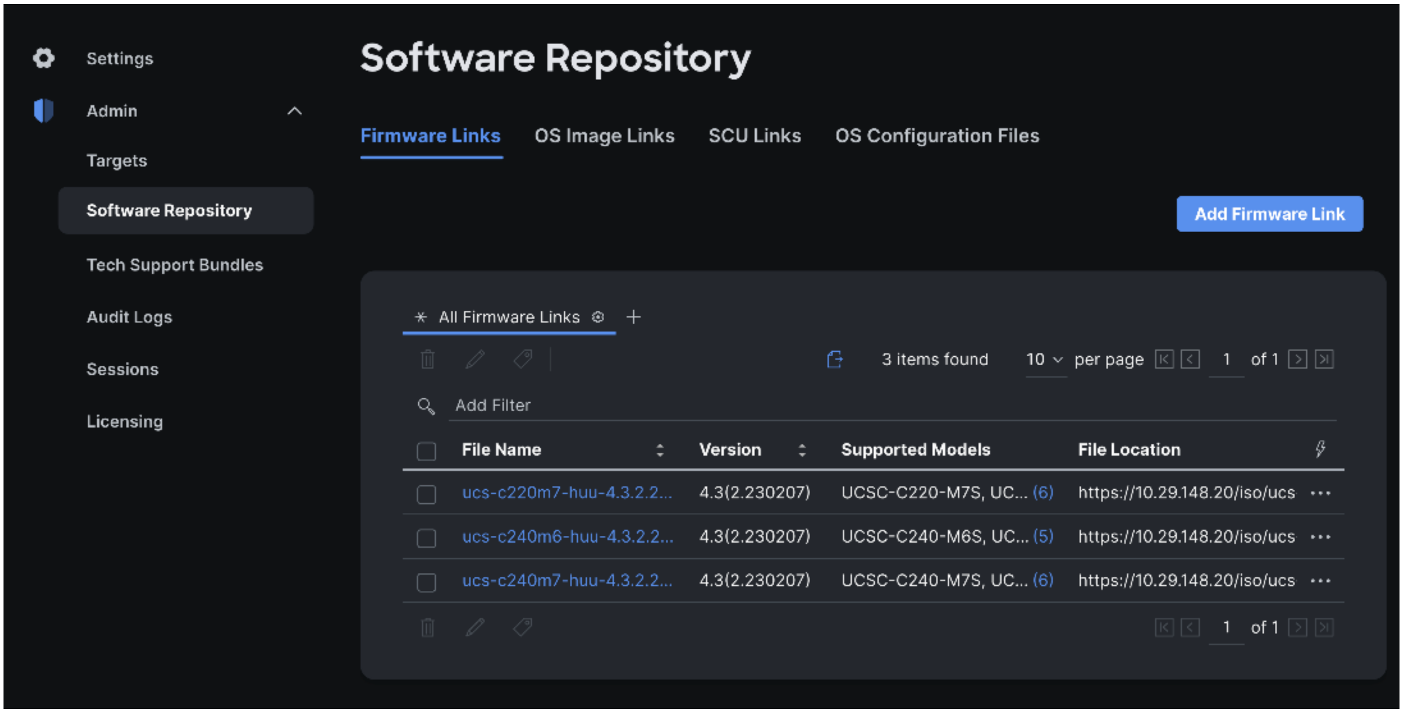
Install Operating System using Cisco Intersight

Prerequisites

Create the NFS or HTTPS file share location to be consumed for the Operating System, Cisco UCS SCU, and the Cisco UCS HUU repository.

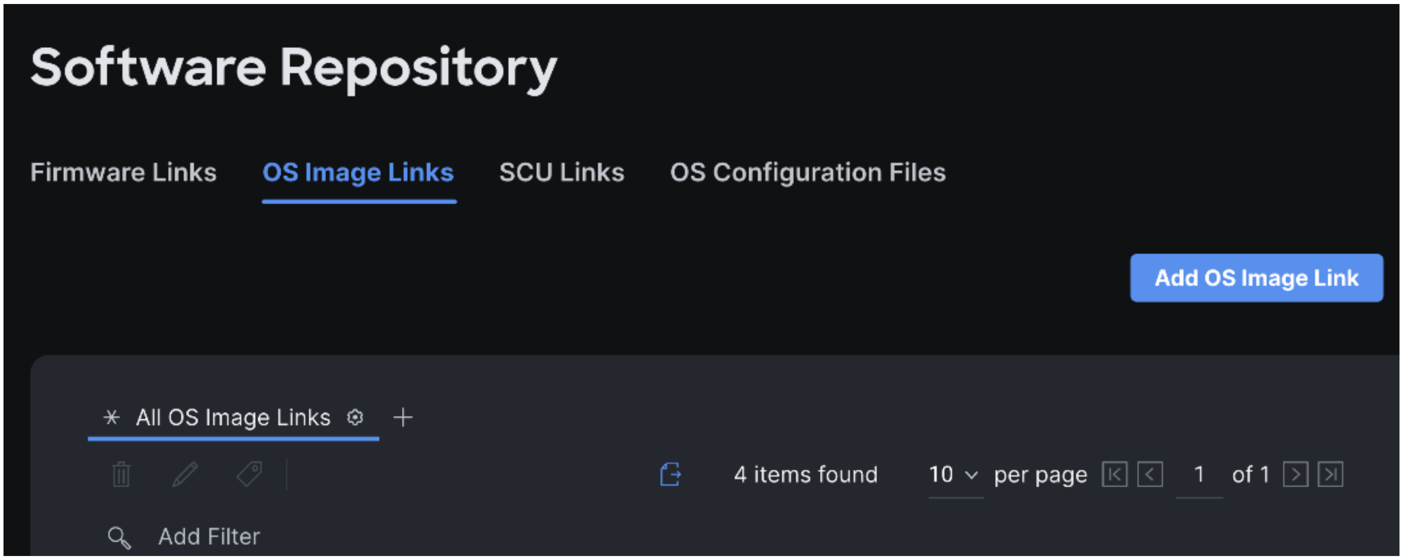
Step 1. Download ISO and copy the path location to be added in Software Repository tab.

Step 2. Log into Cisco Intersight. Go to System > Software Repository.

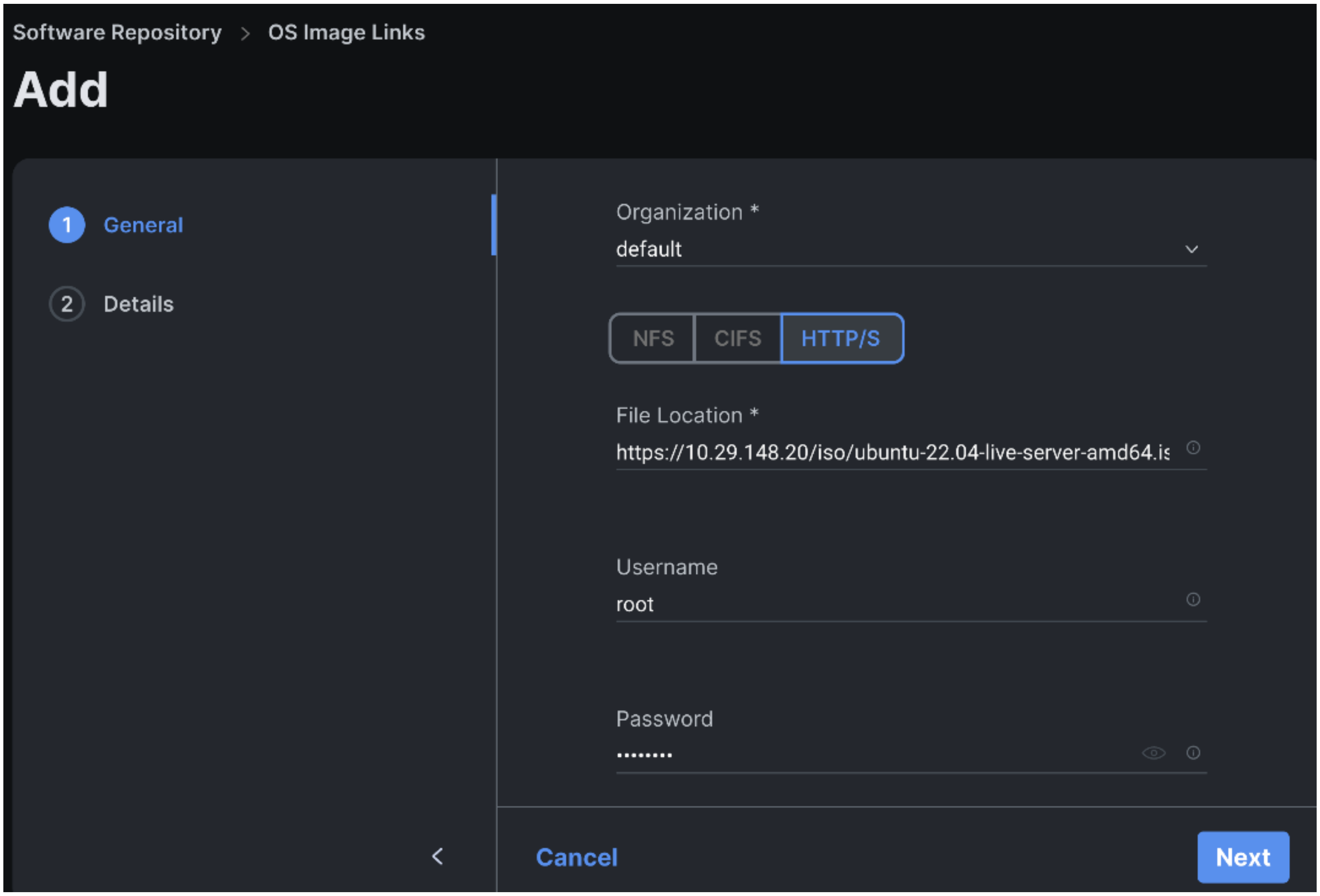


File Name	Version	Supported Models	File Location
ucs-c220m7-huu-4.3.2.2...	4.3(2.230207)	UCSC-C220-M7S, UC... (6)	https://10.29.148.20/iso/ucs
ucs-c240m6-huu-4.3.2.2...	4.3(2.230207)	UCSC-C240-M6S, UC... (5)	https://10.29.148.20/iso/ucs
ucs-c240m7-huu-4.3.2.2...	4.3(2.230207)	UCSC-C240-M7S, UC... (6)	https://10.29.148.20/iso/ucs

Step 3. Go to OS Image Links and click Add OS Image Link.



Step 4. Select NFS or CIFS or HTTP/s, enter file location, username, and password.



Software Repository > OS Image Links

Add

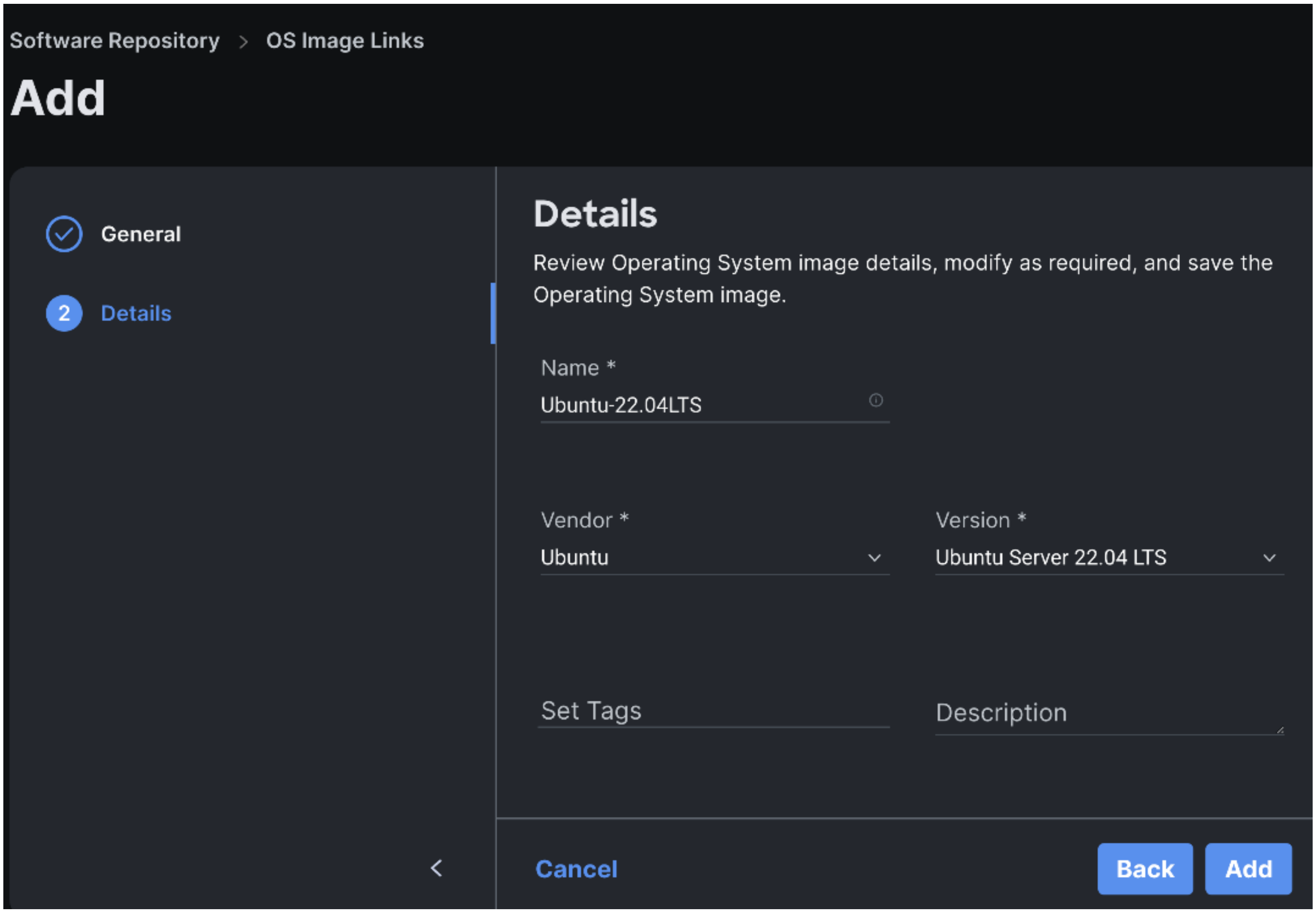
Organization *
default

File Location *
https://10.29.148.20/iso/ubuntu-22.04-live-server-amd64.is

Username
root

Password
••••••••

Step 5. Enter the Details.



Details

Review Operating System image details, modify as required, and save the Operating System image.

Name *
Ubuntu-22.04LTS

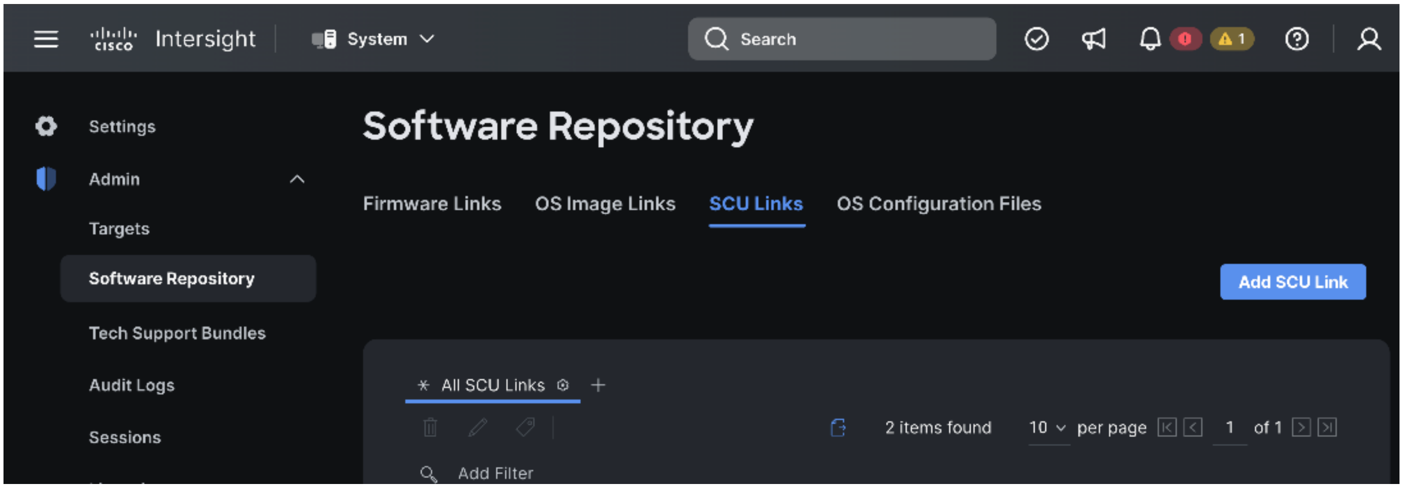
Vendor *
Ubuntu

Version *
Ubuntu Server 22.04 LTS

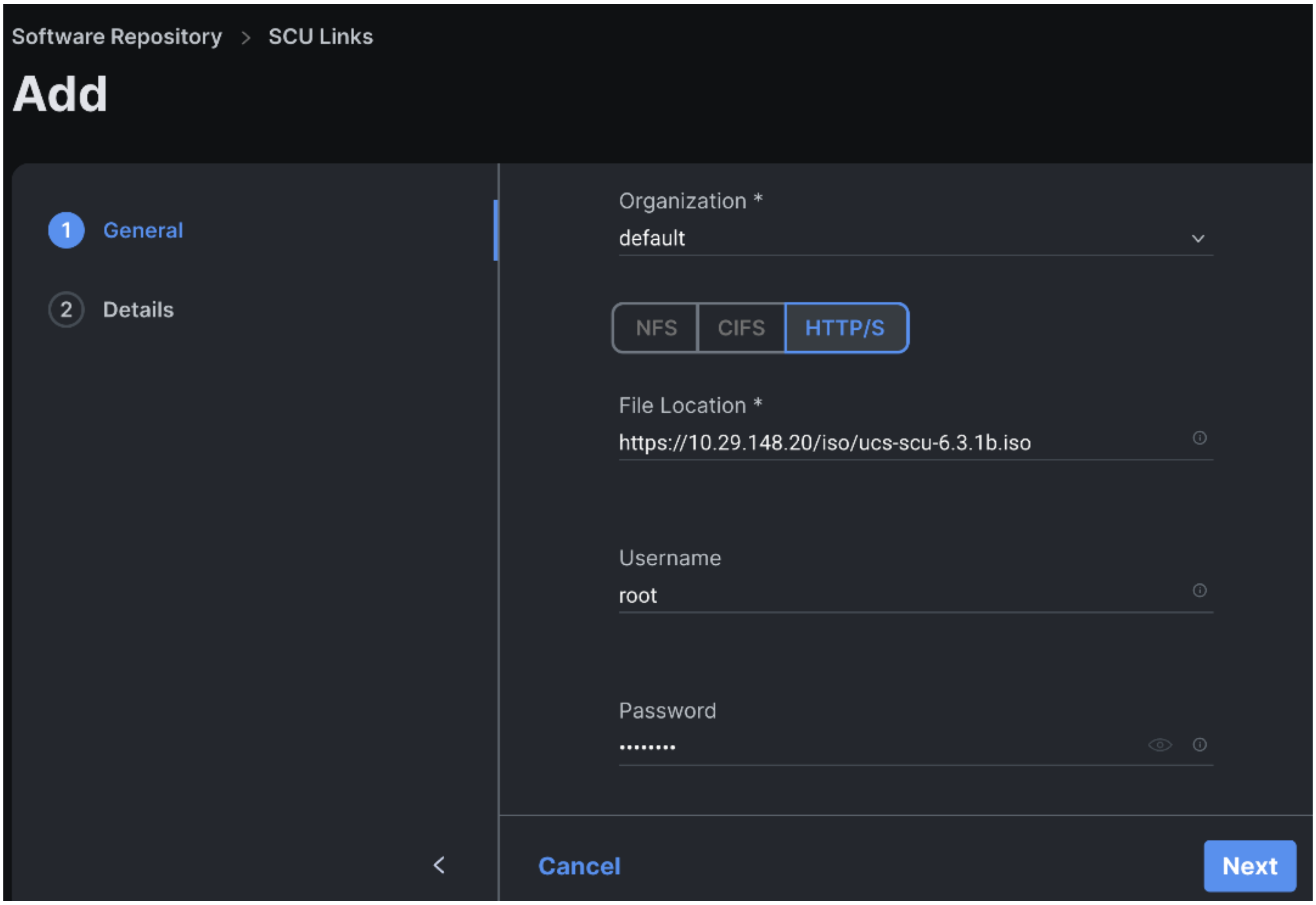
Set Tags

Description

Step 6. Go to SCU Links page System > Software Repository. Click Add SCU Link.



Step 7. Enter the File Location, Username and Password. Click Next.



Software Repository > SCU Links

Add

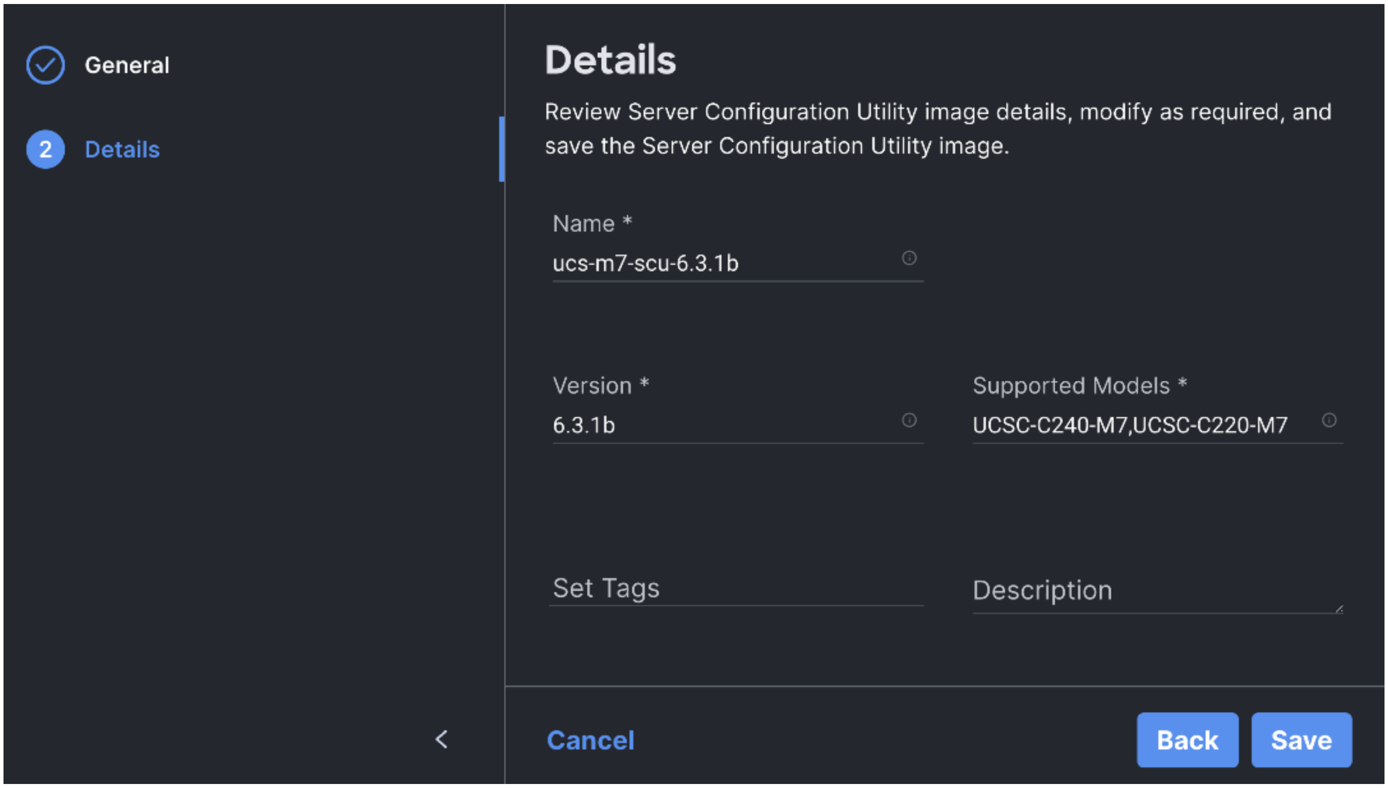
Organization *
default

File Location *
https://10.29.148.20/iso/ucs-scu-6.3.1b.iso

Username
root

Password
••••••••

Step 8. Review the Server Configuration Utility.



Details

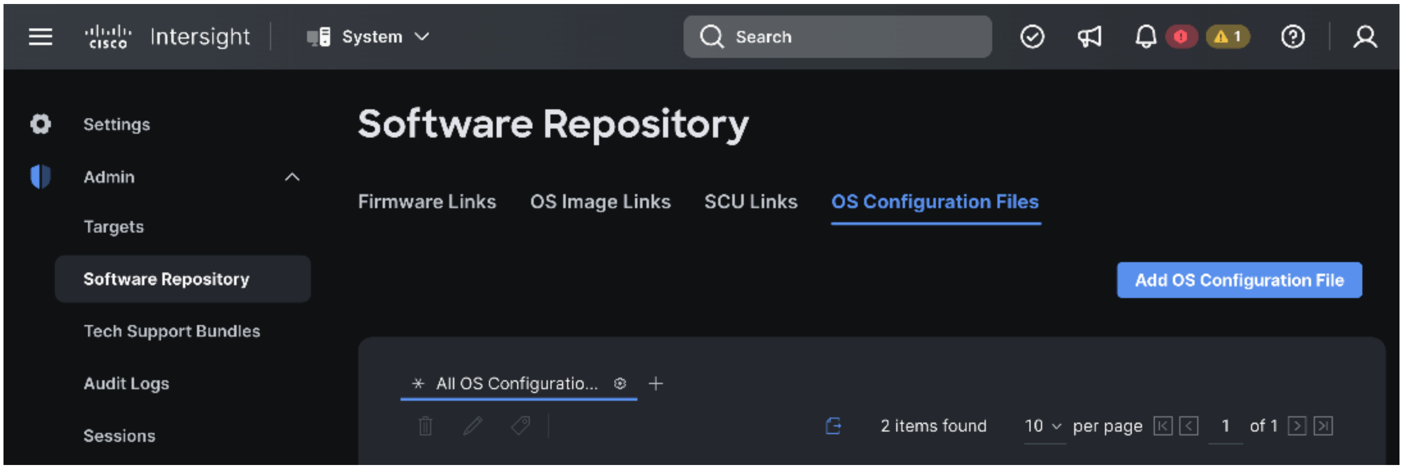
Review Server Configuration Utility image details, modify as required, and save the Server Configuration Utility image.

Name *
ucs-m7-scu-6.3.1b

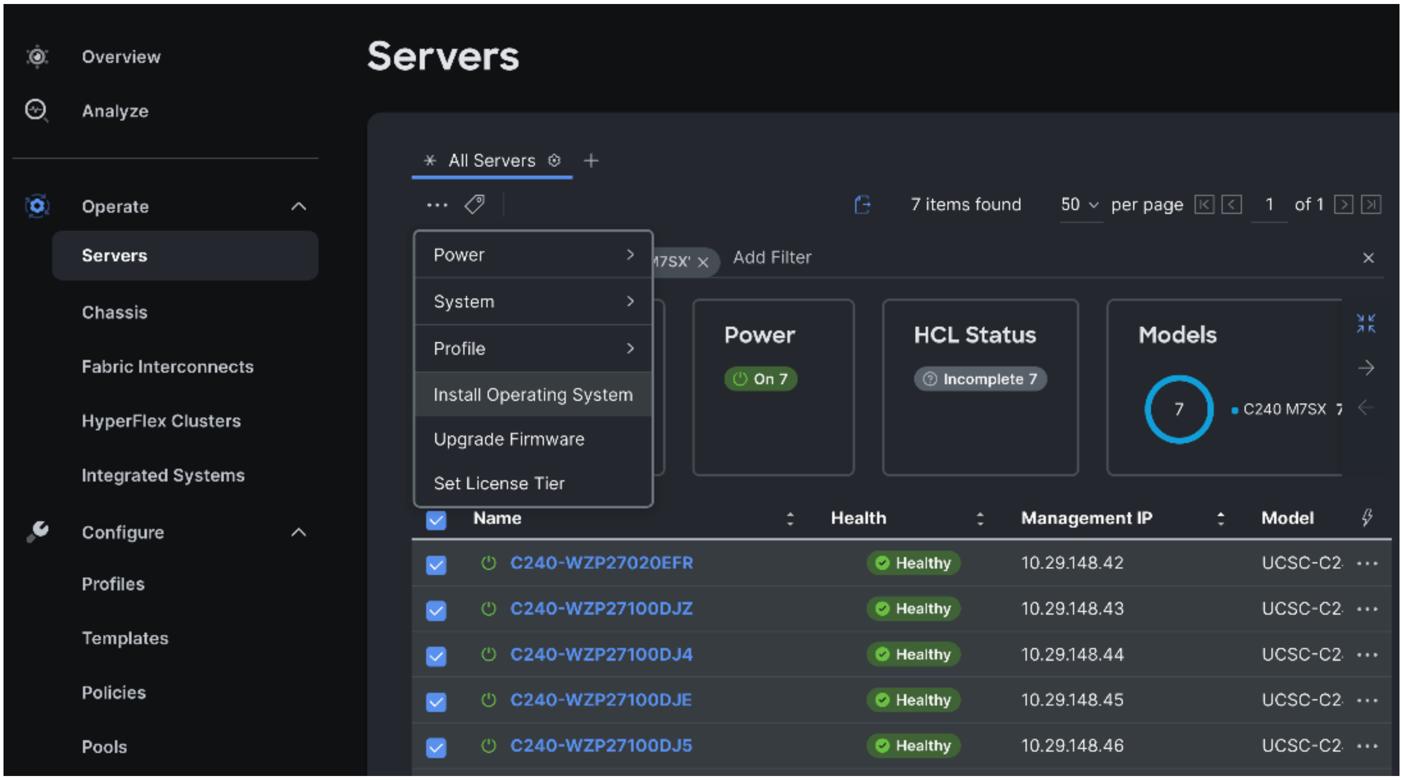
Version *
6.3.1b

Supported Models *
UCSC-C240-M7,UCSC-C220-M7

Step 9. Go to the OS Configuration Files tab. Add the OS configuration file for Operating System Installation (optional).

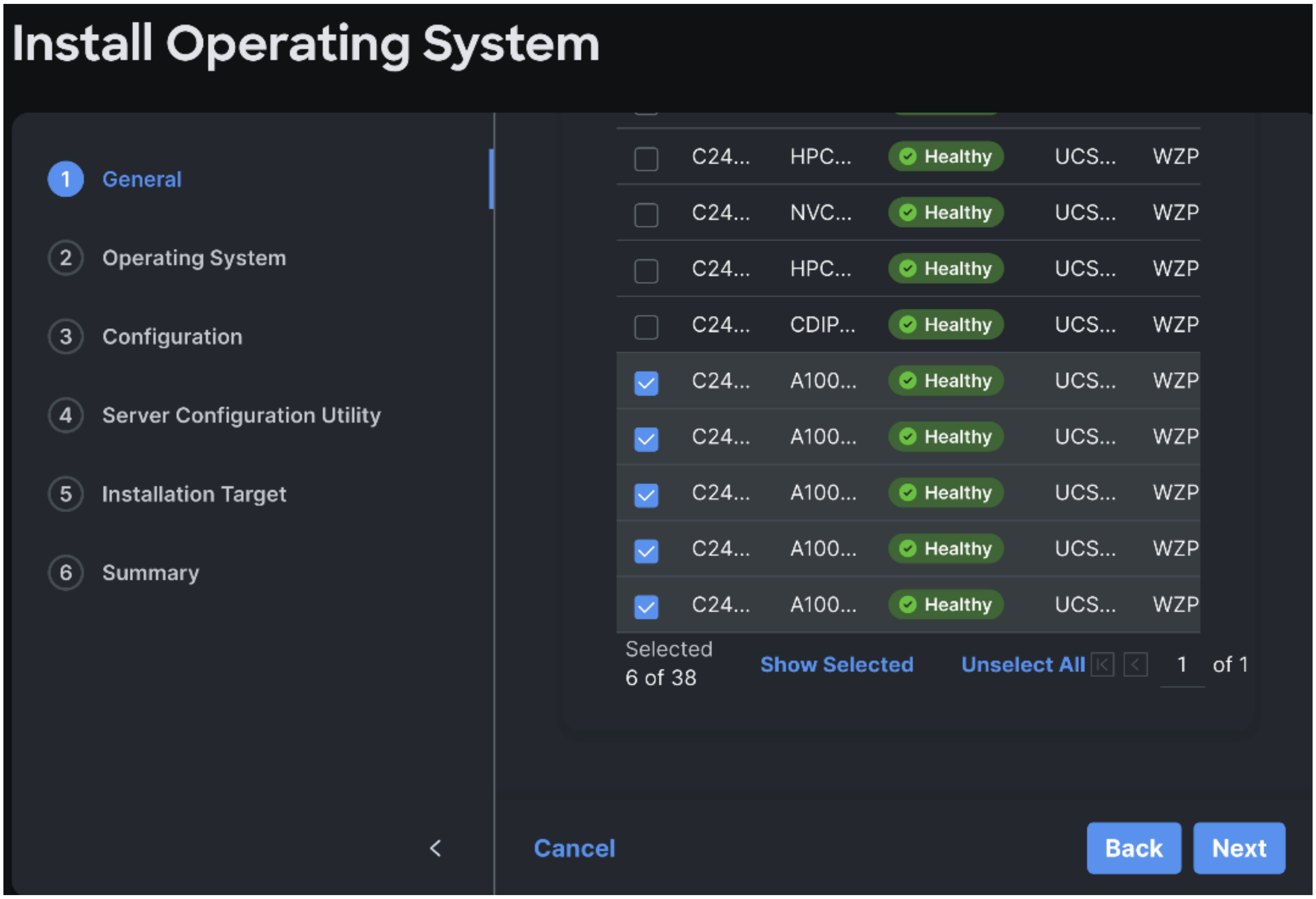


Step 10. Go to Infrastructure Service > Servers. Select system(s) to perform Install Operating System. Right-click on the ellipses and select Install Operating System.



☑	Name	Health	Management IP	Model
☑	C240-WZP27020EFR	Healthy	10.29.148.42	UCSC-C2
☑	C240-WZP27100DJZ	Healthy	10.29.148.43	UCSC-C2
☑	C240-WZP27100DJ4	Healthy	10.29.148.44	UCSC-C2
☑	C240-WZP27100DJE	Healthy	10.29.148.45	UCSC-C2
☑	C240-WZP27100DJ5	Healthy	10.29.148.46	UCSC-C2

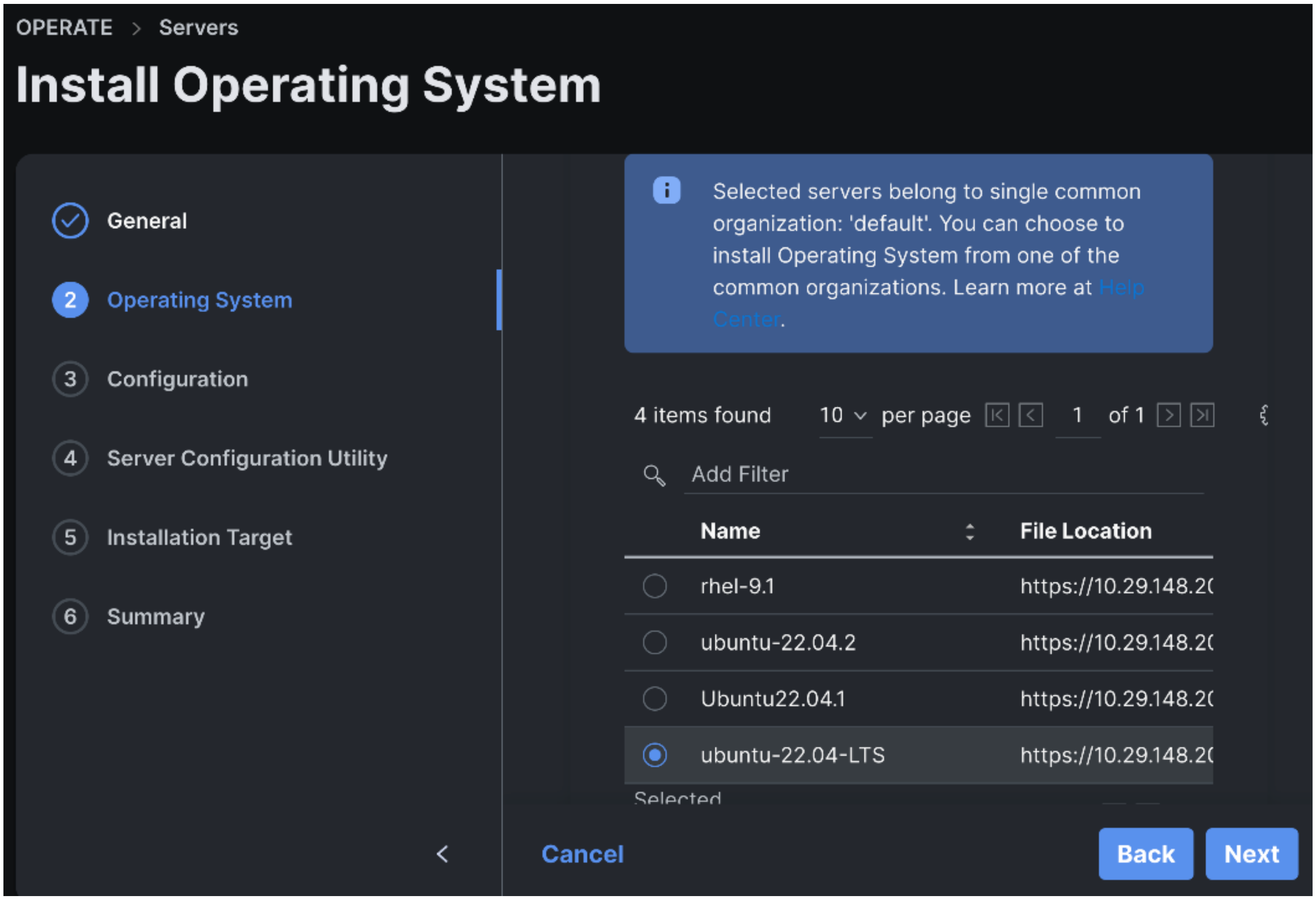
Step 11. The selected system(s) are already part of the Operating System Install task. Edit the list if required. Click Next.



□	C24...	HPC...	Healthy	UCS...	WZP
□	C24...	NVC...	Healthy	UCS...	WZP
□	C24...	HPC...	Healthy	UCS...	WZP
□	C24...	CDIP...	Healthy	UCS...	WZP
☑	C24...	A100...	Healthy	UCS...	WZP
☑	C24...	A100...	Healthy	UCS...	WZP
☑	C24...	A100...	Healthy	UCS...	WZP
☑	C24...	A100...	Healthy	UCS...	WZP
☑	C24...	A100...	Healthy	UCS...	WZP

Selected
6 of 38

Step 12. Select the OS Image Link for the intended operating system to be installed.



OPERATE > Servers

Install Operating System

Selected servers belong to single common organization: 'default'. You can choose to install Operating System from one of the common organizations. Learn more at Help Center.

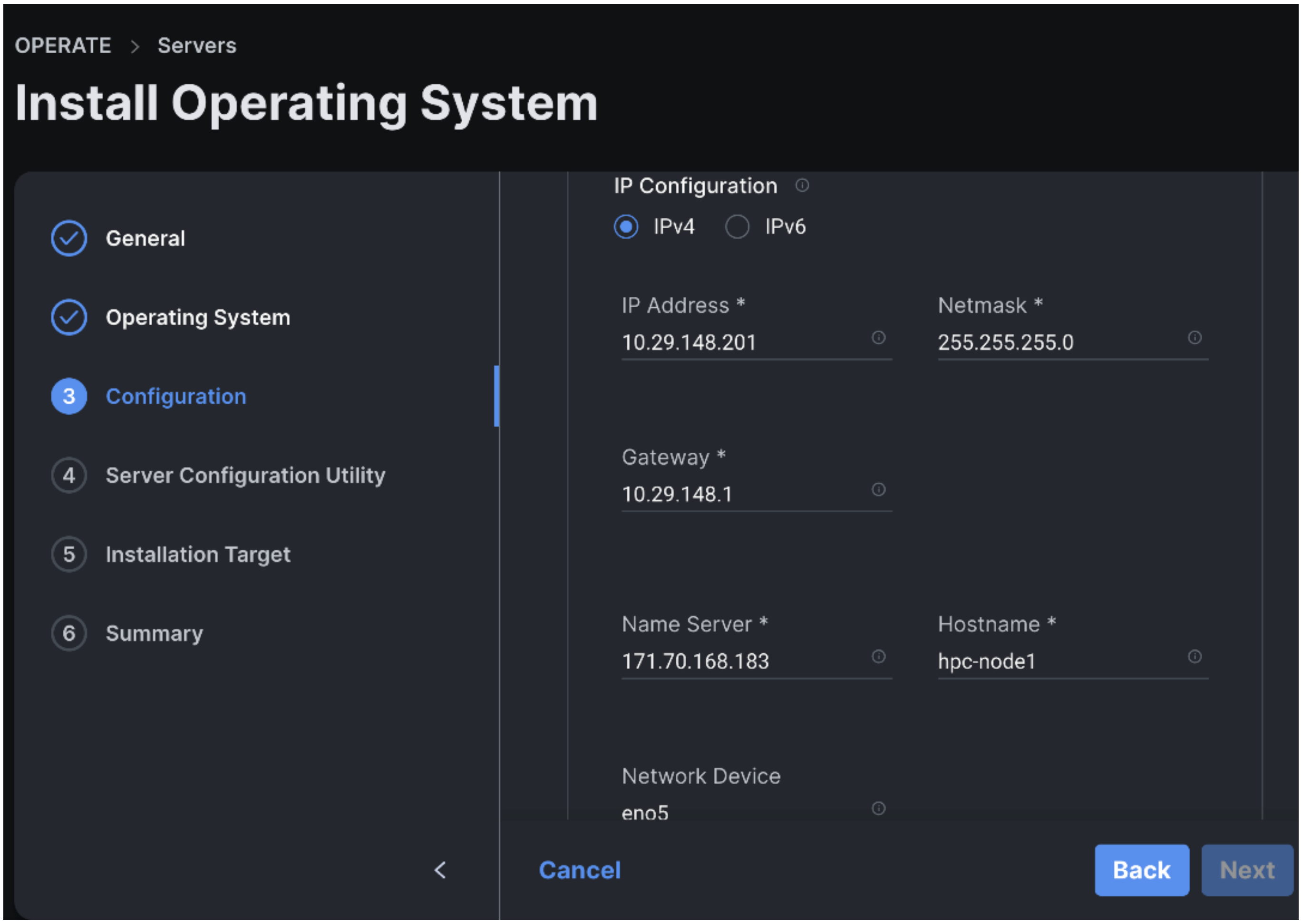
4 items found 10 per page 1 of 1

Add Filter

	Name	File Location
○	rhel-9.1	https://10.29.148.2(
○	ubuntu-22.04.2	https://10.29.148.2(
○	Ubuntu22.04.1	https://10.29.148.2(
●	ubuntu-22.04-LTS	https://10.29.148.2(

Selected

Step 13. Enter the configuration details for the Operating System to be installed as shown in the screenshot below. Repeat these steps for all system(s).



IP Configuration

● IPv4 ○ IPv6

IP Address *: 10.29.148.201

Netmask *: 255.255.255.0

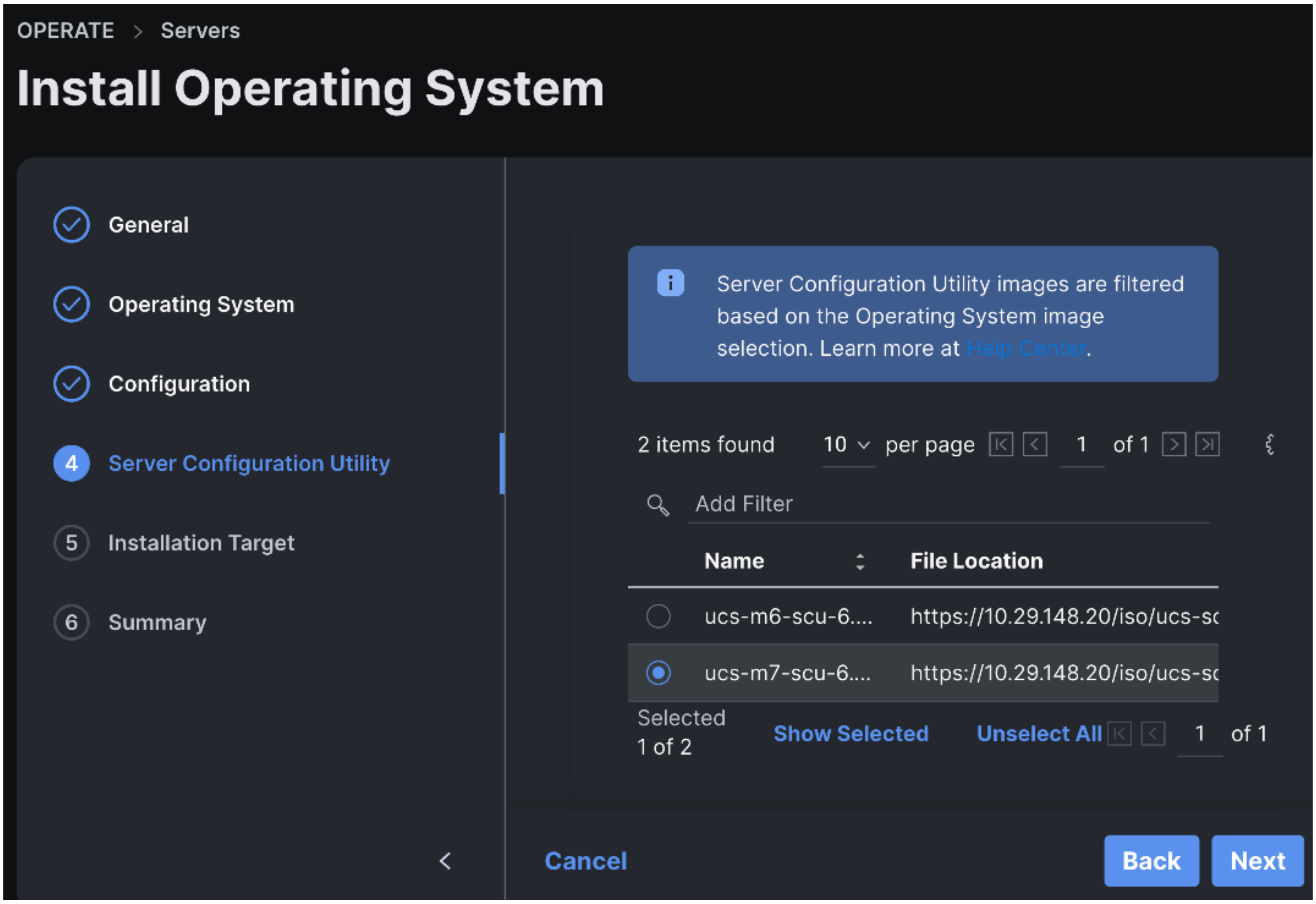
Gateway *: 10.29.148.1

Name Server *: 171.70.168.183

Hostname *: hpc-node1

Network Device: eno5

Step 14. Select the Server Configuration Utility Image.


OPERATE > Servers

Install Operating System

Server Configuration Utility images are filtered based on the Operating System image selection. Learn more at Help Center.

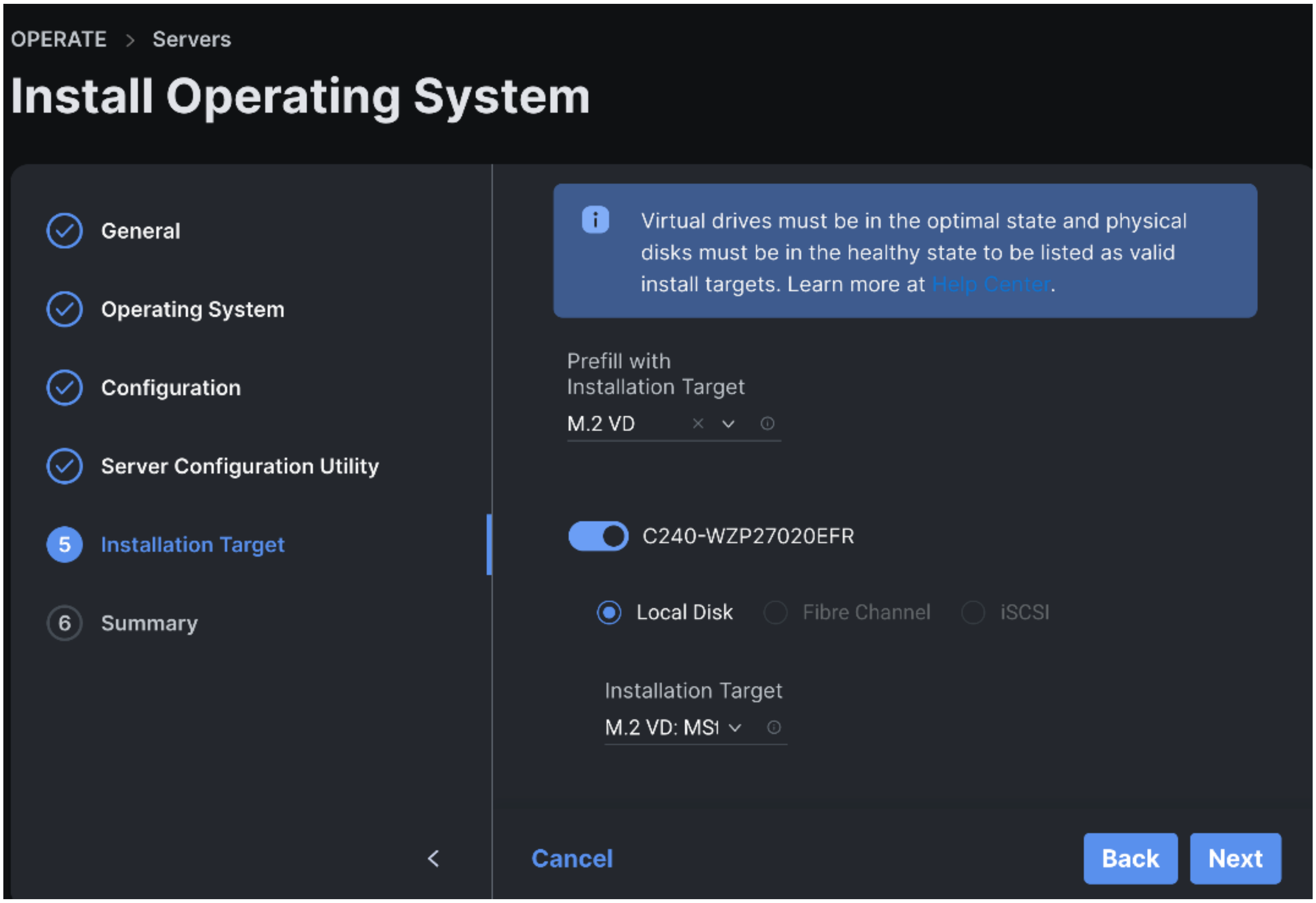
2 items found 10 per page 1 of 1

Add Filter

	Name	File Location
○	ucs-m6-scu-6....	https://10.29.148.20/iso/ucs-sc
●	ucs-m7-scu-6....	https://10.29.148.20/iso/ucs-sc

Selected 1 of 2

Step 15. Select the Installation Target. We selected M.2 VD from the drop-down list.



OPERATE > Servers

Install Operating System

Virtual drives must be in the optimal state and physical disks must be in the healthy state to be listed as valid install targets. Learn more at Help Center.

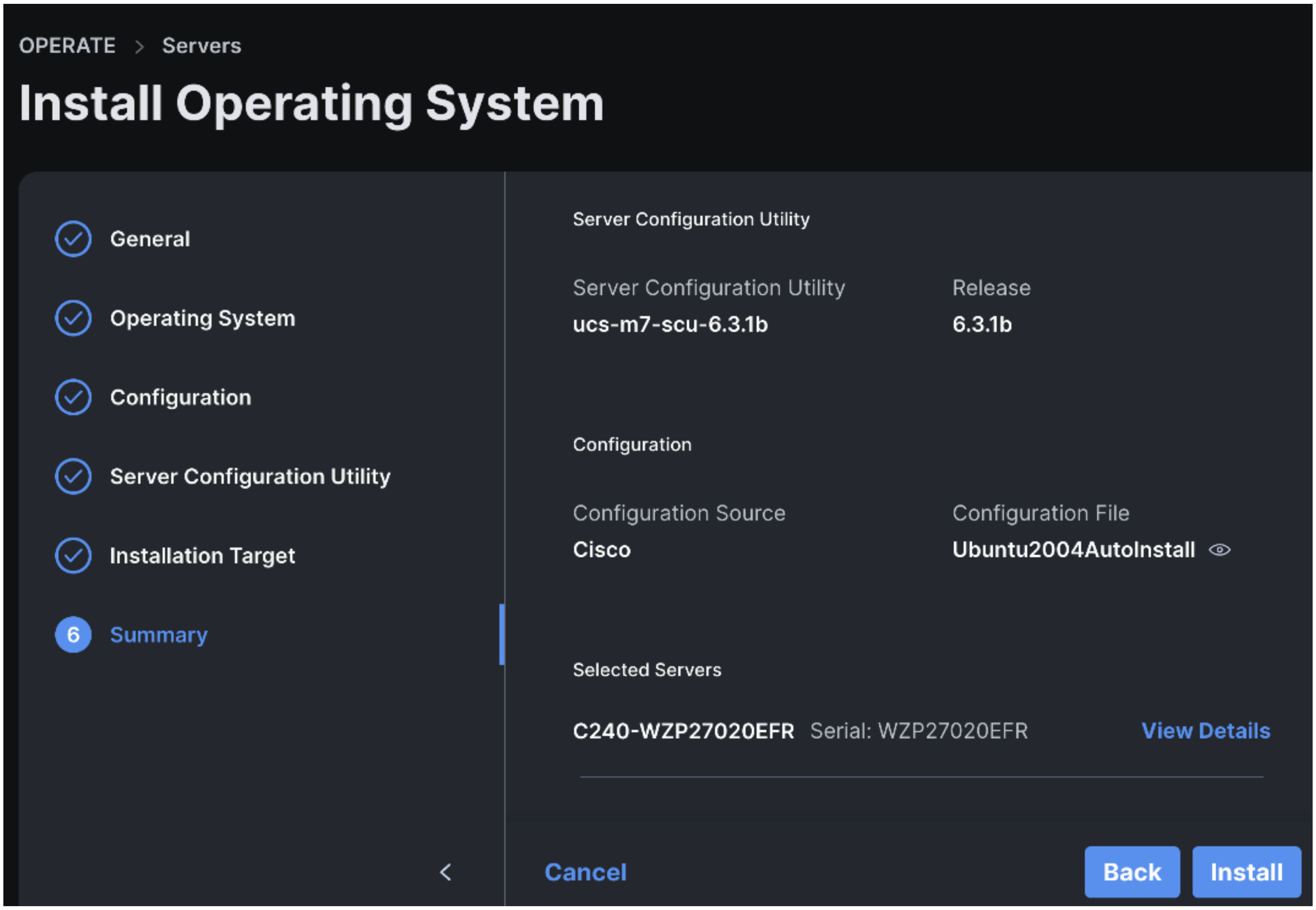
Prefill with Installation Target: M.2 VD

C240-WZP27020EFR

● Local Disk ○ Fibre Channel ○ iSCSI

Installation Target: M.2 VD: MSI

Step 16. Review the Operating System Installation Summary. Click Install.



Install Operating System

Server Configuration Utility

Server Configuration Utility: ucs-m7-scu-6.3.1b

Release: 6.3.1b

Configuration

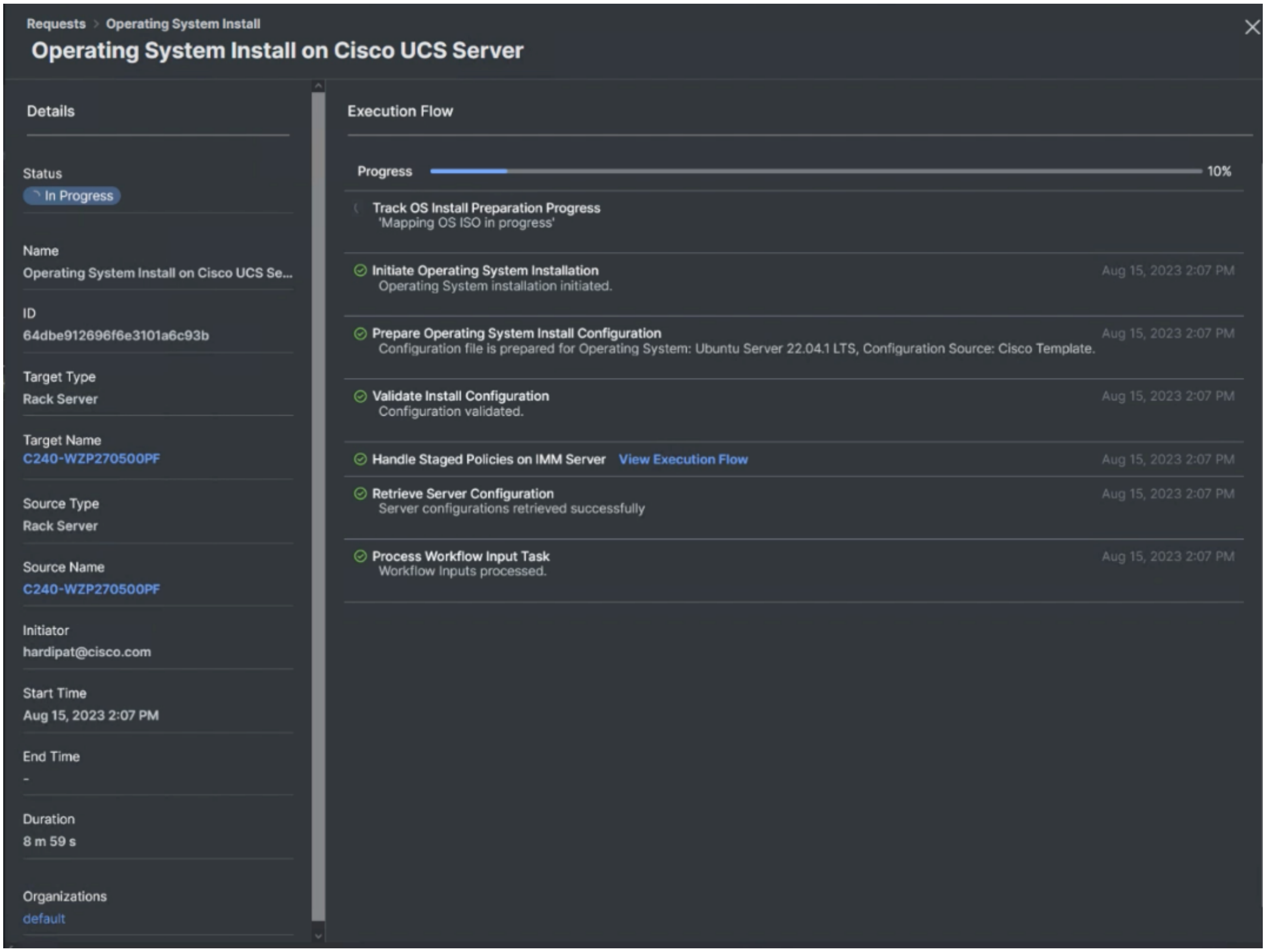
Configuration Source: Cisco

Configuration File: Ubuntu2004AutoInstall

Selected Servers

C240-WZP27020EFR Serial: WZP27020EFR View Details

Step 17. Review the Installation workflow in execution.



Operating System Install on Cisco UCS Server

Details

Status: In Progress

Name: Operating System Install on Cisco UCS Se...

ID: 64dbe912696f6e3101a6c93b

Target Type: Rack Server

Target Name: C240-WZP270500PF

Source Type: Rack Server

Source Name: C240-WZP270500PF

Initiator: hardipat@cisco.com

Start Time: Aug 15, 2023 2:07 PM

End Time: -

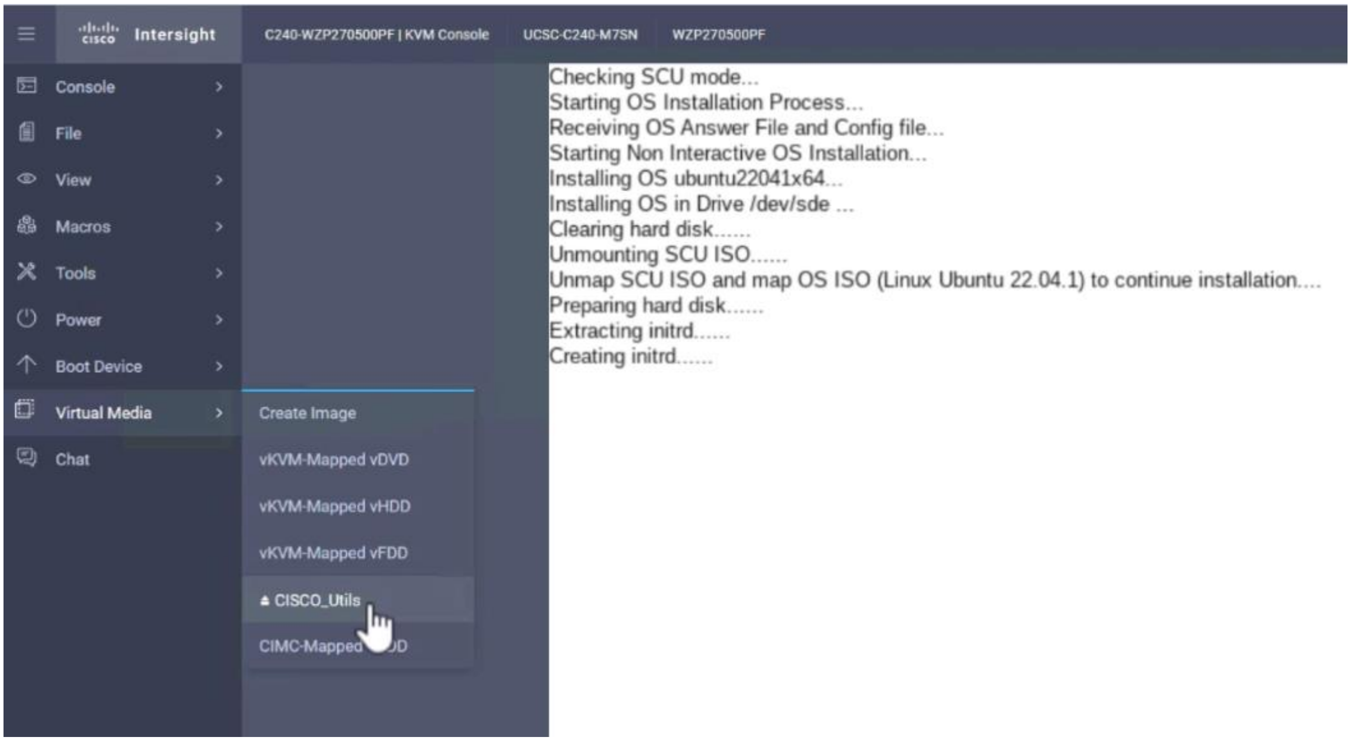
Duration: 8 m 59 s

Organizations: default

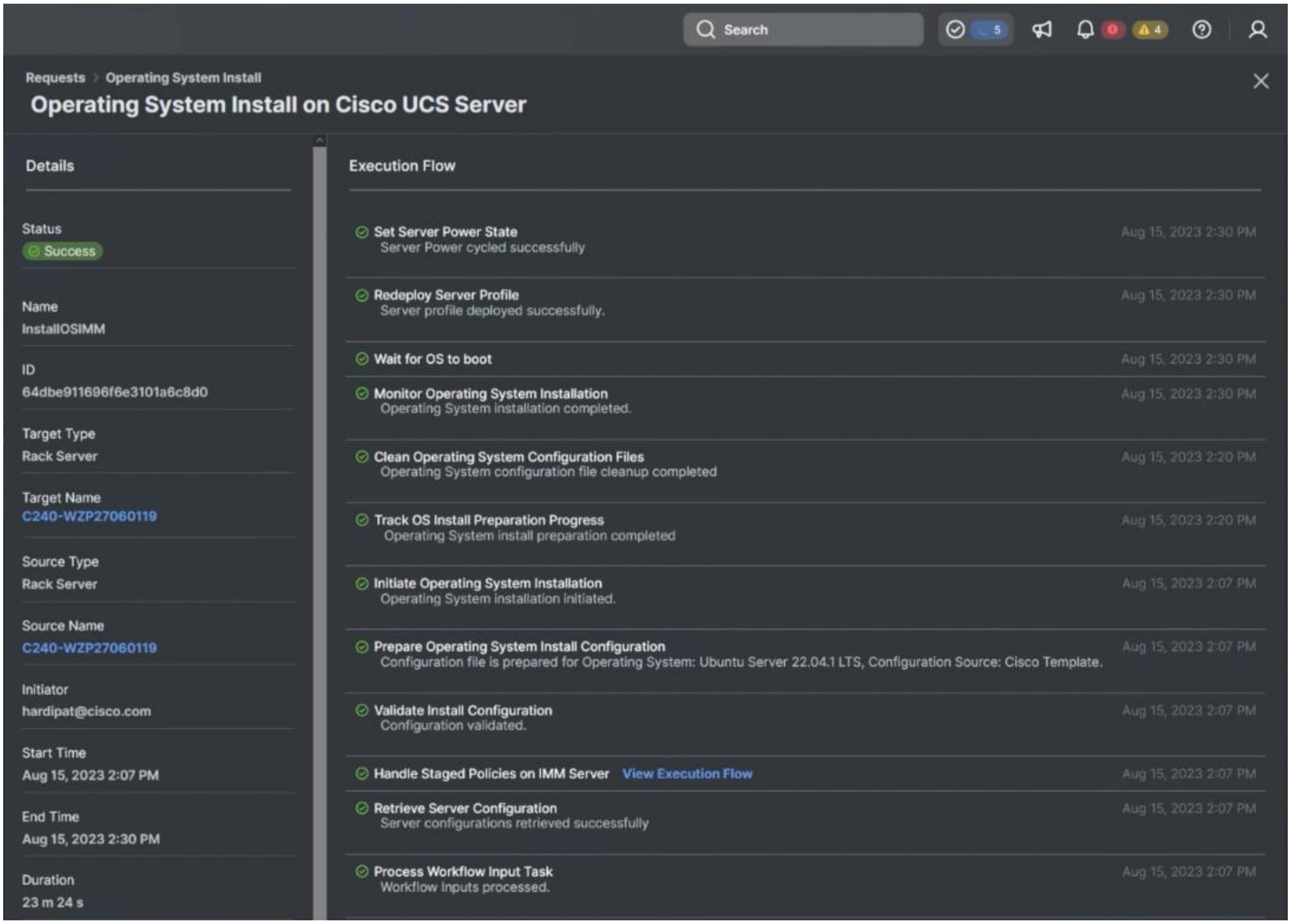
Execution Flow

Progress 10%

- Track OS Install Preparation Progress
  'Mapping OS ISO in progress'
- Initiate Operating System Installation — Aug 15, 2023 2:07 PM
  Operating System installation initiated.
- Prepare Operating System Install Configuration — Aug 15, 2023 2:07 PM
  Configuration file is prepared for Operating System: Ubuntu Server 22.04.1 LTS, Configuration Source: Cisco Template.
- Validate Install Configuration — Aug 15, 2023 2:07 PM
  Configuration validated.
- Handle Staged Policies on IMM Server — View Execution Flow — Aug 15, 2023 2:07 PM
- Retrieve Server Configuration — Aug 15, 2023 2:07 PM
  Server configurations retrieved successfully
- Process Workflow Input Task — Aug 15, 2023 2:07 PM
  Workflow Inputs processed.



```
Checking SCU mode...
Starting OS Installation Process...
Receiving OS Answer File and Config file...
Starting Non Interactive OS Installation...
Installing OS ubuntu22041x64...
Installing OS in Drive /dev/sde ...
Clearing hard disk......
Unmounting SCU ISO......
Unmap SCU ISO and map OS ISO (Linux Ubuntu 22.04.1) to continue installation....
Preparing hard disk......
Extracting initrd......
Creating initrd......
```



Requests > Operating System Install

Operating System Install on Cisco UCS Server

Details

Status
Success

Name
InstallOSIMM

ID
64dbe911696f6e3101a6c8d0

Target Type
Rack Server

Target Name
C240-WZP27060119

Source Type
Rack Server

Source Name
C240-WZP27060119

Initiator
hardipat@cisco.com

Start Time
Aug 15, 2023 2:07 PM

End Time
Aug 15, 2023 2:30 PM

Duration
23 m 24 s

Execution Flow

✓ Set Server Power State — Aug 15, 2023 2:30 PM
Server Power cycled successfully

✓ Redeploy Server Profile — Aug 15, 2023 2:30 PM
Server profile deployed successfully.

✓ Wait for OS to boot — Aug 15, 2023 2:30 PM

✓ Monitor Operating System Installation — Aug 15, 2023 2:30 PM
Operating System installation completed.

✓ Clean Operating System Configuration Files — Aug 15, 2023 2:20 PM
Operating System configuration file cleanup completed

✓ Track OS Install Preparation Progress — Aug 15, 2023 2:20 PM
Operating System install preparation completed

✓ Initiate Operating System Installation — Aug 15, 2023 2:07 PM
Operating System installation initiated.

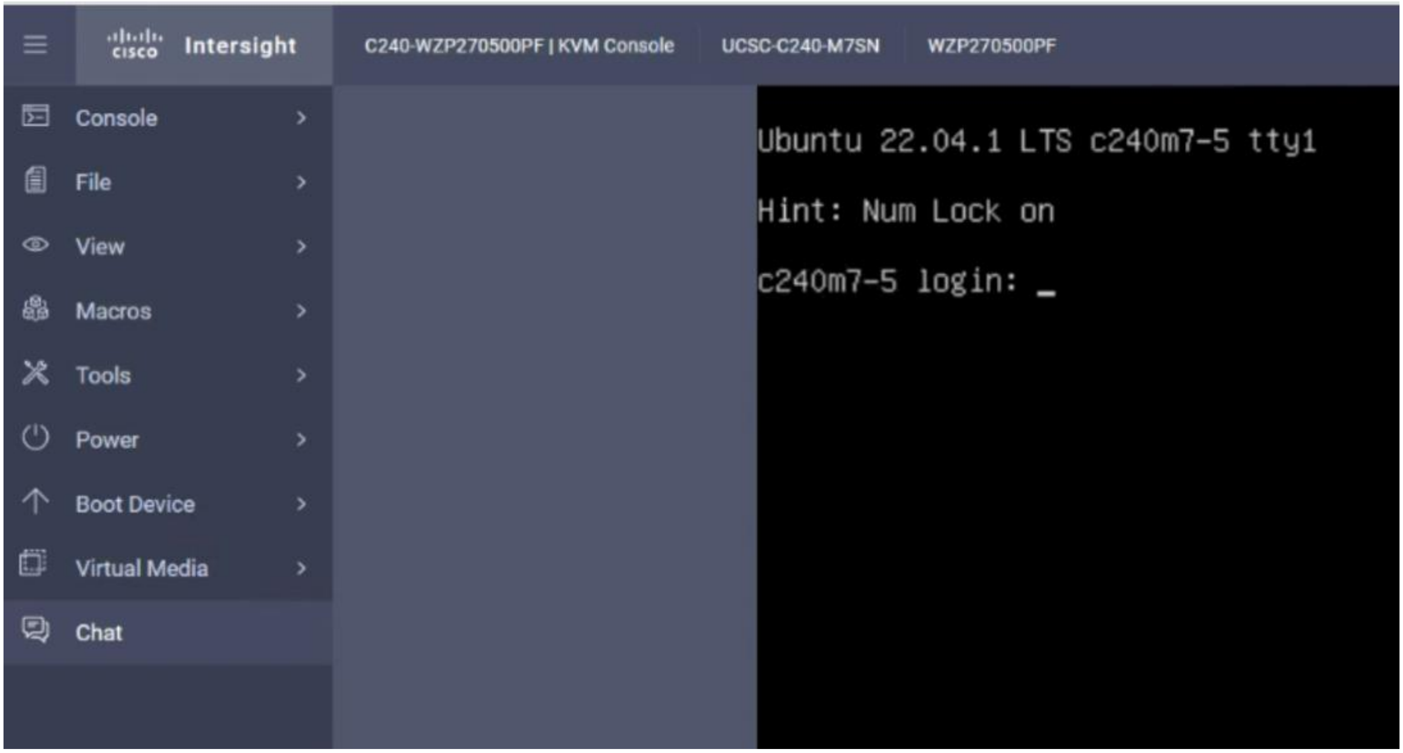
✓ Prepare Operating System Install Configuration — Aug 15, 2023 2:07 PM
Configuration file is prepared for Operating System: Ubuntu Server 22.04.1 LTS, Configuration Source: Cisco Template.

✓ Validate Install Configuration — Aug 15, 2023 2:07 PM
Configuration validated.

✓ Handle Staged Policies on IMM Server View Execution Flow — Aug 15, 2023 2:07 PM

✓ Retrieve Server Configuration — Aug 15, 2023 2:07 PM
Server configurations retrieved successfully

✓ Process Workflow Input Task — Aug 15, 2023 2:07 PM
Workflow Inputs processed.



```
Ubuntu 22.04.1 LTS c240m7-5 tty1

Hint: Num Lock on

c240m7-5 login: _
```

Post-OS Configuration

This section contains the post-OS configuration steps:

- OS Configuration
- Ansible Automation

OS Configuration

Step 1. Log into the Ubuntu OS management IP address configured during the Cisco Intersight based Install Operating System using the SSH client. Enter the username “ubuntu” and the password entered while setting up the custom configuration:

```
$ ssh ubuntu@10.29.148.171
```

Edit /etc/hosts

```
$ cat /etc/hosts

127.0.0.1 localhost

127.0.1.1 hpc-node1


10.29.148.171 hpc-node1

10.29.148.172 hpc-node2

10.29.148.173 hpc-node3

10.29.148.174 hpc-node4

10.29.148.175 hpc-node5

10.29.148.176 hpc-node6

10.29.148.177 hpc-node7

10.29.148.178 hpc-node8


# The following lines are desirable for IPv6 capable hosts

::1     ip6-localhost ip6-loopback

fe00::0 ip6-localnet

ff00::0 ip6-mcastprefix

ff02::1 ip6-allnodes

ff02::2 ip6-allrouters
```

Note: If it’s not already installed, the following steps require openssh-server to be installed using " sudo apt install -y openssh-server"

Step 2. Add a new user:

```
$ adduser <username>
```

```
Adding user `<username>' ...
Adding new group `<username>' (1001) ...
Adding new user `<username>' (1001) with group `<username> ...
Creating home directory `/home/<username>' ...
Copying files from `/etc/skel' ...
New password: <Password!>
Retype new password: <Password!>
passwd: password updated successfully
Changing the user information for <username>
Enter the new value, or press ENTER for the default
        Full Name []: FirstName LastName
        Room Number []:
        Work Phone []:
        Home Phone []:
        Other []:
Is the information correct? [Y/n] Y
$ usermod -aG sudo <username>
$ su - <username>
To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.
```

Step 3. Setup a password-less login:

This process needs to be completed on each node so that all nodes can be accessed without password for HPC cluster test as documented in following section.

```
$ ssh-keygen -N '' -f ~/.ssh/id_rsa
$ for i in {1..8}; do echo "copying hpc-node$i"; ssh-copy-id -i /home/ubuntu/.ssh/id_rsa.pub ubuntu@HPC-Node$i; done;
```

Ansible Automation

Step 1. Install ansible:

```
$ sudo apt update
$ sudo apt install software-properties-common
$ sudo add-apt-repository --update ppa:ansible/ansible --> Press Enter when prompted
$ sudo apt update
$ sudo apt install -y ansible-core ansible
$ ansible --version
ansible [core 2.15.4]
  config file = /etc/ansible/ansible.cfg
  configured module search path = ['/home/hardipat/.ansible/plugins/modules',
'/usr/share/ansible/plugins/modules']
  ansible python module location = /usr/lib/python3/dist-packages/ansible
  ansible collection location = /home/hardipat/.ansible/collections:/usr/share/ansible/collections
  executable location = /usr/bin/ansible
  python version = 3.10.12 (main, Jun 11 2023, 05:26:28) [GCC 11.4.0] (/usr/bin/python3)
  jinja version = 3.0.3
  libyaml = True
```

Step 2. Edit /etc/ansible/hosts:

```
$ sudo vi /etc/ansible/hosts
[hpcnodes]
hpc-node1 ansible_host=10.29.148.171
hpc-node2 ansible_host=10.29.148.172
hpc-node3 ansible_host=10.29.148.173
hpc-node4 ansible_host=10.29.148.174
hpc-node5 ansible_host=10.29.148.175
hpc-node6 ansible_host=10.29.148.176
hpc-node7 ansible_host=10.29.148.177
hpc-node8 ansible_host=10.29.148.178

[all:vars]
ansible_python_interpreter=/usr/bin/python3
```

Step 3. Test ansible:

```
$ ansible-inventory --list -y
all:
  children:
    admin:
      hosts:
        10.29.148.22:
          ansible_python_interpreter: /usr/bin/python3
    hpcnodes:
      hosts:
        hpc-node1:
          ansible_host: 10.29.148.171
          ansible_python_interpreter: /usr/bin/python3
        hpc-node2:
          ansible_host: 10.29.148.172
          ansible_python_interpreter: /usr/bin/python3
        hpc-node3:
          ansible_host: 10.29.148.173
          ansible_python_interpreter: /usr/bin/python3
        hpc-node4:
          ansible_host: 10.29.148.174
          ansible_python_interpreter: /usr/bin/python3
        hpc-node5:
          ansible_host: 10.29.148.175
          ansible_python_interpreter: /usr/bin/python3
        hpc-node6:
          ansible_host: 10.29.148.176
          ansible_python_interpreter: /usr/bin/python3
        hpc-node7:
          ansible_host: 10.29.148.177
          ansible_python_interpreter: /usr/bin/python3
        hpc-node8:
          ansible_host: 10.29.148.178
          ansible_python_interpreter: /usr/bin/python3
$ ansible all -m command -a " uname -r"
hpc-node2 | CHANGED | rc=0 >>
5.15.0-84-generic
hpc-node4 | CHANGED | rc=0 >>
5.15.0-84-generic
```

Tech tip

To enable root login; edit "/etc/ssh/sshd_config" as --> PermitRootLogin yes

```
$ sudo passwd root

[sudo] password for ubuntu:

New password:

Retype new password:

passwd: password updated successfully
```

Step 4. Setup NTP:

```
$ ansible all -m command -a "sudo timedatectl set-timezone America/Los_Angeles"

$ # ansible all -m command -a "sudo timedatectl set-ntp false"

$ ansible all -m command -a "sudo timedatectl set-time hh:mm"

$ ansible all -m command -a "sudo timedatectl set-time true"

$ ansible all -m command -a "sudo apt install ntp -y"
```

Step 5. Edit /etc/ntp.conf and copy on all nodes:

```
$ vi /etc/ntp.conf

pool 72.163.32.44 iburst

$ ansible all -m copy -a "src=/etc/ntp.conf dest=/etc/ntp.conf"
```

Step 6. Start NTP service:

```
$ ansible all -m command -a "sudo systemctl start ntp"

$ ansible all -m command -a "sudo systemctl enable ntp"
```

Step 7. Install required packages:

```
$ ansible all -m command -a "sudo apt-get update"

$ ansible all -m command -a "sudo apt-get install build-essential -y"

$ ansible all -m command -a "sudo apt install -y pip sshpass unzip -y"

$ ansible all -m command -a "sudo apt install environment-modules -y"

$ ansible all -m command -a "sudo apt install dkms -y"

$ ansible all -m command -a “sudo apt install make cmake -y”
```

Step 8. Update Grub by editing /etc/default/grub:

```
$ ansible all -m shell -a "sed -i 's/GRUB__CMDLINE_LINUX_DEFAULT="[^"]*/& iommu=pt
numa_balancing=disable pci=realloc=off processor.max_cstate=0/' /etc/default/grub"

$ ansible all -m shell -a "update-grub"
```

Step 9. Disable Nouveau by running following commands:

```
$ ansible all -m shell -a " bash -c " echo blacklist nouveau > /etc/modprobe.d/blacklist-nvidia-nouveau.conf" "
```

```
$ ansible all -m shell -a " bash -c " echo options nouveau modeset=0 >> /etc/modprobe.d/blacklist-nvidia-nouveau.conf" "
```

```
$ ansible all -m shell -a " update-initramfs -u"
```

Tech tip

The previous steps require a reboot:

```
$ ansible all -m command -a " sudo reboot"
```

Step 10. Disable firewall (or edit firewall configuration to allow NTP, NFS, other network traffic as appropriate):

```
$ ansible all -m shell -a " sudo UFW disable”
```

Step 11. Disable SELinux:

```
$ sudo vi /etc/selinux/config
```

```
SELINUX=disabled
```

```
$ ansible all -m copy -a “src=/etc/selinux/config dest=/etc/selinux/config”
```

Mellanox ConnectX-6 NIC Best Practice

This section highlights the steps required for the Mellanox ConnectX6-DX ehternet network interface card configuration for Ubuntu OS:

- Mellanox OFED Driver Installation
- Configure Network Adapter Ports for Ubuntu
- Mellanox ConnectX-6 NIC best practice for PFC, ECN and DSCP
- Connect NetApp Storage provided FlexVolume(s) using NFS Mount

Mellanox OFED Driver Installation

Step 1. Install Mellanox OFED for Mellanox ConnectX-6 DX Ethernet Network Interface Card. Download Mellanox OFED from the following URL: https://www.mellanox.com/page/mlnx_ofed_eula?mtag=linux_sw_drivers&mrequest=downloads&mtype=ofed&mver=MLNX_OFED-5.8-1.1.2.1&mname=MLNX_OFED_LINUX-5.8-1.1.2.1-ubuntu22.04-x86_64.tgz

Step 2. Accept EUA to download Mellanox OFED Software:

```
$ scp MLNX_OFED_LINUX-5.8-1.1.2.1-ubuntu22.04-x86_64.tgz ubuntu@10.29.148.171:/home/ubuntu/
```

```
$ ansible all -m copy -a “src=/home/ubuntu/ MLNX_OFED_LINUX-5.8-1.1.2.1-ubuntu22.04-x86_64.tgz dest==/home/ubuntu/ MLNX_OFED_LINUX-5.8-1.1.2.1-ubuntu22.04-x86_64.tgz”
```

```
$ ansible all -m shell -a “tar xvf /home/ubuntu/ MLNX_OFED_LINUX-5.8-1.1.2.1-ubuntu22.04-x86_64.tgz”
```

```
ansible all -m command -a " sudo /home/ubuntu/MLNX_OFED_LINUX-5.8-1.1.2.1-ubuntu22.04-x86_64/mlnxofedinstall --without-fw-update --force"
```

```
$ ansible all -m command -a " sudo /etc/init.d/openibd restart"
```

```
$ ansible all -m command -a " sudo reboot"
```

```
$ ansible all -m command -a " ofed_info -s"
```

```
hpc-node1 | CHANGED | rc=0 >>
```

```
MLNX_OFED_LINUX-5.8-1.1.2.1:

hpc-node2 | CHANGED | rc=0 >>

MLNX_OFED_LINUX-5.8-1.1.2.1:
```

Step 3. Start MST:

```
$ sudo mst start

$ sudo mst status -v

MST modules:

------------

    MST PCI module is not loaded

    MST PCI configuration module loaded

PCI devices:

------------

DEVICE_TYPE          MST                              PCI       RDMA         NET                 NUMA

ConnectX6DX(rev:0)     /dev/mst/mt4125_pciconf0.1    27:00.1   mlx5_1        net-ens2f1np1          0

ConnectX6DX(rev:0)     /dev/mst/mt4125_pciconf0     27:00.0   mlx5_0        net-ens2f0np0          0
```

Tech tip

GPU Direct RDMA and GPU Direct Storage link:

https://docs.nvidia.com/datacenter/cloud-native/gpu-operator/23.6.1/gpu-operator-rdma.html

Once tested and validated next version of Cisco Validated Design will cover GPU Direct Storage.

Configure Network Adapter Ports for Ubuntu

Step 1. Run the following commands:

```
$ ansible all -m command -a "sudo apt update"

$ ansible all -m command -a "sudo apt install lldpad -y"

$ ansible all -m command -a "sudo modprobe 8021q"

$ ansible all -m command -a "sudo su -c 'echo "8021q"  >> /etc/modules'"

$ ansible all -m command -a "sudo apt install vlan -y"
```

Step 2. Edit /etc/netplan/00-installer-config.yaml to configure Mellanox NIC port with desired network configuration. For example, the following configuration is for Mellanox port1 (ens2f0np0) and port2 (ens2f1np1) connected to Cisco Nexus Switch A and B in Spine – Leaf architecture for data traffic.

```
$ cat /etc/netplan/00-installer-config.yaml

# This is the network config written by 'subiquity'

network:

  ethernets:
    eno5:
      addresses:
      - 10.29.148.171/24
      dhcp4: false
      nameservers:
        addresses:
        - 171.70.168.183
        search: []
      routes:
      - to: default
        via: 10.29.148.1
    ens2f0np0:
      dhcp4: false
    ens2f1np1:
      dhcp4: false
  vlans:
    ens2f0np0.110:
      id: 110
      link: ens2f0np0
      mtu: 9000
      addresses:
      - 192.168.110.171/24
      routes:
      - to: 192.168.110.0/24
        via: 192.168.110.1
        metric: 100
    ens2f1np1.160:
      id: 160
      link: ens2f1np1
      mtu: 9000
      addresses:
      - 192.168.160.171/24
      routes:
      - to: 192.168.160.0/24
        via: 192.168.160.1
        metric: 100
  version: 2
```

Mellanox ConnectX-6 NIC Best Practice for PFC, ECN and DSCP

Step 1. Enable ECN (Explicit congestion notification) priority 3:

```
$ ansible all -m command -a " sudo echo 1 > /sys/class/net/ens2f0np0/ecn/roce_rp/enable/3"
$ ansible all -m command -a " sudo echo 1 > /sys/class/net/ens2f1np1/ecn/roce_rp/enable/3"
$ ansible all -m command -a " sudo echo 1 > /sys/class/net/ens2f0np0/ecn/roce_np/enable/3"
$ ansible all -m command -a " sudo echo 1 > /sys/class/net/ens2f1np1/ecn/roce_np/enable/3"
```

Step 2. Set CNP L2 egress priority:

```
$ ansible all -m command -a " sudo echo 6 > /sys/class/net/ens2f0np0/ecn/roce_np/cnp_802p_prio"
$ ansible all -m command -a " sudo echo 6 > /sys/class/net/ens2f1np1/ecn/roce_np/cnp_802p_prio"
```

Step 3. Map CNP priority to Differentiated Services Code Point (DSCP):

```
$ ansible all -m command -a " sudo echo 48 > /sys/class/net/ens2f0np0/ecn/roce_np/cnp_dscp"
$ ansible all -m command -a " sudo echo 48 > /sys/class/net/ens2f1np1/ecn/roce_np/cnp_dscp"
```

Step 4. Configure PFC (Priority-based Flow Control) - class 3:

```
$ ansible all -m command -a " sudo mlnx_qos -i ens2f0np0 --pfc 0,0,0,1,0,0,0,0"
$ ansible all -m command -a " sudo mlnx_qos -i ens2f1np1 --pfc 0,0,0,1,0,0,0,0"
```

Step 5. Configure DSCP trust:

```
$ ansible all -m command -a " sudo mlnx_qos -i ens2f0np0 --trust dscp"
$ ansible all -m command -a " sudo mlnx_qos -i ens2f1np1 --trust dscp"
```

Step 6. Enable ECN; edit /etc/sysctl.conf:

```
$ ansible all -m command -a " sudo sysctl -w net.ipv4.tcp_ecn=1"
```

Step 7. Set RoCE mode to v2:

```
$ ansible all -m command -a " sudo cma_roce_mode -d mlx5_0 -p 1 -m 2"
$ ansible all -m command -a " sudo cma_roce_mode -d mlx5_1 -p 1 -m 2"
```

Step 8. Set DSCP value to 24 for RoCE traffic:

```
$ ansible all -m command -a " sudo cma_roce_tos -d mlx5_0 -t 24"
$ ansible all -m command -a " sudo cma_roce_tos -d mlx5_1 -t 24"
```

Step 9. Map roce traffic to priority 3:

```
$ ansible all -m command -a " sudo vconfig set_egress_map ens2f0np0.110 4 3"
$ ansible all -m command -a " sudo vconfig set_egress_map ens2f1np1.160 4 3"
```

Tech tip

```
$ ansible all -m command -a " sudo ip link set ens2f0np0.110 type vlan egress egress 0:0 1:1 2:2 3:3 4:4 5:5 6:6 7:7"
$ ansible all -m command -a " sudo ip link set ens2f1np1.160 type vlan egress egress 0:0 1:1 2:2 3:3 4:4 5:5 6:6 7:7"
```

Step 10. Performance tuning on Mellanox NIC:

```
$ ansible all -m command -a " sudo mlnx_tune -p HIGH_THROUGHPUT"
```

```
$ ansible all -m command -a " sudo ip link set ens2f0np0.110 type vlan egress egress 0:0 1:1 2:2 3:3 4:4 5:5 6:6 7:7"
```

```
$ ansible all -m command -a " sudo ip link set ens2f1np1.160 type vlan egress egress 0:0 1:1 2:2 3:3 4:4 5:5 6:6 7:7"
```

Connect NetApp Storage provided FlexVolume(s) using NFS Mount

Step 1. Install nfs-common on client server:

```
sudo apt install nfs-common -y
```

Step 2. Create mount directory:

```
$ sudo mkdir /opt/hpc -p
```

```
$ sudo mkdir /home/hpcdata -p
```

Step 3. Edit /etc/fstab to add permanent NFS mount:

```
$ sudo vi /etc/fstab
```

```
192.168.110.5:/weather /opt/hpc nfs auto,noatime,nolock,bg,nfsvers=4.2,intr,tcp 0 0
```

```
192.168.110.5:/hpcdata /home/hpcdata/ nfs auto,noatime,nolock,bg,nfsvers=4.2,intr,tcp 0 0
```

Step 4. Mount NFS volume added in /etc/fstab:

```
$ mount -a
```

Step 5. Validate mount point:

```
$ df -h
```

NVIDIA GPU Configuration for HPC Workload

This section highlights the steps required to configure NVIDIA GPU with Ubuntu OS and HPC workload:

- NVIDIA CUDA Installation on Ubuntu 22.04 LTS
- Post Installation Steps for NVIDIA CUDA
- Sample CUDA Test
- Install NVIDIA HPC SDK

NVIDIA CUDA Installation on Ubuntu 22.04 LTS

Step 1. Verify You Have a CUDA-Capable GPU:

```
$ ansible all -m shell -a " lspci | grep -i nvidia"
```

```
hpc-node4 | CHANGED | rc=0 >>
```

```
99:00.0 3D controller: NVIDIA Corporation GA100 [A100 PCIe 80GB] (rev a1)
hpc-node5 | CHANGED | rc=0 >>
99:00.0 3D controller: NVIDIA Corporation GA100 [A100 PCIe 80GB] (rev a1)
hpc-node3 | CHANGED | rc=0 >>
```

Step 2. Verify You Have a Supported Version of Linux:

```
$ ansible all -m shell -a "uname -m && cat /etc/*release"
hpc-node5 | CHANGED | rc=0 >>
x86_64
DISTRIB_ID=Ubuntu
DISTRIB_RELEASE=22.04
DISTRIB_CODENAME=jammy
DISTRIB_DESCRIPTION="Ubuntu 22.04.3 LTS"
PRETTY_NAME="Ubuntu 22.04.3 LTS"
NAME="Ubuntu"
VERSION_ID="22.04"
VERSION="22.04.3 LTS (Jammy Jellyfish)"
VERSION_CODENAME=jammy
ID=ubuntu
ID_LIKE=debian
HOME_URL="https://www.ubuntu.com/"
SUPPORT_URL="https://help.ubuntu.com/"
BUG_REPORT_URL="https://bugs.launchpad.net/ubuntu/"
PRIVACY_POLICY_URL="https://www.ubuntu.com/legal/terms-and-policies/privacy-policy"
UBUNTU_CODENAME=jammy
hpc-node4 | CHANGED | rc=0 >>
```

Step 3. Verify the System Has gcc Installed:

```
$ ansible all -m shell -a "gcc --version"
hpc-node5 | CHANGED | rc=0 >>
gcc (Ubuntu 11.4.0-1ubuntu1~22.04) 11.4.0
Copyright (C) 2021 Free Software Foundation, Inc.
This is free software; see the source for copying conditions.  There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
```

```
hpc-node4 | CHANGED | rc=0 >>
gcc (Ubuntu 11.4.0-1ubuntu1~22.04) 11.4.0
Copyright (C) 2021 Free Software Foundation, Inc.
This is free software; see the source for copying conditions.  There is NO
warranty; not even for MERCHANTABILITY or FITNESS FOR A PARTICULAR PURPOSE.
hpc-node2 | CHANGED | rc=0 >>
```

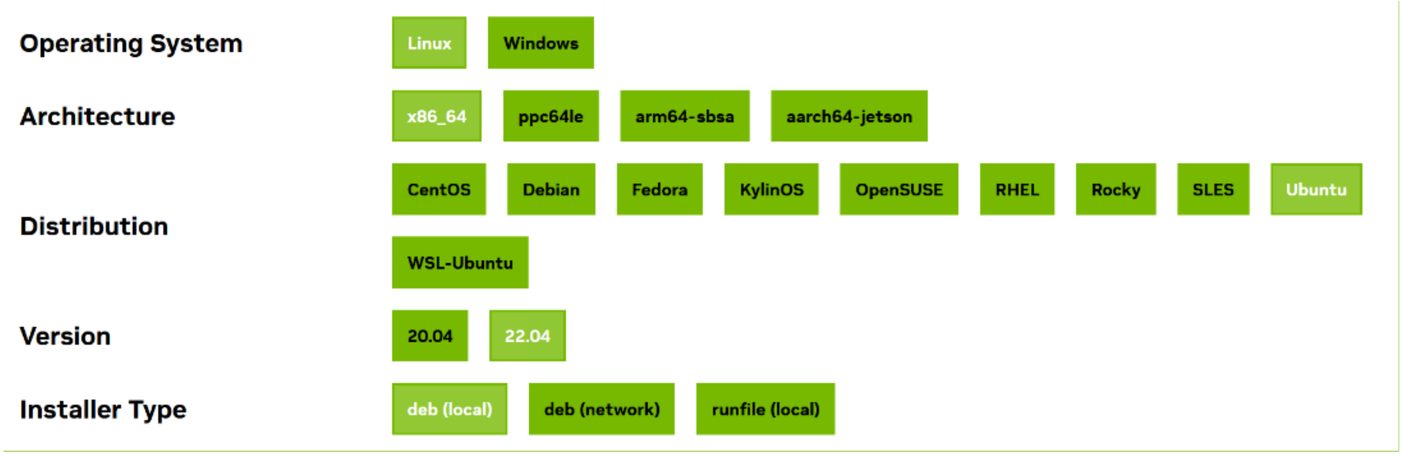
Step 4. Verify the system has the correct kernel headers and development packages installed:

```
$ ansible all -m shell -a " uname -r"
hpc-node4 | CHANGED | rc=0 >>
5.15.0-84-generic
hpc-node5 | CHANGED | rc=0 >>
5.15.0-84-generic
```

Step 5. The kernel headers and development packages for the currently running kernel can be installed running the following:

```
$ ansible all -m shell -a " sudo apt-get install linux-headers-$(uname -r)"
```

Step 6. Download NVIDIA CUDA based on the requirement. Please refer to the screenshot below:



Operating System [✓ Linux] Windows

Architecture [✓ x86_64] ppc64le arm64-sbsa aarch64-jetson

Distribution CentOS Debian Fedora KylinOS OpenSUSE RHEL Rocky SLES [✓ Ubuntu] WSL-Ubuntu

Version 20.04 [✓ 22.04]

Installer Type [✓ deb (local)] deb (network) runfile (local)

Step 7. Choose the Installation method.

Step 8. Remove Outdated Signing Key:

```
$ ansible all -m shell -a " sudo apt-key del 7fa2af80"
```

Step 9. Add the pin file to prioritize CUDA repository:

```
$ wget https://developer.download.nvidia.com/compute/cuda/repos/ubuntu2204/x86_64/cuda-ubuntu2204.pin

$ scp cuda-ubuntu2204.pin ubuntu@10.29.148.171:/home/ubuntu/

$ ansible all -m copy -a " src=/home/ubuntu/cuda-ubuntu2204.pin dest=/home/ubuntu/cuda-ubuntu2204.pin"

$ ansible all -m command -a " sudo mv /home/ubuntu/cuda-ubuntu2204.pin /etc/apt/preferences.d/cuda-repository-pin-600
```

Step 10. Install local repository on file system:

```
$ wget https://developer.download.nvidia.com/compute/cuda/12.2.2/local_installers/cuda-repo-ubuntu2204-12-2-local_12.2.2-535.104.05-1_amd64.deb
```

```
$scp cuda-repo-ubuntu2204-12-2-local_12.2.2-535.104.05-1_amd64.deb ubuntu@10.29.148.171:/home/ubuntu/
```

```
$ ansible all -m copy -a " src=/home/ubuntu/cuda-repo-ubuntu2204-12-2-local_12.2.2-535.104.05-1_amd64.deb dest=/home/ubuntu/cuda-repo-ubuntu2204-12-2-local_12.2.2-535.104.05-1_amd64.deb"
```

```
$ ansible all -m shell -a " sudo dpkg -i /home/ubuntu/cuda-repo-ubuntu2204-12-2-local_12.2.2-535.104.05-1_amd64.deb"
```

```
$ ansible all -m command -a " sudo cp /var/cuda-repo-ubuntu2204-12-2-local/cuda-F73B257B-keyring.gpg /usr/share/keyrings/"
```

Step 11. Update the Apt repository cache:

```
$ ansible all -m command -a " sudo apt-get update"
```

Step 12. Install CUDA SDK

```
$ ansible all -m command -a " sudo apt-get install cuda -y"
```

Step 13. (optional) To include all GDS packages:

```
$ ansible all -m command -a " sudo apt-get install -y nvidia-gds"
```

Step 14. Reboot the system:

```
$ ansible all -m command -a " sudo reboot"
```

Post Installation Steps for NVIDIA CUDA

Step 1. Environment Setup:

```
$ ansible all -m shell -a " export PATH=/usr/local/cuda-12.2/bin${PATH:+:${PATH}}"
```

Note: When using the runfile installation method, the LD_LIBRARY_PATH variable needs to contain /usr/local/cuda-12.2/lib64 on a 64-bit system, or /usr/local/cuda-12.2/lib on a 32-bit system.

Step 2. To change the environment variables for 64-bit operating systems:

Note: The following paths change when using a custom install path with the runfile installation method.

```
$ ansible all -m shell -a " export CUDA_HOME=/usr/local/cuda-12.2"
```

```
$ ansible all -m shell -a " export PATH=${CUDA_HOME}/bin:${PATH}"
```

```
$ ansible all -m shell -a " export LD_LIBRARY_PATH=${CUDA_HOME}/lib64:$LD_LIBRARY_PATH"
```

Note: Recommended Actions – the following steps are recommended to verify the integrity of the installation.

Step 3. Verify the driver version:

```
$ ansible all -m command -a " cat /proc/driver/nvidia/version"
```

```
hpc-node5 | CHANGED | rc=0 >>

NVRM version: NVIDIA UNIX x86_64 Kernel Module  535.104.05  Sat Aug 19 01:15:15 UTC 2023
```

GCC version: gcc version 11.4.0 (Ubuntu 11.4.0-1ubuntu1~22.04)

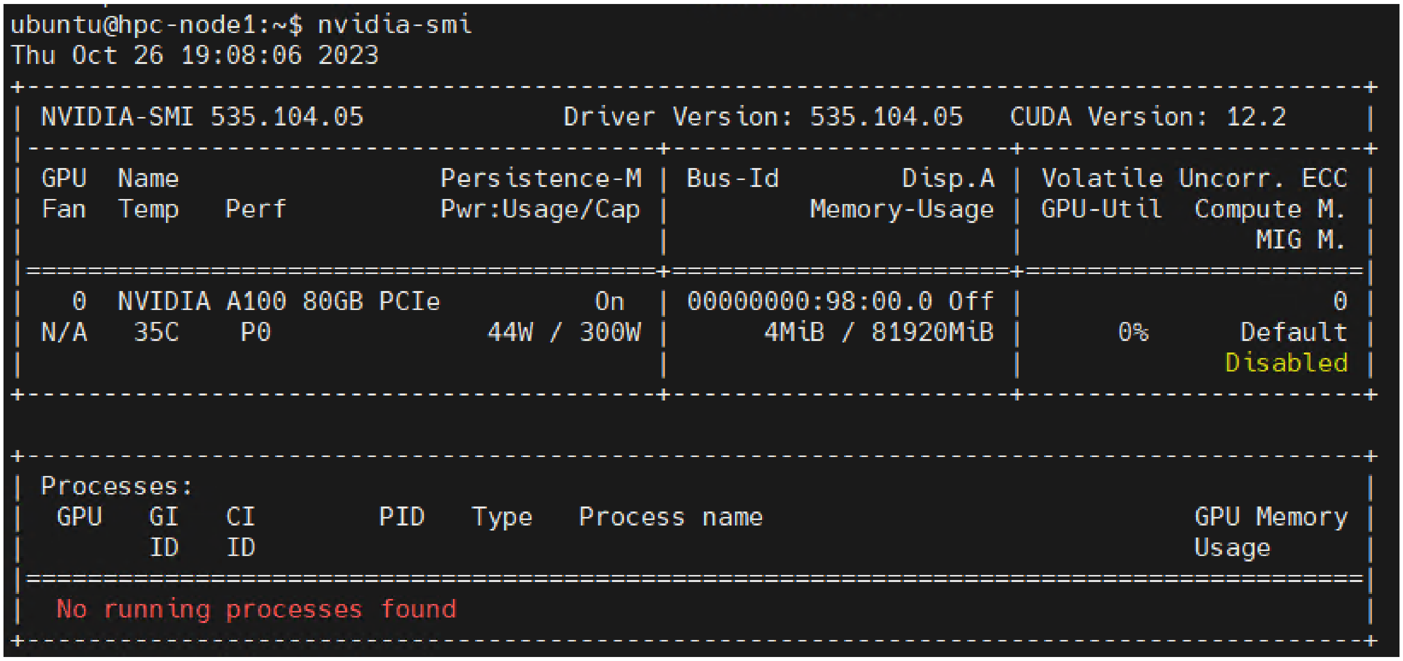
hpc-node4 | CHANGED | rc=0 >>

NVRM version: NVIDIA UNIX x86_64 Kernel Module 535.104.05 Sat Aug 19 01:15:15 UTC 2023

GCC version: gcc version 11.4.0 (Ubuntu 11.4.0-1ubuntu1~22.04)

hpc-node3 | CHANGED | rc=0 >>

Step 4. Run nvidia-smi command:



```
ubuntu@hpc-node1:~$ nvidia-smi
Thu Oct 26 19:08:06 2023
+---------------------------------------------------------------------------------------+
| NVIDIA-SMI 535.104.05             Driver Version: 535.104.05   CUDA Version: 12.2     |
|-----------------------------------------+----------------------+----------------------+
| GPU  Name                 Persistence-M | Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp   Perf          Pwr:Usage/Cap |         Memory-Usage | GPU-Util  Compute M. |
|                                         |                      |               MIG M. |
|=========================================+======================+======================|
|   0  NVIDIA A100 80GB PCIe          On  | 00000000:98:00.0 Off |                    0 |
| N/A   35C    P0              44W / 300W |      4MiB / 81920MiB |      0%      Default |
|                                         |                      |             Disabled |
+-----------------------------------------+----------------------+----------------------+

+---------------------------------------------------------------------------------------+
| Processes:                                                                            |
|  GPU   GI   CI        PID   Type   Process name                            GPU Memory |
|        ID   ID                                                             Usage      |
|=======================================================================================|
|  No running processes found                                                           |
+---------------------------------------------------------------------------------------+
```

Sample CUDA Test

Step 1. Based on github for cuda-samples: https://github.com/NVIDIA/cuda-samples:

hpc-node1:/home/ubuntu/cuda-samples/Samples/1_Utilities/bandwidthTest# ./bandwidthTest

[CUDA Bandwidth Test] - Starting...

Running on...

Device 0: NVIDIA A100 80GB PCIe

Quick Mode

Host to Device Bandwidth, 1 Device(s)

PINNED Memory Transfers

```
   Transfer Size (Bytes)        Bandwidth(GB/s)
   32000000                  25.0
```

```
 Device to Host Bandwidth, 1 Device(s)
 PINNED Memory Transfers
   Transfer Size (Bytes)        Bandwidth(GB/s)
   32000000                     24.9

 Device to Device Bandwidth, 1 Device(s)
 PINNED Memory Transfers
   Transfer Size (Bytes)        Bandwidth(GB/s)
   32000000                     549.7

Result = PASS
```

Note: The CUDA Samples are not meant for performance measurements. Results may vary when GPU Boost is enabled.

Install NVIDIA HPC SDK

Prerequisites

Step 1. Download NVIDIA HPC SDK software: https://developer.nvidia.com/hpc-sdk-downloads

```
$ wget https://developer.download.nvidia.com/hpc-sdk/23.9/nvhpc_2023_239_Linux_x86_64_cuda_multi.tar.gz
```

```
$ scp nvhpc_2023_239_Linux_x86_64_cuda_multi.tar.gz ubuntu@10.29.148.171:/home/ubuntu/
```

Step 2. Copy NVIDIA HPC SDK to all nodes:

```
$ ansible all -m copy -a " src=/home/ubuntu/nvhpc_2023_239_Linux_x86_64_cuda_multi.tar.gz dest=/home/ubuntu/nvhpc_2023_239_Linux_x86_64_cuda_multi.tar.gz"
```

```
$ ansible all -m shell -a " tar xpzf /home/ubuntu/nvhpc_2023_239_Linux_x86_64_cuda_multi.tar.gz"
```

Step 3. Install NVIDIA HPC SDK (optionally – select where it gets installed):

```
$ ansible all -m shell -a " tar xpzf /home/ubuntu/nvhpc_2023_239_Linux_x86_64_cuda_multi.tar.gz"
```

Step 4. Install NVIDIA HPC SDK:

```
$ su – root

$ cd nvhpc_2023_239_Linux_x86_64_cuda_multi/

$ sudo ./install
```

Step 5. Press Enter to continue installing NVIDIA HPC SDK:

Step 6. Select Install option:

```
An auto installation is appropriate for any scenario. The HPC SDK
configuration (localrc) is created at first use and stored in each user's
home directory.
```

```
Installation directory? [/opt/nvidia/hpc_sdk]

1  Single system install

2  Network install

3  Auto install

Please choose install option:

3
```

Step 7. Select default directory or intended location:

```
Please specify the directory path under which the software will be installed.

The default directory is /opt/nvidia/hpc_sdk, but you may install anywhere

you wish, assuming you have permission to do so.

Installation directory? [/opt/nvidia/hpc_sdk]
```

Tech tip

```
Installing NVIDIA HPC SDK version 23.9 into /opt/nvidia/hpc_sdk
Making symbolic link in /opt/nvidia/hpc_sdk/Linux_x86_64
generating environment modules for NV HPC SDK 23.9 ... done.
Installation complete.
HPC SDK successfully installed into /opt/nvidia/hpc_sdk
If you use the Environment Modules package, that is, the module load
command, the NVIDIA HPC SDK includes a script to set up the
appropriate module files.
% module load /opt/nvidia/hpc_sdk/modulefiles/nvhpc/23.9
% module load nvhpc/23.9
Alternatively, the shell environment may be initialized to use the HPC SDK.
In csh, use these commands:
% setenv MANPATH " $MANPATH" :/opt/nvidia/hpc_sdk/Linux_x86_64/23.9/compilers/man
% set path = (/opt/nvidia/hpc_sdk/Linux_x86_64/23.9/compilers/bin $path)
In bash, sh, or ksh, use these commands:
$ MANPATH=$MANPATH:/opt/nvidia/hpc_sdk/Linux_x86_64/23.9/compilers/man; export MANPATH
$ PATH=/opt/nvidia/hpc_sdk/Linux_x86_64/23.9/compilers/bin:$PATH; export PATH
Once the 64-bit compilers are available, you can make the OpenMPI
commands and man pages accessible using these commands.
% set path = (/opt/nvidia/hpc_sdk/Linux_x86_64/23.9/comm_libs/mpi/bin $path)
% setenv MANPATH " $MANPATH" :/opt/nvidia/hpc_sdk/Linux_x86_64/23.9/comm_libs/mpi/man
And the equivalent in bash, sh, and ksh:
$ export PATH=/opt/nvidia/hpc_sdk/Linux_x86_64/23.9/comm_libs/mpi/bin:$PATH
$ export MANPATH=$MANPATH:/opt/nvidia/hpc_sdk/Linux_x86_64/23.9/comm_libs/mpi/man
```

```
Please check https://developer.nvidia.com for documentation,
use of NVIDIA HPC SDK software, and other questions.
```

Step 8. Install environement-modules:

```
$ ansible all -m shell -a " sudo apt-get install -y environment-modules"
$ cat /etc/profile.d/modules.sh
shell=$(/usr/bin/basename $(/bin/ps -p $$ -ocomm=))

if [ -f /usr/share/modules/init/$shell ]; then
   . /usr/share/modules/init/$shell
else
   . /usr/share/modules/init/sh
fi
```

Step 9. Create environment variables to be set at the time of user login:

```
$ vi /etc/environment
# Use the HPC SDK toolkit compilers
export NVIDIA=/opt/hpc/nvidia/hpc_sdk
module use $NVIDIA/modulefiles
module load nvhpc
# But then override their choice of Open MPI to use the HPCX that is inside the HPC SDK
module use /opt/hpc/nvidia/hpc_sdk/Linux_x86_64/2023/comm_libs/12.2/hpcx/hpcx-2.15/modulefiles
module load hpcx
$ source /etc/environment
$printenv
```

Step 10. Verify above configured modules are loaded and “mpirun” and “mpicc”available:

```
$ which mpirun
/opt/hpc/nvidia/hpc_sdk/Linux_x86_64/23.7/comm_libs/12.2/hpcx/hpcx-2.15/ompi/bin/mpirun
$ which mpicc
/opt/hpc/nvidia/hpc_sdk/Linux_x86_64/23.7/comm_libs/12.2/hpcx/hpcx-2.15/ompi/bin/mpicc
```

Solution Validation

This chapter contains the following:

- What is GPUDirect?

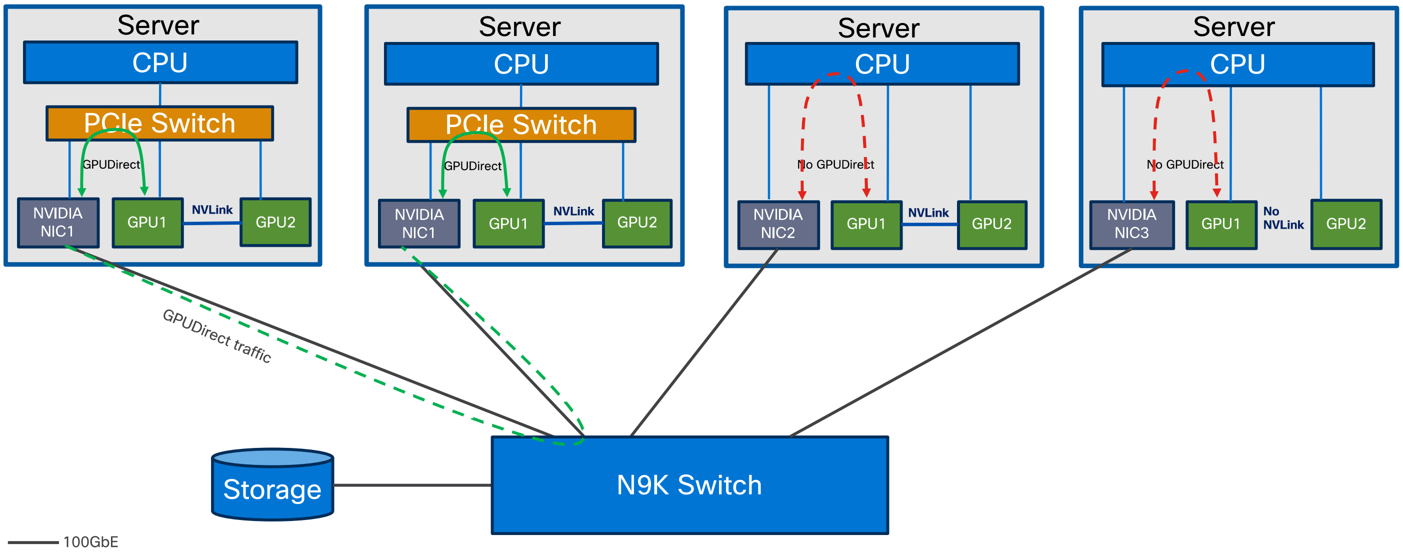
What is GPUDirect?

NVIDIA GPUDirect RDMA (Remote Direct Memory Access) is a technology that enables a direct path for data exchange between the GPU and third-party peer devices using standard PCIe features. GPUDirect RDMA relies on the ability of NVIDIA GPUs to expose portions of device memory in a PCIe base address register region, as shown in Figure 12. The GPUDirect technology requires a PCIe Switch to facilitate direct memory transfer between NVIDIA NIC and GPU.

A PCIe switch is not strictly required to enable GPUDirect RDMA on a supported system. Please refer to How GPUDirect RDMA works, NVIDIA GPUDirect Storage design guide, and GPUDirect RDMA supported systems for more details.

If there is no PCIe switch between network interface card and NVIDIA GPU, data has to traverse through processor. Performance improvement achieved through GPUDirect RDMA, and benefits depend on your use case and system configuration.

Figure 12. GPUDirect Vs No GPUDirect



Note: A requirement for GPUDirect RDMA to work is that the NVIDIA GPU and the Mellanox Adapter share the same root complex through a PCIe switch.

Note: For our solution, we could not use GPUDirect as Cisco UCS C240 M7 rack server does not contain PCIe switch between CPU and Mellanox Ethernet NIC and NVIDIA GPU as shown in Figure 12.

NVIDIA HPC-X Software Toolkit Setup and Configuration

This section details the validation of the HPC/AI cluster previously configured.

- Prerequisites
- Test Result for NVIDIA HPC-X Software Toolkit
- NVIDIA HPC-X Software Toolkit Test Summary

Prerequisites

Test toolkit to validate the end-end connectivity.

Note: We installed NVIDIA HPC-X software toolkit version 2.16 for the validation.

For more details, go to: https://docs.nvidia.com/networking/display/hpcxv216

Tech tip

MPI (Message Passing Interface) is a standard and widely used library and protocol for writing parallel applications in HPC.

“mpirun” is a command used in HPC part of MPI implementation, such as OpenMPI and MPICH which provides the underlying libraries and runtime support for parallel programming. When combined with these MPI libraries, “mpirun” becomes a powerful tool for launching, managing, and scaling parallel applications in HPC environments, making it possible to harness the computational power of clusters and supercomputers for scientific simulations, data analysis, and other compute-intensive tasks.

“mpicc” streamlines the process of compiling parallel C and C++ programs for use in HPC environments, allowing developers to take full advantage of the parallel processing capabilities of these systems.

“mpich” is one of the primary implementations of the MPI standard. It provides a set of libraries, tools, and runtime environments that allow developers to create parallel applications in C, C++, and Fortran.

OpenACC (Open Accelerators) is an open standard for parallel programming of heterogeneous computer systems, including multi-core CPUs and GPUs (Graphics Processing Units). It provides a set of directives, libraries, and APIs that enable developers to accelerate their applications by offloading compute-intensive portions to accelerators, such as GPUs, while maintaining a single source code that can run on both CPUs and GPUs.

UCX (Unified Communication X) s an open-source communication library designed for high-performance computing (HPC) and other parallel computing environments. UCX is particularly valuable for applications that rely on efficient communication in HPC and parallel computing scenarios. It allows these applications to achieve high performance while maintaining portability across diverse hardware and networking environments.

Step 1. Accept EUL agreement to download NVIDIA HPC-X clusterkit:

```
$ wget http://www.mellanox.com/page/hpcx_eula?mrequest=downloads&mtype=hpc&mver=hpc-x&mname=v2.16.2/hpcx-v2.16-gcc-mlnx_ofed-ubuntu22.04-cuda12-gdrcopy2-nccl2.18-x86_64.tbz
```

Step 2. Copy HPC-X software toolkit on all nodes:

```
$ scp hpcx-v2.16-gcc-mlnx_ofed-ubuntu22.04-cuda12-gdrcopy2-nccl2.18-x86_64.tbz ubuntu@10.29.148.171:/home/ubuntu/
```

```
$ ansible all -m copy -a " src=/home/ubuntu/hpcx-v2.16-gcc-mlnx_ofed-ubuntu22.04-cuda12-gdrcopy2-nccl2.18-x86_64.tbz dest=/home/ubuntu/hpcx-v2.16-gcc-mlnx_ofed-ubuntu22.04-cuda12-gdrcopy2-nccl2.18-x86_64.tbz"
```

Step 3. Extract HPC-X software toolkit:

```
$ ansible all -m shell -a " tar -xvf /home/ubuntu/hpcx-v2.16-gcc-mlnx_ofed-ubuntu22.04-cuda12-gdrcopy2-nccl2.18-x86_64.tbz"
```

Step 4. Update shell variable of the location of HPC-X installation:

```
$ cd /home/ubuntu/hpcx-v2.16-gcc-mlnx_ofed-ubuntu22.04-cuda12-gdrcopy2-nccl2.18-x86_64
```

```
$ export HPCX_HOME=$PWD
```

Step 5. Build and Run applications with HPC-X. To load OpenMPI based package run following commands:

```
$ source $HPCX_HOME/hpcx-init.sh
$ hpcx_load

$ env | grep HPCX

$ mpicc $HPCX_MPI_TESTS_DIR/examples/hello_c.c -o $HPCX_MPI_TESTS_DIR/examples/hello_c

$ mpirun -np 2 $HPCX_MPI_TESTS_DIR/examples/hello_c

Hello, world, I am 0 of 2, (Open MPI v4.1.5rc2, package: Open MPI root@hpc-kernel-03 Distribution, ident:
4.1.5rc2, repo rev: v4.1.5rc1-17-gdb10576f40, Unreleased developer copy, 150)

Hello, world, I am 1 of 2, (Open MPI v4.1.5rc2, package: Open MPI root@hpc-kernel-03 Distribution, ident:
4.1.5rc2, repo rev: v4.1.5rc1-17-gdb10576f40, Unreleased developer copy, 150)

$ oshcc $HPCX_MPI_TESTS_DIR/examples/hello_oshmem_c.c -o
$HPCX_MPI_TESTS_DIR/examples/hello_oshmem_c

$ oshrun -np 2 $HPCX_MPI_TESTS_DIR/examples/hello_oshmem_c

Hello, world, I am 1 of 2: http://www.open-mpi.org/ (version: 1.4)

Hello, world, I am 0 of 2: http://www.open-mpi.org/ (version: 1.4)

$ hpcx_unload
```

Step 6. Run following command: (optional) If not installed already; install environment-modules:

```
$ ansible all -m shell -a “sudo apt install environment-modules -y”

$ ansible all -m shell -a “source ~/.bashrc”

$ ansible all -m shell -a “source ~/.profile”

$ ansible all -m shell -a “sudo modprobe knem”
```

Step 7. Building HPC-X with Intel Compiler Suite:

Note: As of version 1.7, HPC-X builds are no longer distributed based on the Intel compiler suite. However, after following the HPC-X deployment example below, HPC-X can subsequently be rebuilt from source with your Intel compiler suite as follows:

```
$ tar xfp ${HPCX_HOME}/sources/openmpi-gitclone.tar.gz

$ cd ${HPCX_HOME}/sources/openmpi-gitclone

$ ls -l ${HPCX_HOME}/sources/openmpi-gitclone.tar.gz

-rw-r--r-- 1 ubuntu ubuntu 18287983 Aug  3 13:59 /home/ubuntu/hpcx-v2.16-gcc-mlnx_ofed-ubuntu22.04-
cuda12-gdrcopy2-nccl2.18-x86_64//sources/openmpi-gitclone.tar.gz

$ cd ${HPCX_HOME}/sources/openmpi-gitclone

$ ./configure CC=icx CXX=icpx F77=ifort FC=ifort --prefix=${HPCX_HOME}/ompi-icc \

--with-hcoll=${HPCX_HOME}/hcoll \

--with-ucx=${HPCX_HOME}/ucx \

--with-platform=contrib/platform/mellanox/optimized \

2>&1 | tee config-icc-output.log
```

```
$ make -j32 all 2>&1 | tee build_icc.log && make -j24 install 2>&1 | tee install_icc.log
```

Step 8. Load HPC-X environment from modules:

```
$ module use $HPCX_HOME/modulefiles

$ module load hpcx

$ mpicc $HPCX_MPI_TESTS_DIR/examples/hello_c.c -o $HPCX_MPI_TESTS_DIR/examples/hello_c

$ mpirun -np 2 $HPCX_MPI_TESTS_DIR/examples/hello_c

Hello, world, I am 1 of 2, (Open MPI v4.1.5rc2, package: Open MPI root@hpc-kernel-03 Distribution, ident: 4.1.5rc2, repo rev: v4.1.5rc1-17-gdb10576f40, Unreleased developer copy, 150)

Hello, world, I am 0 of 2, (Open MPI v4.1.5rc2, package: Open MPI root@hpc-kernel-03 Distribution, ident: 4.1.5rc2, repo rev: v4.1.5rc1-17-gdb10576f40, Unreleased developer copy, 150)

$ oshcc $HPCX_MPI_TESTS_DIR/examples/hello_oshmem_c.c -o $HPCX_MPI_TESTS_DIR/examples/hello_oshmem_c

$ oshrun -np 2 $HPCX_MPI_TESTS_DIR/examples/hello_oshmem_c

Hello, world, I am 1 of 2: http://www.open-mpi.org/ (version: 1.4)

Hello, world, I am 0 of 2: http://www.open-mpi.org/ (version: 1.4)
```

Step 9. To profile MPI API run following command: (Optional)

```
$ export IPM_KEYFILE=$HPCX_IPM_DIR/etc/ipm_key_mpi

$ export IPM_LOG=FULL

$ export LD_PRELOAD=$HPCX_IPM_DIR/lib/libipm.so

$ $HPCX_IPM_DIR/bin/ipm_parse -html outfile.xml

$ export IPM_ADD_BARRIER_TO_REDUCE=1

$ export IPM_ADD_BARRIER_TO_ALLREDUCE=1

$ export IPM_ADD_BARRIER_TO_GATHER=1

$ export IPM_ADD_BARRIER_TO_ALL_GATHER=1

$ export IPM_ADD_BARRIER_TO_ALLTOALL=1

$ export IPM_ADD_BARRIER_TO_ALLTOALLV=1

$ export IPM_ADD_BARRIER_TO_BROADCAST=1

$ export IPM_ADD_BARRIER_TO_SCATTER=1

$ export IPM_ADD_BARRIER_TO_SCATTERV=1

$ export IPM_ADD_BARRIER_TO_GATHERV=1

$ export IPM_ADD_BARRIER_TO_ALLGATHERV=1

$ export IPM_ADD_BARRIER_TO_REDUCE_SCATTER=1
```

Step 10. Create hotfile.txt in /home/ubuntu/hpcx-v2.16-gcc-mlnx_ofed-ubuntu22.04-cuda12-gdrcopy2-nccl2.18-x86_64/clusterkit/bin/

```
$ vi hostfile.txt

hpc-node1

hpc-node2

hpc-node3

....

hpc-node8
```

Step 11. UCX intra-node communication uses the KNEM module, which improves the performance significantly. Make sure this module is loaded on your system:

```
$ modprobe knem
```

Step 12. When HPC-X is launched with Open MPI without a resource manager job environment (slurm,pbs, and so on), or when it is launched from a compute node, the default rsh/ssh-based launcher will be used. This launcher does not propagate environment variables to the compute nodes. Thus, it is important to ensure the propagation of LD_LIBRARY_PATH variable from HPC-x is done as follows:

```
$ mpirun -x LD_LIBRARY_PATH -np 2 -H hpc-node1,hpc-node2,hpc-node3,hpc-node4
$HPCX_MPI_TESTS_DIR/examples/hello_c
```

Sample Command:

```
$ mpirun -x LD_LIBRARY_PATH -np 2 -H host1,host2  $HPCX_MPI_TESTS_DIR/examples/hello_c
```

Step 13. After loading HPC-X package; run clusterkit script or using the “mpirun” command:

```
# mpirun

$ mpirun -x LD_LIBRARY_PATH -np 2 -H c240m7-13,c240m7-14  $HPCX_CLUSTERKIT_DIR/bin/clusterkit
```

Note: ClusterKit runs by default in pairwise test cases, which requires at least two nodes to run.

```
# clusterkit script
```

Note: $ ./clusterkit.sh -h for list of options and parameters.

Test Results for NVIDIA HPC-X Software Toolkit

Clusterkit part of the NVIDIA HPC-X software toolkit is a multifaceted node assessment tool for high performance clusters. Currently, ClusterKit is capable of testing latency, bandwidth, effective bandwidth, memory bandwidth, GFLOPS by node, per-rack collective performance, as well as bandwidth and latency between GPUs and local/remote memory. ClusterKit employs well known techniques and tests to arrive at these performance metrics and is intended to give the user a general look at the health and performance of a cluster.

Step 1. A sample command ran to measure performance and HPC/AI cluster configuration for this solution test and validate:

```
$ ./clusterkit.sh --ssh --hostfile hostfile.txt -y --hca_list " mlx5_0:1,mlx5_1:1"  -z 15
```

Note: mlx5_0 and mlx5_1 are two physical ports on ConnectX6-DX ethernet NIC installed on each Cisco UCS C240 M7 Rack Server

Step 2. Test result generated by HPC-X Clusterkit command which runs for 15 minute interval can be found here:

```
~/hpcx-v2.16-gcc-mlnx_ofed-ubuntu22.04-cuda12-gdrcopy2-nccl2.18-
x86_64/clusterkit/bin/20231103_134557$ cat bandwidth.txt

Cluster: Unknown

User: ubuntu

Testname: bandwidth

Date_and_Time: 2023/11/03 13:45:58

JOBID: 0

PPN: 128

Bidirectional: True

Skip_Intra_Node: True

HCA_Tag: Unknown

Technology: Unknown


Bandwidth_bidir (MB/s):

Message size: 8388608 B  Iterations: 10000

Rank:                  0       1       2       3       4       5       6       7

    0 (hpc-node1):       0.0 48829.3 48381.3 48377.6 48823.9 48840.8 48839.7 48842.8

    1 (hpc-node2):  48829.3     0.0 48393.2 48372.8 48841.4 48853.4 48856.3 48853.9

    2 (hpc-node3):  48381.3 48393.2     0.0 48347.1 48396.5 48387.9 48389.8 48382.1

    3 (hpc-node4):  48377.6 48372.8 48347.1     0.0 48369.2 48378.3 48367.7 48374.7

    4 (hpc-node5):  48823.9 48841.4 48396.5 48369.2     0.0 48839.0 48842.8 48839.5

    5 (hpc-node6):  48840.8 48853.4 48387.9 48378.3 48839.0     0.0 48857.7 48865.4

    6 (hpc-node7):  48839.7 48856.3 48389.8 48367.7 48842.8 48857.7     0.0 48859.3

    7 (hpc-node8):  48842.8 48853.9 48382.1 48374.7 48839.5 48865.4 48859.3     0.0

Minimum bandwidth: 48347.1 MB/s between hpc-node3 and hpc-node4

Maximum bandwidth: 48865.4 MB/s between hpc-node6 and hpc-node8

Average bandwidth: 48628.7 MB/s
```

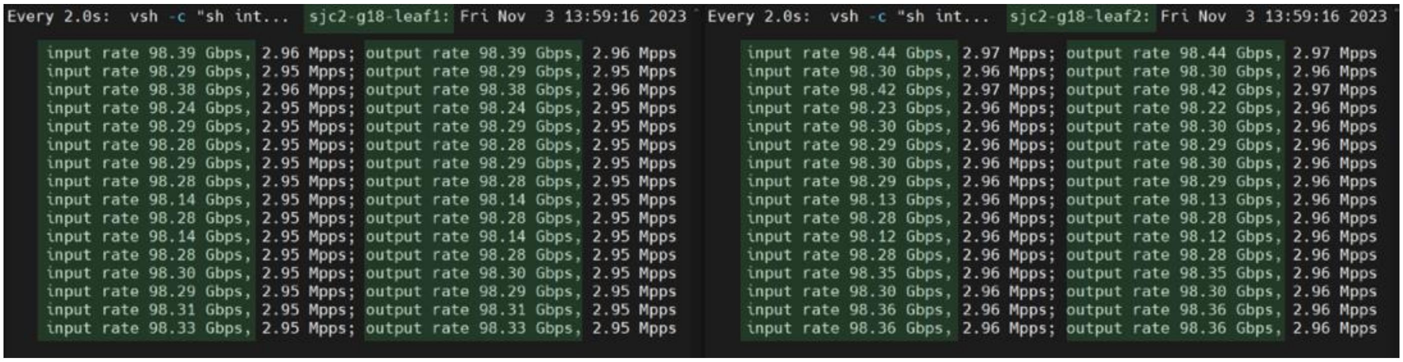
NVIDIA HPC-X Software Toolkit Test Summary

When running NVIDIA HPC-X Software toolkit based Clusterkit test; we observed ~200Gbps bandwidth is achieved (Duplex on two 100Gbps port; mlx5_0 and mlx5_1 are two physical ports on ConnectX6-DX ethernet NIC installed on each Cisco UCS C240 M7 Rack Server) when measuring host connectivity bandwidth between Cisco UCS C240 M7 server and a pair of Cisco Nexus 93600CD-GX leaf switch.

The following screenshot shows line-rate network traffic generated when running NVIDIA HPC-X Clusterkit command above to measure network bandwidth for longer duration. Line-rate traffic was monitored between

Cisco UCS C240 M7 with Mellanox ConnectX-6 ethernet NIC ports connected to a pair of Cisco Nexus 93600CD-GX leaf switch.

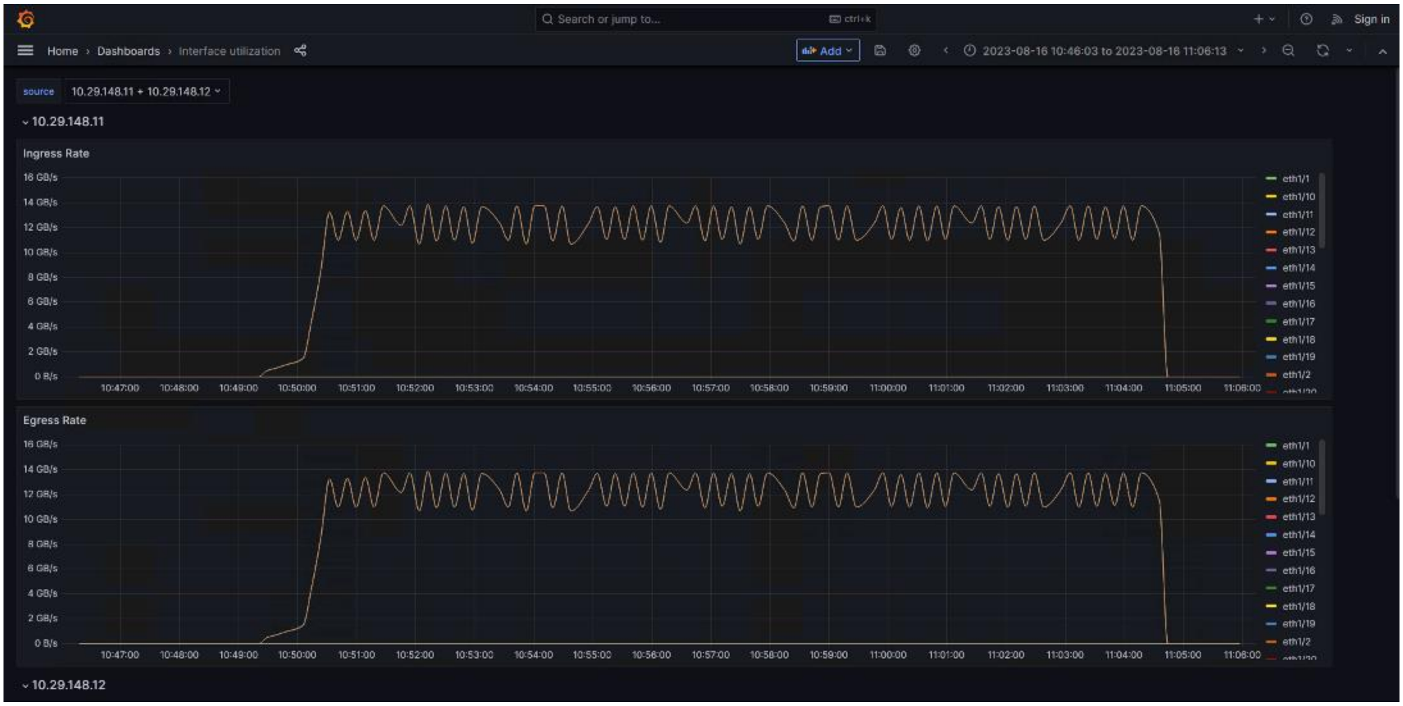
Figure 13. **Screenshot monitoring port utilization on Cisco Nexus 93600CD-GX leaf1(A) and leaf2(B) connected to Cisco UCS C240 M7 Rack Server with 2 x 100GbE Mellanox ConnectX6 Ethernet NIC**



```
Every 2.0s:  vsh -c "sh int...  sjc2-g18-leaf1: Fri Nov  3 13:59:16 2023

    input rate 98.39 Gbps, 2.96 Mpps; output rate 98.39 Gbps, 2.96 Mpps
    input rate 98.29 Gbps, 2.95 Mpps; output rate 98.29 Gbps, 2.95 Mpps
    input rate 98.38 Gbps, 2.96 Mpps; output rate 98.38 Gbps, 2.96 Mpps
    input rate 98.24 Gbps, 2.95 Mpps; output rate 98.24 Gbps, 2.95 Mpps
    input rate 98.29 Gbps, 2.95 Mpps; output rate 98.29 Gbps, 2.95 Mpps
    input rate 98.28 Gbps, 2.95 Mpps; output rate 98.28 Gbps, 2.95 Mpps
    input rate 98.29 Gbps, 2.95 Mpps; output rate 98.29 Gbps, 2.95 Mpps
    input rate 98.28 Gbps, 2.95 Mpps; output rate 98.28 Gbps, 2.95 Mpps
    input rate 98.14 Gbps, 2.95 Mpps; output rate 98.14 Gbps, 2.95 Mpps
    input rate 98.28 Gbps, 2.95 Mpps; output rate 98.28 Gbps, 2.95 Mpps
    input rate 98.14 Gbps, 2.95 Mpps; output rate 98.14 Gbps, 2.95 Mpps
    input rate 98.28 Gbps, 2.95 Mpps; output rate 98.28 Gbps, 2.95 Mpps
    input rate 98.30 Gbps, 2.95 Mpps; output rate 98.30 Gbps, 2.95 Mpps
    input rate 98.29 Gbps, 2.95 Mpps; output rate 98.29 Gbps, 2.95 Mpps
    input rate 98.31 Gbps, 2.95 Mpps; output rate 98.31 Gbps, 2.95 Mpps
    input rate 98.33 Gbps, 2.95 Mpps; output rate 98.33 Gbps, 2.95 Mpps
```

```
Every 2.0s:  vsh -c "sh int...  sjc2-g18-leaf2: Fri Nov  3 13:59:16 2023

    input rate 98.44 Gbps, 2.97 Mpps; output rate 98.44 Gbps, 2.97 Mpps
    input rate 98.30 Gbps, 2.96 Mpps; output rate 98.30 Gbps, 2.96 Mpps
    input rate 98.42 Gbps, 2.97 Mpps; output rate 98.42 Gbps, 2.97 Mpps
    input rate 98.23 Gbps, 2.96 Mpps; output rate 98.22 Gbps, 2.96 Mpps
    input rate 98.30 Gbps, 2.96 Mpps; output rate 98.30 Gbps, 2.96 Mpps
    input rate 98.29 Gbps, 2.96 Mpps; output rate 98.29 Gbps, 2.96 Mpps
    input rate 98.30 Gbps, 2.96 Mpps; output rate 98.30 Gbps, 2.96 Mpps
    input rate 98.29 Gbps, 2.96 Mpps; output rate 98.29 Gbps, 2.96 Mpps
    input rate 98.13 Gbps, 2.96 Mpps; output rate 98.13 Gbps, 2.96 Mpps
    input rate 98.28 Gbps, 2.96 Mpps; output rate 98.28 Gbps, 2.96 Mpps
    input rate 98.12 Gbps, 2.96 Mpps; output rate 98.12 Gbps, 2.96 Mpps
    input rate 98.28 Gbps, 2.96 Mpps; output rate 98.28 Gbps, 2.96 Mpps
    input rate 98.35 Gbps, 2.96 Mpps; output rate 98.35 Gbps, 2.96 Mpps
    input rate 98.30 Gbps, 2.96 Mpps; output rate 98.30 Gbps, 2.96 Mpps
    input rate 98.36 Gbps, 2.96 Mpps; output rate 98.36 Gbps, 2.96 Mpps
    input rate 98.36 Gbps, 2.96 Mpps; output rate 98.36 Gbps, 2.96 Mpps
```

Figure 14. **Grafana dashboard monitoring ingress and egress network bandwidth on Cisco Nexus 93600CD-GX leaf 1**



Test

This section highlights test result for the datasets of different size and application area. Tests were executed to determine cluster scalability, clock time required to complete each said dataset on CPU only and repeat the same on a system with one or two GPU per system.

CPU only tests were executed with all logical cores utilized on each node via adding parameter -np 128*x (x= multiplier representative of number of nodes utilized).

We captured system performance statistics such as CPU utilization (vmstat), GPU utilization (nvidia-smi and NVIDIA GPU exporter Grafana WebUI console) and Network port utilization on Cisco Nexus switch connected to Cisco UCS server and NetApp A400 Storage when running the same test in a clustered configuration.

We tested combination of one, two, four and eight nodes to showcase linear scalability of the solution.

Test result shows clock time in second to complete each test scenario whether running on CPU or GPU.

HPC Workload Dataset

Prerequisites

We tested documented solution with HPC datasets representing different area/applications list below:

Note: Workload listed is for the proof of concept (PoC) purpose only.

1. The MiniWeather Mini App (Weather)

The miniWeather code mimics the basic dynamics seen in atmospheric weather and climate. The dynamics themselves are dry compressible, stratified, non-hydrostatic flows dominated by buoyant forces that are relatively small perturbations on a hydrostatic background state. The equations in this code themselves form the backbone of pretty much all fluid dynamics codes, and this particular flavor forms the base of all weather and climate modeling.

For more details: https://github.com/mrnorman/miniWeather#openacc-accelerator-threading

2. Minisweep (Nuclear Engineering)

Minisweep is a deterministic Sn radiation transport miniapp used for performance optimization and performance model evaluation on HPC architectures.

For more details: https://github.com/wdj/minisweep

3. HPGMG: High-performance Geometric Multigrid (Cosmology/Astrophysics)

HPGMG implements full multigrid (FMG) algorithms using finite-volume and finite-element methods. Different algorithmic variants adjust the arithmetic intensity and architectural properties that are tested. These FMG methods converge up to discretization error in one F-cycle, thus may be considered direct solvers. An F-cycle visits the finest level a total of two times, the first coarsening (8x smaller) 4 times, the second coarsening 6 times, etc.

For more details: https://bitbucket.org/hpgmg/hpgmg/src/master/

Tech tip

Run the following command to find all the parameter.

```
$mpicc –help
```

Subset is pasted below from “mpicc --help” for reference:

```
Target-specific switches:
-acc[=gpu|host|multicore|[no]autopar|[no]routineseq|legacy|strict|verystrict|sync|[no]wait]
                    Enable OpenACC directives
    gpu             OpenACC directives are compiled for GPU execution only; please refer to -gpu for target specific options
    host            Compile for serial execution on the host CPU
    multicore       Compile for parallel execution on the host CPU
    [no]autopar     Enable (default) or disable loop autoparallelization within acc parallel
    [no]routineseq  Compile every routine for the device
    legacy          Suppress warnings about deprecated PGI accelerator directives
```

```
strict         Issue warnings for non-OpenACC accelerator directives
verystrict     Fail with an error for any non-OpenACC accelerator directive
sync           Ignore async clauses
[no]wait       Wait for each device kernel to finish
```

The workload dataset tested in this solution to create a baseline has minimum system requirement based on the application and dataset size. Intention is to target varied cluster sizes with node count, core count and GPU count and their relative impact when running benchmark application to determined overall cluster performance.

- The Small size dataset – target a single larger node or a small cluster of nodes using between 64 and 1024 ranks. It uses a maximum of 480GB of memory per benchmark.
- The Medium size dataset – target a mid-sized cluster of nodes using between 256 and 4096 ranks. It uses a maximum of 4TB of memory per benchmark.
- The Large size dataset – target a larger cluster of nodes using between 2048 and 32,768 ranks. It uses a maximum of 14.5TB of memory per benchmark.

For this solution, datasets were downloaded and configured in the shared NFS volume on NetApp A400 storage and used NetApp FlexClone volumes to mount on each node part of the HPC cluster test. We tested following possible combinations for scale tests on HPC cluster workloads.

Table 6. Configuration tested for scale tests

Scale Test	1-node	2-node	4-node	8-node
C240M7 Server with 1x A100 GPU	✓	✓	✓	✓
C240M7 Server with 2x A100 GPU	✓	✓	✓	
C240M7 Server with CPU only	✓	✓	✓	✓

Note: We will extend this exercise with 8 node HPC cluster with 2 x NVIDIA Tesla A100-80G GPU per node in the future.

Application 1: miniWeather (Large Size Dataset)

Table 7 lists the results from scale out tests on miniWeather.

Table 7. Scale test results with miniWeather large size dataset in second

Scale Test	1-node (Total time in second)	2-node (Total time in second)	4-node (Total time in second)	8-node (Total time in second)
C240M7 Server with 1x A100 GPU	1048.16	518.98	246.16	109.27
C240M7 Server with 2x A100 GPU	518.34	245.61	105.85	NA
C240M7 Server with CPU only	3418.28	1726.53	865.28	436.14

Figure 15. Cluster scalability when running Large miniWeather Dataset

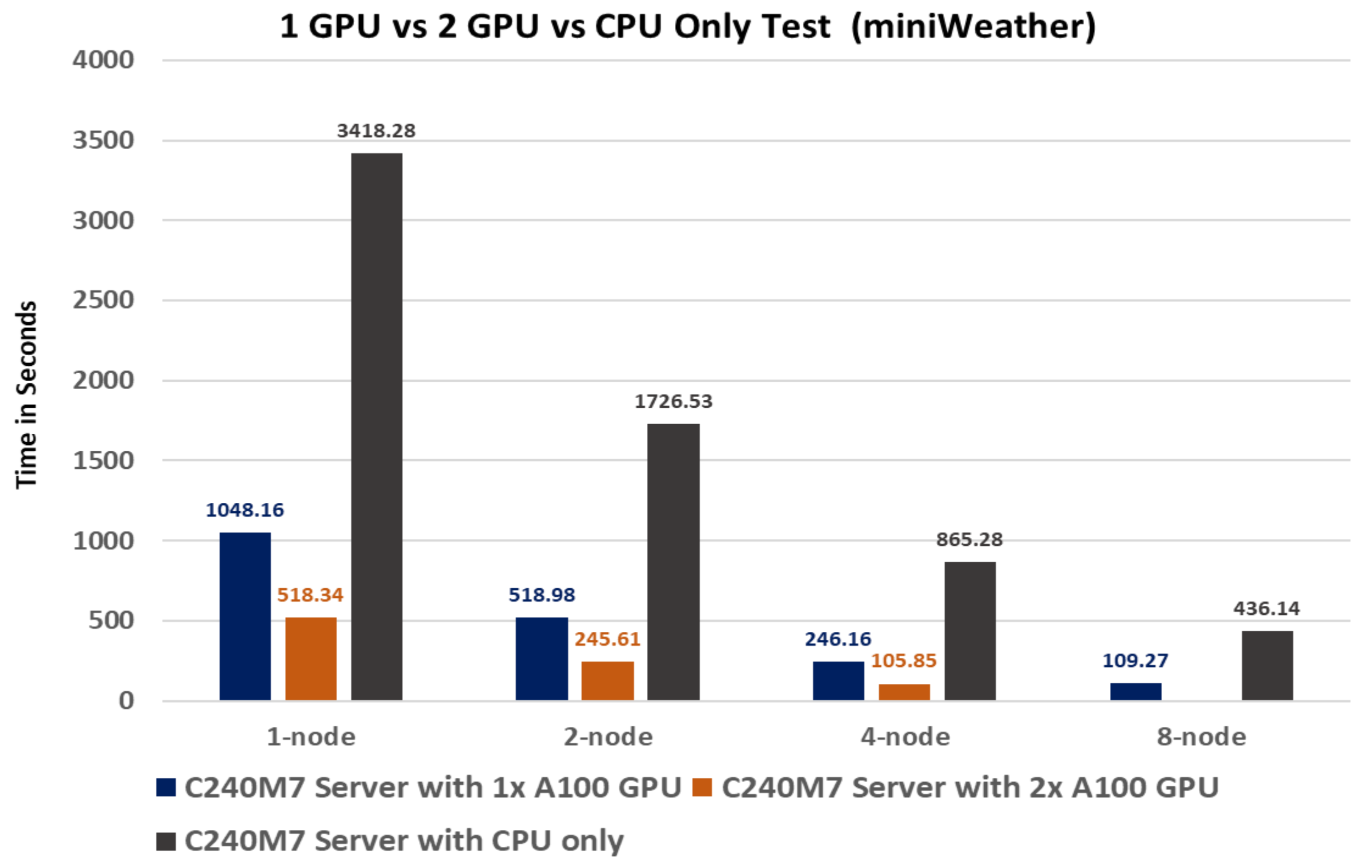
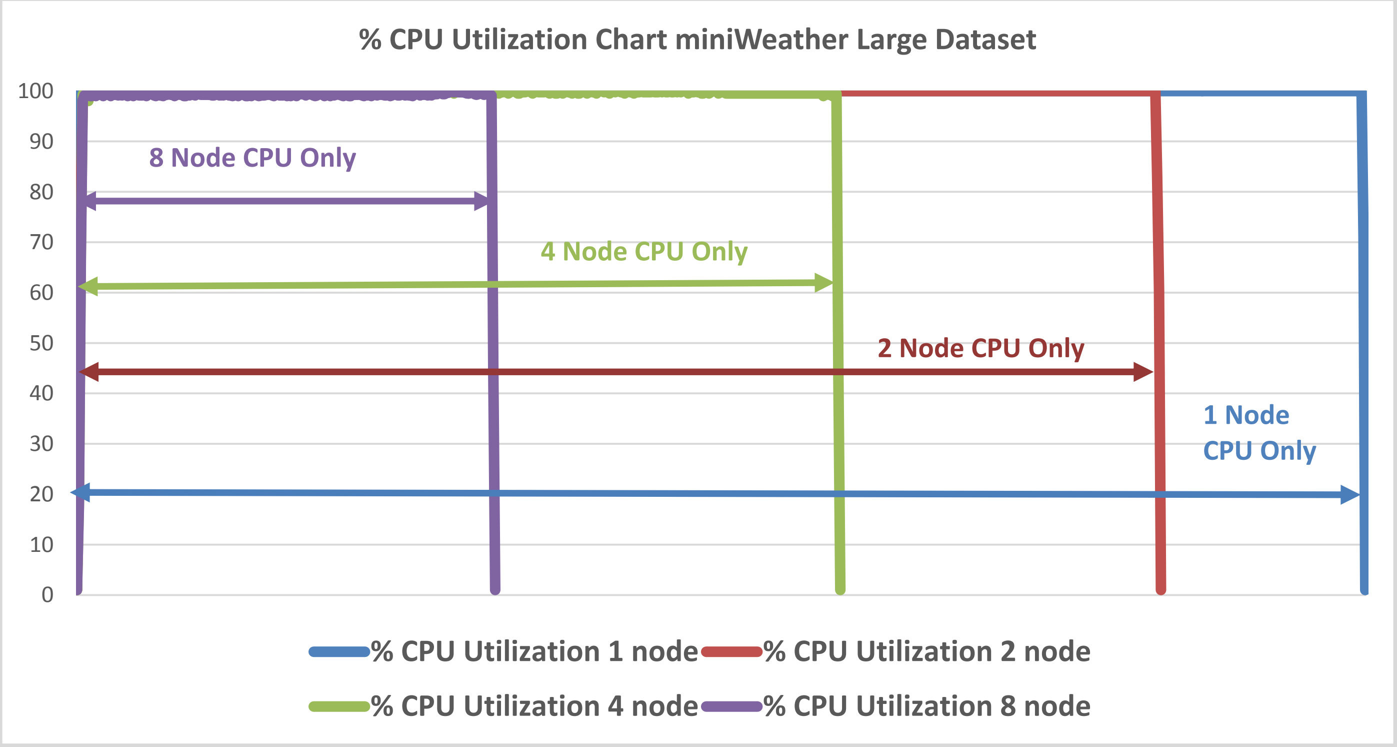
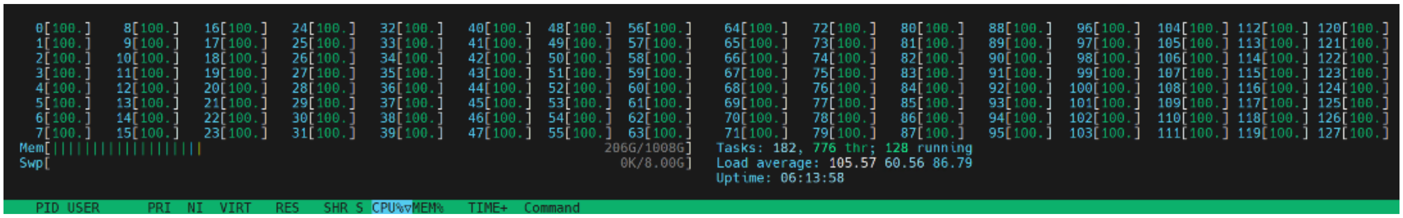


Figure 16. % Avg CPU utilization when running Large miniWeather Dataset only on CPU





```
    0[100.]    8[100.]   16[100.]   24[100.]   32[100.]   40[100.]  48[100.]  56[100.]    64[100.]   72[100.]   80[100.]   88[100.]   96[100.]  104[100.] 112[100.] 120[100.]
    1[100.]    9[100.]   17[100.]   25[100.]   33[100.]   41[100.]  49[100.]  57[100.]    65[100.]   73[100.]   81[100.]   89[100.]   97[100.]  105[100.] 113[100.] 121[100.]
    2[100.]   10[100.]   18[100.]   26[100.]   34[100.]   42[100.]  50[100.]  58[100.]    66[100.]   74[100.]   82[100.]   90[100.]   98[100.]  106[100.] 114[100.] 122[100.]
    3[100.]   11[100.]   19[100.]   27[100.]   35[100.]   43[100.]  51[100.]  59[100.]    67[100.]   75[100.]   83[100.]   91[100.]   99[100.]  107[100.] 115[100.] 123[100.]
    4[100.]   12[100.]   20[100.]   28[100.]   36[100.]   44[100.]  52[100.]  60[100.]    68[100.]   76[100.]   84[100.]   92[100.]  100[100.]  108[100.] 116[100.] 124[100.]
    5[100.]   13[100.]   21[100.]   29[100.]   37[100.]   45[100.]  53[100.]  61[100.]    69[100.]   77[100.]   85[100.]   93[100.]  101[100.]  109[100.] 117[100.] 125[100.]
    6[100.]   14[100.]   22[100.]   30[100.]   38[100.]   46[100.]  54[100.]  62[100.]    70[100.]   78[100.]   86[100.]   94[100.]  102[100.]  110[100.] 118[100.] 126[100.]
    7[100.]   15[100.]   23[100.]   31[100.]   39[100.]   47[100.]  55[100.]  63[100.]    71[100.]   79[100.]   87[100.]   95[100.]  103[100.]  111[100.] 119[100.] 127[100.]
  Mem[|||||||||||||||||||                                            206G/1008G]   Tasks: 182, 776 thr; 128 running
  Swp[                                                                  0K/8.00G]   Load average: 105.57 60.56 86.79
                                                                                    Uptime: 06:13:58

    PID USER       PRI  NI  VIRT   RES   SHR S CPU%▽MEM%   TIME+  Command
```

Figure 17.   % Avg GPU utilization when running Large miniWeather Dataset on nodes w/ 1 NVIDIA A100-80G GPU

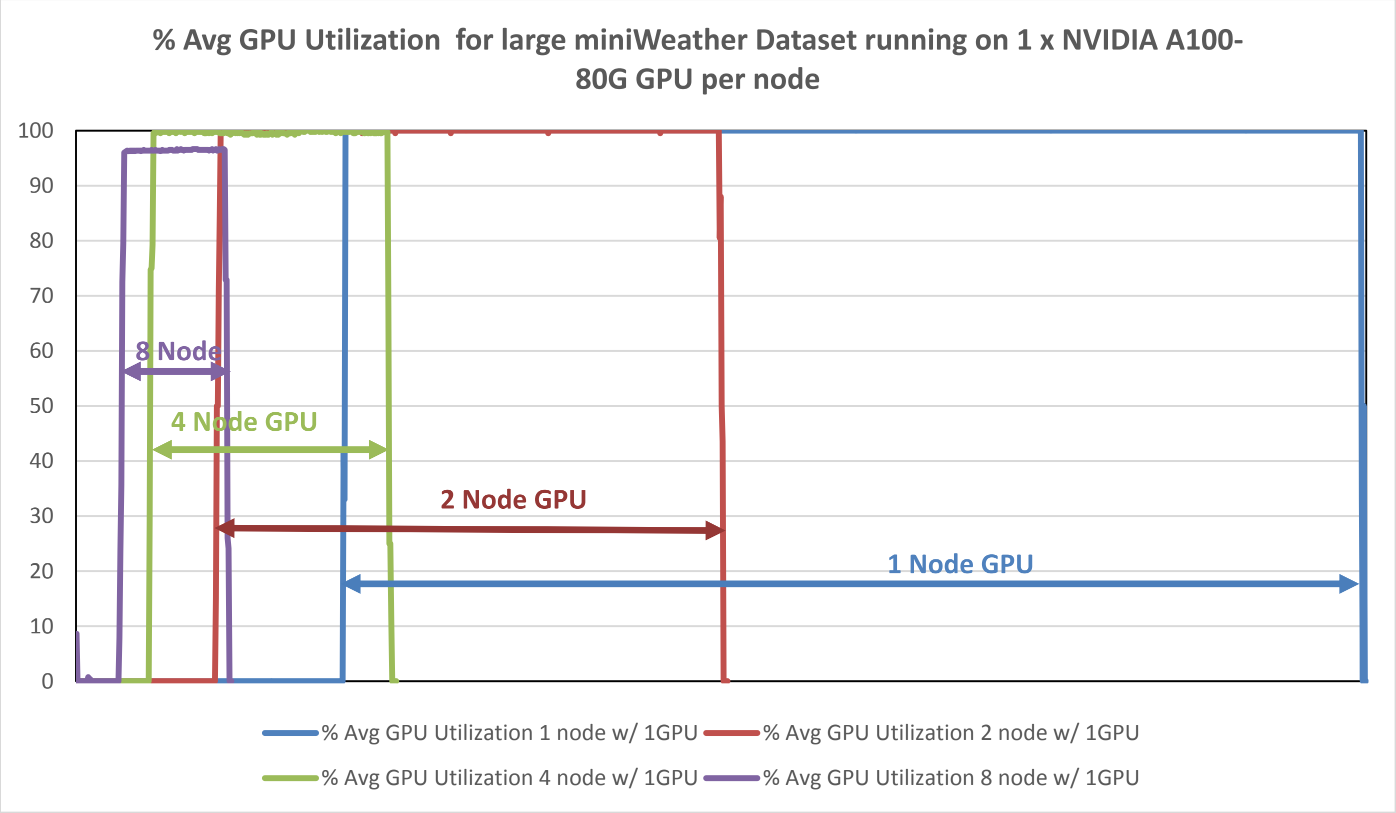


Figure 18. % Avg GPU utilization when running Large miniWeather Dataset on nodes w/ 2 NVIDIA A100-80G GPU

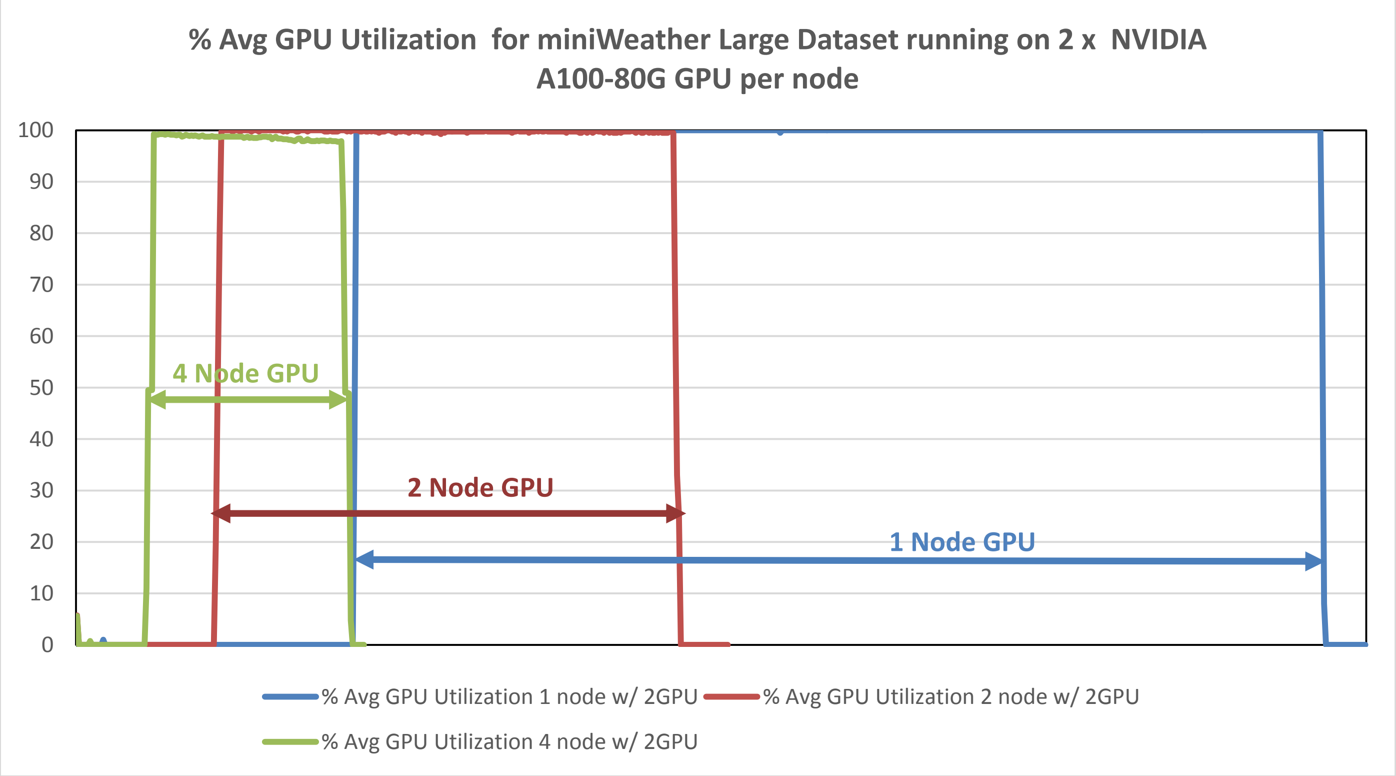


Figure 19. % Avg GPU memory utilization when running Large miniWeather Dataset on nodes w/ 1 NVIDIA A100-80G GPU

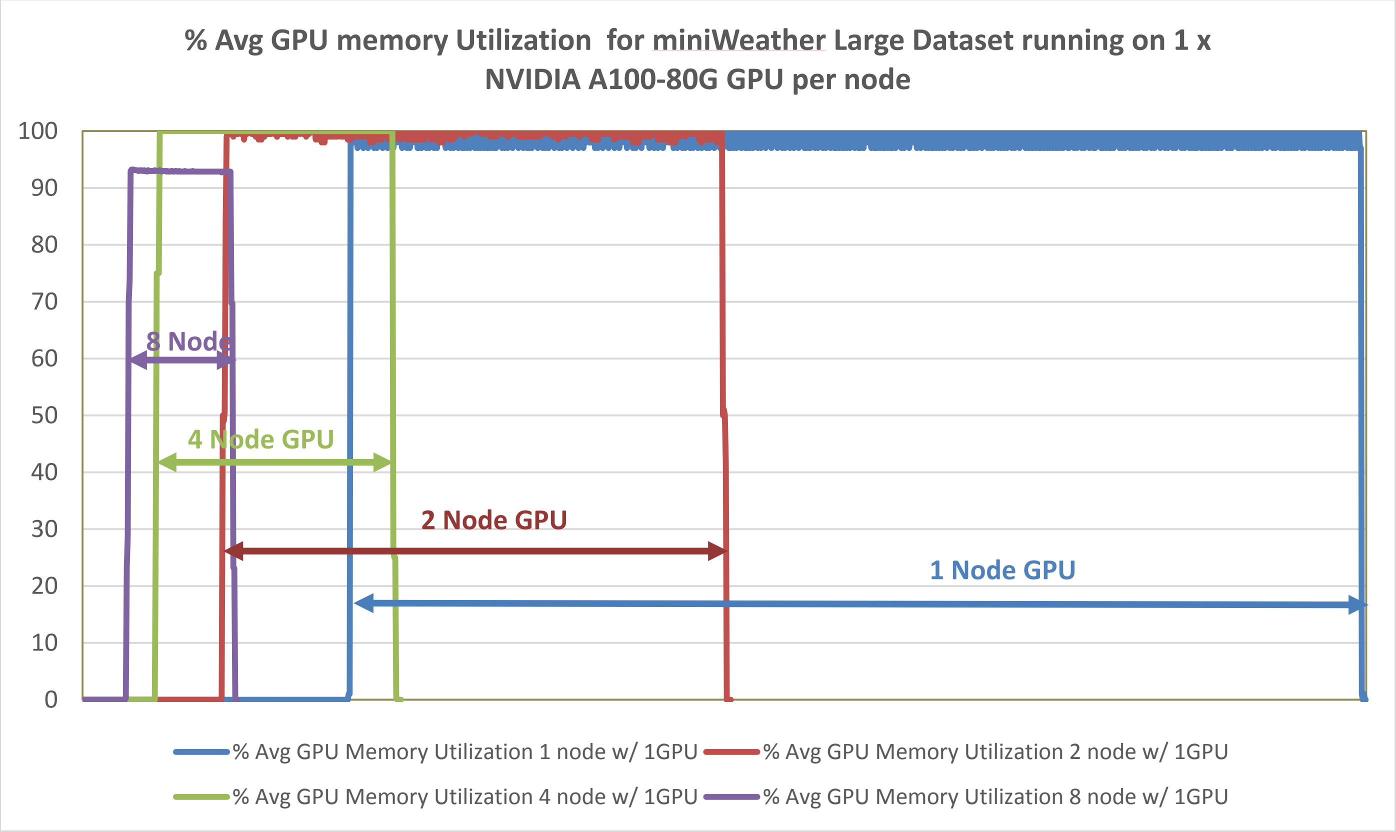


Figure 20. % Avg GPU memory utilization when running Large miniWeather Dataset on nodes w/ 2 NVIDIA A100-80G GPU

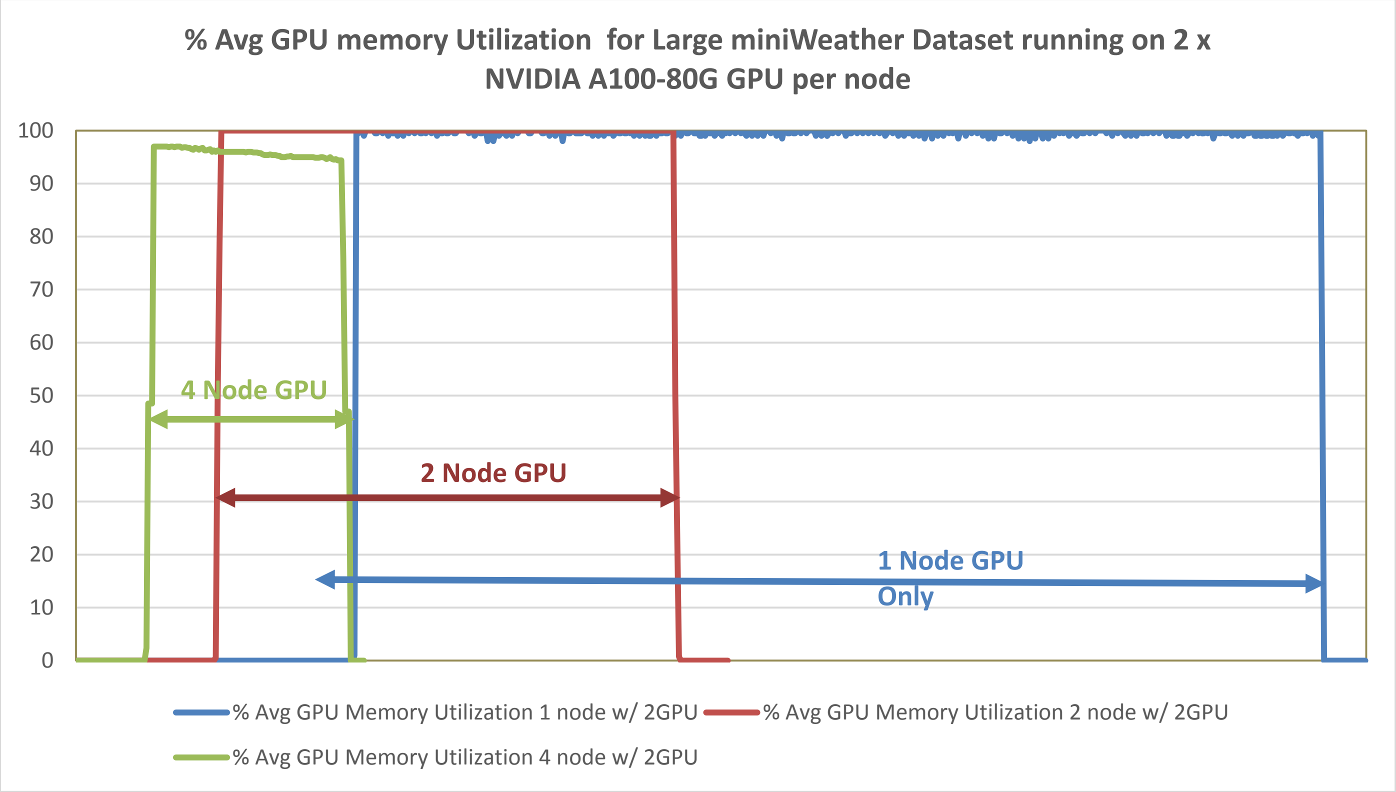
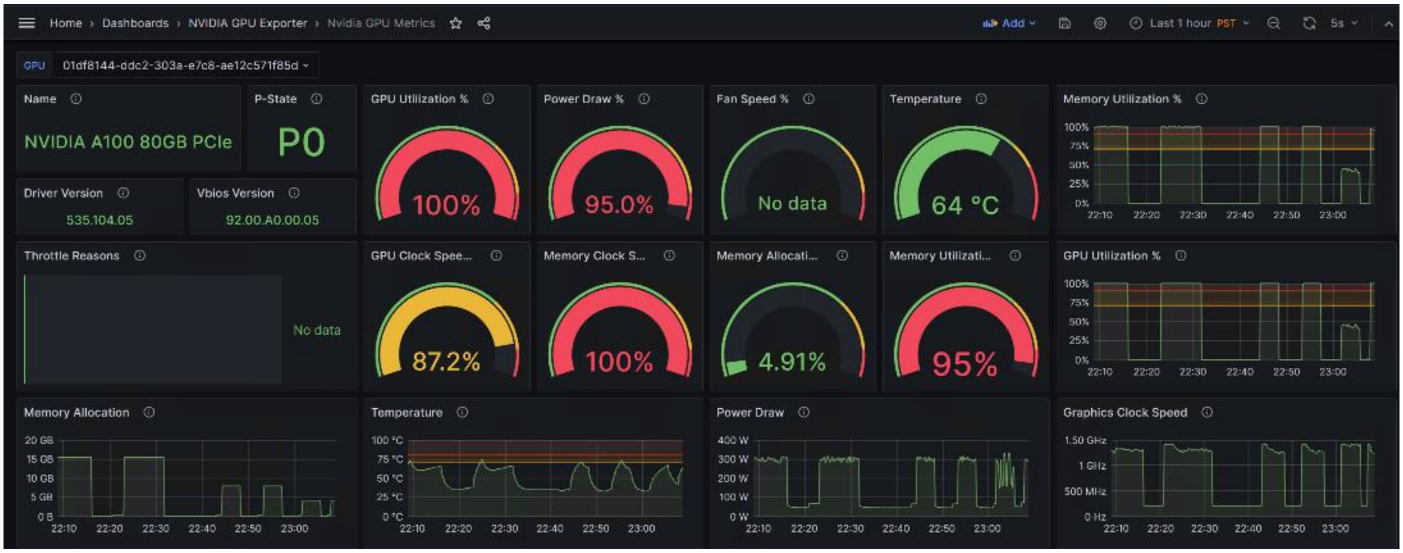


Figure 21. Sample Grafana dashboard showing GPU statistics.


Home › Dashboards › NVIDIA GPU Exporter › Nvidia GPU Metrics
Add
Last 1 hour PST
5s

GPU 01df8144-ddc2-303a-e7c8-ae12c571f85d

Name
NVIDIA A100 80GB PCIe

P-State
P0

Driver Version
535.104.05

Vbios Version
92.00.A0.00.05

GPU Utilization %
100%

Power Draw %
95.0%

Fan Speed %
No data

Temperature
64 °C

Throttle Reasons
No data

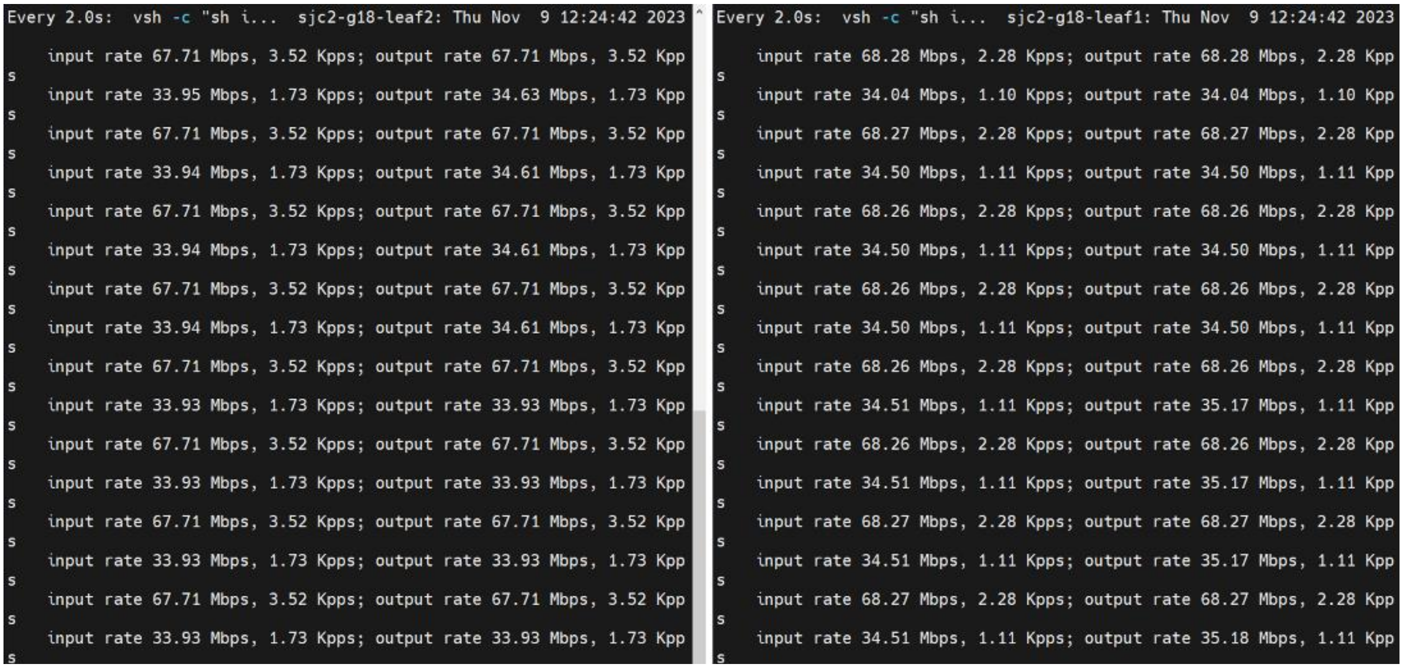
GPU Clock Spee...
87.2%

Memory Clock S...
100%

Memory Allocati...
4.91%

Memory Utilizati...
95%

Figure 22. Sample % Avg network utilization when running Large miniWeather Dataset on 8 node w/ 1 x A100-80G GPU per node

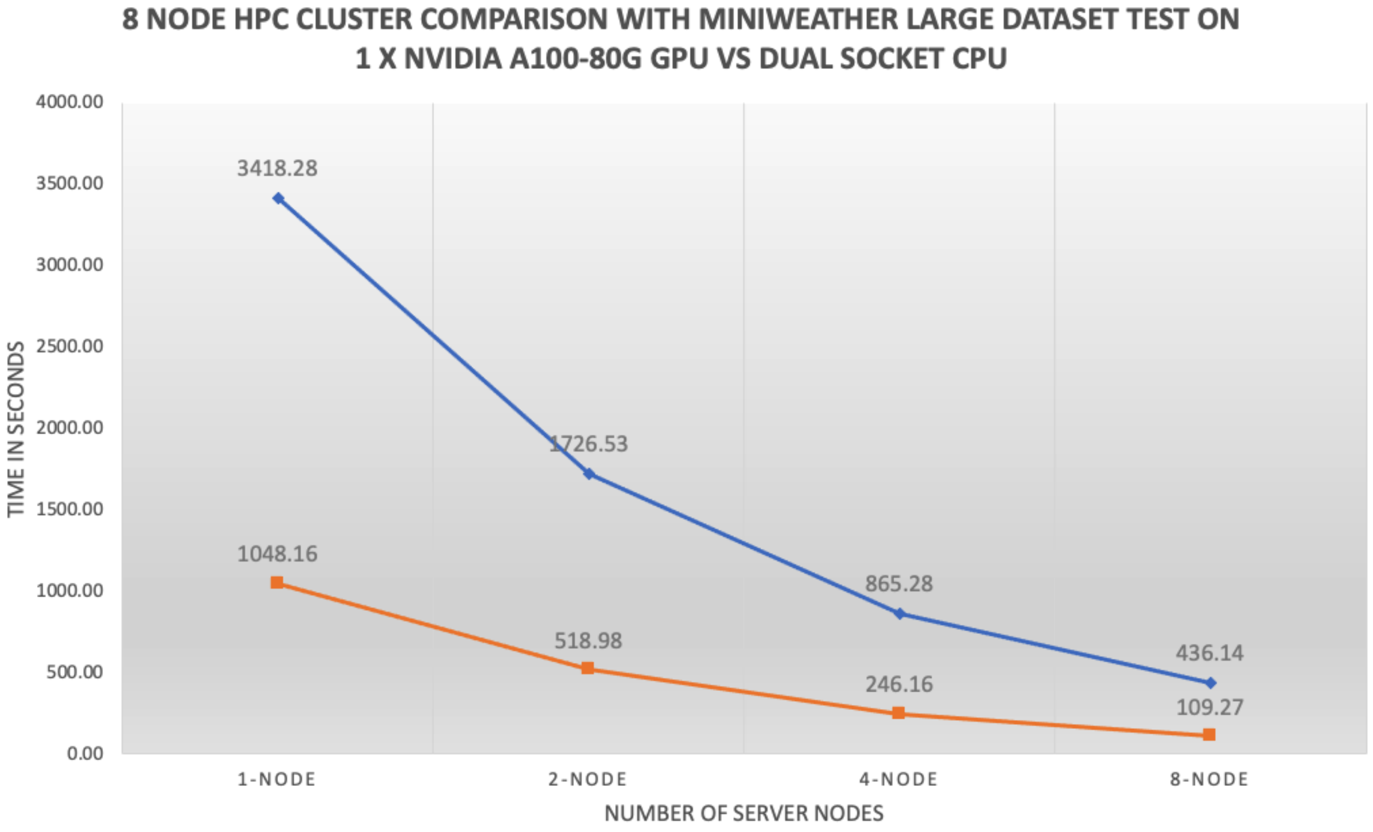


```
Every 2.0s:  vsh -c "sh i...  sjc2-g18-leaf2: Thu Nov  9 12:24:42 2023
    input rate 67.71 Mbps, 3.52 Kpps; output rate 67.71 Mbps, 3.52 Kpp
s
    input rate 33.95 Mbps, 1.73 Kpps; output rate 34.63 Mbps, 1.73 Kpp
s
    input rate 67.71 Mbps, 3.52 Kpps; output rate 67.71 Mbps, 3.52 Kpp
s
    input rate 33.94 Mbps, 1.73 Kpps; output rate 34.61 Mbps, 1.73 Kpp
s
    input rate 67.71 Mbps, 3.52 Kpps; output rate 67.71 Mbps, 3.52 Kpp
s
    input rate 33.94 Mbps, 1.73 Kpps; output rate 34.61 Mbps, 1.73 Kpp
s
    input rate 67.71 Mbps, 3.52 Kpps; output rate 67.71 Mbps, 3.52 Kpp
s
    input rate 33.94 Mbps, 1.73 Kpps; output rate 34.61 Mbps, 1.73 Kpp
s
    input rate 67.71 Mbps, 3.52 Kpps; output rate 67.71 Mbps, 3.52 Kpp
s
    input rate 33.93 Mbps, 1.73 Kpps; output rate 33.93 Mbps, 1.73 Kpp
s
    input rate 67.71 Mbps, 3.52 Kpps; output rate 67.71 Mbps, 3.52 Kpp
s
    input rate 33.93 Mbps, 1.73 Kpps; output rate 33.93 Mbps, 1.73 Kpp
s
    input rate 67.71 Mbps, 3.52 Kpps; output rate 67.71 Mbps, 3.52 Kpp
s
    input rate 33.93 Mbps, 1.73 Kpps; output rate 33.93 Mbps, 1.73 Kpp
s
    input rate 67.71 Mbps, 3.52 Kpps; output rate 67.71 Mbps, 3.52 Kpp
s
    input rate 33.93 Mbps, 1.73 Kpps; output rate 33.93 Mbps, 1.73 Kpp
s
```

```
Every 2.0s:  vsh -c "sh i...  sjc2-g18-leaf1: Thu Nov  9 12:24:42 2023
    input rate 68.28 Mbps, 2.28 Kpps; output rate 68.28 Mbps, 2.28 Kpp
s
    input rate 34.04 Mbps, 1.10 Kpps; output rate 34.04 Mbps, 1.10 Kpp
s
    input rate 68.27 Mbps, 2.28 Kpps; output rate 68.27 Mbps, 2.28 Kpp
s
    input rate 34.50 Mbps, 1.11 Kpps; output rate 34.50 Mbps, 1.11 Kpp
s
    input rate 68.26 Mbps, 2.28 Kpps; output rate 68.26 Mbps, 2.28 Kpp
s
    input rate 34.50 Mbps, 1.11 Kpps; output rate 34.50 Mbps, 1.11 Kpp
s
    input rate 68.26 Mbps, 2.28 Kpps; output rate 68.26 Mbps, 2.28 Kpp
s
    input rate 34.50 Mbps, 1.11 Kpps; output rate 34.50 Mbps, 1.11 Kpp
s
    input rate 68.26 Mbps, 2.28 Kpps; output rate 68.26 Mbps, 2.28 Kpp
s
    input rate 34.51 Mbps, 1.11 Kpps; output rate 35.17 Mbps, 1.11 Kpp
s
    input rate 68.26 Mbps, 2.28 Kpps; output rate 68.26 Mbps, 2.28 Kpp
s
    input rate 34.51 Mbps, 1.11 Kpps; output rate 35.17 Mbps, 1.11 Kpp
s
    input rate 68.27 Mbps, 2.28 Kpps; output rate 68.27 Mbps, 2.28 Kpp
s
    input rate 34.51 Mbps, 1.11 Kpps; output rate 35.17 Mbps, 1.11 Kpp
s
    input rate 68.27 Mbps, 2.28 Kpps; output rate 68.27 Mbps, 2.28 Kpp
s
    input rate 34.51 Mbps, 1.11 Kpps; output rate 35.18 Mbps, 1.11 Kpp
s
```

Observations

Figure 23. 8 Node HPC Cluster comparison with miniWeather larger dataset test on 1 x NVIDIA A100-80G GPU vs Dual Socket CPU



The following observations were made from the test results obtained by running miniWeather large dataset on the 8 x Cisco UCS C240 M7 node based HPC cluster as defined in this solution study:

- The end-end FlexPod HPC cluster as highlighted in this solution scaled linearly whether the cluster test ran by CPU only or w/ GPU.
- Each node resources i.e., compute, storage and network consumed evenly throughout the cluster test.
- 100% GPU utilization and memory utilization.
- No CPU cycles were consumed when ran the test on NVIDIA A100-80G GPU.
- Time to complete the test with one GPU per node in an eight-node cluster is 4x faster than running the same test on eight-node cluster without GPU.

Application 2: Minisweep (Small Size Dataset)

Table 8 lists the results from scale out tests on Minisweep.

Table 8. Scale test results with Minisweep small size dataset in second

Scale Test	1-node (Total time in second)	2-node (Total time in second)	4-node (Total time in second)	8-node (Total time in second)
C240M7 Server with 1x A100 GPU	438.10	217.18	122.93	76.21
C240M7 Server with 2x A100 GPU	216.99	130.58	87.10	NA
C240M7 Server with CPU only	1927.84	1045.48	742.04	435.59

Figure 24. Cluster scalability when running small miniSweep Dataset.

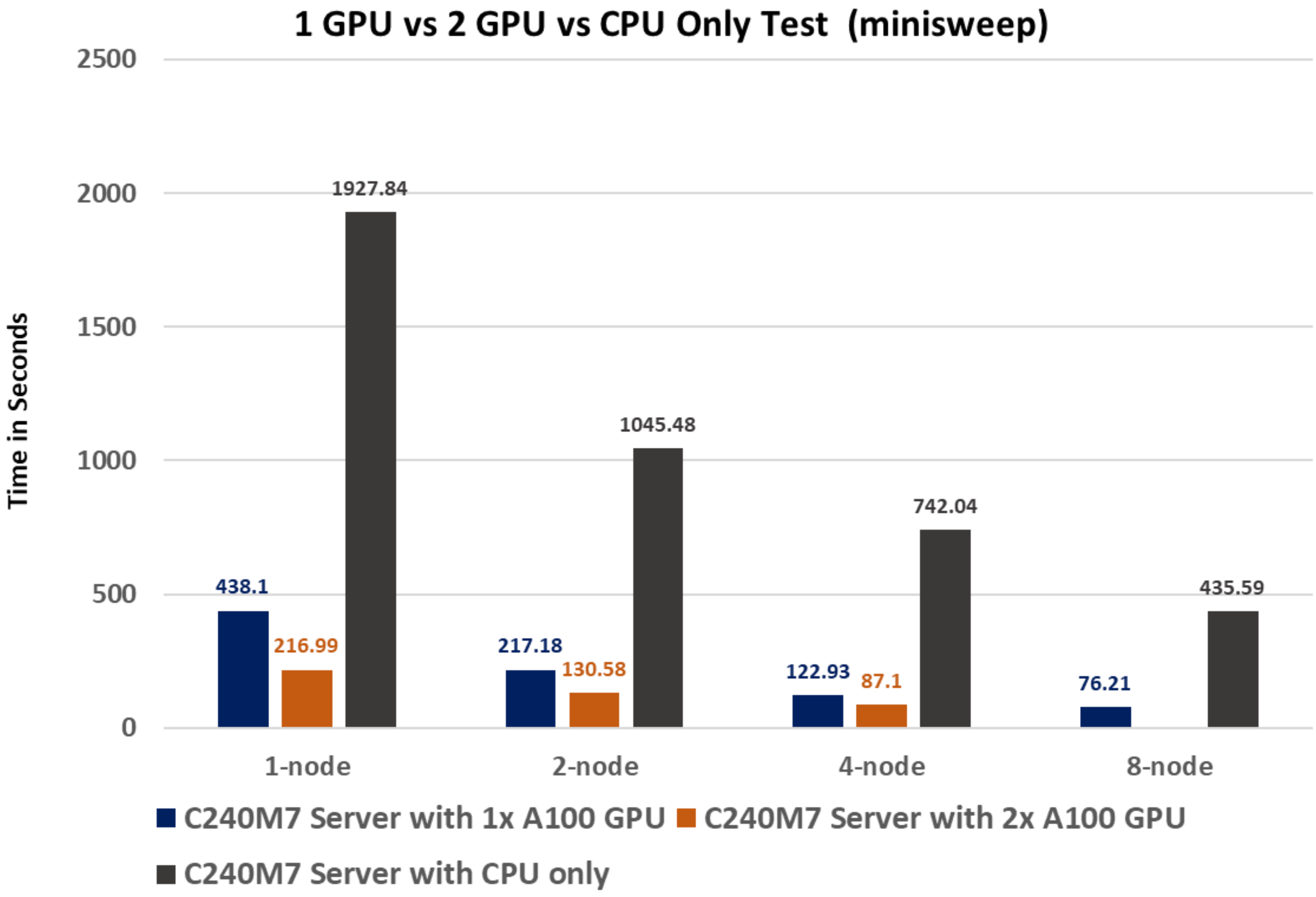
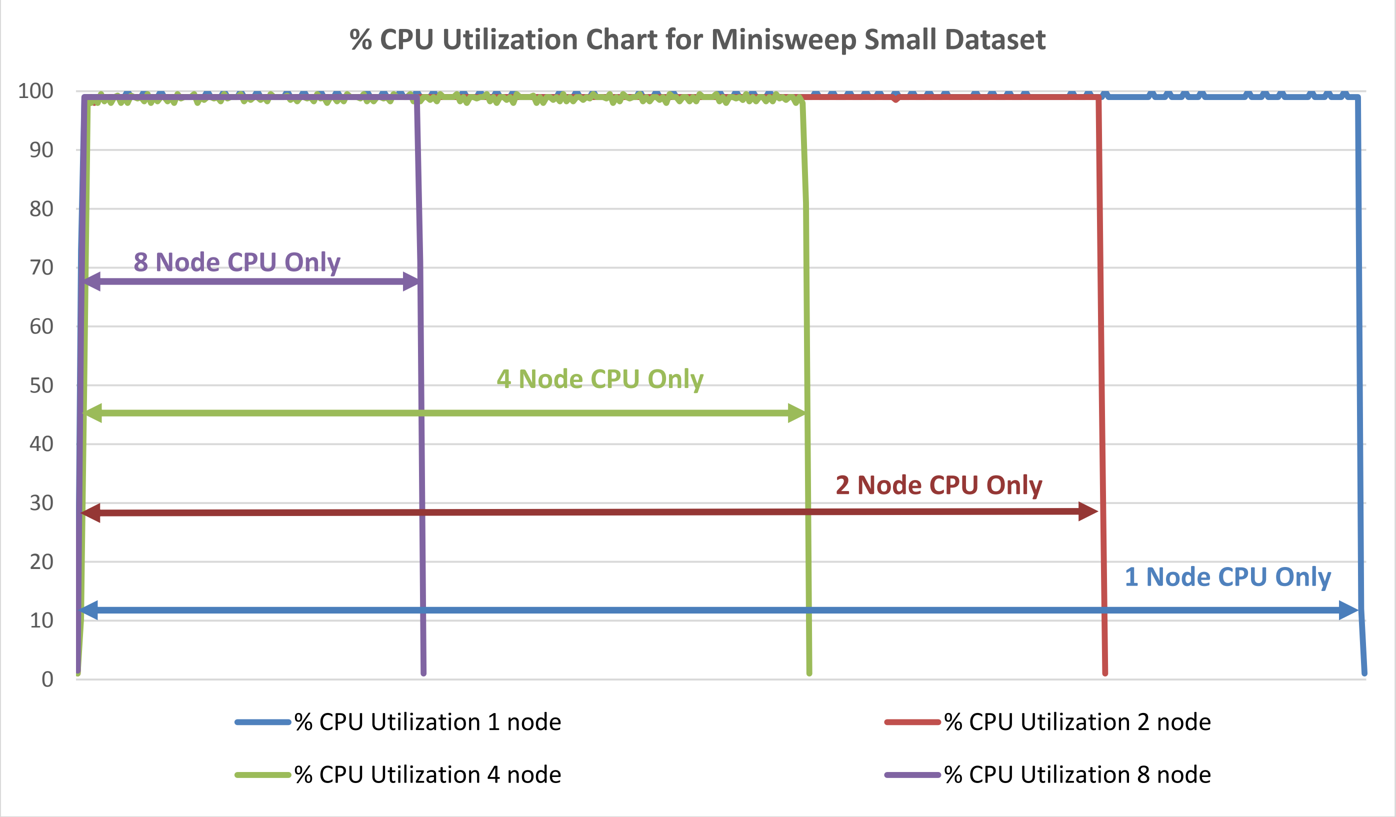
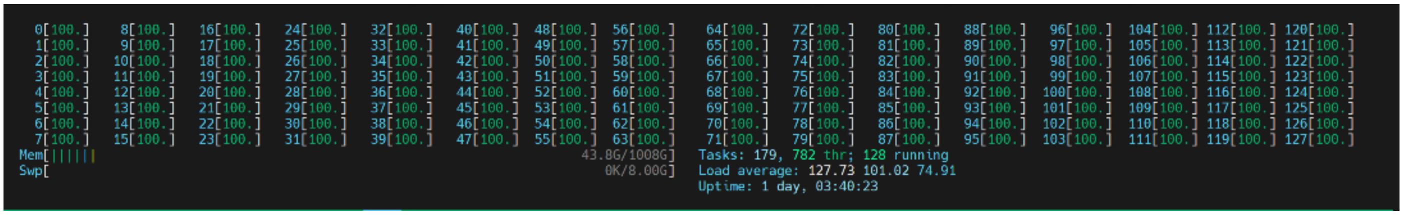


Figure 25. % Avg CPU utilization when running Small miniSweep Dataset only on CPU





```
  0[100.]    8[100.]   16[100.]   24[100.]   32[100.]   40[100.]  48[100.]  56[100.]    64[100.]   72[100.]   80[100.]   88[100.]    96[100.]  104[100.] 112[100.] 120[100.]
  1[100.]    9[100.]   17[100.]   25[100.]   33[100.]   41[100.]  49[100.]  57[100.]    65[100.]   73[100.]   81[100.]   89[100.]    97[100.]  105[100.] 113[100.] 121[100.]
  2[100.]   10[100.]   18[100.]   26[100.]   34[100.]   42[100.]  50[100.]  58[100.]    66[100.]   74[100.]   82[100.]   90[100.]    98[100.]  106[100.] 114[100.] 122[100.]
  3[100.]   11[100.]   19[100.]   27[100.]   35[100.]   43[100.]  51[100.]  59[100.]    67[100.]   75[100.]   83[100.]   91[100.]    99[100.]  107[100.] 115[100.] 123[100.]
  4[100.]   12[100.]   20[100.]   28[100.]   36[100.]   44[100.]  52[100.]  60[100.]    68[100.]   76[100.]   84[100.]   92[100.]   100[100.]  108[100.] 116[100.] 124[100.]
  5[100.]   13[100.]   21[100.]   29[100.]   37[100.]   45[100.]  53[100.]  61[100.]    69[100.]   77[100.]   85[100.]   93[100.]   101[100.]  109[100.] 117[100.] 125[100.]
  6[100.]   14[100.]   22[100.]   30[100.]   38[100.]   46[100.]  54[100.]  62[100.]    70[100.]   78[100.]   86[100.]   94[100.]   102[100.]  110[100.] 118[100.] 126[100.]
  7[100.]   15[100.]   23[100.]   31[100.]   39[100.]   47[100.]  55[100.]  63[100.]    71[100.]   79[100.]   87[100.]   95[100.]   103[100.]  111[100.] 119[100.] 127[100.]
Mem[||||||                                                       43.8G/1008G]   Tasks: 179, 782 thr; 128 running
Swp[                                                                0K/8.00G]   Load average: 127.73 101.02 74.91
                                                                                Uptime: 1 day, 03:40:23
```

Figure 26. % Avg GPU utilization when running small Minisweep Dataset on nodes w/ 1 NVIDIA A100-80G GPU

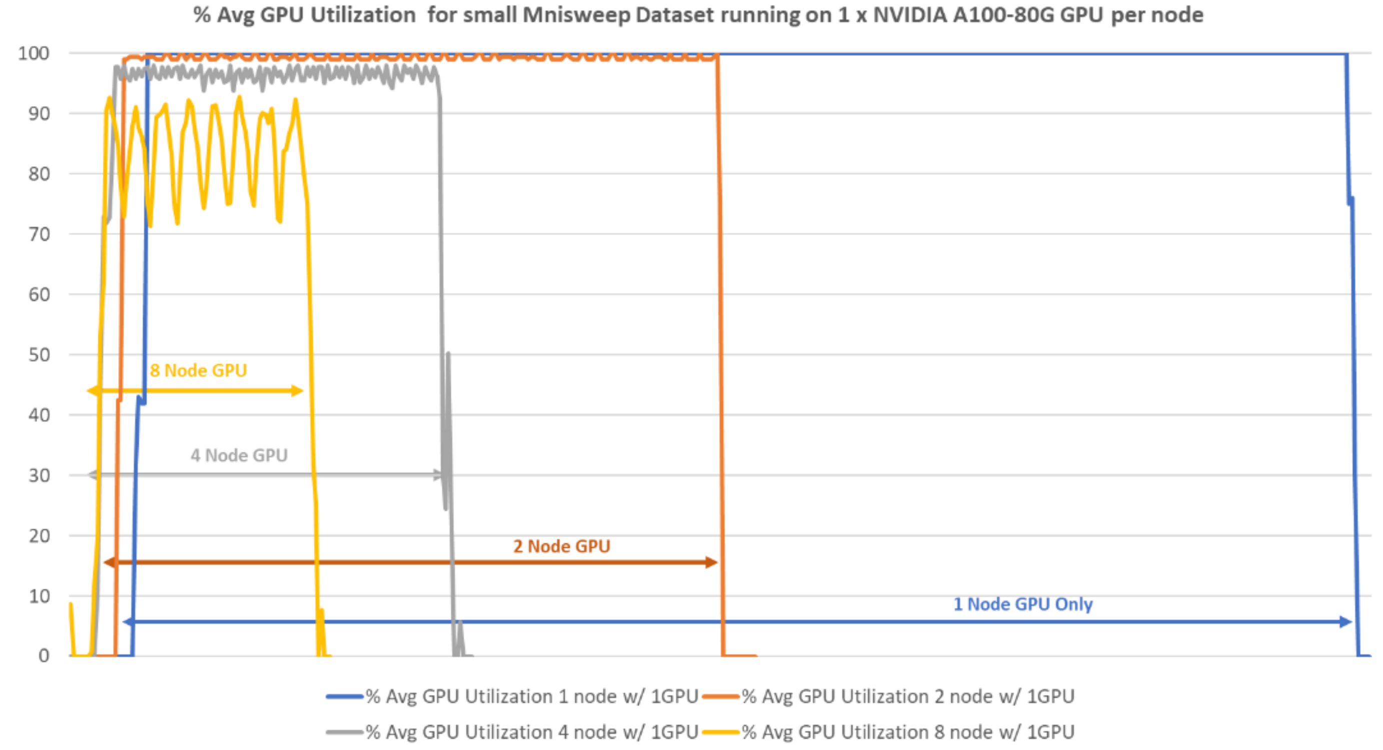


Figure 27. % Avg GPU utilization when running small Minisweep Dataset on nodes w/ 2 NVIDIA A100-80G GPU

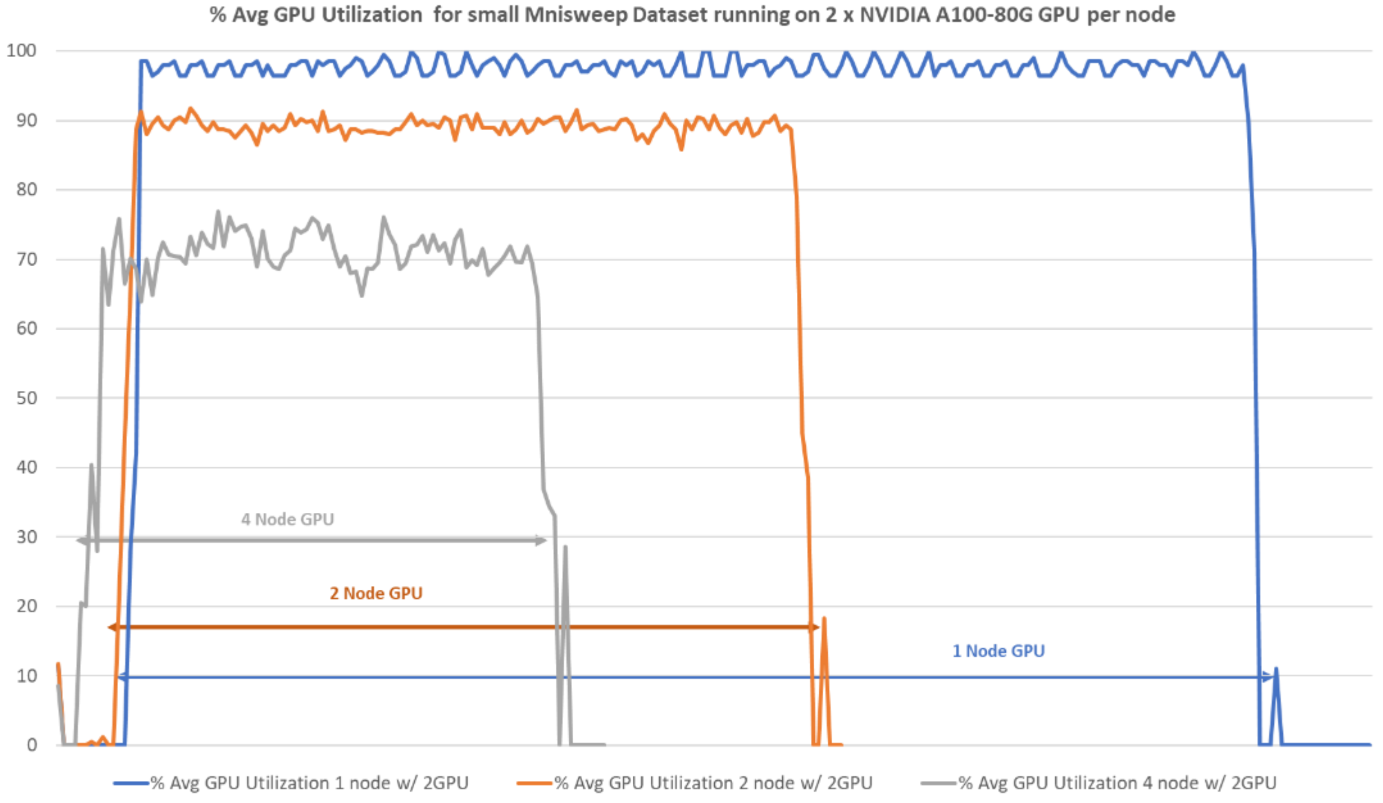


Figure 28. % Avg GPU memory utilization when running small Minisweep Dataset on nodes w/ 1 NVIDIA A100-80G GPU

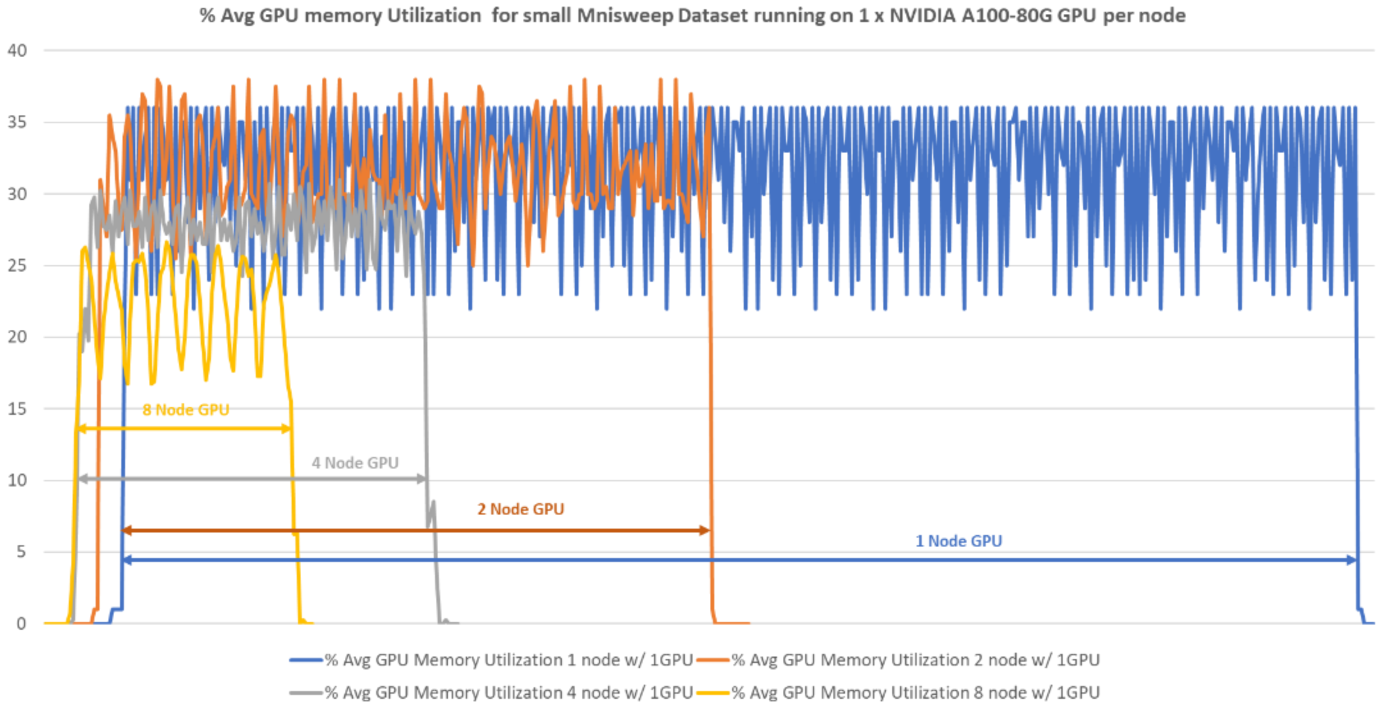


Figure 29. % Avg GPU memory utilization when running small Minisweep Dataset on nodes w/ 2 NVIDIA A100-80G GPU

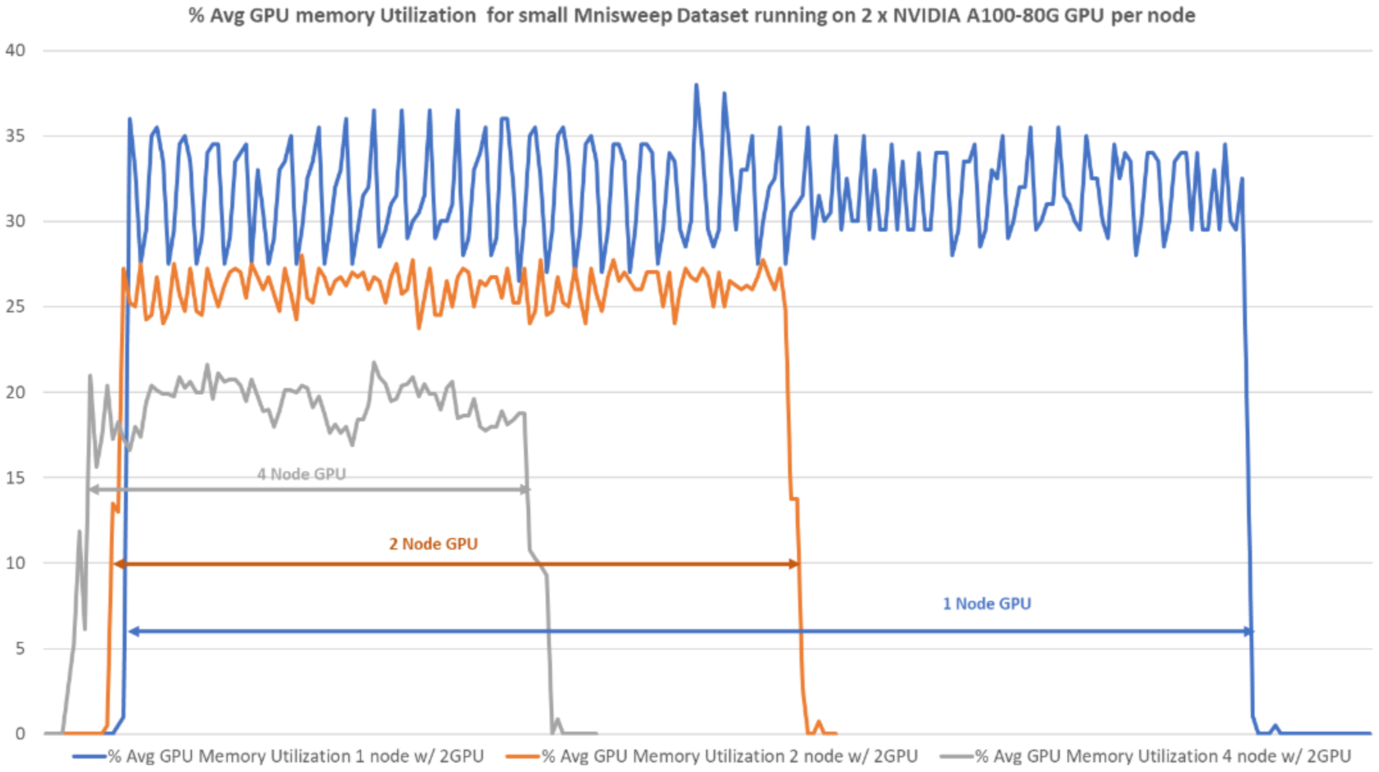
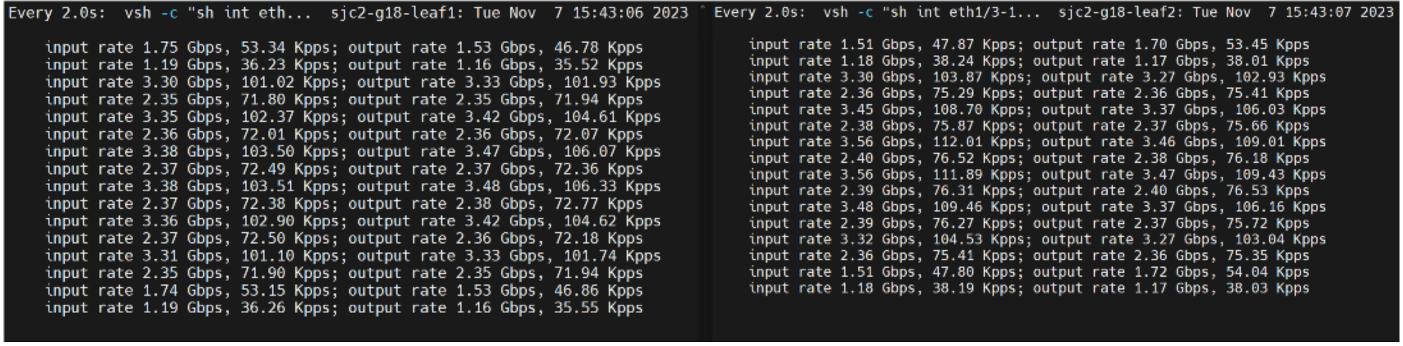


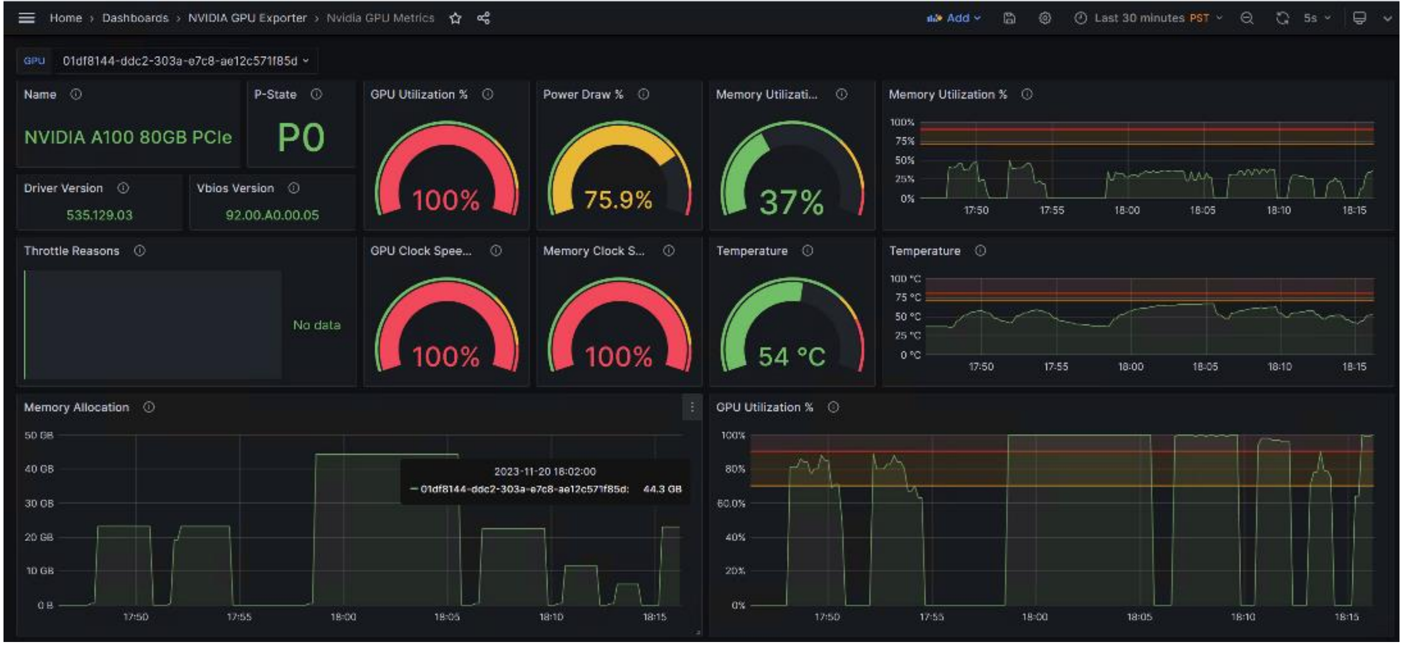
Figure 30. **Sample % Avg network utilization when running small Minisweep Dataset on 8 node w/ 1 x A100-80G GPU per node**



```
Every 2.0s:  vsh -c "sh int eth...  sjc2-g18-leaf1: Tue Nov  7 15:43:06 2023

    input rate 1.75 Gbps, 53.34 Kpps; output rate 1.53 Gbps, 46.78 Kpps
    input rate 1.19 Gbps, 36.23 Kpps; output rate 1.16 Gbps, 35.52 Kpps
    input rate 3.30 Gbps, 101.02 Kpps; output rate 3.33 Gbps, 101.93 Kpps
    input rate 2.35 Gbps, 71.80 Kpps; output rate 2.35 Gbps, 71.94 Kpps
    input rate 3.35 Gbps, 102.37 Kpps; output rate 3.42 Gbps, 104.61 Kpps
    input rate 2.36 Gbps, 72.01 Kpps; output rate 2.36 Gbps, 72.07 Kpps
    input rate 3.38 Gbps, 103.50 Kpps; output rate 3.47 Gbps, 106.07 Kpps
    input rate 2.37 Gbps, 72.49 Kpps; output rate 2.37 Gbps, 72.36 Kpps
    input rate 3.38 Gbps, 103.51 Kpps; output rate 3.48 Gbps, 106.33 Kpps
    input rate 2.37 Gbps, 72.38 Kpps; output rate 2.38 Gbps, 72.77 Kpps
    input rate 3.36 Gbps, 102.90 Kpps; output rate 3.42 Gbps, 104.62 Kpps
    input rate 2.37 Gbps, 72.50 Kpps; output rate 2.36 Gbps, 72.18 Kpps
    input rate 3.31 Gbps, 101.10 Kpps; output rate 3.33 Gbps, 101.74 Kpps
    input rate 2.35 Gbps, 71.90 Kpps; output rate 2.35 Gbps, 71.94 Kpps
    input rate 1.74 Gbps, 53.15 Kpps; output rate 1.53 Gbps, 46.86 Kpps
    input rate 1.19 Gbps, 36.26 Kpps; output rate 1.16 Gbps, 35.55 Kpps
```

```
Every 2.0s:  vsh -c "sh int eth1/3-1...  sjc2-g18-leaf2: Tue Nov  7 15:43:07 2023

    input rate 1.51 Gbps, 47.87 Kpps; output rate 1.70 Gbps, 53.45 Kpps
    input rate 1.18 Gbps, 38.24 Kpps; output rate 1.17 Gbps, 38.01 Kpps
    input rate 3.30 Gbps, 103.87 Kpps; output rate 3.27 Gbps, 102.93 Kpps
    input rate 2.36 Gbps, 75.29 Kpps; output rate 2.36 Gbps, 75.41 Kpps
    input rate 3.45 Gbps, 108.70 Kpps; output rate 3.37 Gbps, 106.03 Kpps
    input rate 2.38 Gbps, 75.87 Kpps; output rate 2.37 Gbps, 75.66 Kpps
    input rate 3.56 Gbps, 112.01 Kpps; output rate 3.46 Gbps, 109.01 Kpps
    input rate 2.40 Gbps, 76.52 Kpps; output rate 2.38 Gbps, 76.18 Kpps
    input rate 3.56 Gbps, 111.89 Kpps; output rate 3.47 Gbps, 109.43 Kpps
    input rate 2.39 Gbps, 76.31 Kpps; output rate 2.40 Gbps, 76.53 Kpps
    input rate 3.48 Gbps, 109.46 Kpps; output rate 3.37 Gbps, 106.16 Kpps
    input rate 2.39 Gbps, 76.27 Kpps; output rate 2.37 Gbps, 75.72 Kpps
    input rate 3.32 Gbps, 104.53 Kpps; output rate 3.27 Gbps, 103.04 Kpps
    input rate 2.36 Gbps, 75.41 Kpps; output rate 2.36 Gbps, 75.35 Kpps
    input rate 1.51 Gbps, 47.80 Kpps; output rate 1.72 Gbps, 54.04 Kpps
    input rate 1.18 Gbps, 38.19 Kpps; output rate 1.17 Gbps, 38.03 Kpps
```

Figure 31. **Sample Grafana dashboard showing GPU statistics**



GPU: 01df8144-ddc2-303a-e7c8-ae12c571f85d

Name: NVIDIA A100 80GB PCIe

P-State: P0

Driver Version: 535.129.03

Vbios Version: 92.00.A0.00.05

GPU Utilization %: 100%

Power Draw %: 75.9%

Memory Utilizati...: 37%

GPU Clock Spee...: 100%

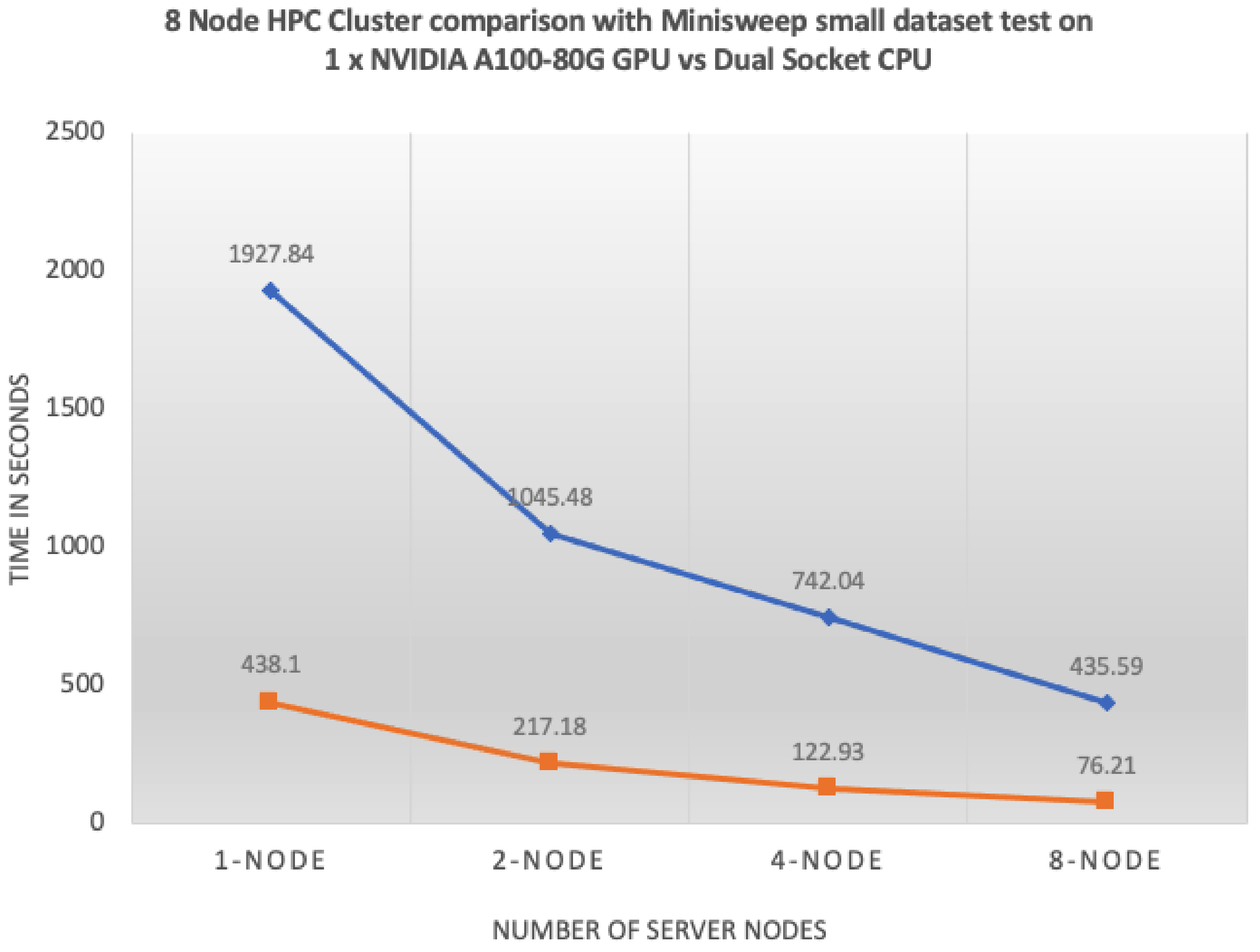
Memory Clock S...: 100%

Temperature: 54 °C

2023-11-20 18:02:00
— 01df8144-ddc2-303a-e7c8-ae12c571f85d: 44.3 GB

Observations

Figure 32. 8 Node HPC Cluster comparison with Minisweep small dataset test on 1 x NVIDIA A100-80G GPU vs Dual Socket CPU



The following observations were made from the test results obtained by running Minisweep small dataset on the 8 x Cisco UCS C240 M7 node based HPC cluster as defined in this solution study:

- The end-end FlexPod HPC cluster as highlighted in this solution scaled linearly whether the cluster test ran by CPU only or w/ GPU.
- Each node resources i.e., compute, storage and network consumed evenly throughout the cluster test.
- Different than weather simulation exercise above the Nuclear Engineering - Radiation Transport based Minisweep small dataset showed difference in overall GPU utilization; while we saw at the full cluster test approximately 90% GPU utilization and 70% memory utilization.
- No CPU cycles were consumed when ran the test on NVIDIA A100-80G GPU.
- Time to complete the test with one GPU per node in an eight-node cluster is 5.7x faster than running the same test on eight-node cluster without GPU.

Application 3: HPGMG (Medium Size Dataset)

Table 9 lists the results from scale out tests on HPGMG.

Table 9. Scale test results with HPGMG medium size dataset in second.

Scale Test	1-node (Total time in second)	2-node (Total time in second)	4-node (Total time in second)	8-node (Total time in second)
C240M7 Server with 1x A100 GPU	NA	NA	308.76	190.16
C240M7 Server with 2x A100 GPU	NA	305.33	182.86	NA
C240M7 Server with CPU only	4524.42	2330.06	1229.69563	677.1356146

Figure 33. Cluster scalability when running medium HPGMG Dataset

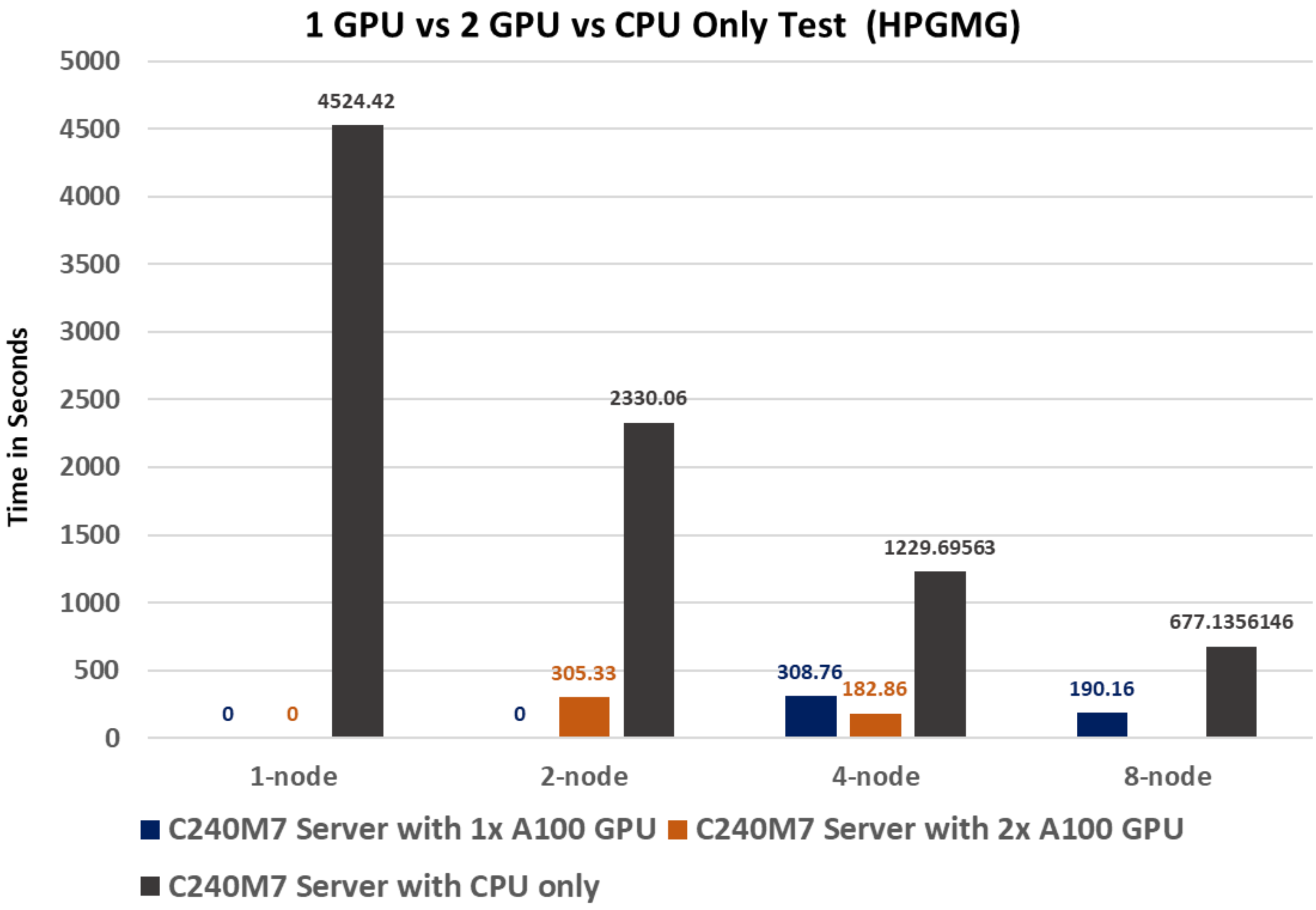
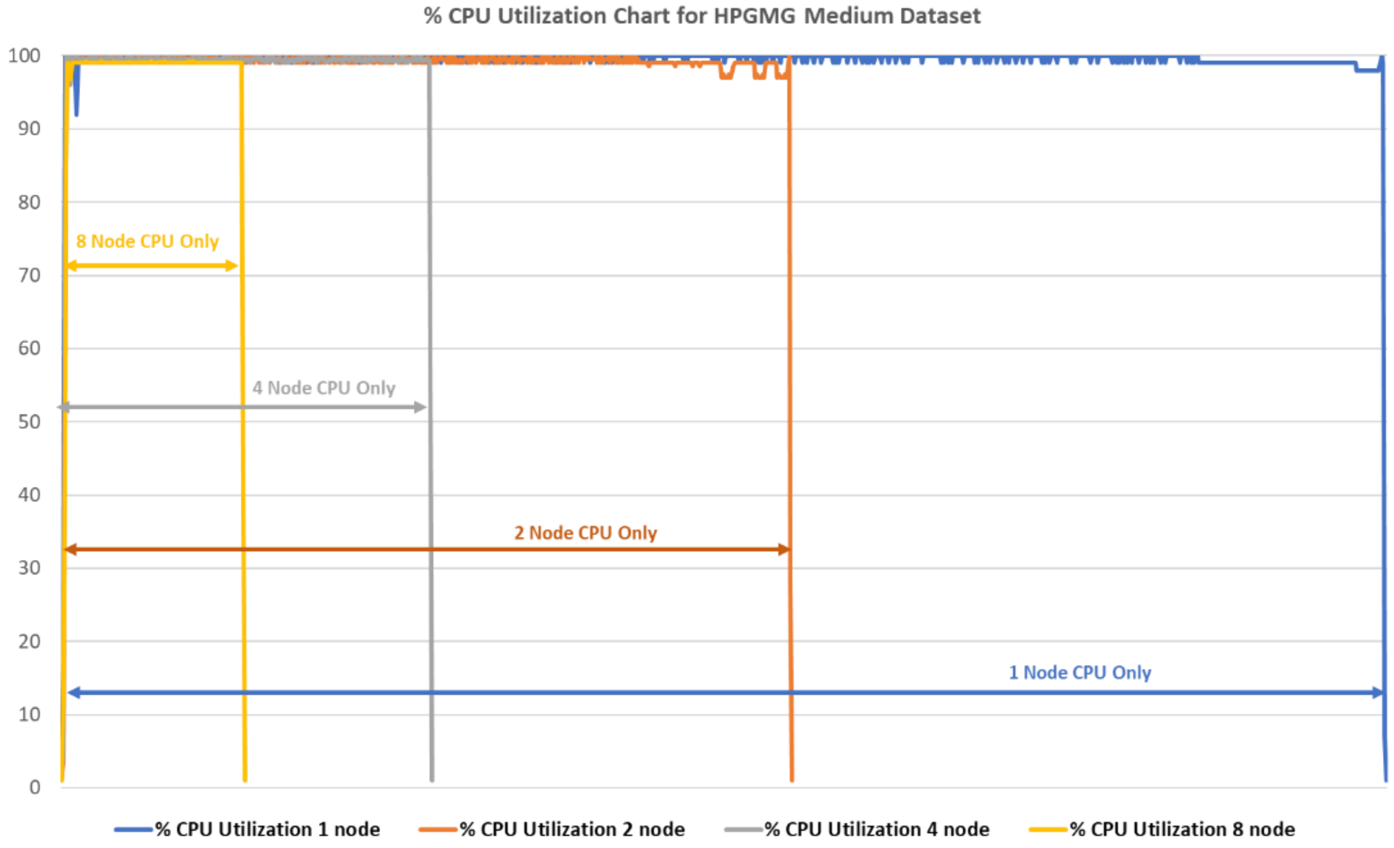
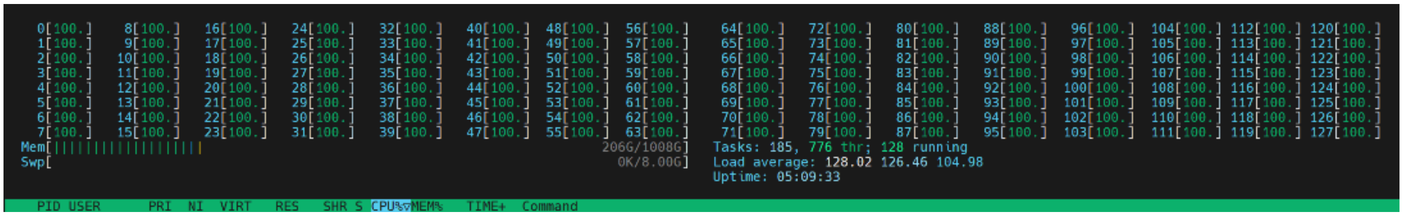


Figure 34. % Avg CPU utilization when running Medium HPGMG Dataset only on CPU





```
    0[100.]    8[100.]   16[100.]   24[100.]   32[100.]   40[100.]  48[100.]  56[100.]    64[100.]   72[100.]   80[100.]   88[100.]   96[100.]  104[100.] 112[100.] 120[100.]
    1[100.]    9[100.]   17[100.]   25[100.]   33[100.]   41[100.]  49[100.]  57[100.]    65[100.]   73[100.]   81[100.]   89[100.]   97[100.]  105[100.] 113[100.] 121[100.]
    2[100.]   10[100.]   18[100.]   26[100.]   34[100.]   42[100.]  50[100.]  58[100.]    66[100.]   74[100.]   82[100.]   90[100.]   98[100.]  106[100.] 114[100.] 122[100.]
    3[100.]   11[100.]   19[100.]   27[100.]   35[100.]   43[100.]  51[100.]  59[100.]    67[100.]   75[100.]   83[100.]   91[100.]   99[100.]  107[100.] 115[100.] 123[100.]
    4[100.]   12[100.]   20[100.]   28[100.]   36[100.]   44[100.]  52[100.]  60[100.]    68[100.]   76[100.]   84[100.]   92[100.]  100[100.]  108[100.] 116[100.] 124[100.]
    5[100.]   13[100.]   21[100.]   29[100.]   37[100.]   45[100.]  53[100.]  61[100.]    69[100.]   77[100.]   85[100.]   93[100.]  101[100.]  109[100.] 117[100.] 125[100.]
    6[100.]   14[100.]   22[100.]   30[100.]   38[100.]   46[100.]  54[100.]  62[100.]    70[100.]   78[100.]   86[100.]   94[100.]  102[100.]  110[100.] 118[100.] 126[100.]
    7[100.]   15[100.]   23[100.]   31[100.]   39[100.]   47[100.]  55[100.]  63[100.]    71[100.]   79[100.]   87[100.]   95[100.]  103[100.]  111[100.] 119[100.] 127[100.]
  Mem[|||||||||||||||||||                                              206G/1008G]   Tasks: 185, 776 thr; 128 running
  Swp[                                                                   0K/8.00G]   Load average: 128.02 126.46 104.98
                                                                                     Uptime: 05:09:33

    PID USER       PRI  NI  VIRT   RES   SHR S CPU%▽MEM%   TIME+  Command
```

Figure 35. % Avg GPU utilization when running medium HPGMG Dataset on nodes w/ 1 NVIDIA A100-80G GPU

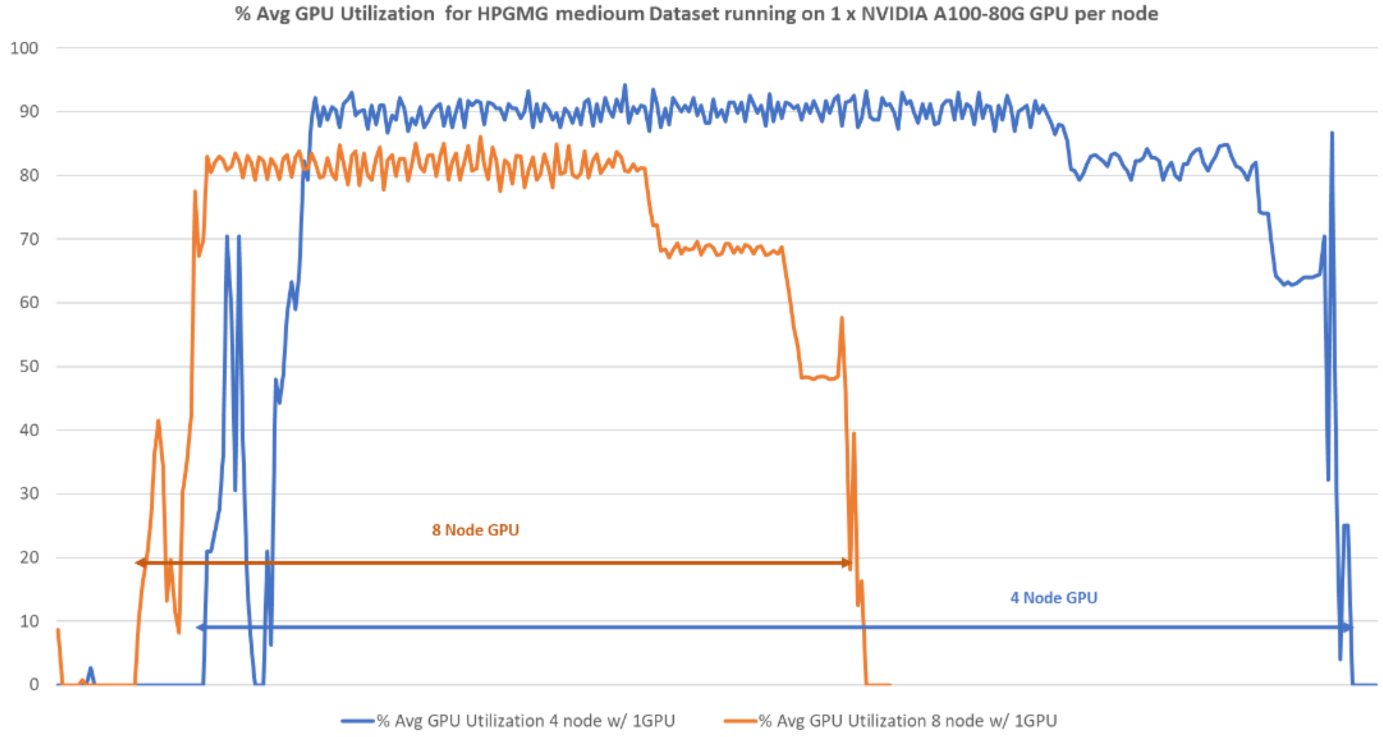


Figure 36. % Avg GPU utilization when running medium HPGMG Dataset on nodes w/ 2 NVIDIA A100-80G GPU

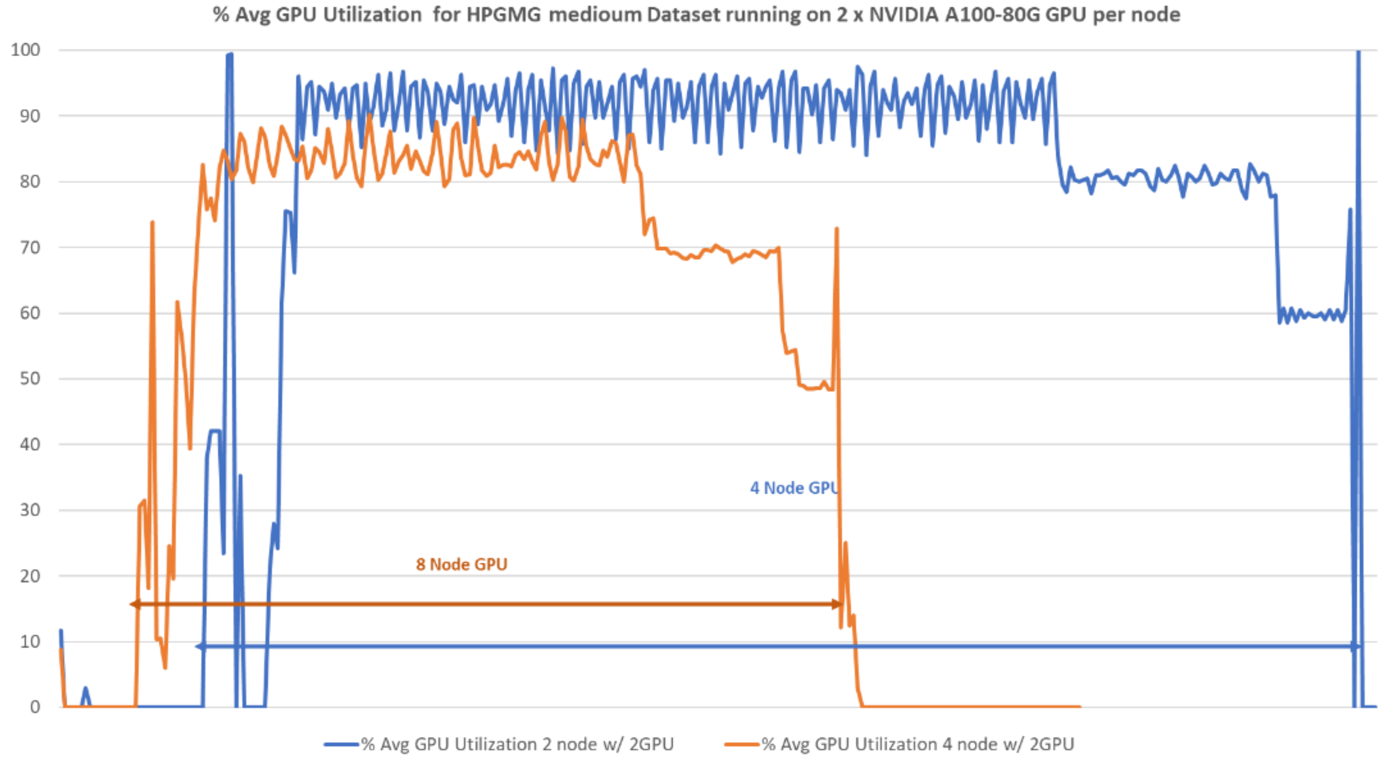


Figure 37. % Avg GPU memory utilization when running medium HPGMG Dataset on nodes w/ 1 NVIDIA A100-80G GPU

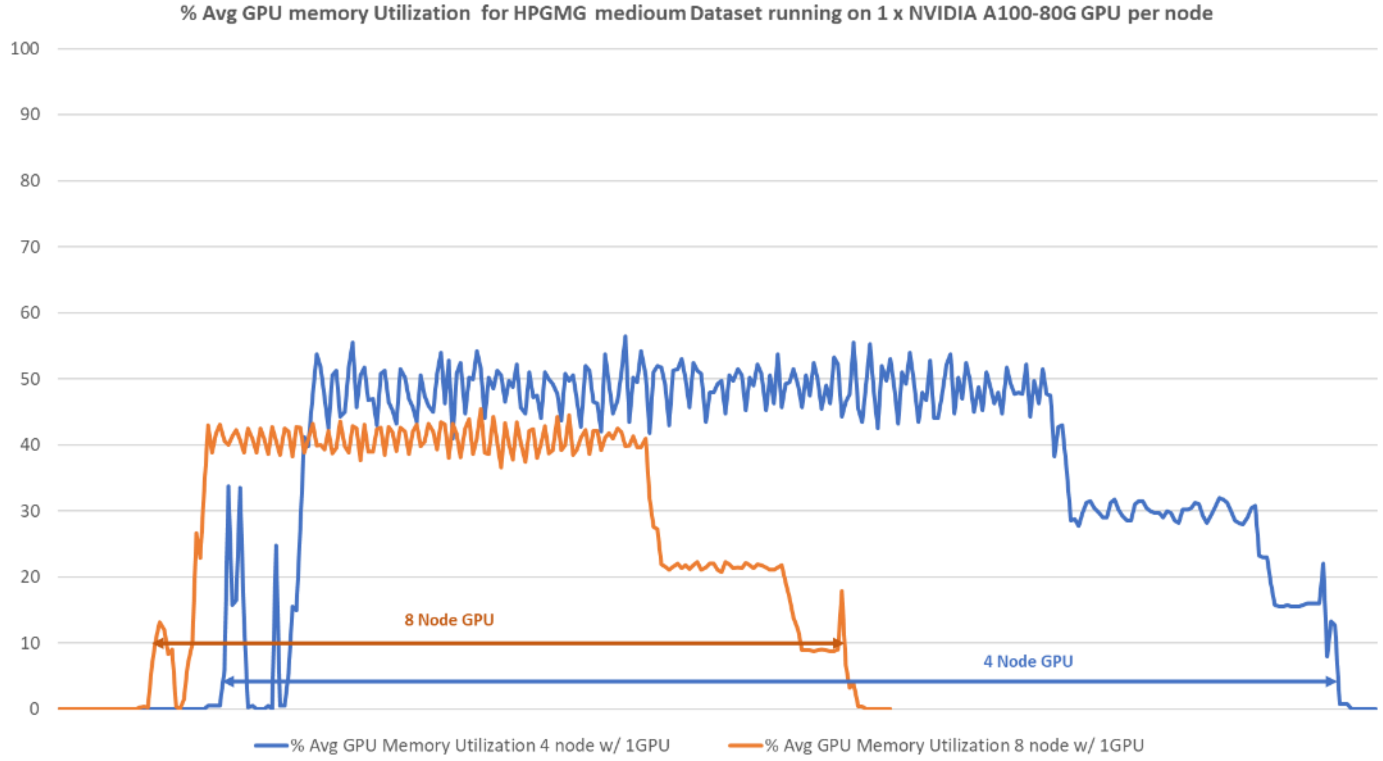


Figure 38. % Avg GPU memory utilization when running medium HPGMG Dataset on nodes w/ 2 NVIDIA A100-80G GPU

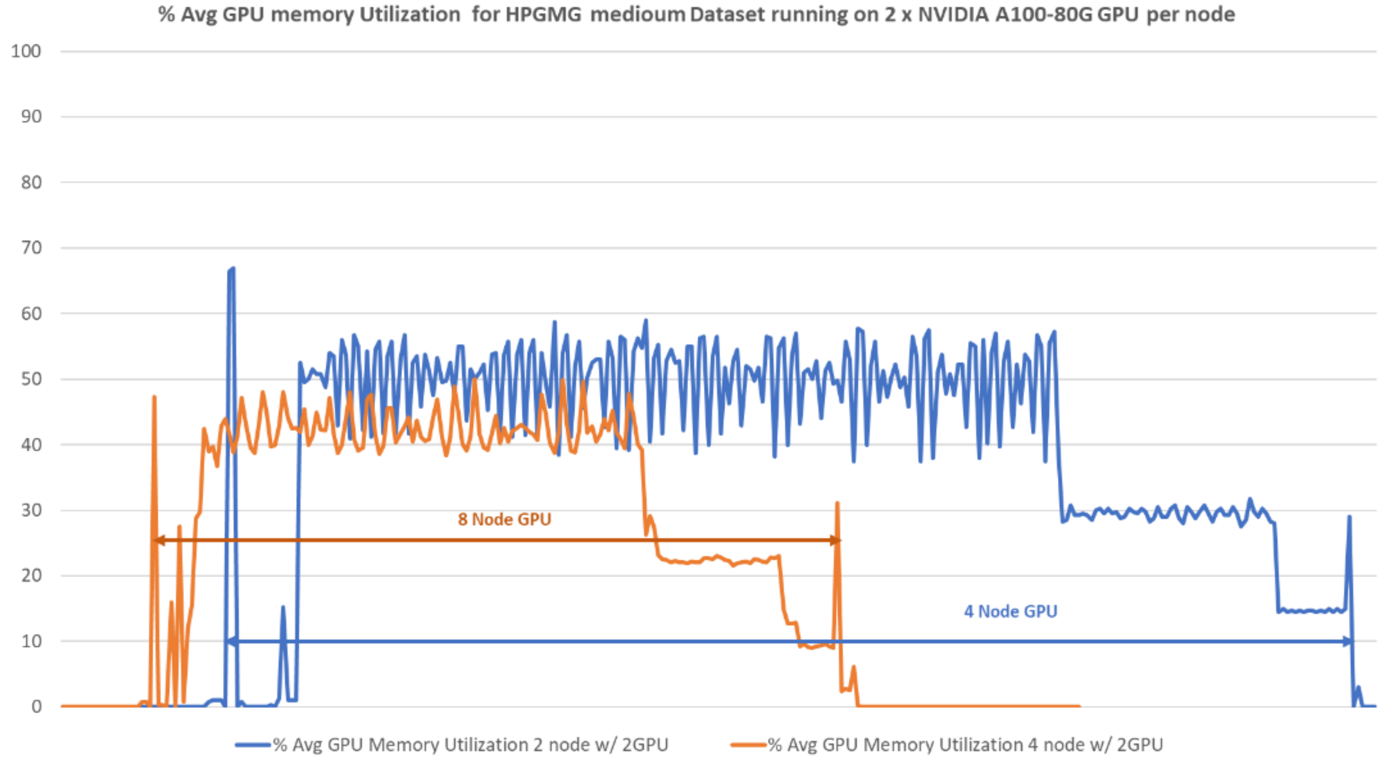
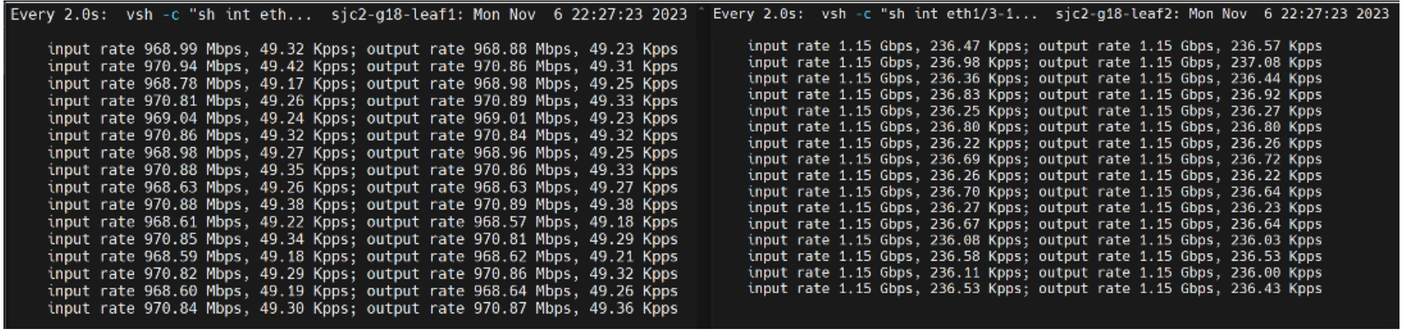


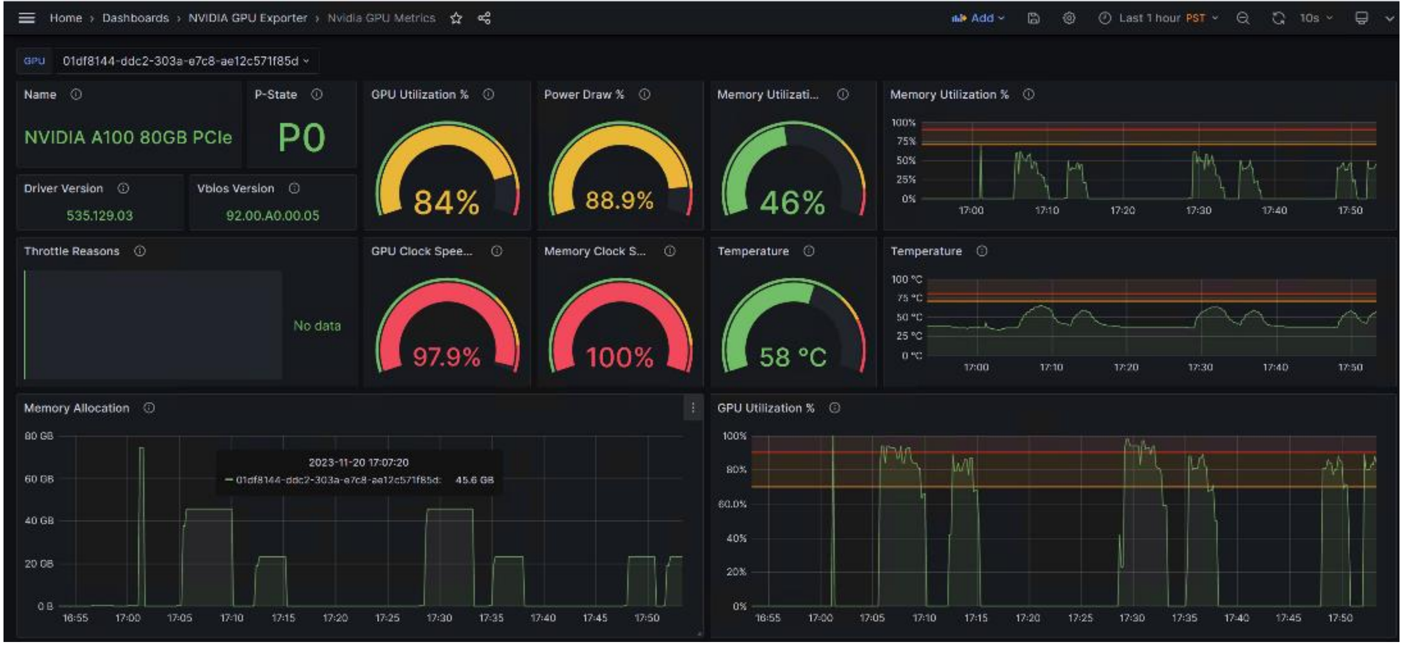
Figure 39. **Sample % Avg network utilization when running medium HPGMG Dataset on 8 node w/ 1 x A100-80G GPU per node**



```
Every 2.0s:  vsh -c "sh int eth...  sjc2-g18-leaf1: Mon Nov  6 22:27:23 2023

    input rate 968.99 Mbps, 49.32 Kpps; output rate 968.88 Mbps, 49.23 Kpps
    input rate 970.94 Mbps, 49.42 Kpps; output rate 970.86 Mbps, 49.31 Kpps
    input rate 968.78 Mbps, 49.17 Kpps; output rate 968.98 Mbps, 49.25 Kpps
    input rate 970.81 Mbps, 49.26 Kpps; output rate 970.89 Mbps, 49.33 Kpps
    input rate 969.04 Mbps, 49.24 Kpps; output rate 969.01 Mbps, 49.23 Kpps
    input rate 970.86 Mbps, 49.32 Kpps; output rate 970.84 Mbps, 49.32 Kpps
    input rate 968.98 Mbps, 49.27 Kpps; output rate 968.96 Mbps, 49.25 Kpps
    input rate 970.88 Mbps, 49.35 Kpps; output rate 970.86 Mbps, 49.33 Kpps
    input rate 968.63 Mbps, 49.26 Kpps; output rate 968.63 Mbps, 49.27 Kpps
    input rate 970.88 Mbps, 49.38 Kpps; output rate 970.89 Mbps, 49.38 Kpps
    input rate 968.61 Mbps, 49.22 Kpps; output rate 968.57 Mbps, 49.18 Kpps
    input rate 970.85 Mbps, 49.34 Kpps; output rate 970.81 Mbps, 49.29 Kpps
    input rate 968.59 Mbps, 49.18 Kpps; output rate 968.62 Mbps, 49.21 Kpps
    input rate 970.82 Mbps, 49.29 Kpps; output rate 970.86 Mbps, 49.32 Kpps
    input rate 968.60 Mbps, 49.19 Kpps; output rate 968.64 Mbps, 49.26 Kpps
    input rate 970.84 Mbps, 49.30 Kpps; output rate 970.87 Mbps, 49.36 Kpps
```

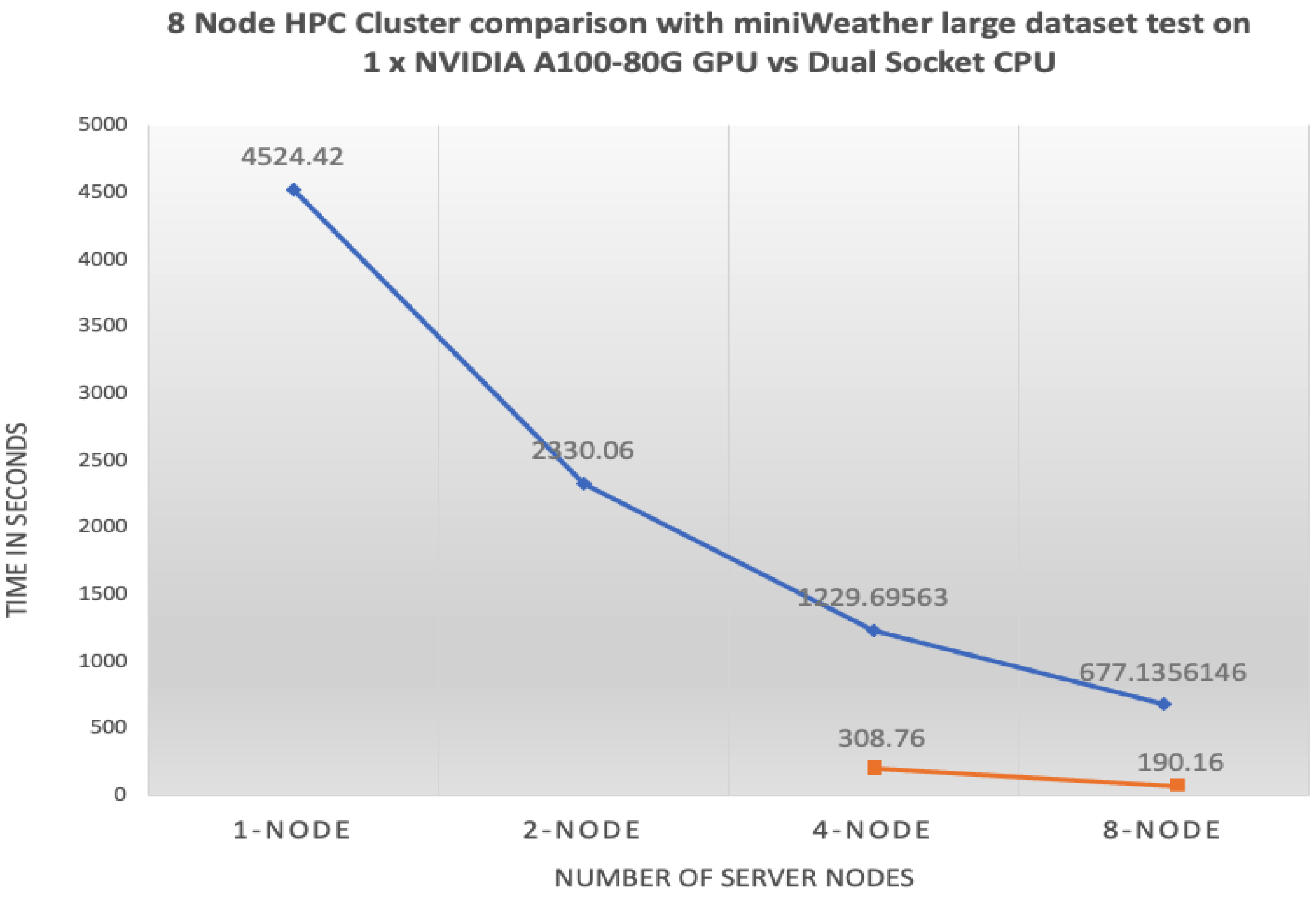
```
Every 2.0s:  vsh -c "sh int eth1/3-1...  sjc2-g18-leaf2: Mon Nov  6 22:27:23 2023

    input rate 1.15 Gbps, 236.47 Kpps; output rate 1.15 Gbps, 236.57 Kpps
    input rate 1.15 Gbps, 236.98 Kpps; output rate 1.15 Gbps, 237.08 Kpps
    input rate 1.15 Gbps, 236.36 Kpps; output rate 1.15 Gbps, 236.44 Kpps
    input rate 1.15 Gbps, 236.83 Kpps; output rate 1.15 Gbps, 236.92 Kpps
    input rate 1.15 Gbps, 236.25 Kpps; output rate 1.15 Gbps, 236.27 Kpps
    input rate 1.15 Gbps, 236.80 Kpps; output rate 1.15 Gbps, 236.80 Kpps
    input rate 1.15 Gbps, 236.22 Kpps; output rate 1.15 Gbps, 236.26 Kpps
    input rate 1.15 Gbps, 236.69 Kpps; output rate 1.15 Gbps, 236.72 Kpps
    input rate 1.15 Gbps, 236.26 Kpps; output rate 1.15 Gbps, 236.22 Kpps
    input rate 1.15 Gbps, 236.70 Kpps; output rate 1.15 Gbps, 236.64 Kpps
    input rate 1.15 Gbps, 236.27 Kpps; output rate 1.15 Gbps, 236.23 Kpps
    input rate 1.15 Gbps, 236.67 Kpps; output rate 1.15 Gbps, 236.64 Kpps
    input rate 1.15 Gbps, 236.08 Kpps; output rate 1.15 Gbps, 236.03 Kpps
    input rate 1.15 Gbps, 236.58 Kpps; output rate 1.15 Gbps, 236.53 Kpps
    input rate 1.15 Gbps, 236.11 Kpps; output rate 1.15 Gbps, 236.00 Kpps
    input rate 1.15 Gbps, 236.53 Kpps; output rate 1.15 Gbps, 236.43 Kpps
```

Figure 40. **Sample Grafana dashboard showing GPU statistics**



Observations

Figure 41. 8 Node HPC Cluster comparison with HPGMG medium dataset test on 1 x NVIDIA A100-80G GPU vs Dual Socket CPU



The following observations were made from the test results obtained by running HPGMG medium dataset on the 8 x Cisco UCS C240 M7 node based HPC cluster as defined in this solution study:

- Depends on the workload and dataset size more GPU is required. HPGMG medium dataset consumed.
- The end-end FlexPod HPC cluster as highlighted in this solution scaled linearly whether the cluster test ran by CPU only or w/ GPU.
- Each node resources i.e., compute, storage and network consumed evenly throughout the cluster test.
- Compared to miniWeather and Minisweep test exercise above HPGMG medium dataset which is targeting application area of Cosmology, Astrophysics, Combustion showed 80% GPU utilization and 40% memory utilization.
- Due to the minimum memory required to execute the HPGMG medium dataset was higher than other two dataset we were not able to run the test on 1 GPU or 2 GPU in a single system.
- No CPU cycles were consumed when ran the test on NVIDIA A100-80G GPU.
- Time to complete the test with one GPU per node in an eight-node cluster is 3.5x faster than running the same test on eight-node cluster without GPU.

Conclusion

The amalgamation of High-Performance Computing (HPC) and Artificial Intelligence (AI) represents a powerful synergy that unleashes unprecedented computational capabilities, enabling us to tackle complex and data-intensive challenges with greater speed, accuracy, and efficiency. The combination of CPUs and GPUs with high-speed data fabric with end-end 100GbE network is essential for achieving optimal performance, scalability, and responsiveness.

Here's the importance of each component because it allows for the best of HPC and AI worlds:

- **Diverse Workload Support:** CPUs are essential for handling diverse tasks, including system management, control flow, and sequential processes, making them crucial for both HPC and AI infrastructure.
- **Parallel Processing:** GPUs are vital for parallelizable workloads, such as deep learning and scientific simulations, where their massive parallel processing power accelerates complex calculations.
- **Task Offloading:** Combining CPUs and GPUs allows for intelligent task distribution, enabling CPUs to offload parallel workloads to GPUs for enhanced efficiency and speed.
- **Optimal Performance:** Together, CPUs and GPUs offer a balanced and high-performance computing environment, capable of handling a wide range of workloads seamlessly.
- **Energy Efficiency:** CPUs are generally more power-efficient for certain tasks and are important for overall system management. GPUs, on the other hand, excel in computational throughput. Combining the two can lead to better energy efficiency and performance.
- **Fast data pipeline:** Data intensive workloads of HPC and AI often involve large datasets. A 100GbE network provides an extensive data pipeline, ensuring efficient data exchange between CPUs, GPUs, storage rapidly and without bottlenecks, improving overall performance.
- **Low Latency:** Low-latency communication is crucial for HPC and AI workloads, as it reduces the time spent waiting for data transfers and results in faster overall processing.
- **Scalability:** High-speed networking supports the scaling of resources, enabling you to add more compute nodes, GPUs, or storage as needed for growing workloads.
- **Resource Utilization:** CPUs and GPUs are fully utilized as data moves quickly between them, minimizing idle times and maximizing the overall system efficiency.

In this solution study, we tested various application (use cases) targeted for weather simulation (miniWeather), Nuclear Engineering - Radiation Transport (Minisweep), and Cosmology, Astrophysics, Combustion (HPGMG).

We documented recommended tunable parameters to achieve balanced configuration amongst compute, network and storage components and proved near linear scalability of the solution as the size of the cluster grew from 1 to 8 node.

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Acknowledgements

For their support and contribution to the design, validation, and creation of this Cisco Validated Design, the authors would like to thank:

- Arthur Raefsky, Principal Software Engineer, Cisco Systems, Inc.
- Jeff Squyres, Principal Software Engineer, Cisco Systems, Inc.
- Vijay Durairaj, Technical Marketing Engineering, Cisco Systems, Inc.
- Rajendra Yogendra, Technical Marketing Engineering, Cisco Systems, Inc.
- Esteban Marin, Lead Software Engineer, Cisco Systems, Inc.
- Bobby Oomen, Sr. Manager FlexPod Solutions, NetApp

Appendix

This appendix contains the following:

- Appendix A – Bill of Materials
- Appendix B – Cisco Nexus 9000 Switch Configuration
- Appendix C – NetApp AFF A400 Storage Configuration
- Appendix D – Monitor GPU Utilization
- Appendix E – References used in this guide
- Appendix F – Recommended for you

Appendix A – Bill of Materials

Cisco UCS C240 M7

Table 10 lists the bill of materials for the Cisco UCS C240 M7.

Cisco Nexus 93600CD-GX

Table 11 lists the bill of materials for the Cisco Nexus 93600CD-GX.

Table 10. Bill of Material for Cisco UCS C240 M7

Part ID	Description	Qty
UCS-M7-MLB	UCS M7 RACK MLB	1
DC-MGT-SAAS	Cisco Intersight SaaS	1
DC-MGT-IS-SAAS-ES	Infrastructure Services SaaS/CVA - Essentials	8
SVS-DCM-SUPT-BAS	Basic Support for DCM	1
DC-MGT-UCSC-1S	UCS Central Per Server - 1 Server License	8
UCSC-C240-M7SX	UCS C240M7 Rack w/oCPU, mem, drv, 2Uw24SFF HDD/SSD backplane	8
UCSC-GPUAD-C240M7	GPU AIR DUCT FOR C240M7	8
UCS-M2-960G-D	960GB M.2 SATA Micron G2 SSD	16
UCS-M2-HWRAID-D	Cisco Boot optimized M.2 Raid controller	8
UCSX-TPM-002C-D	TPM 2.0, TCG, FIPS140-2, CC EAL4+ Certified, for servers	8
UCSC-RAIL-D	Ball Bearing Rail Kit for C220 & C240 M7 rack servers	8

Part ID	Description	Qty
CIMC-LATEST-D	IMC SW (Recommended) latest release for C-Series Servers.	8
UCSC-HSLP-C220M7	UCS C220 M7 Heatsink for & C240 GPU Heatsink	16
UCSC-BBLKD-M7	UCS C-Series M7 SFF drive blanking panel	176
UCS-DDR5-BLK	UCS DDR5 DIMM Blanks	128
UCSC-RISAB-24XM7	UCS C-Series M7 2U Air Blocker GPU only	8
CBL-FNVME-C240M7	C240M7 NVMe CABLE, MB P-4 to BP (NVMe 3-4)	8
UCSC-M2EXT-240-D	C240M7 2U M.2 Extender board	8
UCS-P100CBL-240-D	C240M7 NVIDIA P100 /A100 /A40 / A16 / A30 Cable	16
UCS-CPU-I6448H	Intel I6448H 2.4GHz/250W 32C/60MB DDR5 4800MT/s	16
UCS-MRX64G2RE1	64GB DDR5-4800 RDIMM 2Rx4 (16Gb)	128
UCSC-RIS1C-24XM7	UCS C-Series M7 2U Riser 1C PCIe Gen5 (2x16)	8
UCSC-RIS2C-24XM7	UCS C-Series M7 2U Riser 2C PCIe Gen5 (2x16) (CPU2)	8
UCSC-RIS3B-24XM7	UCS C-Series M7 2U Riser 3B support rear SAS & NVMe Drives	8
UCS-NVME4-1920-D	1.9TB 2.5in U.2 15mm P5520 Hg Perf Med End NVMe	32
UCSC-P-MCD100GF-D	Cisco-MLNX MCX623106AC-CDAT 2x100GbE QSFP56 PCIe NIC	8
UCSC-GPUA100-80-D	TESLA A100, PASSIVE, 300W, 80GB	8
NV-GRID-OPT-OUT-D	NVIDIA GRID SW OPT-OUT	8
UCSC-GPUA100-80-D	TESLA A100, PASSIVE, 300W, 80GB	8
NV-GRID-OPT-OUT-D	NVIDIA GRID SW OPT-OUT	8
UCSC-PSU1-2300W-D	Cisco UCS 2300W AC Power Supply for Rack Servers Titanium	16

Part ID	Description	Qty
CAB-C19-CBN	Cabinet Jumper Power Cord, 250 VAC 16A, C20-C19 Connectors	16
UCS-SID-INFR-UNK-D	Unknown	8
UCS-SID-WKL-UNK-D	Unknown	8
CON-OSP-UCSCPC34	SNTC-24X7X4OS UCS C240M7 Rack w/oCPU, mem, drv, 2Uw24S	8

Table 11. Bill of Material for Cisco Nexus 93600CD-GX

Part ID	Description	Qty
N9K-C93600CD-GX	Nexus 9300 with 28p 100G and 8p 400G	2
NXK-AF-PI	Dummy PID for Airflow Selection Port-side Intake	2
MODE-NXOS	Mode selection between ACI and NXOS	2
NXOS-9.3.10	Nexus 9500, 9300, 3000 Base NX-OS Software Rel 9.3.10	2
NXK-ACC-KIT-1RU	Nexus 3K/9K Fixed Accessory Kit, 1RU front and rear removal	2
NXA-FAN-35CFM-PI	Nexus Fan, 35CFM, port side intake airflow	12
NXA-PAC-1100W-PI2	Nexus AC 1100W PSU - Port Side Intake	4
CAB-C13-C14-AC	Power cord, C13 to C14 (recessed receptacle), 10A	4
C1-SUBS-OPTOUT	OPT OUT FOR " Default" DCN Subscription Selection	2
CON-SNC-N9KC936G	SNTC-NCD Nexus 9300 with 28p 100G and 8p 400G	2

Appendix B – Cisco Nexus 9000 Switch Configuration

Procedure 1. Virtual Port-Channel (vPC) Configuration

A port channel bundles individual links into a channel group to create a single logical link that provides the aggregate bandwidth of up to eight physical links. If a member port within a port channel fails, traffic previously carried over the failed link switches to the remaining member ports within the port channel. Port channeling also load balances traffic across these physical interfaces. The port channel stays operational as long as at least one physical interface within the port channel is operational. Using port channels, Cisco NX-OS provides wider bandwidth, redundancy, and load balancing across the channels.

In the Cisco Nexus Switch topology, a single vPC feature is enabled to provide HA, faster convergence in the event of a failure, and greater throughput. The Cisco Nexus vPC configurations with the vPC domains and corresponding vPC names and IDs for Oracle Database Servers are listed in Table 12.

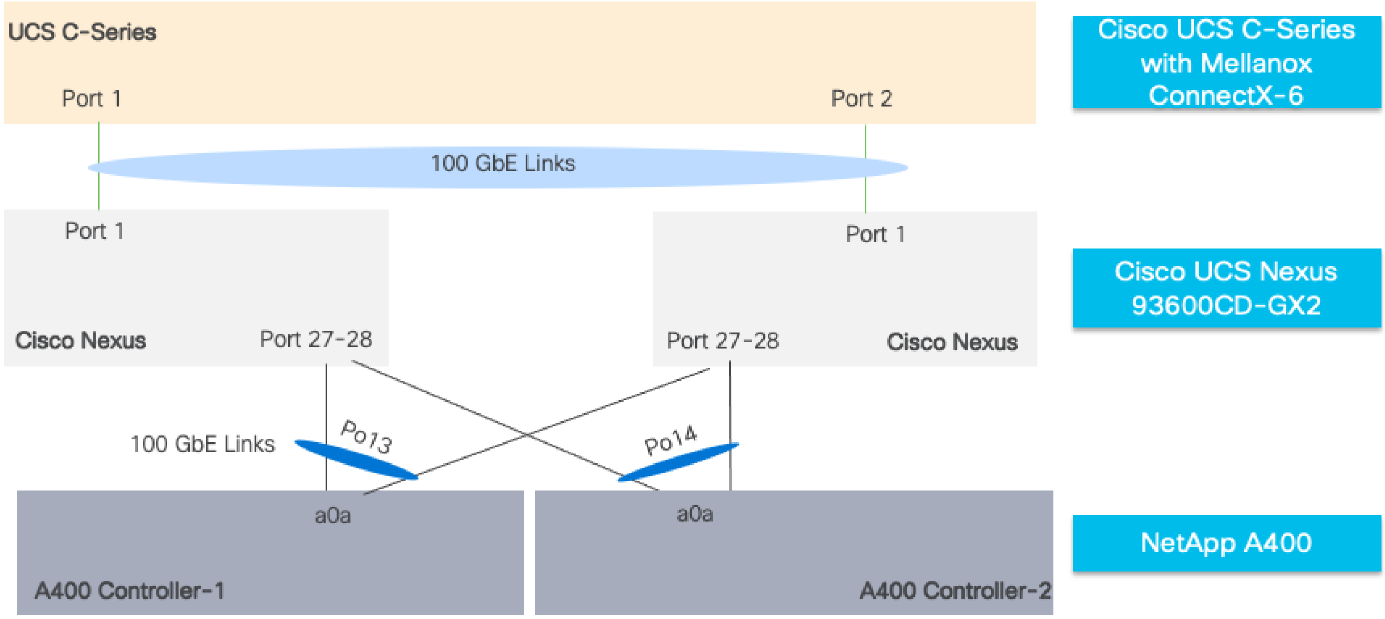
Table 12. vPC Summary

vPC Domain	vPC Name	vPC ID
18	Peer-Link	1
18	vPC Storage A	13
18	vPC Storage B	14

As listed in Table 12, a single vPC domain with Domain ID 1 is created across two Nexus switches to define vPC members to carry specific VLAN network traffic. In this topology, we defined a total number of 11 vPCs.

vPC ID 1 is defined as Peer link communication between the two Cisco Nexus switches. vPC IDs 13 and 14 are configured between both Cisco Nexus Switches and NetApp Storage Controller. vPC IDs 71-78 are configured between Mellanox ConnectX-6 Ehternet network interface card (NIC) ports on each Cisco UCS C240 M7 server connecting to Cisco Nexus Switches.

Figure 42. **Virtual Port-Channel on Cisco Nexus Switches**



Procedure 2. Create Virtual Port-Channel Domain

Step 1. Login as admin user into the Cisco Nexus A switch, run the following commands:

```
vpc domain 18
  peer-keepalive destination 10.29.148.12 source 10.29.148.11
  delay restore 150
  peer-gateway
  auto-recovery
  ip arp synchronize
  role priority 10
```

Step 2. Login as admin user into the Cisco Nexus B switch, run the following commands:

```
vpc domain 18
  peer-keepalive destination 10.29.148.11 source 10.29.148.12
delay restore 150
  peer-gateway
  auto-recovery
  ip arp synchronize
  role priority 20
interface Ethernet1/33
  description Peer link connected to Leaf3-Spine1
  switchport mode trunk
  switchport trunk allowed vlan 1,110,160,248
  priority-flow-control mode on
interface Ethernet1/34
  description Peer link connected to Leaf3-Spine1
  switchport mode trunk
  switchport trunk allowed vlan 1,110,160,248
  priority-flow-control mode on
interface Ethernet1/35
  description Peer link connected to Leaf3-Spine2
  switchport mode trunk
  switchport trunk allowed vlan 1,110,160,248
  priority-flow-control mode on
  interface Ethernet1/36
  description Peer link connected to Leaf3-Spine2
  switchport mode trunk
  switchport trunk allowed vlan 1,110,160,248
```

Step 1. Repeat this procedure on Cisco Nexus B switch.

Procedure 3. Create Virtual Port-Channel between Cisco Nexus and NetApp Storage

Step 1. Login as admin user into the Cisco Nexus A switch, run the following commands:

```
interface port-channel13
  description PC-NetApp-A
  switchport mode trunk
  switchport trunk allowed vlan 110,160
  spanning-tree port type edge trunk
  mtu 9216
  service-policy type qos input QOS_MARKING
  vpc 13
  no shutdown
interface port-channel14
  description PC-NetApp-B
  switchport mode trunk
  switchport trunk allowed vlan 110,160
  spanning-tree port type edge trunk
  mtu 9216
  service-policy type qos input QOS_MARKING
  vpc 14
  no shutdown
interface Ethernet1/27
  description FlexPod-A400-CT1:e5a
  switchport mode trunk
  switchport trunk allowed vlan 110,160
  mtu 9216
  channel-group 13 mode active
  no shutdown
interface Ethernet1/28
  description FlexPod-A400-CT2:e5a
  switchport mode trunk
  switchport trunk allowed vlan 110,160
  mtu 9216
  channel-group 14 mode active

  no shutdown
```

Step 2. Repeat this procedure on Cisco Nexus B switch for FlexPod-A400-CT1:e5b and FlexPod-A400-CT2:e5b

Procedure 4. Create Virtual Port-Channel between Cisco UCS C Series server and Cisco Nexus Switches

Step 1. Login as admin user into the Cisco Nexus A switch, run the following commands:

```
interface Ethernet1/3-10

switchport mode trunk

switchport trunk allowed vlan 110

priority-flow-control mode on

spanning-tree port type edge trunk

mtu 9216

service-policy type qos input QOS_MARKING

no shutdown
```

Step 2. Repeat this procedure on the Cisco Nexus A switch for all C-Series rack servers with Mellanox ConnectX6-DX Ethernet NIC connected to Nexus 93600CD-GX

Step 3. Repeat this procedure on the Cisco Nexus B switch.

Appendix C – NetApp AFF A400 Configuration

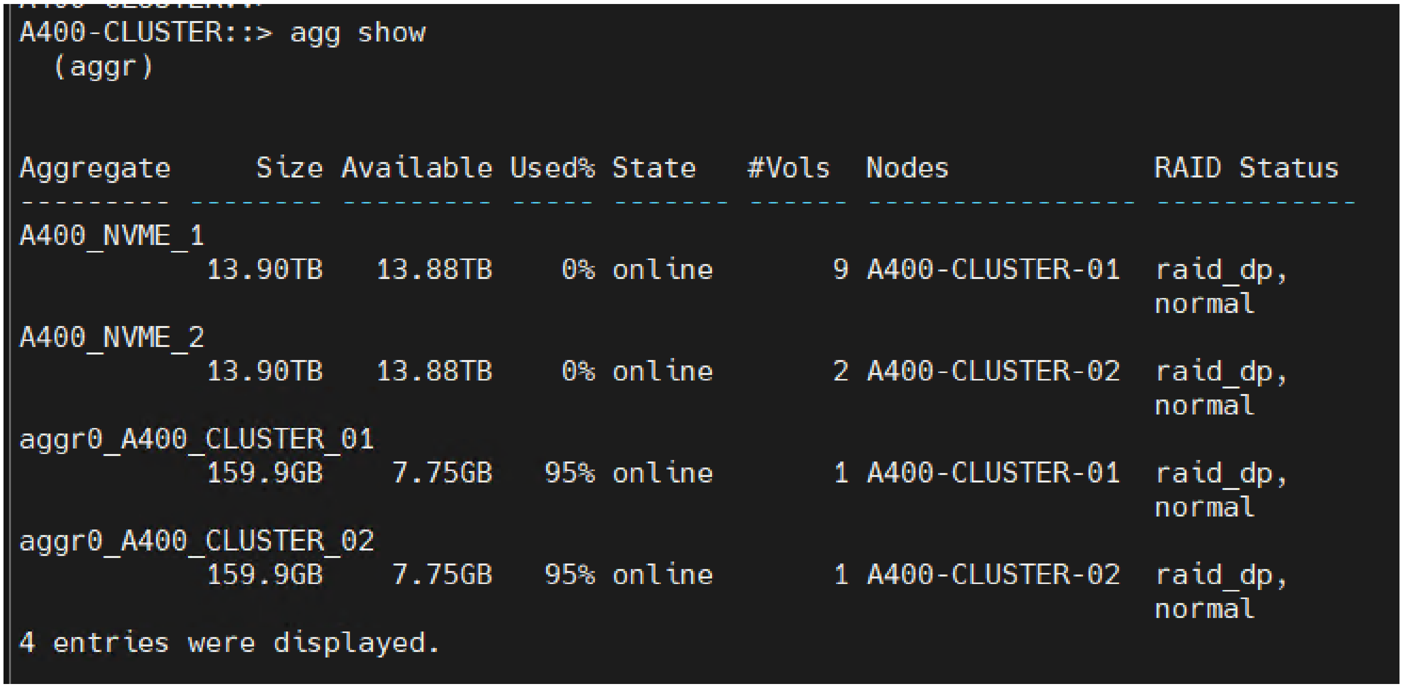
NetApp ONTAP 9.12.1

Procedure 1. Complete Configuration Worksheet

Before running the setup script, complete the Cluster setup worksheet in the NetApp ONTAP 9 Documentation Center. You must have access to the NetApp Support site to open the cluster setup worksheet.

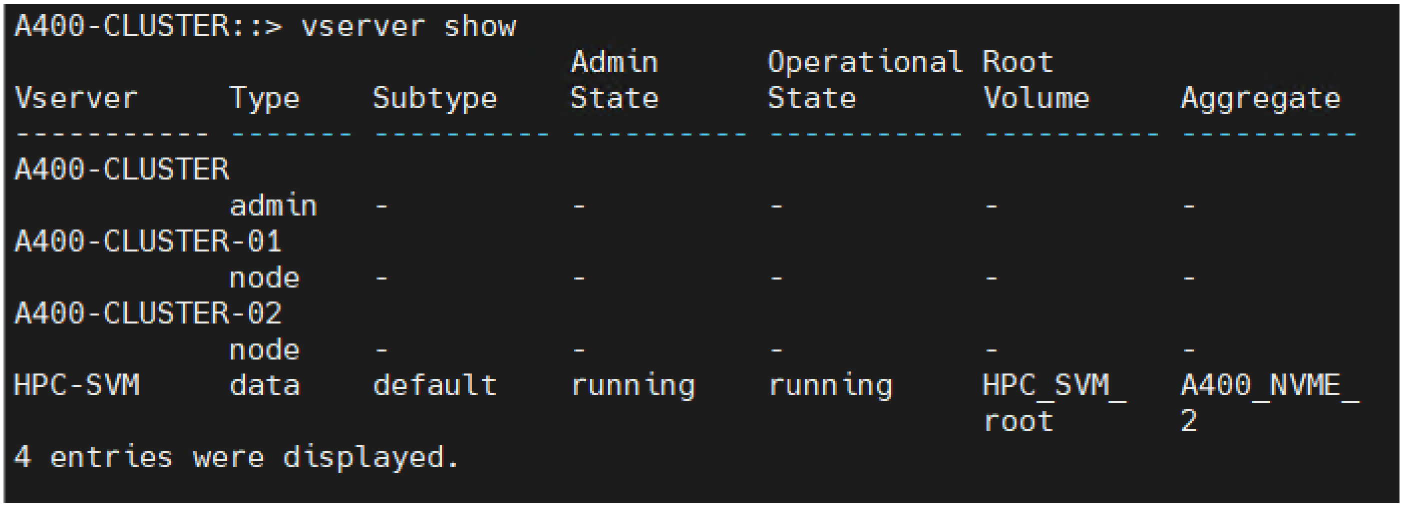
> **Tech tip**
>
> It is beyond the scope of this document to explain the detailed information about the NetApp storage connectivity and infrastructure configuration. For installation and setup instruction for the NetApp AFF A400 System, go to: https://docs.netapp.com/us-en/ontap-systems/a400/index.html
>
> For more information, visit FlexPod Design Guides: https://www.cisco.com/c/en/us/solutions/design-zone/data-center-design-guides/flexpod-design-guides.html

Step 1. For all the nodes data storage as part of the HPC cluster deployment, two large data aggregates (one aggregate on each storage node) were configured as shown below:



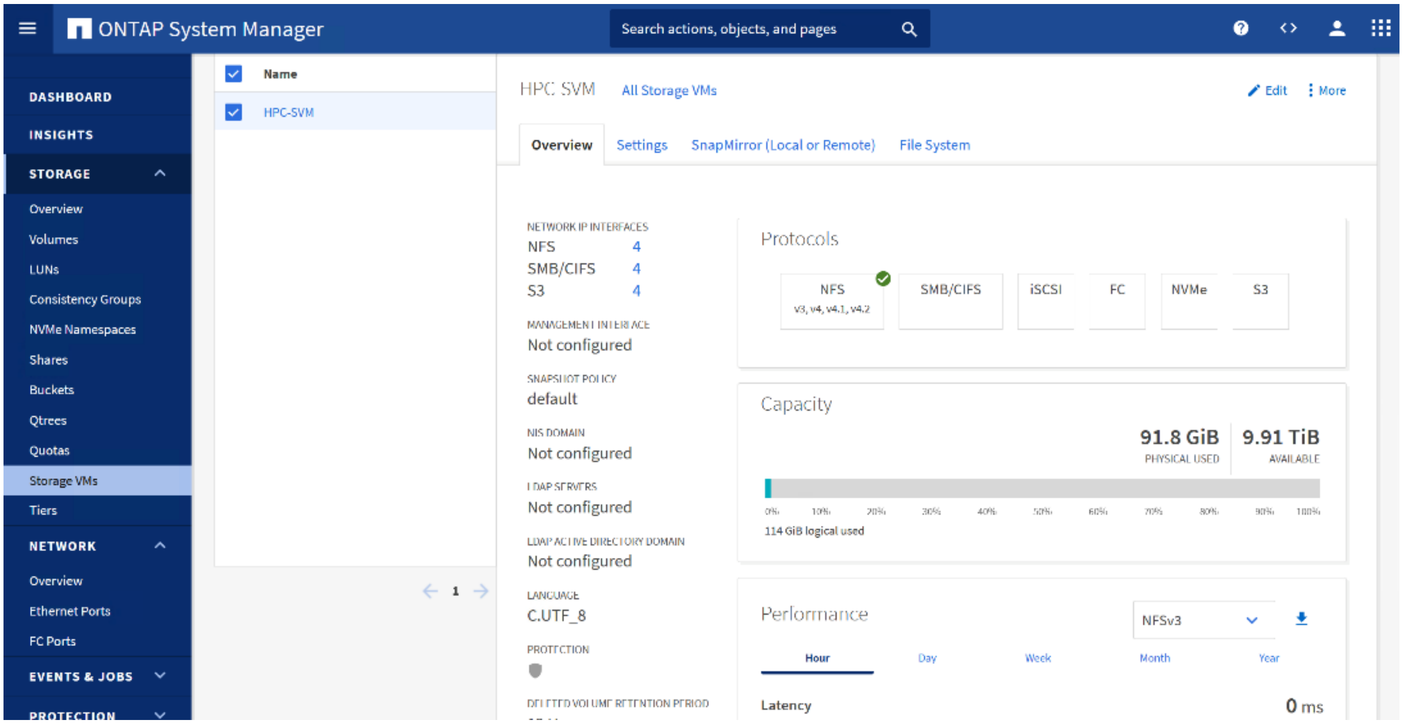
```
A400-CLUSTER::> agg show
  (aggr)


Aggregate     Size Available Used% State   #Vols  Nodes            RAID Status
--------- -------- --------- ----- ------- ------ ---------------- ------------
A400_NVME_1
           13.90TB   13.88TB    0% online       9 A400-CLUSTER-01  raid_dp,
                                                                   normal
A400_NVME_2
           13.90TB   13.88TB    0% online       2 A400-CLUSTER-02  raid_dp,
                                                                   normal
aggr0_A400_CLUSTER_01
           159.9GB    7.75GB   95% online       1 A400-CLUSTER-01  raid_dp,
                                                                   normal
aggr0_A400_CLUSTER_02
           159.9GB    7.75GB   95% online       1 A400-CLUSTER-02  raid_dp,
                                                                   normal
4 entries were displayed.
```

Step 2. The screenshot below shows the Storage VMs (formally known as vserver) configured as “HPC-SVM” for this solution:



```
A400-CLUSTER::> vserver show
                               Admin      Operational Root
Vserver     Type    Subtype    State      State       Volume     Aggregate
----------- ------- ---------- ---------- ----------- ---------- ----------
A400-CLUSTER
            admin   -          -          -           -          -
A400-CLUSTER-01
            node    -          -          -           -          -
A400-CLUSTER-02
            node    -          -          -           -          -
HPC-SVM     data    default    running    running     HPC_SVM_   A400_NVME_
                                                      root       2
4 entries were displayed.
```

Step 3. The SVM named “HPC-SVM” was configured to carry all NFS traffic for this HPC Data Analytics solution.



NETWORK IP INTERFACES

NFS	4
SMB/CIFS	4
S3	4

MANAGEMENT INTERFACE
Not configured

SNAPSHOT POLICY
default

NIS DOMAIN
Not configured

LDAP SERVERS
Not configured

LDAP ACTIVE DIRECTORY DOMAIN
Not configured

LANGUAGE
C.UTF_8

PROTECTION

DELETED VOLUME RETENTION PERIOD

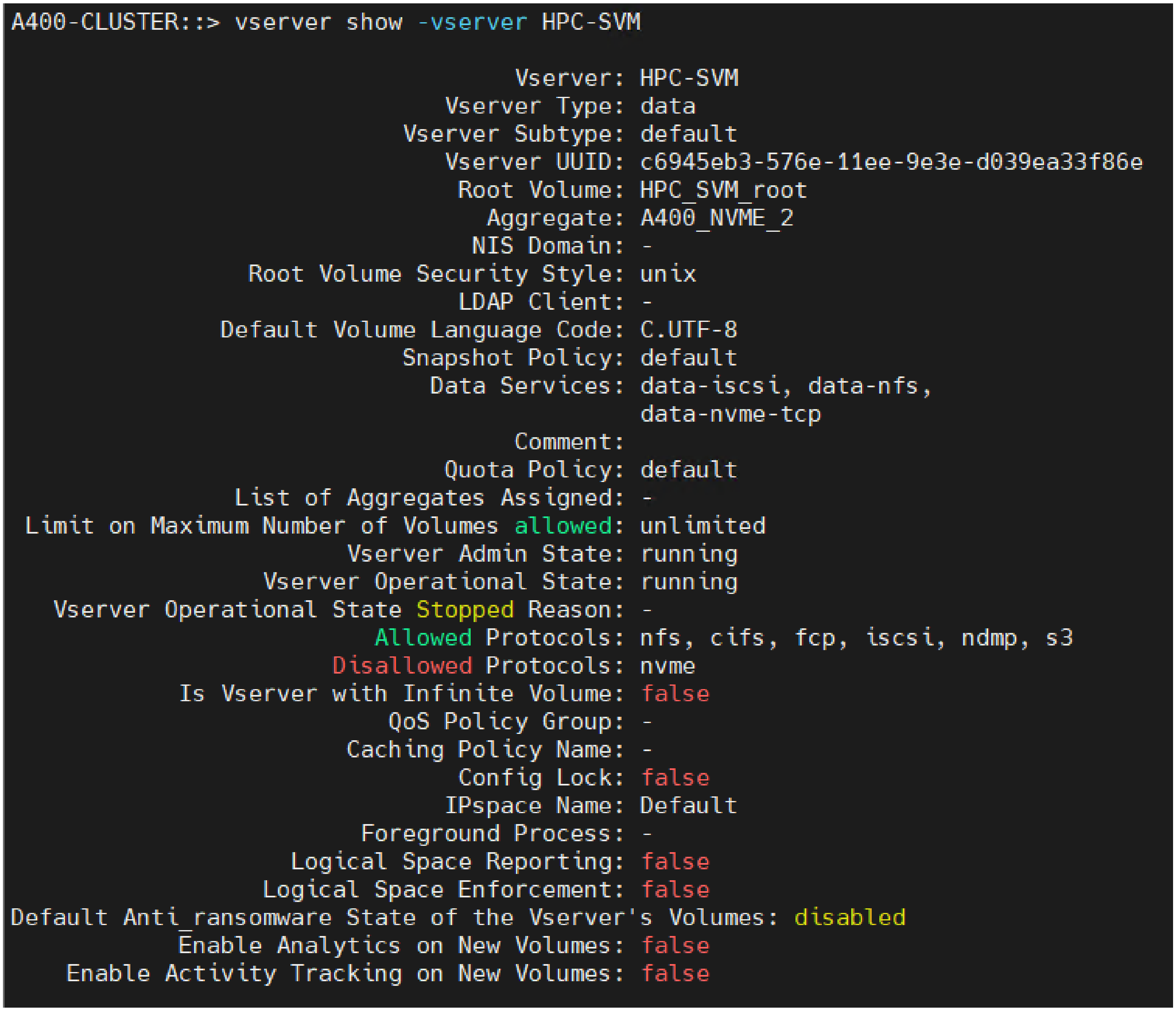
91.8 GiB PHYSICAL USED

9.91 TiB AVAILABLE

114 GiB logical used

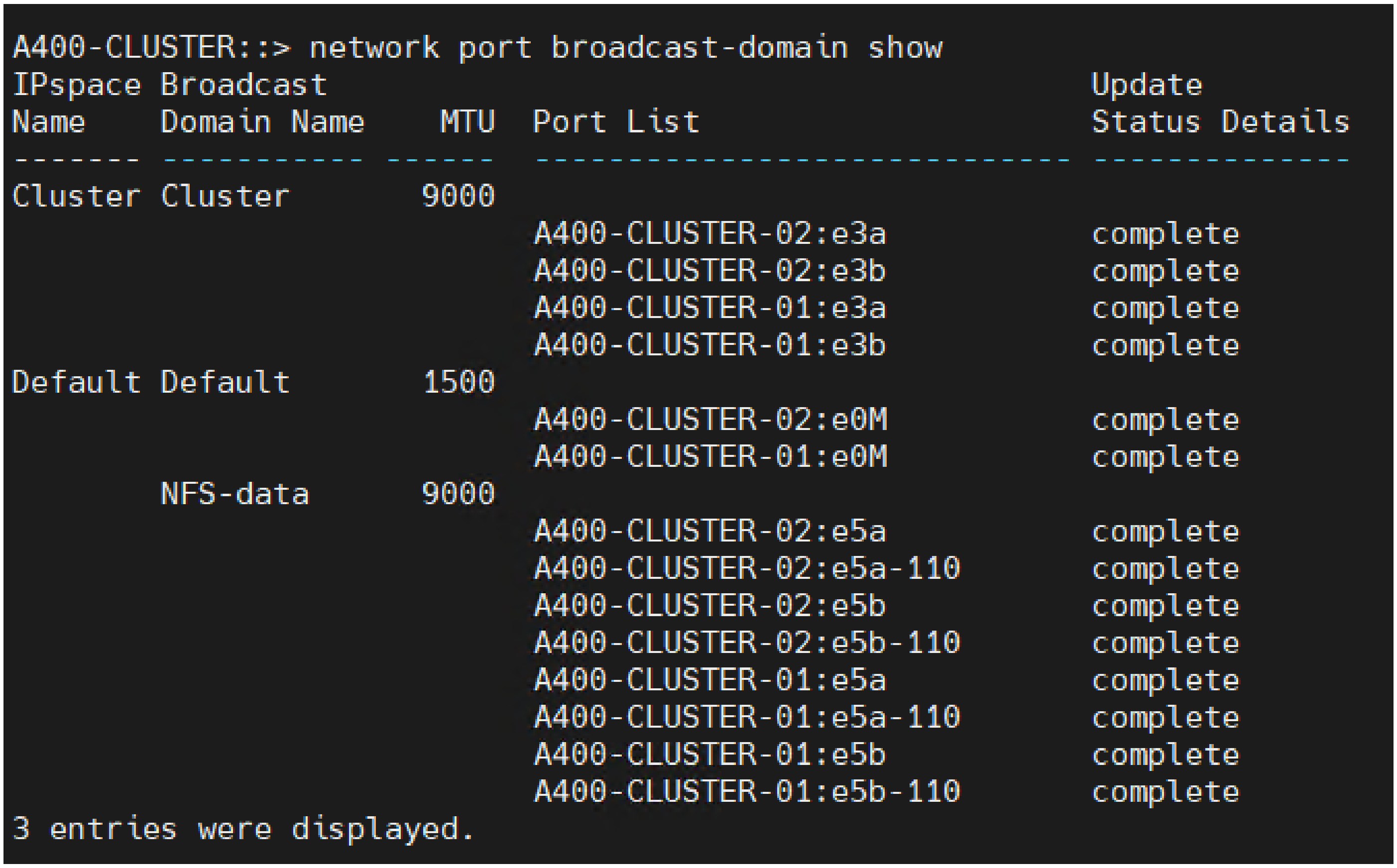
Latency 0 ms

Step 4. Detailed configuration for HPC-SVM is shown below:



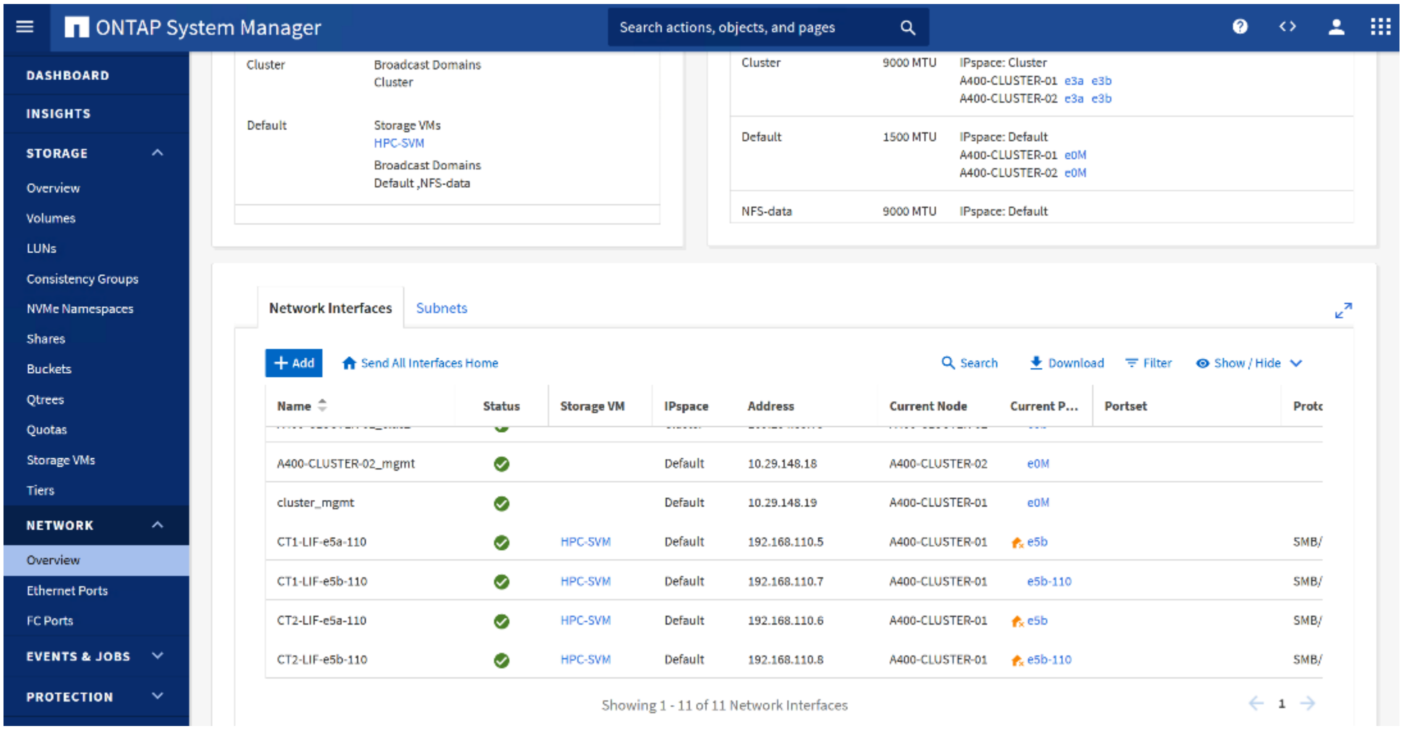
```
A400-CLUSTER::> vserver show -vserver HPC-SVM

                                    Vserver: HPC-SVM
                               Vserver Type: data
                            Vserver Subtype: default
                               Vserver UUID: c6945eb3-576e-11ee-9e3e-d039ea33f86e
                                Root Volume: HPC_SVM_root
                                  Aggregate: A400_NVME_2
                                 NIS Domain: -
                 Root Volume Security Style: unix
                                LDAP Client: -
               Default Volume Language Code: C.UTF-8
                            Snapshot Policy: default
                              Data Services: data-iscsi, data-nfs,
                                             data-nvme-tcp
                                    Comment:
                               Quota Policy: default
                List of Aggregates Assigned: -
 Limit on Maximum Number of Volumes allowed: unlimited
                        Vserver Admin State: running
                  Vserver Operational State: running
   Vserver Operational State Stopped Reason: -
                          Allowed Protocols: nfs, cifs, fcp, iscsi, ndmp, s3
                       Disallowed Protocols: nvme
            Is Vserver with Infinite Volume: false
                           QoS Policy Group: -
                        Caching Policy Name: -
                                Config Lock: false
                               IPspace Name: Default
                         Foreground Process: -
                    Logical Space Reporting: false
                  Logical Space Enforcement: false
Default Anti_ransomware State of the Vserver's Volumes: disabled
            Enable Analytics on New Volumes: false
    Enable Activity Tracking on New Volumes: false
```

Step 5. The broadcast-domain was configured as “NFS-data” with MTU 9000 and assigned to default IPspace as shown below:



```
A400-CLUSTER::> network port broadcast-domain show
IPspace Broadcast                                         Update
Name    Domain Name    MTU  Port List                     Status Details
------- ----------- ------  ----------------------------- --------------
Cluster Cluster       9000
                            A400-CLUSTER-02:e3a           complete
                            A400-CLUSTER-02:e3b           complete
                            A400-CLUSTER-01:e3a           complete
                            A400-CLUSTER-01:e3b           complete
Default Default       1500
                            A400-CLUSTER-02:e0M           complete
                            A400-CLUSTER-01:e0M           complete
        NFS-data      9000
                            A400-CLUSTER-02:e5a           complete
                            A400-CLUSTER-02:e5a-110       complete
                            A400-CLUSTER-02:e5b           complete
                            A400-CLUSTER-02:e5b-110       complete
                            A400-CLUSTER-01:e5a           complete
                            A400-CLUSTER-01:e5a-110       complete
                            A400-CLUSTER-01:e5b           complete
                            A400-CLUSTER-01:e5b-110       complete
3 entries were displayed.
```

Step 6. The following screenshot shows the overview of the network configuration



Cluster	Broadcast Domains Cluster
Default	Storage VMs HPC-SVM Broadcast Domains Default ,NFS-data

Cluster	9000 MTU	IPspace: Cluster A400-CLUSTER-01 e3a e3b A400-CLUSTER-02 e3a e3b
Default	1500 MTU	IPspace: Default A400-CLUSTER-01 e0M A400-CLUSTER-02 e0M
NFS-data	9000 MTU	IPspace: Default

Name	Status	Storage VM	IPspace	Address	Current Node	Current P...	Portset	Protc
A400-CLUSTER-02_mgmt	✓		Default	10.29.148.18	A400-CLUSTER-02	e0M		
cluster_mgmt	✓		Default	10.29.148.19	A400-CLUSTER-01	e0M		
CT1-LIF-e5a-110	✓	HPC-SVM	Default	192.168.110.5	A400-CLUSTER-01	e5b		SMB/
CT1-LIF-e5b-110	✓	HPC-SVM	Default	192.168.110.7	A400-CLUSTER-01	e5b-110		SMB/
CT2-LIF-e5a-110	✓	HPC-SVM	Default	192.168.110.6	A400-CLUSTER-01	e5b		SMB/
CT2-LIF-e5b-110	✓	HPC-SVM	Default	192.168.110.8	A400-CLUSTER-01	e5b-110		SMB/

Showing 1 - 11 of 11 Network Interfaces

Step 7. The export policy “default” was configured and added rules with clients subnets for UNIX systems to allow the NFSv4 protocol as shown below:

Step 8. Enable Cisco Discovery protocol.

```
A400-CLUSTER::> node run -node * options cdpd.enable on
```

Step 9. Enable Link-Layer Discovery protocol on all ethernet ports:

```
A400-CLUSTER::> node run * options lldp.enable on
```

Appendix D – Monitor GPU Utilization

To monitor GPU utilization of our HPC cluster node while running different application; we created local Grafana dashboard for our solution test setup. This is for education purposes and recommended for lab/PoC only.

Prerequisites

1. Install and configure Grafana open-source server.
2. Verify Grafana server is running:

```
$ sudo systemctl status grafana-server
```

Install Prometheus and configure Prometheus to run as service

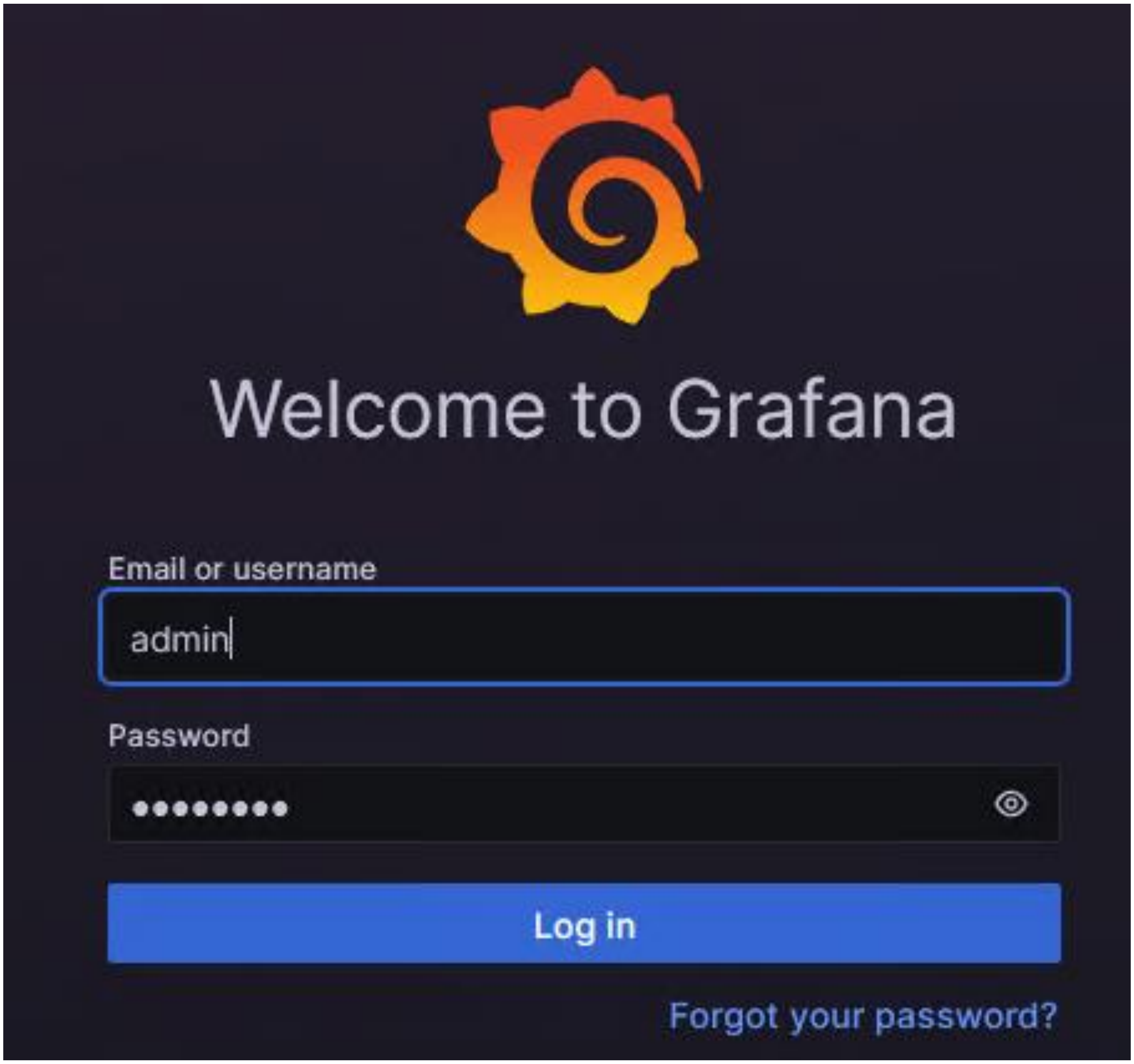
3. Verify that Prometheus is successfully installed using the below command:

```
$ prometheus –version
```

```
$ sudo systemctl start prometheus
```

sys

Step 1. Go to http://<Grafana_Server_IP_Address>:3000; Log into Grafana using default username and password admin/password.



Welcome to Grafana

Email or username

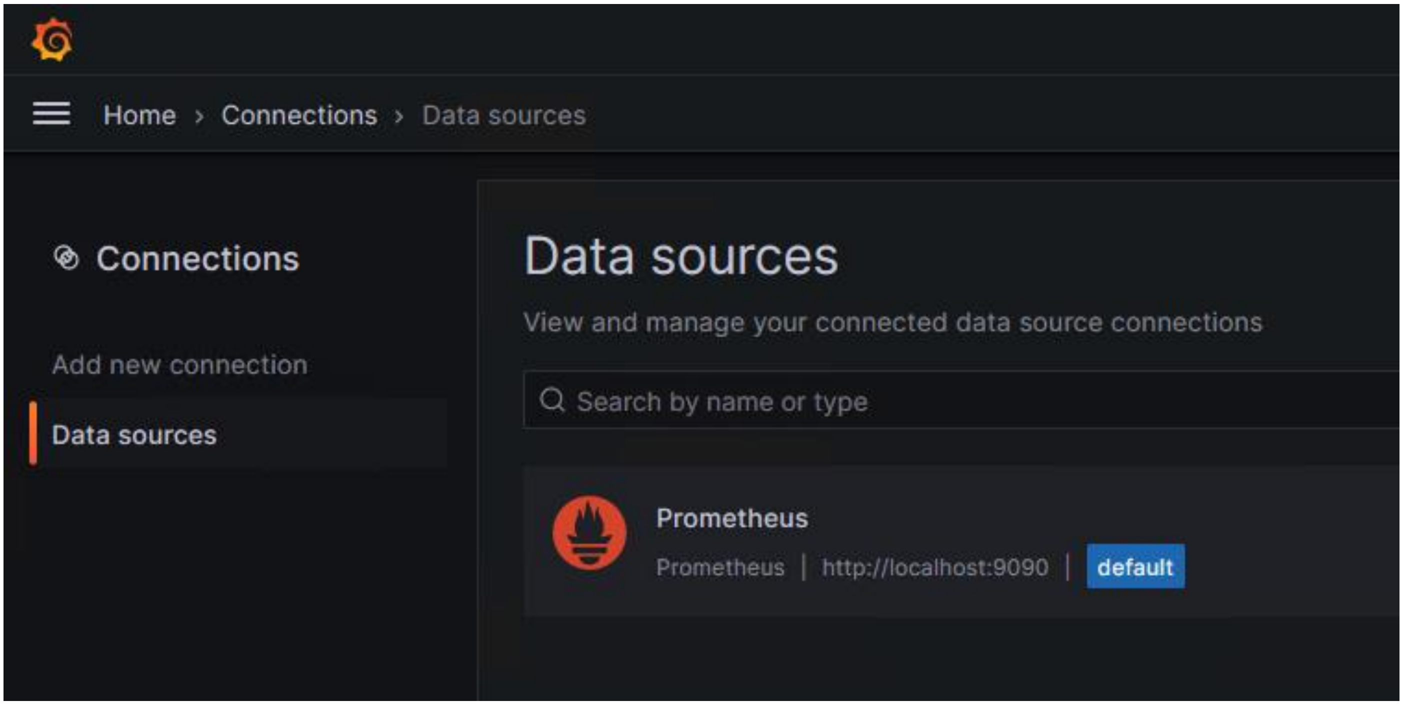
admin

Password

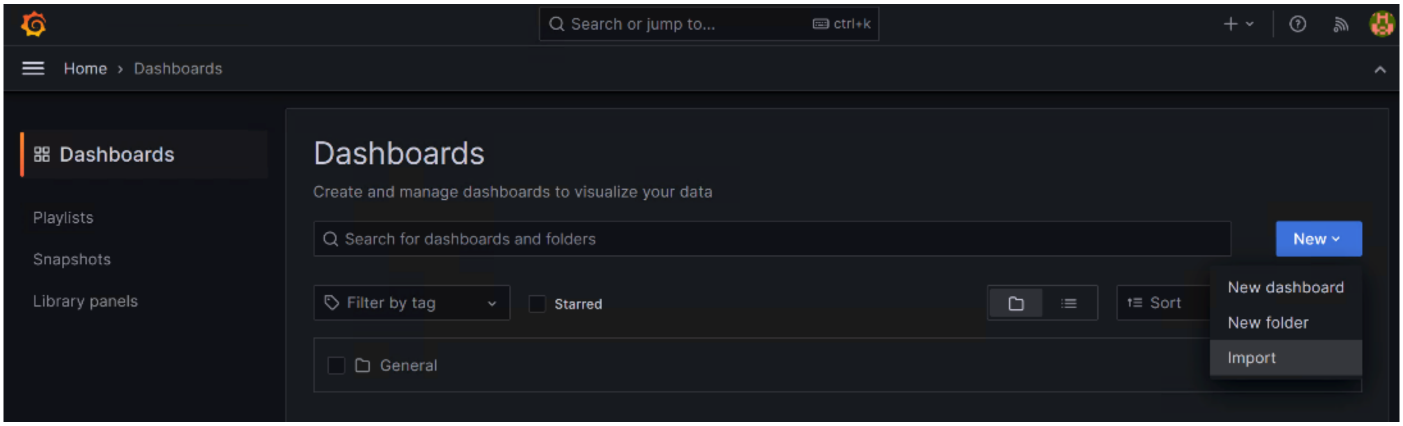
●●●●●●●●●

Step 2. Change the password when prompted.

Step 3. Add Prometheus as data source.

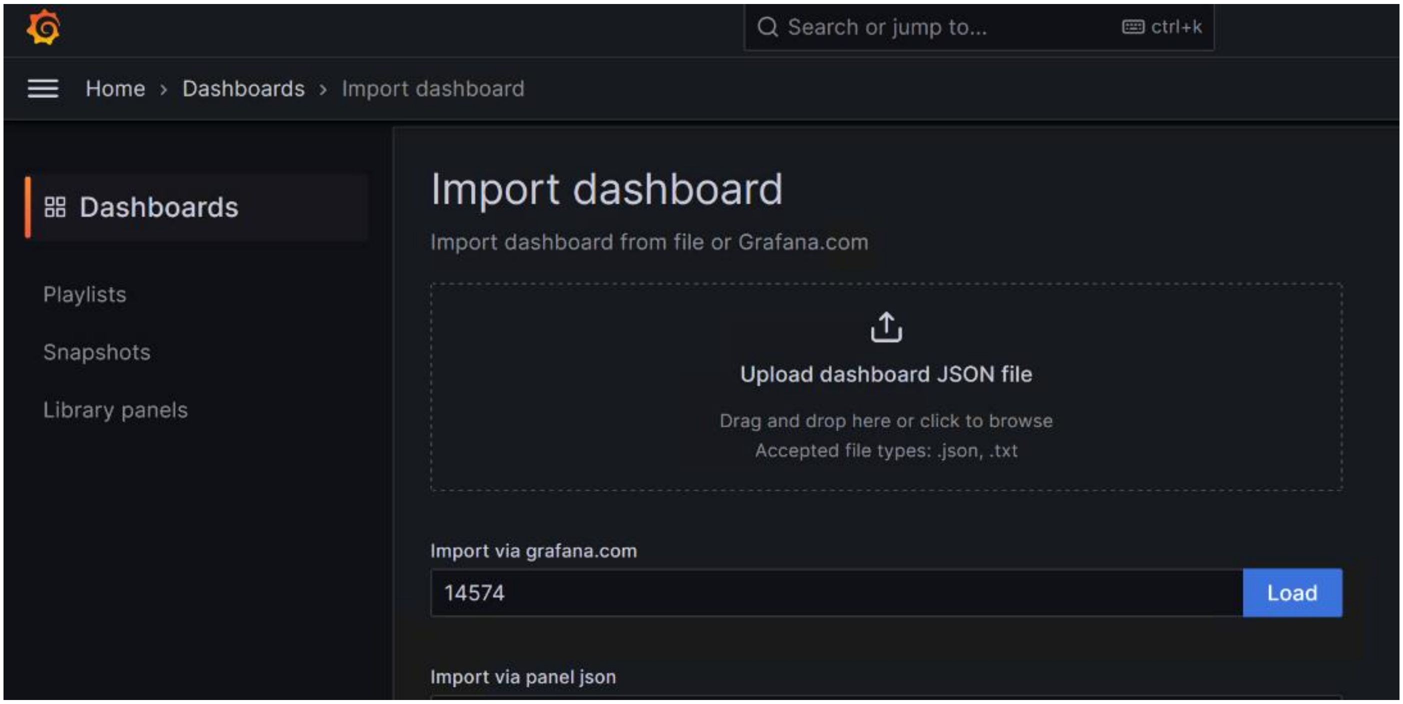

Home › Connections › Data sources
Connections
Add new connection
Data sources
Data sources
View and manage your connected data source connections
Search by name or type
Prometheus
Prometheus | http://localhost:9090 | default

Step 4. Add a new dashboard in Grafana. Go to home > Dashboard > new > import.



Step 5. Copy Grafana Dashboard ID “14574” for Nvidia GPU Metris: https://grafana.com/grafana/dashboards/14574-nvidia-gpu-metrics/

Step 6. Enter the Dashboard ID in Import via Grafana.com; click Load.



Import dashboard

Import dashboard from file or Grafana.com

Drag and drop here or click to browse
Accepted file types: .json, .txt

Import via grafana.com

14574

Import via panel json

Step 7. Edit /etc/prometheus/prometheus.yml file as shown in the example below:

```
$ sudo vi /etc/prometheus/prometheus.yml
# my global config
global:
  scrape_interval: 15s # Set the scrape interval to every 15 seconds. Default is every 1 minute.
  evaluation_interval: 15s # Evaluate rules every 15 seconds. The default is every 1 minute.
  # scrape_timeout is set to the global default (10s).

# Alertmanager configuration
alerting:
  alertmanagers:
    - static_configs:
        - targets:
          # - alertmanager:9093

# Load rules once and periodically evaluate them according to the global 'evaluation_interval'.
rule_files:
  # - " first_rules.yml"
  # - " second_rules.yml"
# A scrape configuration containing exactly one endpoint to scrape:
# Here it's Prometheus itself.
scrape_configs:
  # The job name is added as a label `job=<job_name>` to any timeseries scraped from this config.
  - job_name: " prometheus"

    # metrics_path defaults to '/metrics'
    # scheme defaults to 'http'.

    static_configs:
      - targets: [" 10.29.148.171:9835" ]
      - targets: [" 10.29.148.172:9835" ]
      - targets: [" 10.29.148.173:9835" ]
      - targets: [" 10.29.148.174:9835" ]
      - targets: [" 10.29.148.175:9835" ]
      - targets: [" 10.29.148.176:9835" ]
      - targets: [" 10.29.148.177:9835" ]
      - targets: [" 10.29.148.178:9835" ]
```

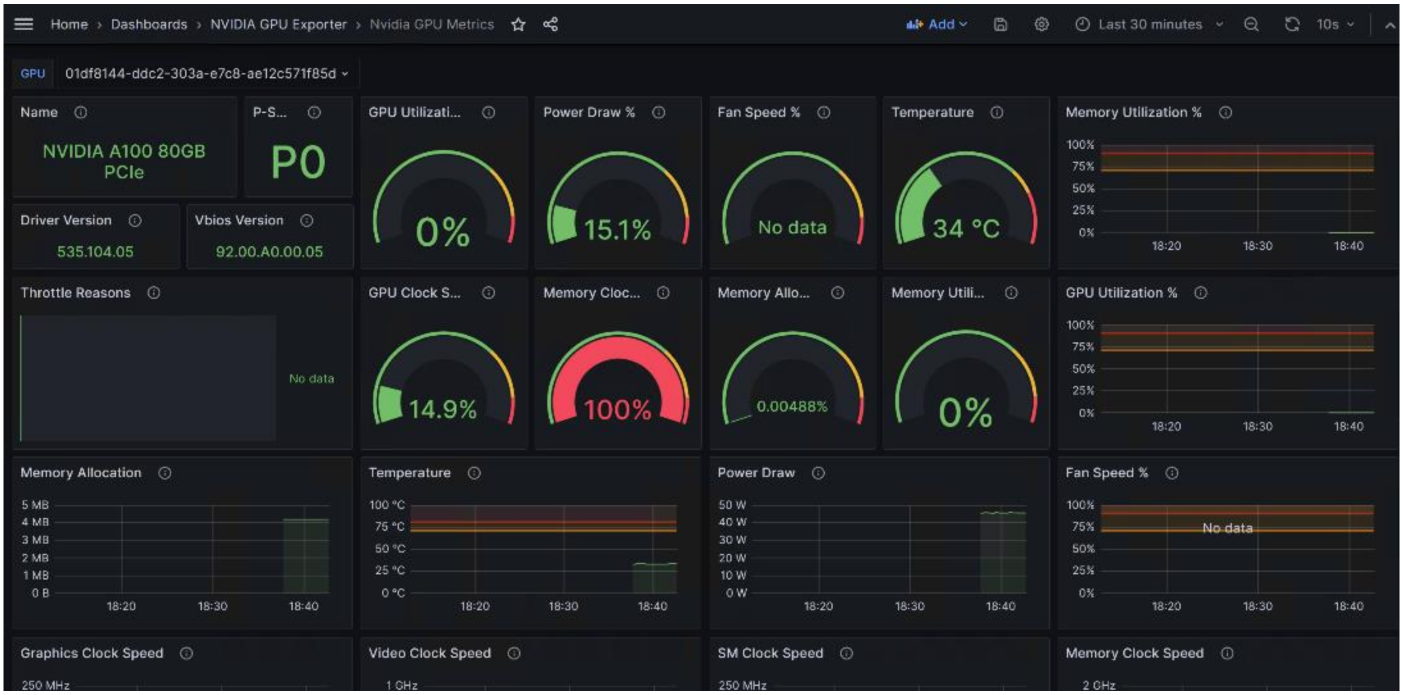
Step 8. Download node exporter from GitHub:

https://github.com/utkuozdemir/nvidia_gpu_exporter/releases

Step 9. On each client node install nvidia-gpu-exporter; for example:

```
$ sudo dpkg -i nvidia-gpu-exporter_1.2.0_linux_amd64.deb
```

Step 10. Log into Grafana webUI; go to dashboard created for Grafana. From the drop-down list next to GPU allows to switch between different GPU monitoring.



GPU 01df8144-ddc2-303a-e7c8-ae12c571f85d

Name: NVIDIA A100 80GB PCIe

P-S...: P0

Driver Version: 535.104.05

Vbios Version: 92.00.A0.00.05

GPU Utilizati...: 0%

Power Draw %: 15.1%

Fan Speed %: No data

Temperature: 34 °C

GPU Clock S...: 14.9%

Memory Cloc...: 100%

Memory Allo...: 0.00488%

Memory Utili...: 0%

Appendix E- References used in this guide

Anycast RP Technology White Paper:
https://www.cisco.com/c/en/us/td/docs/ios/solutions_docs/ip_multicast/White_papers/anycast.html

Campus Network for High Availability Design Guide, Tuning for Optimized Convergence:
https://www.cisco.com/c/en/us/td/docs/solutions/Enterprise/Campus/HA_campus_DG/hacampusdg.html#wp1107578

Campus Network for High Availability Design Guide:
https://www.cisco.com/c/en/us/td/docs/solutions/Enterprise/Campus/HA_campus_DG/hacampusdg.html

Appendix F – Recommended for you

Cisco Unified Computing System: https://www.cisco.com/site/us/en/products/computing/servers-unified-computing-systems/index.html

Cisco UCS 6536 Fabric Interconnects: https://www.cisco.com/c/en/us/products/collateral/servers-unified-computing/ucs6536-fabric-interconnect-ds.html

Cisco UCS X9508 Chassis: https://www.cisco.com/c/en/us/products/collateral/servers-unified-computing/ucs-x-series-modular-system/datasheet-c78-2472574.html

Cisco UCS X210c M7 Compute Node: https://www.cisco.com/c/en/us/products/collateral/servers-unified-computing/ucs-x-series-modular-system/ucs-x210c-m7-compute-node-ds.html

Cisco UCS X440p PCIe Node: https://www.cisco.com/c/en/us/products/collateral/servers-unified-computing/ucs-x-series-modular-system/ucs-x440p-pcie-node-ds.html

Cisco UCS C240 M7 Rack Server: https://www.cisco.com/c/en/us/products/collateral/servers-unified-computing/ucs-c-series-rack-servers/ucs-c240-m7-rack-server-ds.html

Cisco UCS VIC 1500 Adapters: https://www.cisco.com/c/en/us/products/collateral/interfaces-modules/unified-computing-system-adapters/ucs-vic-15000-series-ds.html

Cisco Intersight Infrastructure Service: https://www.cisco.com/c/en/us/products/collateral/cloud-systems-management/intersight/intersight-ds.html

Cisco UCS Manager: https://www.cisco.com/c/en/us/products/servers-unified-computing/ucs-manager/index.html

NVIDIA GPU Cloud: https://www.nvidia.com/en-us/gpu-cloud/

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

NVIDIA HPC SDK: https://developer.nvidia.com/hpc-sdk

Cisco Nexus 9300-GX Series Switch: https://www.cisco.com/c/en/us/products/collateral/switches/nexus-9000-series-switches/nexus-9300-gx-series-switches-ds.html

Cisco Nexus 9336C-FX2 Switch: https://www.cisco.com/c/en/us/products/collateral/switches/nexus-9000-series-switches/datasheet-c78-742282.html

NetApp Data ONTAP: https://www.netapp.com/data-management/ontap-data-management-software/

NetApp AFF A400: https://www.netapp.com/data-storage/aff-a-series/aff-a400/

SpecHPC 2021 Benchmark Suite: https://www.spec.org/hpc2021/

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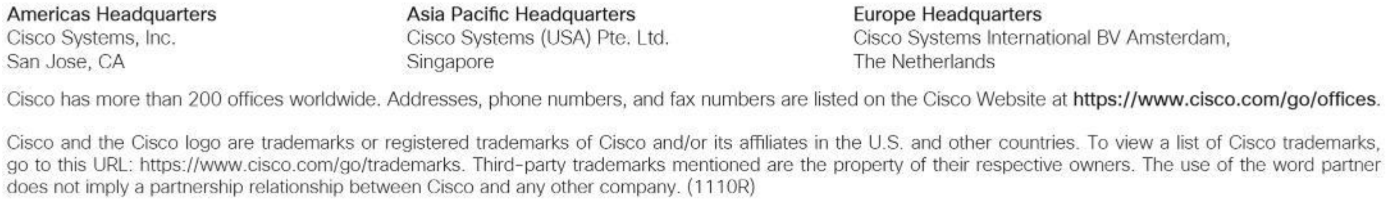

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