FlashStack for Enterprise RAG Pipeline with NVIDIA NIM, NIM Operator, and RAG Blueprint

Design and Deployment Guide

May 2025

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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

The Generative AI revolution necessitates secure integration with unique enterprise data to realize its full potential. Retrieval Augmented Generation (RAG) is the pivotal technology for this, yet deploying robust, enterprise-grade RAG pipelines has traditionally presented significant complexity, prolonged timelines, and considerable integration challenges.

This document introduces a Cisco Validated Design (CVD), specifically engineered to simplify, and accelerate the deployment of advanced RAG solutions. The design synergistically integrates the best-in-class FlashStack converged infrastructure—a high-performance foundation of Cisco UCS X-Series compute, Nexus networking, and Pure Storage FlashArray and FlashBlade—with NVIDIA's cutting-edge AI platform. This platform features the NVIDIA RAG Blueprint, providing a foundational structure with extensive customization freedom for tailoring pipelines to specific enterprise needs, and utilizes NVIDIA Inference Microservices (NIM) ensuring maximally optimized execution of AI inference tasks on the underlying NVIDIA GPUs. Orchestrated on Red Hat OpenShift Container Platform and managed via Cisco Intersight, this integrated system constitutes a dedicated AI enablement platform.

Lengthy integration cycles and associated deployment uncertainties are substantially mitigated by this approach. The validated blueprint provides a fast track for deploying powerful, private RAG pipelines, constructed upon meticulously tested, enterprise-grade components. This solution empowers enterprises to unlock their data's potential, establish trustworthy AI applications, and achieve a competitive advantage with unprecedented speed and operational confidence. This guide provides the detailed RAG design, while the FlashStack with Red Hat OpenShift Container and Virtualization Platform using Cisco UCS X-Series CVD offers the core infrastructure specifications.

If you are interested in understanding the FlashStack design and deployment details, including configuration of various elements of design and associated best practices, refer to the Cisco Validated Designs for FlashStack here: https://www.cisco.com/c/en/us/solutions/design-zone/data-center-design-guides/data-center-design-guides-all.html#FlashStack.

Solution Overview

This chapter contains the following:

Introduction

As enterprises seek to harness Generative AI with their proprietary data, Retrieval Augmented Generation (RAG) emerges as a critical technique. RAG enhances Large Language Models (LLMs) by grounding them in specific enterprise information, enabling accurate, context-aware responses for use cases like internal knowledge base querying. However, deploying robust, scalable, and secure RAG pipelines presents significant infrastructure and integration challenges.

This document introduces a Cisco validated solution addressing these challenges: Enterprise RAG Pipeline on FlashStack, leveraging NVIDIA RAG Blueprint and NVIDIA NIMs. This collaborative solution, jointly engineered by Cisco, Pure Storage and NVIDIA, provides a pre-integrated and optimized stack for deploying demanding GenAI workloads.

The foundation is FlashStack converged infrastructure. Layered upon this infrastructure is the NVIDIA AI software stack. The solution utilizes the NVIDIA RAG Blueprint, a reference architecture that accelerates the development of customizable RAG pipelines. This blueprint leverages NVIDIA Inference Microservices (NIM) – optimized, self-hosted endpoints for LLM inferencing, text embedding, and reranking – ensuring data privacy and low latency. NIMs are deployed and managed using the NIM Operator on Red Hat OpenShift Container Platform, orchestrated across NVIDIA GPU-accelerated Cisco UCS servers.

By integrating these best-in-class components into a Cisco Validated Design (CVD), this solution offers enterprises a streamlined path to deploying powerful, private RAG capabilities, reducing operational complexity, and accelerating time-to-value for GenAI initiatives.

Audience

The intended audience of this document includes IT decision makers such as CTOs and CIOs, IT architects, sales engineers, field consultants, professional services, IT managers, partner engineers, and customers. It is designed for those interested in the design, deployment, and life cycle management of Retrieval Augmented Generation pipelines with Cisco AI ready datacenter.

Purpose of this document

This document provides design and deployment guidance set up Retrieval Augmented Generation pipeline that uses NVIDIA NIM and GPU-accelerated components on FlashStack Datacenter.

New in this release

The following design elements are built on the CVD FlashStack with Red Hat OCP Bare Metal Manual Configuration with Cisco UCS X-Series Direct Deployment Guide to implement an end-to-end Retrieval Augmented Generation pipeline using NVIDIA RAG Blueprint and NVIDIA NIMs.

- Installation and configuration of RAG pipeline components on FlashStack:
    - NVIDIA GPUs
    - NVIDIA AI Enterprise (NVAIE)

- NVIDIA NIM Operator
- NVIDIA NIM microservices - NVIDIA NIMs for LLM Inferencing, text embedding and text reranking.
- NVIDIA AI Blueprint version 1.0.0 for RAG
- RAG Evaluation
- NIM for LLM Benchmarking
- Vector Database Benchmarking

Solution Summary

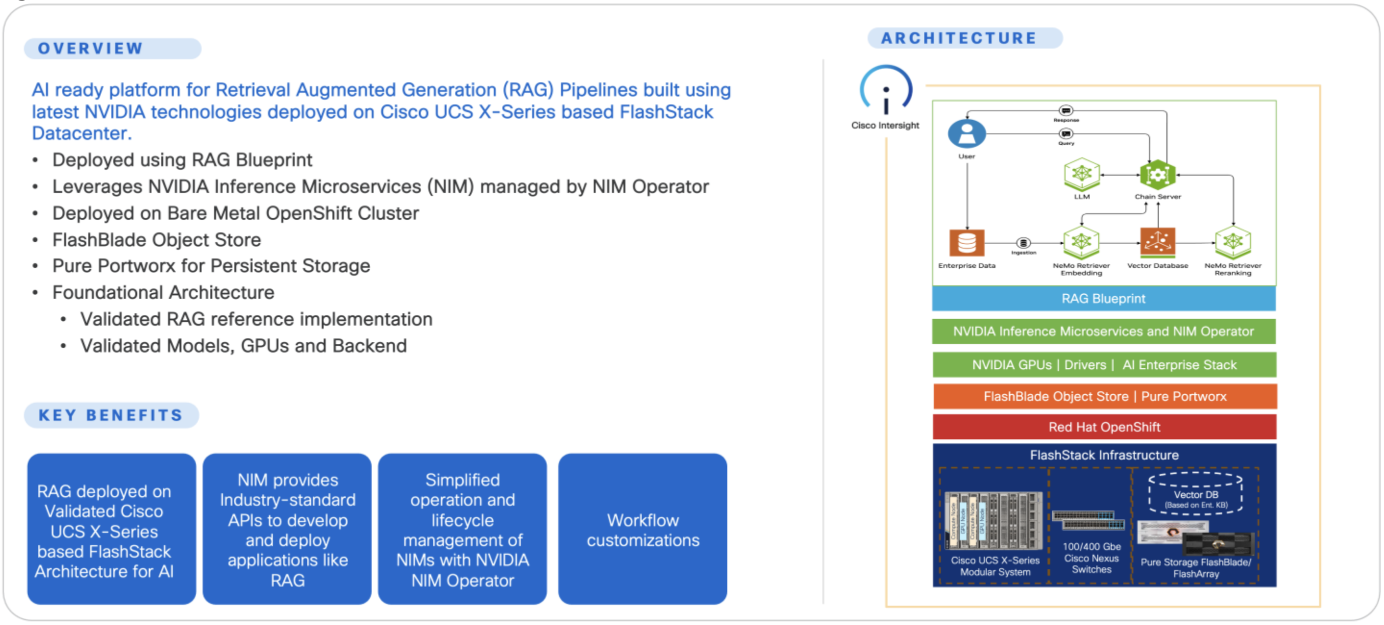
This solution provides a validated, foundational architecture for deploying enterprise-grade Retrieval Augmented Generation pipelines. It leverages a Cisco UCS X-Series based FlashStack Datacenter as the high-performance converged infrastructure foundation. Key NVIDIA AI technologies, including the RAG Blueprint reference implementation and NVIDIA Inference Microservices (NIM) running on NVIDIA GPUs, power the AI workload. NVIDIA NIM Operator manages the life cycle of the NVIDIA NIM for LLMs, Text Embedding NIM and Reranking NIMs.

The entire stack is deployed on a bare-metal Red Hat OpenShift cluster, utilizing Portworx by Pure Storage for container-native persistent storage. This pre-tested integration of validated models, GPUs, and backend components, accessible via NIM's industry-standard APIs, delivers an optimized and AI-ready platform, significantly simplifying the deployment and management of secure, private RAG applications.

This architecture represents a rigorously tested and validated integration across all layers - compute, networking, storage, NVIDIA GPUs, AI models, and the software stack (OCP, Portworx, NVIDIA AI Enterprise). NVIDIA NIM facilitates streamlined application development and integration via industry-standard APIs (including OpenAI compatibility). The resultant platform is an optimized, secure, and AI-ready infrastructure solution designed to mitigate deployment complexities, reduce operational overhead, and accelerate the delivery of high-performance, private RAG capabilities within the enterprise.

Figure 1 illustrates the solution overview.

Figure 1. Solution Overview



OVERVIEW

AI ready platform for Retrieval Augmented Generation (RAG) Pipelines built using latest NVIDIA technologies deployed on Cisco UCS X-Series based FlashStack Datacenter.

- Deployed using RAG Blueprint
- Leverages NVIDIA Inference Microservices (NIM) managed by NIM Operator
- Deployed on Bare Metal OpenShift Cluster
- FlashBlade Object Store
- Pure Portworx for Persistent Storage
- Foundational Architecture
  - Validated RAG reference implementation
  - Validated Models, GPUs and Backend

KEY BENEFITS

- RAG deployed on Validated Cisco UCS X-Series based FlashStack Architecture for AI
- NIM provides Industry-standard APIs to develop and deploy applications like RAG
- Simplified operation and lifecycle management of NIMs with NVIDIA NIM Operator
- Workflow customizations

ARCHITECTURE
Cisco Intersight
User
Response
Query
LLM
Chain Server
Enterprise Data
Ingestion
NeMo Retriever Embedding
Vector Database
NeMo Retriever Reranking
RAG Blueprint
NVIDIA Inference Microservices and NIM Operator
NVIDIA GPUs | Drivers | AI Enterprise Stack
FlashBlade Object Store | Pure Portworx
Red Hat OpenShift
FlashStack Infrastructure
Vector DB (Based on Ent. KB)
Cisco UCS X-Series Modular System
100/400 Gbe Cisco Nexus Switches
Pure Storage FlashBlade/ FlashArray

The FlashStack solution as a platform for Retrieval Augmented Generation offers the following key benefits:

- The ability to implement a Retrieval Augmented Generation pipeline quickly and easily on a powerful platform with high-speed persistent storage.
- Blueprint leverages NVIDIA NIM microservices deployed on-premise to meet specific data governance and latency requirements.
- Evaluation of performance of platform components.
- Simplified cloud-based management of solution components using policy-driven modular design.
- Cooperative support model and Cisco Solution Support.
- Easy to deploy, consume, and manage architecture, which saves time and resources required to research, procure, and integrate off-the-shelf components.
- Support for component monitoring, solution automation and orchestration, and workload optimization.

Like all other FlashStack solution designs, FlashStack for Enterprise RAG Pipeline with NVIDIA NIM, NIM Operator and RAG Blueprint is configurable according to demand and usage. You can purchase exactly the infrastructure you need for your current application requirements and then scale-up/scale-out to meet future needs.

Technology Overview

This chapter contains the following:

- Retrieval Augmented Generation
- NVIDIA AI Blueprint for RAG
- NVIDIA AI Enterprise
- NVIDIA Inference Microservices
- NVIDIA NIM for Large Language Models
- NeMo Text Retriever NIM
- FlashStack Components
- Benefits of Portworx Enterprise with OpenShift Container Platform
- Benefits of Portworx Enterprise with Pure Storage FlashArray
- Benefits of Pure Storage FlashBlade

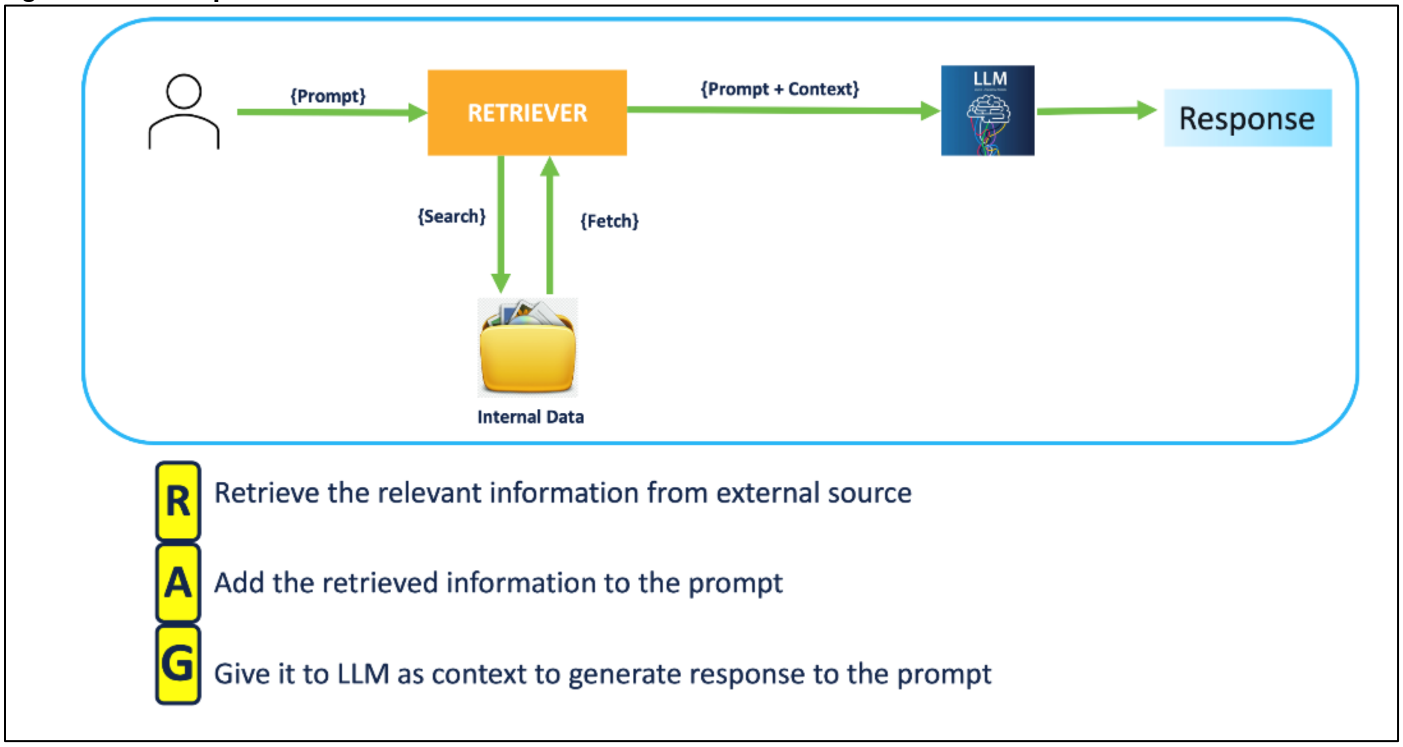
Retrieval Augmented Generation

Retrieval Augmented Generation (RAG) is an enterprise application of Generative AI. RAG represents a category of large language model (LLM) applications that enhance the LLM's context by incorporating external data. It overcomes the limitation of knowledge cutoff date (events occurring after the model's training). LLMs lack access to an organization's internal data or services. This absence of up-to-date and domain-specific or organization-specific information prevents their effective use in enterprise applications.

RAG Pipeline

Figure 2 illustrates the RAG Pipeline overview.

Figure 2. RAG Pipeline Overview

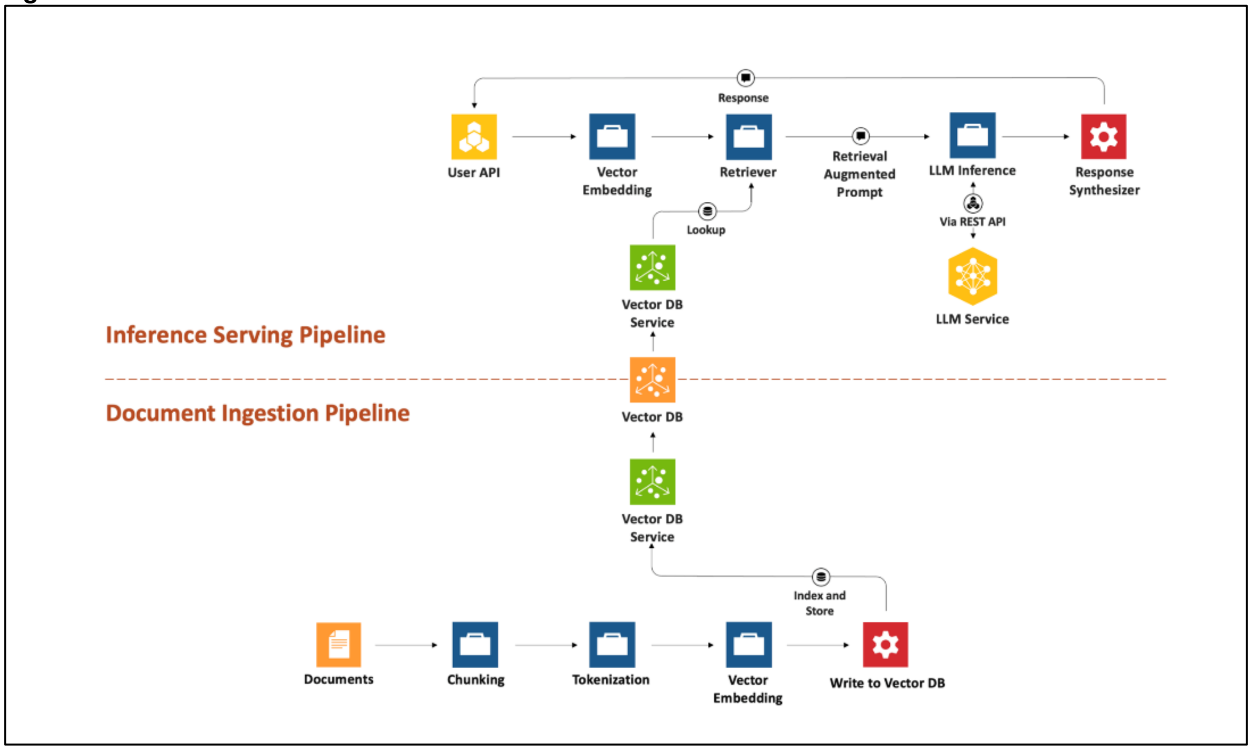

{Prompt}
RETRIEVER
{Prompt + Context}
LLM
Response
{Search}
{Fetch}
Internal Data
R Retrieve the relevant information from external source
A Add the retrieved information to the prompt
G Give it to LLM as context to generate response to the prompt

In this pipeline, when you enter a prompt/query, document chunks relevant to the prompt are searched and fetched to the system. The retrieved relevant information is augmented to the prompt as context. LLM is asked to generate a response to the prompt in the context and the user receives the response.

RAG Architecture

RAG is an end-to-end architecture that combines information retrieval component with a response generator.

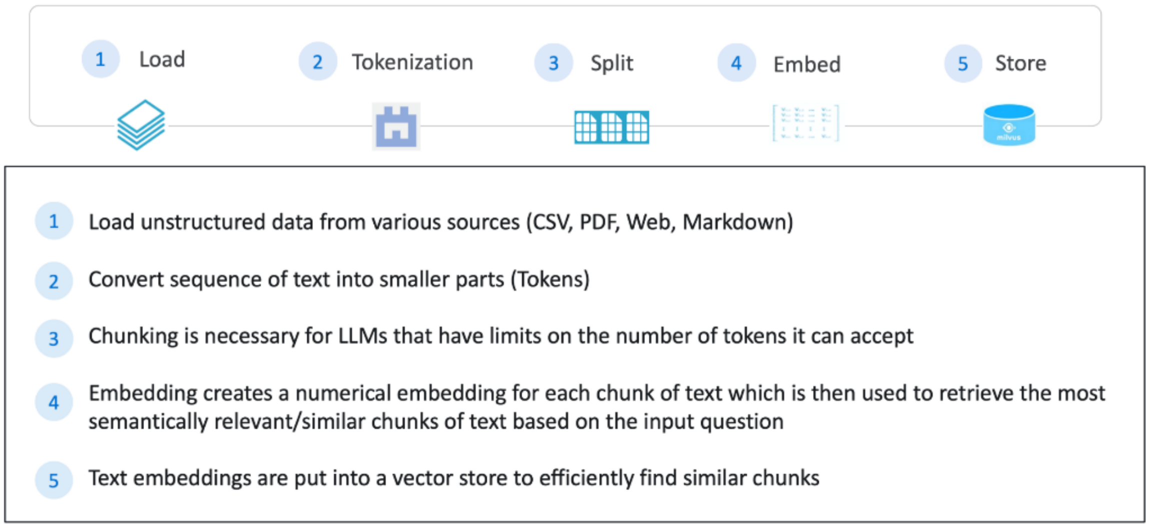
Figure 3. RAG architecture



RAG can be broken into two process flows; document ingestion and inferencing.

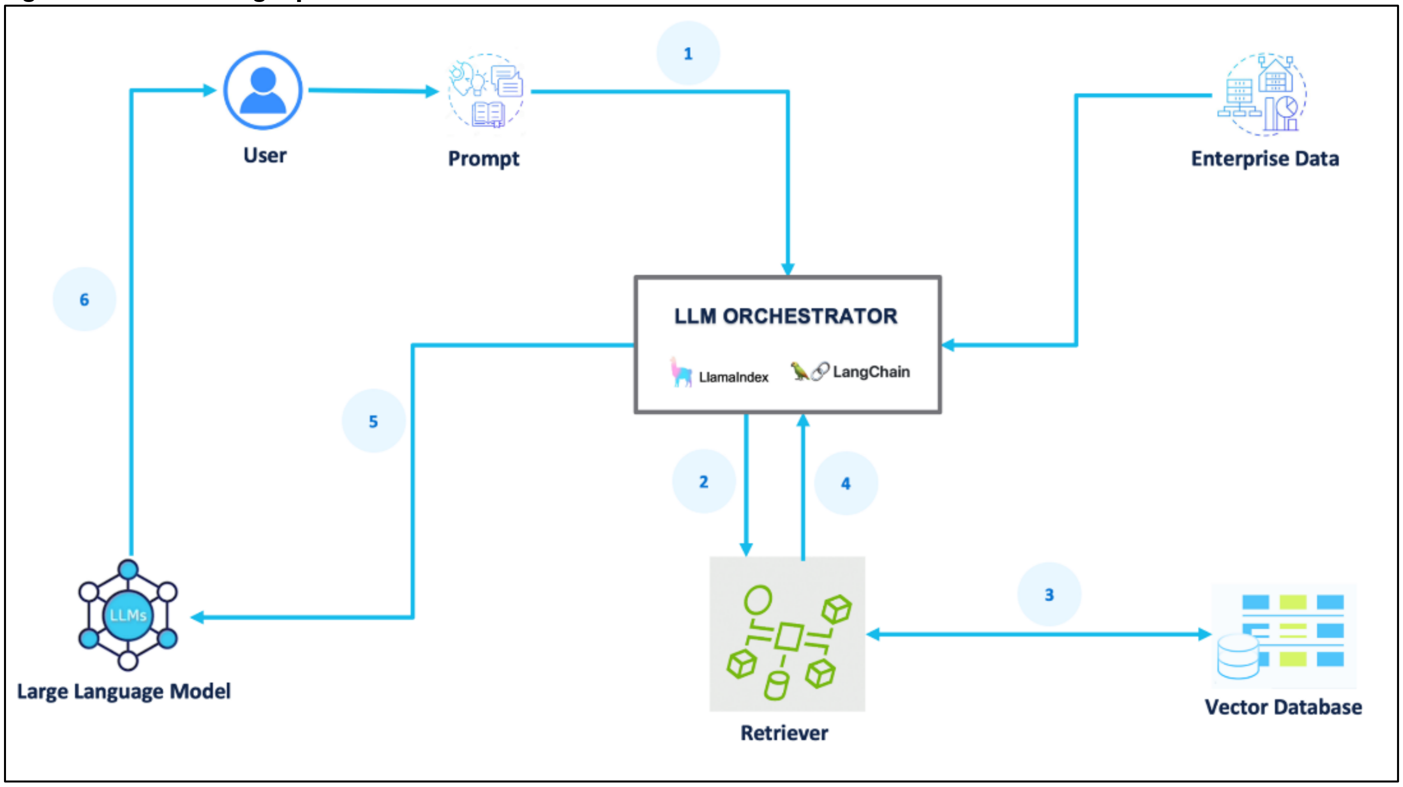
Figure 4 illustrates the document ingestion pipeline.

Figure 4. Document Ingestion Pipeline overview


1 Load
2 Tokenization
3 Split
4 Embed
5 Store
1 Load unstructured data from various sources (CSV, PDF, Web, Markdown)
2 Convert sequence of text into smaller parts (Tokens)
3 Chunking is necessary for LLMs that have limits on the number of tokens it can accept
4 Embedding creates a numerical embedding for each chunk of text which is then used to retrieve the most semantically relevant/similar chunks of text based on the input question
5 Text embeddings are put into a vector store to efficiently find similar chunks

[Figure 5](#) illustrates the inferencing pipeline.

Figure 5. Inferencing Pipeline overview



The process for the inference serving pipeline is as follows:

1. A prompt is passed to the LLM orchestrator.
2. The orchestrator sends a search query to the retriever.
3. The retriever fetches relevant information from the Vector Database.

4. The retriever returns the retrieved information to the orchestrator.

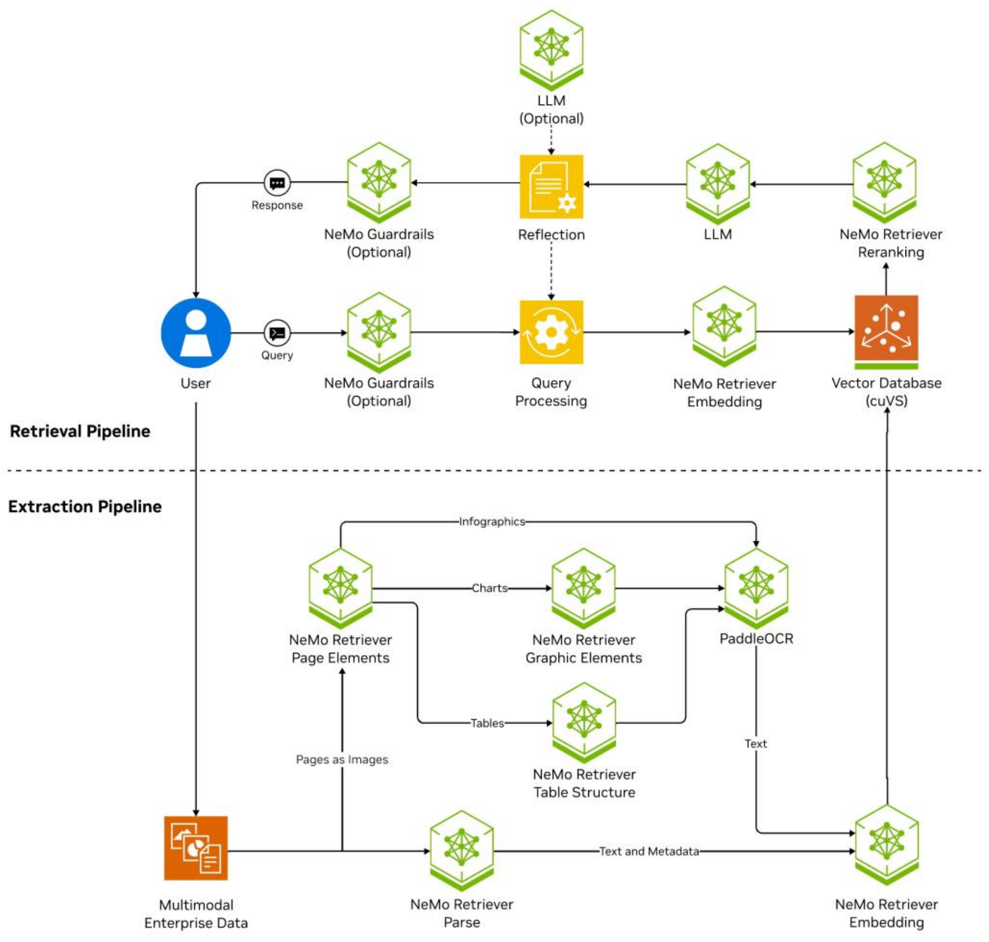
5. The orchestrator augments the original prompt with the context and sends it to the LLM.

6. The LLM responds with generated text/ response and presents it to the user.

NVIDIA AI Blueprint for RAG

The NVIDIA AI Blueprint for RAG gives developers a foundational starting point for building scalable, customizable retrieval pipelines that deliver both high accuracy and throughput. Use this blueprint to build RAG applications that provide context-aware responses by connecting LLMs to extensive multimodal enterprise data—including text, tables, charts, and infographics from millions of PDFs. With 15x faster multimodal PDF data extraction and 50 percent fewer incorrect answers, enterprises can unlock actionable insights from data and drive productivity at scale.

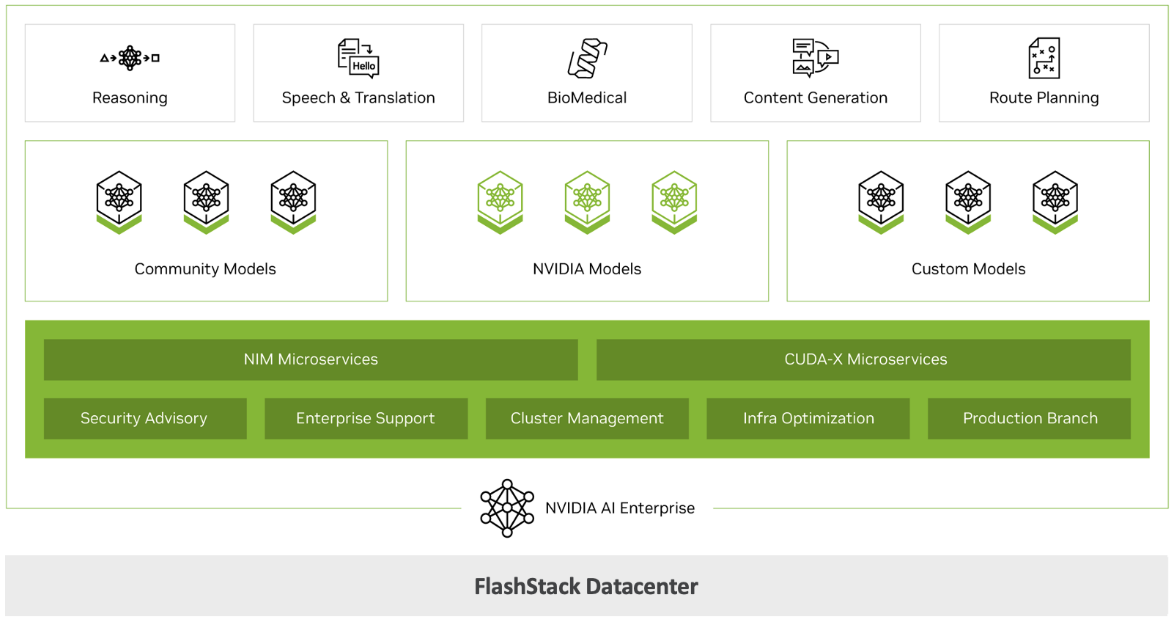
This blueprint can be used as-is, combined with other NVIDIA Blueprints, such as the Digital Human blueprint or the AI Assistant for customer service blueprint, or integrated with an agent to support more advanced use cases. Get started with this reference architecture to ground AI-driven decisions in relevant enterprise data - wherever it resides.



NVIDIA AI Enterprise

The NVIDIA AI Enterprise (NVAIE) platform was deployed on Red Hat OpenShift as the foundation for the RAG pipeline. NVIDIA AI Enterprise simplifies the development and deployment of generative AI workloads, including Retrieval Augmented Generation, at scale.

Figure 6. NVIDIA AI Enterprise with FlashStack

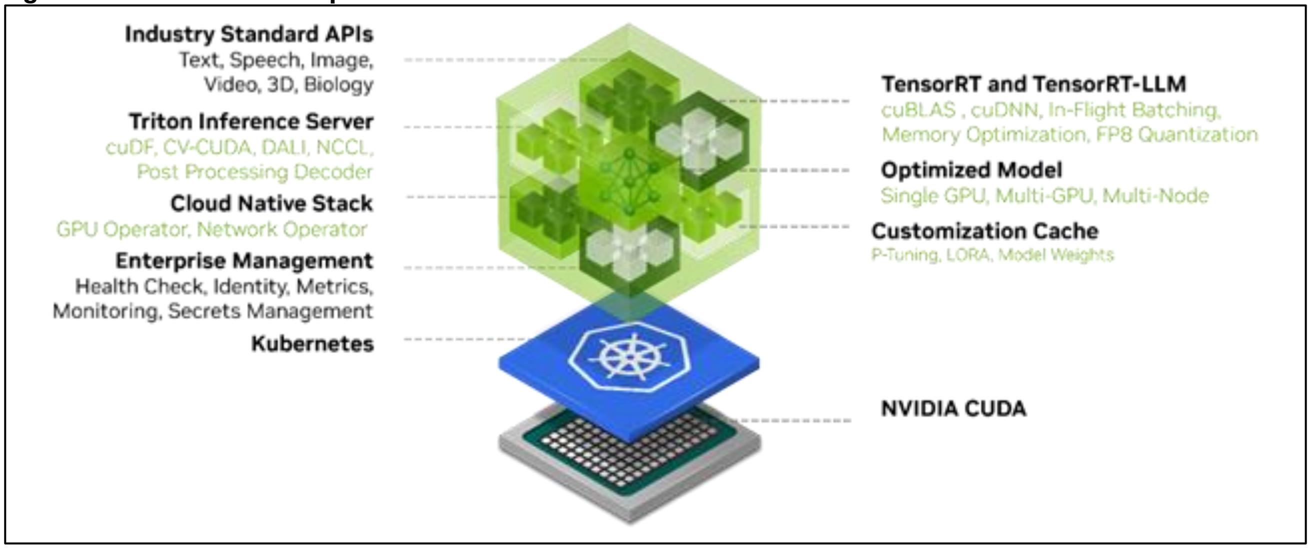


NVIDIA Inference Microservices

NVIDIA Inference Microservice (NIM), a component of NVIDIA AI Enterprise, offers an efficient route for creating AI-driven enterprise applications and deploying AI models in production environments. NIM consists of microservices that accelerate and simplify the deployment of generative AI models via automation using prebuilt containers, Helm charts, optimized models, and industry-standard APIs.

NIM simplifies the process for IT and DevOps teams to self-host large language models (LLMs) within their own managed environments. It provides developers with industry-standard APIs, enabling them to create applications such as copilots, chatbots, and AI assistants that can revolutionize their business operations. Content Generation, Sentiment Analysis, and Language Translation services are just a few additional examples of applications that can be rapidly deployed to meet various use cases. NIM ensures the quickest path to inference with unmatched performance.

Figure 7. NVIDIA NIM for optimized AI inference


Industry Standard APIs
Text, Speech, Image, Video, 3D, Biology
Triton Inference Server
cuDF, CV-CUDA, DALI, NCCL, Post Processing Decoder
Cloud Native Stack
GPU Operator, Network Operator
Enterprise Management
Health Check, Identity, Metrics, Monitoring, Secrets Management
Kubernetes
TensorRT and TensorRT-LLM
cuBLAS , cuDNN, In-Flight Batching, Memory Optimization, FP8 Quantization
Optimized Model
Single GPU, Multi-GPU, Multi-Node
Customization Cache
P-Tuning, LORA, Model Weights
NVIDIA CUDA

NIMs are distributed as container images tailored to specific models or model families. Each NIM is encapsulated in its own container and includes an optimized model. These containers come with a runtime compatible with any NVIDIA GPU that has adequate GPU memory, with certain model/GPU combinations being optimized for better performance. One or more GPUs can be passed through to containers via the NVIDIA Container Toolkit to provide the horsepower needed for any workload. NIM automatically retrieves the model from NGC (NVIDIA GPU Cloud), utilizing a local filesystem cache if available. Since all NIMs are constructed from a common base, once a NIM has been downloaded, acquiring additional NIMs becomes significantly faster. The NIM catalog currently offers nearly 150 models and agent blueprints.

Utilizing domain specific models, NIM caters to the demand for specialized solutions and enhanced performance through a range of pivotal features. It incorporates NVIDIA CUDA (Compute Unified Device Architecture) libraries and customized code designed for distinct fields like language, speech, video processing, healthcare, retail, and others. This method ensures that applications are precise and pertinent to their particular use cases. Think of it like a custom toolkit for each profession; just as a carpenter has specialized tools for woodworking, NIM provides tailored resources to meet the unique needs of various domains.

NIM is designed with a production-ready base container that offers a robust foundation for enterprise AI applications. It includes feature branches, thorough validation processes, enterprise support with service-level agreements (SLAs), and frequent security vulnerability updates. This optimized framework makes NIM an essential tool for deploying efficient, scalable, and tailored AI applications in production environments. Think of NIM as the bedrock of a skyscraper; just as a solid foundation is crucial for supporting the entire structure, NIM provides the necessary stability and resources for building scalable and reliable portable enterprise AI solutions.

NVIDIA NIM for Large Language Models

NVIDIA NIM for Large Language Models (LLMs) (NVIDIA NIM for LLMs) brings the power of state-of-the-art large language models (LLMs) to enterprise applications, providing unmatched natural language processing (NLP) and understanding capabilities.

Whether developing chatbots, content analyzers, or any application that needs to understand and generate human language – NVIDIA NIM for LLMs is the fastest path to inference. Built on the NVIDIA software platform, NVIDIA NIM brings state of the art GPU accelerated large language model serving.

High Performance Features

NVIDIA NIM for LLMs abstracts away model inference internals such as execution engine and runtime operations. NVIDIA NIM for LLMs provides the most performant option available whether it be with TensorRT, vLLM or LLM others.

- Scalable Deployment: NVIDIA NIM for LLMs is performant and can easily and seamlessly scale from a few users to millions.
- Advanced Language Models: Built on cutting-edge LLM architectures, NVIDIA NIM for LLMs provides optimized and pre-generated engines for a variety of popular models. NVIDIA NIM for LLMs includes tooling to help create GPU optimized models.
- Flexible Integration: Easily incorporate the microservice into existing workflows and applications. NVIDIA NIM for LLMs provides an OpenAI API compatible programming model and custom NVIDIA extensions for additional functionality.
- Enterprise-Grade Security: Data privacy is paramount. NVIDIA NIM for LLMs emphasizes security by using safetensors, constantly monitoring and patching CVEs in our stack and conducting internal penetration tests.

Applications

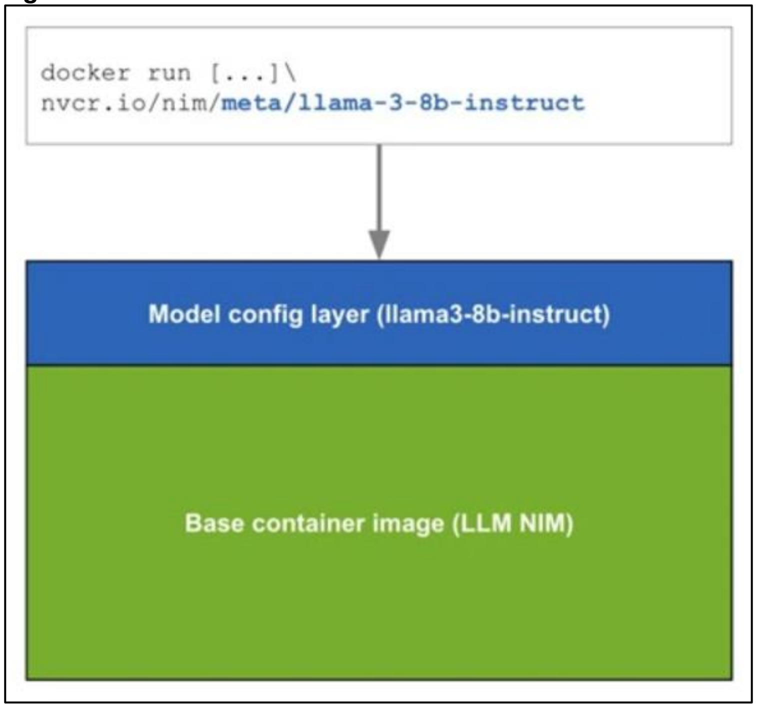
The potential applications of NVIDIA NIM for LLMs are vast, spanning across various industries and use cases:

- Chatbots & Virtual Assistants: Empower bots with human-like language understanding and responsiveness.
- Content Generation & Summarization: Generate high-quality content or distill lengthy articles into concise summaries with ease.
- Sentiment Analysis: Understand user sentiments in real-time, driving better business decisions.
- Language Translation: Break language barriers with efficient and accurate translation services.

Architecture

NVIDIA NIM for LLMs is one of what will become many NIMs. Each NIM has its own Docker container with a model, such as meta/llama3-8b-instruct. These containers include the runtime capable of running the model on any NVIDIA GPU. The NIM automatically downloads the model from NGC, leveraging a local filesystem cache if available. Each NIM is built from a common base, so once a NIM has been downloaded, downloading additional NIMs is extremely fast.

Figure 8. **NIM Architecture**


Model config layer (llama3-8b-instruct)
Base container image (LLM NIM)

```
docker run [...]\
nvcr.io/nim/meta/llama-3-8b-instruct
```

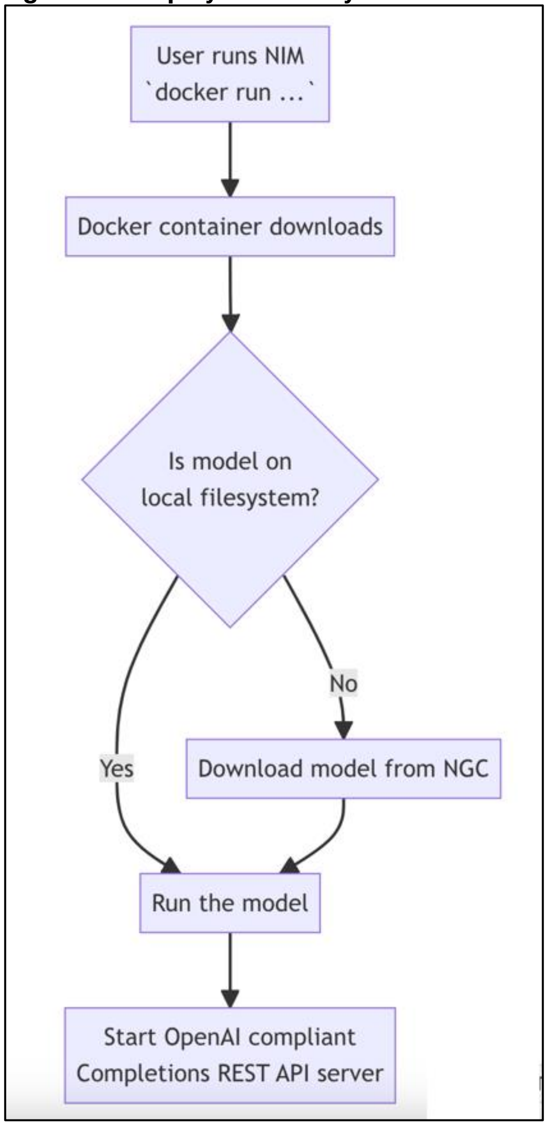
When a NIM is first deployed, NIM inspects the local hardware configuration, and the available optimized model in the model registry, and then automatically chooses the best version of the model for the available hardware. For a subset of NVIDIA GPUs, see: Support Matrix, NIM downloads the optimized TRT (TensorRT) engine and runs an inference using the TRT-LLM library. For all other NVIDIA GPUs, NIM downloads a non-optimized model and runs it using the vLLM library.

NIMs are distributed as NGC container images through the NVIDIA NGC Catalog. A security scan report is available for each container within the NGC catalog, which provides a security rating of that image, breakdown of CVE severity by package, and links to detailed information on CVEs.

Deployment Lifecycle

Figure 9 illustrates the deployment lifecycle.

Figure 9. Deployment Lifecycle

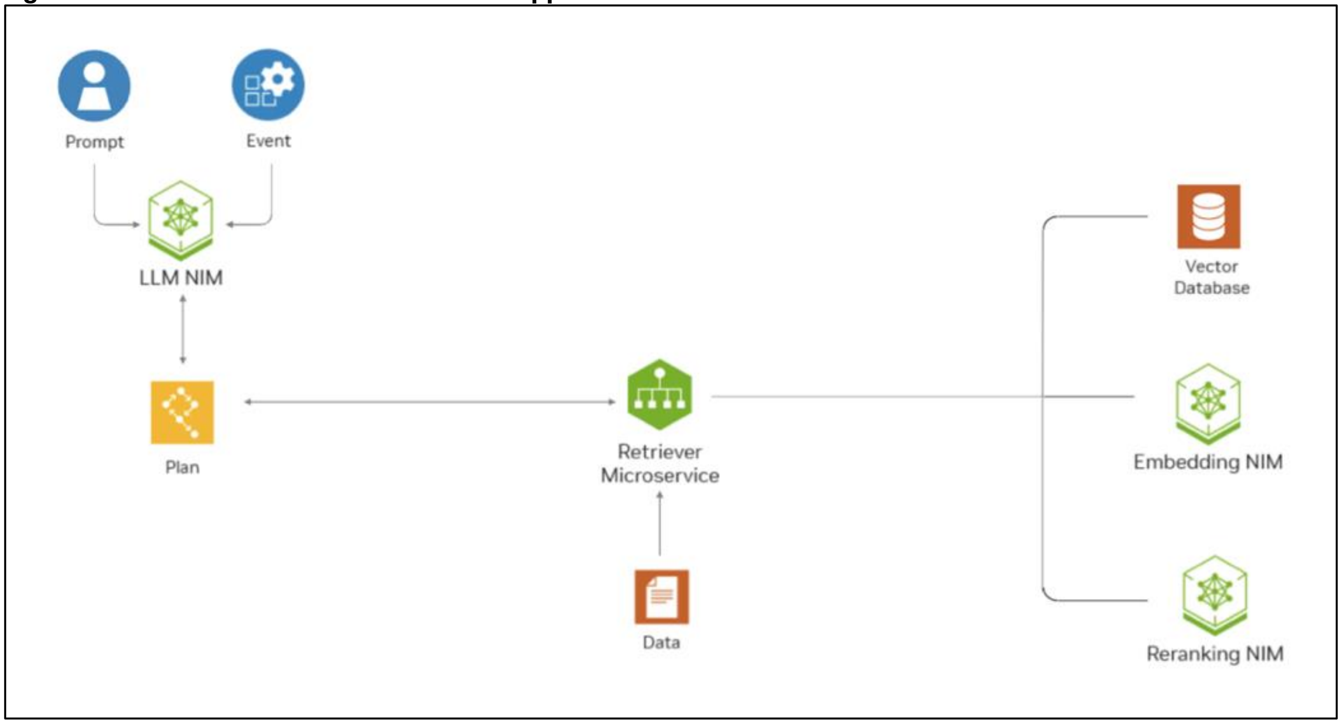

User runs NIM `docker run ...`
Docker container downloads
Is model on local filesystem?
No
Yes
Download model from NGC
Run the model
Start OpenAI compliant Completions REST API server

NeMo Text Retriever NIM

NeMo Text Retriever NIM APIs facilitate access to optimized embedding models – essential components for RAG applications that deliver precise and faithful answers. By using NVIDIA software (including CUDA, TensorRT, and Triton Inference Server), the Text Retriever NIM provides the tools needed by developers to create ready-to-use, GPU-accelerated applications. NeMo Retriever Text Embedding NIM enhances the performance of text-based question-answering retrieval by generating optimized embeddings. For this RAG CVD, the Snowflake Arctic-Embed-L embedding model was harnessed to encode domain-specific content which was then stored in a vector database. The NIM combines that data with an embedded version of the user's query to deliver a relevant response.

Figure 10 shows how the Text Retriever NIM APIs can help a question-answering RAG application find the most relevant data in an enterprise setting.

Figure 10. Text Retriever NIM APIs for RAG Application



Enterprise-Ready Features

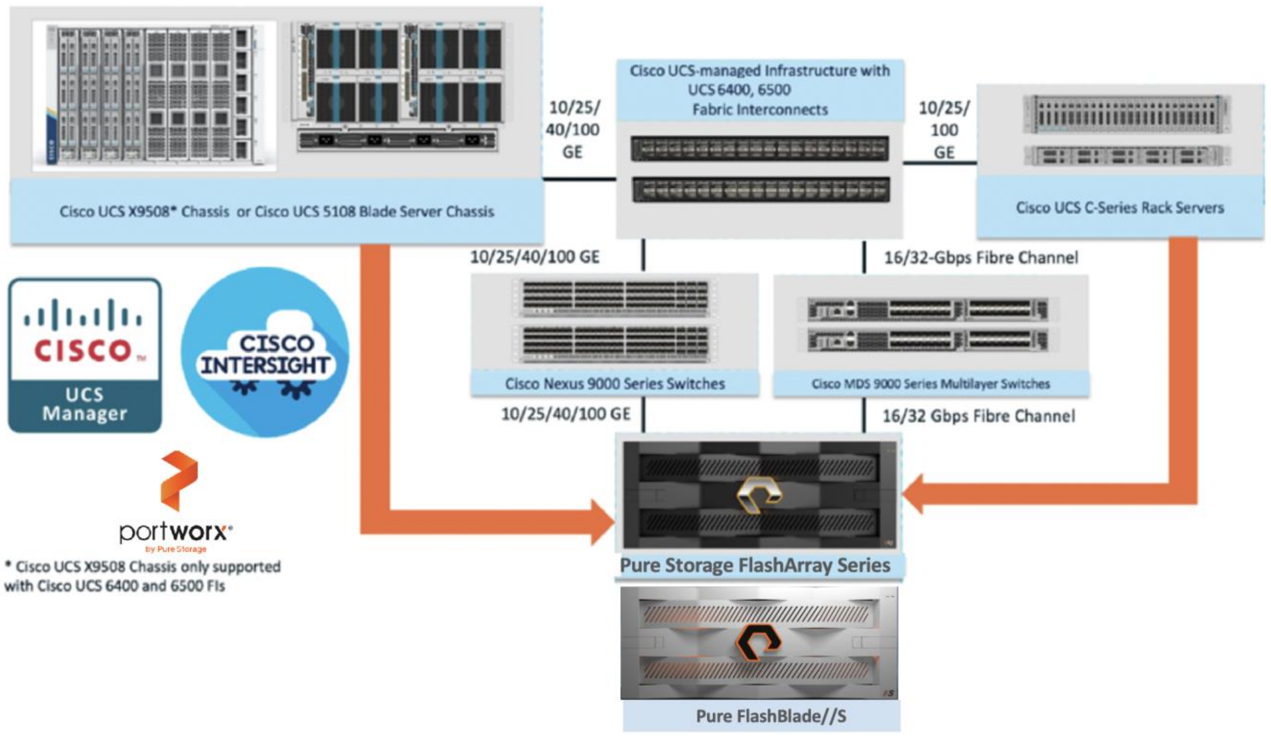
Text Embedding NIM comes with enterprise-ready features, such as a high-performance inference server, flexible integration, and enterprise-grade security.

- High Performance: Text Embedding NIM is optimized for high-performance deep learning inference with NVIDIA TensorRT and NVIDIA Triton Inference Server.
- Scalable Deployment: Text Embedding NIM seamlessly scales from a few users to millions.
- Flexible Integration: Text Embedding NIM can be easily incorporated into existing data pipelines and applications. Developers are provided with an OpenAI-compatible API in addition to custom NVIDIA extensions.
- Enterprise-Grade Security: Text Embedding NIM comes with security features such as the use of safetensors, continuous patching of CVEs, and constant monitoring with our internal penetration tests.

FlashStack Components

The FlashStack architecture was jointly developed by Cisco and Pure Storage. All FlashStack components are integrated, allowing customers to deploy the solution quickly and economically while eliminating many of the risks associated with researching, designing, building, and deploying similar solutions from the foundation. One of the main benefits of FlashStack is its ability to maintain consistency at scale. Figure 11 illustrates the series of hardware components used for building the FlashStack architectures.

Figure 11. FlashStack Components


Cisco UCS X9508* Chassis or Cisco UCS 5108 Blade Server Chassis
10/25/40/100 GE
Cisco UCS-managed Infrastructure with UCS 6400, 6500 Fabric Interconnects
10/25/100 GE
Cisco UCS C-Series Rack Servers
10/25/40/100 GE
16/32-Gbps Fibre Channel
Cisco Nexus 9000 Series Switches
Cisco MDS 9000 Series Multilayer Switches
10/25/40/100 GE
16/32 Gbps Fibre Channel
CISCO UCS Manager
CISCO INTERSIGHT
portworx by Pure Storage
* Cisco UCS X9508 Chassis only supported with Cisco UCS 6400 and 6500 FIs
Pure Storage FlashArray Series
Pure FlashBlade//S

All FlashStack components are integrated, so you can deploy the solution quickly and economically while eliminating many of the risks associated with researching, designing, building, and deploying similar solutions from the foundation. One of the main benefits of FlashStack is its ability to maintain consistency at scale. Each of the component families shown in Figure 11 (Cisco UCS, Cisco Nexus, Cisco MDS, Portworx by Pure Storage, Pure Storage FlashArray and FlashBlade systems) offers platform and resource options to scale up or scale out the infrastructure while supporting the same features and functions.

Benefits of Portworx Enterprise with OpenShift Container Platform

Portworx Enterprise is a multi-cloud solution, providing cloud-native storage for workloads running anywhere, from on-prem to cloud to hybrid/multi-cloud environments. Portworx Enterprise is deployed on Red Hat OpenShift cluster using the Red Hat certified Portworx Enterprise operator, available on Red Hat's OperatorHub. Portworx with Red Hat OpenShift Container Platform enhances data management for container workloads by offering integrated, enterprise-grade storage. It includes simplified storage operations through Kubernetes, high availability and resiliency across environments, advanced disaster recovery options, and automated scaling capabilities. This integration supports a unified infrastructure where traditional and modern workloads coexist, providing flexibility in deployment across diverse infrastructures and ensuring robust data security.

Portworx and Stork offer a combined solution for managing persistent data and stateful applications within Red Hat OpenShift (OCP), providing features like storage orchestration, disaster recovery, and data protection. Portworx provides a software-defined storage solution that works natively within Kubernetes, including OpenShift, while Stork acts as a storage scheduler and orchestrator, enhancing the functionality of Portworx.

Benefits of Portworx Enterprise with Pure Storage FlashArray

Portworx on FlashArray offers flexible storage deployment options for Kubernetes. Using FlashArray as cloud drives enables automatic volume provisioning, cluster expansion, and supports PX Backup and Autopilot. Direct Access volumes allow for efficient on-premises storage management, offering file system operations, IOPS, and snapshot capabilities. Multi-tenancy features isolate storage access per user, enhancing security in shared environments.

Portworx on FlashArray enhances Kubernetes environments with robust data reduction, resiliency, simplicity, and support. It lowers storage costs through deduplication, compression, and thin provisioning, providing 2-10x data reduction. FlashArray's reliable infrastructure ensures high availability, reducing server-side rebuilds. Portworx simplifies Kubernetes deployment with minimal configuration and end-to-end visibility via Pure1. Additionally, unified support, powered by Pure1 telemetry, offers centralized, proactive assistance for both storage hardware and Kubernetes services, creating an efficient and scalable solution for enterprise needs.

Benefits of Pure Storage FlashBlade

Pure Storage FlashBlade//S is a scale-out storage system that is designed to grow with your unstructured data needs for AI/ML, analytics, high performance computing (HPC), and other data-driven file and object use cases in areas of healthcare, genomics, financial services, and more. FlashBlade//S provides a simple, high-performance solution for Unified Fast File and Object (UFFO) storage with an all-QLC based, distributed architecture that can support NFS, SMB, and S3 protocol access. The cloud-based Pure1® data management platform provides a single view to monitor, analyze, and optimize storage from a centralized location.

FlashBlade//S is the ideal data storage platform for AI, as it was purpose-built from the ground up for modern, unstructured workloads and accelerates AI processes with the most efficient storage platform at every step of your data pipeline. A centralized data platform in a deep learning architecture increases the productivity of AI engineers and data scientists and makes scaling and operations simpler and more agile for the data architect.

An AI project that uses a single-chassis system during early model development can expand non-disruptively as data requirements grow during training and continue to expand as more live data is accumulated during production.

Table 1. FlashBlade//S Specifications

FlashBlade	Scalability	Capacity	Connectivity	Physical
FlashBlade//S	Start with a minimum of 7 blades and scale up to 10 blades in a single chassis	Up to 4 DirectFlash Modules per blade (24TB or 37TB or 48TB or 75TB DirectFlash Modules)	Uplink networking 8 x 100GbE	5U per chassis Dimensions: 8.59” x 17.43” x 32.00” x 32.00”
	Independently scale capacity and performance with all-QLC architecture	Up to 300TB per blade	Future-proof midplane	2,400W (nominal at full configuration)

Solution Design

This chapter contains the following:

- Design Considerations
- FlashStack Topology
- Red Hat OpenShift Container Platform on Bare Metal Server Configuration
- RAG Design Summary

Design Considerations

The FlashStack Datacenter with Cisco UCS and Cisco Intersight meets the following general design requirements:

- Resilient design across all the layers of 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 the 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
- Repeatable design for accelerating the provisioning of end-to-end Retrieval Augmented Generation pipeline
- Provide a testing methodology to evaluate the performance of the solution
- Provide an example implementation of Cisco Webex Chat Bot integration with RAG

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

FlashStack Topology

The FlashStack for Accelerated RAG Pipeline with NVIDIA NIM and NIVIDIA Blueprint is built using the following reference hardware components:

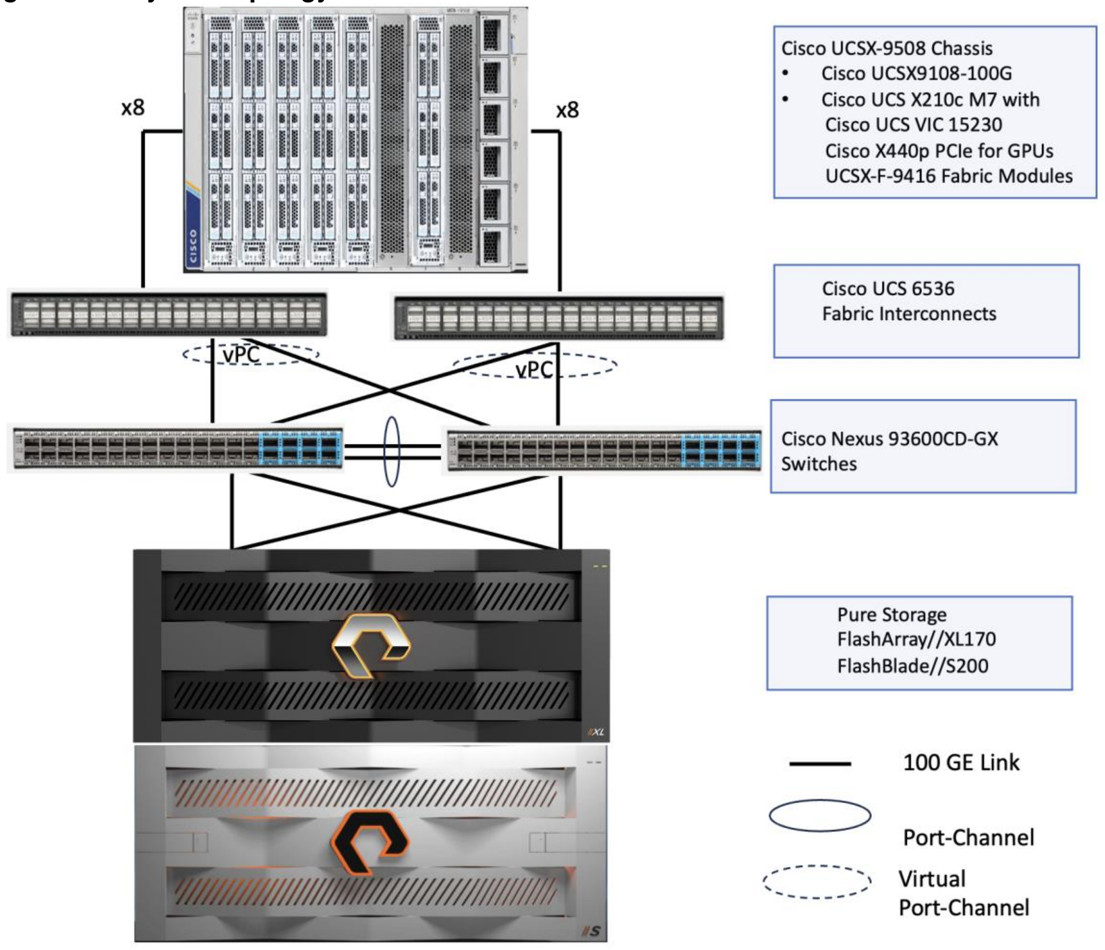
- One Cisco UCS X9508 chassis, equipped with a pair of Cisco UCS X9108 100G IFMs, contains six Cisco UCS X210c M7 compute nodes and two Cisco UCS X440p PCIe nodes each with two NVIDIA L40S GPUs. Other configurations of servers with and without GPUs are also supported. Each compute node is equipped with fifth-generation Cisco VIC card 15231 providing 100-G ethernet connectivity on each side of the fabric. A pair of Fabric Modules installed at the rear side of the chassis enables connectivity between the X440p PCIe nodes and X210c M7 nodes.
- Cisco fifth-generation 6536 fabric interconnects are used to provide connectivity to the compute nodes installed in the chassis.
- High-speed Cisco NXOS-based Nexus C93600CD-GX switching design to support up to 100 and 400-GE connectivity.
- FlashBlade//S200 is used as S3 compatible object storage to persist Milvus Vector database large-scale files, such as index files and binary logs. It is directly exposed to Milvus vector database pods hosted on the OpenShift cluster. The OpenShift cluster is configured to route the object storage traffic from Milvus Pods to FlashBlade via worker node's object storage network interface. Pure Storage FlashBlade is a

unified and scale out storage platform providing native file and object storage, offering a modular architecture for unstructured data workloads, enabling independent scaling of compute and capacity.

- FlashArray//XL170 is used as high performing back end storage for Portworx Enterprise which provides cloud native persistent storage with enterprise grade features for containers and other workloads running on the OpenShift cluster.

Figure 12 shows the physical topology and network connections used for this Ethernet-based FlashStack design.

Figure 12. Physical Topology



The software components consist of:

- Cisco Intersight platform to deploy, maintain, and support the FlashStack components.
- Cisco Intersight Assist virtual appliance to help connect the Pure Storage FlashArray and Cisco Nexus Switches with the Cisco Intersight platform to enable visibility into these platforms from Intersight.
- Red Hat OpenShift Container Platform for providing a consistent hybrid cloud foundation for building and scaling containerized and virtualized applications.
- Portworx by Pure Storage (Portworx Enterprise) data platform for providing enterprise grade storage for containerized workloads hosted on OpenShift platform.
- Pure Storage Pure1 is a cloud-based, AI-driven SaaS platform that simplifies and optimizes data storage management for Pure Storage arrays, offering features like proactive monitoring, predictive analytics, and automated tasks.

FlashStack Cabling

The information in this section is provided as a reference for cabling the physical equipment in a FlashStack environment.

Compute Infrastructure Design

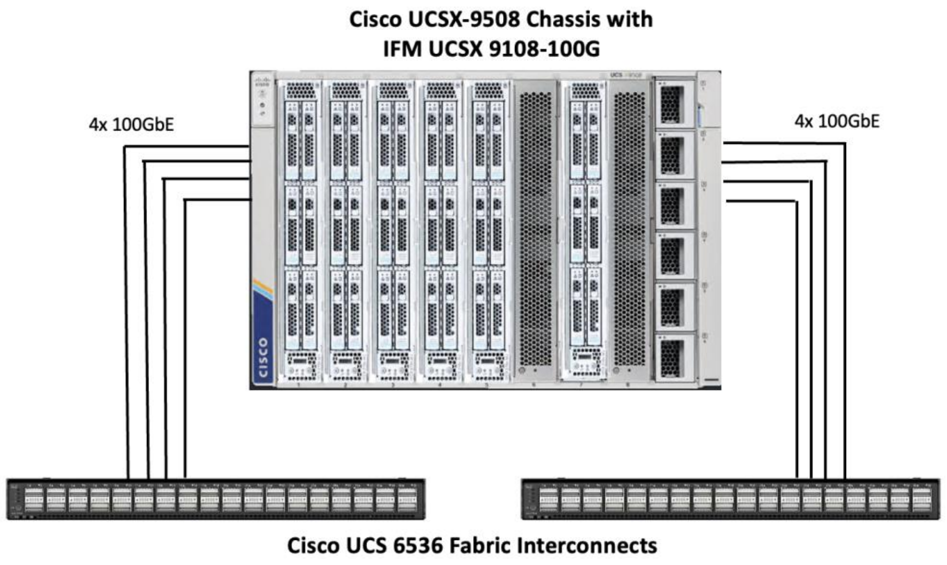
The compute infrastructure in FlashStack solution consists of the following:

- Cisco UCS X210c M7 Compute Nodes
- Cisco UCS X-Series chassis (Cisco UCSX-9508) with Intelligent Fabric Modules (Cisco UCSX-I-9108-25G)
- Cisco UCS Fabric Interconnects (Cisco UCS-FI-6536)

Compute System Connectivity

The Cisco UCS X9508 Chassis is equipped with the Cisco UCSX 9108-100G intelligent fabric modules (IFMs). The Cisco UCS X9508 Chassis connects to each Cisco UCS 6536 FI using four 100GE ports, as shown in Figure 13. If you require more bandwidth, all eight ports on the IFMs can be connected to each FI.

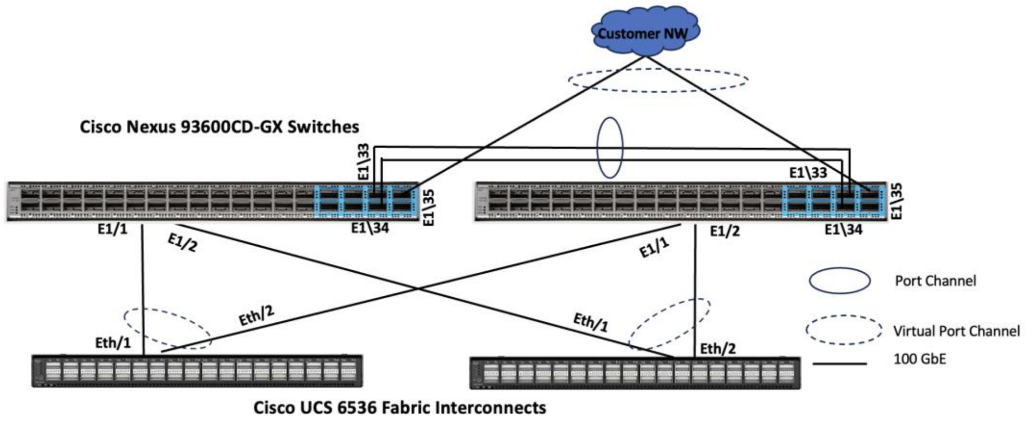
Figure 13. Cisco UCSX-9508 Chassis Connectivity


Cisco UCSX-9508 Chassis with
IFM UCSX 9108-100G
4x 100GbE
4x 100GbE
Cisco UCS 6536 Fabric Interconnects

Compute UCS Fabric Interconnect 6536 Ethernet Connectivity

Cisco UCS 6536 FIs are connected to Cisco Nexus 93600CD-GX switches using 100GE connections configured as virtual port channels. Each FI is connected to both Cisco Nexus switches using a 100G connections; additional links can easily be added to the port channel to increase the bandwidth as needed. Below figure illustrates the physical connectivity details.

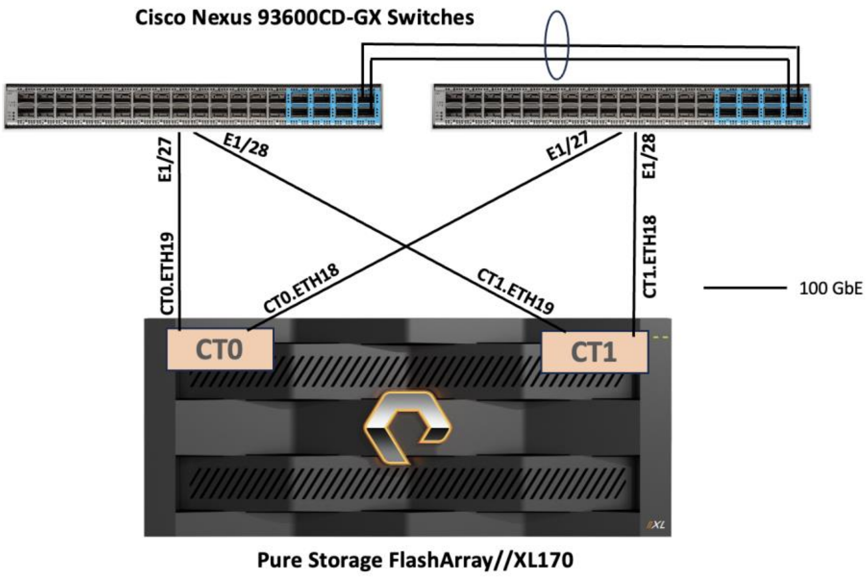
Figure 14. Fabric Interconnect to Nexus Switches Connectivity



Pure Storage FlashArray//XL170 Ethernet Connectivity

Pure Storage FlashArray controllers are connected to Cisco Nexus 93600CD-GX switches using redundant 100-GE. Figure 15 illustrates the physical connectivity details.

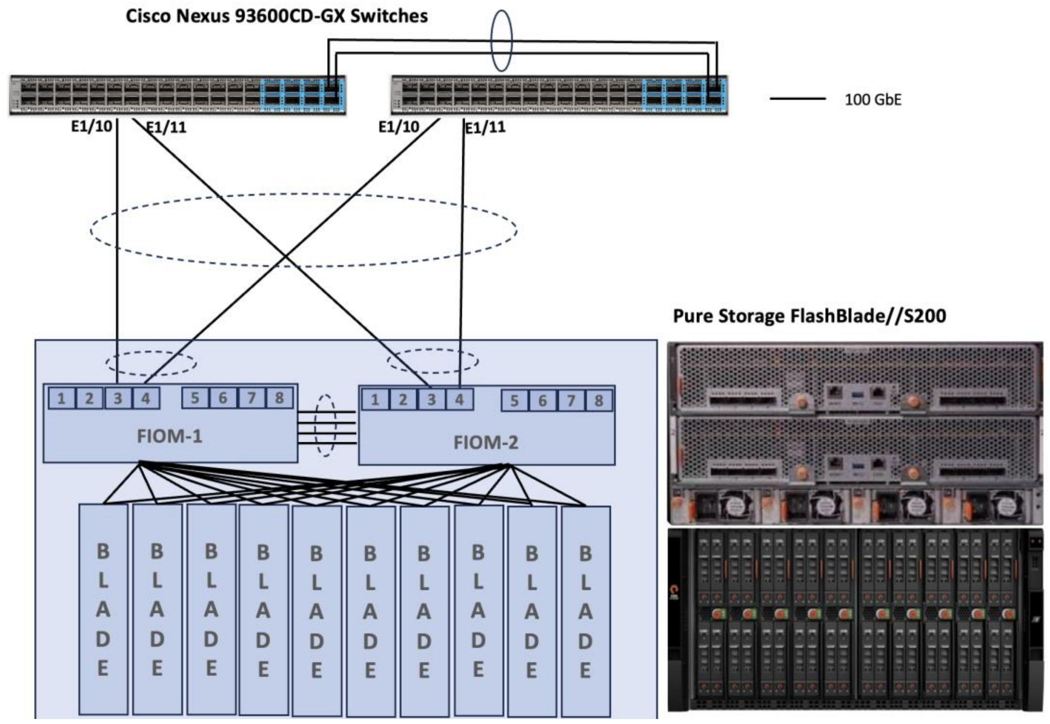
Figure 15. Pure Storage FlashArray//XL170 Connectivity



Pure Storage FlashBlade//S200 Ethernet Connectivity

Pure Storage FlashBlade uplink ports (2x 100GbE from each FIOM) are connected to Cisco Nexus 93600CD-GX switches as shown in Figure 16. Additional links can easily be added (up to 8x 100GbE on each FIOM) to the port channel to increase the bandwidth as needed. Following figure illustrates the physical connectivity details.

Figure 16. **Pure Storage FlashBlade//S200 Connectivity**


Cisco Nexus 93600CD-GX Switches
100 GbE
E1/10
E1/11
E1/10
E1/11
Pure Storage FlashBlade//S200
1
2
3
4
5
6
7
8
FIOM-1
FIOM-2
BLADE

Note: Additional 1Gb management connections are needed for one or more out-of-band network switches that are apart from the FlashStack infrastructure. Each Cisco UCS fabric interconnect and Cisco Nexus switch is connected to the out-of-band network switches, Pure Storage FlashArray controllers and FlashBlade//S200 have connections to the out-of-band network switches. Layer 3 network connectivity is required between the Out-of-Band (OOB) and In-Band (IB) Management Subnets.

Red Hat OpenShift Container Platform on Bare Metal Server Configuration

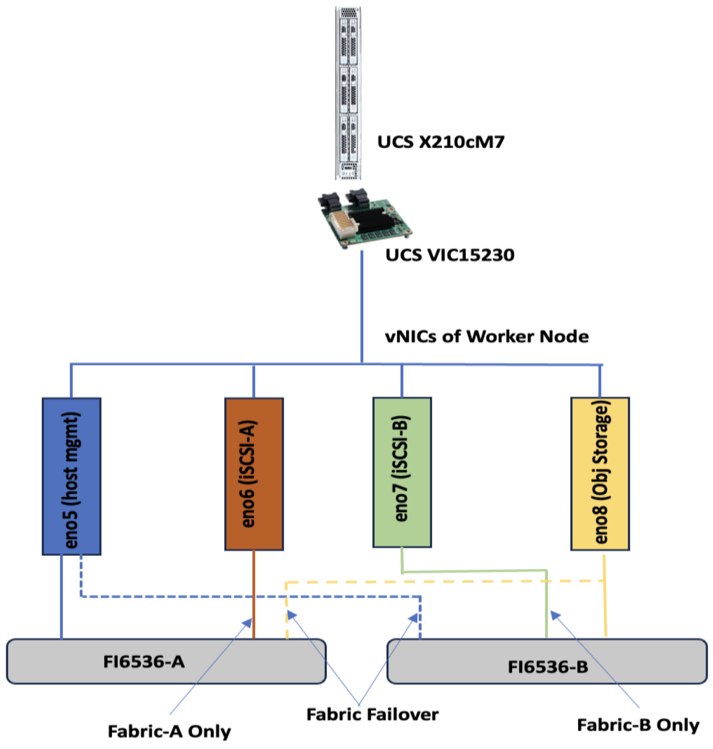
A simple Red Hat OpenShift cluster consists of at least five servers – 3 Master or Control Plane Nodes and 2 or more Worker or compute Nodes where applications and VMs are run. In this lab validation 3 Worker Nodes were utilized. Based on published Red Hat requirements, the three Master Nodes were configured with 64GB RAM, and the three Worker Nodes were configured with 1024GB memory to handle containerized applications and Virtual Machines. Each Node was booted from RAID1 disk created using two M.2 SSD drives. Also, the servers paired with X440p PCIe Nodes were configured as Workers. From a networking perspective, both the Masters and the Workers were configured with a single vNIC with UCS Fabric Failover in the Bare Metal or Management VLAN. The Workers were configured with extra NICs (vNICs) to allow storage attachment to the Workers.

Each worker node is configured with two additional vNICs with the iSCSI A and B VLANs tagged as native to allow iSCSI persistent storage attachment from FlashArray//XL170 and future iSCSI boot. Finally, each worker is also configured with one additional vNIC with the OCP Object-Storage VLAN tagged as native VLAN to provide object persistent storage from FlashBlade//S200.

Worker Node Network Configuration

The worker node is configured with four vNICs. The first three vNICs are used by worker node for OpenShift cluster management traffic (eno5) and storage traffic using iSCSI protocol (eno6 and eno7). While the last vNIC (eno8) is used for object storage traffic over ethernet. vNICs eno5 and eno8 vNICs are configured with Fabric-Failover option while the vNICs eno6 and eno7 are used as independent interfaces for iSCSI storage traffic via Fabric-A and B, respectively. The following figure illustrates the vNIC configuration of OpenShift worker nodes.

Figure 17. Worker Node vNIC configuration



The control plane (master node) will just have one vNIC eno5 with Fabric-Failover option enabled. This vNIC is used to carry the worker management and OCP cluster traffic.

VLAN Configuration

Table 2 lists the VLANs configured for setting up the FlashStack environment along with their usage.

Table 2. VLAN Usage

VLAN ID	NAME	Usage	IP Subnet used in this deployment
2	Native-VLAN	VLAN2 is used as native VLAN instead of default VLAN1	
1060	OOB-Mgmt-VLAN	Out-of-band management VLAN to connect management port for various devices	10.106.0.24/0 BW: 10.106.0.254
1061	IB-Mgmt-VLAN	Routable Bare Metal VLAN used for OpenShift cluster and node management	10.106.1.0/24 GW: 10.106.1.254
3010	OCP-iSCSI-A	Used for OpenShift iSCSI persistent storage via Fabric-A	192.168.51.0/24
3020	OCP-iSCSI-B	Used for OpenShift iSCSI persistent storage via Fabric-B	192.168.52.0/24
3040	OCP-Object-storage	Used for Object Storage traffic	192.168.40.0/24

Table 3 lists the infrastructure services running on either virtual machines or bar mental servers required for deployment as outlined in the document. All these services are hosted on pre-existing infrastructure with in the FlashStack

Table 3. Infrastructure services

Service Description	VLAN	IP Address
AD/DNS-1 & DHCP	1061	10.106.1.21
AD/DNS-2	1061	10.106.1.22
OCP installer/bastion node	1061	10.106.1.23
Cisco Intersight Assist Virtual Appliance	1061	10.106.1.24

Software Revisions

The FlashStack Solution with Red Hat OpenShift on Bare Metal infrastructure configuration is built using the following components.

Table 4 lists the required software revisions for various components of the solution.

Table 4. Software Revisions

Layer	Device	Image Bundle version	Comments
Compute	Pair of Cisco UCS Fabric Interconnect - 6530	4.3(4.240066)	
	6x Cisco UCS X210 M7 with Cisco VIC 15230	5.2(2.240053)	
Network	Cisco Nexus 93699CD-GX-NX-OS	10.3(5)(M)	
Storage	Pure Storage FlashArray Purity //FA Pure Storage FlashBlade//S200	Purity//FA 6.6.10 Purity//FB 4.1.12	
Software	Red Hat OpenShift	4.17	
	Portworx Enterprise	3.1.6	
	Cisco Intersight Assist Appliance	1.1.1-0	
	NVIDIA L40S Driver	550.90.07	

RAG Design Summary

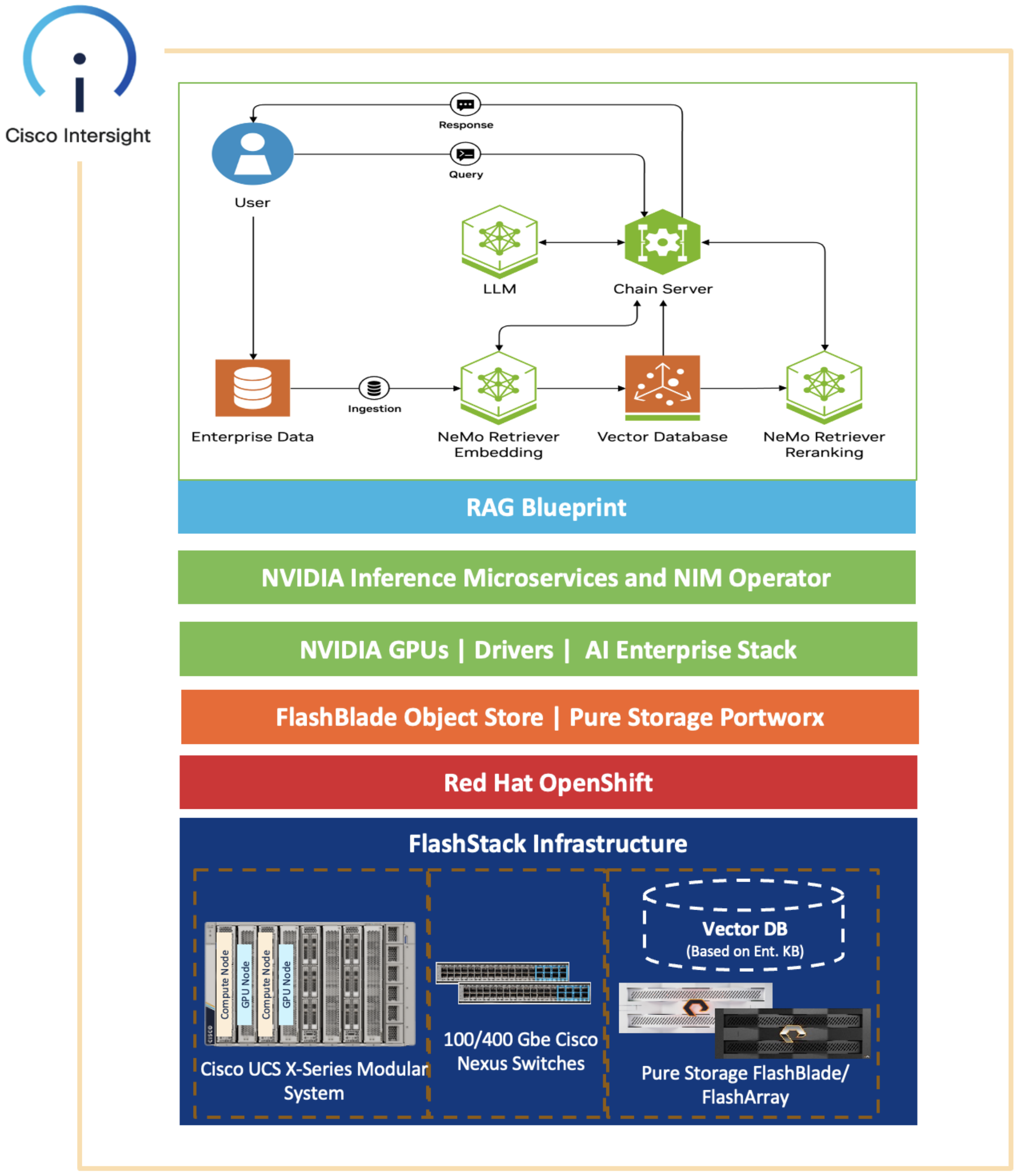
This solution implements a validated Retrieval Augmented Generation (RAG) pipeline architected to enhance Large Language Model (LLM) capabilities with real-time access to enterprise-specific data, thereby increasing user trust and mitigating hallucinations. The design adheres to core RAG principles aligning with the robust methodologies.

This entire RAG pipeline is deployed upon a validated FlashStack architecture, specifically configured following the best practices outlined here: FlashStack with Red Hat OpenShift Container and Virtualization Platform using Cisco UCS X-Series Design and Deployment Guide.

The layered infrastructure, running on Red Hat OpenShift Container Platform with persistent storage managed by Portworx Enterprise, provides a high-performance, secure, and scalable environment. The use of locally deployed NVIDIA NIMs within this secure infrastructure ensures data privacy and control.

This design leverages the NVIDIA RAG Blueprint as a foundational framework, implemented with optimized NVIDIA NIMs. It directly addresses the goals of RAG by providing up-to-date, proprietary information to the LLM securely. The underlying FlashStack platform offers significant performance and reliability, while also being extensible for future AI initiatives such as model fine-tuning, training, or other inferencing use cases, contingent on appropriate resource allocation.

Figure 18. Solution Components


Cisco Intersight
Response
Query
User
LLM
Chain Server
Ingestion
Enterprise Data
NeMo Retriever Embedding
Vector Database
NeMo Retriever Reranking
RAG Blueprint
NVIDIA Inference Microservices and NIM Operator
NVIDIA GPUs | Drivers | AI Enterprise Stack
FlashBlade Object Store | Pure Storage Portworx
Red Hat OpenShift
FlashStack Infrastructure
Compute Node
GPU Node
Compute Node
GPU Node
Cisco UCS X-Series Modular System
100/400 Gbe Cisco Nexus Switches
Vector DB
(Based on Ent. KB)
Pure Storage FlashBlade/ FlashArray

Network Switch Configuration

This chapter contains the following:

- Physical Connectivity
- Cisco Nexus Switch Manual Configuration
- Claim Cisco Nexus Switches into Cisco Intersight

Physical Connectivity

Physical cabling should be completed by following the diagram and table references in section FlashStack Cabling.

The following procedures describe how to configure the Cisco Nexus 93600CD-GX switches for use in a FlashStack environment. This procedure assumes the use of Cisco Nexus 9000 10.1(2), the Cisco suggested Nexus switch release at the time of this validation.

The 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 document assumes that initial day-0 switch configuration is already done using switch console ports and ready to use the switches using their management IPs.

Cisco Nexus Switch Manual Configuration

Procedure 1. Enable features on Cisco Nexus A and Cisco Nexus B

Step 1. Log into both Nexus switches as admin using ssh.

Step 2. Enable the switch features as described below:

```
config t
feature nxapi
cfs eth distribute
feature udld
feature interface-vlan
feature netflow
feature hsrp
feature lacp
feature vpc
feature lldp
```

Procedure 2. Set Global Configurations on Cisco Nexus A and Cisco Nexus B

Step 1. Log into both Nexus switches as admin using ssh.

Step 2. Run the following commands to set the global configurations:

```
spanning-tree port type edge bpduguard default
spanning-tree port type edge bpdufilter default
spanning-tree port type network default
system default switchport
system default switchport shutdown
```

```
port-channel load-balance src-dst l4port

ntp server <Global-ntp-server-ip> use-vrf default

ntp master 3

clock timezone <timezone> <hour-offset> <minute-Offset>

clock summer-time <timezone> <start-weekk> <start-day> <start-month> <start-time> <end-week> <end-day> <enb-month> <end-time> <offset-minutes>

ip route 0.0.0.0/0 <IB-Mgmt-VLAN-gatewayIP>

copy run start
```

Note: It is important to configure the local time so that logging time alignment and any backup schedules are correct. For more information on configuring the timezone and daylight savings time or summer time, go to: https://www.cisco.com/c/en/us/td/docs/dcn/nx-os/nexus9000/102x/configuration/fundamentals/cisco-nexus-9000-nx-os-fundamentals-configuration-guide-102x/m-basic-device-management.html#task_1231769

Sample clock commands for the United States Eastern timezone are:

clock timezone EST -5 0

clock summer-time EDT 2 Sunday March 02:00 1 Sunday November 02:00 60

Procedure 3. Create VLANs on Cisco Nexus A and Cisco Nexus B

Step 1. From the global configuration mode, run the following commands:

```
Vlan <oob-mgmt-vlan-id>

name OOB-Mgmt-VLAN

Vlan <ib-mgmt-vlan-id>

name IB-Mgmt-VLAN

Vlan <native-vlan-id>

name Native-VLAN

Vlan <ocp-iscsi-a-vlan-id>

name OCP-iSCSI-A

Vlan <ocp-iscsi-b-vlan-id>

name OCP-iSCSI-B

Vlan <vm-mgmt-vlan-id>

name VM-Mgmt-VLAN
```

Procedure 4. Add NTP Distribution Interface

Cisco Nexus - A

Step 1. From the global configuration mode, run the following commands:

```
interface vlan <ib-mgmt-vlan-id>

ip address <switch-a-ntp-ip>/<ib-mgmt-vlan-netmask-length>

no shut

exit

ntp peer <switch-b-ntp-ip> use-vrf default
```

Cisco Nexus - B

Step 1. From the global configuration mode, run the following commands:

```
interface vlan <ib-mgmt-vlan-id>
ip address <switch-b-ntp-ip>/<ib-mgmt-vlan-netmask-length>
no shut
exit
ntp peer <switch-a-ntp-ip> use-vrf default
```

Procedure 5. Define Port Channels on Cisco Nexus A and Cisco Nexus B

Cisco Nexus – A and B

Step 1. From the global configuration mode, run the following commands:

```
interface port-channel 10
description vPC Peer Link
switchport mode trunk
switchport trunk native vlan 2
switchport trunk allowed vlan 1060-1062,3010,3020
spanning-tree port type network

interface port-channel 20
switchport mode trunk
switchport trunk native vlan 2
switchport trunk allowed vlan 1060-1062,3010,3020
spanning-tree port type edge trunk
mtu 9216

interface port-channel 30
switchport mode trunk
switchport trunk native vlan 2
switchport trunk allowed vlan 1060-1062,3010,3020
spanning-tree port type edge trunk
mtu 9216

interface port-channel 100
description vPC to AC10-Pure-FB-S200
switchport mode trunk
switchport trunk allowed vlan 3040,3030
spanning-tree port type edge trunk
mtu 9216

### Optional: The below port channels is for connecting the Nexus switches to the existing customer network
interface port-channel 106
description connectting-to-customer-Core-Switches
switchport mode trunk
switchport trunk native vlan 2
switchport trunk allowed vlan 1060-1062
spanning-tree port type normal
```

```
mtu 9216
```

Procedure 6. Configure Virtual Port Channel Domain on Nexus A and Cisco Nexus B

Cisco Nexus - A

Step 1. From the global configuration mode, run the following commands:

```
vpc domain <nexus-vpc-domain-id>
peer-switch
role priority 10
peer-keepalive destination 10.106.0.6 source 10.106.0.5
delay restore 150
peer-gateway
auto-recovery
ip arp synchronize
```

Cisco Nexus - B

Step 1. From the global configuration mode, run the following commands:

```
vpc domain <nexus-vpc-domain-id>
peer-switch
role priority 20
peer-keepalive destination 10.106.0.5 source 10.106.0.6
delay restore 150
peer-gateway
auto-recovery
ip arp synchronize
```

Procedure 7. Configure individual Interfaces

Cisco Nexus-A

Step 1. From the global configuration mode, run the following commands:

```
interface Ethernet1/1
description FI6536-A-uplink-Eth1
channel-group 20 mode active
no shutdown

interface Ethernet1/2
description FI6536-B-uplink-Eth1
channel-group 30 mode active
no shutdown

interface Ethernet1/35
description Nexus-B-35
channel-group 10 mode active
no shutdown
```

```
interface Ethernet1/36
description Nexus-B-36
channel-group 10 mode active
no shutdown

## Optional: Configuration for interfaces that connected to the customer existing management network
interface Ethernet1/33/1
description customer-Core-1:Eth1/37
channel-group 106 mode active
no shutdown

interface Ethernet1/33/2
description customer-Core-2:Eth1/37
channel-group 106 mode active
no shutdown
```

Cisco Nexus-B

Step 1. From the global configuration mode, run the following commands:

```
interface Ethernet1/1
description FI6536-A-uplink-Eth2
channel-group 20 mode active
no shutdown

interface Ethernet1/2
description FI6536-B-uplink-Eth2
channel-group 30 mode active
no shutdown

interface Ethernet1/35
description Nexus-A-35
channel-group 10 mode active
no shutdown

interface Ethernet1/36
description Nexus-A-36
channel-group 10 mode active
no shutdown

## Optional: Configuration for interfaces that connected to the customer existing management network
interface Ethernet1/33/1
description customer-Core-1:Eth1/38
channel-group 106 mode active
no shutdown

interface Ethernet1/33/2
```

```
description customer-Core-2:Eth1/38
channel-group 106 mode active
no shutdown
```

Procedure 8. Update the port channels

Cisco Nexus-A and B

Step 1. From the global configuration mode, run the following commands:

```
interface port-channel 10
vpc peer-link
interface port-channel 20
vpc 20
interface port-channel 30
vpc 30
interface port-channel 100
vpc 100
interface port-channel 106
vpc 106

copy run start
```

Step 2. To check for correct switch configuration, run the following commands:

```
Show run
show vpc
show port-channel summary
show ntp peer-status
show cdp neighbours
show lldp neighbours
show udld neighbours
show run int
show int
show int status
```

Cisco Nexus Configuration for Storage Traffic

Procedure 1. Configure Interfaces for Pure Storage on Cisco Nexus and Cisco Nexus B

Cisco Nexus - A

Step 1. From the global configuration mode, run the following commands:

```
### Configuration for FlashArray//XL170
interface Ethernet1/27
description PureXL170-ct0-eth19
switchport access vlan 3010
spanning-tree port type edge
mtu 9216
```

```
no shutdown

interface Ethernet1/28
description PureXL170-ct1-eth19
switchport access vlan 3010
spanning-tree port type edge
mtu 9216
no shutdown
copy run start

### Configuration for FlashBlade//S200
interface Ethernet1/10
description vPC to AC10-Pure-FB-S200
switchport mode trunk
switchport trunk allowed vlan 3030,3040
spanning-tree port type edge
mtu 9216
channel-group 100 mode active
no shutdown

interface Ethernet1/11
description vPC to AC10-Pure-FB-S200
switchport mode trunk
switchport trunk allowed vlan 3030,3040
spanning-tree port type edge
mtu 9216
channel-group 100 mode active
no shutdown
```

Cisco Nexus - B

Step 1. From the global configuration mode, run the following commands:

```
### Configuration for FlashArray//XL170
interface Ethernet1/27
description PureXL170-ct0-eth18
switchport access vlan 3020
spanning-tree port type edge
mtu 9216
no shutdown

interface Ethernet1/28
description PureXL170-ct1-eth18
switchport access vlan 3020
spanning-tree port type edge
mtu 9216
no shutdown
```

```
copy run start
### Configuration for FlashBlade//S200
interface Ethernet1/10
description vPC to AC10-Pure-FB-S200
switchport mode trunk
switchport trunk allowed vlan 3030,3040
spanning-tree port type edge
mtu 9216
channel-group 100 mode active
no shutdown

interface Ethernet1/11
description vPC to AC10-Pure-FB-S200
switchport mode trunk
switchport trunk allowed vlan 3030,3040
spanning-tree port type edge
mtu 9216
channel-group 100 mode active
no shutdown
```

Claim Cisco Nexus Switches into Cisco Intersight

Cisco Nexus switches can be claimed into the Cisco Intersight either using Cisco Intersight Assist or Direct claim using Device ID and Claim Codes.

This section provides the steps to claim the Cisco Nexus switches using Cisco Intersight Assist.

Note: This procedure assumes that Cisco Intersight is already hosted outside the OpenShift cluster and claimed into Intersight.com.

Procedure 1. Claim Cisco Nexus Switches into Cisco Intersight using Cisco Intersight Assist

Cisco Nexus - A

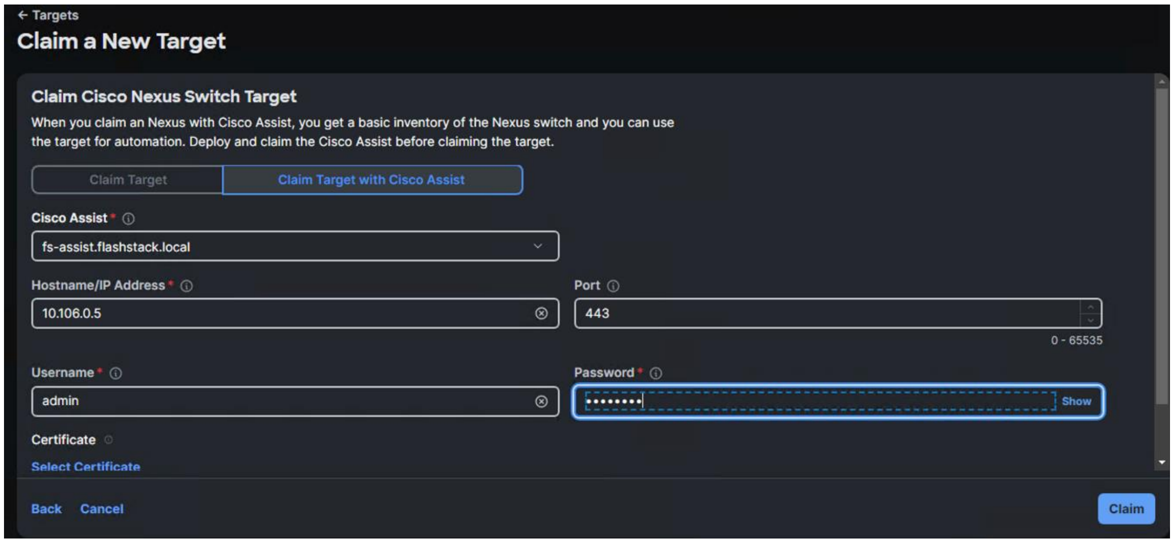
Step 1. Log into **Nexus Switches** and confirm the **nxapi** feature is enabled:

```
show nxapi
nxapi enabled
NXAPI timeout 10
HTTPS Listen on port 443
Certificate Information:
    Issuer:   issuer=C = US, ST = CA, L = San Jose, O = Cisco Systems Inc., OU = dcnxos, CN = nxos
    Expires:  Sep 12 06:08:58 2024 GMT
```

Step 2. Log into **Cisco Intersight** with your login credentials. From the drop-down list select **System.**

Step 3. Under **Admin**, click **Target** then click **Claim a New Target.** Under **Categories**, select **Network**, click **Cisco Nexus Switch,** and then click **Start.**

Step 4. Select the **Cisco Assist** name which is already deployed and configured. Provide the Cisco Nexus Switch management **IP address**, **username** and **password** details and click **Claim.**



Claim Cisco Nexus Switch Target

When you claim an Nexus with Cisco Assist, you get a basic inventory of the Nexus switch and you can use the target for automation. Deploy and claim the Cisco Assist before claiming the target.

Claim Target | Claim Target with Cisco Assist

Cisco Assist *: fs-assist.flashstack.local

Hostname/IP Address *: 10.106.0.5

Port: 443 (0 - 65535)

Username *: admin

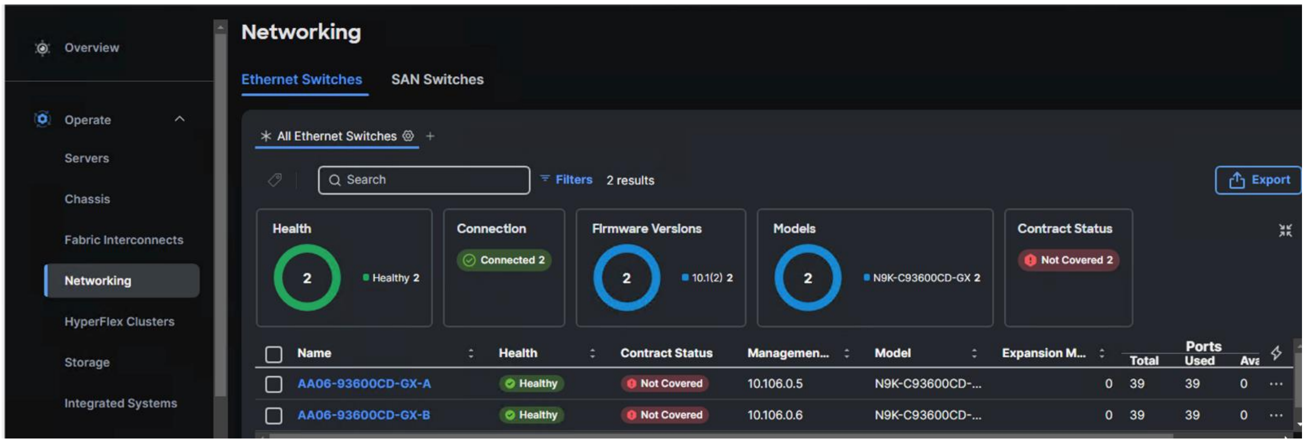
Password *: •••••••• Show

Certificate: Select Certificate

Back Cancel Claim

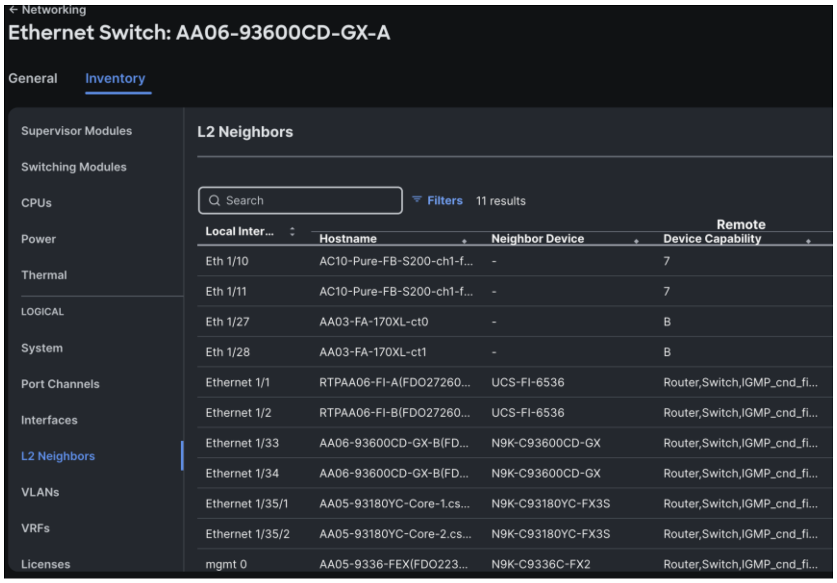
Step 5. Repeat steps 1 through 4 to claim the remaining Switch B.

Step 6. When the storage is successfully claimed, from the drop-down list, select **Infrastructure Services**. Under **Operate**, click **Networking** tab. On the right you will find the newly claimed Cisco Nexus switch details and browse through the Switches for viewing the inventory details.



Name	Health	Contract Status	Managemen...	Model	Expansion M...	Ports Total	Ports Used	Ports Ava
AA06-93600CD-GX-A	Healthy	Not Covered	10.106.0.5	N9K-C93600CD-...	0	39	39	0
AA06-93600CD-GX-B	Healthy	Not Covered	10.106.0.6	N9K-C93600CD-...	0	39	39	0

The L2 neighbors of the Cisco Nexus Switch-A is shown below:



Ethernet Switch: AA06-93600CD-GX-A

L2 Neighbors

11 results

Local Inter...	Remote		
	Hostname	Neighbor Device	Device Capability
Eth 1/10	AC10-Pure-FB-S200-ch1-f...	-	7
Eth 1/11	AC10-Pure-FB-S200-ch1-f...	-	7
Eth 1/27	AA03-FA-170XL-ct0	-	B
Eth 1/28	AA03-FA-170XL-ct1	-	B
Ethernet 1/1	RTPAA06-FI-A(FDO27260...	UCS-FI-6536	Router,Switch,IGMP_cnd_fi...
Ethernet 1/2	RTPAA06-FI-B(FDO27260...	UCS-FI-6536	Router,Switch,IGMP_cnd_fi...
Ethernet 1/33	AA06-93600CD-GX-B(FD...	N9K-C93600CD-GX	Router,Switch,IGMP_cnd_fi...
Ethernet 1/34	AA06-93600CD-GX-B(FD...	N9K-C93600CD-GX	Router,Switch,IGMP_cnd_fi...
Ethernet 1/35/1	AA05-93180YC-Core-1.cs...	N9K-C93180YC-FX3S	Router,Switch,IGMP_cnd_fi...
Ethernet 1/35/2	AA05-93180YC-Core-2.cs...	N9K-C93180YC-FX3S	Router,Switch,IGMP_cnd_fi...
mgmt 0	AA05-9336-FEX(FDO223...	N9K-C9336C-FX2	Router,Switch,IGMP_cnd_fi...

Cisco Intersight Managed Mode Configuration for Cisco UCS

The chapter contains the following:

The procedures in this chapter describe how to configure a Cisco UCS domain for use in a base FlashStack environment. A Cisco UCS domain is defined as a pair for Cisco UCS FIs and all the servers connected to it. These can be managed using two methods: UCSM and IMM. The procedures detailed below are for Cisco UCS Fabric Interconnects running in Intersight managed mode (IMM).

The Cisco Intersight platform is a management solution delivered as a service with embedded analytics for Cisco and third-party IT infrastructures. The Cisco Intersight Managed Mode (also referred to as Cisco IMM or Intersight Managed Mode) is an architecture that manages Cisco Unified Computing System (Cisco UCS) fabric interconnect-attached systems through a Redfish-based standard model. Cisco Intersight managed mode standardizes both policy and operation management for Cisco UCS C-Series M7 and Cisco UCS X210c M7 compute nodes used in this deployment guide.

Note: This deployment guide assumes an Intersight account is already created, configured with required licenses and ready to use. Intersight Default Resource Group and Default Organizations are used for claiming all the physical components of the FlashStack solution.

Note: This deployment guide assumes that the initial day-0 configuration of Fabric Interconnects is already done in the IMM mode and claimed into the Intersight account.

Procedure 1. Fabric Interconnect Domain Profile and Policies

Step 1. Log into the **Intersight portal** and select **Infrastructure Service**. On the left select **Profiles** then under **Profiles** select **UCS Domain Profiles**.

Step 2. Click **Create UCS Domain Profile** to create a new domain profile for Fabric Interconnects. Under the **General** tab, select the **Default Organization**, enter **name** and **descriptions** of the profile.

Step 3. Click **Next** to go to UCS Domain Assignment. Click **Assign Later**.

Step 4. Click **Next** to go to VLAN & VSAN Configuration.

Step 5. Under **VLAN & VSAN Configuration** > **VLAN Configuration**, click **Select Policy** then click **Create New**.

Step 6. On the **Create VLAN** page, go to the **General** tab, enter a **name** (AA06-FI-VLANs), and click **Next** to go to Policy Details.

Step 7. To add a VLAN, click **Add VLANs**.

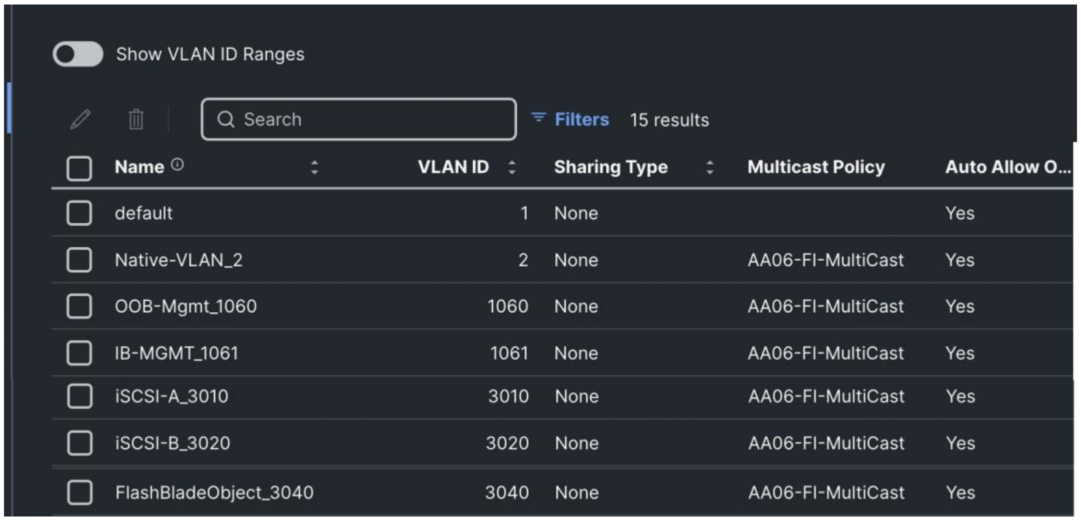
Step 8. For the **Prefix**, enter the **VLAN name** as **OOB-Mgmt-VLAN**. For the **VLAN ID**, enter the **VLAN ID 1061**. Leave **Auto Allow on Uplinks enabled** and **Enable VLAN Sharing disabled.**

Step 9. Under **Multicast Policy**, click **Select Policy** and select **Create New** to create a Multicast policy.

Step 10. On the **Create Multicast Policy** page, enter the **name** (AA06-FI-MultiCast) of the policy and click **Next** to go to **Policy Details**. Leave the **Snooping State** and **Source IP Proxy state** checked/enabled and click **Create.** Select the newly created **Multicast policy.**

Step 11. Repeat steps 1 through 10 to add all the required VLANs to the VLAN policy.

Step 12. After adding all the VLANs, click **Set Native VLAN ID** and enter the **native VLANs** (for example 2) and click **Create.** The VLANs used for this solution are shown below:



Name	VLAN ID	Sharing Type	Multicast Policy	Auto Allow O...
default	1	None		Yes
Native-VLAN_2	2	None	AA06-FI-MultiCast	Yes
OOB-Mgmt_1060	1060	None	AA06-FI-MultiCast	Yes
IB-MGMT_1061	1061	None	AA06-FI-MultiCast	Yes
iSCSI-A_3010	3010	None	AA06-FI-MultiCast	Yes
iSCSI-B_3020	3020	None	AA06-FI-MultiCast	Yes
FlashBladeObject_3040	3040	None	AA06-FI-MultiCast	Yes

Step 13. Select the newly created **VLAN policy** for both **Fabric Interconnects A** and **B.** Click **Next** to go to **Port Configuration.**

Step 14. Enter the **name** of the policy (AA06-FI-PortConfig) and click **Next** then click **Next** again to go to **Port Roles Page.**

Step 15. In the right pane, under **ports**, select **port 1** and **2** and click **Configure.**

Step 16. Set **Role** as **Server** and leave **Auto Negotiation enabled** and click **Save.**

Step 17. In the right pane click the **Port Channel** tab and click **Create Port Channel.**

Step 18. For the Role, select **Ethernet Uplink Port Channel.** Enter **201** as Port Channel ID. Set **Admin speed** as **100Gbps** and **FEC** as **Cl91.**

Step 19. Under **Link Control**, create a new link control policy with the following options. Once created, select the **policy.**

Table 5. UDLD policy

Policy Name	Setting Name
AA06-FI-LinkControll	UDLD Admin State: True UDLD mode: Normal

Step 20. For the **Uplink Port Channel** select **Ports 1** and **2** and click **Create** to complete the Port Roles policy.

Step 21. Click **Next** to go to UCS Domain Configuration page.

Table 6 lists the **Management** and **Network** related policies that are created and used.

Table 6. NTP policy

Policy Name	Setting Name
AA06-FI-OCP-NTP	Enable ntp: on Server list: **172.20.10.11,172.20.10.12,172.20.10.13** Timezone: America/New_York

Table 7. Network Connectivity Policy

Policy Name	Setting Name
AA06-FS-OCP-NWPolicy	Proffered IPV4 DNS Server: 10.106.1.21 Alternate IPV4 DNS Server: 10.106.1.22

Table 8. SNMP Policy

Policy Name	Setting Name
AA06-FS-OCP-SNMP	Enable SNMP: On (select **Both v2c and v3**) Snmp Port: 161 System Contact: your snmp admin email address System location: Location details snmp user: Name: snmpadmin Security level: AuthPriv Set Auth and Privacy passwords.

Table 9. QoS Policy

Policy Name	Setting Name
AA06-FS-OCP-SystemQoS	Best Effort: Enable Weight: 5 MTU: 9216

Step 22. When the UCS Domain profile is created with the above mentioned policies, edit the policy and assign it to the Fabric Interconnects.

Intersight will go through the discovery process and discover all the Cisco UCS C and X -Series compute nodes attached to the Fabric Interconnects.

Procedure 2. Server Profile Templates and Policies

In the Cisco Intersight platform, a server profile enables resource management by simplifying policy alignment and server configuration. The server profiles are derived from a server profile template. A Server profile template and its associated policies can be created using the server profile template wizard. After creating the server profile template, you can derive multiple consistent server profiles from the template.

The server profile templates captured in this deployment guide supports Cisco UCS X210c M7 compute nodes with 5th Generation VICs and can be modified to support other Cisco UCS blades and rack mount servers.

Create Pools

The following pools need to be created before proceeding with server profile template creation.

MAC Pools

Table 10 lists the two MAC pools for the vNICs that will be configured in the templates.

Table 10. MAC Pool Names and Address Ranges

MAC Pool Name	Address Ranges
AA06-OCP-IB-MGMT-IPPool-A	From: 00:25:B5:A6:0A:00 Size: 64
AA06-OCP-IB-MGMT-IPPool-B	From: 00:25:B5:A6:0B:00 Size: 64

UUID pool

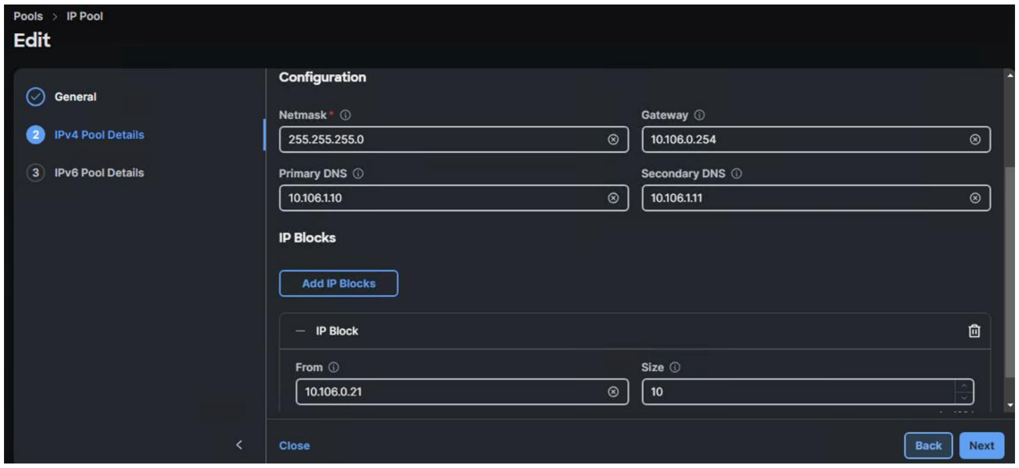
Table 11 lists the settings for the UUID pools.

Table 11. UUID Pool Names and Settings

UUID Pool Name	Settings
AA06-OCP-UUIDPool	UUID Prefix: AA060000-0000-0001 From: AA06-000000000001 To: AA06-000000000080 Size: 128
AA06-OCP-IB-MGMT-IPPool-B	From: 00:25:B5:A6:0B:00 Size: 64

Out-Of-Band (OOB) Management IP Pool

A OOB management IP pool (AA06-OCP-OOB-MGMT-IPPool) is created with following settings:


Pools > IP Pool

Edit

Configuration

Netmask *: 255.255.255.0

Gateway: 10.106.0.254

Primary DNS: 10.106.1.10

Secondary DNS: 10.106.1.11

IP Blocks

From: 10.106.0.21

Size: 10

vNIC Templates and vNICs

In this deployment, separate server profile templates are created for Worker and Master Nodes where Worker Nodes have storage network interfaces to support workloads, but Master Nodes do not. The vNIC layout is explained below. While most of the policies are common across various templates, the LAN connectivity policies are unique and use the information in the tables below.

The following vNIC templates are used for deriving the vNICs for OpenShift worker nodes for host management, VM management and iSCSI storage traffics.

Table 12. vNIC Templates for Ethernet Traffic

Template Name	AA06-OCP-Mgmt-vNIC Template	AA06-OCP-iSCSIA-vNIC Template	AA06-OCP-iSCSIB-vNIC Template	AA06-OCP-ObjStorage vNIC Template
Purpose	Carries In-Band management of OpenShift hosts	Carries iSCSI traffic through fabric-A	Carries iSCSI traffic through fabric-B	Carries Object storage of workers nodes
Mac Pool	AA06-OCP-MACPool-A	AA06-OCP-MACPool-A	AA06-OCP-MACPool-B	AA06-OCP-MACPool-B
Switch ID	A	A	B	B
CDN Source setting	vNIC Name	vNIC Name	vNIC Name	vNIC Name
Fabric Failover setting	Yes	No	No	Yes
Network Group Policy name and Allowed VLANs and Native VLAN	AA06-OCP-BareMetal-NetGrp : Native and Allowed VLAN: 1061	AA06-OCP-iSCSI-A-NetGrp: Native and Allowed VLAN: 3010	AA06-OCP-iSCSIB-NetGrp: Native and Allowed VLAN: 3020	AA06-OCP-ObjectStore_NetGrp Native and Allowed VLAN: 3040
Network Control Policy Name and CDP and LLDP settings	AA06-OCP-CDPLLDP: CDP Enabled LLDP (Tx and Rx) Enable	AA06-OCP-CDPLLDP: CDP Enabled LLDP (Tx and Rx) Enable	AA06-OCP-CDPLLDP: CDP Enabled LLDP (Tx and Rx) Enable	AA06-OCP-CDPLLDP: CDP Enabled LLDP (Tx and Rx) Enable

Template Name	AA06-OCP-Mgmt-vNIC Template	AA06-OCP-iSCSIA-vNIC Template	AA06-OCP-iSCSIB-vNIC Template	AA06-OCP-ObjStorage vNIC Template
QoS Policy name and Settings	AA06-OCP-MTU1500-MgmtQoS: Best Effort MTU: 1500 Rate Limit (Mbps): 100000	AA06-OCP-iSCSI-QoS: Best-effort MTU:9000 Rate Limit (Mbps): 100000	AA06-OCP-iSCSI-QoS: Best-effort MTU:9000 Rate Limit (Mbps): 100000	AA06-OCP-iSCSI-QoS: Best Effort MTU: 9000 Rate Limit (Mbps): 100000
Ethernet Adapter Policy Name and Settings	AA06-OCP-EthAdapter-Linux-v2: Uses system defined Policy: Linux-V2	AA06-OCP-EthAdapter-16RXQs-5G (refer below section)	AA06-OCP-EthAdapter-16RXQs-5G (refer below section)	AA06-OCP-EthAdapter-16RXQs-5G (refer below section)

Ethernet Adapter Policy for Storage Traffic

The ethernet adapter policy is used to set the interrupts, send and receive queues, and queue ring size. The values are set according to the best-practices guidance for the operating system in use. Cisco Intersight provides a default Linux Ethernet Adapter policy for typical Linux deployments.

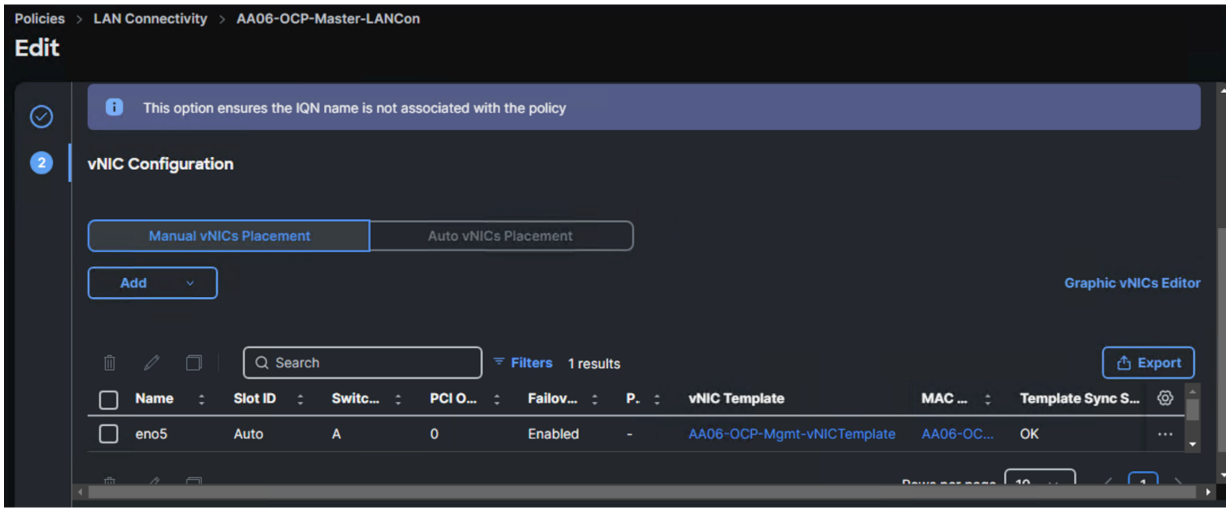
You can optionally configure a tweaked ethernet adapter policy for additional hardware receive queues handled by multiple CPUs in scenarios where there is a lot of traffic and multiple flows. In this deployment, a modified ethernet adapter policy, AA06-EthAdapter-16RXQs-5G, is created and attached to storage vNICs. Non-storage vNICs will use the default Linux-v2 Ethernet Adapter policy. Table 13 lists the settings that are changed from defaults in the Adapter policy used for the iSCSI traffic. The remaining settings are left at defaults.

Table 13. Settings and Values

Setting Name	Value
Name of the Policy	AA06-OCP-EthAdapter-16RXQs-5G
Interrupt Settings	Interrupts: 19, Interrupt Mode: MSX ,Interrupt Timer: 125
Receive	Receive Queue Count: 16, Receive Ring Size: 16384
Transmit	Transmit Queue Count: 1, Transmit Ring Size: 16384
Completion	Completion Queue Count: 17, Completion Ring Size: 1

Using the templates listed in Table 12, separate LAN connectivity policies are created for control and worker nodes.

Control nodes are configured with one vNIC which is derived from the AA06-OCP-Mgmt-vNIC template. The following screenshot shows the LAN connectivity policy (AA06-OCP-master-LANCon) created with one vNIC for control node.


Policies > LAN Connectivity > AA06-OCP-Master-LANCon

Edit

This option ensures the IQN name is not associated with the policy

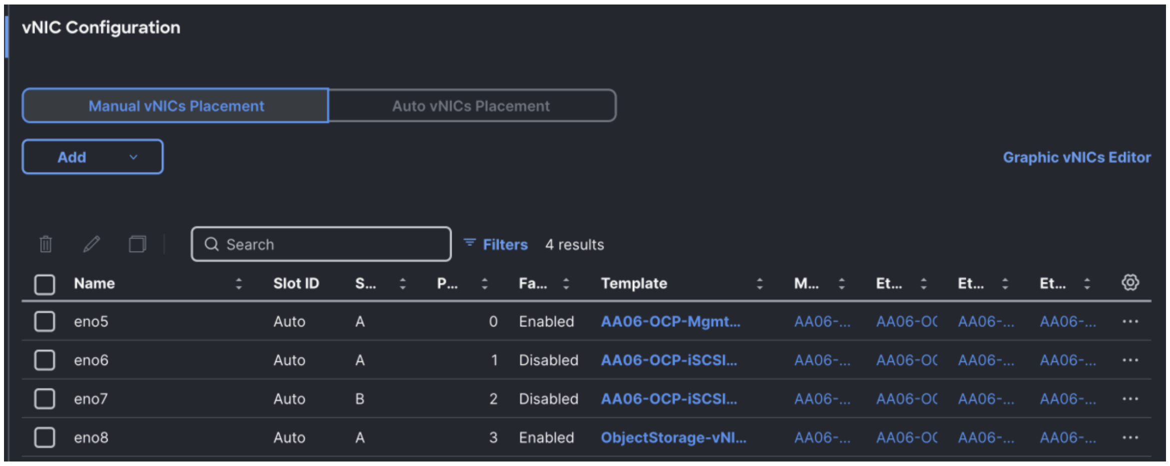
vNIC Configuration

Manual vNICs Placement | Auto vNICs Placement

1 results

Name	Slot ID	Switc...	PCI O...	Failov...	P.	vNIC Template	MAC ...	Template Sync S...
eno5	Auto	A	0	Enabled	-	AA06-OCP-Mgmt-vNICTemplate	AA06-OC...	OK

Worker nodes are configured with four vNICs which are derived from the templates discussed above. Following screenshot shows the LAN connectivity policy (AA06-OCP-Worker-LANConn) created with four vNICs for worker nodes.


vNIC Configuration

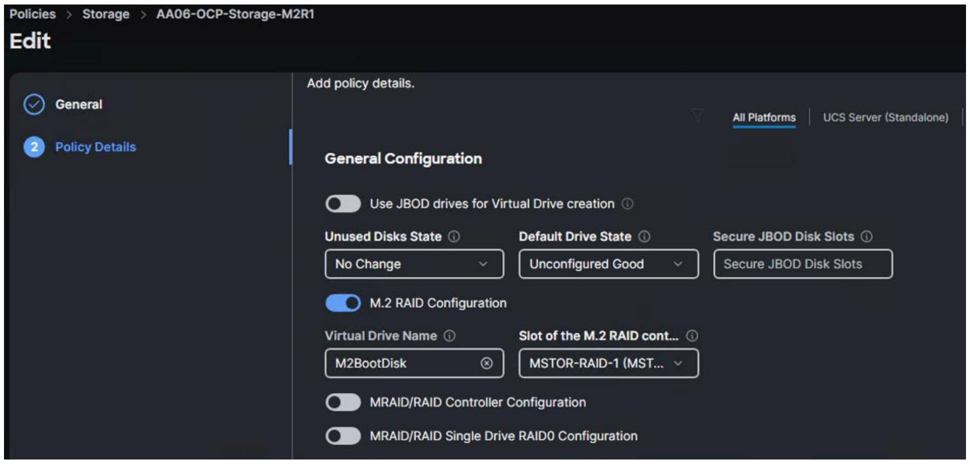
Manual vNICs Placement | Auto vNICs Placement

4 results

Name	Slot ID	S...	P...	Fa...	Template	M...	Et...	Et...	Et...
eno5	Auto	A	0	Enabled	AA06-OCP-Mgmt...	AA06-...	AA06-OC	AA06-...	AA06-...
eno6	Auto	A	1	Disabled	AA06-OCP-iSCSI...	AA06-...	AA06-OC	AA06-...	AA06-...
eno7	Auto	B	2	Disabled	AA06-OCP-iSCSI...	AA06-...	AA06-OC	AA06-...	AA06-...
eno8	Auto	A	3	Enabled	ObjectStorage-vNI...	AA06-...	AA06-OC	AA06-...	AA06-...

Storage Policy

For this solution, Cisco UCS X210c nodes are configured to boot from local M.2 SSD disks. Two M.2 disks are used and configured with RAID-1 configuration. Boot from SAN option will be supported in the next releases. The following screenshot shows the storage policy (AA06-OCP-Storage-M2R1), and the settings used for configuring the M.2 disks in RAID-1 mode.


Policies > Storage > AA06-OCP-Storage-M2R1

Edit

General

Policy Details

Add policy details.

All Platforms | UCS Server (Standalone)

General Configuration

Use JBOD drives for Virtual Drive creation: Off

Unused Disks State: No Change

Default Drive State: Unconfigured Good

Secure JBOD Disk Slots: Secure JBOD Disk Slots

M.2 RAID Configuration: On

Virtual Drive Name: M2BootDisk

Slot of the M.2 RAID cont...: MSTOR-RAID-1 (MST...

MRAID/RAID Controller Configuration: Off

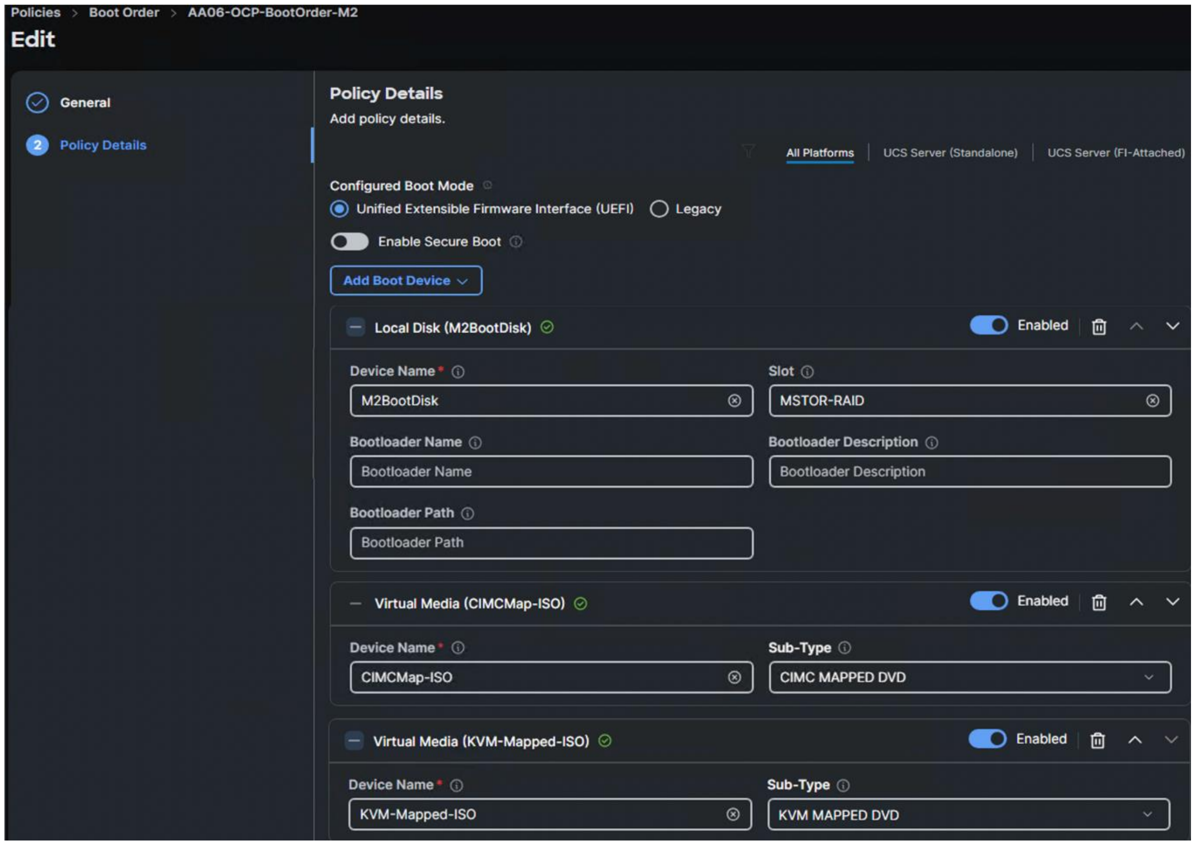
MRAID/RAID Single Drive RAID0 Configuration: Off

Compute Configuration Policies

Boot Policy

To facilitate the automatic boot from the Red Hat CoreOS Discovery ISO image, CIMC Mapped DVD boot option is used. The following boot policy is used for both controller and workers nodes.

Note: It is critical to not enable UEFI Secure Boot. Secure Boot needs to be disabled for the proper functionality of Portworx Enterprise and the NVIDIA GPU Operator GPU driver initialization.



Policy Details

Configured Boot Mode: [✓ Unified Extensible Firmware Interface (UEFI)] Legacy

Enable Secure Boot: off

Local Disk (M2BootDisk) — Enabled
- Device Name *: M2BootDisk
- Slot: MSTOR-RAID
- Bootloader Name: Bootloader Name
- Bootloader Description: Bootloader Description
- Bootloader Path: Bootloader Path

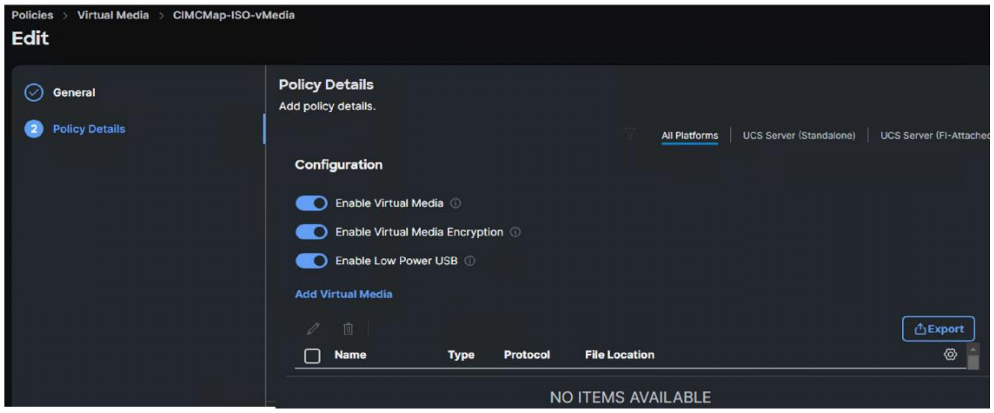
Virtual Media (CIMCMap-ISO) — Enabled
- Device Name *: CIMCMap-ISO
- Sub-Type: CIMC MAPPED DVD

Virtual Media (KVM-Mapped-ISO) — Enabled
- Device Name *: KVM-Mapped-ISO
- Sub-Type: KVM MAPPED DVD

Local Disk boot option being at the top ensures that the nodes always boot from the M.2 disks once after CoreOS installed. The CIMC Mapped DVC option at the second is used to install the CoreOS using Discovery ISO which is mapped using a Virtual Media policy (CIMCMap-ISO). KVM Mapped DVD will be used if you want to manually mount any ISO to the KVM session of the server and install the OS. This option will be used when installing CoreOS during the OpenShift cluster expansion by adding additional worker node.

Virtual Media (vMedia) Policy

Virtual Media policy is used to mount the Red Hat CoreOS Discovery ISO to the server using CIMC Mapped DVD policy as previously explained. A file share service is required to be configured and must be accessed by OOB-Mgmt network. In this solution, the HTTP file share service is used to share the Discovery ISO over the network.


Policies > Virtual Media > CIMCMap-ISO-vMedia

Edit

Policy Details

Add policy details.

Configuration

Enable Virtual Media: enabled

Enable Virtual Media Encryption: enabled

Enable Low Power USB: enabled

Add Virtual Media

Name	Type	Protocol	File Location

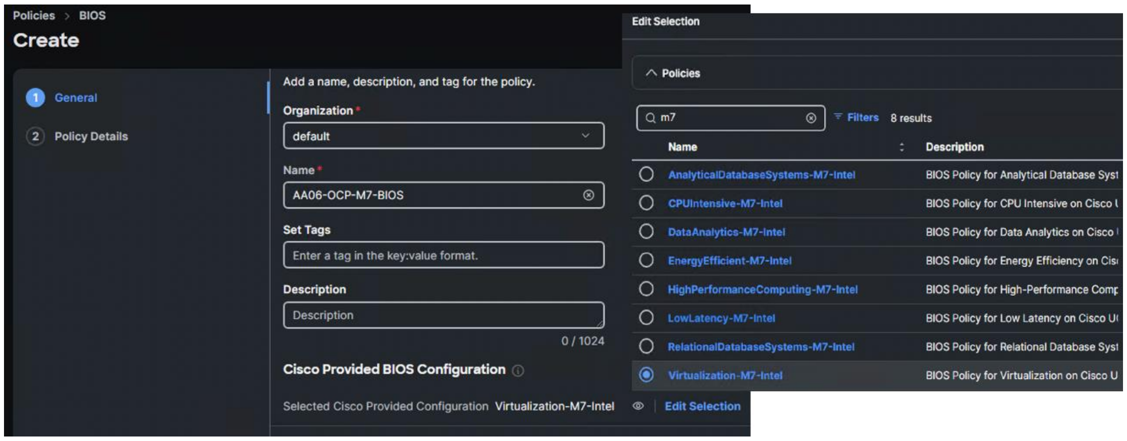
NO ITEMS AVAILABLE

Note: Do not Add Virtual Media at this time, but the policy can be modified later and used to map an OpenShift Discovery ISO to a CIMC Mapped DVD policy.

Procedure 1. Bios Policy

Note: For the OpenShift containerized and Virtualized solution, which is based on Intel M7 platform, the system defined "virtualization-M7-Intel" policy is used in this solution.

Step 1. Create the **BIOS policy** and select the pre-defined policy as shown below and click **Next**.


Policies > BIOS

Create

Add a name, description, and tag for the policy.

Organization: default

Name: AA06-OCP-M7-BIOS

Set Tags: Enter a tag in the key:value format.

Description: Description 0 / 1024

Cisco Provided BIOS Configuration

Selected Cisco Provided Configuration Virtualization-M7-Intel

Edit Selection

m7 — 8 results

	Name	Description
○	AnalyticalDatabaseSystems-M7-Intel	BIOS Policy for Analytical Database Syst
○	CPUIntensive-M7-Intel	BIOS Policy for CPU Intensive on Cisco U
○	DataAnalytics-M7-Intel	BIOS Policy for Data Analytics on Cisco
○	EnergyEfficient-M7-Intel	BIOS Policy for Energy Efficiency on Cis
○	HighPerformanceComputing-M7-Intel	BIOS Policy for High-Performance Comp
○	LowLatency-M7-Intel	BIOS Policy for Low Latency on Cisco U
○	RelationalDatabaseSystems-M7-Intel	BIOS Policy for Relational Database Syst
●	Virtualization-M7-Intel	BIOS Policy for Virtualization on Cisco U

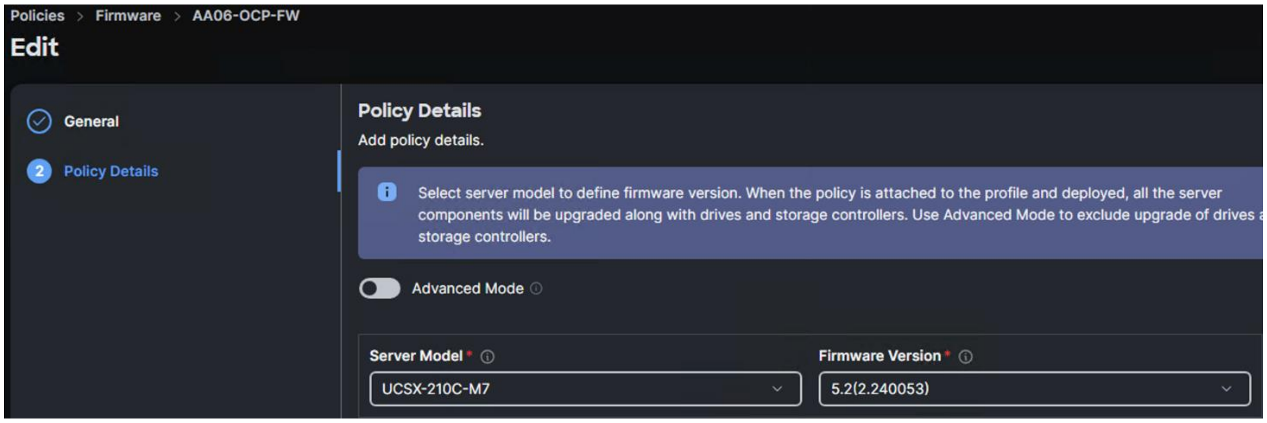
Step 2. Expand **Server Management** and set **Consistent Device Name (CDN)** to **enabled** for **Consistent Device Naming within the Operating System**.

Note: The remaining bios tokens and their values mentioned are based on the best practices guide from the M7 platform. For more details, go to: Performance Tuning Best Practices Guide for Cisco UCS M7 Platforms.

Step 3. Click **Create** to complete the BIOS policy.

Procedure 2. Firmware Policy (optional)

Step 1. Create a **Firmware policy** (AA06-OCP-FW) and under the **Policy Detail** tab, set the **Server Model** as **UCSX-210C-M7** and set **Firmware Version** to the latest version. The following screenshot shows the firmware policy used in this solution:


Policies > Firmware > AA06-OCP-FW

Edit

General

Policy Details

Policy Details

Add policy details.

Select server model to define firmware version. When the policy is attached to the profile and deployed, all the server components will be upgraded along with drives and storage controllers. Use Advanced Mode to exclude upgrade of drives a storage controllers.

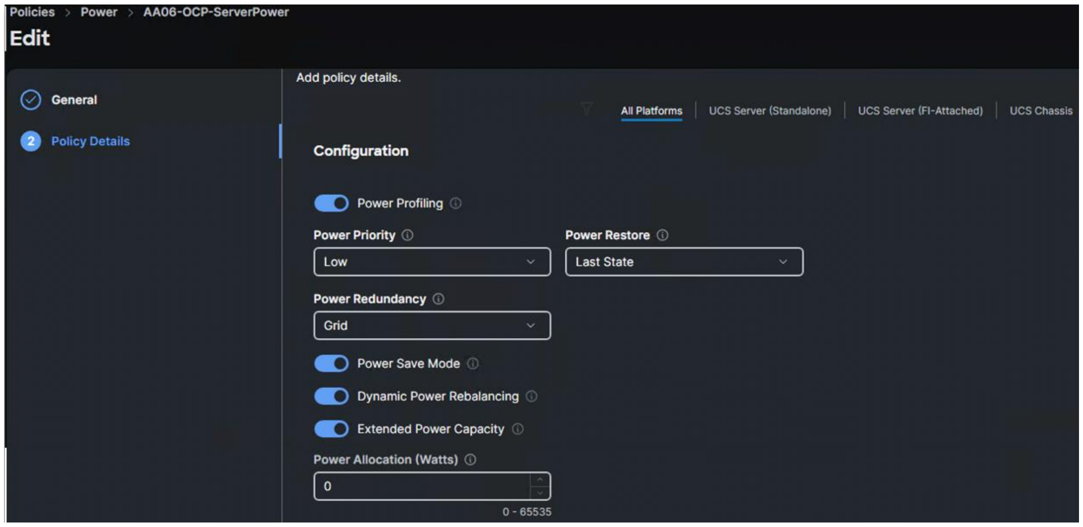
Advanced Mode

Server Model * UCSX-210C-M7

Firmware Version * 5.2(2.240053)

Procedure 3. Create a Power Policy

Step 1. Select **All Platform** (unless you want to create a dedicated power policy for FI-Attached servers). Select the following options and leave the rest of the settings at default. When you apply this policy to the server profile template, the system will take appropriate settings and apply to the server.


Policies > Power > AA06-OCP-ServerPower

Edit

General

Policy Details

Add policy details.

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

Configuration

Power Profiling: enabled

Power Priority: Low

Power Restore: Last State

Power Redundancy: Grid

Power Save Mode: enabled

Dynamic Power Rebalancing: enabled

Extended Power Capacity: enabled

Power Allocation (Watts): 0

0 - 65535

Management Configuration Policies

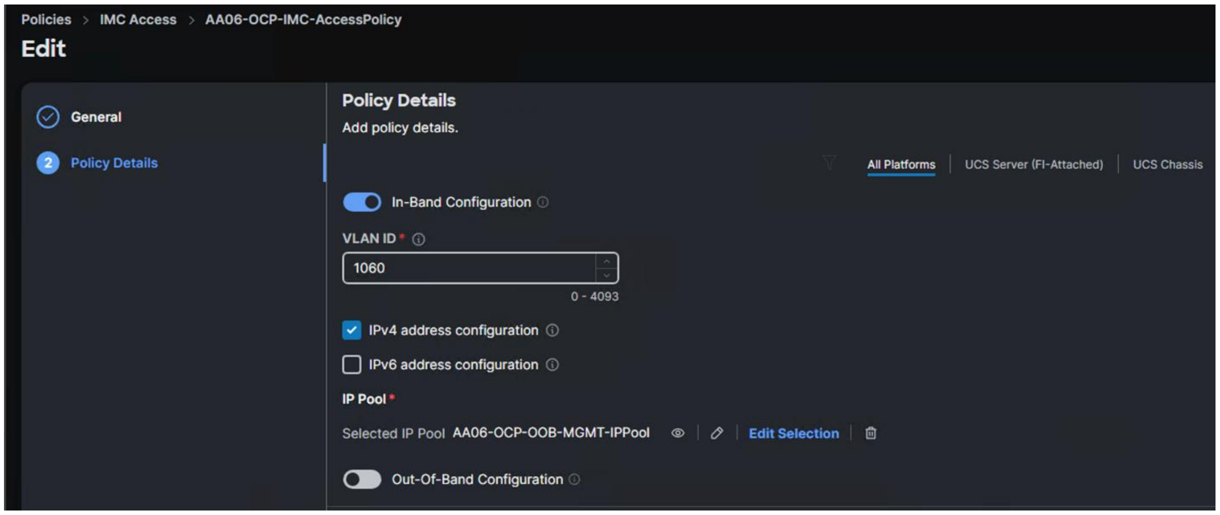
The following policies will be added to the management configuration:

- IMC Access to define the pool of IP addresses for compute node KVM access
- IPMI Over LAN to allow the servers to be managed by IPMI or redfish through the BMC or CIMC
- Local User to provide local administrator to access KVM
- Virtual KVM to allow the Tunneled KVM

Cisco IMC Access Policy

Create a CIMC Access Policy with settings as shown in the following screenshot.

Note: Since certain features are not yet enabled for Out-of-Band Configuration (accessed using the Fabric Interconnect mgmt0 ports), you need to access the OOB-MGMT VLAN (1060) through the Fabric Interconnect Uplinks and mapping it as the In-Band Configuration VLAN.



Policies > IMC Access > AA06-OCP-IMC-AccessPolicy

Edit

Policy Details

Add policy details.

In-Band Configuration: enabled

VLAN ID *: 1060 (0 - 4093)

IPv4 address configuration: checked

IPv6 address configuration: unchecked

IP Pool *

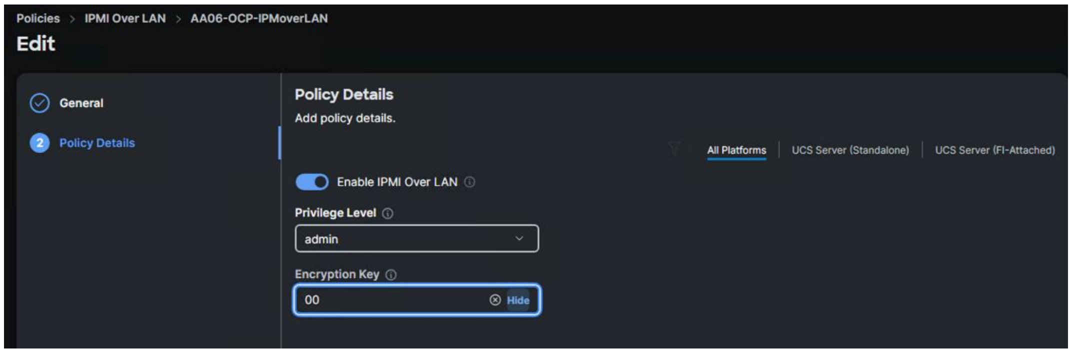
Selected IP Pool AA06-OCP-OOB-MGMT-IPPool

Out-Of-Band Configuration: disabled

IPMI over LAN and Local User Policies

The IPMI Over LAN Policy can be used to allow both IPMI and Redfish connectivity to Cisco UCS Servers. Red Hat OpenShift platform uses these two policies to power manage (power off, restart, and so on) the baremetal servers.

Create the IPMI over LAN policy (AA06-IPMIOvelLan) as shown below:



Policies > IPMI Over LAN > AA06-OCP-IPMoverLAN

Edit

Policy Details

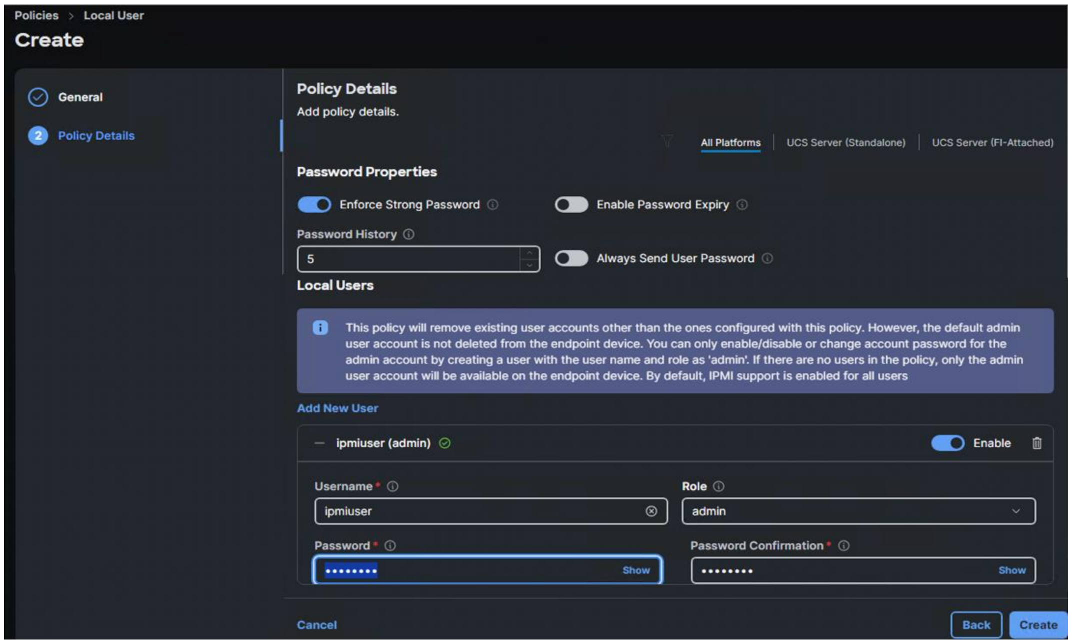
Add policy details.

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

Enable IPMI Over LAN: enabled

Privilege Level: admin

Encryption Key: 00



Policies > Local User

Create

Policy Details

Add policy details.

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

Password Properties

Enforce Strong Password: enabled

Enable Password Expiry: disabled

Password History: 5

Always Send User Password: disabled

Local Users

This policy will remove existing user accounts other than the ones configured with this policy. However, the default admin user account is not deleted from the endpoint device. You can only enable/disable or change account password for the admin account by creating a user with the user name and role as 'admin'. If there are no users in the policy, only the admin user account will be available on the endpoint device. By default, IPMI support is enabled for all users

ipmiuser (admin) — Enable: enabled

Username *: ipmiuser

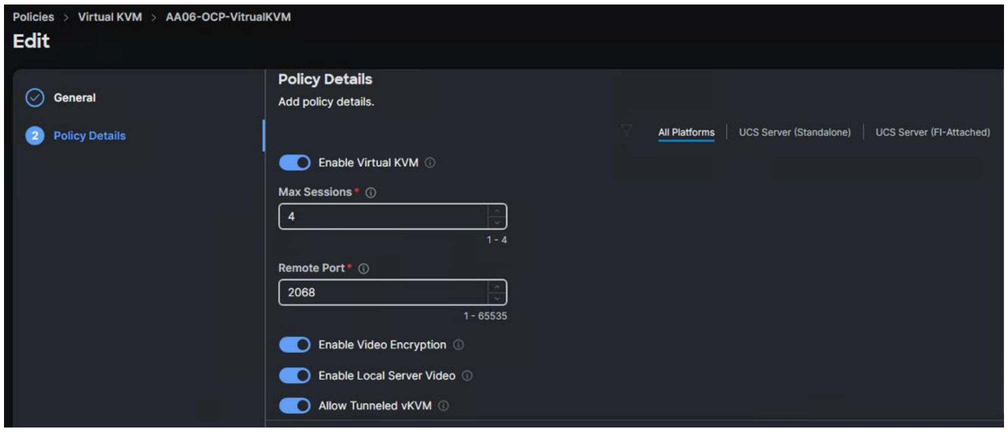
Role: admin

Password *: ••••••••

Password Confirmation *: ••••••••

Virtual KVM Policy

The following screenshot shows the virtual KVM policy (AA06-OCP-VirtualKVM) used in the solution:



Enable Virtual KVM

Max Sessions* 4 (1 - 4)

Remote Port* 2068 (1 - 65535)

Enable Video Encryption

Enable Local Server Video

Allow Tunneled vKVM

Create Server Profile Templates

When you have the required pools, polices, vNIC templates created, Server profile templates can be created. Two separate Server Profile Templates are used for control and workers node.

Table 14 lists the polices and pools used to create the Server Profile template (AA06-OCP-Master-M.2) for Control nodes.

Table 14. Policies and Pools for Control Nodes

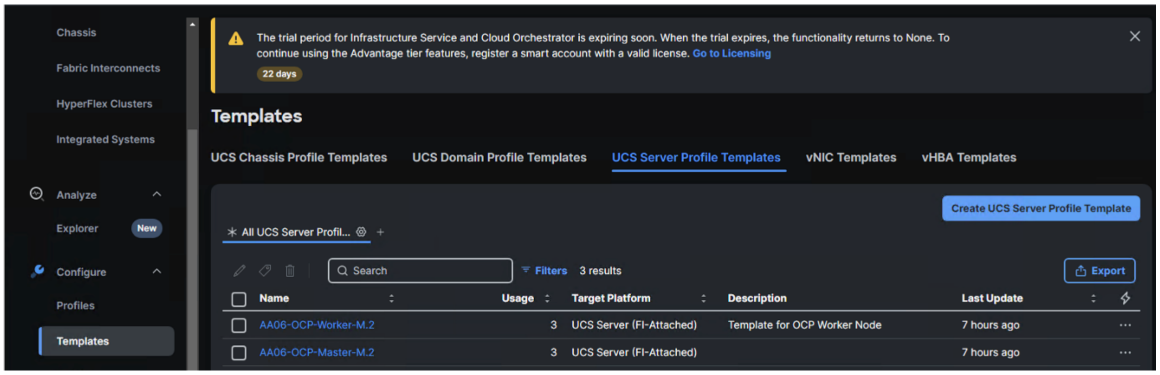
Page Name	Setting
General	Name: AA06-OCP-Master-M.2
Compute Configuration	UUID: AA06-OCP-UUIDPool BIOS: AA06-OCP-M7-BIOS Boot Order: AA06-OCP-BootOrder-M2 Firmware: AA06-OCP-FW Power: AA06-OCP-ServerPower Virtual Media: CIMCMap-ISO-vMedia
Management Configuration:	IMC Access: AA06-OCP-IMC-AccessPolicy IPMI Over LAN: AA06-OCP-IPMoverLAN Local User: AA06-OCP-IMCLocalUser Virtual KVM: AA06-OCP-VitrualKVM
Storage Configuration	Storage: AA06-OCP-Storage-M2R1
Network Configuration	LAN Connectivity: AA06-OCP-Master-LANCon

Table 15 lists the polices and pools used to create the Server Profile template (AA06-OCP-Worker-M.2) for worker nodes.

Table 15. Policies and Pools for Worder Nodes

Page Name	Setting
General	Name: AA06-OCP-Worker-M.2
Compute Configuration	UUID: AA06-OCP-UUIDPool BIOS: AA06-OCP-M7-BIOS Boot Order: AA06-OCP-BootOrder-M2 Firmware: AA06-OCP-FW Power: AA06-OCP-ServerPower Virtual Media: CIMCMap-ISO-vMedia
Management Configuration:	IMC Access: AA06-OCP-IMC-AccessPolicy IPMI Over LAN: AA06-OCP-IPMoverLAN Local User: AA06-OCP-IMCLocalUser Virtual KVM: AA06-OCP-VitrualKVM
Storage Configuration	Storage: AA06-OCP-Storage-M2R1
Network Configuration	LAN Connectivity: AA06-OCP-Worker-LANConn

The following screenshot shows the two server profile templates created for the control and worker nodes:



The trial period for Infrastructure Service and Cloud Orchestrator is expiring soon. When the trial expires, the functionality returns to None. To continue using the Advantage tier features, register a smart account with a valid license. Go to Licensing
22 days

Templates

UCS Chassis Profile Templates | UCS Domain Profile Templates | UCS Server Profile Templates | vNIC Templates | vHBA Templates

Create UCS Server Profile Template

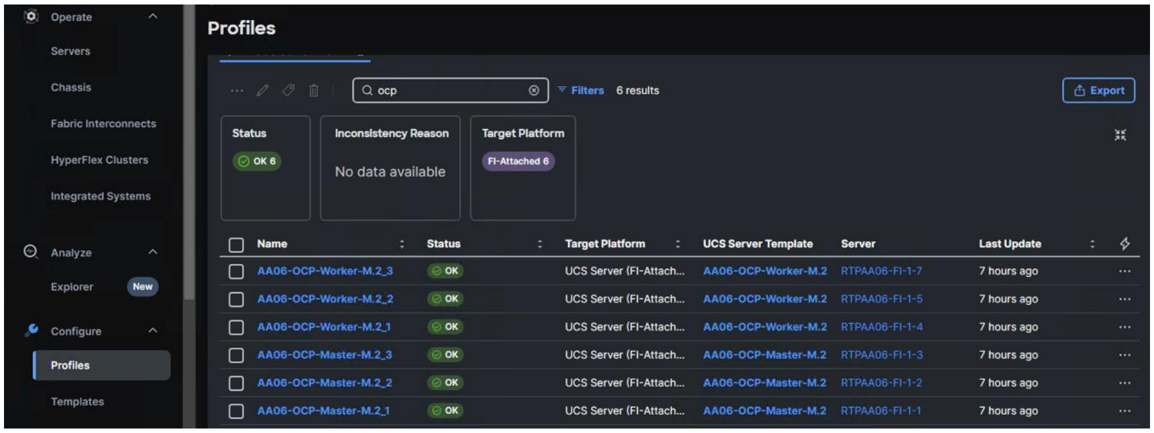
All UCS Server Profil...

Search | Filters | 3 results | Export

Name	Usage	Target Platform	Description	Last Update
AA06-OCP-Worker-M.2	3	UCS Server (FI-Attached)	Template for OCP Worker Node	7 hours ago
AA06-OCP-Master-M.2	3	UCS Server (FI-Attached)		7 hours ago

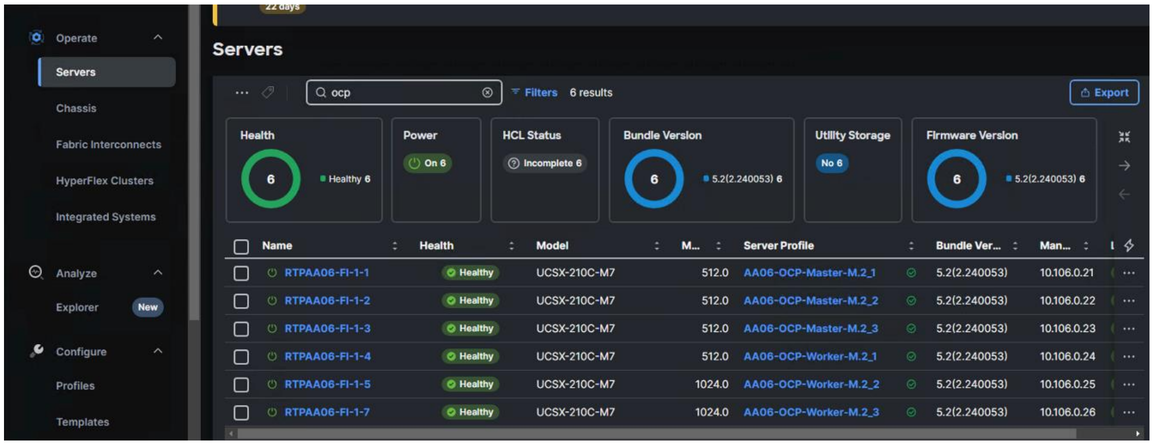
Create Server Profiles

Once Server Profile Templates are created, the server profiles can be derived from the template. The following screenshot shows a total of six profiles are derived (three for control nodes and three for worker nodes).



Name	Status	Target Platform	UCS Server Template	Server	Last Update
AA06-OCP-Worker-M.2_3	OK	UCS Server (FI-Attach...	AA06-OCP-Worker-M.2	RTPAA06-FI-1-7	7 hours ago
AA06-OCP-Worker-M.2_2	OK	UCS Server (FI-Attach...	AA06-OCP-Worker-M.2	RTPAA06-FI-1-5	7 hours ago
AA06-OCP-Worker-M.2_1	OK	UCS Server (FI-Attach...	AA06-OCP-Worker-M.2	RTPAA06-FI-1-4	7 hours ago
AA06-OCP-Master-M.2_3	OK	UCS Server (FI-Attach...	AA06-OCP-Master-M.2	RTPAA06-FI-1-3	7 hours ago
AA06-OCP-Master-M.2_2	OK	UCS Server (FI-Attach...	AA06-OCP-Master-M.2	RTPAA06-FI-1-2	7 hours ago
AA06-OCP-Master-M.2_1	OK	UCS Server (FI-Attach...	AA06-OCP-Master-M.2	RTPAA06-FI-1-1	7 hours ago

When the Server profiles are created, associate these server profiles to the control and workers nodes as shown below:



Name	Health	Model	M...	Server Profile	Bundle Ver...	Man...
RTPAA06-FI-1-1	Healthy	UCSX-210C-M7	512.0	AA06-OCP-Master-M.2_1	5.2(2.240053)	10.106.0.21
RTPAA06-FI-1-2	Healthy	UCSX-210C-M7	512.0	AA06-OCP-Master-M.2_2	5.2(2.240053)	10.106.0.22
RTPAA06-FI-1-3	Healthy	UCSX-210C-M7	512.0	AA06-OCP-Master-M.2_3	5.2(2.240053)	10.106.0.23
RTPAA06-FI-1-4	Healthy	UCSX-210C-M7	512.0	AA06-OCP-Worker-M.2_1	5.2(2.240053)	10.106.0.24
RTPAA06-FI-1-5	Healthy	UCSX-210C-M7	1024.0	AA06-OCP-Worker-M.2_2	5.2(2.240053)	10.106.0.25
RTPAA06-FI-1-7	Healthy	UCSX-210C-M7	1024.0	AA06-OCP-Worker-M.2_3	5.2(2.240053)	10.106.0.26

Now the Cisco UCS X210c M7 blades are ready and OpenShift can be installed on these machines.

Pure Storage FlashArray Configuration

This chapter contains the following:

- Configure iSCSI Interfaces
- Claim Pure Storage FlashArray//XL170 into Intersight

In this solution, Pure Storage FlashArray//XL170 is used as the storage provider for all the application pods and virtual machines provisioned on the OpenShift cluster using Portworx Enterprise. The Pure Storage FlashArray//XL170 array will be used as Cloud Storage Provider for Portworx which allows us to store data on-premises with FlashArray while benefiting from Portworx Enterprise cloud drive features.

This chapter describes the high-level steps to configure Pure Storage FlashArray//X170 network interfaces required for storage connectivity over iSCSI. For this solution, Pure Storage FlashArray was loaded with Purity//FA Version 6.6.10.

Note: This document is not intended to explain every day-0 initial configuration steps to bring the array up and running. For detailed day-0 configuration steps, see: https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/UCS_CVDs/flashstack_ucs_xseries_e2e_5gen.html#FlashArrayConfiguration

The compute nodes are redundantly connected to the storage controllers through 4 x 100Gb connections (2 x 100Gb per storage controller module) from the redundant Cisco Nexus switches.

The Pure Storage FlashArray network settings were configured with three subnets across three VLANs. Storage Interfaces CT0.Eth0 and CT1.Eth0 were configured to access management for the storage on VLAN 1063. Storage Interfaces (CT0.Eth18, CT0.Eth19, CT1.Eth18, and CT1.Eth19) were configured to run iSCSI Storage network traffic on the VLAN 3010 and VLAN 3020.

The following tables provide the IP addressing configured on the interfaces used for storage access.

Table 16. iSCSI A Pure Storage FlashArray//XL170 Interface Configuration Settings

FlashArray Controller	iSCSI Port	IP Address	Subnet
FlashArray//X170 Controller 0	CT0.ETH18	192.168.51.4	255.255.255.0
FlashArray//X170 Controller 1	CT1.ETH18	192.168.51.5	255.255.255.0

Table 17. iSCSI B Pure Storage FlashArray//XL170 Interface Configuration Settings

FlashArray Controller	iSCSI Port	IP Address	Subnet
FlashArray//X170 Controller 0	CT0.ETH19	192.168.52.4	255.255.255.0
FlashArray//X170 Controller 1	CT1.ETH19	192.168.52.5	255.255.255.0

Procedure 1. Configure iSCSI Interfaces

Step 1. Log into **Pure FlashArray//XL170** using its **management IP addresses**.

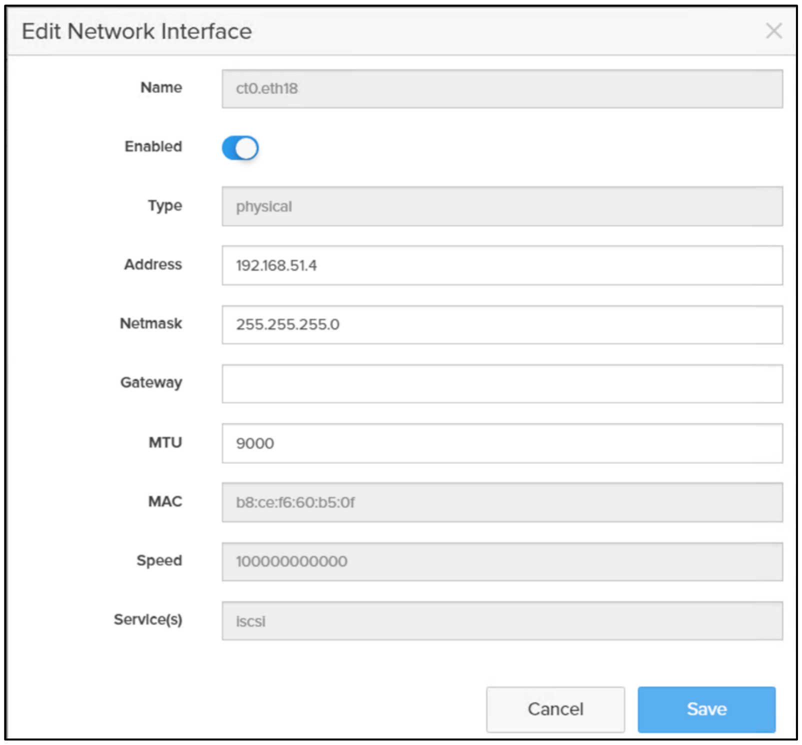
Step 2. Click **Settings** > **Network** > **Connectors** > **Ethernet**.

Step 3. Click **Edit** for **Interface CT0.eth18**.

Step 4. Click **Enable** and add the IP information from Table 16 and Table 17 and set the **MTU** to **9000**.

Step 5. Click **Save**.

Step 6. Repeat steps 1 through 5 to configure the remaining interfaces CT0.eth19, CT1.eth18 and CT1.eth19.



Edit Network Interface

Name	ct0.eth18
Enabled	●
Type	physical
Address	192.168.51.4
Netmask	255.255.255.0
Gateway	
MTU	9000
MAC	b8:ce:f6:60:b5:0f
Speed	100000000000
Service(s)	iscsi

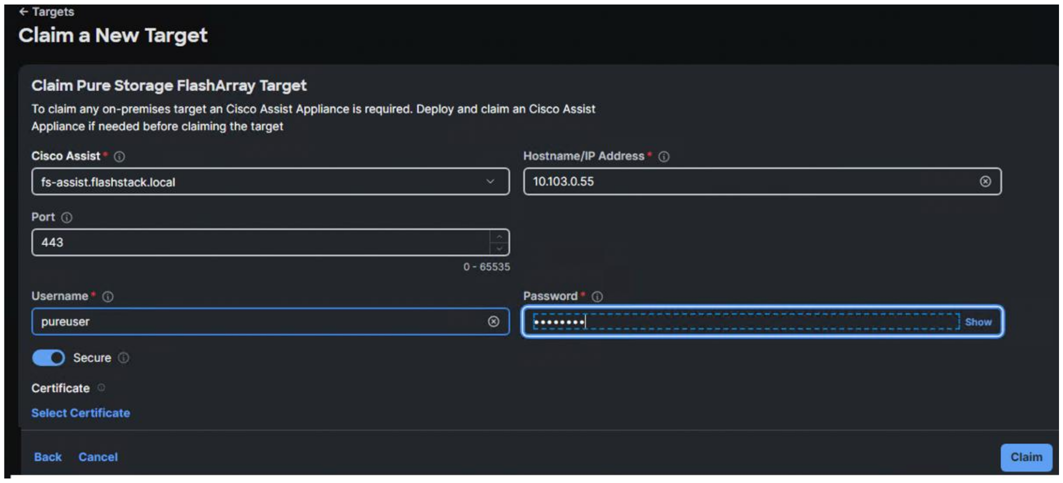
Procedure 2. Claim Pure Storage FlashArray//XL170 into Intersight

Note: This procedure assumes that Cisco Intersight is already hosted outside the OpenShift cluster and Pure Storage FlashArray//XL170 is claimed into the Intersight.com.

Step 1. Log into **Cisco Intersight** using your login credentials. From the drop-down menu select **System**.

Step 2. Under **Admin**, select **Target** and click **Claim a New Target**. Under **Categories**, select **Storage**, click **Pure Storage FlashArray** and then click **Start**.

Step 3. Select the **Cisco Assist** name which is already deployed and configured. Provide the Pure Storage FlashArray management **IP address**, **username**, and **password** details and click **Claim**.


← Targets

Claim a New Target

Claim Pure Storage FlashArray Target

To claim any on-premises target an Cisco Assist Appliance is required. Deploy and claim an Cisco Assist Appliance if needed before claiming the target

Cisco Assist *: fs-assist.flashstack.local

Hostname/IP Address *: 10.103.0.55

Port: 443 (0 - 65535)

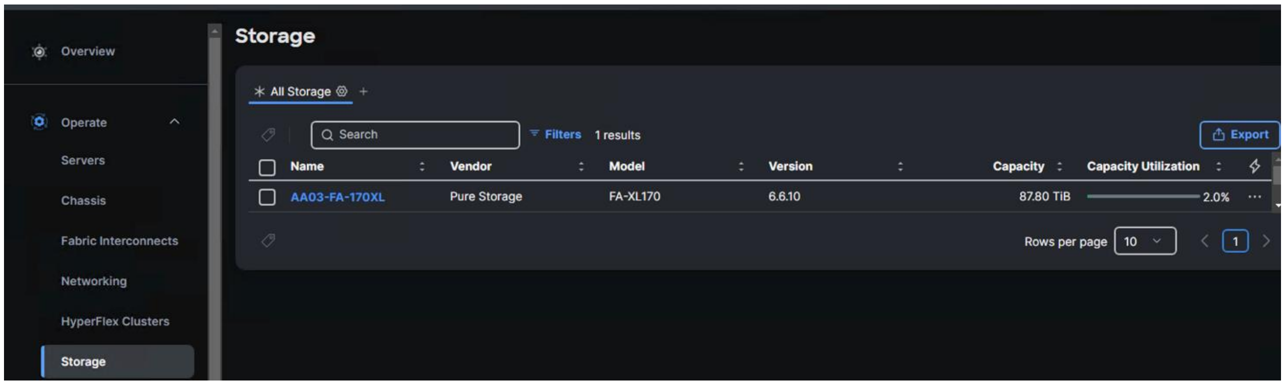
Username *: pureuser

Password *: ••••••••

Secure: On

Certificate: Select Certificate

Step 4. When the storage is successfully claimed, from the drop-down list, select **Infrastructure Services**. Under **Operate**, click **Storage.** You will see the newly claimed Pure Storage FlashArray; browse through it to view the inventory details.



Storage

1 results

Name	Vendor	Model	Version	Capacity	Capacity Utilization
AA03-FA-170XL	Pure Storage	FA-XL170	6.6.10	87.80 TiB	2.0%

Pure Storage FlashBlade Configuration

This chapter contains the following:

- Object Store Configuration

In this solution, Pure Storage FlashBlade//S200 is used as the persistent object storage provider for the Milvus vector database hosted on the OpenShift cluster. The FlashBlade is directly accessed by the Milvus vector database pod by using Workers node's interface that carries object storage traffic (eno8). This section describes high-level steps to configure Pure Storage FlashBlade//S200 network interfaces required for storage connectivity over ethernet. Pure Storage FlashBlade was loaded with Purity//FB V4.1.12.

The FlashBlade//S200 provides up to 8x 100GbE interfaces for data traffic. In this solution, 2x 100GbE from each FIOM (with aggregated network bandwidth of 400 GbE) are connected to a pair of Nexus switches. For more details about FlashBlade connectivity, see section Pure Storage FlashBlade//S200 Ethernet Connectivity.

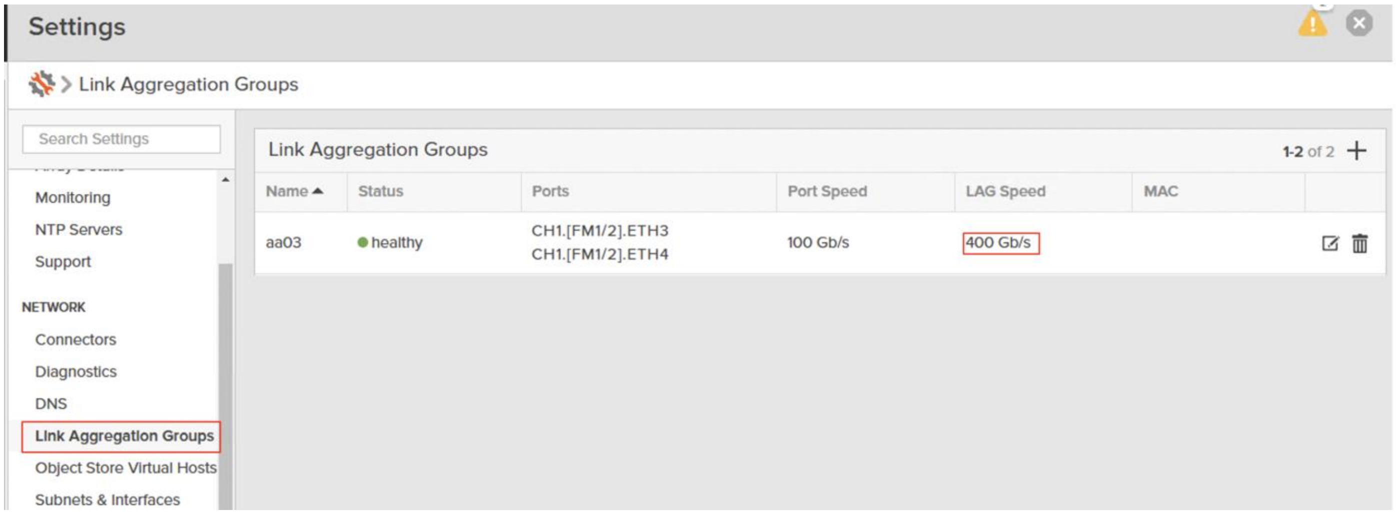
Note: This document is not intended to explain every day-0 initial configuration steps to bring the array up and running. For day-0 configuration steps, see: https://support.purestorage.com/bundle/m_flashblades/page/FlashBlade/FlashBlade_Hardware/topics/concept/c_flashblades.html

Table 18 provides the IP addressing configured on the interfaces used for objects storage access.

Table 18. Link Aggregation Groups (LAG)

LAG Name	FM	Ethernet Ports
AA03	1	CH1. FM1.ETH3 & CH1. FM1.ETH4
	2	CH1. FM2.ETH3 & CH1. FM2.ETH4

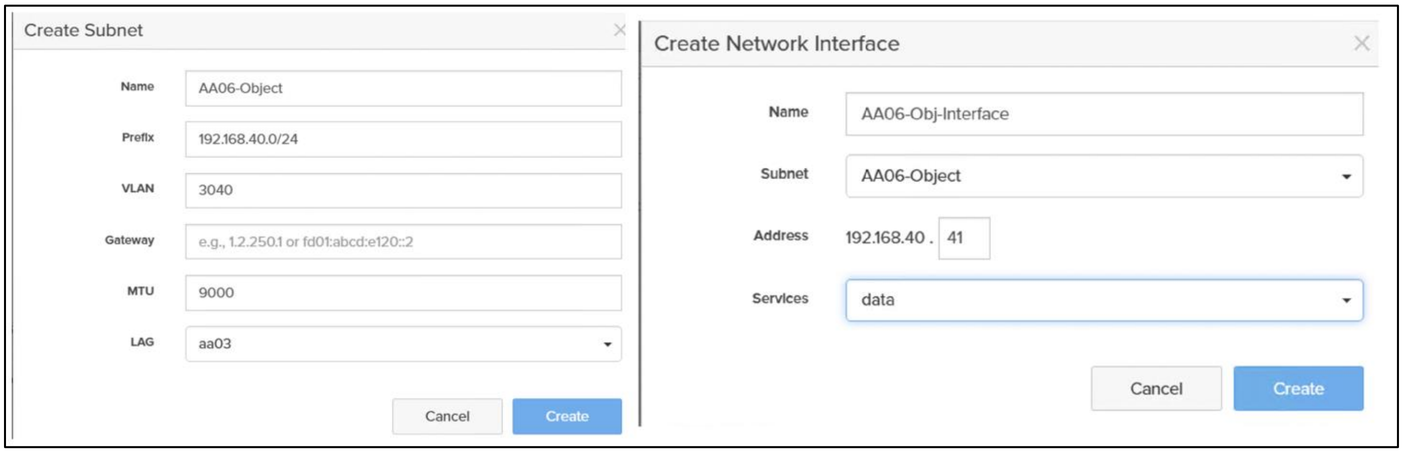
A Link Aggregation Group is created using CH1.FM1.ETH3, CH1.FM1.ETH4, CH1.FM2.ETH3, and CH1.FM2.ETH4 interfaces as shown below. Notice that the aggregated bandwidth of the LAG is 400GbE as it is created with 4x 100GbE interfaces as shown below:



Link Aggregation Groups 1-2 of 2

Name	Status	Ports	Port Speed	LAG Speed	MAC
aa03	healthy	CH1.[FM1/2].ETH3 CH1.[FM1/2].ETH4	100 Gb/s	400 Gb/s	

Once the LAG is created, a Subnet (AA06-Object) and an interface (AA06-Obj-Interface) is created as shown below. For the subnet, ensure to set MTU as 9000, VLAN as 3040 and select "aa03" for the LAG. Ensure to set Services as "Data" for the interface.



Create Subnet

Name	AA06-Object
Prefix	192.168.40.0/24
VLAN	3040
Gateway	e.g., 1.2.250.1 or fd01:abcd:e120::2
MTU	9000
LAG	aa03

Create Network Interface

Name	AA06-Obj-Interface
Subnet	AA06-Object
Address	192.168.40 . 41
Services	data

Object Store Configuration

FlashBlade Object Store configuration involves creating an Object Store Account, user, Access Keys and finally a bucket.

Procedure 1. Create a Object Store Account, User, Access Keys and Bucket

Step 1. Log into **Pure FlashBlade//S200** using its **management IP addresses**.

Step 2. Click **Storage** > **Object Store** > **Accounts** > Click **+** to create an account.

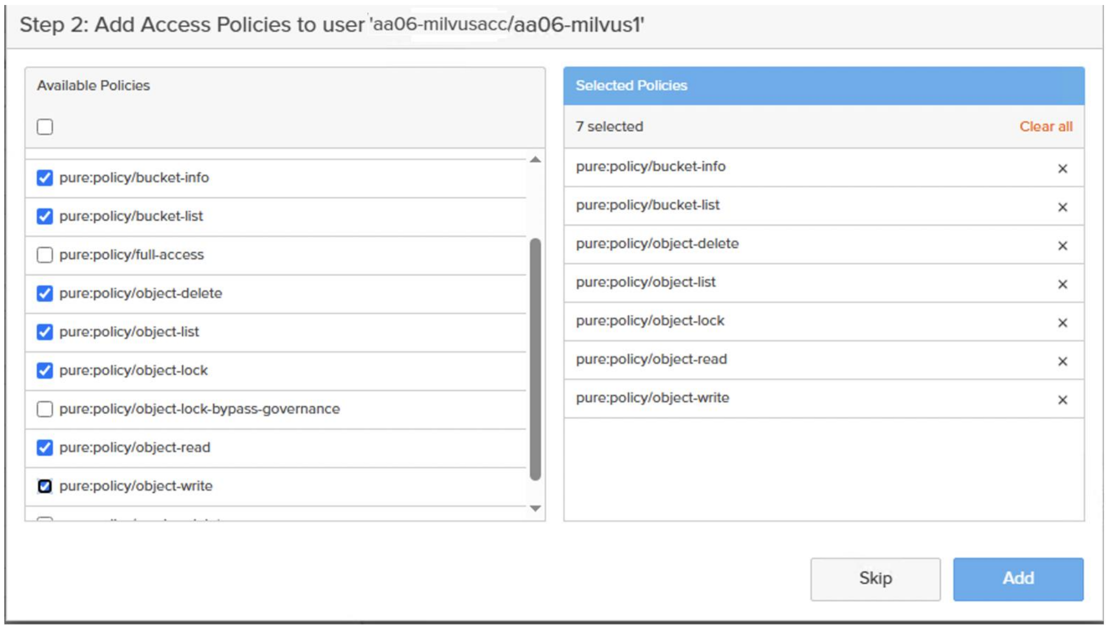
Step 3. Provide a **name** for Account, Quota Limit and Bucket Default Quota Limit as per your requirements. Click on **Create**.

Step 4. Click the newly created Account name and click **+** to create a new user for the account.

Step 5. Provide a **username** and click **Create**.

Step 6. In the **Add Access Policies** window, select the pre-defined access policies as shown below. Or create your own access policy with a set of rules and finally select it.

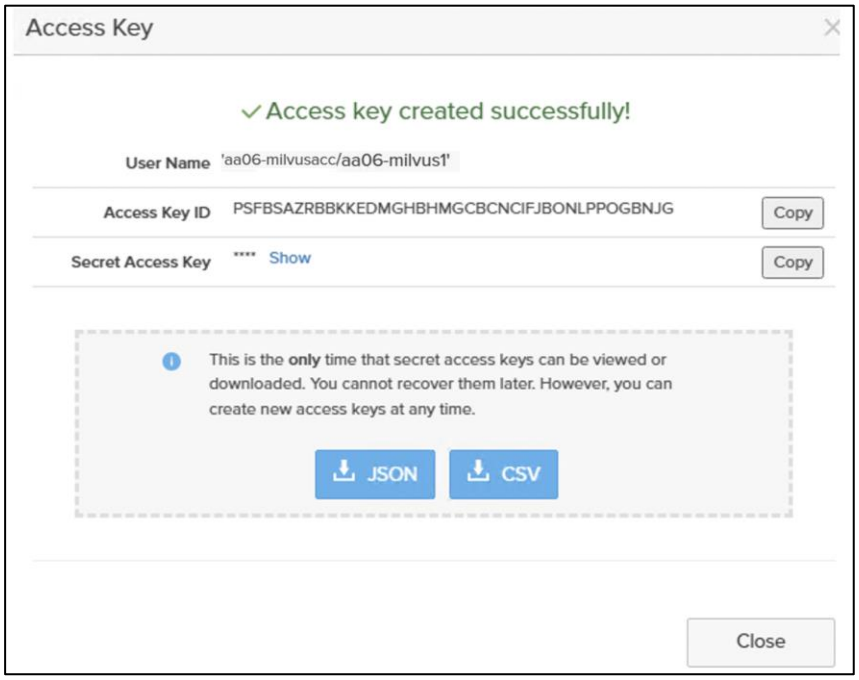
Step 7. Click **Add** when Access Policy is selected.


Step 2: Add Access Policies to user 'aa06-milvusacc/aa06-milvus1'

Available Policies	
☐	
☑	pure:policy/bucket-info
☑	pure:policy/bucket-list
☐	pure:policy/full-access
☑	pure:policy/object-delete
☑	pure:policy/object-list
☑	pure:policy/object-lock
☐	pure:policy/object-lock-bypass-governance
☑	pure:policy/object-read
☑	pure:policy/object-write

Selected Policies	
7 selected	Clear all
pure:policy/bucket-info	×
pure:policy/bucket-list	×
pure:policy/object-delete	×
pure:policy/object-list	×
pure:policy/object-lock	×
pure:policy/object-read	×
pure:policy/object-write	×

Step 8. Click **Create a new key** and click **Create** to create a pair of access and secret keys. Preserve the Access and Secret Keys for later use. Click **Close**.


Access Key

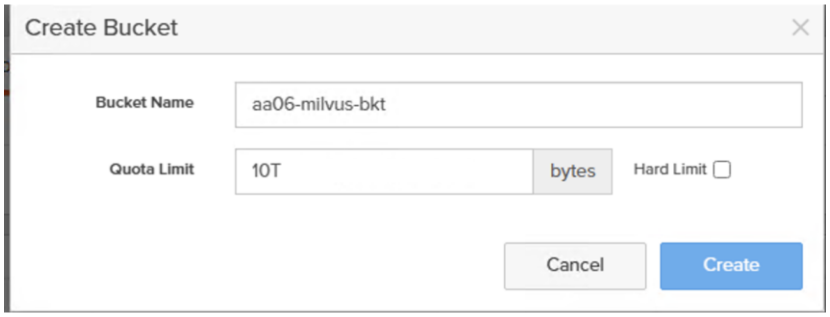
✓Access key created successfully!

User Name	'aa06-milvusacc/aa06-milvus1'
Access Key ID	PSFBSAZRBBKKEDMGHBHMGCBCNCIFJBONLPPOGBNJG
Secret Access Key	**** Show

This is the **only** time that secret access keys can be viewed or downloaded. You cannot recover them later. However, you can create new access keys at any time.

Step 9. Click **Account name** and go to the **Buckets** sections. Click **+** to create a bucket and add it to the account.

Step 10. Provide a bucket **name** and **Quota Limit**. Click **Create**.



Create Bucket

Bucket Name	aa06-milvus-bkt
Quota Limit	10T bytes
Hard Limit	☐

This completes the FlashBlade configuration for object store access by the Milvus vector database pods.

OpenShift Container Platform Installation and Configuration

This chapter contains the following:

- OpenShift Container Platform – Installation Requirements
- Prerequisites
- Network Requirements

OpenShift 4.16 is deployed on the Cisco UCS infrastructure as M.2 booted bare metal servers. The Cisco UCS X210C M7 servers need to be equipped with an M.2 controller (SATA or NVMe) card and two identical M.2 drives. Three master nodes and three worker nodes are deployed in the validation environment and additional worker nodes can easily be added to increase the scalability of the solution. This document will guide you through the process of using the Assisted Installer to deploy OpenShift 4.17.

OpenShift Container Platform – Installation Requirements

The Red Hat OpenShift Assisted Installer provides support for installing OpenShift Container Platform on bare metal nodes. This guide provides a methodology to achieving a successful installation using the Assisted Installer.

Prerequisites

The FlashStack for OpenShift utilizes the Assisted Installer for OpenShift installation. Therefore, when provisioning and managing the FlashStack infrastructure, you must provide all the supporting cluster infrastructure and resources, including an installer VM or host, networking, storage, and individual cluster machines.

The following supporting cluster resources are required for the Assisted Installer installation:

- The control plane and compute machines that make up the cluster
- Cluster networking
- Storage for the cluster infrastructure and applications
- The Installer VM or Host

Network Requirements

The following infrastructure services need to be deployed to support the OpenShift cluster, during the validation of this solution we have provided VMs on your hypervisor of choice to run the required services. You can use the existing DNS and DHCP services available in the data center.

There are various infrastructure services prerequisites for deploying OpenShift 4.17. These prerequisites are as follows:

- DNS and DHCP services – these services were configured on Microsoft Windows Server VMs in this validation
- NTP Distribution was done with Nexus switches
- Specific DNS entries for deploying OpenShift – added to the DNS server
- A Linux VM for initial automated installation and cluster management – a Rocky Linux / RHEL VM with appropriate packages

NTP

Each OpenShift Container Platform node in the cluster must have access to at least two NTP servers.

NICs

NICs configured on the Cisco UCS servers based on the design previously discussed.

DNS

Clients access the OpenShift Container Platform cluster nodes over the bare metal network. Configure a subdomain or subzone where the canonical name extension is the cluster name.

The following domain and OpenShift cluster names are used in this deployment guide:

- Base Domain: flashstack.local
- OpenShift Cluster Name: fs-ocp1

The DNS domain name for the OpenShift cluster should be the cluster name followed by the base domain, for example fs-ocp1. flashstack.local.

Table 19 lists the information for fully qualified domain names used during validation. The API and Nameserver addresses begin with canonical name extensions. The hostnames of the control plane and worker nodes are exemplary, so you can use any host naming convention you prefer.

Table 19. DNS FQDN Names Used

Usage	Hostname	IP Address
API	api.fs-ocp1.flashstack.local	10.106.1.31
Ingress LB (apps)	*.apps.fs-ocp1.flashstack.local	10.106.1.32
master1	master1.fs-ocp1.flashstack.local	10.106.1.33
master2	master2.fs-ocp1.flashstack.local	10.106.1.34
master3	master3.fs-ocp1.flashstack.local	10.106.1.35
worker1	worker1.fs-ocp1.flashstack.local	10.106.1.36
worker2	worker2.fs-ocp1.flashstack.local	10.106.1.37
worker3	worker3.fs-ocp1.flashstack.local	10.106.1.38

DHCP

For the bare metal network, a network administrator must reserve several IP addresses, including:

- One IP address for the API endpoint
- One IP address for the wildcard Ingress endpoint
- One IP address for each master node (DHCP server assigns to the node)
- One IP address for each worker node (DHCP server assigns to the node)

Note: Get the MAC addresses of the bare metal Interfaces from the UCS Server Profile for each node to be used in the DHCP configuration to assign reserved IP addresses (reservations) to the nodes. The KVM IP address also needs to be gathered for the master and worker nodes from the server profiles.

Procedure 1. Gather MAC Addresses of Node Bare Metal Interfaces

Step 1. Log into **Cisco Intersight**.

Step 2. Go to **Infrastructure Service** > **Profiles** > **UCS Server Profile** (for example, AA06-OCP-Worker-M.2_3).

Step 3. In the center pane, go to **Inventory** > **Network Adapters** > **Network Adapter** (for example, UCSX-ML-V5D200G).

Step 4. In the center pane, click **Interfaces.**

Step 5. Record the **MAC address** for NIC Interface eno5.

Step 6. Select the **General** tab and click **Identifiers**.

Step 7. Record the **Management IP** assigned from the AA06-OCP-OOB-MGMT-IP Pool.

Table 20 lists the IP addresses used for the OpenShift cluster including bare metal network IPs and UCS KVM Management IPs for IMPI or Redfish access.

Table 20. Host BMC Information

Hostname	Management IP Address	UCS KVM Mgmt. IP Address	BareMetal MAC Address (eno5)
master1.fs-ocp1.flashstack.local	10.106.1.33	10.106.0.21	00-25-B5-A6-0A-00
master2.fs-ocp1.flashstack.local	10.106.1.34	10.106.0.22	00-25-B5-A6-0A-01
master3.fs-ocp1.flashstack.local	10.106.1.35	10.106.0.23	00-25-B5-A6-0A-02
worker1.fs-ocp1.flashstack.local	10.106.1.36	10.106.0.24	00-25-B5-A6-0A-03
worker2.fs-ocp1.flashstack.local	10.106.1.37	10.106.0.25	00-25-B5-A6-0A-09
worker3.fs-ocp1.flashstack.local	10.106.1.38	10.106.0.26	00-25-B5-A6-0A-0B

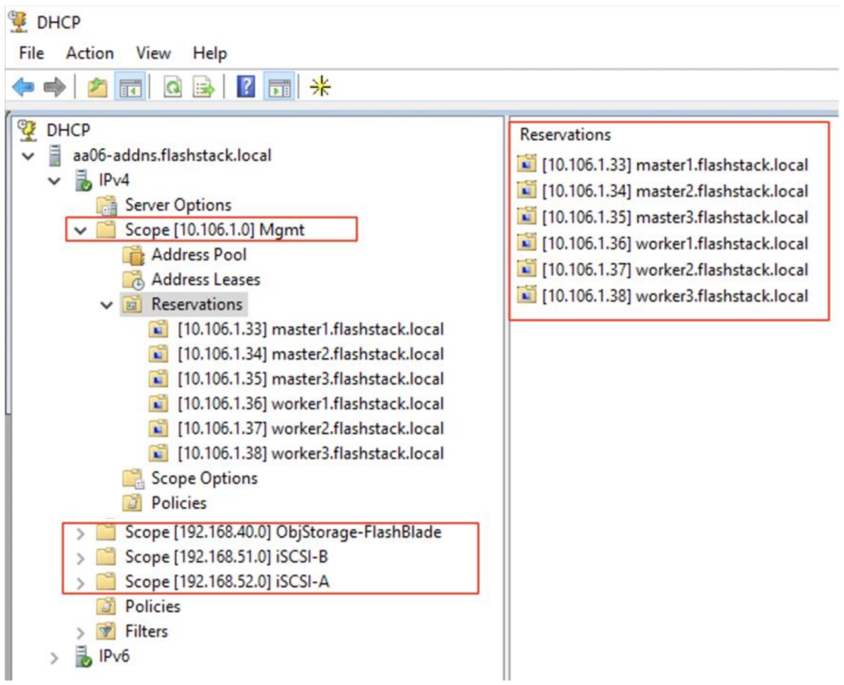
Step 8. From Table 20, enter the **hostnames**, **IP addresses**, and **MAC addresses** as reservations in your DHCP and DNS server(s) or configure the DHCP server to dynamically update DNS.

Step 9. You need to pipe **VLAN interfaces** for all 3 storage VLANs (3010, 3020 and 3040) and 1 management VLANs (1061) into your DHCP server(s) and assign IPs in the storage networks on those interfaces.

Step 10. Create a **DHCP scope** for each management and storage VLANs with the appropriate subnets.

Step 11. Ensure that the IPs assigned by the scope do not overlap with the already consumed IPs (like FlashArray//XL170 storage iSCSI interface IPs, FlashBlade//S200 interfaces and OpenShift reserved IPs).

Step 12. Enter the nodes in the DNS server or configure the DHCP server to forward entries to the DNS server. For the cluster nodes, create reservations to map the hostnames to the desired IP addresses as shown below:



DHCP
aa06-addns.flashstack.local
IPv4
Server Options
Scope [10.106.1.0] Mgmt
Address Pool
Address Leases
Reservations
[10.106.1.33] master1.flashstack.local
[10.106.1.34] master2.flashstack.local
[10.106.1.35] master3.flashstack.local
[10.106.1.36] worker1.flashstack.local
[10.106.1.37] worker2.flashstack.local
[10.106.1.38] worker3.flashstack.local
Scope Options
Policies
Scope [192.168.40.0] ObjStorage-FlashBlade
Scope [192.168.51.0] iSCSI-B
Scope [192.168.52.0] iSCSI-A
Policies
Filters
IPv6

Reservations
[10.106.1.33] master1.flashstack.local
[10.106.1.34] master2.flashstack.local
[10.106.1.35] master3.flashstack.local
[10.106.1.36] worker1.flashstack.local
[10.106.1.37] worker2.flashstack.local
[10.106.1.38] worker3.flashstack.local

Note: With these DHCP scopes in place, the Management and storage IPs will be assigned automatically from the corresponding DHCP pools to the respective interfaces of master and worker nodes. No manual IP configuration is required.

Step 13. Setup either a **VM** (installer/bastion node) or **spare server** with the network interface connected to the Bare Metal VLAN.

Step 14. Install either **Red Hat Enterprise Linux (RHEL) 9.4** or **Rocky Linux 9.4 Server with GUI** and create an administrator user. Once the VM or host is up and running, update it and install and configure XRDP. Connect to this host with a Windows Remote Desktop client as the admin user.

Step 15. **ssh** into the **installer node VM**, open a **terminal session** and create an **SSH key pair** to use to communicate with the OpenShift hosts:

```
cd

ssh-keygen -t ed25519 -N '' -f ~/.ssh/id_ed25519
```

Step 16. Copy the public SSH key to the user directory:

```
cp ~/.ssh/id_ed25519.pub ~/
```

Step 17. Add the private key to the ssh-agent:

```
sshadd ~/.ssh/id_ed25519
```

Procedure 2. Install Red Hat OpenShift Container Platform using the Assisted Installer

Step 1. Launch **Firefox** and connect to https://console.redhat.com/openshift/cluster-list. Log into your **Red Hat account.**

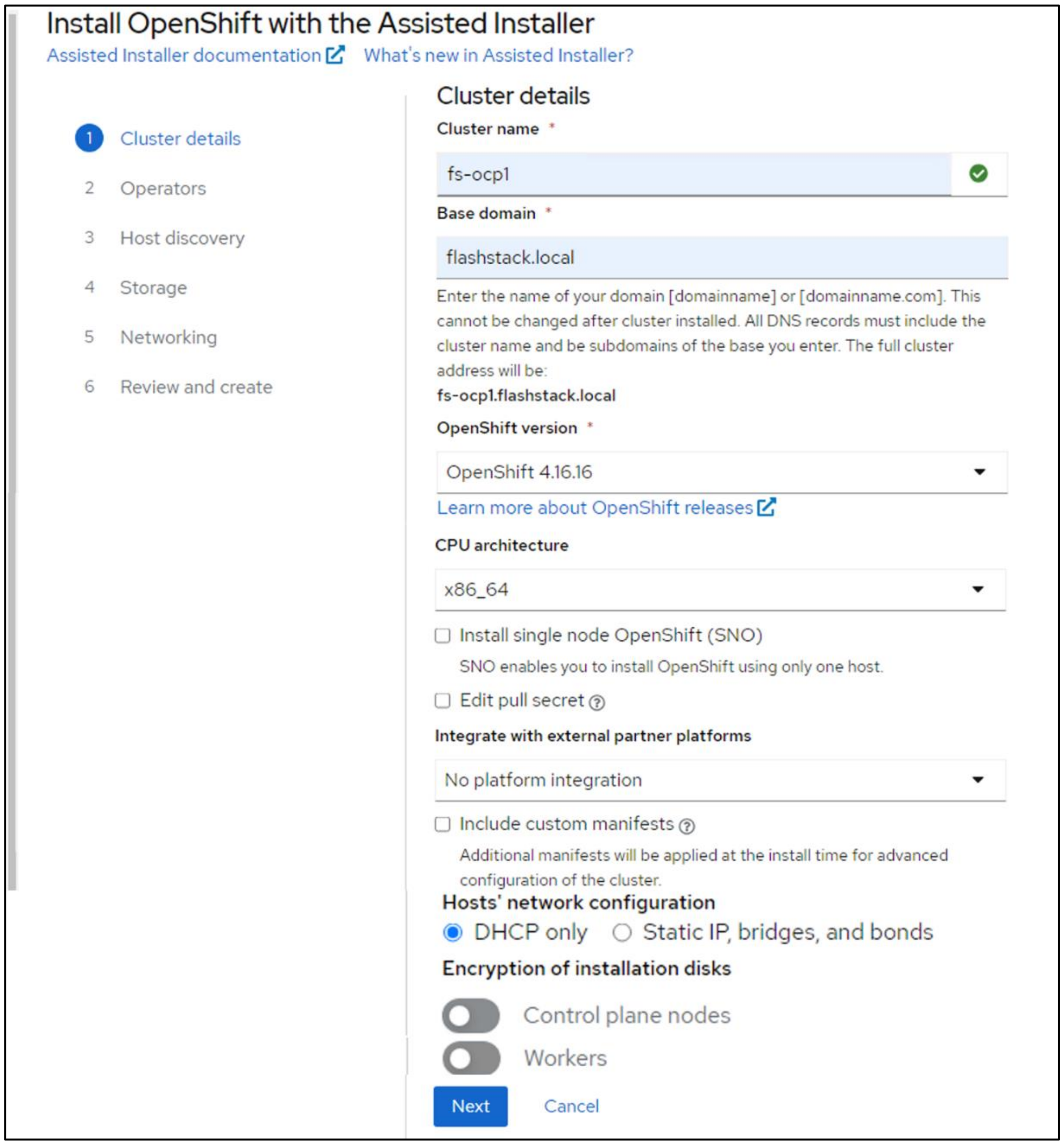
Step 2. Click **Create cluster** to create an OpenShift cluster.

Step 3. Select **Datacenter** and then select **Bare Metal (x86_64)**.

Step 4. Select **Interactive** to launch the Assisted Installer.

Step 5. Provide the **cluster name** and **base domain.**

Step 6. Select the latest **OpenShift version**, scroll down and click **Next.**



Install OpenShift with the Assisted Installer

Cluster details

Cluster name *: fs-ocp1

Base domain *: flashstack.local

Enter the name of your domain [domainname] or [domainname.com]. This cannot be changed after cluster installed. All DNS records must include the cluster name and be subdomains of the base you enter. The full cluster address will be:
fs-ocp1.flashstack.local

OpenShift version *: OpenShift 4.16.16

Learn more about OpenShift releases

CPU architecture: x86_64

☐ Install single node OpenShift (SNO)
SNO enables you to install OpenShift using only one host.

☐ Edit pull secret

Integrate with external partner platforms: No platform integration

☐ Include custom manifests
Additional manifests will be applied at the install time for advanced configuration of the cluster.

Hosts' network configuration: [✓ DHCP only] Static IP, bridges, and bonds

Encryption of installation disks

Control plane nodes: off

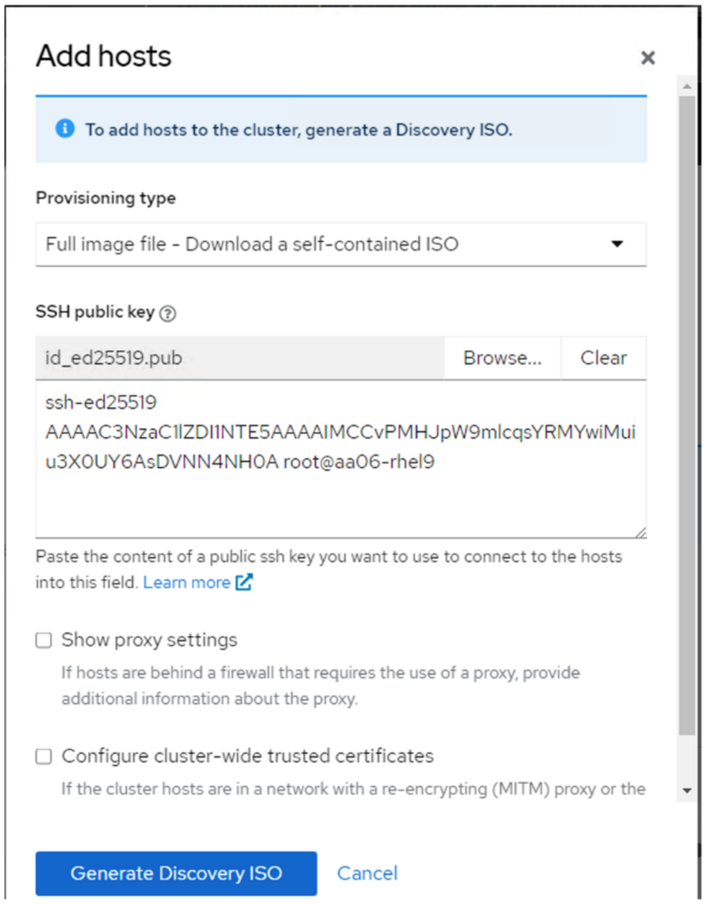
Workers: off

Step 7. Select the latest **OpenShift version**, scroll down and click **Next.**

Step 8. Select **Install OpenShift Virtualization** operator and click **Next.**

Step 9. Click **Add hosts.**

Step 10. Under **Provisioning type**, from the drop-down list select the **Full Image file**. Under **SSH public key**, click **Browse** and browse to, select, and open the **id_ed25519.pub** file. The contents of the public key should now appear in the box. Click **Generate Discovery ISO** and click **Download Discovery ISO** to download the Discovery ISO.



Add hosts

To add hosts to the cluster, generate a Discovery ISO.

Provisioning type

Full image file - Download a self-contained ISO

SSH public key

id_ed25519.pub

ssh-ed25519 AAAAC3NzaC1lZDI1NTE5AAAAIMCCvPMHJpW9mlcqsYRMYwiMui u3X0UY6AsDVNN4NH0A root@aa06-rhel9

Paste the content of a public ssh key you want to use to connect to the hosts into this field. Learn more

Show proxy settings

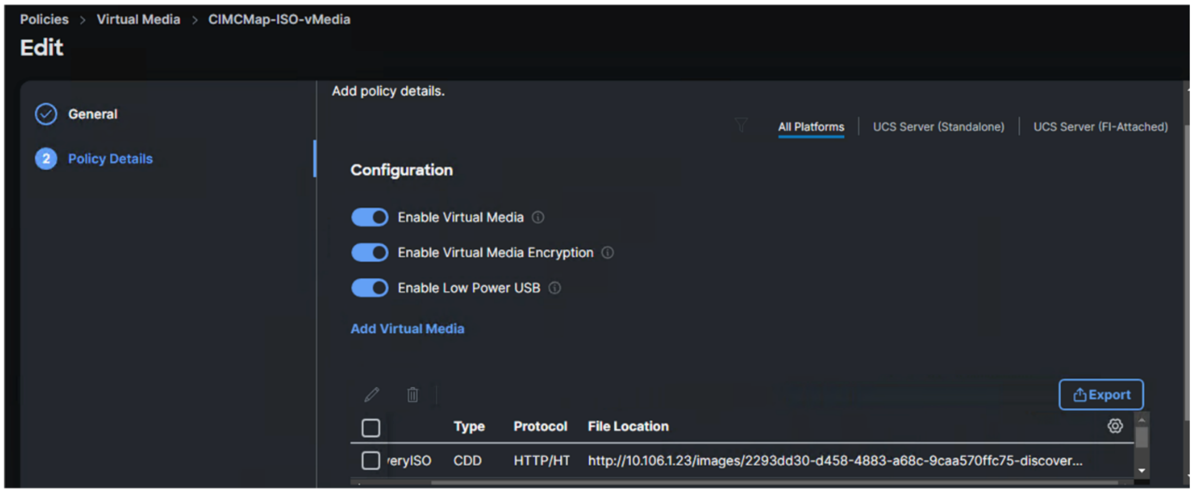
If hosts are behind a firewall that requires the use of a proxy, provide additional information about the proxy.

Configure cluster-wide trusted certificates

If the cluster hosts are in a network with a re-encrypting (MITM) proxy or the

Step 11. Copy the **Discovery ISO** to a http or https file share server, use a web browser to get a copy of the URL for the Discovery ISO.

Step 12. Log into **Cisco Intersight** and update the virtual Media policy with the Discovery ISO URL as shown below. This Discovery ISO image will be mapped to the server using CIMC Mapped DVD option defined in the Boot policy.



Policies > Virtual Media > CIMCMap-ISO-vMedia

Edit

Add policy details.

Configuration

Enable Virtual Media

Enable Virtual Media Encryption

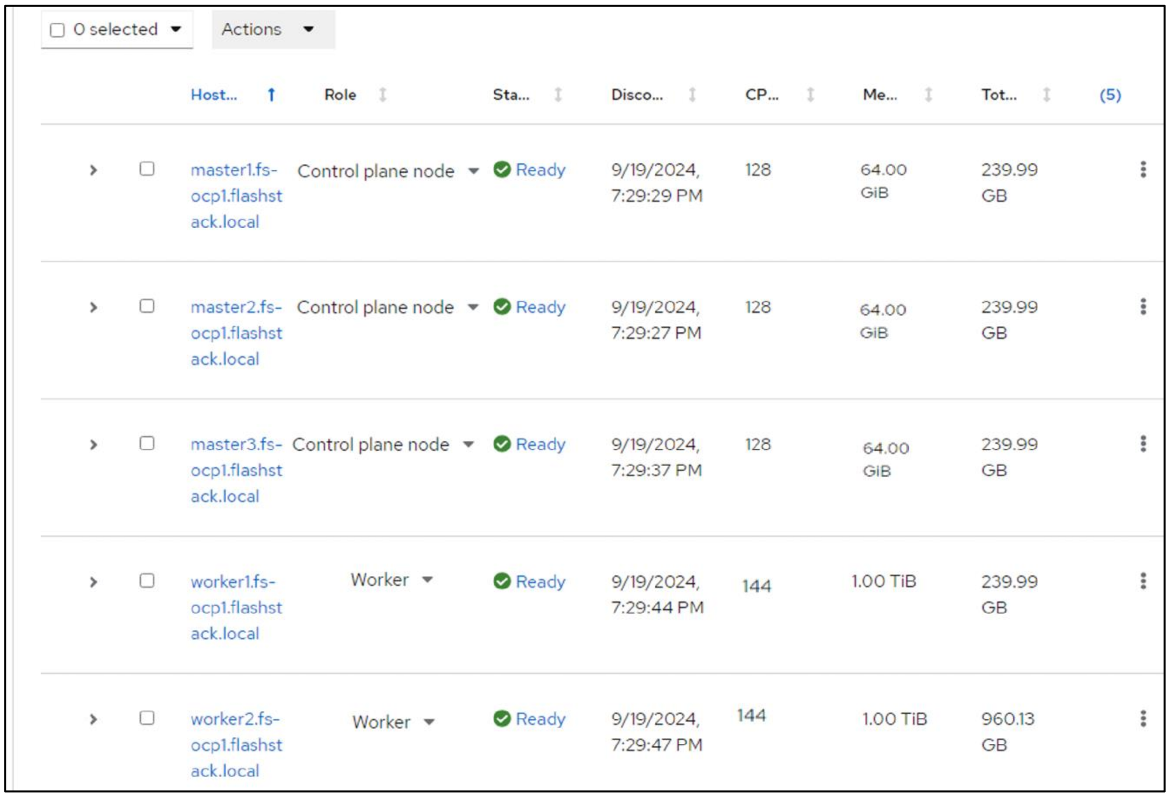
Enable Low Power USB

	Type	Protocol	File Location
'eryISO	CDD	HTTP/HT	http://10.106.1.23/images/2293dd30-d458-4883-a68c-9caa570ffc75-discover...

Note: To demonstrate the OpenShift cluster expansion (adding additional worker node), only the first five nodes (3 master/control and 2 workers) will be used for the initial OpenShift cluster deployment. The sixth node is reserved for now and will be used for cluster expansion which will be discussed in the following sections.

Step 13. Go to **Operate** > **Power** > **Reset System** to reset first five UCSX-201c M7 servers.

Step 14. When all five servers have booted **RHEL CoreOS (Live)** from the Discovery ISO, they will appear in the Assisted Installer. From the drop-down lists under **Role** assign the appropriate server roles. Scroll down and click **Next**.

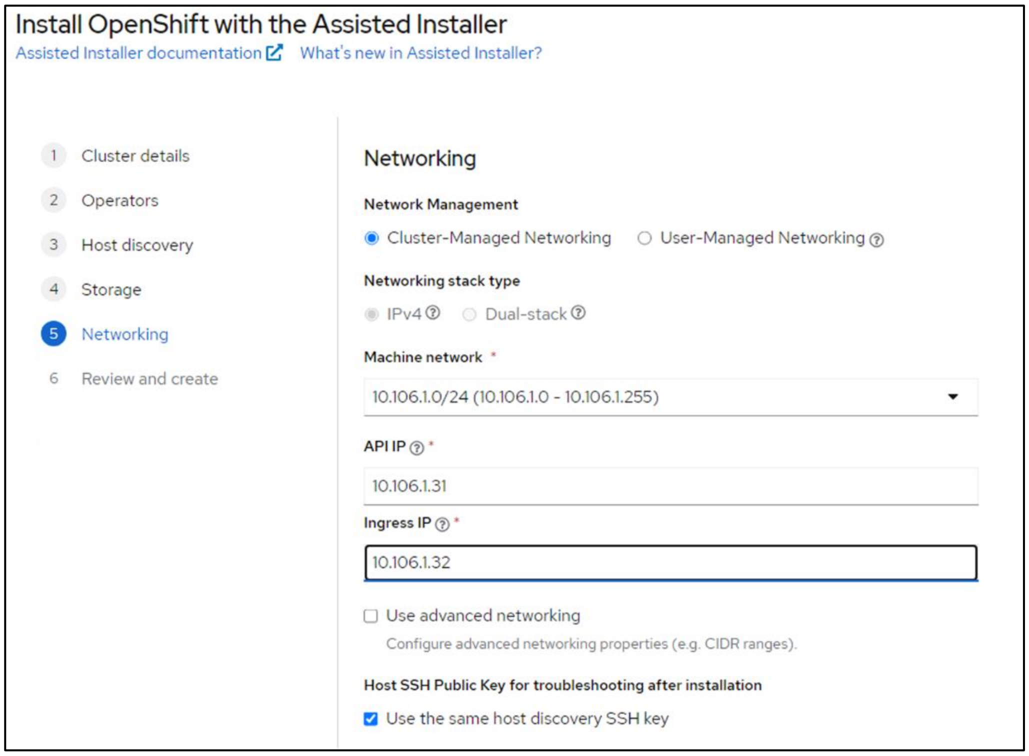


Host...	Role	Sta...	Disco...	CP...	Me...	Tot...
master1.fs-ocp1.flashstack.local	Control plane node	Ready	9/19/2024, 7:29:29 PM	128	64.00 GiB	239.99 GB
master2.fs-ocp1.flashstack.local	Control plane node	Ready	9/19/2024, 7:29:27 PM	128	64.00 GiB	239.99 GB
master3.fs-ocp1.flashstack.local	Control plane node	Ready	9/19/2024, 7:29:37 PM	128	64.00 GiB	239.99 GB
worker1.fs-ocp1.flashstack.local	Worker	Ready	9/19/2024, 7:29:44 PM	144	1.00 TiB	239.99 GB
worker2.fs-ocp1.flashstack.local	Worker	Ready	9/19/2024, 7:29:47 PM	144	1.00 TiB	960.13 GB

(5)

Step 15. Expand each node and confirm the role of the M.2 disk is set to Installation disk. Click **Next.**

Step 16. Under **Network Management**, make sure **Cluster-Managed Networking** is selected. Under **Machine network**, from the drop-down list, select the **subnet** for the **BareMetal VLAN**. Enter the **API IP** for the api.cluster.basedomain entry in the DNS servers. For the Ingress IP, enter the IP for the *.apps.cluster.basedomain entry in the DNS servers.



Install OpenShift with the Assisted Installer

Assisted Installer documentation | What's new in Assisted Installer?

Networking

Network Management: [✓ Cluster-Managed Networking] User-Managed Networking

Networking stack type: [✓ IPv4] Dual-stack

Machine network *: 10.106.1.0/24 (10.106.1.0 - 10.106.1.255)

API IP *: 10.106.1.31

Ingress IP *: 10.106.1.32

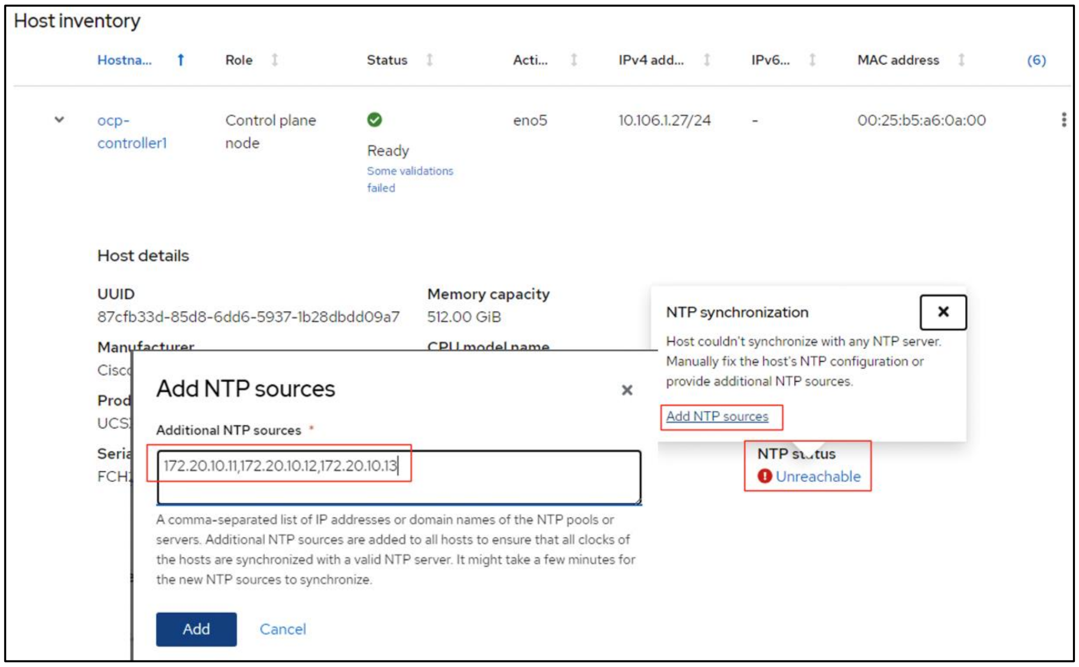
☐ Use advanced networking
Configure advanced networking properties (e.g. CIDR ranges).

Host SSH Public Key for troubleshooting after installation

☑ Use the same host discovery SSH key

Step 17. Scroll down. All nodes should have a status of Ready.

Note: If you see insufficient warning message for the nodes due to missing ntp server information, expand one of the nodes, click **Add NTP Sources** and provide the NTP servers IPs separated by a comma.



Host inventory

Hostname	Role	Status	Active NIC	IPv4 address	IPv6	MAC address
ocp-controller1	Control plane node	Ready Some validations failed	eno5	10.106.1.27/24	-	00:25:b5:a6:0a:00

Host details

UUID: 87cfb33d-85d8-6dd6-5937-1b28dbdd09a7

Memory capacity: 512.00 GiB

NTP synchronization

Host couldn't synchronize with any NTP server. Manually fix the host's NTP configuration or provide additional NTP sources.

Add NTP sources

NTP status: Unreachable

Add NTP sources

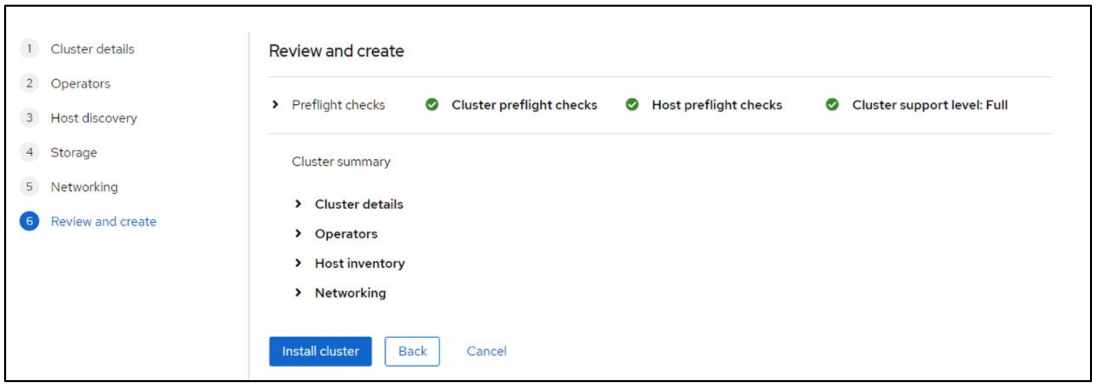
Additional NTP sources *: 172.20.10.11,172.20.10.12,172.20.10.13

A comma-separated list of IP addresses or domain names of the NTP pools or servers. Additional NTP sources are added to all hosts to ensure that all clocks of the hosts are synchronized with a valid NTP server. It might take a few minutes for the new NTP sources to synchronize.

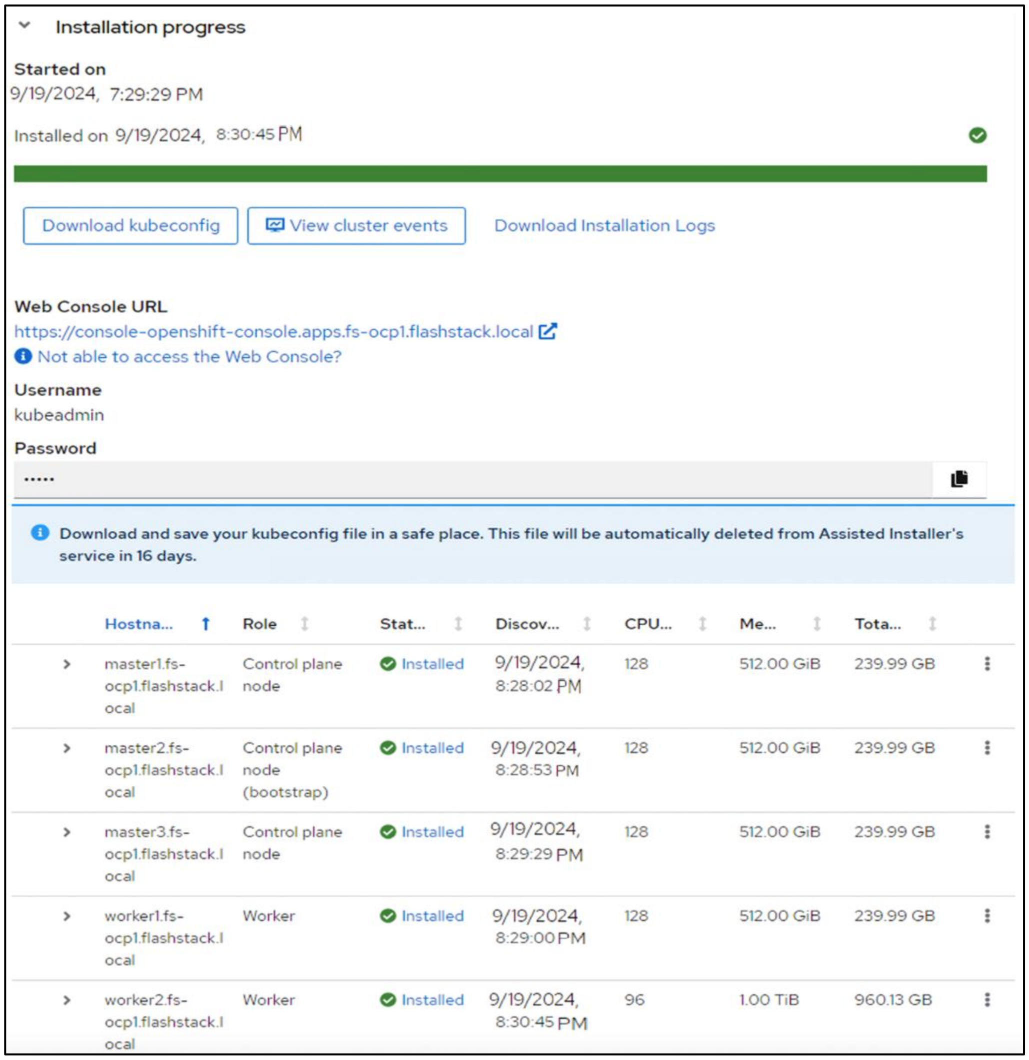
Note: A warning message may display about each worker node having multiple network devices on the L2 network. To resolve this, SSH into each worker and deactivate eno8,eno9, and eno10 interfaces using nmtui utility.

Step 18. When all the nodes are in ready status, click **Next**.

Step 19. Review the information and click **Install cluster** to begin the cluster installation.



Step 20. On the **Installation progress** page, expand the **Host inventory**. The installation will take 30-45 minutes. When the installation is complete, all nodes will show a Status of Installed.



Installation progress

Started on
9/19/2024, 7:29:29 PM

Installed on 9/19/2024, 8:30:45 PM

Download kubeconfig | View cluster events | Download Installation Logs

Web Console URL
https://console-openshift-console.apps.fs-ocp1.flashstack.local
Not able to access the Web Console?

Username
kubeadmin

Password
•••••

Download and save your kubeconfig file in a safe place. This file will be automatically deleted from Assisted Installer's service in 16 days.

Hostna...	Role	Stat...	Discov...	CPU...	Me...	Tota...
master1.fs-ocp1.flashstack.local	Control plane node	Installed	9/19/2024, 8:28:02 PM	128	512.00 GiB	239.99 GB
master2.fs-ocp1.flashstack.local	Control plane node (bootstrap)	Installed	9/19/2024, 8:28:53 PM	128	512.00 GiB	239.99 GB
master3.fs-ocp1.flashstack.local	Control plane node	Installed	9/19/2024, 8:29:29 PM	128	512.00 GiB	239.99 GB
worker1.fs-ocp1.flashstack.local	Worker	Installed	9/19/2024, 8:29:00 PM	128	512.00 GiB	239.99 GB
worker2.fs-ocp1.flashstack.local	Worker	Installed	9/19/2024, 8:30:45 PM	96	1.00 TiB	960.13 GB

Step 21. Select **Download kubeconfig** to download the kubeconfig file. In a terminal window, setup a cluster directory and save credentials:

```
cd
mkdir <clustername> # for example, ocp
cd <clustername>
```

```
mkdir auth
cd auth
mv ~/Downloads/kubeconfig ./
mkdir ~/.kube
cp kubeconfig ~/.kube/config
```

Step 22. In the **Assisted Installer**, click the icon to copy the kubeadmin password:

```
echo <paste password> > ./kubeadmin-password
```

Step 23. Click **Open console** to launch the OpenShift Console. Log in using the kubeadmin and the kubeadmin password.

Step 24. Click the **?** mask. Links for various tools are provided in that page. Download **oc for Linux** for x86_64 and virtctl for Linux for x86_64 Common Line Tools.

```
cd ..
mkdir client
cd client
ls ~/Downloads
mv ~/Downloads/oc.tar.gz ./
mv ~/Downloads/virtctl.tar.gz ./
tar xvf oc.tar
tar xvf virtctl.tar.gf
ls
sudo mv oc /usr/local/bin/
sudo mv virtcl /usr/local/bin/
sudo mv kubectl /usr/local/bin/
oc get nodes
```

Step 25. To enable oc tab completion for bash, run the following:

```
oc completion bash > oc_bash_completion
sudo mv oc_bash_completion /etc/bash_completion.d/
```

Step 26. In **Cisco Intersight**, edit the **Virtual Media policy** and remove the link to the **Discovery ISO**.

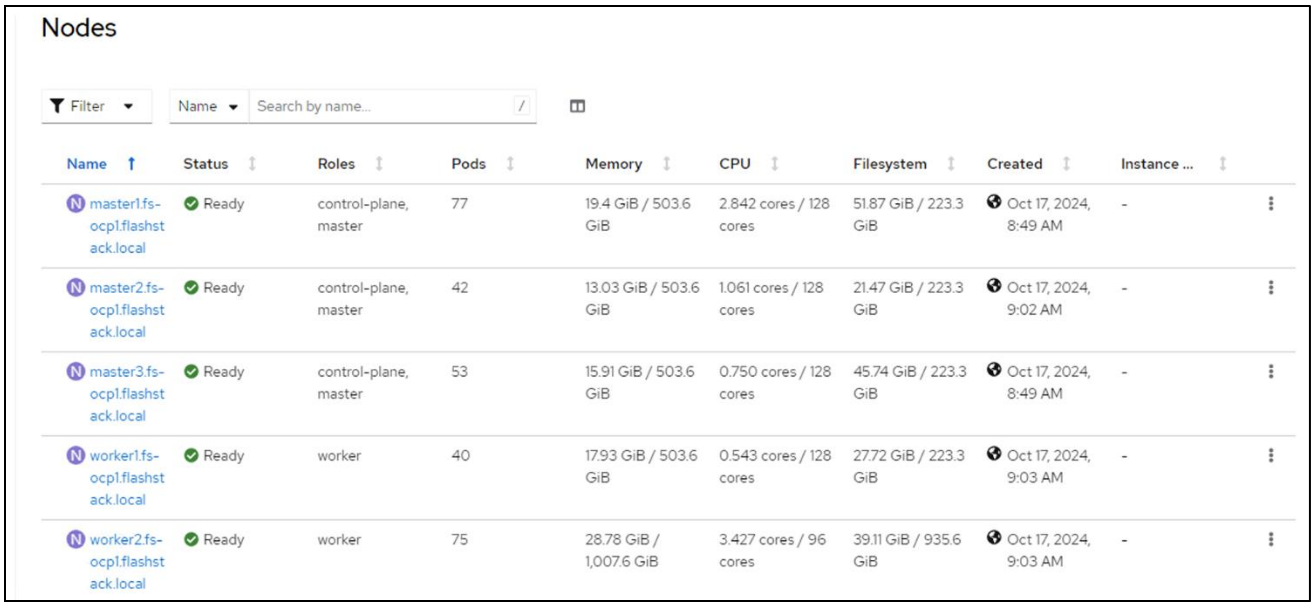
Step 27. Click **Save & Deploy** then click **Save & Proceed**.

Step 28. Do not select “Reboot Immediately to Activate.”

Step 29. Click **Deploy**. The virtual media mount will be removed from the servers without rebooting them.

Step 30. In **Firefox**, in the **Assisted Installer** page, click **Open console** to launch the OpenShift Console. Log in using the kubeadmin and the kubeadmin password.

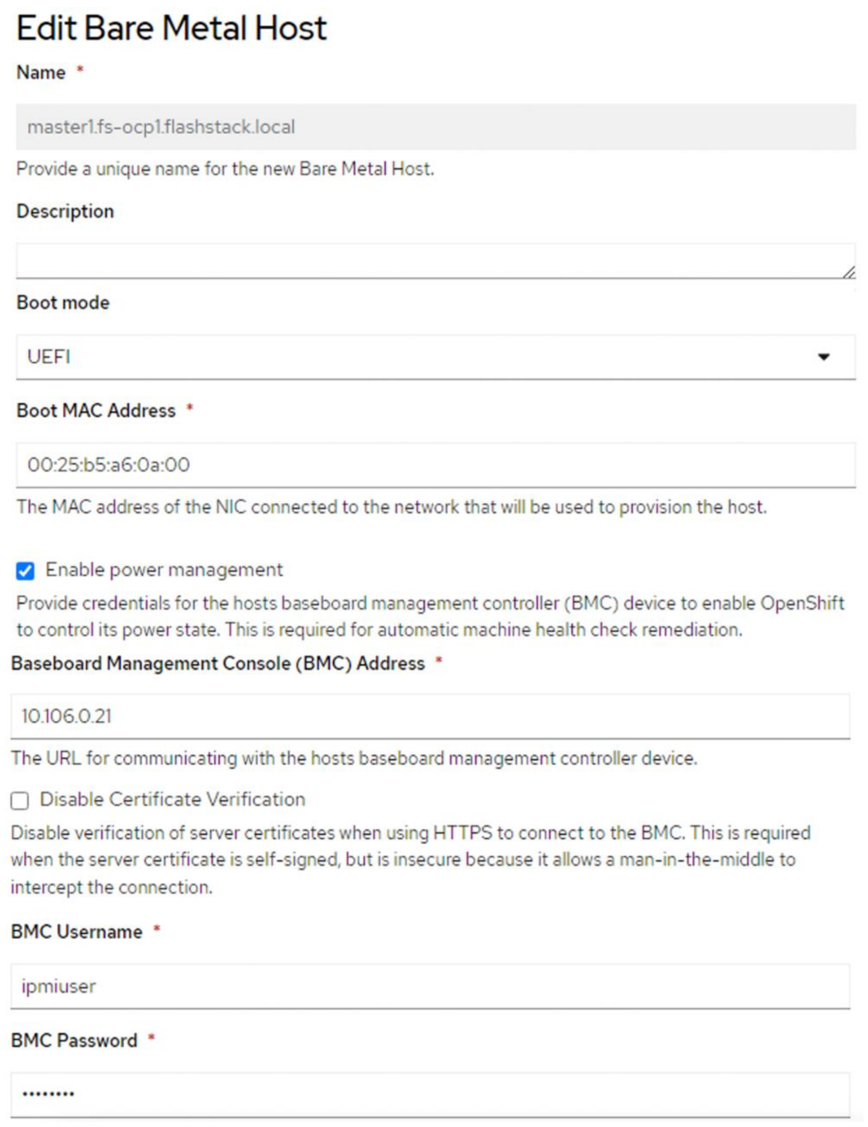
Step 31. Go to **Compute** > **Nodes** to see the status of the OpenShift nodes.


Nodes

Name	Status	Roles	Pods	Memory	CPU	Filesystem	Created	Instance ...
master1.fs-ocp1.flashstack.local	Ready	control-plane, master	77	19.4 GiB / 503.6 GiB	2.842 cores / 128 cores	51.87 GiB / 223.3 GiB	Oct 17, 2024, 8:49 AM	-
master2.fs-ocp1.flashstack.local	Ready	control-plane, master	42	13.03 GiB / 503.6 GiB	1.061 cores / 128 cores	21.47 GiB / 223.3 GiB	Oct 17, 2024, 9:02 AM	-
master3.fs-ocp1.flashstack.local	Ready	control-plane, master	53	15.91 GiB / 503.6 GiB	0.750 cores / 128 cores	45.74 GiB / 223.3 GiB	Oct 17, 2024, 8:49 AM	-
worker1.fs-ocp1.flashstack.local	Ready	worker	40	17.93 GiB / 503.6 GiB	0.543 cores / 128 cores	27.72 GiB / 223.3 GiB	Oct 17, 2024, 9:03 AM	-
worker2.fs-ocp1.flashstack.local	Ready	worker	75	28.78 GiB / 1,007.6 GiB	3.427 cores / 96 cores	39.11 GiB / 935.6 GiB	Oct 17, 2024, 9:03 AM	-

Step 32. In the **Red Hat OpenShift console**, go to **Compute** > **Bare Metal Hosts**. For each Bare Metal Host, click the **ellipses** to the right of the host and select **Edit Bare Metal Host**. Select **Enable power management**.

Step 33. From Table 20, fill in the **BMC Address**. Also, make sure the Boot MAC Address matches the MAC address in Table 20. For the BMC Username and BMC Password, use what was entered into the Cisco Intersight IPMI over LAN policy. Click **Save** to save the changes. Repeat this step for all Bare Metal Hosts.



Edit Bare Metal Host

Name *

master1.fs-ocp1.flashstack.local

Provide a unique name for the new Bare Metal Host.

Description

Boot mode

UEFI

Boot MAC Address *

00:25:b5:a6:0a:00

The MAC address of the NIC connected to the network that will be used to provision the host.

☑ Enable power management

Provide credentials for the hosts baseboard management controller (BMC) device to enable OpenShift to control its power state. This is required for automatic machine health check remediation.

Baseboard Management Console (BMC) Address *

10.106.0.21

The URL for communicating with the hosts baseboard management controller device.

☐ Disable Certificate Verification

Disable verification of server certificates when using HTTPS to connect to the BMC. This is required when the server certificate is self-signed, but is insecure because it allows a man-in-the-middle to intercept the connection.

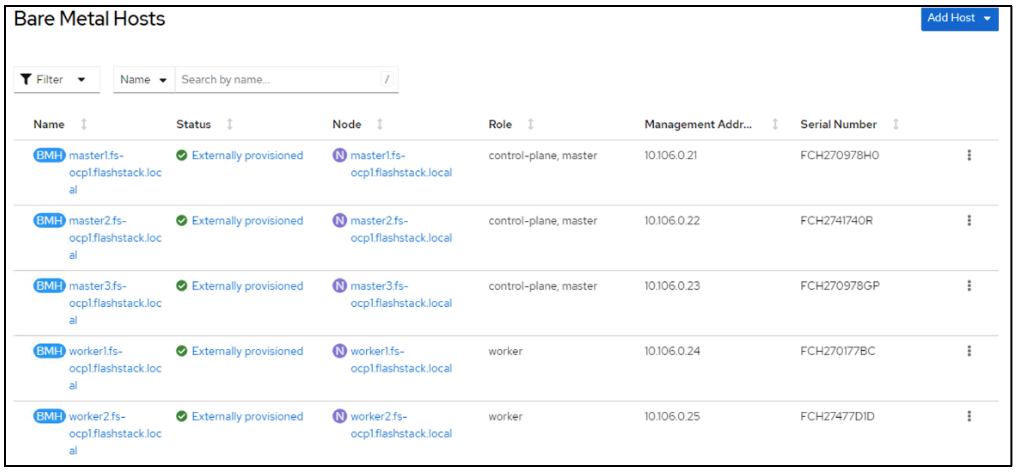
BMC Username *

ipmiuser

BMC Password *

••••••••

Step 34. Go to **Compute** > **Bare Metal Hosts**. When all hosts have been configured, the Status displays "Externally provisioned," and the Management Address are populated. You can now manage power on the OpenShift hosts from the OpenShift console.



Bare Metal Hosts

Name	Status	Node	Role	Management Addr...	Serial Number
BMH master1.fs-ocp1.flashstack.local	Externally provisioned	N master1.fs-ocp1.flashstack.local	control-plane, master	10.106.0.21	FCH270978H0
BMH master2.fs-ocp1.flashstack.local	Externally provisioned	N master2.fs-ocp1.flashstack.local	control-plane, master	10.106.0.22	FCH2741740R
BMH master3.fs-ocp1.flashstack.local	Externally provisioned	N master3.fs-ocp1.flashstack.local	control-plane, master	10.106.0.23	FCH270978GP
BMH worker1.fs-ocp1.flashstack.local	Externally provisioned	N worker1.fs-ocp1.flashstack.local	worker	10.106.0.24	FCH270177BC
BMH worker2.fs-ocp1.flashstack.local	Externally provisioned	N worker2.fs-ocp1.flashstack.local	worker	10.106.0.25	FCH27477D1D

Note: For an IPMI connection to the server, use the BMC IP address. However, for Redfish to connect to the server, use this format for the BMS address; redfish://<BMC IP>/redfish/v1/Systems/<server Serial Number> and make sure to check **Disable Certificate Verification.** For Instance, for master1.fs-ocp1.flashstack.local Bare Metal node, the redfish BMC management Address will be: redfish://10.106.0.21/redfish/v1/Systems/FCH270978H0. When using Redfish to connect to the server, it is critical to check the box for **Disable Certificate Verification**.

Note: It is recommended to reserve enough resources (CPU and memory) for system components like kubelet and kube-proxy on the nodes. OpenShift Container Platform can automatically determine the optimal system-reserved CPU and memory resources for nodes associated with a specific machine config pool and update the nodes with those values when the nodes start.

Step 35. To automatically determine and allocate the system-reserved resources on nodes, create a **KubeletConfig CUSTOM RESOURCE** (CR) to set the autoSizingReserved: true parameter as shown below and apply the machine configuration files:

```
cat dynamic-resource-alloc-workers.yaml
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: dynamic-node-worker
spec:
  autoSizingReserved: true
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/worker: ""

cat dynamic-resource-alloc-master.yaml
apiVersion: machineconfiguration.openshift.io/v1
kind: KubeletConfig
metadata:
  name: dynamic-resource-allow-master
spec:
  autoSizingReserved: true
  machineConfigPoolSelector:
    matchLabels:
      pools.operator.machineconfiguration.openshift.io/master: ""



oc apply -f dynamic-resource-alloc-workers.yaml
oc apply -f dynamic-resource-alloc-master.yaml
```

Note: To manually configure the resources for the system components on the nodes, go to: https://docs.openshift.com/container-platform/4.16/nodes/nodes/nodes-nodes-resources-configuring.html#nodes-nodes-resources-configuring-setting_nodes-nodes-resources-configuring

Expand OpenShift Cluster by Adding a Worker Node

This chapter contains the following:

- OpenShift Cluster expansion
- Link the Machine and Bare Metal Host, Node and Bare Metal Host

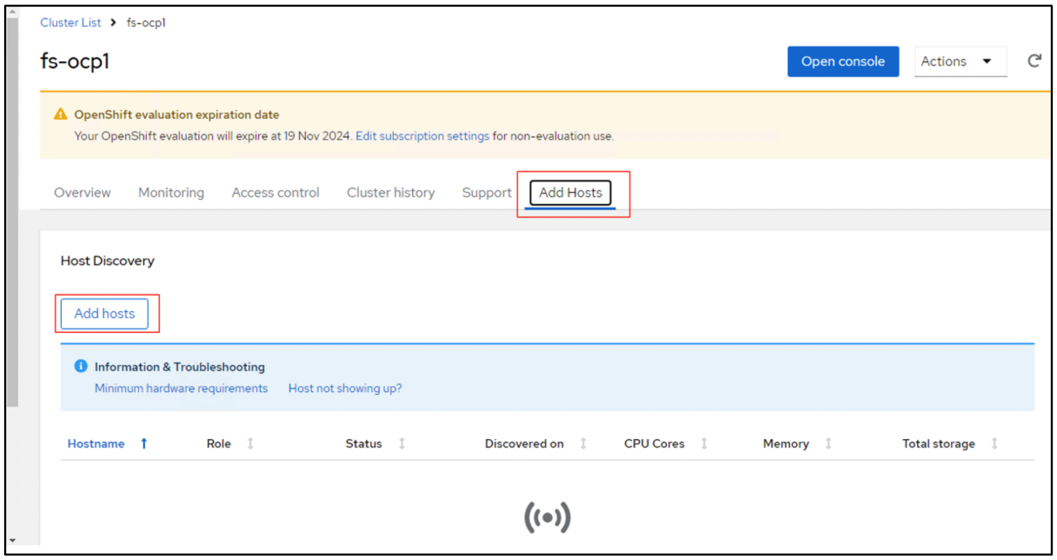
This chapter provides detailed steps to scale up the worker nodes of OpenShift cluster by adding a new worker node to the existing cluster. For this exercise, the sixth blade in the chassis will be used and be part of the cluster by the end of this exercise.

Note: This chapter assumes that a new server profile is already derived from the existing template and assigned to the new server successfully.

Procedure 1. OpenShift Cluster expansion

Step 1. Launch **Firefox** and go to https://console.redhat.com/openshift/cluster-list. Log into your **Red Hat account**.

Step 2. Click your cluster name and go to **Add Hosts.**



OpenShift evaluation expiration date

Your OpenShift evaluation will expire at 19 Nov 2024. Edit subscription settings for non-evaluation use.

Host Discovery

Information & Troubleshooting

Minimum hardware requirements Host not showing up?

Step 3. Under Host Discovery, click **Add hosts**.

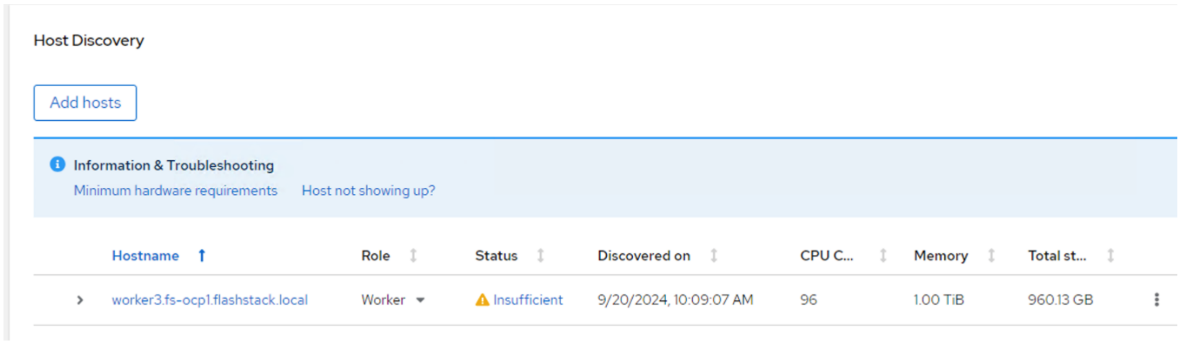
Step 4. In the **Add hosts** wizard, for the **CPU architecture** select **x86_64** and for the **Host's network configuration** select **DHCP Only**. Click **Next**.

Step 5. For the **Provision type** select **Full image** file from the drop-down list, for **SSH public key** browse or copy/paste the contents of **id-ed25519.pub file**. Click **Generate Discovery ISO** and when the file is generated and click **Download Discovery ISO file.**

Step 6. Copy the **Discovery ISO** to a http or https file share server, use a web browser to get a copy of the URL for the new Discovery ISO.

Step 7. Log into **Cisco Intersight** and update the **virtual Media policy** as explained in the previous section. This Discovery ISO image is a mapped server using the CIMC Mapped DVD option. Go to **Power** > **Reset System** to reset the sixth UCSX-201c M7 server.

Step 8. When the server has booted "RHEL CoreOS (live)" from the newly generated Discovery ISO, it will appear in the assisted installer under Add hosts.


Host Discovery

Add hosts

Information & Troubleshooting

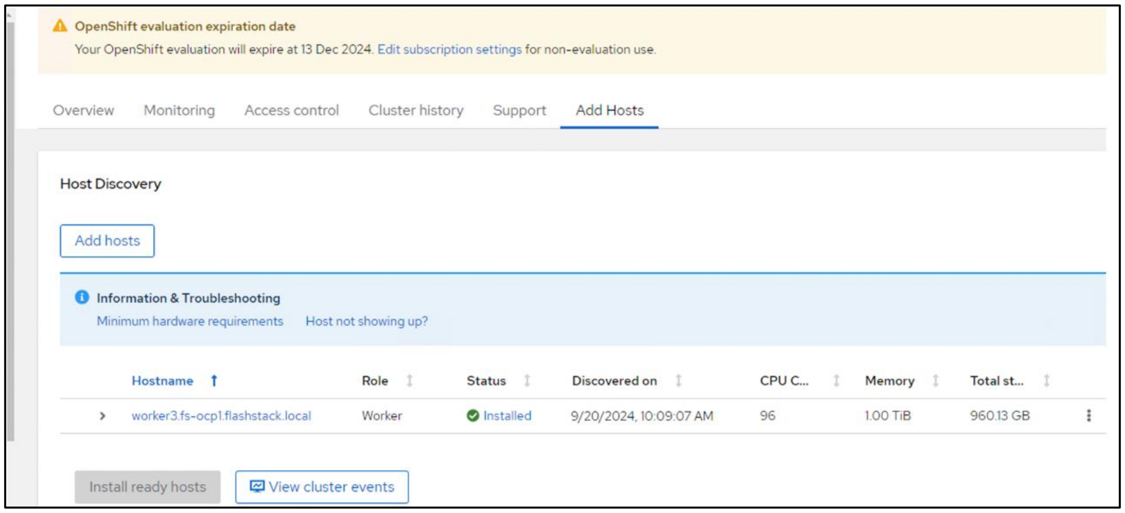
Minimum hardware requirements Host not showing up?

Hostname	Role	Status	Discovered on	CPU C...	Memory	Total st...
worker3.fs-ocp1.flashstack.local	Worker	Insufficient	9/20/2024, 10:09:07 AM	96	1.00 TiB	960.13 GB

Note: If you see insufficient warning messages for the node due to missing ntp server information, expand one of the nodes, click **Add NTP Sources** and provide the NTP servers IPs separated by a comma.

Note: If a warning message appears stating you have multiple network devices on the L2 network, ssh into worker node and deactivate eno8,eno9, and eno10 interfaces using the nmtui utility.

Step 9. When the node status shows Ready, click **Install ready hosts.** After few minutes, the required components will be installed on the node and displays the status as Installed.


OpenShift evaluation expiration date

Your OpenShift evaluation will expire at 13 Dec 2024. Edit subscription settings for non-evaluation use.

Overview Monitoring Access control Cluster history Support Add Hosts

Host Discovery

Add hosts

Information & Troubleshooting

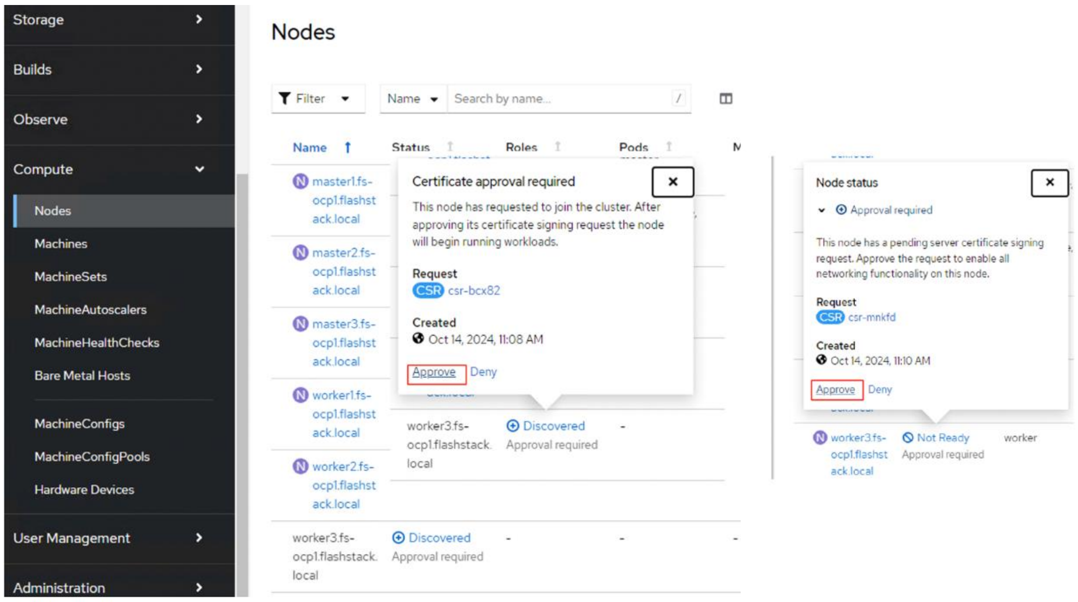
Minimum hardware requirements Host not showing up?

Hostname	Role	Status	Discovered on	CPU C...	Memory	Total st...
worker3.fs-ocp1.flashstack.local	Worker	Installed	9/20/2024, 10:09:07 AM	96	1.00 TiB	960.13 GB

Install ready hosts View cluster events

Step 10. When the server successfully produces the CoreOS installed, log into **Cisco Intersight**, edit the **vMedia policy** and remove the **virtual media mount**. Go to **Profiles** > **Server Profiles page**, deploy the profile to the newly added worker profile without rebooting the host. The Inconsistent state on the remaining profiles should be cleared.

Step 11. Log into the cluster with kubeadmin user and go to **Compute** > **Nodes** > and select the newly added worker node and approve the Cluster join request of the worker node and request for server certificate signing.



Nodes

Name	Status	Roles	Pods
master1.fs-ocp1.flashstack.local			
master2.fs-ocp1.flashstack.local			
master3.fs-ocp1.flashstack.local			
worker1.fs-ocp1.flashstack.local			
worker2.fs-ocp1.flashstack.local			
worker3.fs-ocp1.flashstack.local	Discovered Approval required	-	-

Certificate approval required

This node has requested to join the cluster. After approving its certificate signing request the node will begin running workloads.

Request
CSR csr-bcx82

Created
Oct 14, 2024, 11:08 AM

Node status

Approval required

This node has a pending server certificate signing request. Approve the request to enable all networking functionality on this node.

Request
CSR csr-mnkfd

Created
Oct 14, 2024, 11:10 AM

worker3.fs-ocp1.flashstack.local Not Ready Approval required worker

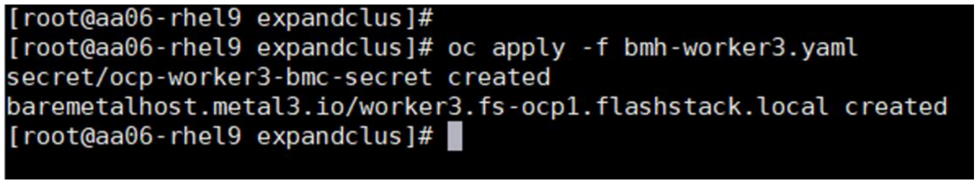
Step 12. Wait for a few seconds and the node will be ready and the pods are scheduled on the newly added worker node.

Step 13. Create **secret** and **BareMetalHost objects** in openshift-machine-api namespace by executing the following manifest (bmh-worker3.yaml):

```
cat bmh-worker3.yaml
---
apiVersion: v1
kind: Secret
metadata:
  name: ocp-worker3-bmc-secret
  namespace: openshift-machine-api
type: Opaque
data:
  username: aXBtaXVzZXIK
  password: SDFnaFYwbHQK
---
apiVersion: metal3.io/v1alpha1
kind: BareMetalHost
metadata:
  name: worker3.fs-ocp1.flashstack.local
  namespace: openshift-machine-api
spec:
  online: True
  bootMACAddress: 00:25:B5:A6:0A:0B
  bmc:
    address: redfish://10.106.0.26/redfish/v1/Systems/FCH27477BZU
    credentialsName: ocp-worker3-bmc-secret
    disableCertificateVerification: True
  customDeploy:
    method: install_coreos
  externallyProvisioned: true
```

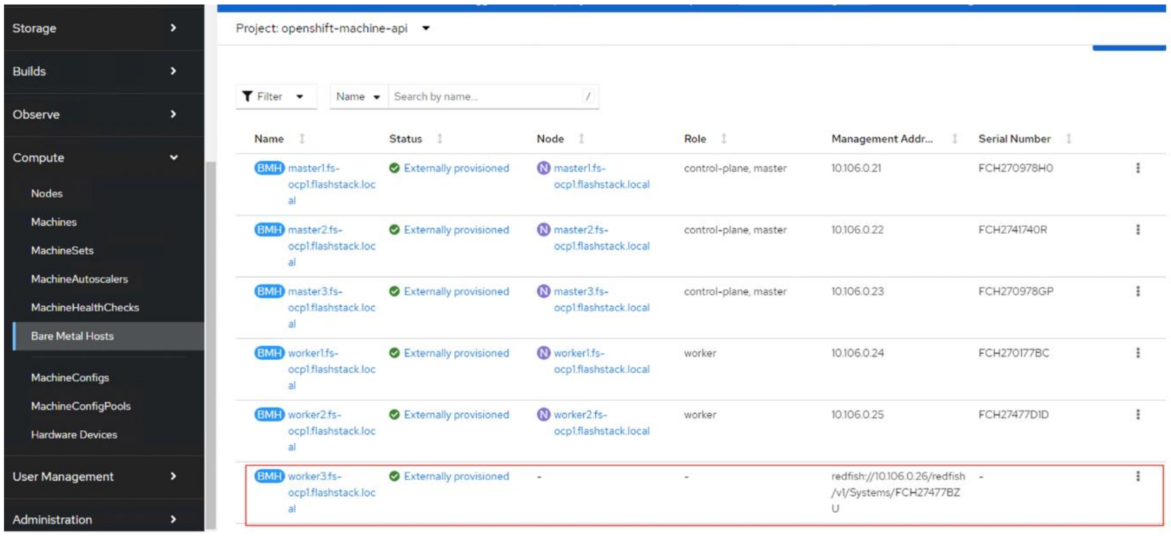
Note: The username and password shown in the above file are base64 encoded values.

Note: In this case, redfish connection is used for connecting to the server. 00:25:B5:A6:0A:0B is the MAC address of eno5 interface, 10.106.0.26 is the OOB management IP and FCH27477BZU is the serial number of the newly added worker node. These values are updated in the table 5. If you would like to use IPMI over LAN instead of redfish, just put the server's out of band management IP for the bmc address field.



```
[root@aa06-rhel9 expandclus]#
[root@aa06-rhel9 expandclus]# oc apply -f bmh-worker3.yaml
secret/ocp-worker3-bmc-secret created
baremetalhost.metal3.io/worker3.fs-ocp1.flashstack.local created
[root@aa06-rhel9 expandclus]#
```

A new entry will be created for the newly added worker node under Compute > Bare Metal Hosts.



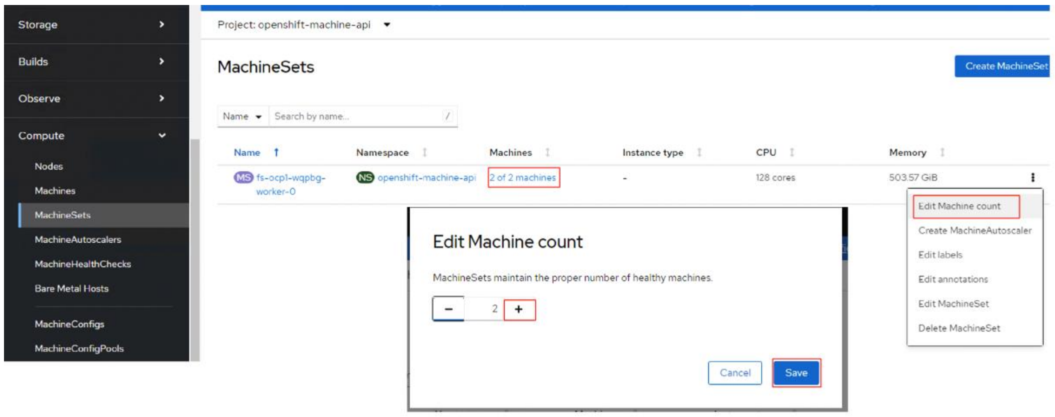
Project: openshift-machine-api

Name	Status	Node	Role	Management Addr...	Serial Number
BMH master1.fs-ocp1.flashstack.local	Externally provisioned	N master1.fs-ocp1.flashstack.local	control-plane, master	10.106.0.21	FCH270978H0
BMH master2.fs-ocp1.flashstack.local	Externally provisioned	N master2.fs-ocp1.flashstack.local	control-plane, master	10.106.0.22	FCH2741740R
BMH master3.fs-ocp1.flashstack.local	Externally provisioned	N master3.fs-ocp1.flashstack.local	control-plane, master	10.106.0.23	FCH270978GP
BMH worker1.fs-ocp1.flashstack.local	Externally provisioned	N worker1.fs-ocp1.flashstack.local	worker	10.106.0.24	FCH270177BC
BMH worker2.fs-ocp1.flashstack.local	Externally provisioned	N worker2.fs-ocp1.flashstack.local	worker	10.106.0.25	FCH27477D1D
BMH worker3.fs-ocp1.flashstack.local	Externally provisioned	-	-	redfish://10.106.0.26/redfish/v1/Systems/FCH27477BZU	-

Note: The node field is not yet populated for this bare metal host as it is not yet logically linked to any OpenShift Machine.

Note: Since there are only two machines (workers) in the cluster, the worker MachineSets count needs to be increased from 2 to 3.

Step 14. To increase the worker's machineset count, go to **Compute** > **MachineSets**. Click the **ellipses** of worker-0 machineset and select **Edit Machine Count** and increase the count from **2** to **3**. Click **Save**.



MachineSets

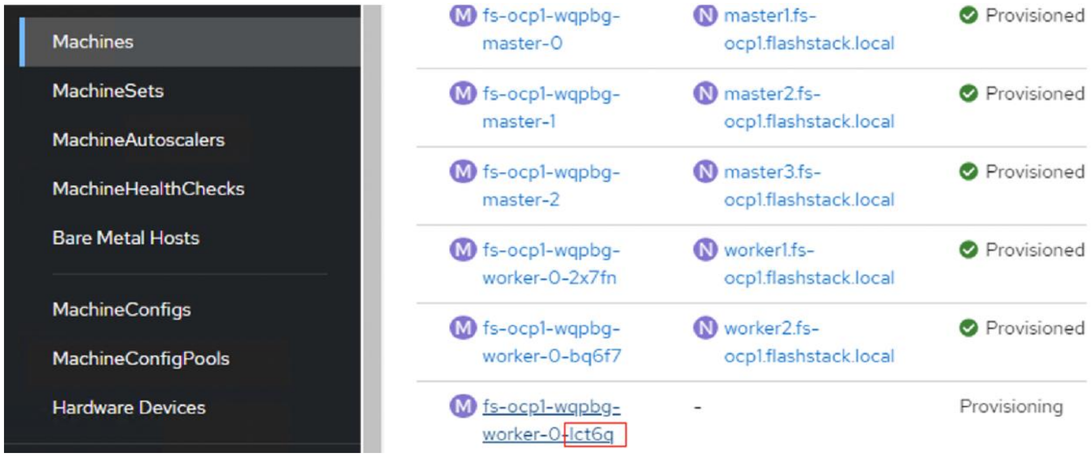
Name	Namespace	Machines	Instance type	CPU	Memory
MS fs-ocp1-wqpbg-worker-0	NS openshift-machine-api	2 of 2 machines	-	128 cores	503.57 GiB

Edit Machine count

MachineSets maintain the proper number of healthy machines.

− 2 +

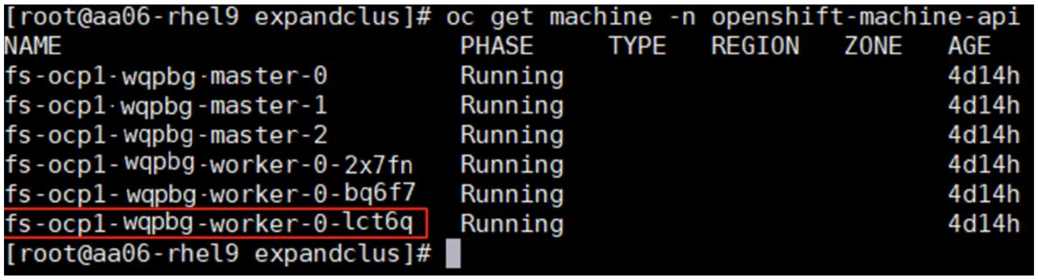
A new worker node will be provisioned to match to the worker machine count of 3. It will be under the provisioning state until the node is logically mapped to the Bare Metal Host.



M fs-ocp1-wqpbg-master-0	N master1.fs-ocp1.flashstack.local	✓ Provisioned
M fs-ocp1-wqpbg-master-1	N master2.fs-ocp1.flashstack.local	✓ Provisioned
M fs-ocp1-wqpbg-master-2	N master3.fs-ocp1.flashstack.local	✓ Provisioned
M fs-ocp1-wqpbg-worker-0-2x7fn	N worker1.fs-ocp1.flashstack.local	✓ Provisioned
M fs-ocp1-wqpbg-worker-0-bq6f7	N worker2.fs-ocp1.flashstack.local	✓ Provisioned
M fs-ocp1-wqpbg-worker-0-lct6q	-	Provisioning

Procedure 2. Link the Machine and Bare Metal Host, Node and Bare Metal Host

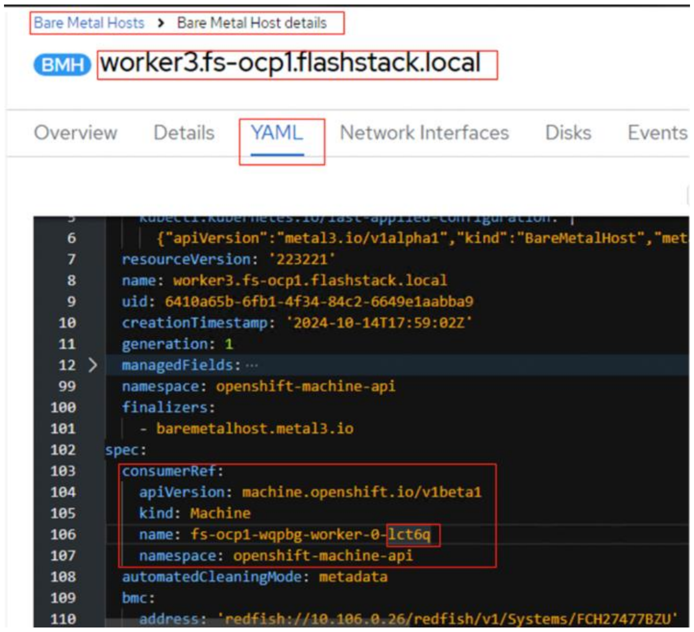
Step 1. To logically link Bare Metal Host to Machine, obtain the name of the newly created machine from its manifest file or by executing **oc get machine -n openshift-machine-api**:



```
[root@aa06-rhel9 expandclus]# oc get machine -n openshift-machine-api
NAME                             PHASE     TYPE   REGION   ZONE   AGE
fs-ocp1-wqpbg-master-0           Running                          4d14h
fs-ocp1-wqpbg-master-1           Running                          4d14h
fs-ocp1-wqpbg-master-2           Running                          4d14h
fs-ocp1-wqpbg-worker-0-2x7fn     Running                          4d14h
fs-ocp1-wqpbg-worker-0-bq6f7     Running                          4d14h
fs-ocp1-wqpbg-worker-0-lct6q     Running                          4d14h
[root@aa06-rhel9 expandclus]#
```

Step 2. Update the machine name in the Bare Metal Host's manifest file under **spec. consumerRef** as shown below. Save the **Yaml** and **reload**:

```
consumerRef:
    apiVersion: machine.openshift.io/v1beta1
    kind: Machine
    name: fs-ocp1-wqpbg-worker-0-lct6q
    namespace: openshift-machine-api
```

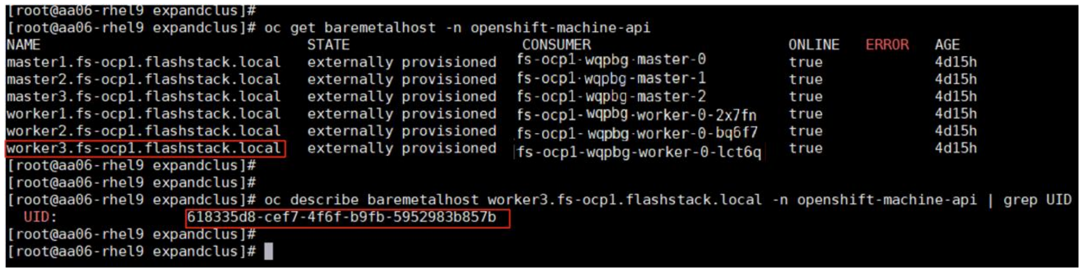

Bare Metal Hosts > Bare Metal Host details
BMH worker3.fs-ocp1.flashstack.local
Overview
Details
YAML
Network Interfaces
Disks
Events

```
    {"apiVersion":"metal3.io/v1alpha1","kind":"BareMetalHost","met
  resourceVersion: '223221'
  name: worker3.fs-ocp1.flashstack.local
  uid: 6410a65b-6fb1-4f34-84c2-6649e1aabba9
  creationTimestamp: '2024-10-14T17:59:02Z'
  generation: 1
  managedFields: ···
  namespace: openshift-machine-api
  finalizers:
    - baremetalhost.metal3.io
spec:
  consumerRef:
    apiVersion: machine.openshift.io/v1beta1
    kind: Machine
    name: fs-ocp1-wqpbg-worker-0-lct6q
    namespace: openshift-machine-api
  automatedCleaningMode: metadata
  bmc:
    address: 'redfish://10.106.0.26/redfish/v1/Systems/FCH27477BZU'
```

After updating the machine name under **Bare Metal Host yaml manifest**, the newly created machine will turn to **Provisioned as node** state from **Provisioning** state.

Note: The Bare Metal Host ProviderID needs to be generated and updated in the newly added worker (worker3.fs-ocp1.flashstack.local).

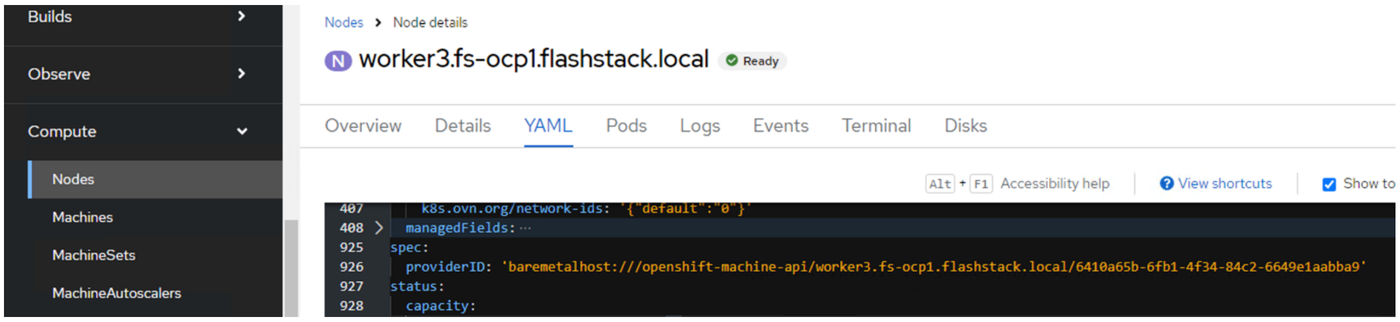
The **ProviderID** is a combination of the name and UUID of the Bare Metal Host and is shown below. These details can be gathered by running providerID: **'baremetalhost:///openshift-machine-api/<Bare Metal Host Name>/<Bare Metal Host UID>.'**



```
[root@aa06-rhel9 expandclus]#
[root@aa06-rhel9 expandclus]# oc get baremetalhost -n openshift-machine-api
NAME                              STATE                  CONSUMER                       ONLINE   ERROR   AGE
master1.fs-ocp1.flashstack.local  externally provisioned  fs-ocp1-wqpbg-master-0        true             4d15h
master2.fs-ocp1.flashstack.local  externally provisioned  fs-ocp1-wqpbg-master-1        true             4d15h
master3.fs-ocp1.flashstack.local  externally provisioned  fs-ocp1-wqpbg-master-2        true             4d15h
worker1.fs-ocp1.flashstack.local  externally provisioned  fs-ocp1-wqpbg-worker-0-2x7fn  true             4d15h
worker2.fs-ocp1.flashstack.local  externally provisioned  fs-ocp1-wqpbg-worker-0-bq6f7  true             4d15h
worker3.fs-ocp1.flashstack.local  externally provisioned  fs-ocp1-wqpbg-worker-0-lct6q  true             4d15h
[root@aa06-rhel9 expandclus]#
[root@aa06-rhel9 expandclus]#
[root@aa06-rhel9 expandclus]# oc describe baremetalhost worker3.fs-ocp1.flashstack.local -n openshift-machine-api | grep UID
  UID:                  618335d8-cef7-4f6f-b9fb-5952983b857b
[root@aa06-rhel9 expandclus]#
[root@aa06-rhel9 expandclus]#
```

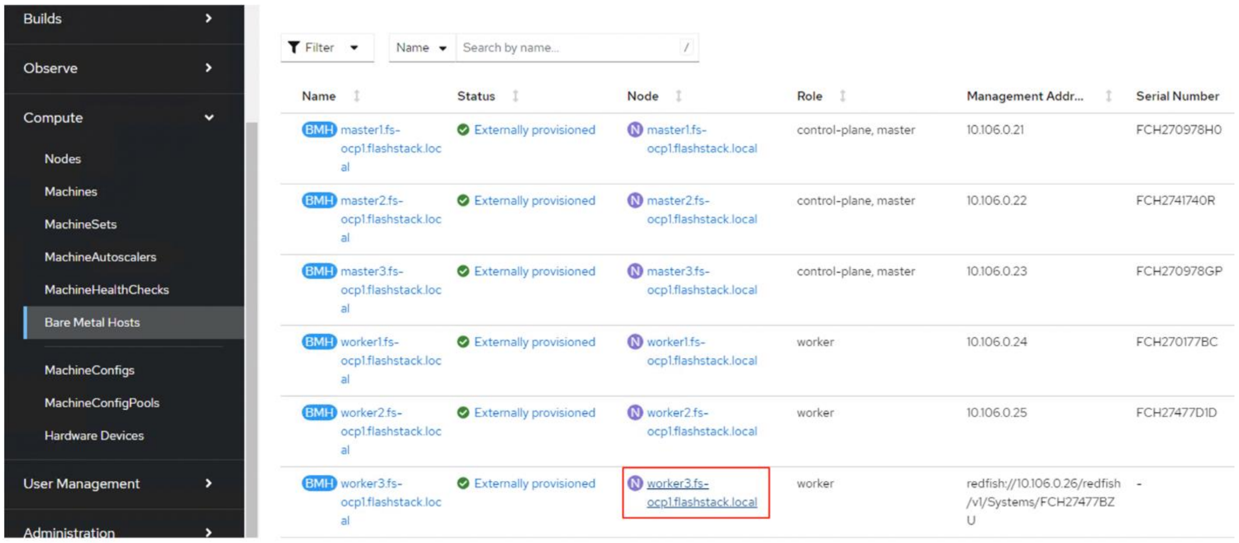
By using the provided information, the providerID for of the newly added Bare Metal Host is built as providerID: **'baremetalhost:///openshift-machine-api/worker3.fs-ocp1.flashstack.local/6410a65b-6fb1-4f34-84c2-6649e1aabba9.'**

Step 3. Copy the **providerID** of the **Bare Metal Host** into the third node yaml manifest file under spec. as shown below:



```
      k8s.ovn.org/network-ids: '{"default":"0"}'
    managedFields: ···
spec:
  providerID: 'baremetalhost:///openshift-machine-api/worker3.fs-ocp1.flashstack.local/6410a65b-6fb1-4f34-84c2-6649e1aabba9'
status:
  capacity:
```

When the providerID of worker3 is updated, the node details are automatically populated for the newly added Bare Metal Host as shown below:



Name	Status	Node	Role	Management Addr...	Serial Number
BMH master1.fs-ocp1.flashstack.local	Externally provisioned	N master1.fs-ocp1.flashstack.local	control-plane, master	10.106.0.21	FCH270978H0
BMH master2.fs-ocp1.flashstack.local	Externally provisioned	N master2.fs-ocp1.flashstack.local	control-plane, master	10.106.0.22	FCH2741740R
BMH master3.fs-ocp1.flashstack.local	Externally provisioned	N master3.fs-ocp1.flashstack.local	control-plane, master	10.106.0.23	FCH270978GP
BMH worker1.fs-ocp1.flashstack.local	Externally provisioned	N worker1.fs-ocp1.flashstack.local	worker	10.106.0.24	FCH270177BC
BMH worker2.fs-ocp1.flashstack.local	Externally provisioned	N worker2.fs-ocp1.flashstack.local	worker	10.106.0.25	FCH27477D1D
BMH worker3.fs-ocp1.flashstack.local	Externally provisioned	N worker3.fs-ocp1.flashstack.local	worker	redfish://10.106.0.26/redfish/v1/Systems/FCH27477BZU	-

Install NVIDIA GPU Operator and Drivers

This chapter contains the following:

- Install NVIDIA GPU Operator
- Enable the GPU Monitoring Dashboard

This chapter provides the procedures to install the required NVIDIA GPU operators, CUDA drivers and so on, to work with NVIDIA GPUs.

Procedure 1. Install NVIDIA GPU Operator

If you have GPUs installed in your Cisco UCS servers, you need to install the Node Feature Discovery (NFD) Operator to detect NVIDIA GPUs and the NVIDIA GPU Operator to make these GPUs available to containers and virtual machines.

Step 1. In the **OpenShift Container Platform web console**, click **Operators** > **OperatorHub**.

Step 2. Type **Node Feature** in the filter box and then click the **Node Feature Discovery Operator with Red Hat** in the upper right corner. Click **Install**.

Step 3. Do not change any settings and click **Install**.

Step 4. When the Install operator is ready for use, click **View Operator**.

Step 5. In the bar to the right of Details, click **NodeFeatureDiscovery**.

Step 6. Click **Create NodeFeatureDiscovery**.

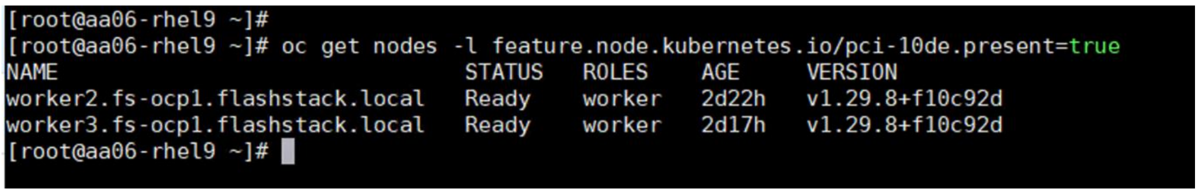
Step 7. Click **Create**.

Step 8. When the nfd-instance has a status of Available, Upgradeable, select **Compute** > **Nodes**.

Step 9. Select a node that has one or more GPUs and then click **Details**.

The label **feature.node.kubernetes.io/pci-10de.present=true** should be present on the host.

This label appears on all nodes with GPUs:



```
[root@aa06-rhel9 ~]#
[root@aa06-rhel9 ~]# oc get nodes -l feature.node.kubernetes.io/pci-10de.present=true
NAME                              STATUS   ROLES    AGE    VERSION
worker2.fs-ocp1.flashstack.local   Ready    worker   2d22h   v1.29.8+f10c92d
worker3.fs-ocp1.flashstack.local   Ready    worker   2d17h   v1.29.8+f10c92d
[root@aa06-rhel9 ~]#
```

Step 10. Go to **Operators** > **OperatorHub**.

Step 11. Type **NVIDIA** in the filter box and then click the **NVIDIA GPU Operator**. Click **Install**.

Step 12. Do not change any settings and click **Install**.

Step 13. When the Install operator is ready for use, click **View Operator**.

Step 14. In the bar to the right of Details, click **ClusterPolicy**.

Step 15. Click Create **ClusterPolicy**.

Step 16. Do not change any settings and scroll down and click **Create**. This will install the latest GPU driver.

Step 17. Wait for the gpu-cluster-policy Status to become Ready.

Step 18. Connect to a terminal window on the OpenShift Installer machine. Type the following commands. The output shown is for two servers that are equipped with GPUs:

```
oc project nvidia-gpu-operator
Already on project "nvidia-gpu-operator" on server "https://api.fs-ocp1.flashstack.local:6443".
oc get pods
NAME                                                  READY   STATUS      RESTARTS        AGE
gpu-feature-discovery-cp9cg                           1/1     Running     0               5m23s
gpu-feature-discovery-gdt7j                           1/1     Running     0               5m14s
gpu-operator-7d8447447-9gnpq                          1/1     Running     0               2m49s
nvidia-container-toolkit-daemonset-4js4p              1/1     Running     0               5m23s
nvidia-container-toolkit-daemonset-wr6gv              1/1     Running     0               5m14s
nvidia-cuda-validator-828rz                           0/1     Completed   0               2m56s
nvidia-dcgm-44zbh                                     1/1     Running     0               5m23s
nvidia-dcgm-exporter-kq7jp                            1/1     Running     2 (3m ago)      5m23s
nvidia-dcgm-exporter-thjlc                            1/1     Running     2 (2m33s ago)   5m14s
nvidia-dcgm-h8mzq                                     1/1     Running     0               5m14s
nvidia-device-plugin-daemonset-pz87g                  1/1     Running     0               5m14s
nvidia-device-plugin-daemonset-x9hrk                  1/1     Running     0               5m23s
nvidia-driver-daemonset-416.94.202410020522-0-6hm42   2/2     Running     0               6m17s
nvidia-driver-daemonset-416.94.202410020522-0-nshpt   2/2     Running     0               6m17s
nvidia-node-status-exporter-hv8xp                     1/1     Running     0               6m16s
nvidia-node-status-exporter-msv56                     1/1     Running     0               6m16s
nvidia-operator-validator-66b4x                       1/1     Running     0               5m14s
nvidia-operator-validator-km9tb                       1/1     Running     0               5m23s
```

Step 19. Connect to one of the nvidia-driver-daemonset containers and view the GPU status:

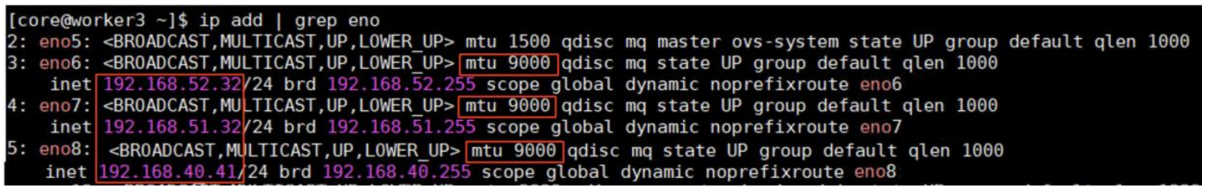
```
oc exec -it nvidia-driver-daemonset-416.94.202410020522-0-6hm42 -- bash
[root@nvidia-driver-daemonset-416 drivers]# nvidia-smi
Mon Nov  4 15:36:49 2024
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 550.127.05             Driver Version: 550.127.05     CUDA Version: 12.4     |
|-----------------------------------------+------------------------+----------------------+
| 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 L40S                    On  |   00000000:3D:00.0 Off |                    0 |
| N/A   28C    P8             35W /  350W |       1MiB /  46068MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+
|   1  NVIDIA L40S                    On  |   00000000:E1:00.0 Off |                    0 |
| N/A   28C    P8             36W /  350W |       1MiB /  46068MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+
+---------------------------------------------------------------------------------------+
| Processes:                                                                            |
|  GPU   GI   CI        PID   Type   Process name                            GPU Memory |
|        ID   ID                                                             Usage      |
|=======================================================================================|
|  No running processes found                                                           |
+---------------------------------------------------------------------------------------+
```

Procedure 2. Enable the GPU Monitoring Dashboard

Step 1. Go to https://docs.nvidia.com/datacenter/cloud-native/openshift/latest/enable-gpu-monitoring-dashboard.html, enable the **GPU Monitoring Dashboard to monitor GPUs in the OpenShift Web-Console**.

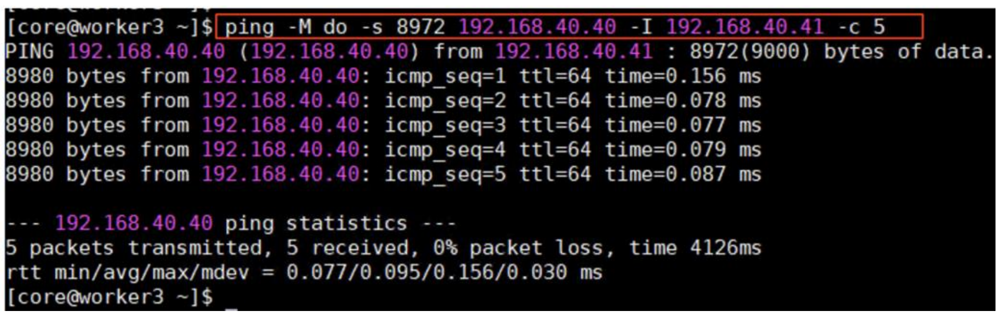
Verify Connectivity from Worker nodes to Pure Storage FlashBlade

Once the OpenShift cluster is up, each worker node will get IP addresses from the corresponding DHCP server scopes and assigned to the storage interfaces (eno6,eno7 and eno8) automatically for worker3 as shown below. The storage Interfaces eno6, eno7 and eno8 configured with corresponding IP addresses and MTU as 9000 as defined in the Intersight vNIC configuration.



```
[core@worker3 ~]$ ip add | grep eno
2: eno5: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc mq master ovs-system state UP group default qlen 1000
3: eno6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 9000 qdisc mq state UP group default qlen 1000
    inet 192.168.52.32/24 brd 192.168.52.255 scope global dynamic noprefixroute eno6
4: eno7: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 9000 qdisc mq state UP group default qlen 1000
    inet 192.168.51.32/24 brd 192.168.51.255 scope global dynamic noprefixroute eno7
5: eno8: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 9000 qdisc mq state UP group default qlen 1000
    inet 192.168.40.41/24 brd 192.168.40.255 scope global dynamic noprefixroute eno8
```

Ensure that each worker node is able to reach the target object storage IP address configured on the FlashBlade//S200 with lager transfer unit and without fragmenting the packet.



```
[core@worker3 ~]$ ping -M do -s 8972 192.168.40.40 -I 192.168.40.41 -c 5
PING 192.168.40.40 (192.168.40.40) from 192.168.40.41 : 8972(9000) bytes of data.
8980 bytes from 192.168.40.40: icmp_seq=1 ttl=64 time=0.156 ms
8980 bytes from 192.168.40.40: icmp_seq=2 ttl=64 time=0.078 ms
8980 bytes from 192.168.40.40: icmp_seq=3 ttl=64 time=0.077 ms
8980 bytes from 192.168.40.40: icmp_seq=4 ttl=64 time=0.079 ms
8980 bytes from 192.168.40.40: icmp_seq=5 ttl=64 time=0.087 ms

--- 192.168.40.40 ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4126ms
rtt min/avg/max/mdev = 0.077/0.095/0.156/0.030 ms
[core@worker3 ~]$ _
```

Install and Configure Portworx Enterprise on OpenShift with Pure Storage FlashArray

This chapter contains the following:

- Storage Architecture
- Prerequisites
- Configure Physical Environment
- Portworx Enterprise Console Plugin for OpenShift

Portworx by Pure Storage is fully integrated with Red Hat OpenShift. Hence you can install and manage Portworx Enterprise from OpenShift web console itself. Portworx Enterprise can be installed with Pure Storage FlashArray as a cloud storage provider. This allows you to store your data on-premises with Pure Storage FlashArray while benefiting from Portworx Enterprise cloud drive features, such as:

- Automatically provisioning block volumes
- Expanding a cluster by adding new drives or expanding existing ones
- Support for PX-Backup and Autopilot

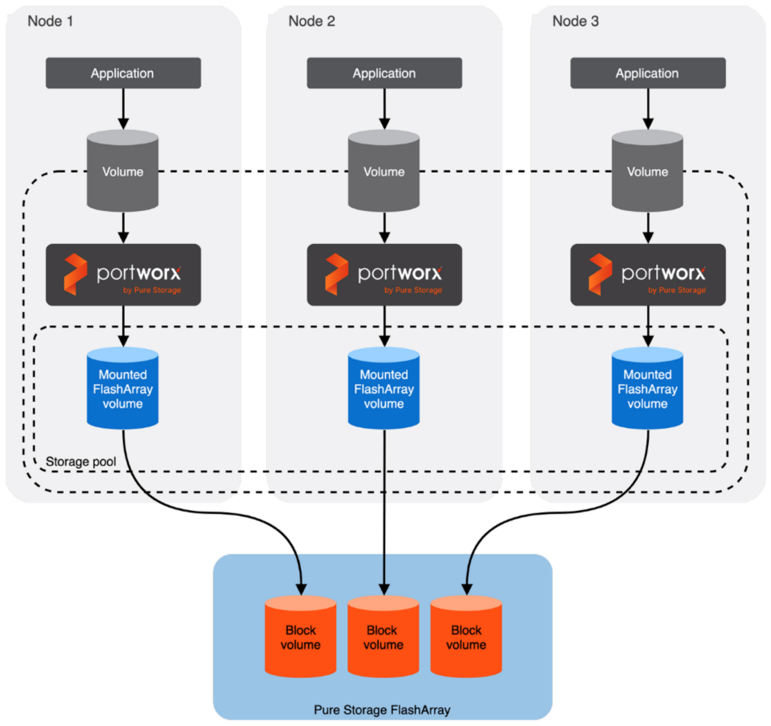
Portworx Enterprise will create and manage the underlying storage pool volumes on the registered arrays.

Note: Pure Storage recommends installing Portworx Enterprise with Pure Storage FlashArray Cloud Drives before using Pure Storage FlashArray Direct Access volumes.

Storage Architecture

This section provides the steps for installing Portworx Enterprise on OpenShift Container Platform running on Cisco UCSX-210C M7 bare metal servers. In this solution, Pure Storage FlashArray//XL170 is used as a backend storage connected over Ethernet to provide required Cloud Drives to be used by Portworx Enterprise. Figure 19 shows the high-level logical storage architecture of Portworx Enterprise deployment on Pure Storage FlashArray.

Figure 19. Portworx Enterprise deployment on OpenShift with Pure Storage FlashArray



This is the high-level summary of the Portworx Enterprise implementation of distributed storage on a typical Kubernetes based Cluster:

- Portworx Enterprise runs on each worker node as Daemonset pod and based on the configuration information provided in the StorageClass spec, Portworx Enterprise provisions one or more volumes on Pure Storage FlashArray for each worker node.
- All these Pure Storage FlashArray volumes are pooled together to form one or more Distributed Storage Pools.
- When a user creates a PVC, Portworx Enterprise provisions the volume from the storage pool.
- The PVCs consume space on the storage pool, and if space begins to run low, Portworx Enterprise can add or expand drive space from Pure Storage FlashArray.
- If a worker node goes down for less than 2 minutes, Portworx Enterprise will reattach Pure Storage FlashArray volumes when it recovers. If a node goes down for more than two minutes, a storageless node in the same zone or fault domain will take up the volumes and assume the identity of the downed storage node.

Prerequisites

These prerequisites must be met before installing the Portworx Enterprise on OpenShift with Pure Storage FlashArray:

- SecureBoot mode option must be disabled.
- The Pure Storage FlashArray should be time-synced with the same time service as the Kubernetes cluster.
- Pure Storage FlashArray must be running a minimum Purity//FA version of at least 4.8. Refer to the Supported models and versions topic for more information.
- Both multipath and iSCSI, if being used, should have their services enabled in systemd so that they start after reboots. These services are already enabled in systemd within the Red Hat CoreOS Linux.

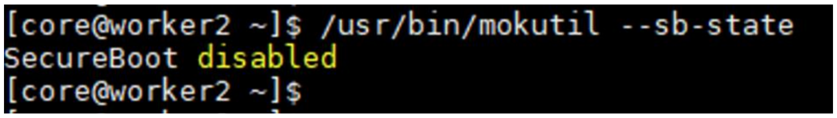
Configure Physical Environment

Before you install Portworx Enterprise, ensure that your physical network is configured appropriately and that you meet the prerequisites. You must provide Portworx Enterprise with your Pure Storage FlashArray configuration details during installation:

- Each Pure Storage FlashArray management IP address can be accessed by each node.
- Your cluster contains an up-and-running Pure Storage FlashArray with an existing data plane connectivity layout (iSCSI, Fibre Channel).
- If you're using iSCSI, the storage node iSCSI initiators are on the same VLAN as the Pure Storage FlashArray iSCSI target ports.
- You have an API token for a user on your Pure Storage FlashArray with at least storage_admin permissions.

Procedure 1. Prepare for the Portworx Enterprise Deployment

Step 1. Secure the boot option already disabled at the Intersight Boot Policy level. To reconfirm at the OS level, SSH into any of the worker node from the installer VM and ensure that SecureBoot mode is disabled at the OS level.



```
[core@worker2 ~]$ /usr/bin/mokutil --sb-state
SecureBoot disabled
[core@worker2 ~]$
```

Step 2. Apply the following MachineConfig to the cluster configures each worker node with the following:

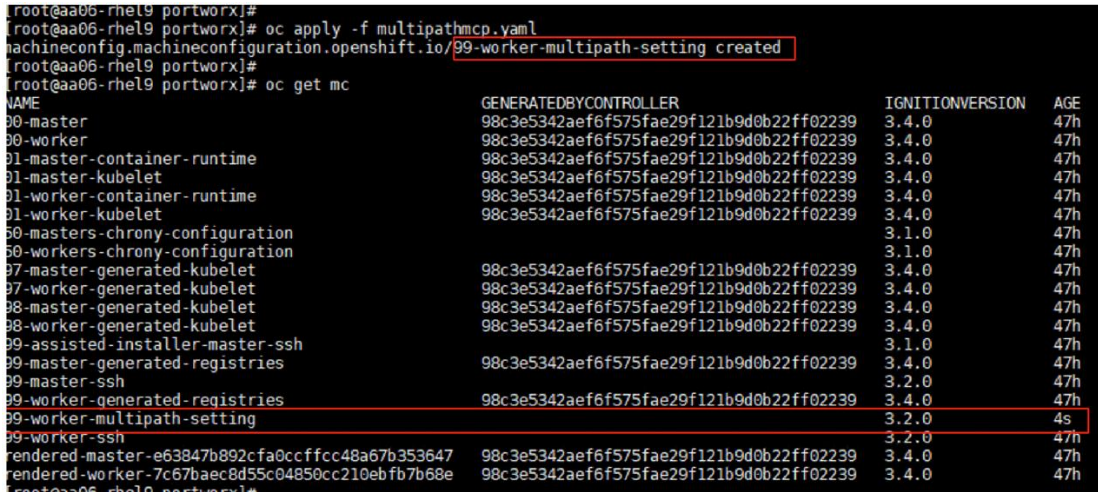
- Enable and start the multipathd.service with the specified multipath.conf configuration file.
- Enable and start the iscsid.service service.
- Applies the Queue Settings with Udev rules.

The settings of multipath and Udev rules are defined as shown below:

```
cat multipath.conf
blacklist {
      devnode "^pxd[0-9]*"
      devnode "^pxd*"
      device {
        vendor "VMware"
        product "Virtual disk"
      }
}
defaults {
 user_friendly_names no
 find_multipaths yes
 polling_interval  10
}
devices {
    device {
        vendor                    "PURE"
        product                   "FlashArray"
        path_selector            "service-time 0"
        hardware_handler         "1 alua"
        path_grouping_policy     group_by_prio
        prio                     alua
        failback                 immediate
        path_checker             tur
        fast_io_fail_tmo         10
        user_friendly_names      no
        no_path_retry            0
        features                 0
        dev_loss_tmo             600
    }
}


cat udevrules.txt
# Recommended settings for Pure Storage FlashArray.
# Use none scheduler for high-performance solid-state storage for SCSI devices
ACTION=="add|change", KERNEL=="sd*[!0-9]", SUBSYSTEM=="block", ENV{ID_VENDOR}=="PURE",
ATTR{queue/scheduler}="none"
ACTION=="add|change", KERNEL=="dm-[0-9]*", SUBSYSTEM=="block", ENV{DM_NAME}=="3624a937*",
ATTR{queue/scheduler}="none"


# Reduce CPU overhead due to entropy collection
ACTION=="add|change", KERNEL=="sd*[!0-9]", SUBSYSTEM=="block", ENV{ID_VENDOR}=="PURE",
ATTR{queue/add_random}="0"
ACTION=="add|change", KERNEL=="dm-[0-9]*", SUBSYSTEM=="block", ENV{DM_NAME}=="3624a937*",
ATTR{queue/add_random}="0"


# Spread CPU load by redirecting completions to originating CPU
ACTION=="add|change", KERNEL=="sd*[!0-9]", SUBSYSTEM=="block", ENV{ID_VENDOR}=="PURE",
ATTR{queue/rq_affinity}="2"
ACTION=="add|change", KERNEL=="dm-[0-9]*", SUBSYSTEM=="block", ENV{DM_NAME}=="3624a937*",
ATTR{queue/rq_affinity}="2"


# Set the HBA timeout to 60 seconds
ACTION=="add|change", KERNEL=="sd*[!0-9]", SUBSYSTEM=="block", ENV{ID_VENDOR}=="PURE",
ATTR{device/timeout}="60"
```

The following is the MachineConfig file that takes the base64 encode results of the previous two files and copies them to the corresponding directory on each worker node. It also enables and starts iscsid and multipathd services:

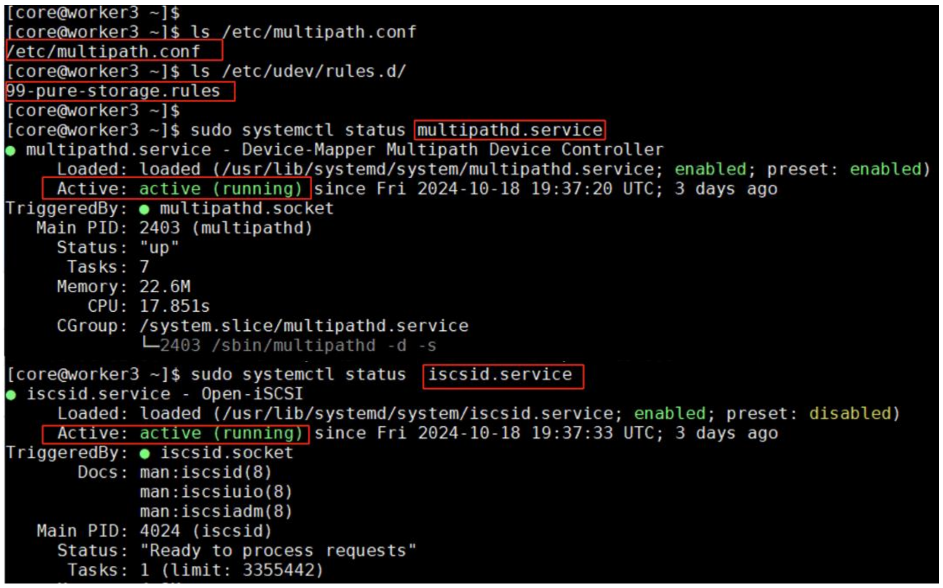
```
cat multipathmcp.yaml
apiVersion: machineconfiguration.openshift.io/v1
kind: MachineConfig
metadata:
  creationTimestamp:
  labels:
    machineconfiguration.openshift.io/role: worker
  name: 99-worker-multipath-setting

spec:

  config:

    ignition:

      version: 3.2.0

    storage:

      files:

      - contents:

          source: data:text/plain;charset=utf-
8;base64,YmxhY2tsaXN0IHsKICAgICAgZGV2bm9kZSAiXnB4ZFswLTldKiIKICAgICAgZGV2bm9kZSAiXnB4ZCoiCiAgICAgIGRldmljZSB
7CiAgICAgICAgdmVuZG9yICJWTXdhcmUiCiAgICAgICAgcHJvZHVjdCAiVmlydHVhbCBkaXNrIgogICAgICB9Cn0KZGVmYXVsdHMgewogdXN
lcl9mcmllbmRseV9uYW1lcyBubwogZmluZF9tdWx0aXBhdGhzIHllcwogcG9sbGluZ19pbnRlcnZhbCAgMTAKfQpkZXZpY2VzIHsKICAgIGR
ldmljZSB7CiAgICAgICAgdmVuZG9yICAgICAgICAgICAgICAgICAgICJQVVJFIgogICAgICAgIHByb2R1Y3QgICAgICAgICAgICAgICAgICA
iRmxhc2hBcnJheSIKICAgICAgICBwYXRoX3NlbGVjdG9yICAgICAgICAgICAgInNlcnZpY2UtdGltZSAwIgogICAgICAgIGhhcmR3YXJlX2h
hbmRsZXIgICAgICAgICAiMSBhbHVhIgogICAgICAgIHBhdGhfZ3JvdXBpbmdfcG9saWN5ICAgICBncm91cF9ieV9wcmlvCiAgICAgICAgcHJ
pbyAgICAgICAgICAgICAgICAgICAgIGFsdWEKICAgICAgICBmYWlsYmFjayAgICAgICAgICAgICAgICAgaW1tZWRpYXRlCiAgICAgICAgcGF
0aF9jaGVja2VyICAgICAgICAgICAgIHR1cgogICAgICAgIGZhc3RfaW9fZmFpbF90bW8gICAgICAxMAogICAgICAgIHVzZXJfZnJpZW5
kbHlfbmFtZXMgICAgICBubwogICAgICAgIG5vX3BhdGhfcmV0cnkgICAgICAgICAwCiAgICAgICAgZmVhdHVyZXMgICAgICAgICAgICA
gICAgIDAKICAgICAgICBkZXZfbG9zc190bW8gICAgICAgICAgNjAwCiAgICB9Cn0K

        filesystem: root

        mode: 0644

        overwrite: true

        path: /etc/multipath.conf

      - contents:

          source: data:text/plain;charset=utf-
8;base64,IyBSZWNvbW1lbmRlZCBzZXR0aW5ncyBmb3IgUHVyZSBTdG9yYWdlIEZsYXNoQXJyYXkuCiMgVXNlIG5vbmUgc2NoZWR1bGVyIGZ
vciBoaWdoLXBlcmZvcm1hbmNlIHNvbGlkLXN0YXRlIHN0b3JhZ2UgZm9yIFNDU0kgZGV2aWNlcwpBQ1RJT049PSJhZGR8Y2hhbmdlIiwgS0V
STkVMPT0ic2QqWyEwLTldIiwgU1VCU1lTVEVNPT0iYmxvY2siLCBFTlZ7SURfVkVORE9SfT09IlBVUkUiLCBBVFRSe3F1ZXVlL3NjaGVkdWx
lcn09Im5vbmUiCkFDVElPTj09ImFkZHxjaGFuZ2UiLCBLRVJORUw9PSJkbS1bMC05XSoiLCBTVUJTWVNURU09PSJibG9jayIsIEVOVntETV9
OQU1FfT09IjM2MjRhOTM3KiIsIEFUVFJ7cXVldWUvc2NoZWR1bGVyfT0ibm9uZSIKCiMgUmVkdWNlIENQVSBvdmVyaGVhZCBkdWUgdG8gZW5
0cm9weSBjb2xsZWN0aW9uCkFDVElPTj09ImFkZHxjaGFuZ2UiLCBLRVJORUw9PSJzZCpbITAtOV0iLCBTVUJTWVNURU09PSJibG9jayIsIEV
OVntJRF9WRU5ET1J9PT0iUFVSRSIsIEFUVFJ7cXVldWUvYWRkX3JhbmRvbX09IjAiCkFDVElPTj09ImFkZHxjaGFuZ2UiLCBLRVJORUw9PSJ
kbS1bMC05XSoiLCBTVUJTWVNURU09PSJibG9jayIsIEVOVntETV9OQU1FfT09IjM2MjRhOTM3KiIsIEFUVFJ7cXVldWUvYWRkX3JhbmRvbX0
9IjAiCgojIFNwcmVhZCBDUFUgbG9hZCBieSByZWRpcmVjdGluZyBjb21wbGV0aW9ucyB0byBvcmlnaW5hdGluZyBDUFUKQUNUSU9OPT0iYWR
kfGNoYW5nZSIsIEtFUk5FTD09InNkKlshMC05XSIsIFNVQlNZU1RFTT09ImJsb2NrIiwgRU5We0lEX1ZFTkRPUn09PSJQVVJFIiwgQVRUUnt
xdWV1ZS9ycV9hZmZpbml0eX09IjIiCkFDVElPTj09ImFkZHxjaGFuZ2UiLCBLRVJORUw9PSJkbS1bMC05XSoiLCBTVUJTWVNURU09PSJibG9
jayIsIEVOVntETV9OQU1FfT09IjM2MjRhOTM3KiIsIEFUVFJ7cXVldWUvcnFfYWZmaW5pdHl9PSIyIgoKIyBTZXQgdGhlIEhCQSB0aW1lb3V
0IHRvIDYwIHNlY29uZHMKQUNUSU9OPT0iYWRkfGNoYW5nZSIsIEtFUk5FTD09InNkKlshMC05XSIsIFNVQlNZU1RFTT09ImJsb2NrIiwgRU5
We0lEX1ZFTkRPUn09PSJQVVJFIiwgQVRUUntkZXZpY2UvdGltZW91dH09IjYwIgo=

        filesystem: root

        mode: 0644

        overwrite: true

        path: /etc/udev/rules.d/99-pure-storage.rules

    systemd:

      units:

      - enabled: true

        name: iscsid.service

      - enabled: true

        name: multipathd.service
```



```
[root@aa06-rhel9 portworx]#
[root@aa06-rhel9 portworx]# oc apply -f multipathmcp.yaml
machineconfig.machineconfiguration.openshift.io/99-worker-multipath-setting created
[root@aa06-rhel9 portworx]#
[root@aa06-rhel9 portworx]# oc get mc
NAME                                               GENERATEDBYCONTROLLER                      IGNITIONVERSION   AGE
00-master                                          98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
00-worker                                          98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
01-master-container-runtime                        98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
01-master-kubelet                                  98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
01-worker-container-runtime                        98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
01-worker-kubelet                                  98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
50-masters-chrony-configuration                                                               3.1.0             47h
50-workers-chrony-configuration                                                               3.1.0             47h
97-master-generated-kubelet                        98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
97-worker-generated-kubelet                        98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
98-master-generated-kubelet                        98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
98-worker-generated-kubelet                        98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
99-assisted-installer-master-ssh                                                              3.1.0             47h
99-master-generated-registries                     98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
99-master-ssh                                                                                 3.2.0             47h
99-worker-generated-registries                     98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
99-worker-multipath-setting                                                                   3.2.0             4s
99-worker-ssh                                                                                 3.2.0             47h
rendered-master-e63847b892cfa0ccffcc48a67b353647   98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
rendered-worker-7c67baec8d55c04850cc210ebfb7b68e   98c3e5342aef6f575fae29f121b9d0b22ff02239   3.4.0             47h
```

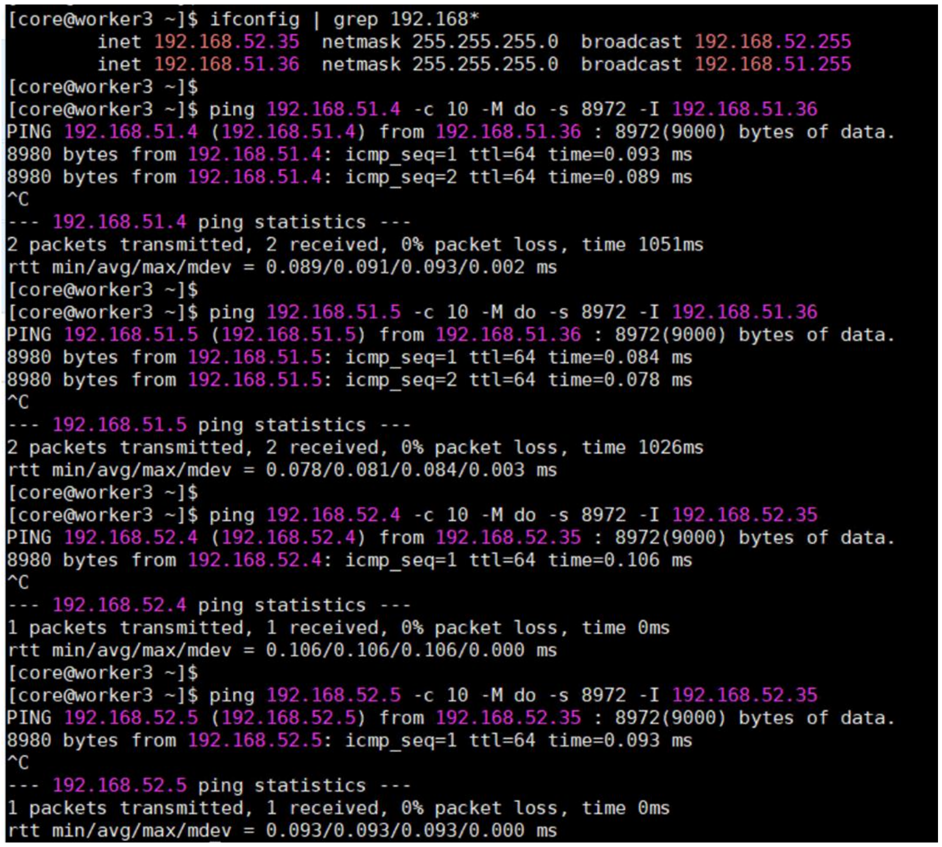
Step 3. This machine config is applied to each worker node one by one. To view the status of this process, from the cluster console go to **Administration** > **Cluster Settings**.

Step 4. After the MachineConfig is applied on all the worker nodes, ssh into one of the worker nodes and verify:



```
[core@worker3 ~]$
[core@worker3 ~]$ ls /etc/multipath.conf
/etc/multipath.conf
[core@worker3 ~]$ ls /etc/udev/rules.d/
99-pure-storage.rules
[core@worker3 ~]$
[core@worker3 ~]$ sudo systemctl status multipathd.service
● multipathd.service - Device-Mapper Multipath Device Controller
     Loaded: loaded (/usr/lib/systemd/system/multipathd.service; enabled; preset: enabled)
     Active: active (running) since Fri 2024-10-18 19:37:20 UTC; 3 days ago
TriggeredBy: ● multipathd.socket
   Main PID: 2403 (multipathd)
     Status: "up"
      Tasks: 7
     Memory: 22.6M
        CPU: 17.851s
     CGroup: /system.slice/multipathd.service
             └─2403 /sbin/multipathd -d -s

[core@worker3 ~]$ sudo systemctl status  iscsid.service
● iscsid.service - Open-iSCSI
     Loaded: loaded (/usr/lib/systemd/system/iscsid.service; enabled; preset: disabled)
     Active: active (running) since Fri 2024-10-18 19:37:33 UTC; 3 days ago
TriggeredBy: ● iscsid.socket
       Docs: man:iscsid(8)
             man:iscsiuio(8)
             man:iscsiadm(8)
   Main PID: 4024 (iscsid)
     Status: "Ready to process requests"
      Tasks: 1 (limit: 3355442)
```

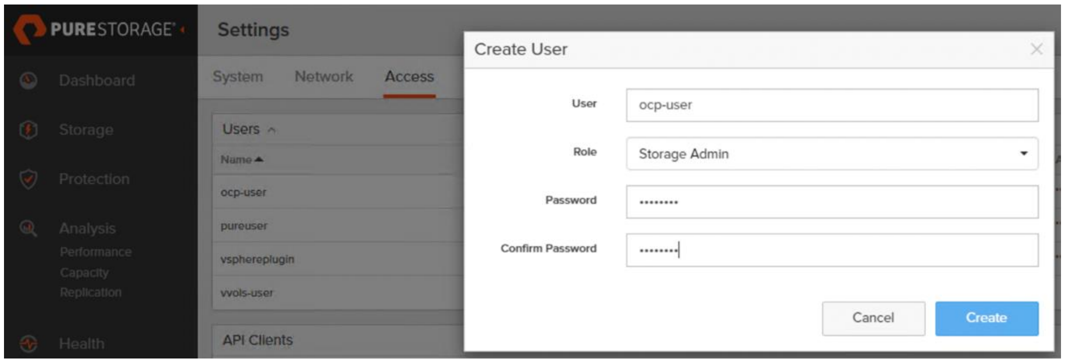
Step 5. From each worker node, ensure the Pure Storage FlashArray storage IPs are reachable with large packet size (8972) and without fragmenting the packets:



```
[core@worker3 ~]$ ifconfig | grep 192.168*
        inet 192.168.52.35  netmask 255.255.255.0  broadcast 192.168.52.255
        inet 192.168.51.36  netmask 255.255.255.0  broadcast 192.168.51.255
[core@worker3 ~]$
[core@worker3 ~]$ ping 192.168.51.4 -c 10 -M do -s 8972 -I 192.168.51.36
PING 192.168.51.4 (192.168.51.4) from 192.168.51.36 : 8972(9000) bytes of data.
8980 bytes from 192.168.51.4: icmp_seq=1 ttl=64 time=0.093 ms
8980 bytes from 192.168.51.4: icmp_seq=2 ttl=64 time=0.089 ms
^C
--- 192.168.51.4 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1051ms
rtt min/avg/max/mdev = 0.089/0.091/0.093/0.002 ms
[core@worker3 ~]$
[core@worker3 ~]$ ping 192.168.51.5 -c 10 -M do -s 8972 -I 192.168.51.36
PING 192.168.51.5 (192.168.51.5) from 192.168.51.36 : 8972(9000) bytes of data.
8980 bytes from 192.168.51.5: icmp_seq=1 ttl=64 time=0.084 ms
8980 bytes from 192.168.51.5: icmp_seq=2 ttl=64 time=0.078 ms
^C
--- 192.168.51.5 ping statistics ---
2 packets transmitted, 2 received, 0% packet loss, time 1026ms
rtt min/avg/max/mdev = 0.078/0.081/0.084/0.003 ms
[core@worker3 ~]$
[core@worker3 ~]$ ping 192.168.52.4 -c 10 -M do -s 8972 -I 192.168.52.35
PING 192.168.52.4 (192.168.52.4) from 192.168.52.35 : 8972(9000) bytes of data.
8980 bytes from 192.168.52.4: icmp_seq=1 ttl=64 time=0.106 ms
^C
--- 192.168.52.4 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.106/0.106/0.106/0.000 ms
[core@worker3 ~]$
[core@worker3 ~]$ ping 192.168.52.5 -c 10 -M do -s 8972 -I 192.168.52.35
PING 192.168.52.5 (192.168.52.5) from 192.168.52.35 : 8972(9000) bytes of data.
8980 bytes from 192.168.52.5: icmp_seq=1 ttl=64 time=0.093 ms
^C
--- 192.168.52.5 ping statistics ---
1 packets transmitted, 1 received, 0% packet loss, time 0ms
rtt min/avg/max/mdev = 0.093/0.093/0.093/0.000 ms
```

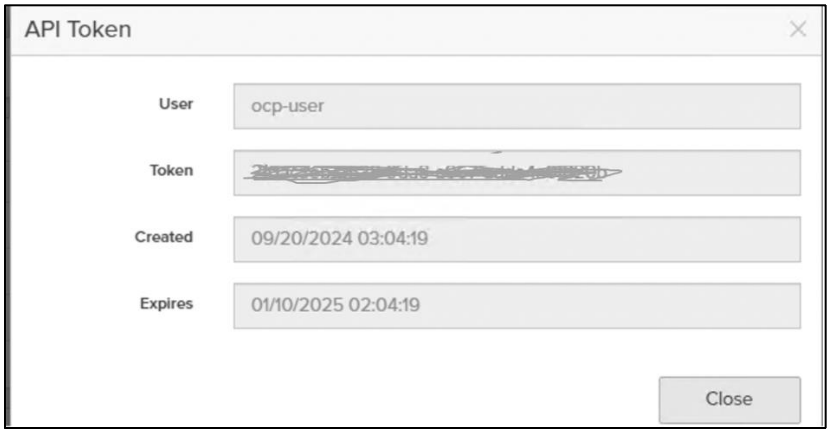
Step 6. Create Kubernetes secret object constituting the Pure Storage FlashArray API endpoints and API Tokens that Portworx Enterprise needs to communicate with and manage the Pure Storage FlashArray storage device.

Step 7. Log into **Pure Storage FlashArray** and go to **Settings** > **Users and Polices**. Create a dedicated user (for instance ocp-user) with storage Admin role for Portworx Enterprise authentication.



User	ocp-user
Role	Storage Admin
Password	••••••••
Confirm Password	••••••••

Step 8. Click the **ellipses** of the user previously created and select **Create API Token.** In the **Create API Token** wizard, set the number of weeks (for instance 24) for the API key to expire and click **Create.** A new API Token for the ocp-user will be created and will display. Copy the **API key** and preserve it since it will be used later to create Kubernetes Secret.


API Token

User: ocp-user

Token: [redacted]

Created: 09/20/2024 03:04:19

Expires: 01/10/2025 02:04:19

Step 9. Create **Kubernetes secret** with the API key (located above) using the following manifest:

```
## Create a json file constituting FlashArray Management IP addresses and API key created in the above step.


cat pure.json
{
  "FlashArrays": [
    {
      "MgmtEndPoint": "10.103.0.55",
      "APIToken": "< your API KEY >"
    }
  ]
}


## secret name must match with below name
kubectl create secret generic px-pure-secret --namespace px --from-file=pure.json
```

Note: If multiple arrays configured with Availability Zones labels (AZs) are available, then you can use these AZ topology labels and enter those into pure.json to distinguish the arrays. For more details, go to: https://docs.portworx.com/portworx-enterprise/operations/operate-kubernetes/cluster-topology/csi-topology

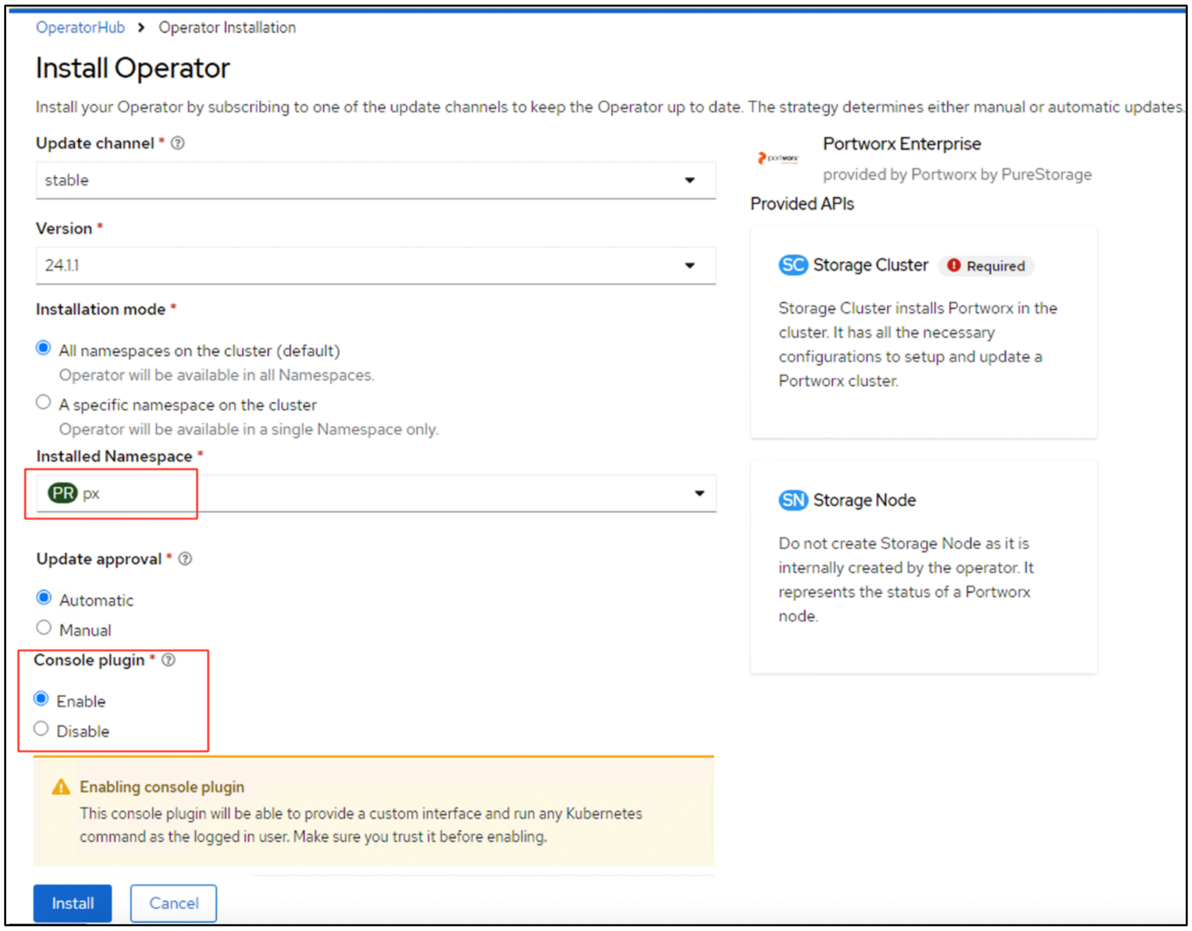
Procedure 2. Deploy Portworx Enterprise

Step 1. Log into the **OpenShift cluster console** using the kubeadmin account and go to **Operators** > **OperatorHub**.

Step 2. In the right pane, enter **Portworx Enterprise** to filter the available operators in the Operator Hub. Select **Portworx Enterprise** and click **Install.**

Step 3. In the **Operator Installation** window, from the **Installed Namespace** drop-down list, select **Create Project** and create a **new project** (for instance px) and select the newly created project to install the Portworx Operator.

Step 4. Install the **Portworx plugin** for **OpenShift** by clicking **Enable** under the Console Plugin. Click **Install.**


OperatorHub > Operator Installation

Install Operator

Install your Operator by subscribing to one of the update channels to keep the Operator up to date. The strategy determines either manual or automatic updates.

Update channel *: stable

Version *: 24.1.1

Installation mode *: [✓ All namespaces on the cluster (default)] — Operator will be available in all Namespaces. / A specific namespace on the cluster — Operator will be available in a single Namespace only.

Installed Namespace *: PR px

Update approval *: [✓ Automatic] / Manual

Console plugin *: [✓ Enable] / Disable

Enabling console plugin

This console plugin will be able to provide a custom interface and run any Kubernetes command as the logged in user. Make sure you trust it before enabling.

Portworx Enterprise

provided by Portworx by PureStorage

Provided APIs

SC Storage Cluster — Required

Storage Cluster installs Portworx in the cluster. It has all the necessary configurations to setup and update a Portworx cluster.

SN Storage Node

Do not create Storage Node as it is internally created by the operator. It represents the status of a Portworx node.

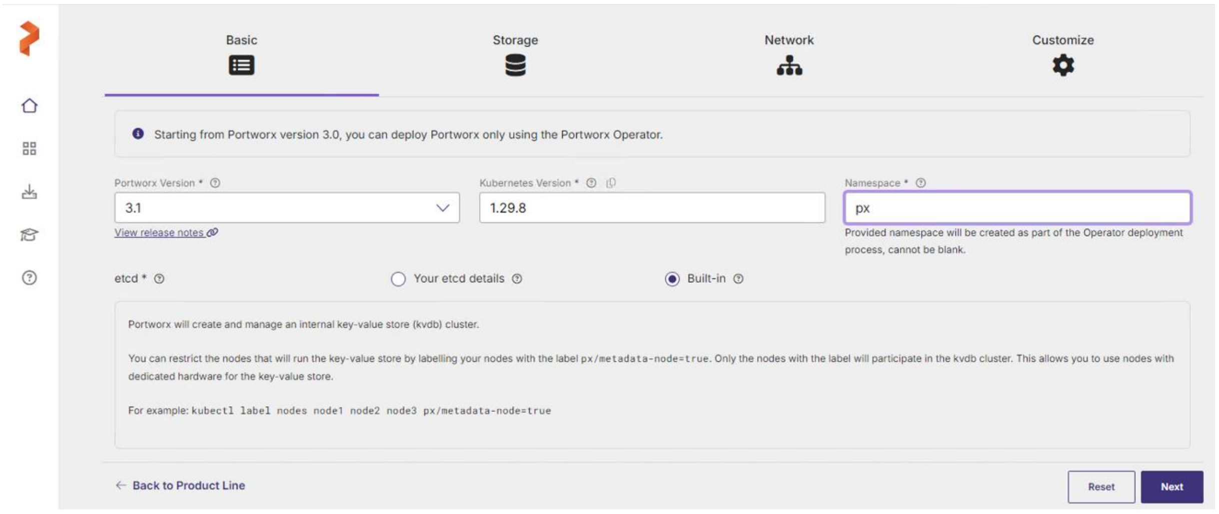
Note: The Portworx Console Plugin for OpenShift will be activated and shown only after installing the StorageCluster. Follow the below steps to create Portworx StorageCluster.

Step 5. When the Portworx operator is successfully installed, the **StorageCluster** needs to be created. To create the **StorageCluster Specifications** (manifest file) log into https://central.portworx.com/ and use your credentials and click **Get Started**.

Step 6. Select **Portworx Enterprise** and click **Continue**.

Step 7. From the **Generate Spec** page, select the latest **Portworx version** (version 3.1 was the latest when this solution was validated). Select **Pure Storage FlashArray** as the platform. Select **OpenShift 4+** for the **Distribution** drop-down list, provide **px** for the Namespace field. Click **Customize**.

Step 8. Get the Kubernetes version by running **kubectl version | grep -i 'Server Version'**. Click **Next**.


Basic
Storage
Network
Customize

Starting from Portworx version 3.0, you can deploy Portworx only using the Portworx Operator.

Portworx Version * : 3.1
View release notes
Kubernetes Version * : 1.29.8
Namespace * : px
Provided namespace will be created as part of the Operator deployment process, cannot be blank.

etcd * : ( ) Your etcd details [✓ Built-in]

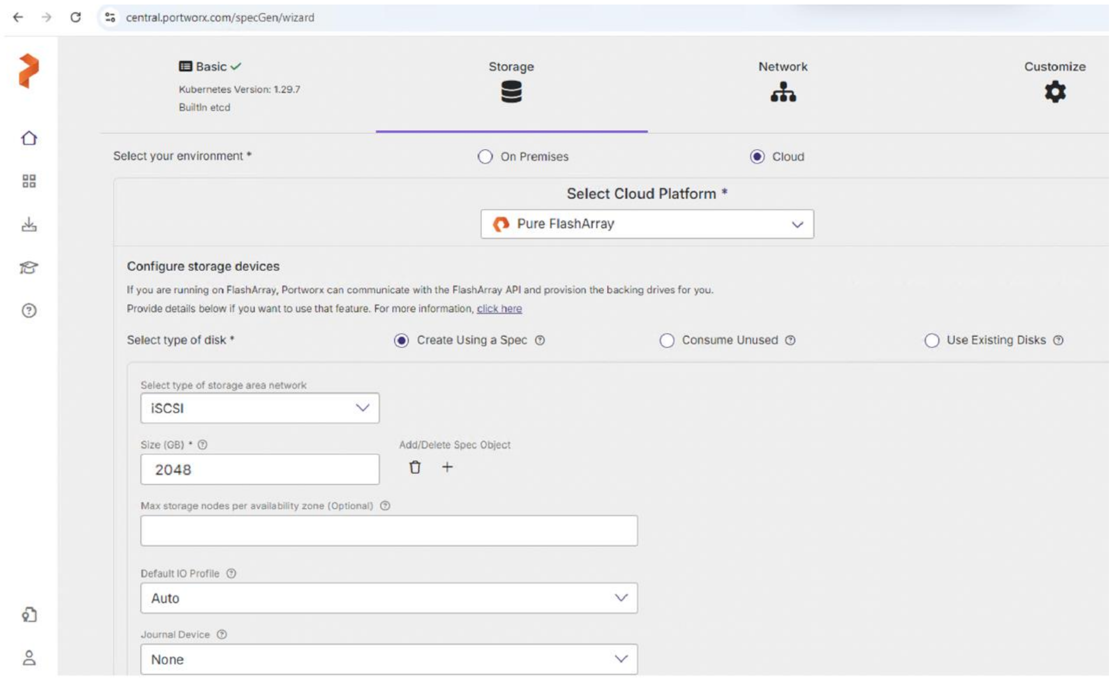
Portworx will create and manage an internal key-value store (kvdb) cluster.

You can restrict the nodes that will run the key-value store by labelling your nodes with the label `px/metadata-node=true`. Only the nodes with the label will participate in the kvdb cluster. This allows you to use nodes with dedicated hardware for the key-value store.

For example: `kubectl label nodes node1 node2 node3 px/metadata-node=true`

← Back to Product Line
Reset
Next

Step 9. From the **Storage tab**, select **iSCSI** for Storage Area Network. Provide the size of the Cloud drive and click plus (**+**) to add additional disks. Click **Next.**


central.portworx.com/specGen/wizard

Basic ✓
Kubernetes Version: 1.29.7
Builtin etcd
Storage
Network
Customize

Select your environment * : ( ) On Premises [✓ Cloud]

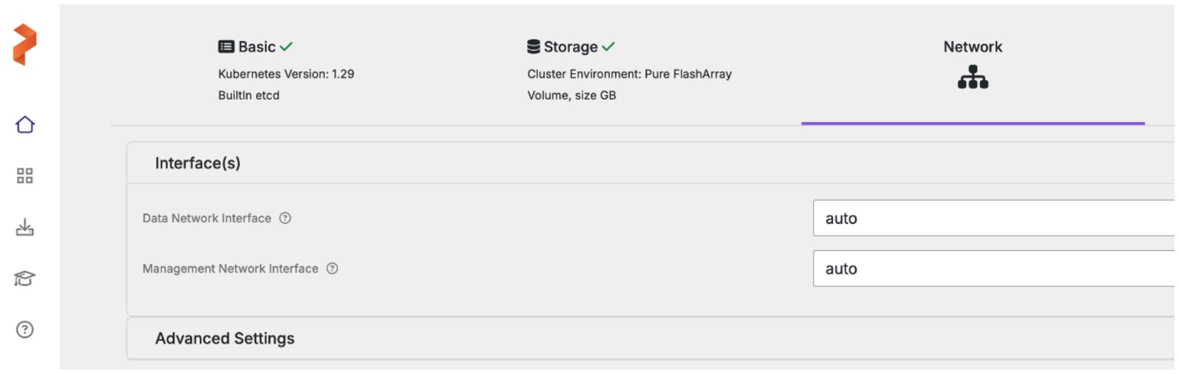
Select Cloud Platform * : Pure FlashArray

Configure storage devices
If you are running on FlashArray, Portworx can communicate with the FlashArray API and provision the backing drives for you.
Provide details below if you want to use that feature. For more information, click here

Select type of disk * : [✓ Create Using a Spec] ( ) Consume Unused ( ) Use Existing Disks

Select type of storage area network: iSCSI
Size (GB) * : 2048
Add/Delete Spec Object
Max storage nodes per availability zone (Optional):
Default IO Profile: Auto
Journal Device: None

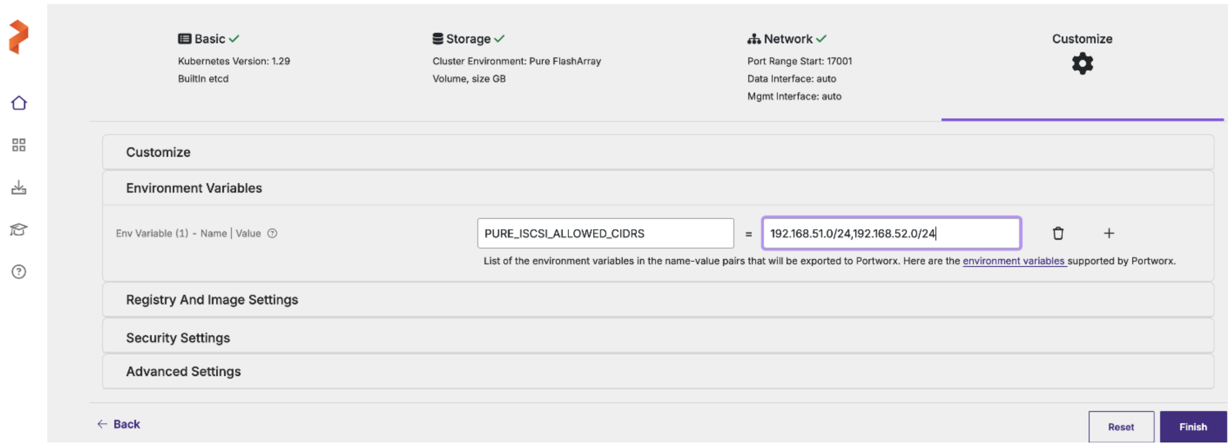
Step 10. From the **Network** tab, set **Auto** for both **Data** and **Management Network Interfaces**. Click **Next.**


Basic ✓
Kubernetes Version: 1.29
Builtin etcd
Storage ✓
Cluster Environment: Pure FlashArray
Volume, size GB
Network

Interface(s)
Data Network Interface: auto
Management Network Interface: auto

Advanced Settings

Step 11. From the **Customize tab**, click **Auto** for both **Data** and **Management Network Interfaces**. Click **Next**.

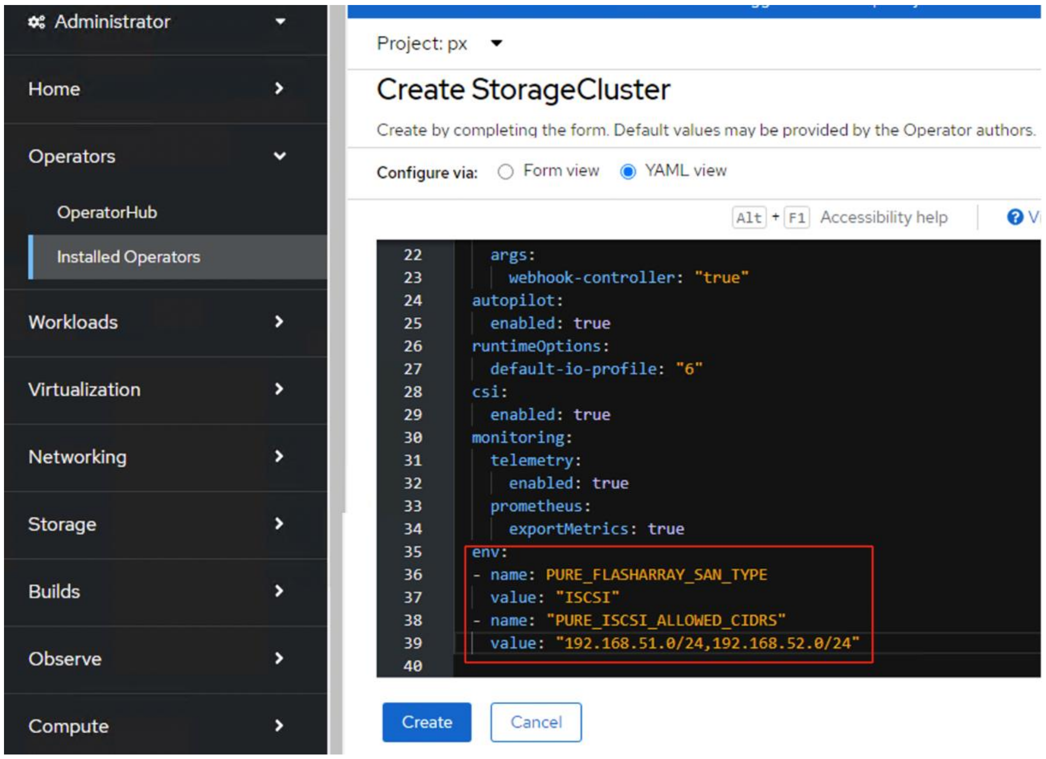


Note: Ensure to enter both the iSCSI network subnets. This enables the iSCSI volumes on the workers nodes to leverage all the available data paths to access target volumes.

Step 12. Click **Advanced Settings**, enter the **name** of the portworx cluster (for instance, ocp-pxclus). Click **Finish**. Click **Download.yaml** to download the StorageCluster specification file.

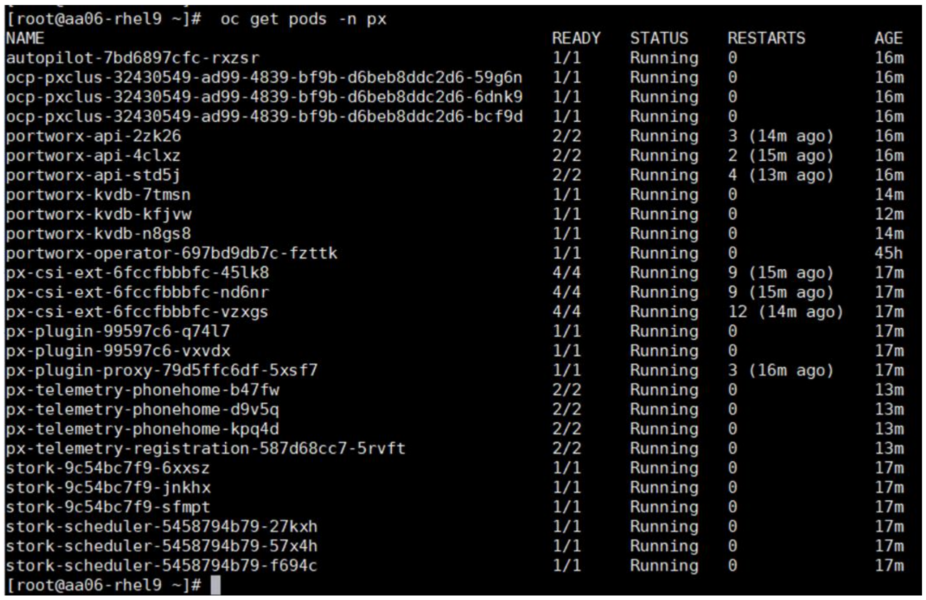
Step 13. From the **OpenShift console**, go to **Operators** > **Installed Operators** > **Portworx Enterprise**. Click the **StorageCluster tab** and click **Create Storage Cluster** to create StorageCluster. This opens the YAML view of Storage Cluster.

Step 14. Copy the contents of the spec file previously downloaded and paste it in the yaml body. Verify that both the iSCSI subnet networks are listed under env: as shown below. Click **Create** to create the StorageCluster.



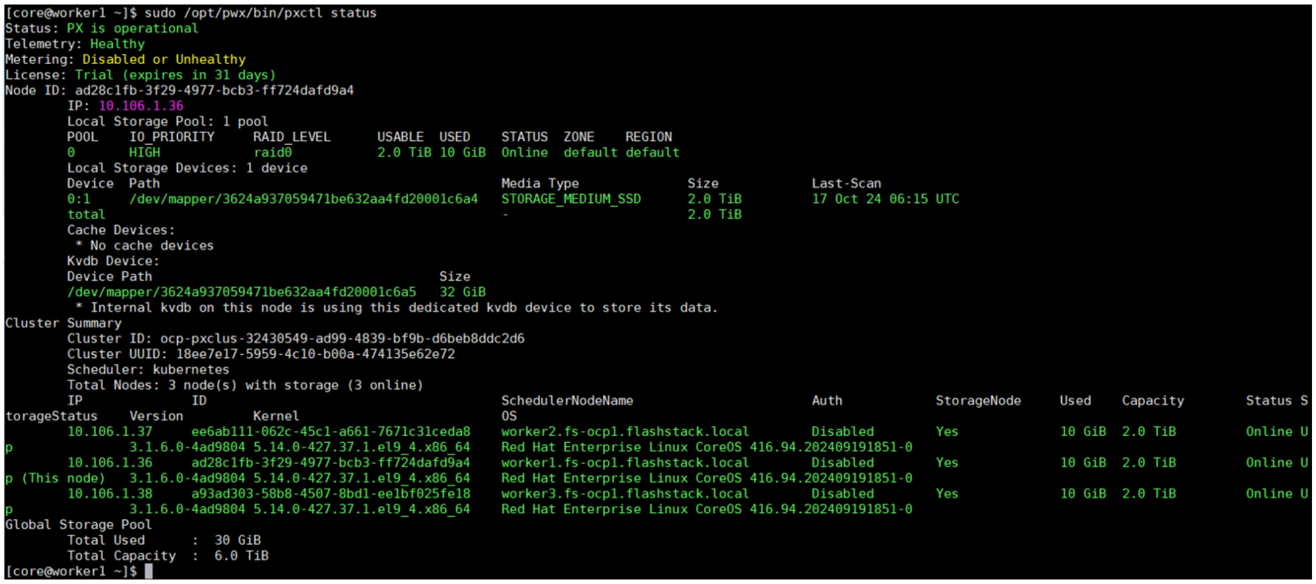
```
    args:
      webhook-controller: "true"
  autopilot:
    enabled: true
  runtimeOptions:
    default-io-profile: "6"
  csi:
    enabled: true
  monitoring:
    telemetry:
      enabled: true
    prometheus:
      exportMetrics: true
  env:
  - name: PURE_FLASHARRAY_SAN_TYPE
    value: "ISCSI"
  - name: "PURE_ISCSI_ALLOWED_CIDRS"
    value: "192.168.51.0/24,192.168.52.0/24"
```

Step 15. Wait until all Portworx related pods are online.



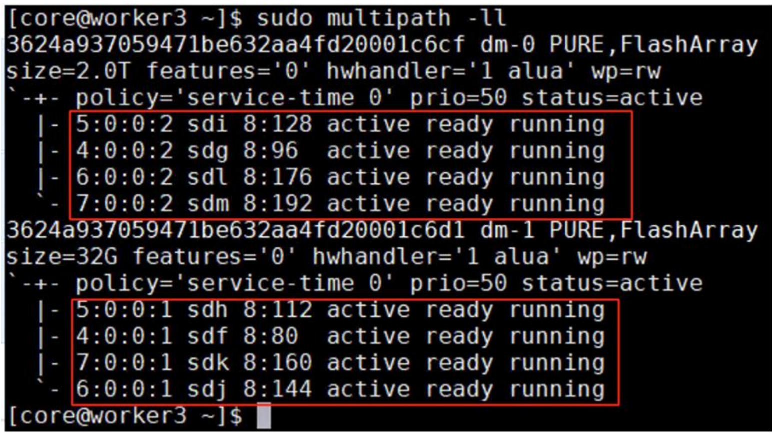
```
[root@aa06-rhel9 ~]#  oc get pods -n px
NAME                                                    READY   STATUS    RESTARTS       AGE
autopilot-7bd6897cfc-rxzsr                              1/1     Running   0              16m
ocp-pxclus-32430549-ad99-4839-bf9b-d6beb8ddc2d6-59g6n   1/1     Running   0              16m
ocp-pxclus-32430549-ad99-4839-bf9b-d6beb8ddc2d6-6dnk9   1/1     Running   0              16m
ocp-pxclus-32430549-ad99-4839-bf9b-d6beb8ddc2d6-bcf9d   1/1     Running   0              16m
portworx-api-2zk26                                      2/2     Running   3 (14m ago)    16m
portworx-api-4clxz                                      2/2     Running   2 (15m ago)    16m
portworx-api-std5j                                      2/2     Running   4 (13m ago)    16m
portworx-kvdb-7tmsn                                     1/1     Running   0              14m
portworx-kvdb-kfjvw                                     1/1     Running   0              12m
portworx-kvdb-n8gs8                                     1/1     Running   0              14m
portworx-operator-697bd9db7c-fzttk                      1/1     Running   0              45h
px-csi-ext-6fccfbbbfc-45lk8                             4/4     Running   9 (15m ago)    17m
px-csi-ext-6fccfbbbfc-nd6nr                             4/4     Running   9 (15m ago)    17m
px-csi-ext-6fccfbbbfc-vzxgs                             4/4     Running   12 (14m ago)   17m
px-plugin-99597c6-q74l7                                 1/1     Running   0              17m
px-plugin-99597c6-vxvdx                                 1/1     Running   0              17m
px-plugin-proxy-79d5ffc6df-5xsf7                        1/1     Running   3 (16m ago)    17m
px-telemetry-phonehome-b47fw                            2/2     Running   0              13m
px-telemetry-phonehome-d9v5q                            2/2     Running   0              13m
px-telemetry-phonehome-kpq4d                            2/2     Running   0              13m
px-telemetry-registration-587d68cc7-5rvft               2/2     Running   0              13m
stork-9c54bc7f9-6xxsz                                   1/1     Running   0              17m
stork-9c54bc7f9-jnkhx                                   1/1     Running   0              17m
stork-9c54bc7f9-sfmpt                                   1/1     Running   0              17m
stork-scheduler-5458794b79-27kxh                        1/1     Running   0              17m
stork-scheduler-5458794b79-57x4h                        1/1     Running   0              17m
stork-scheduler-5458794b79-f694c                        1/1     Running   0              17m
[root@aa06-rhel9 ~]#
```

Step 16. Verify the cluster status by running the command on any worker node: **sudo /opt/pwx/bin/pxctl status**.



```
[core@worker1 ~]$ sudo /opt/pwx/bin/pxctl status
Status: PX is operational
Telemetry: Healthy
Metering: Disabled or Unhealthy
License: Trial (expires in 31 days)
Node ID: ad28c1fb-3f29-4977-bcb3-ff724dafd9a4
        IP: 10.106.1.36
        Local Storage Pool: 1 pool
        POOL    IO_PRIORITY     RAID_LEVEL      USABLE  USED    STATUS  ZONE    REGION
        0       HIGH            raid0           2.0 TiB 10 GiB  Online  default default
        Local Storage Devices: 1 device
        Device  Path                                            Media Type              Size            Last-Scan
        0:1     /dev/mapper/3624a937059471be632aa4fd20001c6a4   STORAGE_MEDIUM_SSD      2.0 TiB         17 Oct 24 06:15 UTC
        total                                                   -                       2.0 TiB
        Cache Devices:
         * No cache devices
        Kvdb Device:
        Device Path                                     Size
        /dev/mapper/3624a937059471be632aa4fd20001c6a5   32 GiB
         * Internal kvdb on this node is using this dedicated kvdb device to store its data.
Cluster Summary
        Cluster ID: ocp-pxclus-32430549-ad99-4839-bf9b-d6beb8ddc2d6
        Cluster UUID: 18ee7e17-5959-4c10-b00a-474135e62e72
        Scheduler: kubernetes
        Total Nodes: 3 node(s) with storage (3 online)
        IP              ID                                      SchedulerNodeName                       Auth            StorageNode     Used    Capacity        Status S
torageStatus    Version         Kernel                          OS
        10.106.1.37     ee6ab111-062c-45c1-a661-7671c31ceda8    worker2.fs-ocp1.flashstack.local        Disabled        Yes             10 GiB  2.0 TiB         Online U
p               3.1.6.0-4ad9804 5.14.0-427.37.1.el9_4.x86_64    Red Hat Enterprise Linux CoreOS 416.94.202409191851-0
        10.106.1.36     ad28c1fb-3f29-4977-bcb3-ff724dafd9a4    worker1.fs-ocp1.flashstack.local        Disabled        Yes             10 GiB  2.0 TiB         Online U
p (This node)   3.1.6.0-4ad9804 5.14.0-427.37.1.el9_4.x86_64    Red Hat Enterprise Linux CoreOS 416.94.202409191851-0
        10.106.1.38     a93ad303-58b8-4507-8bd1-ee1bf025fe18    worker3.fs-ocp1.flashstack.local        Disabled        Yes             10 GiB  2.0 TiB         Online U
p               3.1.6.0-4ad9804 5.14.0-427.37.1.el9_4.x86_64    Red Hat Enterprise Linux CoreOS 416.94.202409191851-0
Global Storage Pool
        Total Used      :  30 GiB
        Total Capacity  :  6.0 TiB
[core@worker1 ~]$
```

Step 17. Run the **sudo multipath -ll** command on one of the worker nodes to verify all four paths from the worker node to storage target are being used. As shown below, there are four active running paths for each volume:



```
[core@worker3 ~]$ sudo multipath -ll
3624a937059471be632aa4fd20001c6cf dm-0 PURE,FlashArray
size=2.0T features='0' hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 5:0:0:2 sdi 8:128 active ready running
  |- 4:0:0:2 sdg 8:96  active ready running
  |- 6:0:0:2 sdl 8:176 active ready running
  `- 7:0:0:2 sdm 8:192 active ready running
3624a937059471be632aa4fd20001c6d1 dm-1 PURE,FlashArray
size=32G features='0' hwhandler='1 alua' wp=rw
`-+- policy='service-time 0' prio=50 status=active
  |- 5:0:0:1 sdh 8:112 active ready running
  |- 4:0:0:1 sdf 8:80  active ready running
  |- 7:0:0:1 sdk 8:160 active ready running
  `- 6:0:0:1 sdj 8:144 active ready running
[core@worker3 ~]$
```

Now the Portworx StorageCluster is ready to use.

Procedure 3. Dynamic Volume Provisioning and Data Protection

Portworx by Pure Storage allows platform administrators to create custom Kubernetes StorageClasses to offer different classes of service to their developers. Administrators can customize things like the replication factors, snapshot schedules, file system types, io-profiles, etc. in their storage class definitions.

This procedure details how to create customized Storage Classes (SCs) for dynamic provisioning of volumes (PVs) using PersistentVolumeClaims (PVCs).

For instance, the following manifest file shows a sample file Storage Class for provisioning shared volume with ReadWriteMany (RWX) attribute to share the volume among multiple pods at the same time for read-write access. For provisioning volumes for typical application pods, predefined SCs can be leveraged.

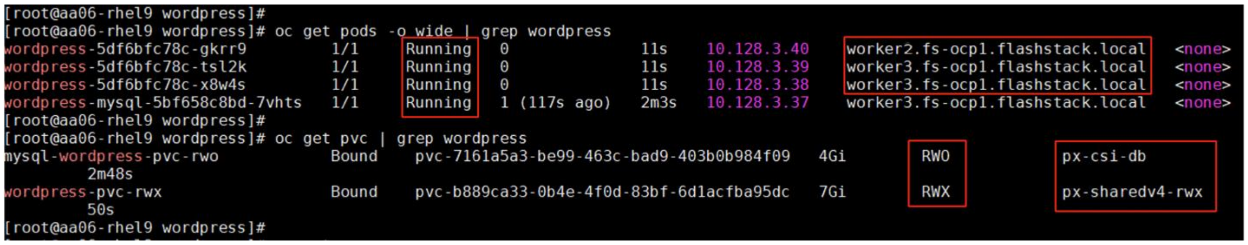
```
## This SC is used to provision sharedv4 Service volumes (exposed as CLusterIP service) with two replicas.
## cat sharedv4-sc-svc.yaml
apiVersion: storage.k8s.io/v1
kind: StorageClass
metadata:
  name: px-sharedv4-svc
provisioner: pxd.portworx.com
parameters:
  repl: "2"
  sharedv4: "true"
  sharedv4_svc_type: "ClusterIP"
reclaimPolicy: Retain
allowVolumeExpansion: trueDeploy sample WordPress Application with Portworx Sharedv4 Service volumes
```

Step 1. Use the following manifests to create a sharedv4 service volumes to be consumed by multiple WordPress application accessing the sharev4 service volume (consumed by multiple WordPress pods) and ReadWriteOnce volume (Consumed by one MySQL pod):

```
## Deploying MySql database manifests
## create password.txt and update it with mysql root password.
kubectl create secret generic mysql-pass --from-file=./password.txt
## mysql PVC: cat mysql-pvc.yaml
apiVersion: v1
```

```
kind: PersistentVolumeClaim
metadata:
  name: mysql-wordpress-pvc-rwo
  annotations:
spec:
  storageClassName: px-csi-db
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 4Gi
## mysql deployment manifest: cat mysql-dep.yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: wordpress-mysql
  labels:
    app: wordpress
spec:
  selector:
    matchLabels:
      app: wordpress
  strategy:
    type: Recreate
  template:
    metadata:
      labels:
        app: wordpress
        tier: mysql
    spec:
      # Use the Stork scheduler to enable more efficient placement of the pods
      schedulerName: stork
      containers:
      - image: mysql:5.6
        imagePullPolicy:
        name: mysql
        env:
          # $ kubectl create secret generic mysql-pass --from-file=password.txt
          # make sure password.txt does not have a trailing newline
        - name: MYSQL_ROOT_PASSWORD
          valueFrom:
            secretKeyRef:
              name: mysql-pass
              key: password.txt
        ports:
        - containerPort: 3306
          name: mysql
        volumeMounts:
        - name: mysql-persistent-storage
          mountPath: /var/lib/mysql
      volumes:
      - name: mysql-persistent-storage
        persistentVolumeClaim:
          claimName: mysql-wordpress-pvc-rwo

##worpess PVC created with ReadWriteMany access mode: cat wp-pvc.yaml
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: wordpress-pvc-rwx
  labels:
    app: wordpress
spec:
  storageClassName: px-sharedv4-rwx
  accessModes:
    - ReadWriteMany
  resources:
    requests:
      storage: 7Gi

## Deployment manifest for wordpress application: cat wp-dep.yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: wordpress
  labels:
    app: wordpress
spec:
  selector:
    matchLabels:
      app: wordpress
  replicas: 3
  strategy:
    type: Recreate
  template:
    metadata:
      labels:
        app: wordpress
        tier: frontend
    spec:
      # Use the Stork scheduler to enable more efficient placement of the pods
      schedulerName: stork
      containers:
      - image: wordpress:4.8-apache
        name: wordpress
        imagePullPolicy:
        env:
        - name: WORDPRESS_DB_HOST
          value: wordpress-mysql
        - name: WORDPRESS_DB_PASSWORD
          valueFrom:
            secretKeyRef:
              name: mysql-pass
              key: password.txt
        ports:
        - containerPort: 80
          name: wordpress
        volumeMounts:
        - name: wordpress-persistent-storage
          mountPath: /var/www/html
      volumes:
      - name: wordpress-persistent-storage
        persistentVolumeClaim:
          claimName: wordpress-pvc-rwx
```

The following screenshot shows that 3 WordPress pods are created accessing the same sharedv4 volume with ReadWriteMany access mode and one mysql pod created with single volume with ReadWriteOnce access mode:



```
[root@aa06-rhel9 wordpress]#
[root@aa06-rhel9 wordpress]# oc get pods -o wide | grep wordpress
wordpress-5df6bfc78c-gkrr9          1/1     Running   0              11s     10.128.3.40    worker2.fs-ocp1.flashstack.local   <none>
wordpress-5df6bfc78c-tsl2k          1/1     Running   0              11s     10.128.3.39    worker3.fs-ocp1.flashstack.local   <none>
wordpress-5df6bfc78c-x8w4s          1/1     Running   0              11s     10.128.3.38    worker3.fs-ocp1.flashstack.local   <none>
wordpress-mysql-5bf658c8bd-7vhts    1/1     Running   1 (117s ago)   2m3s    10.128.3.37    worker3.fs-ocp1.flashstack.local   <none>
[root@aa06-rhel9 wordpress]#
[root@aa06-rhel9 wordpress]# oc get pvc | grep wordpress
mysql-wordpress-pvc-rwo             Bound    pvc-7161a5a3-be99-463c-bad9-403b0b984f09   4Gi        RWO            px-csi-db
      2m48s
wordpress-pvc-rwx                   Bound    pvc-b889ca33-0b4e-4f0d-83bf-6d1acfba95dc   7Gi        RWX            px-sharedv4-rwx
      50s
[root@aa06-rhel9 wordpress]#
```

Sharedv4 Volume with ReadWriteMany (RWX) Access: Three WordPress pods are accessing the same sharedv4 volume with the ReadWriteMany access mode, meaning multiple pods can concurrently read from and write to this single volume. This is especially useful for applications like WordPress that may need to scale out to handle load but still rely on a shared data volume.

ReadWriteOnce (RWO) Access for MySQL: There is also a single MySQL pod accessing a volume with the ReadWriteOnce access mode, which allows only one pod to mount the volume at a time. This setup is common for databases, where concurrent access could lead to data inconsistencies.

This setup highlights Portworx's ability to support various access modes for different use cases, allowing flexible storage configurations that suit both shared applications (like WordPress) and single-instance databases (like MySQL). By providing the ReadWriteMany access mode with sharedv4, Portworx enables efficient scaling and resource usage, allowing applications to use shared storage across multiple pods and hosts

Snapshots and Clones: Portworx Enterprise offers data protection of volumes using volume snapshots and restore them for point in time recovery of the data. Any Storage Class that implements portworx csi driver pxd.portworx.com supports volume Snapshots.

Step 2. Run the following scripts to create the **VolumeSnapshotClass**, a **PVC** and then a **Snapshot** of a PVC and then restore the snapshot as a new **PVC.**

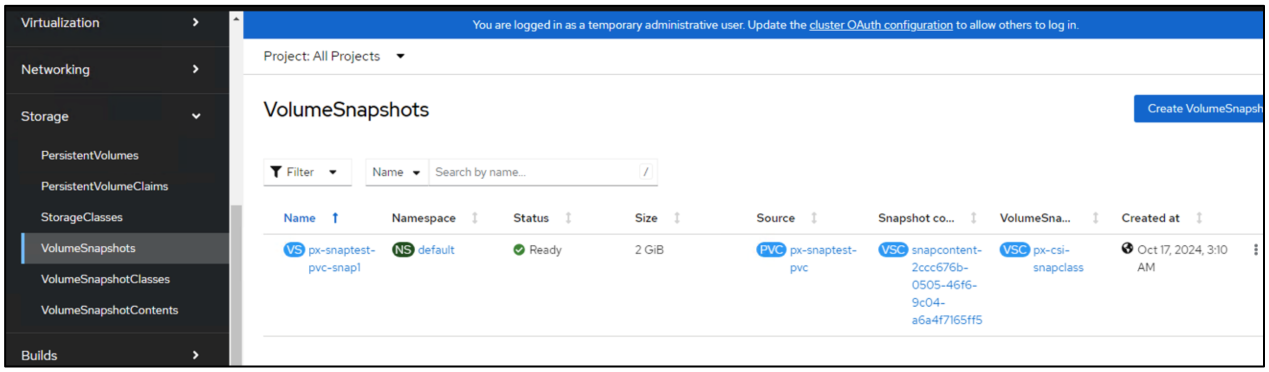
```
## For Openshift platform, px-csi-account service account needs to be added to the privileged security context.
oc adm policy add-scc-to-user privileged system:serviceaccount:kube-system:px-csi-account


## Now creat VolumeSnapshotClass using below manifest
## cat VolumeStroageClass.yaml
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshotClass
metadata:
  name: px-csi-snapclass
  annotations:
    snapshot.storage.kubernetes.io/is-default-class: "true"
driver: pxd.portworx.com
deletionPolicy: Delete
parameters:
  csi.openstorage.org/snapshot-type: local
```

Step 3. Use the following sample manifest to create a sample PVC:

```
## cat px-snaptest-pvc.yaml
kind: PersistentVolumeClaim
apiVersion: v1
metadata:
  name: px-snaptest-pvc
spec:
  storageClassName: px-csi-db. ## Any Storage Class can be used which implements Portworx CSI driver.
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 2Gi
## Assume this pvc is attached to a pod and the pod has written some data into the pvc.
## Now create Snapshot of the above volume. It can be created using UI also.
## cat create-snapshot-snaptest-pvc.yaml
apiVersion: snapshot.storage.k8s.io/v1
kind: VolumeSnapshot
```

```
metadata:
  name: px-snaptest-pvc-snap1
spec:
  volumeSnapshotClassName: px-csi-snapclass
  source:
    persistentVolumeClaimName: px-snaptest-pvc. ## the name of the pvc
```

The following screenshot shows px-snaptest-pvc-snap1 is the snapshot of the PVC px-snaptest-pvc:



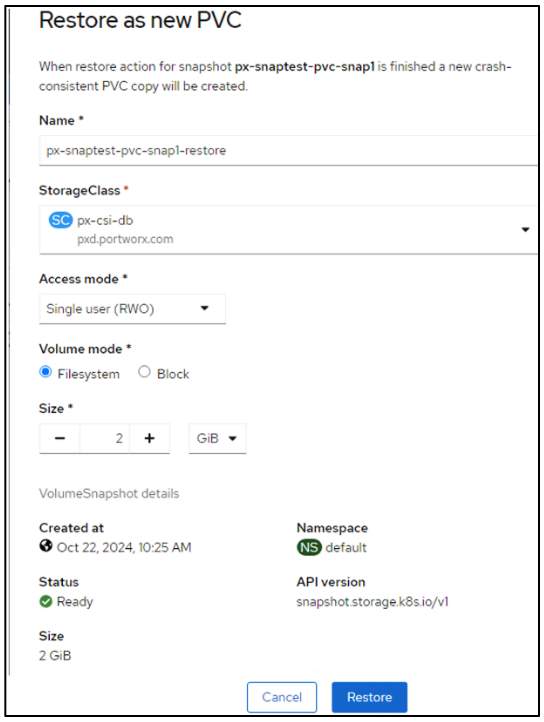
You are logged in as a temporary administrative user. Update the cluster OAuth configuration to allow others to log in.

VolumeSnapshots

Name	Namespace	Status	Size	Source	Snapshot co...	VolumeSna...	Created at
VS px-snaptest-pvc-snap1	NS default	Ready	2 GiB	PVC px-snaptest-pvc	VSC snapcontent-2ccc676b-0505-46f6-9c04-a6a4f7165ff5	VSC px-csi-snapclass	Oct 17, 2024, 3:10 AM

Step 4. You can now restore this as snapshot as a new PVC and then can be mounted to any other pod.

Step 5. Click the **ellipses** of the snapshot and select **Restore as new PVC**. In the Restore as new PVC window, click **Restore**.



Restore as new PVC

When restore action for snapshot **px-snaptest-pvc-snap1** is finished a new crash-consistent PVC copy will be created.

Name *: px-snaptest-pvc-snap1-restore

StorageClass *: SC px-csi-db pxd.portworx.com

Access mode *: Single user (RWO)

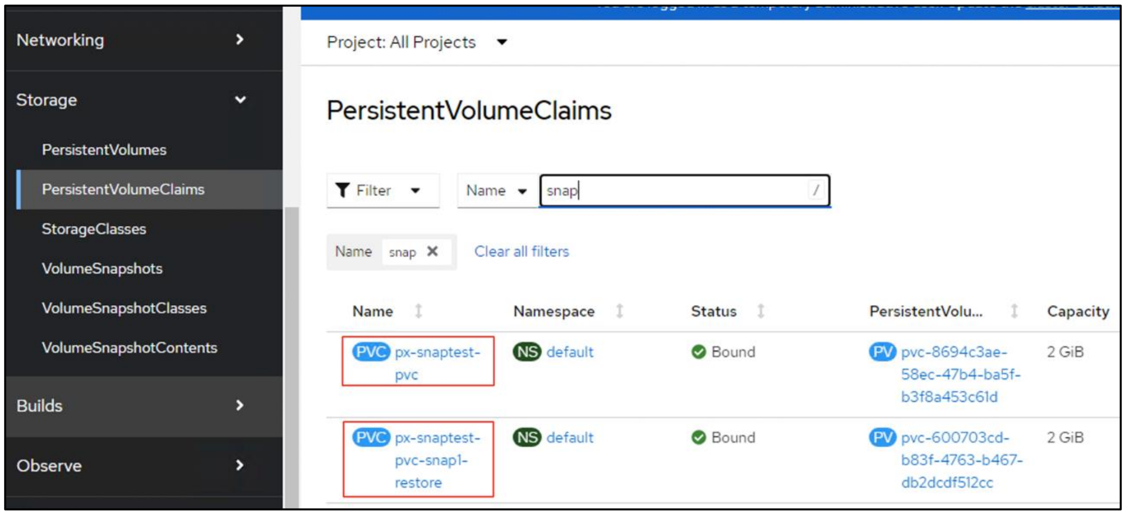
Volume mode *: [✓ Filesystem] Block

Size *: 2 GiB

VolumeSnapshot details

Created at: Oct 22, 2024, 10:25 AM	Namespace: NS default
Status: Ready	API version: snapshot.storage.k8s.io/v1
Size: 2 GiB	

Step 6. You can view the original and restored PVC under PVC list.

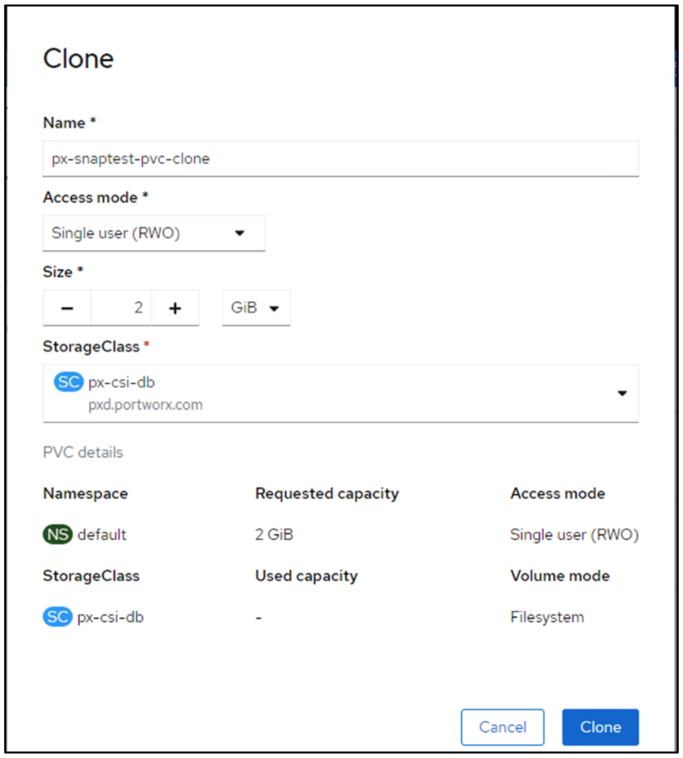


PersistentVolumeClaims

Name: snap

Name	Namespace	Status	PersistentVolu...	Capacity
PVC px-snaptest-pvc	NS default	Bound	PV pvc-8694c3ae-58ec-47b4-ba5f-b3f8a453c61d	2 GiB
PVC px-snaptest-pvc-snap1-restore	NS default	Bound	PV pvc-600703cd-b83f-4763-b467-db2dcdf512cc	2 GiB

Step 7. To clone of a PVC (px-snaptest-pvc), click **three** of the **PVC** and select **Clone PVC**. Click **Clone**.



Clone

Name *: px-snaptest-pvc-clone

Access mode *: Single user (RWO)

Size *: 2 GiB

StorageClass *: SC px-csi-db pxd.portworx.com

PVC details

Namespace	Requested capacity	Access mode
NS default	2 GiB	Single user (RWO)
StorageClass	**Used capacity**	**Volume mode**
SC px-csi-db	-	Filesystem

Portworx Enterprise Console Plugin for OpenShift

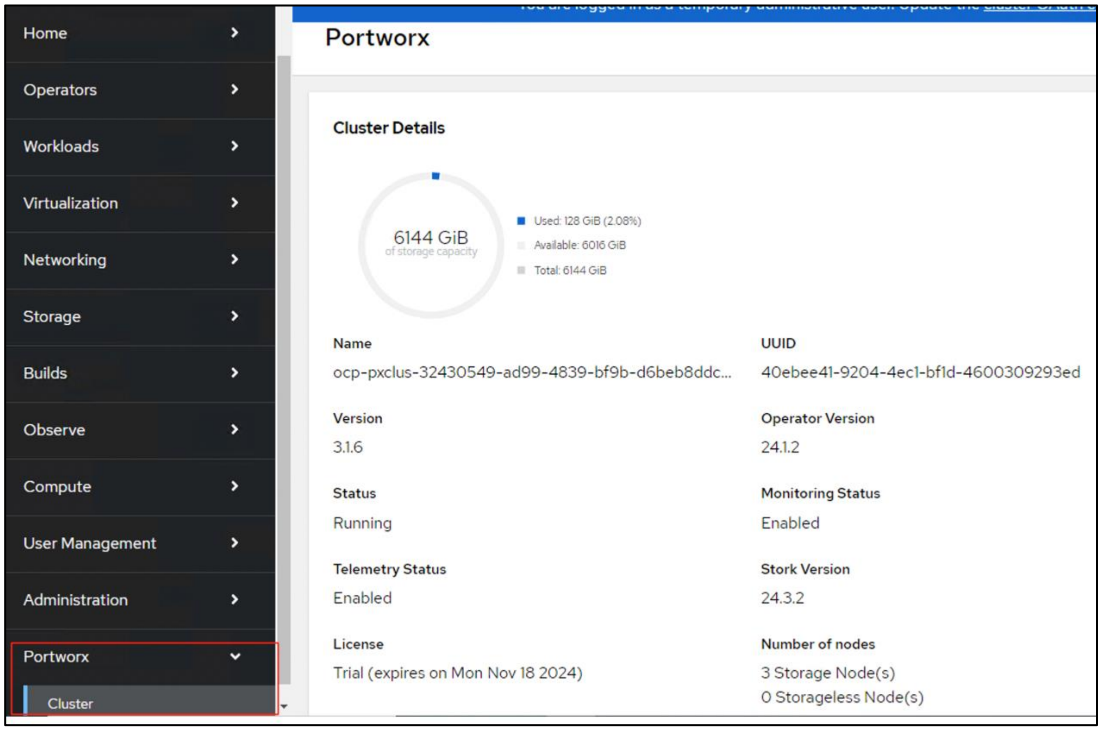
Portworx by Pure Storage has built an OpenShift Dynamic console plugin that enables single-pane-of-glass management of storage resources running on Red Hat OpenShift clusters. This allows platform administrators to use the OpenShift web console to manage not just their applications and their OpenShift cluster, but also their Portworx Enterprise installation and their stateful applications running on OpenShift.

This plugin can be installed with a single click during the Installation of Portworx Operator as explained in the previous sections. Once the plugin is enabled, the Portworx Operator will automatically install the plugin pods in the same OpenShift project as the Portworx storage cluster. When the pods are up and running, administrators will see a message in the OpenShift web console to refresh their browser window for the Portworx tabs to show up in the UI.

With this plugin, Portworx has built three different UI pages, including a Portworx Cluster Dashboard that shows up in the left navigation menu, a Portworx tab under Storage > Storage Class section, and another Portworx tab under Storage > Persistent Volume Claims.

Portworx Cluster Dashboard

Platform administrators can use the Portworx Cluster Dashboard to monitor the status of their Portworx Storage Cluster and their persistent volumes and storage nodes. Here are a few operations that are now streamlined by the OpenShift Dynamic plugin from Portworx.

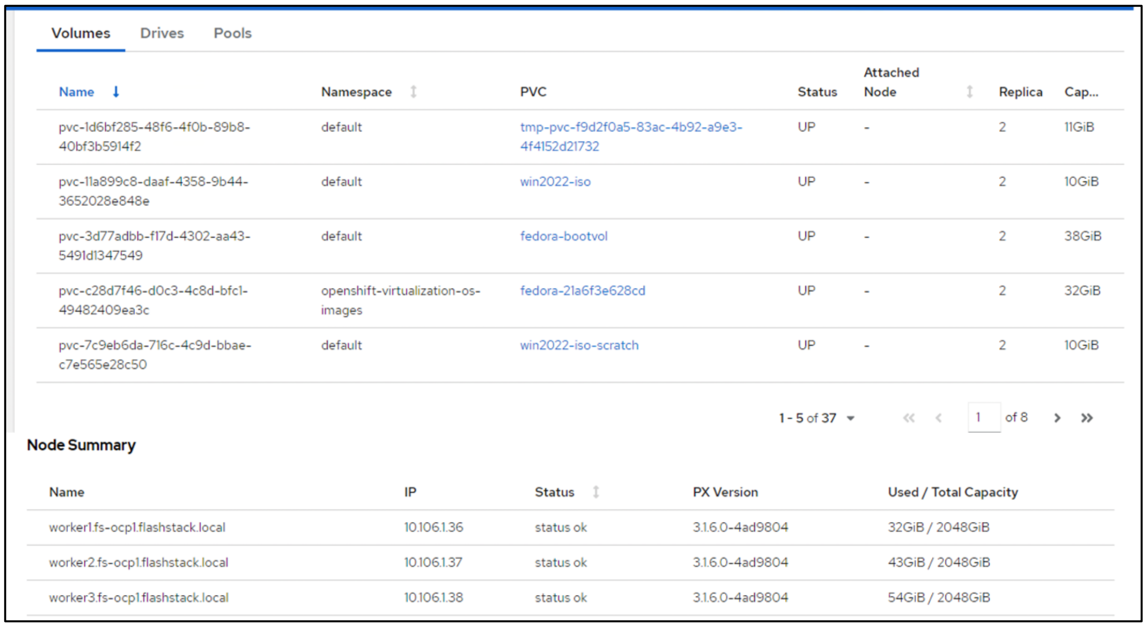


Cluster Details

6144 GiB of storage capacity

- Used: 128 GiB (2.08%)
- Available: 6016 GiB
- Total: 6144 GiB

Name	UUID
ocp-pxclus-32430549-ad99-4839-bf9b-d6beb8ddc...	40ebee41-9204-4ec1-bf1d-4600309293ed
Version	Operator Version
3.1.6	24.1.2
Status	Monitoring Status
Running	Enabled
Telemetry Status	Stork Version
Enabled	24.3.2
License	Number of nodes
Trial (expires on Mon Nov 18 2024)	3 Storage Node(s) 0 Storageless Node(s)



Name	Namespace	PVC	Status	Attached Node	Replica	Cap...
pvc-1d6bf285-48f6-4f0b-89b8-40bf3b5914f2	default	tmp-pvc-f9d2f0a5-83ac-4b92-a9e3-4f4152d21732	UP	-	2	11GiB
pvc-11a899c8-daaf-4358-9b44-3652028e848e	default	win2022-iso	UP	-	2	10GiB
pvc-3d77adbb-f17d-4302-aa43-5491d1347549	default	fedora-bootvol	UP	-	2	38GiB
pvc-c28d7f46-d0c3-4c8d-bfc1-49482409ea3c	openshift-virtualization-os-images	fedora-21a6f3e628cd	UP	-	2	32GiB
pvc-7c9eb6da-716c-4c9d-bbae-c7e565e28c50	default	win2022-iso-scratch	UP	-	2	10GiB

1 - 5 of 37 1 of 8

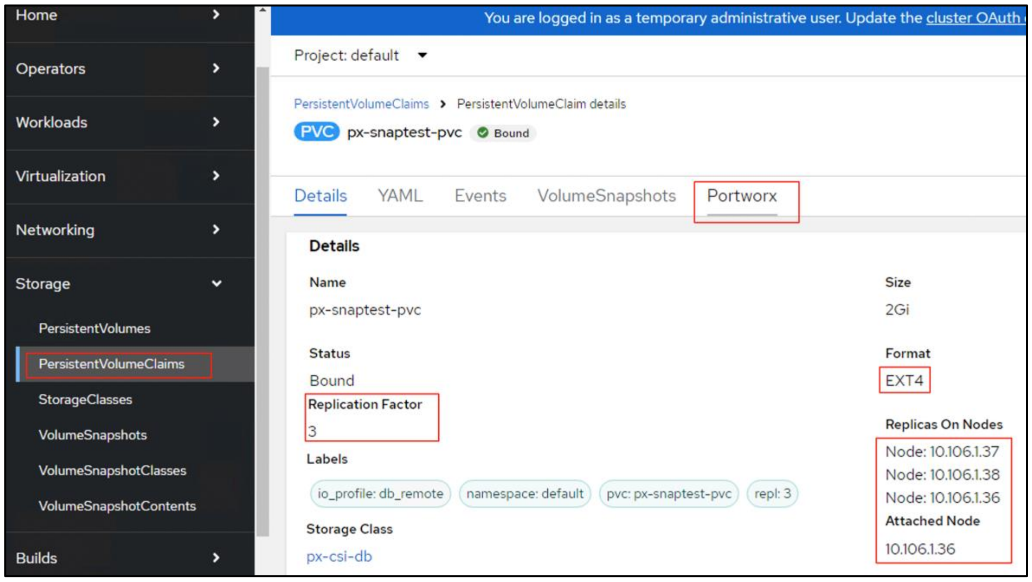
Node Summary

Name	IP	Status	PX Version	Used / Total Capacity
worker1.fs-ocp1.flashstack.local	10.106.1.36	status ok	3.1.6.0-4ad9804	32GiB / 2048GiB
worker2.fs-ocp1.flashstack.local	10.106.1.37	status ok	3.1.6.0-4ad9804	43GiB / 2048GiB
worker3.fs-ocp1.flashstack.local	10.106.1.38	status ok	3.1.6.0-4ad9804	54GiB / 2048GiB

To obtain detailed inventory information of the Portworx Cluster, click the **Drives** and **Pools** tabs.

Portworx PVC Dashboard

This dashboard shows some of the important attributes of a PVC like Replication Factor, node details of replicas, attached node and so on. You may have to use multiple pxctl inspect volume CLI commands to get these details. Instead, all this information can be found in Console Plugin.



Details

Name
px-snaptest-pvc

Status
Bound

Replication Factor
3

Labels
io_profile: db_remote namespace: default pvc: px-snaptest-pvc repl: 3

Storage Class
px-csi-db

Size
2Gi

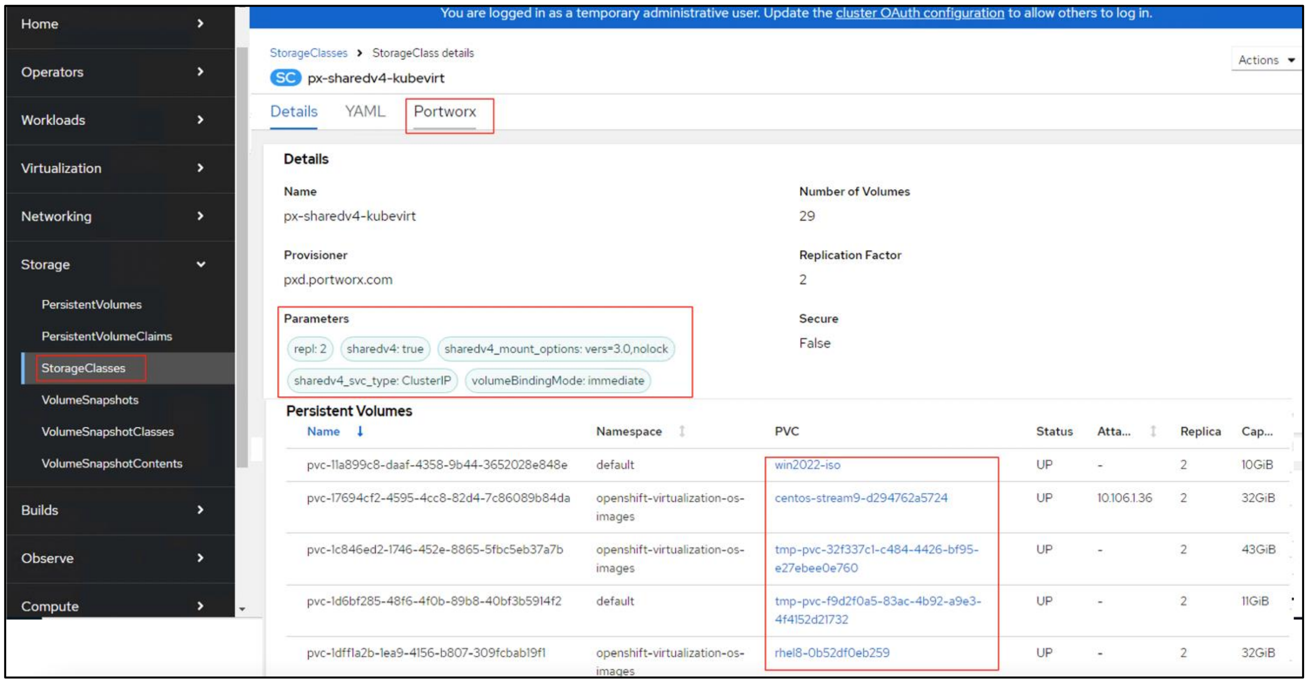
Format
EXT4

Replicas On Nodes
Node: 10.106.1.37
Node: 10.106.1.38
Node: 10.106.1.36

Attached Node
10.106.1.36

Portworx StorageClass Dashboard

From the Portworx storage cluster tab, administrators can get details about the custom parameters set for each storage class, the number of persistent volumes dynamically provisioned using the storage class, and a table that lists all the persistent volumes deployed using that storage class. The OpenShift dynamic plugin eliminates the need for administrators to use multiple “kubectl get” and “kubectl describe” commands to find all these details—instead, they can just use a simple UI to monitor their storage classes.



Details

Name
px-sharedv4-kubevirt

Provisioner
pxd.portworx.com

Parameters
repl: 2 sharedv4: true sharedv4_mount_options: vers=3.0,nolock sharedv4_svc_type: ClusterIP volumeBindingMode: immediate

Number of Volumes
29

Replication Factor
2

Secure
False

Persistent Volumes

Name	Namespace	PVC	Status	Atta...	Replica	Cap...
pvc-11a899c8-daaf-4358-9b44-3652028e848e	default	win2022-iso	UP	-	2	10GiB
pvc-17694cf2-4595-4cc8-82d4-7c86089b84da	openshift-virtualization-os-images	centos-stream9-d294762a5724	UP	10.106.1.36	2	32GiB
pvc-1c846ed2-1746-452e-8865-5fbc5eb37a7b	openshift-virtualization-os-images	tmp-pvc-32f337c1-c484-4426-bf95-e27ebee0e760	UP	-	2	43GiB
pvc-1d6bf285-48f6-4f0b-89b8-40bf3b5914f2	default	tmp-pvc-f9d2f0a5-83ac-4b92-a9e3-4f4152d21732	UP	-	2	11GiB
pvc-1dff1a2b-1ea9-4156-b807-309fcbab19f1	openshift-virtualization-os-images	rhel8-0b52df0eb259	UP	-	2	32GiB

RAG Pipeline Installation and Configuration

This chapter contains the following:

- NVIDIA NIM Operator and NIMs
- Vector Database
- RAG Blueprint
- Access Services and Application

The reference RAG Blueprint leverages the NIMs deployed for LLMs, Text Embedding, and Text Reranking. It uses the Milvus vector database to store the vector embeddings.

Note: It is required to deploy NIMs, and the Milvus Vector database first and then deploy RAG Blueprint.

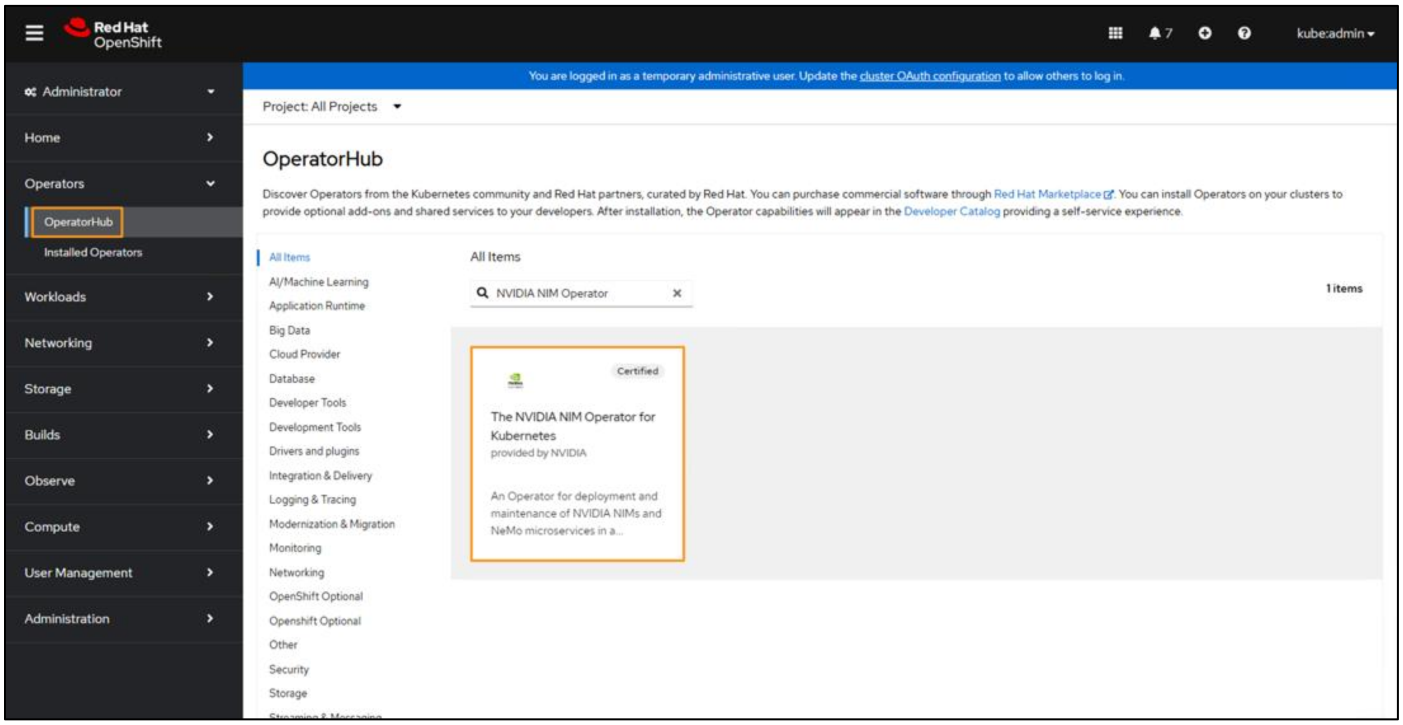
NVIDIA NIM Operator and NIMs

NIMs can be installed independently using its respective helm charts from https://catalog.ngc.nvidia.com/helm-charts. It can also be installed and managed using NVIDIA NIM Operator. In this design, NIMs will be installed and managed using NVIDIA NIM Operator.

Procedure 1. Install NIM Operator

Step 1. In the **Red Hat OpenShift console**, go to **Operators** > **OperatorHub**.

Step 2. Search for **NVIDIA NIM Operator**.



You are logged in as a temporary administrative user. Update the cluster OAuth configuration to allow others to log in.

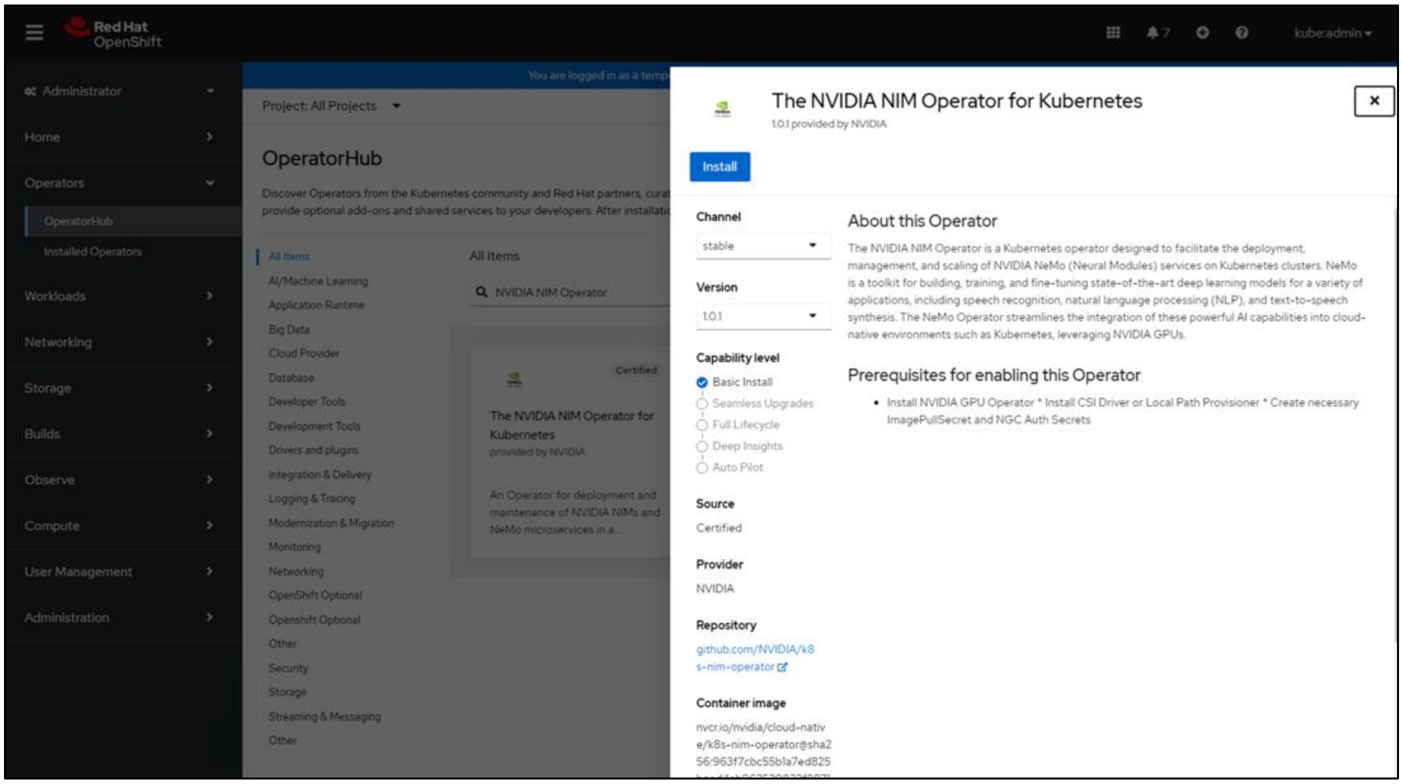
OperatorHub

Discover Operators from the Kubernetes community and Red Hat partners, curated by Red Hat. You can purchase commercial software through Red Hat Marketplace. You can install Operators on your clusters to provide optional add-ons and shared services to your developers. After installation, the Operator capabilities will appear in the Developer Catalog providing a self-service experience.

The NVIDIA NIM Operator for Kubernetes
provided by NVIDIA

An Operator for deployment and maintenance of NVIDIA NIMs and NeMo microservices in a...

Step 3. Click **Install**.



The NVIDIA NIM Operator for Kubernetes
1.0.1 provided by NVIDIA

Channel: stable

Version: 1.0.1

Capability level: Basic Install

Source: Certified

Provider: NVIDIA

Repository: github.com/NVIDIA/k8s-nim-operator

Container image: nvcr.io/nvidia/cloud-native/k8s-nim-operator@sha256:963f7cbc55b1a7ed825

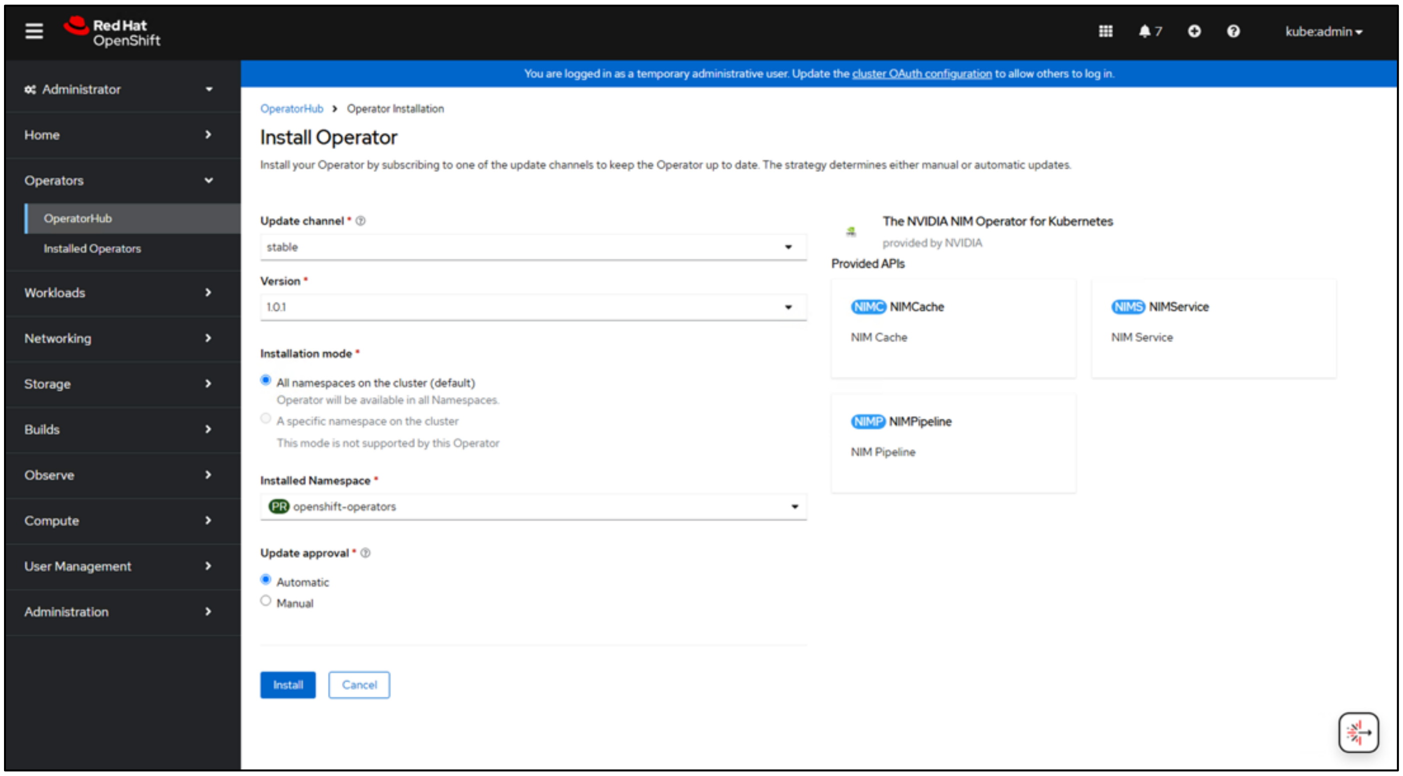
About this Operator

The NVIDIA NIM Operator is a Kubernetes operator designed to facilitate the deployment, management, and scaling of NVIDIA NeMo (Neural Modules) services on Kubernetes clusters. NeMo is a toolkit for building, training, and fine-tuning state-of-the-art deep learning models for a variety of applications, including speech recognition, natural language processing (NLP), and text-to-speech synthesis. The NeMo Operator streamlines the integration of these powerful AI capabilities into cloud-native environments such as Kubernetes, leveraging NVIDIA GPUs.

Prerequisites for enabling this Operator

- Install NVIDIA GPU Operator * Install CSI Driver or Local Path Provisioner * Create necessary ImagePullSecret and NGC Auth Secrets

Step 4. Retain Installed Namespace as **openshift-operators**. Click **Install**.



You are logged in as a temporary administrative user. Update the cluster OAuth configuration to allow others to log in.

Install Operator

Install your Operator by subscribing to one of the update channels to keep the Operator up to date. The strategy determines either manual or automatic updates.

Update channel *: stable

Version *: 1.0.1

Installation mode *: [✓ All namespaces on the cluster (default)] Operator will be available in all Namespaces. / A specific namespace on the cluster — This mode is not supported by this Operator

Installed Namespace *: openshift-operators

Update approval *: [✓ Automatic] / Manual

The NVIDIA NIM Operator for Kubernetes provided by NVIDIA

Provided APIs

NIMCache — NIM Cache	NIMService — NIM Service
NIMPipeline — NIM Pipeline	

Create Caching Models

NIM Operator uses a custom resource called NIM cache (nimcaches.apps.nvidia.com). This custom resource enables downloading models from NVIDIA NGC and persisting them on Portworx persistent storage.

One advantage to caching a model is that when multiple instances of the same NIM microservice start, the microservices use the single cached model. However, caching is optional. Without caching, each NIM microservice instance downloads a copy of the model when it starts.

It is recommended to cache the models for NVIDIA NIM microservices. By caching a model, the microservice startup time is improved. For deployments that scale to more than one NIM microservice pod, a single cached model in persistent volume with a storage class from Portworx provisioner can serve multiple pods.

This section provides the procedures to create caching models for LLMs, Text Embedding, and Text Reranking.

Procedure 1. Create namespace

Step 1. To create the namespace, run the following command:

```
oc create namespace nim
```

Procedure 2. Secrets for NGC API key

Step 1. NIM cache uses the NGC API key as an image pull secret to download container images and models from NVIDIA NGC. Add a Docker registry secret for downloading the NIM container image from NVIDIA NGC:

```
oc create secret -n nim docker-registry ngc-secret \
    --docker-server=nvcr.io \
    --docker-username='$oauthtoken' \
    --docker-password=<ngc-api-key>
```

Step 2. Add a generic secret that the model puller init container uses to download the model from NVIDIA NGC:

```
oc create secret -n nim generic ngc-api-secret \
    --from-literal=NGC_API_KEY=<ngc-api-key>
```

NIM cache for LLM

Refer to the following sample manifest as an example:

```
apiVersion: apps.nvidia.com/v1alpha1
kind: NIMCache
metadata:
  name: meta-llama3-8b
spec:
  source:
    ngc:
      modelPuller: nvcr.io/nim/meta/llama3-8b-instruct:1.0.3
      pullSecret: ngc-secret
      authSecret: ngc-api-secret
      model:
        gpus:
        - product: "l40s"
        engine: tensorrt_llm
        tensorParallelism: "1"
  storage:
    pvc:
      create: true
      storageClass: <storage_class_naME>
      size: "100Gi"
      volumeAccessMode: ReadWriteMany
```

When you create a NIM cache resource, the NIM Operator starts a pod that lists the available model profiles. The Operator creates a config map of the model profiles.

If you specify one or more model profile IDs to cache, the Operator starts a job that caches the model profiles that you specified.

If you did not specify model profile IDs but do specify engine: tensorrt_llm or engine: tensorrt, the Operator attempts to match the model profiles with the GPUs on the nodes in the cluster. The Operator uses the value of the nvidia.com/gpu.product node label that is set by Node Feature Discovery.

You can let the Operator automatically detect the model profiles to cache or you can constrain the model profiles by specifying values for spec.source.ngc.model, such as the engine, GPU model, and so on, that must match the model profile.

More information about the option is available here: https://docs.nvidia.com/nim-operator/latest/cache.html

NIM Cache for Text Embedding

Refer to the following example sample manifest:

```
apiVersion: apps.nvidia.com/v1alpha1
kind: NIMCache
metadata:
  name: llama-3.2-nv-embedqa-1b-v2
spec:
  source:
    ngc:
      modelPuller: nvcr.io/nim/nvidia/llama-3.2-nv-embedqa-1b-v2:latest
      pullSecret: ngc-secret
      authSecret: ngc-api-secret
      model:
        profiles:
        - all
  storage:
    pvc:
      create: true
      storageClass: <storage_class_name>
      size: "100Gi"
      volumeAccessMode: ReadWriteMany
```

NIM Cache for Text Reranking

Refer to the following example sample manifest:

```
apiVersion: apps.nvidia.com/v1alpha1
apiVersion: apps.nvidia.com/v1alpha1
kind: NIMCache
metadata:
  name: rerankqa
spec:
  source:
    ngc:
      modelPuller: nvcr.io/nim/nvidia/llama-3.2-nv-rerankqa-1b-v2:latest
      pullSecret: ngc-secret
      authSecret: ngc-api-secret
      model:
        profiles:
        - all
  storage:
    pvc:
      create: true
      storageClass: kubevirt
      size: "100Gi"
      volumeAccessMode: ReadWriteMany
```

Procedure 1. Create Resources

Step 1. Apply the YAML manifests to all three models:

```
oc apply -n nim -f <yaml_manifest_name>
```

Step 2. View the NIM cache resource to view the status:

```
[root@aa06-rhel9 blueprint]# oc get nimcaches.apps.nvidia.com -n nim
NAME                         STATUS   PVC                              AGE
llama-3.2-nv-embedqa-1b-v2   Ready    llama-3.2-nv-embedqa-1b-v2-pvc   11d
meta-llama3.1-8b             Ready    meta-llama3.1-8b-pvc             11d
rerankqa                     Ready    rerankqa-pvc                     11d
```

Create Services

NIM Services (nimservices.apps.nvidia.com) custom resource represents a NIM microservice. Adding and updating a NIM service resource creates a Kubernetes deployment for the microservice in a namespace. The custom resource supports using a model from an existing NIM cache resource or a persistent volume claim.

NIM Service for LLM

Refer to the following example sample manifest:

```
apiVersion: apps.nvidia.com/v1alpha1
kind: NIMService
metadata:
  name: llm
spec:
  image:
    repository:  nvcr.io/nim/meta/llama-3.1-8b-instruct
    tag: 1.3.3
    pullPolicy: IfNotPresent
    pullSecrets:
      - ngc-secret
  authSecret: ngc-api-secret
  storage:
    nimCache:
      name: meta-llama3.1-8b
      profile: ''
  replicas: 1
  resources:
    limits:
      nvidia.com/gpu: 1
  expose:
    service:
      type: NodePort
      port: 8000
```

NIM Service for Text Embedding

Refer to the following example sample manifest:

```
apiVersion: apps.nvidia.com/v1alpha1
kind: NIMService
metadata:
  name: embedqa
spec:
  image:
    repository: nvcr.io/nim/nvidia/llama-3.2-nv-embedqa-1b-v2
    tag: latest
    pullPolicy: IfNotPresent
    pullSecrets:
      - ngc-secret
  authSecret: ngc-api-secret
  storage:
    nimCache:
      name: llama-3.2-nv-embedqa-1b-v2
      profile: ''
  replicas: 1
  resources:
    limits:
      nvidia.com/gpu: 1
  expose:
    service:
      type: ClusterIP
      port: 8000
```

NIM Service for Text Reranking

Refer to the following example sample manifest:

```
apiVersion: apps.nvidia.com/v1alpha1
kind: NIMService
metadata:
  name: rerankqa
spec:
  image:
    repository: nvcr.io/nim/nvidia/llama-3.2-nv-rerankqa-1b-v2
    tag: latest
    pullPolicy: IfNotPresent
    pullSecrets:
      - ngc-secret
  authSecret: ngc-api-secret
  storage:
    nimCache:
      name: rerankqa
      profile: ''
  replicas: 1
  resources:
    limits:
      nvidia.com/gpu: 1
  expose:
    service:
      type: ClusterIP
      port: 8000
```

View the NIM services custom resources:

```
oc get nimservices.apps.nvidia.com -n nim
```

Create NIM Pipelines

As an alternative to managing NIM services individually using multiple NIMService custom resources, you can manage multiple NIM services using one NIMPipeline custom resource.

The following sample manifest deploys all NIMs mentioned above without creating individual NIM services:

```
apiVersion: apps.nvidia.com/v1alpha1
kind: NIMPipeline
metadata:
  name: pipeline-all
spec:
  services:
    - name: llm
      enabled: true
      spec:
        image:
          repository: nvcr.io/nim/meta/llama-3.1-8b-instruct
          tag: 1.3.3
          pullPolicy: IfNotPresent
          pullSecrets:
          - ngc-secret
        authSecret: ngc-api-secret
        storage:
          nimCache:
            name: meta-llama3.1-8b
            profile: ''
        replicas: 1
        resources:
          limits:
            nvidia.com/gpu: 1
        expose:
          service:
            type: ClusterIP
            port: 8000
    - name: embedqa
      enabled: true
      spec:
        image:
          repository: nvcr.io/nim/nvidia/llama-3.2-nv-embedqa-1b-v2
          tag: latest
          pullPolicy: IfNotPresent
          pullSecrets:
          - ngc-secret
        authSecret: ngc-api-secret
        storage:
          nimCache:
            name: llama-3.2-nv-embedqa-1b-v2
            profile: ''
        replicas: 1
        resources:
          limits:
            nvidia.com/gpu: 1
        expose:
          service:
            type: ClusterIP
            port: 8000
    - name: rerankqa
      enabled: true
      spec:
        image:
          repository: nvcr.io/nim/nvidia/llama-3.2-nv-rerankqa-1b-v2
          tag: latest
          pullPolicy: IfNotPresent
          pullSecrets:
          - ngc-secret
        authSecret: ngc-api-secret
        storage:
          nimCache:
            name: rerankqa
            profile: ''
        replicas: 1
        resources:
          limits:
            nvidia.com/gpu: 1
        expose:
          service:
            type: ClusterIP
            port: 8000
```

More information about NIM Pipelines is available here: https://docs.nvidia.com/nim-operator/latest/pipelines.html

Procedure 1. Verification

After all the NIMs are deployed, you can verify the status of the services by calling “/v1/health/ready” API endpoint. First, get the services exposed to access the LLM, Embedding and Reranking models.

Step 1. Note that the service names will be the same as name given while creating the NIM Service. In the previous example, NIM service for Llama-3.1 is created using name llm, Llama-3.2 Text Embedding NIM with embedqa and Llama 3.2 1B Reranking with the name rerankqa:

```
[root@aa06-rhel9 blueprint]# oc get svc -n nim
NAME                           TYPE        CLUSTER-IP       EXTERNAL-IP   PORT(S)
embedqa                        NodePort    172.30.103.111   <none>        8000:30765/TCP
llm                            NodePort    172.30.73.126    <none>        8000:30604/TCP
rerankqa                       NodePort    172.30.160.141   <none>        8000:32630/TCP
```

```
[root@aa06-rhel9 blueprint]# oc get svc -o custom-
columns=NAME:.metadata.name,PORT_TYPE:.spec.type,NODE_PORT:.spec.ports[*].nodePort

NAME                            PORT_TYPE    NODE_PORT

embedqa                         NodePort     30765

llm                             NodePort     30604

rerankqa                        NodePort     32630
```

Step 2. From the previous output, Llama-3.1 is available using NodePort 30604, embedding model at 30765 and rerank model at 32630. All services with ClusterIP Port 8000.

Step 3. Get the IP or DNS name of the node ports by running the following command:

```
[root@aa06-rhel9 blueprint]# oc get nodes -o wide
```

Step 4. Verify the status of each service running using "/v1/health/ready" endpoint:

```
[root@aa06-rhel9 blueprint]# curl http://10.106.1.33:30604/v1/health/ready

{"object":"health.response","message":"Service is ready."}



[root@aa06-rhel9 blueprint]# curl http://10.106.1.33:30765/v1/health/ready

{"object":"health-response","message":"Service is ready."}



[root@aa06-rhel9 blueprint]# curl http://10.106.1.33:32630/v1/health/ready

{"object":"health-response","message":"Service is ready."}
```

Vector Database

This section provides the procedures to deploy the Milvus vector database:

- Before deploying Milvus vector database deployment, ensure the following pre-requisites are configured on the FlashBlade//S.
- For the Object storage traffic between the FlashBlade//S and workers nodes, create required Link Aggregation Groups (LAGs), Subnets and Interface on the FlashBlade//S and assign IP address to the Interface.
- On each worker node, ensure an interface is configured with IP addresses in the same subnet as that of FlashBlade//S interface and ensure IPs are reachable from each other.
- In the FlashBlade//S array, ensure that an account with at least one User ID is created and configured with required access policy and Access key. Also ensure, at least one Bucket is created and mapped to the account created in the above step.

In this architecture, FlashBlade//S is used as S3 compatible backend object storage as required by Milvus vector database for storing Milvus collections (Vector embeddings) and Indexes. While the FlashArray//XL170 is used for storing other Milvus components like Pulsar's bookie journal, Zookeeper and so on.

Procedure 1. Configure Portworx storage class

Step 1. Run the following script to configure one of portworx storage classes configured with FlashArray //XL170 and back-end storage as 'Default storage class':

```
kubectl patch storageclass <<your Preffered StorageClass Name>> -p '{"metadata":
{"annotations":{"storageclass.kubernetes.io/is-default-class":"true"}}}'
```

Step 2. Ensure the routingViaHost is set to true by running the below script. This will ensure the Milvus Pod to directly access the FlashBlade//S interfaces via worker node network interfaces for object storage traffic:

```
oc patch Network.operator.openshift.io cluster --type=merge \
--patch '{
"spec":{
"defaultNetwork":{
"ovnKubernetesConfig":{
"gatewayConfig": {
"ipForwarding": "Global",
"routingViaHost": true
}}}}}'

oc describe Network.operator.openshift.io cluster
Name:         cluster
Namespace:
Labels:       <none>
Annotations:  <none>
API Version:  operator.openshift.io/v1
Kind:         Network
Metadata:
  Creation Timestamp:  2025-01-02T09:32:18Z
  Generation:          157
  Resource Version:    54848544
  UID:                 a44accc1-8efa-4635-aa52-ca6defdf21af
Spec:
  Cluster Network:
    Cidr:         10.128.0.0/14
    Host Prefix:  23
  Default Network:
    Ovn Kubernetes Config:
      Egress IP Config:
      Gateway Config:
        Ip Forwarding:  Global
        ipv4:
        ipv6:
        Routing Via Host:  true
      Geneve Port:         6081
      Ipsec Config:
      ---
      ---
```

Step 3. Run the following script on oc terminal to update the Security context (SCC) to allow anyuid for the service accounts created by the milvus helm chart:

```
oc adm policy add-scc-to-user anyuid -z milvus-deployment-pulsarv3-bookie -n milvus
oc adm policy add-scc-to-user anyuid -z milvus-deployment-pulsarv3-broker-acct -n milvus
oc adm policy add-scc-to-user anyuid -z milvus-deployment-pulsarv3-proxy -n milvus
oc adm policy add-scc-to-user anyuid -z milvus-deployment-pulsarv3-recovery -n milvus
oc adm policy add-scc-to-user anyuid -z milvus-deployment-pulsarv3-zookeeper -n milvus
oc adm policy add-scc-to-user anyuid -z default -n milvus
```

Before proceeding with the Milvus deployment, gather the following details listed in Table 21 and keep them available.

Table 21. Storage Details required for Vector Database deployment

Item	Details
Object Storage IP Interface IP	192.168.40.40
Port	80
Access Key	<<The Access Key generated while configuring the user id in the FlashBlade//S>>
Secret Key	<< The Secret Key generated while configuring the user id in the FlashBlade//S >>
Bucket Name	aa06-milvus-bkt
Worker node IPs designated for Object storage traffic	192.168.40.41, 192.168.40.42, 192.168.40.43
Default Storage Class created by Portworx	<< Name of your Default Portworx Storage Class>>

Procedure 2. Milvus Deployment with Pure Storage FlashBlade//S

Step 1. Create a new namespace for milvus:

```
oc create namespace milvus
```

Step 2. Add the milvus repository:

```
helm repo add milvus https://zilliztech.github.io/milvus-helm/
```

Step 3. Update the helm repository:

```
helm repo update
```

Note: The RAG deployment can work with either Standalone or Distributed Milvus vector database. For more details on the type of Milvus vector database is suitable for your RAG deployment, refer: https://zilliz.com/blog/choose-the-right-milvus-deployment-mode-ai-applications

Step 4. Create a file named custom_value.yaml for customizing the Milvus deployment. Specify Attu details, milvus version that supports GPU based indexes, number of replicas, GPU resources and FlashBlade details for object storage as shown in sample manifest file:

```
##################custom_values.yaml for distributed Milvus deployment##########################
attu:
  enabled: true
  name: attu
  image:
    repository: zilliz/attu
    tag: v2.3.10
    pullPolicy: IfNotPresent
  service:
    annotations: {}
    labels: {}
    type: NodePort
    port: 3000
    # loadBalancerIP: ""
  resources: {}
  podLabels: {}
  ingress:
    enabled: false
    ingressClassName: ""
    annotations: {}
    # Annotation example: set nginx ingress type
    # kubernetes.io/ingress.class: nginx
    labels: {}
    hosts:
      - milvus-attu.local
    tls: []
    #  - secretName: chart-attu-tls
    #    hosts:
    #      - milvus-attu.local

## For this testing, Milvus vector database version 2.5.2 is used. Set the tag to “latest” if you would like to use latest version
## For HSNW CPU based index, use version v2.5.2; For GPU-Optmized Indexes of Milvus, use version v2.5.2-gpu

image:
  all:
    repository: milvusdb/milvus
    tag: v2.5.2-gpu
    pullPolicy: IfNotPresent

## For HSNW CPU based index, do not mentioned below section that contains the GPU details.
## Update the number of GPUs to be assigned to the Query and Index nodes

indexNode:
  resources:
    requests:
      nvidia.com/gpu: "1"
    limits:
      nvidia.com/gpu: "1"
```

```
queryNode:
  resources:
    requests:
      nvidia.com/gpu: "1"
    limits:
      nvidia.com/gpu: "1"

dataNode:
  replicas: 2

minio:
  enabled: false

# Update host, accessKey, secretKey and bucketName based on your setup
externalS3:
  enabled: true
  host: "192.168.40.40"
  port: "80"
  accessKey: "<<Access Key>>"
  secretKey: "<<Secret Key>>"
  useSSL: false
  bucketName: "aa06-milvus-bkt"
  rootPath: ""
  useIAM: false
  cloudProvider: ""
  iamEndpoint:

#####################custom_values.yaml for standalone Milvus deployment #############

attu:
  enabled: true
  name: attu
  image:
    repository: zilliz/attu
    tag: v2.3.10
    pullPolicy: IfNotPresent
  service:
    annotations: {}
    labels: {}
    type: NodePort
    port: 3000
    # loadBalancerIP: ""
  resources: {}
  podLabels: {}
  ingress:
    enabled: false
    ingressClassName: ""
    annotations: {}
    # Annotation example: set nginx ingress type
    # kubernetes.io/ingress.class: nginx
    labels: {}
    hosts:
      - milvus-attu.local
    tls: []
    #  - secretName: chart-attu-tls
    #    hosts:
    #      - milvus-attu.local

## For this testing, Milvus vector database version 2.5.2 is used. Set the tag to “latest” if you would like
to use latest version
## For HSNW CPU based index, use version v2.5.2; For GPU-Optmized Indexes of Milvus, use version v2.5.2-gpu

image:
  all:
    repository: milvusdb/milvus
    tag: v2.5.2-gpu
    pullPolicy: IfNotPresent

## For HSNW CPU based index, do not make use of GPUs. Hence GPU section can be ignored.
## Update the number of GPUs to be assigned to the Query and Index nodes

standalone:
  resources:
    requests:
      nvidia.com/gpu: "1"
    limits:
      nvidia.com/gpu: "1"

minio:
  enabled: false

# Update host, accessKey, secretKey and bucketName based on your setup
externalS3:
  enabled: true
  host: "192.168.40.40"
  port: "80"
  accessKey: "<<Access Key>>"
  secretKey: "<<Secret Key>>"
  useSSL: false
  bucketName: "aa06-milvus-bkt"

  rootPath: ""

  useIAM: false

  cloudProvider: ""

  iamEndpoint:
```

Step 5. Install the helm chart and point to the previously created file using -f argument as shown below:

```
### use below command to deploy distributed Milvus vector database

helm install milvus-deployment  milvus/milvus -f custom_value.yaml -n milvus


### use below command to deploy standard Milvus vector database

helm install milvus-deployment milvus/milvus --set cluster.enabled=false --set etcd.replicaCount=1 --set
minio.mode=standalone --set pulsar.enabled=false -f s3-milvus-gpuimage_stand.yaml -n milvus
```

Step 6. Check the status of the pods:

```
oc get pods -n milvus
```

All pods should be running and in a ready state within couple of minutes:

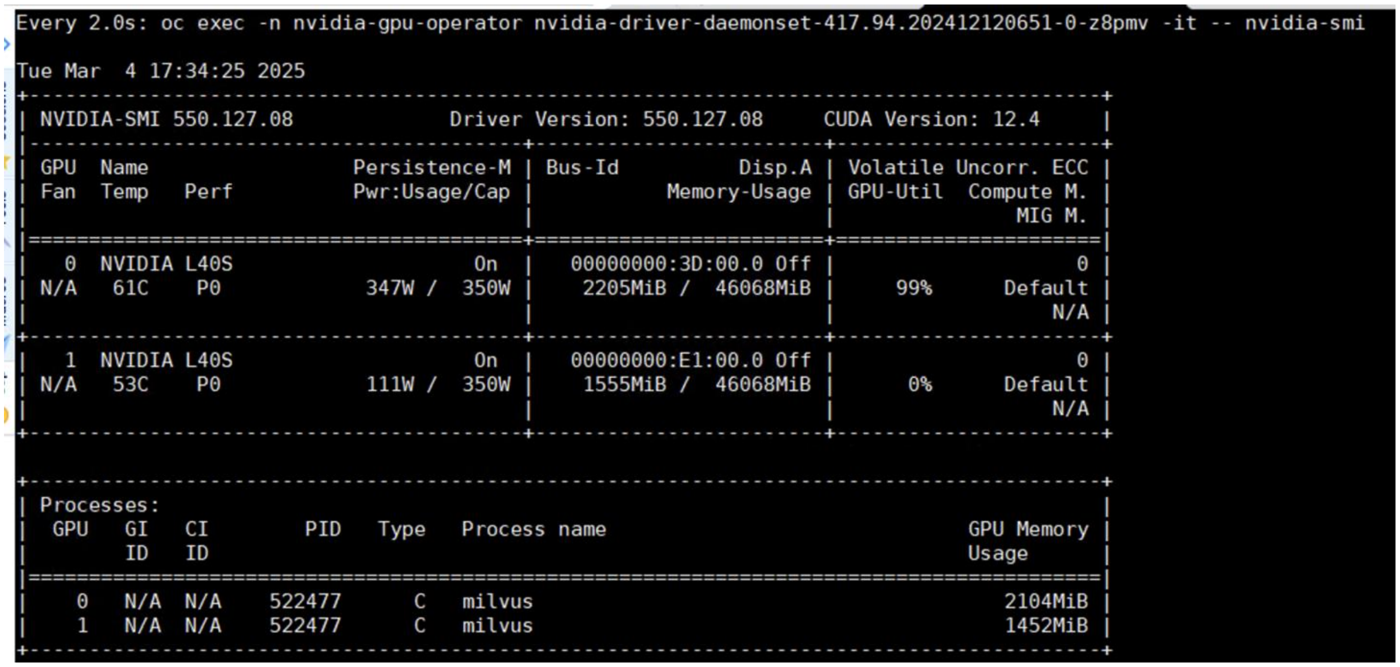
```
[root@aa06-rhel9 milvus]# oc get all -n milvus

Warning: apps.openshift.io/v1 DeploymentConfig is deprecated in v4.14+, unavailable in v4.10000+

Warning: kubevirt.io/v1 VirtualMachineInstancePresets is now deprecated and will be removed in v2.

NAME                                                  READY   STATUS      RESTARTS        AGE

pod/milvus-cli                                        1/1     Running     0               59d

pod/milvus-deployment-attu-c5f766b57-gnkrx            1/1     Running     0               4m55s

pod/milvus-deployment-datanode-6ffcfc775b-rd8sz       1/1     Running     2 (4m33s ago)   4m55s

pod/milvus-deployment-datanode-6ffcfc775b-s7mpb       1/1     Running     2 (4m33s ago)   4m55s

pod/milvus-deployment-etcd-0                          1/1     Running     0               4m55s

pod/milvus-deployment-etcd-1                          1/1     Running     0               4m55s

pod/milvus-deployment-etcd-2                          1/1     Running     0               4m55s

pod/milvus-deployment-indexnode-85987bc575-fbxm4      1/1     Running     2 (4m33s ago)   4m55s

pod/milvus-deployment-mixcoord-76cc8fd974-ctq5p       1/1     Running     2 (4m33s ago)   4m55s

pod/milvus-deployment-proxy-6f88b49dd6-xqvk9          1/1     Running     2 (4m33s ago)   4m55s

pod/milvus-deployment-pulsarv3-bookie-0               1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-bookie-1               1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-bookie-2               1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-bookie-init-szcb4      0/1     Completed   0               4m55s

pod/milvus-deployment-pulsarv3-broker-0               1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-broker-1               1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-proxy-0                1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-proxy-1                1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-pulsar-init-n7lnf      0/1     Completed   0               4m55s

pod/milvus-deployment-pulsarv3-recovery-0             1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-zookeeper-0            1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-zookeeper-1            1/1     Running     0               4m55s

pod/milvus-deployment-pulsarv3-zookeeper-2            1/1     Running     0               4m55s
```

```
pod/milvus-deployment-querynode-7d8f4b9f49-5pmkb   1/1     Running     2 (4m33s ago)   4m55s


NAME                                             TYPE        CLUSTER-IP       EXTERNAL-IP   PORT(S)
AGE
service/milvus-deployment                        ClusterIP   172.30.199.87    <none>        19530/TCP,9091/TCP
4m55s
service/milvus-deployment-attu                   NodePort    172.30.203.187   <none>        3000:30245/TCP
4m55s
service/milvus-deployment-datanode               ClusterIP   None             <none>        9091/TCP
4m55s
service/milvus-deployment-etcd                   ClusterIP   172.30.29.129    <none>        2379/TCP,2380/TCP
4m55s
service/milvus-deployment-etcd-headless          ClusterIP   None             <none>        2379/TCP,2380/TCP
4m55s
service/milvus-deployment-indexnode              ClusterIP   None             <none>        9091/TCP
4m55s
service/milvus-deployment-mixcoord               ClusterIP   172.30.36.164    <none>        9091/TCP
4m55s
service/milvus-deployment-pulsarv3-bookie        ClusterIP   None             <none>        3181/TCP,8000/TCP
4m55s
service/milvus-deployment-pulsarv3-broker        ClusterIP   None             <none>        8080/TCP,6650/TCP
4m55s
service/milvus-deployment-pulsarv3-proxy         ClusterIP   172.30.103.87    <none>        80/TCP,6650/TCP
4m55s
service/milvus-deployment-pulsarv3-recovery      ClusterIP   None             <none>        8000/TCP
4m55s
service/milvus-deployment-pulsarv3-zookeeper     ClusterIP   None             <none>
8000/TCP,2888/TCP,3888/TCP,2181/TCP   4m55s
service/milvus-deployment-querynode              ClusterIP   None             <none>        9091/TCP
4m55s


NAME                                            READY   UP-TO-DATE   AVAILABLE   AGE
deployment.apps/milvus-deployment-attu          1/1     1            1           4m55s
deployment.apps/milvus-deployment-datanode      2/2     2            2           4m55s
deployment.apps/milvus-deployment-indexnode     1/1     1            1           4m55s
deployment.apps/milvus-deployment-mixcoord      1/1     1            1           4m55s
deployment.apps/milvus-deployment-proxy         1/1     1            1           4m55s
deployment.apps/milvus-deployment-querynode     1/1     1            1           4m55s


NAME                                                        DESIRED   CURRENT   READY   AGE
replicaset.apps/milvus-deployment-attu-c5f766b57           1         1         1       4m55s
replicaset.apps/milvus-deployment-datanode-6ffcfc775b      2         2         2       4m55s
replicaset.apps/milvus-deployment-indexnode-85987bc575     1         1         1       4m55s
replicaset.apps/milvus-deployment-mixcoord-76cc8fd974      1         1         1       4m55s
replicaset.apps/milvus-deployment-proxy-6f88b49dd6         1         1         1       4m55s
replicaset.apps/milvus-deployment-querynode-7d8f4b9f49     1         1         1       4m55s


NAME                                                      READY   AGE
statefulset.apps/milvus-deployment-etcd                   3/3     4m55s
statefulset.apps/milvus-deployment-pulsarv3-bookie        3/3     4m55s
statefulset.apps/milvus-deployment-pulsarv3-broker      2/2     4m55s
statefulset.apps/milvus-deployment-pulsarv3-proxy       2/2     4m55s
statefulset.apps/milvus-deployment-pulsarv3-recovery    1/1     4m55s
statefulset.apps/milvus-deployment-pulsarv3-zookeeper   3/3     4m55s

NAME                                              STATUS     COMPLETIONS   DURATION   AGE
job.batch/milvus-deployment-pulsarv3-bookie-init   Complete   1/1           15s        4m55s
job.batch/milvus-deployment-pulsarv3-pulsar-init   Complete   1/1           23s        4m55s
[root@aa06-rhel9 milvus]#
```

The milvus version used in the solution is 2.5.3:

```
[root@aa06-rhel9 milvus]# helm list -n milvus
NAME                    NAMESPACE       REVISION        UPDATED                                 STATUS
CHART           APP VERSION
milvus-deployment       milvus          1               2025-03-17 00:24:27.338223289 -0400 EDT deployed
milvus-4.2.36   2.5.3
[root@aa06-rhel9 milvus]#
```

When GPU-optimized Milvus is deployed, the consumption of GPUs by Milvus components such as query node or Index node can be verified using **nvidia-smi** command as shown below. In this screenshot, two GPU are being consumed by the distributed Milvus deployment as query node and index node pods are scheduled on the same worker node.



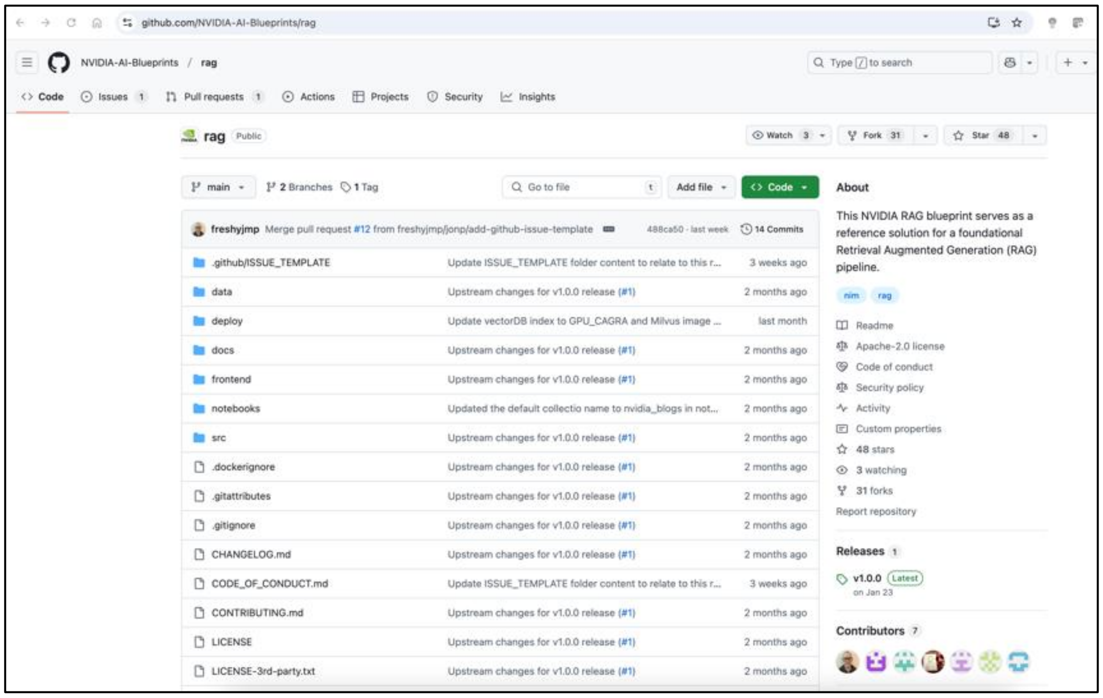
```
Every 2.0s: oc exec -n nvidia-gpu-operator nvidia-driver-daemonset-417.94.202412120651-0-z8pmv -it -- nvidia-smi

Tue Mar  4 17:34:25 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 550.127.08             Driver Version: 550.127.08     CUDA Version: 12.4     |
|-----------------------------------------+------------------------+----------------------+
| 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 L40S                    On  |   00000000:3D:00.0 Off |                    0 |
| N/A   61C    P0            347W /  350W |    2205MiB /  46068MiB |     99%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+
|   1  NVIDIA L40S                    On  |   00000000:E1:00.0 Off |                    0 |
| N/A   53C    P0            111W /  350W |    1555MiB /  46068MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI        PID   Type   Process name                              GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|    0   N/A  N/A    522477      C   milvus                                       2104MiB |
|    1   N/A  N/A    522477      C   milvus                                       1452MiB |
+-----------------------------------------------------------------------------------------+
```

RAG Blueprint

This blueprint serves as a reference solution for a foundational Retrieval Augmented Generation (RAG) pipeline. Foundational RAG Pipeline blueprint is available in NVIDIA AI Blueprints GitHub.

Procedure 1. Deploy the RAG pipeline using the RAG blueprint version 1.0.1.

Step 1. Fork the NVIDIA-AI-Blueprints/rag repository on GitHub - https://github.com/NVIDIA-AI-Blueprints.



.github/ISSUE_TEMPLATE	Update ISSUE_TEMPLATE folder content to relate to this r...	3 weeks ago
data	Upstream changes for v1.0.0 release (#1)	2 months ago
deploy	Update vectorDB index to GPU_CAGRA and Milvus image ...	last month
docs	Upstream changes for v1.0.0 release (#1)	2 months ago
frontend	Upstream changes for v1.0.0 release (#1)	2 months ago
notebooks	Updated the default collectio name to nvidia_blogs in not...	2 months ago
src	Upstream changes for v1.0.0 release (#1)	2 months ago
.dockerignore	Upstream changes for v1.0.0 release (#1)	2 months ago
.gitattributes	Upstream changes for v1.0.0 release (#1)	2 months ago
.gitignore	Upstream changes for v1.0.0 release (#1)	2 months ago
CHANGELOG.md	Upstream changes for v1.0.0 release (#1)	2 months ago
CODE_OF_CONDUCT.md	Update ISSUE_TEMPLATE folder content to relate to this r...	3 weeks ago
CONTRIBUTING.md	Upstream changes for v1.0.0 release (#1)	2 months ago
LICENSE	Upstream changes for v1.0.0 release (#1)	2 months ago
LICENSE-3rd-party.txt	Upstream changes for v1.0.0 release (#1)	2 months ago

This NVIDIA RAG blueprint serves as a reference solution for a foundational Retrieval Augmented Generation (RAG) pipeline.

Step 2. Clone the forked copy of this repository:

```
git clone https://github.com/<your-username>/rag-blueprint.git -b v1.0.0
```

Step 3. Navigate to rag/deploy/helm/charts.

Note: This directory contains multiple helm charts for deploying required NIMs and Milvus. Since NIMs and Milvus are deployed, you don't need to install them as part of Blueprint. Hence all the directories under charts can be deleted.

Step 4. Navigate to rag/deploy/templates directory. Open the file rag-server-sts.yaml:

Note: In **spec.template.spec.initContainers**, there is a command which waits for the reranking, embedding and milvus services to be up before bringing up the RAG blueprint. Update that line with the services you defined.

```
[root@aa06-rhel9 blueprint]# oc get svc -n nim
NAME                           TYPE        CLUSTER-IP       EXTERNAL-IP    PORT(S)
embedqa                        NodePort    172.30.103.111   <none>         8000:30765/TCP
llm                            NodePort    172.30.73.126    <none>         8000:30604/TCP
rerankqa                       NodePort    172.30.160.141   <none>         8000:32630/TCP

[root@aa06-rhel9 blueprint]# oc -n milvus get svc
NAME                                   TYPE        CLUSTER-IP       EXTERNAL-IP    PORT(S)
milvus-deployment                      ClusterIP   172.30.192.196   <none>         19530/TCP,9091/TCP
milvus-deployment-attu                 NodePort    172.30.99.124    <none>         3000:32160/TCP
milvus-deployment-etcd                 ClusterIP   172.30.172.6     <none>         2379/TCP,2380/TCP
milvus-deployment-etcd-headless        ClusterIP   None             <none>         2379/TCP,2380/TCP
milvus-deployment-pulsarv3-bookie      ClusterIP   None             <none>         3181/TCP,8000/TCP
milvus-deployment-pulsarv3-broker      ClusterIP   None             <none>         8080/TCP,6650/TCP
milvus-deployment-pulsarv3-proxy       ClusterIP   172.30.24.192    <none>         80/TCP,6650/TCP
```

```
milvus-deployment-pulsarv3-recovery    ClusterIP   None             <none>        8000/TCP

milvus-deployment-pulsarv3-zookeeper   ClusterIP   None             <none>
8000/TCP,2888/TCP,3888/TCP,2181/TCP
```

Step 5. In the previous example, embedqa is the service for Embedding model, rerankqa is the service for re-ranking model in nim namespace and milvus-deployment is the service for Milvus in milvus namespace. To update, run the following:

```
initContainers:

      - name: init-check-rag-server

        imagePullPolicy: Always

        image: nvcr.io/nvidia/base/ubuntu:22.04_20240212

        command:

        - /bin/bash

        - -c

        - |

          apt update && apt install curl -y &&

          until curl -sf http://rerankqa.nim:8000/v1/health/ready  && curl -sf
http://embedqa.nim:8000/v1/health/ready && curl -sf http://milvus-deployment.milvus:9091/healthz ; do

            echo "Waiting for all APIs to be healthy..."

            sleep 10

          done

          echo "Grace time for all services to be ready after health check passes.."

          sleep 30
```

Step 6. The RAG Blueprint application can be kept in a separate namespace. You are creating a namespace called rag and deploy the RAG Blueprint in rag namespace:

```
oc create namespace rag
```

Step 7. The RAG Blueprint makes use of default service account. This default service account in the rag namespace should have the ability to run pods with any user ID, overriding the default restrictions. You can also configure a custom service account if required:

```
oc adm policy  add-scc-to-user  anyuid -z default -n rag
```

Step 8. Blueprint uses the NGC API key as an image pull secret to download container images and models from NVIDIA NGC. Add a Docker registry secret for downloading the NIM container image from NVIDIA NGC:

```
oc create secret -n rag docker-registry ngc-secret \

    --docker-server=nvcr.io \

    --docker-username='$oauthtoken' \

    --docker-password=<ngc-api-key>
```

Step 9. Add a generic secret that the model puller init container uses to download the model from NVIDIA NGC:

```
oc create secret -n rag generic ngc-api-secret \

    --from-literal=NGC_API_KEY=<ngc-api-key>
```

Step 10. Open the file rag/deploy/helm/values.yaml.

Step 11. Update the file with server URL and Model name for LLM, Embedding and Reranking models in the env section.

Step 12. Get the model's name and other information of the models deployed using v1/models API endpoint:

```
[root@aa06-rhel9 blueprint]# curl http://10.106.1.33:30765/v1/models

{"object":"list","data":[{"id":"nvidia/llama-3.2-nv-embedqa-1b-
v2","created":0,"object":"model","owned_by":"organization-owner"}]}



[root@aa06-rhel9 blueprint]# curl http://10.106.1.33:30765/v1/models

{"object":"list","data":[{"id":"nvidia/llama-3.2-nv-embedqa-1b-
v2","created":0,"object":"model","owned_by":"organization-owner"}]}



[root@aa06-rhel9 blueprint]# curl http://10.106.1.33:32630/v1/models

{"object":"list","data":[{"id":"nvidia/llama-3.2-nv-rerankqa-1b-v2"}]}
```

Sample environment values:

```
env:
      EXAMPLE_PATH: 'src/'
      PROMPT_CONFIG_FILE: "/prompt.yaml"
      APP_VECTORSTORE_URL: "http://milvus-deployment.milvus:19530"
      APP_VECTORSTORE_NAME: "milvus"
      APP_VECTORSTORE_INDEXTYPE: GPU_CAGRA
      COLLECTION_NAME: nvidia_blogs
      APP_LLM_SERVERURL: "llm.nim:8000"
      APP_LLM_MODELNAME: meta/llama-3.1-8b-instruct
      APP_LLM_MODELENGINE: nvidia-ai-endpoints
      APP_EMBEDDINGS_SERVERURL: "embedqa.nim:8000"
      APP_EMBEDDINGS_MODELNAME: nvidia/llama-3.2-nv-embedqa-1b-v2
      APP_EMBEDDINGS_MODELENGINE: nvidia-ai-endpoints
      APP_RANKING_MODELNAME: nvidia/llama-3.2-nv-rerankqa-1b-v2
      APP_RANKING_MODELENGINE: nvidia-ai-endpoints
      APP_RANKING_SERVERURL: "rerankqa.nim:8000"
      APP_TEXTSPLITTER_MODELNAME: nvidia/llama-3.2-nv-embedqa-1b-v1
      APP_TEXTSPLITTER_CHUNKSIZE: 2000
      APP_TEXTSPLITTER_CHUNKOVERLAP: 200
      APP_RETRIEVER_SCORETHRESHOLD: 0.25
      CONVERSATION_HISTORY: 5
      APP_RETRIEVER_TOPK: 4
      VECTOR_DB_TOPK: 20
      LOGLEVEL: INFO
      ENABLE_MULTITURN: true
      ENABLE_QUERYREWRITER: true
```

Step 13. Update the imagePullSecret:

```
imagePullSecret:
  name: "ngc-secret"
```

Step 14. Set the concurrent users:

```
ragServer:
  concurrentWorkers: 32
  image:
    repository: nvcr.io/nvidia/blueprint/rag-server
    tag: "1.0.0"
    pullPolicy: IfNotPresent
```

Step 15. Update the LLM model in the ragPlayground:

```
ragPlayground:
  image:
    repository: nvcr.io/nvidia/blueprint/rag-playground
    tag: "1.0.0"
    pullPolicy: IfNotPresent
  name: rag-playground
  replicas: 1
  nodeSelector: {}
  tolerations: {}
  affinity: {}
  env:
      APP_SERVERURL: "http://rag-server"
      APP_SERVERPORT: 8081
      APP_MODELNAME: meta/llama-3.1-8b-instruct
  service:
      type: NodePort
      targetPort: 8090
      ports:
        - port: 8090
          targetPort: http
          protocol: TCP
          name: http
```

Procedure 2. Install RAG Blueprint

Step 1. Navigate to rag/deploy/helm directory and do helm install:

```
helm install rag . -n rag
```

Step 2. Make sure pods and services are up for rag-server and rag-playground:

```
[root@aa06-rhel9 helm]# oc -n rag get pods
NAME                READY   STATUS    RESTARTS   AGE
rag-playground-0    1/1     Running   0          75m
rag-server-0        1/1     Running   0          75m
```

```
[root@aa06-rhel9 helm]# oc -n rag get svc
NAME              TYPE        CLUSTER-IP       EXTERNAL-IP    PORT(S)          AGE
rag-playground    NodePort    172.30.29.46     <none>         8090:32665/TCP   70m
rag-server        NodePort    172.30.156.186   <none>         8081:32068/TCP   70m
```

The RAG Server is running on NodePort 32068, and RAG Playground is running on 32665.

Access Services and Application

NIMs can be installed independently using its respective helm charts from https://catalog.ngc.nvidia.com/helm-charts. It can also be installed and managed using NVIDIA NIM Operator. In this design, NIMs will be installed and managed using NVIDIA NIM Operator.

Procedure 1. Access RAG Playground

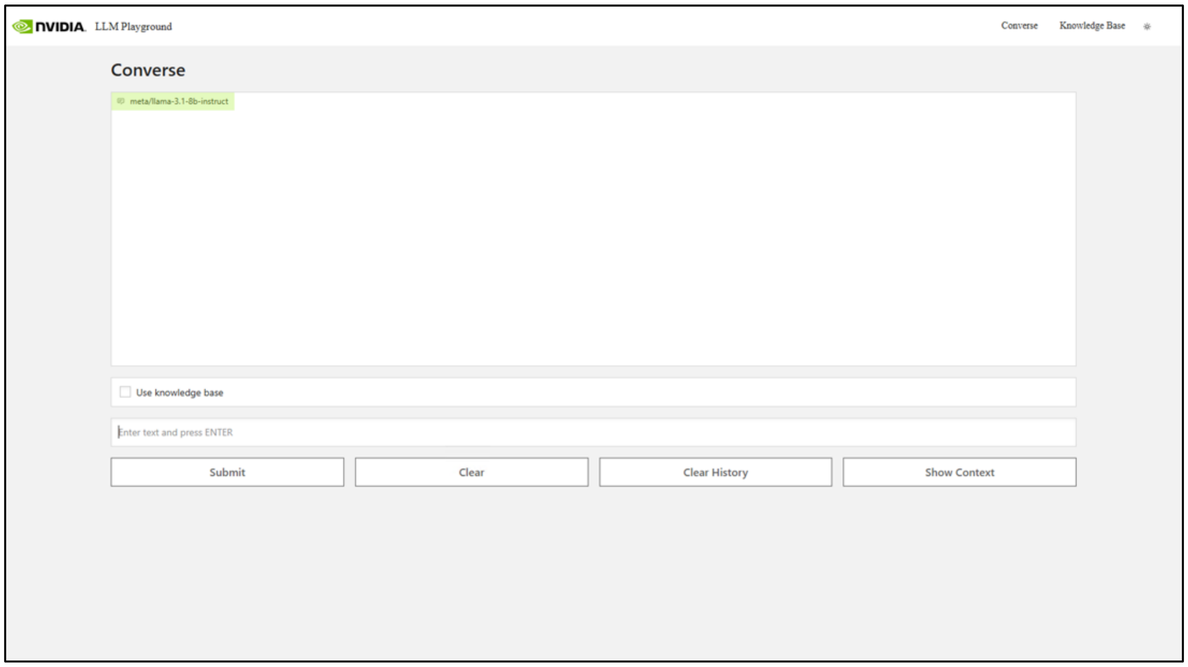
Step 1. RGA Playground can be accessed using any of the node's IP or DNS name and port:

```
http://<Node_IP/DNS>:32665
```

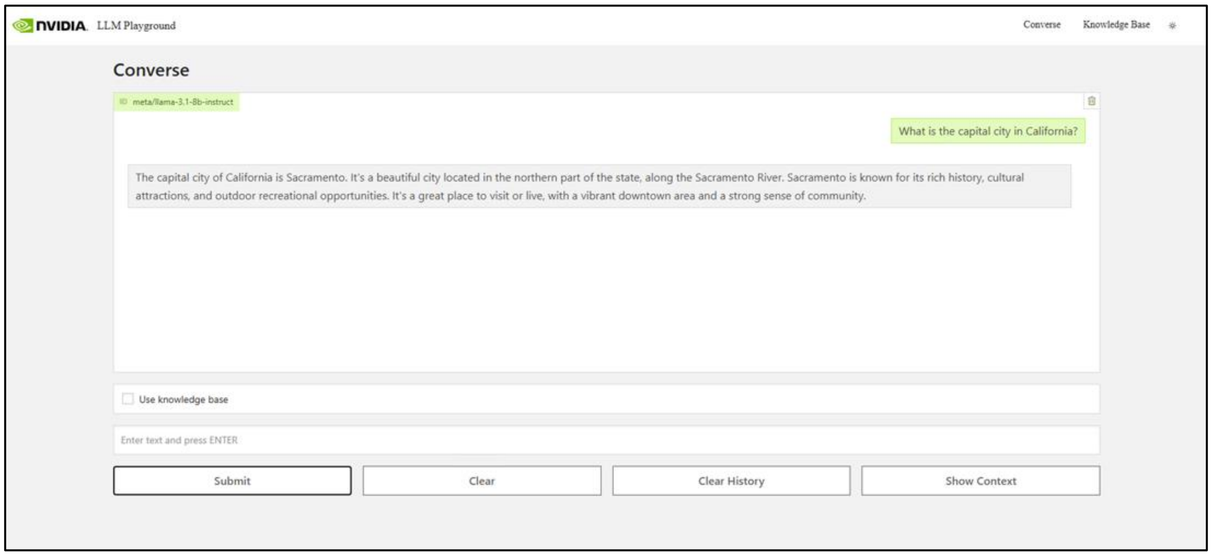
Step 2. You can access the application running on port 8090 of rag-playground service in rag namespace on localhost port 30001 using the following command:

```
oc -n rag port-forward service/rag-playground 30001:8090
```

Step 3. Open browser and access the rag-playground UI.



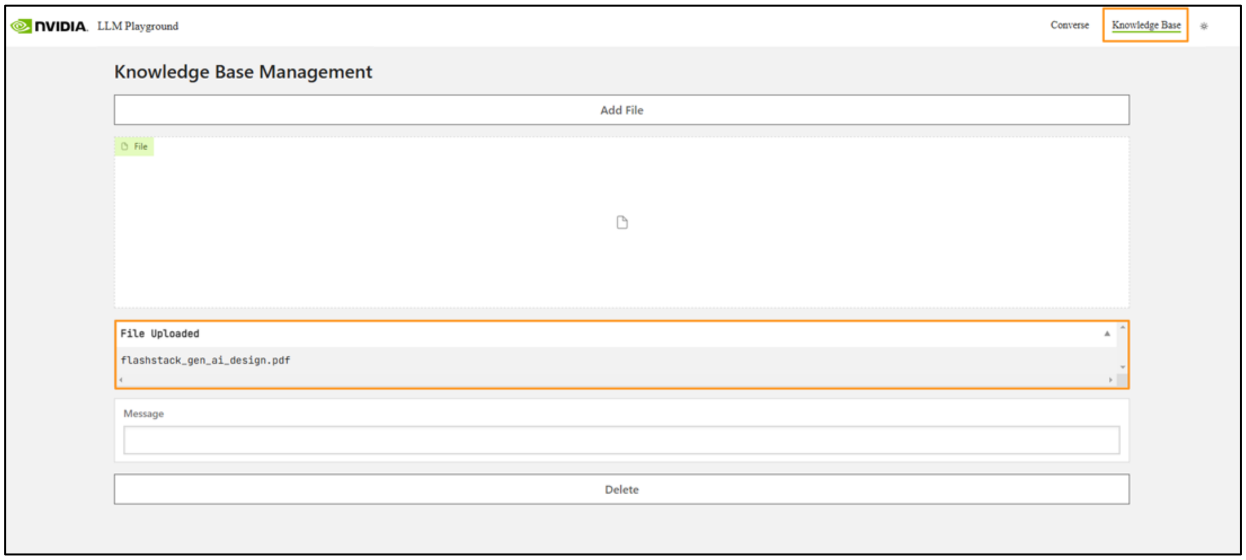
Step 4. Submit a question and make sure you get response from LLM.



What is the capital city in California?

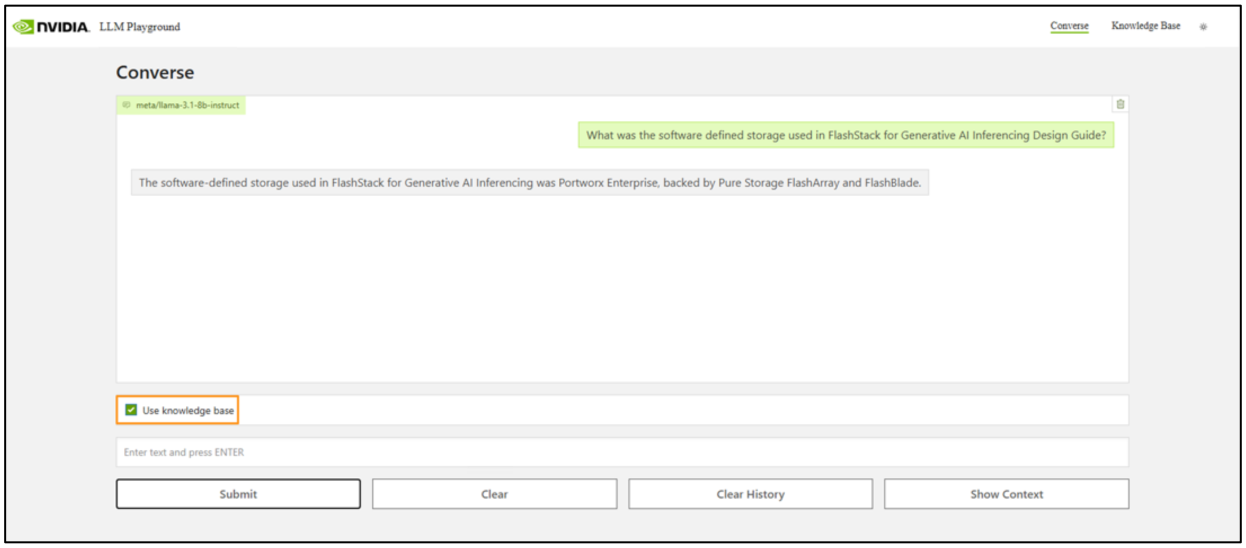
The capital city of California is Sacramento. It's a beautiful city located in the northern part of the state, along the Sacramento River. Sacramento is known for its rich history, cultural attractions, and outdoor recreational opportunities. It's a great place to visit or live, with a vibrant downtown area and a strong sense of community.

Step 5. Click **Knowledge Base** and upload a document to Knowledge Base and make sure it's updated.



```
File Uploaded
flashstack_gen_ai_design.pdf
```

Step 6. Click **Converse**. Ask a question. Click **Use Knowledge Base** so that LLM refers to the uploaded document to provide an accurate answer.



What was the software defined storage used in FlashStack for Generative AI Inferencing Design Guide?

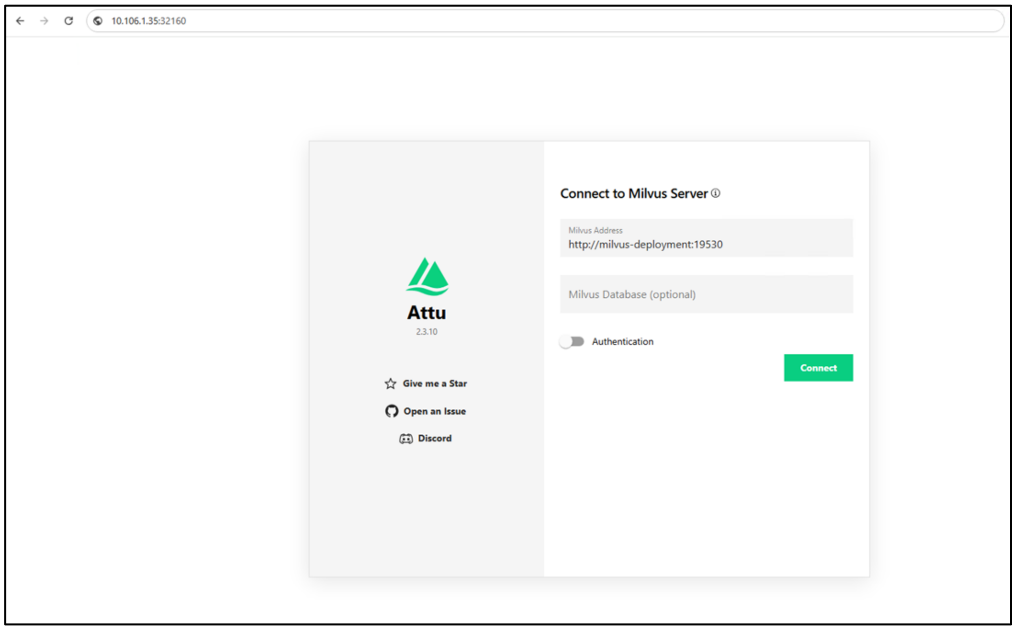
The software-defined storage used in FlashStack for Generative AI Inferencing was Portworx Enterprise, backed by Pure Storage FlashArray and FlashBlade.

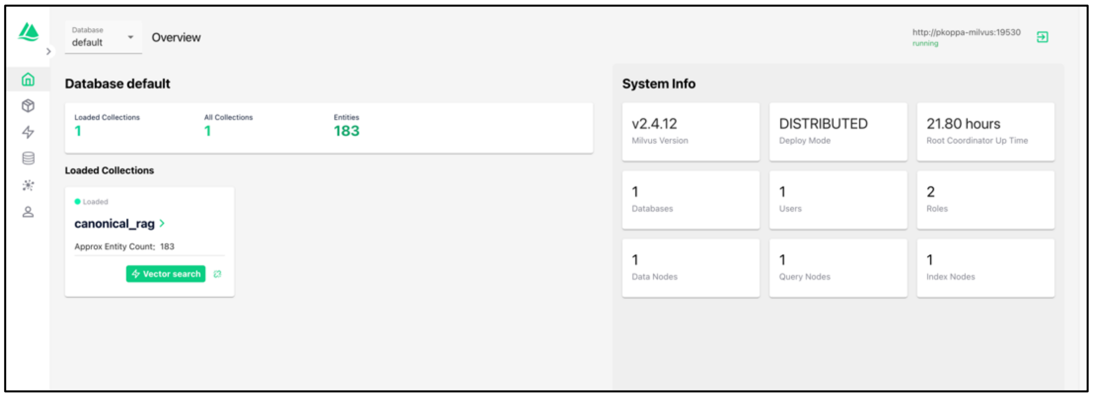
Procedure 2. Milvus Vector Database

Step 1. Get the compute node IP/DNS for one of the nodes and get the node port for Attu:

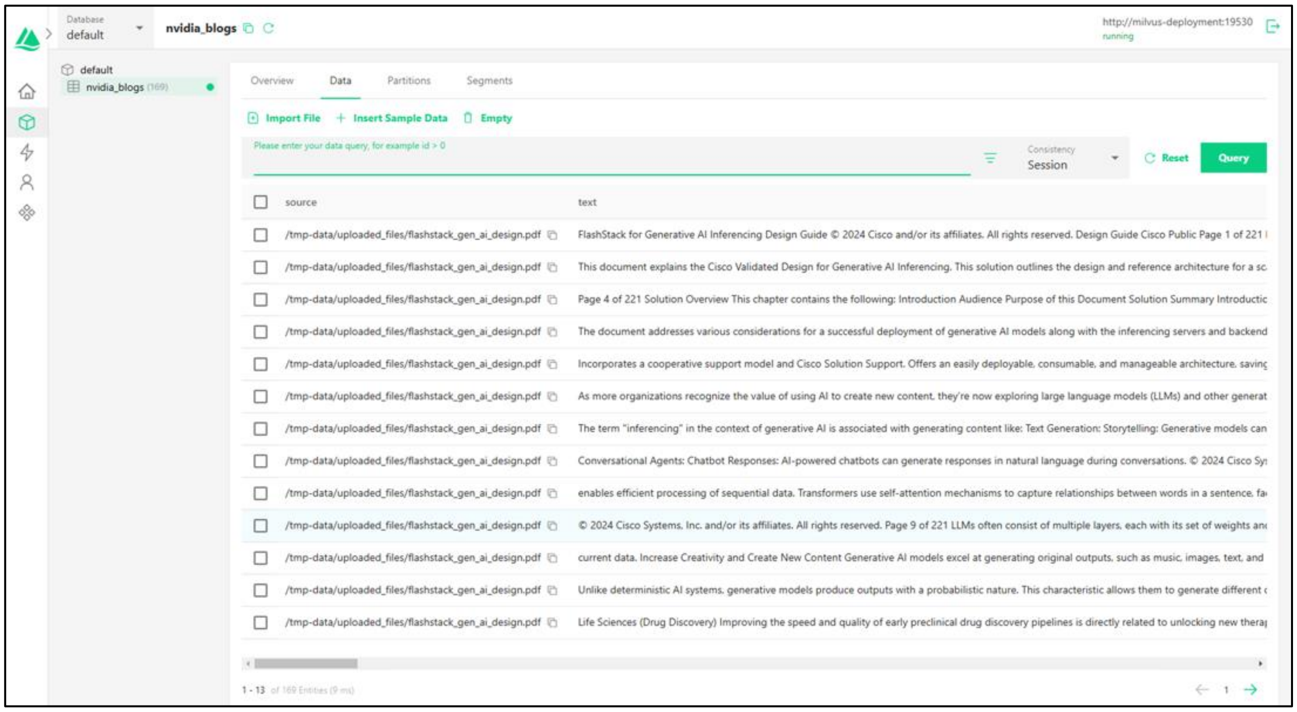
```
[root@aa06-rhel9 helm]# oc -n milvus get svc
NAME                                      TYPE        CLUSTER-IP       EXTERNAL-IP   PORT(S)
milvus-deployment                         ClusterIP   172.30.192.196   <none>        19530/TCP,9091/TCP
milvus-deployment-attu                    NodePort    172.30.99.124    <none>        3000:32160/TCP
milvus-deployment-etcd                    ClusterIP   172.30.172.6     <none>        2379/TCP,2380/TCP
milvus-deployment-etcd-headless           ClusterIP   None             <none>        2379/TCP,2380/TCP
milvus-deployment-pulsarv3-bookie         ClusterIP   None             <none>        3181/TCP,8000/TCP
milvus-deployment-pulsarv3-broker         ClusterIP   None             <none>        8080/TCP,6650/TCP
milvus-deployment-pulsarv3-proxy          ClusterIP   172.30.24.192    <none>        80/TCP,6650/TCP
milvus-deployment-pulsarv3-recovery       ClusterIP   None             <none>        8000/TCP
milvus-deployment-pulsarv3-zookeeper      ClusterIP   None             <none>
8000/TCP,2888/TCP,3888/TCP,2181/TCP
```

Step 2. Access Attu, the UI interface for Milvus vector database using Node IP and NodePort and click on Connect.





Step 3. Click the **default database** and select the **collection** and navigate to **Data** and observe that embeddings are stored in **Milvus.**



source	text
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	FlashStack for Generative AI Inferencing Design Guide © 2024 Cisco and/or its affiliates. All rights reserved. Design Guide Cisco Public Page 1 of 221
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	This document explains the Cisco Validated Design for Generative AI Inferencing. This solution outlines the design and reference architecture for a sc
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	Page 4 of 221 Solution Overview This chapter contains the following: Introduction Audience Purpose of this Document Solution Summary Introductic
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	The document addresses various considerations for a successful deployment of generative AI models along with the inferencing servers and backend
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	Incorporates a cooperative support model and Cisco Solution Support. Offers an easily deployable, consumable, and manageable architecture, saving
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	As more organizations recognize the value of using AI to create new content, they're now exploring large language models (LLMs) and other generat
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	The term "inferencing" in the context of generative AI is associated with generating content like: Text Generation: Storytelling: Generative models can
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	Conversational Agents: Chatbot Responses: AI-powered chatbots can generate responses in natural language during conversations. © 2024 Cisco Sy
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	enables efficient processing of sequential data. Transformers use self-attention mechanisms to capture relationships between words in a sentence, fa
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	© 2024 Cisco Systems, Inc. and/or its affiliates. All rights reserved. Page 9 of 221 LLMs often consist of multiple layers, each with its set of weights an
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	current data. Increase Creativity and Create New Content Generative AI models excel at generating original outputs, such as music, images, text, and
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	Unlike deterministic AI systems, generative models produce outputs with a probabilistic nature. This characteristic allows them to generate different
/tmp-data/uploaded_files/flashstack_gen_ai_design.pdf	Life Sciences (Drug Discovery) Improving the speed and quality of early preclinical drug discovery pipelines is directly related to unlocking new thera

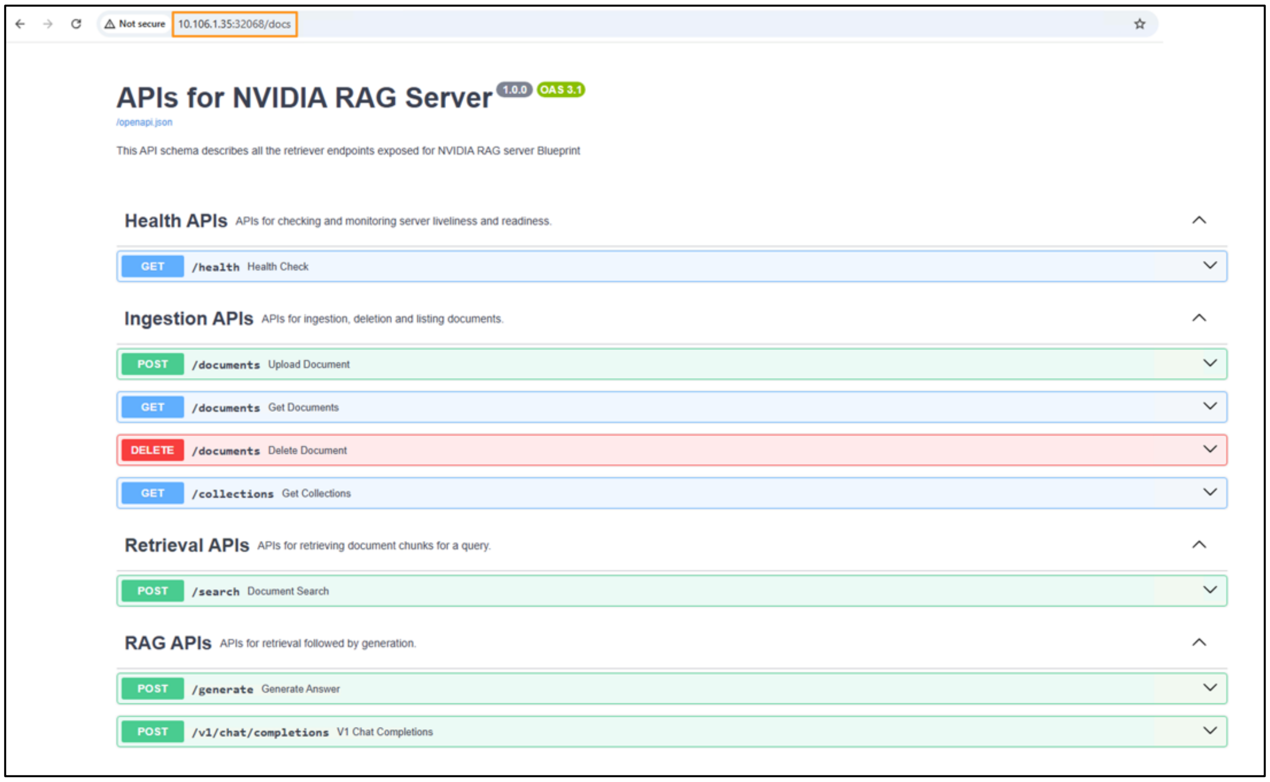
1 - 13 of 169 Entities (9 ms)

Procedure 3. RAG Server

Step 1. Get the compute node IP/DNS for one of the nodes and get the node port for rag-server:

```
[root@aa06-rhel9 helm]# oc get svc -n rag
NAME              TYPE       CLUSTER-IP       EXTERNAL-IP   PORT(S)          AGE
rag-playground    NodePort   172.30.29.46     <none>        8090:32665/TCP   174m
rag-server        NodePort   172.30.156.186   <none>        8081:32068/TCP   174m
```

Step 2. View all the APIs by accessing <Node_IP/DNS>:NodePort/docs endpoint.


Not secure 10.106.1.35:32068/docs

APIs for NVIDIA RAG Server 1.0.0 OAS 3.1

/openapi.json

This API schema describes all the retriever endpoints exposed for NVIDIA RAG server Blueprint

Health APIs APIs for checking and monitoring server liveliness and readiness.

GET /health Health Check

Ingestion APIs APIs for ingestion, deletion and listing documents.

POST /documents Upload Document

GET /documents Get Documents

DELETE /documents Delete Document

GET /collections Get Collections

Retrieval APIs APIs for retrieving document chunks for a query.

POST /search Document Search

RAG APIs APIs for retrieval followed by generation.

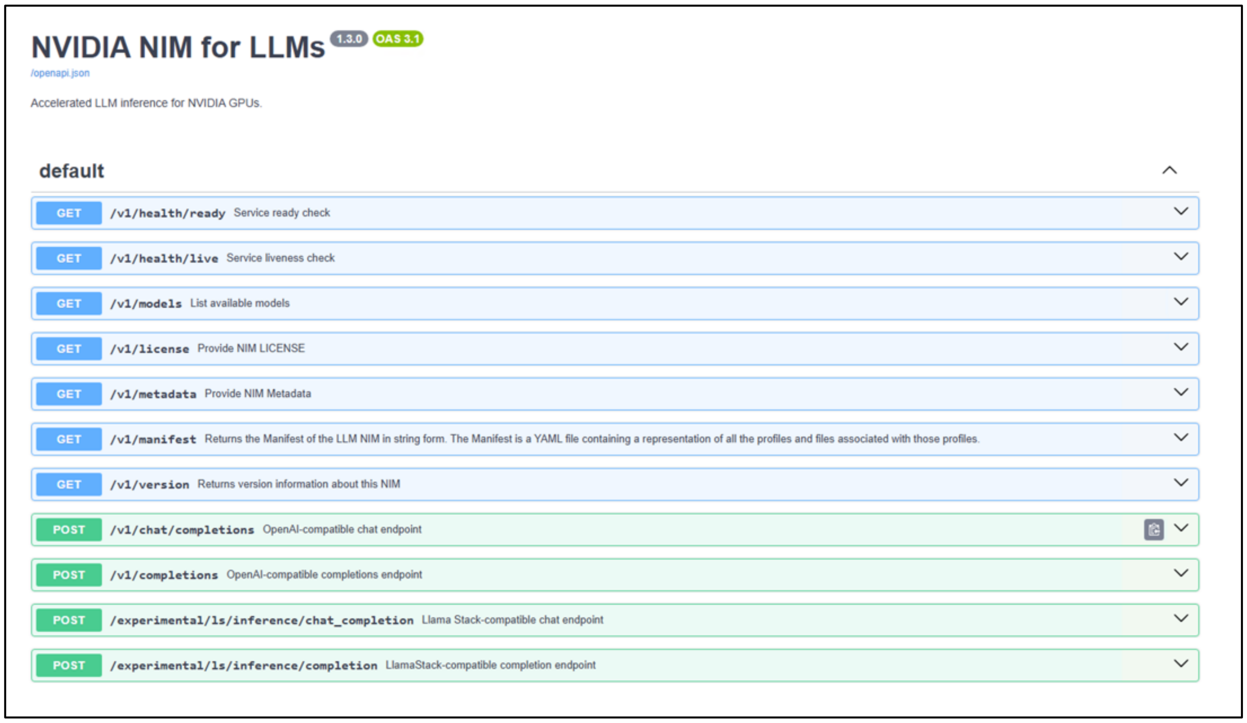
POST /generate Generate Answer

POST /v1/chat/completions V1 Chat Completions

NIM Services

Like the RAG Server, API documentation can be accessed for any NIMs with /docs endpoint.

APIs available for NIM for LLMs is shown below:


NVIDIA NIM for LLMs 1.3.0 OAS 3.1

/openapi.json

Accelerated LLM inference for NVIDIA GPUs.

default

GET /v1/health/ready Service ready check

GET /v1/health/live Service liveness check

GET /v1/models List available models

GET /v1/license Provide NIM LICENSE

GET /v1/metadata Provide NIM Metadata

GET /v1/manifest Returns the Manifest of the LLM NIM in string form. The Manifest is a YAML file containing a representation of all the profiles and files associated with those profiles.

GET /v1/version Returns version information about this NIM

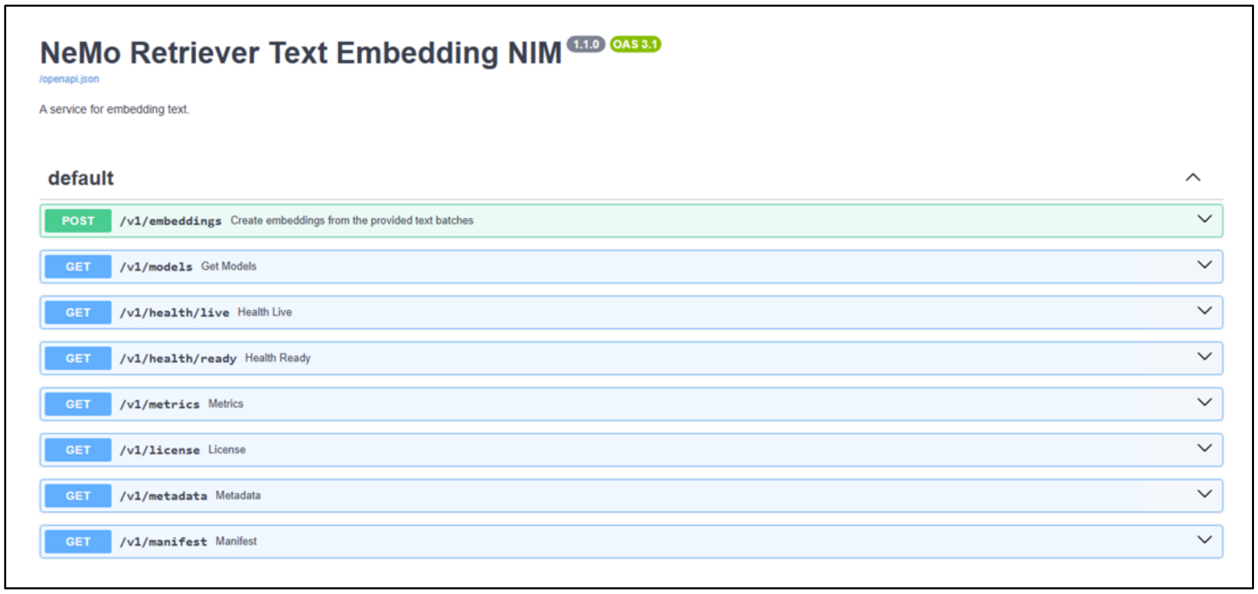
POST /v1/chat/completions OpenAI-compatible chat endpoint

POST /v1/completions OpenAI-compatible completions endpoint

POST /experimental/ls/inference/chat_completion Llama Stack-compatible chat endpoint

POST /experimental/ls/inference/completion LlamaStack-compatible completion endpoint

APIs available for NIM for NeMo Retriever Text Embedding NIM is shown below:



NeMo Retriever Text Embedding NIM 1.1.0 OAS 3.1

/openapi.json

A service for embedding text.

default

POST /v1/embeddings Create embeddings from the provided text batches

GET /v1/models Get Models

GET /v1/health/live Health Live

GET /v1/health/ready Health Ready

GET /v1/metrics Metrics

GET /v1/license License

GET /v1/metadata Metadata

GET /v1/manifest Manifest

Any API can be called referring to the API documentation. The example below shows the API to get embeddings for the test.

Request URL:

```
http://10.106.1.35:30765/v1/embeddings
```

Curl Request:

```
curl -X 'POST' \
  'http://10.106.1.35:30765/v1/embeddings' \
  -H 'accept: application/json' \
  -H 'Content-Type: application/json' \
  -d '{
  "input": "This is some text to be embedded.",
  "model": "nvidia/llama-3.2-nv-embedqa-1b-v2",
  "input_type": "passage",
  "encoding_format": "float",
  "dimensions": null,
  "user": "user-identifier",
  "truncate": "NONE"
}'
```

Benchmarking, Evaluation, and Sizing

This chapter contains the following:

This chapter examines the performance benchmarking of NIM for LLM, RAG Evaluation using RAGAS framework, Sizing guidance for GPU and model selection and vector database benchmarking.

NIM for LLM Benchmarking

Benchmarking the deployment of Large Language Models (LLMs) involves understanding key metrics such as inference latency and throughput, which are crucial for evaluating performance. Developers and enterprise system owners can utilize various benchmarking tools, each with distinct features and capabilities, to measure these metrics effectively.

GenAI-Perf is a tool for measuring and analyzing the performance indicators, ensuring their LLM deployments are optimized for efficiency and scalability.

How LLM Inference Works

Before examining benchmark metrics, it is crucial to understand the mechanics of LLM inference and the associated terminologies. An LLM application generates results through a multi-stage inference process. Initially, the user submits a query (prompt), which enters a queue, awaiting its turn for processing—this is the queuing phase. Next, the LLM model processes the prompt during the prefill phase. Finally, the model generates a response token by token in the generation phase.

A token, a fundamental concept in LLMs, serves as a core performance metric for LLM inference. It represents the smallest unit of natural language that the LLM processes. The aggregation of all tokens forms the vocabulary, with each LLM employing a tokenizer learned from data to efficiently represent input text. Typically, for many popular LLMs, one token approximates 0.75 English words.

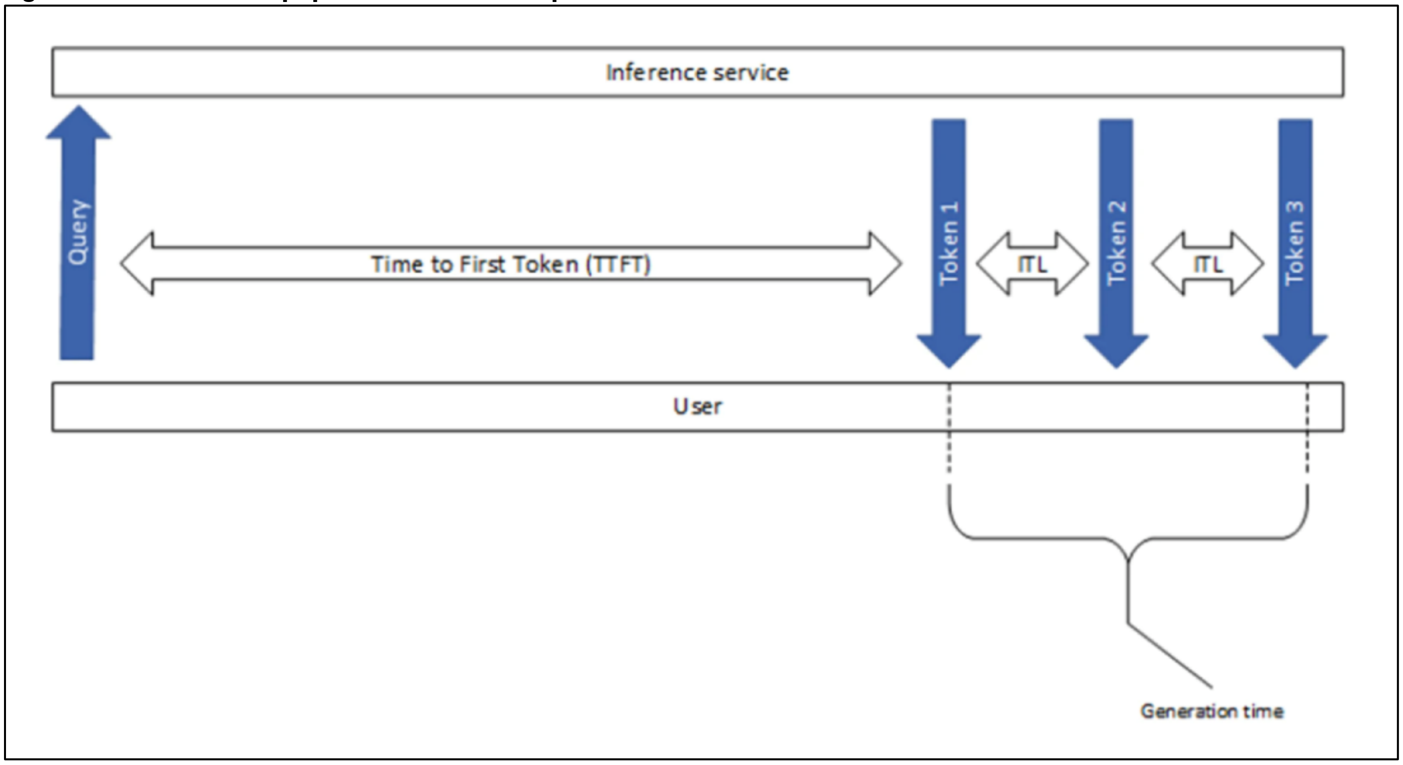
Sequence length pertains to the length of the data sequence. The Input Sequence Length (ISL) denotes the number of tokens the LLM receives, encompassing the user query, system prompts (e.g., model instructions), previous chat history, chain-of-thought reasoning, and documents from the retrieval-augmented generation (RAG) pipeline. The Output Sequence Length (OSL) indicates the number of tokens the LLM generates. Context length refers to the number of tokens the LLM utilizes at each generation step, including both input and output tokens generated thus far. Each LLM has a maximum context length that can be allocated to both input and output tokens.

Streaming is a feature that allows partial LLM outputs to be returned to users incrementally, in chunks of tokens generated so far. This is particularly advantageous for chatbot applications, where receiving an initial response quickly is desirable. While the user processes the partial content, the subsequent chunk of the result is generated in the background. Conversely, in non-streaming mode, the complete answer is returned in a single response.

Metrics

There can be variations in the benchmarking results between different tools. Figure 20 illustrates some of the widely used LLM inference metrics.

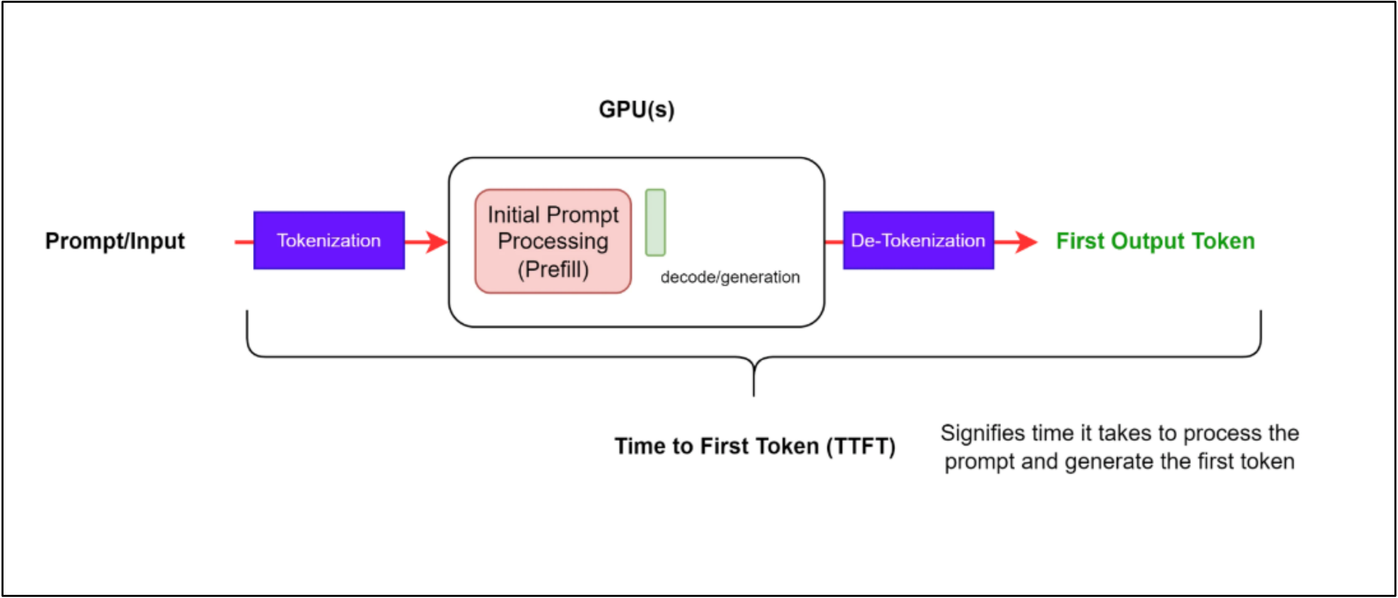
Figure 20. Overview of popular LLM inference performance metrics



Time to First Token

Time to First Token (TTFT) measures the duration from submitting a query to receiving the first token of the model's output. This metric encompasses request queuing time, prefill time, and network latency. Generally, a longer prompt results in a higher TTFT due to the attention mechanism, which requires the entire input sequence to compute and create the key-value cache (KV-cache) before the iterative generation loop can commence. In production environments, multiple requests may be processed simultaneously, causing the prefill phase of one request to overlap with the generation phase of another, further impacting TTFT.

Figure 21. Overview of popular LLM inference performance metrics


GPU(s)
Prompt/Input
Tokenization
Initial Prompt Processing (Prefill)
decode/generation
De-Tokenization
First Output Token
Time to First Token (TTFT)
Signifies time it takes to process the prompt and generate the first token

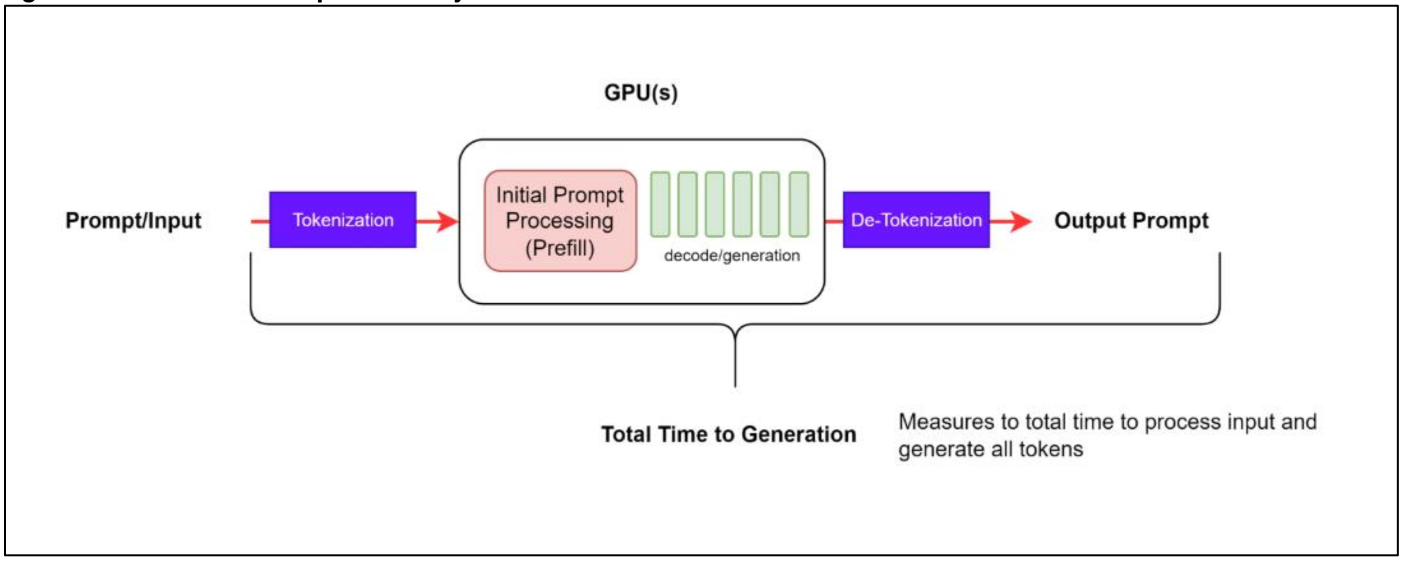
Generation Time

Generation time is the duration from the first token received to the final token received. GenAI-Perf removes the last [done] signal or empty response, so they don't get included in the e2e latency.

End-to-End Request Latency (e2e_latency)

End-to-End Request Latency (e2e_latency) quantifies the total time from submitting a query to receiving the complete response. This metric encompasses the performance of queuing/batching mechanisms and network latencies as demonstrated in Figure 22.

Figure 22. End-to-end Request latency



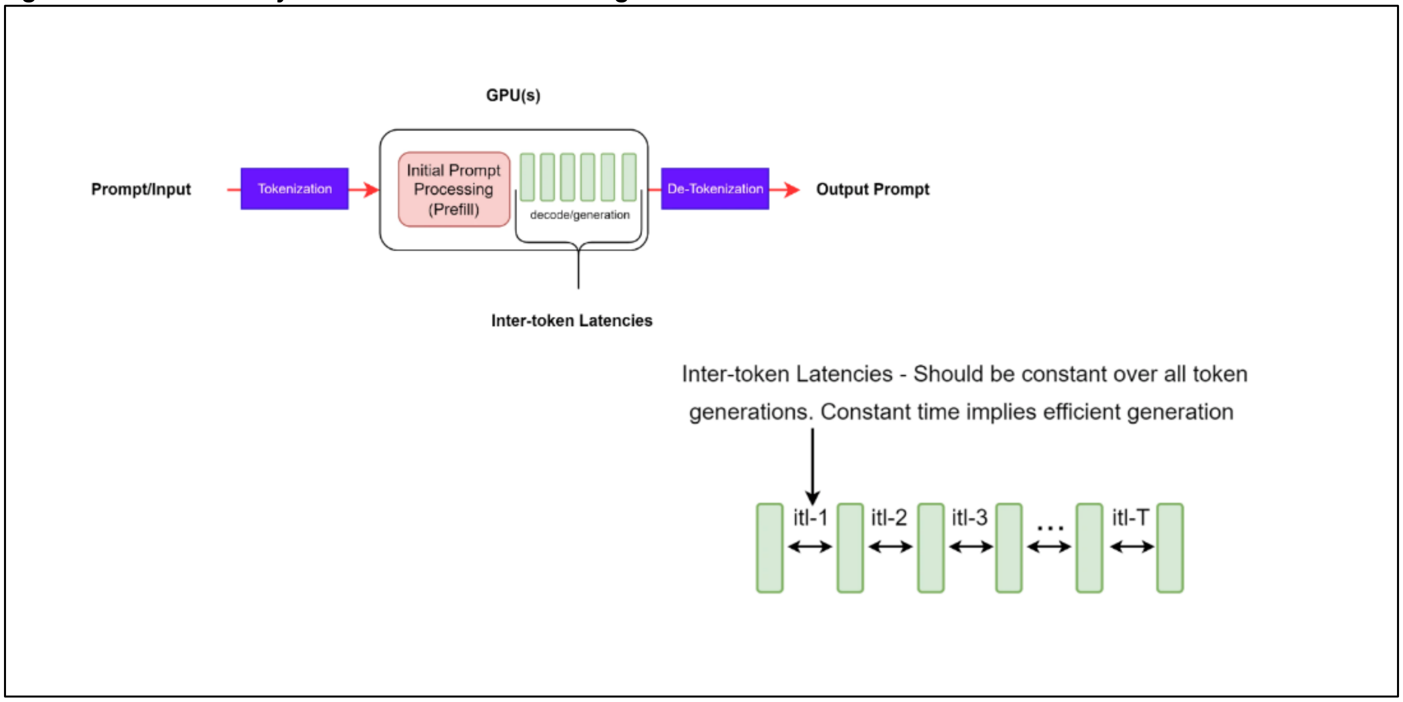
Mathematically, it is expressed as: e2e_latency=TTFT + Generation Time

For an individual request, the end-to-end request latency is the time difference between when the request is sent and when the final token is received. This metric provides a comprehensive measure of the system's responsiveness, accounting for all stages of the request processing pipeline.

Inter Token Latency (ITL)

This is defined as the average time between consecutive tokens and is also known as time per output token (TPOT).

Figure 23. ITL - Latency between successive token generations


GPU(s)
Prompt/Input
Tokenization
Initial Prompt Processing (Prefill)
decode/generation
De-Tokenization
Output Prompt
Inter-token Latencies
Inter-token Latencies - Should be constant over all token generations. Constant time implies efficient generation
itl-1
itl-2
itl-3
...
itl-T

GenAI-Perf defines ITL as follows:

$$\frac{e2e\_latency - TTFT}{Total\_output\_tokens - 1}$$

The equation for this metric excludes the first token (hence subtracting 1 in the denominator) to ensure that Inter-Token Latency (ITL) reflects only the decoding phase of request processing.

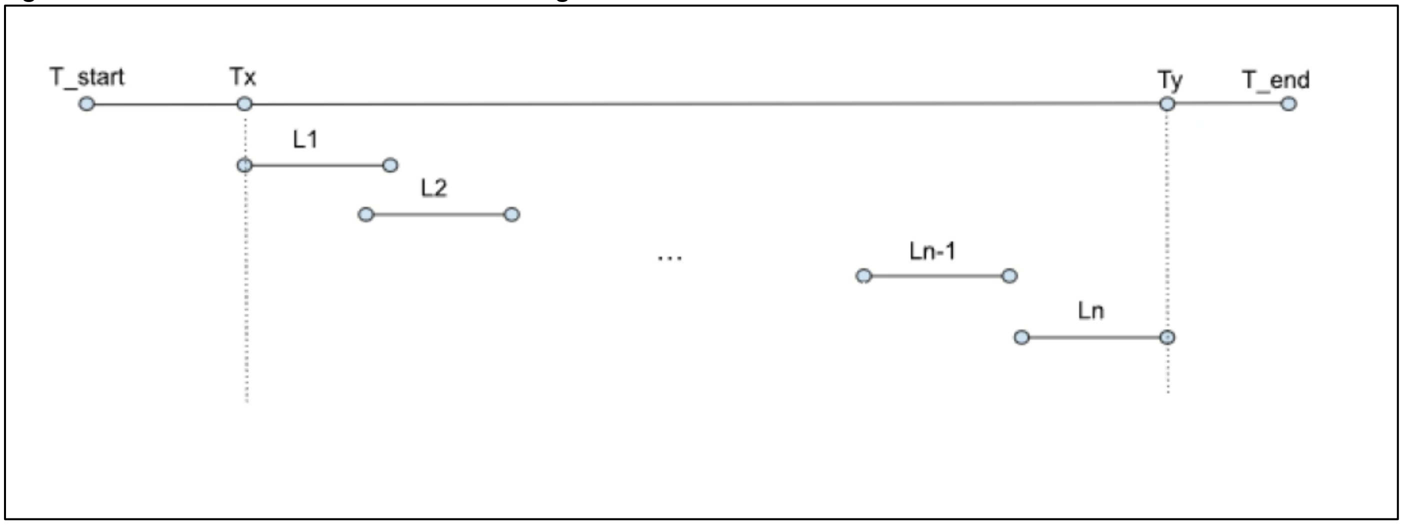
Longer output sequences increase the size of the KV cache, thereby raising memory costs. Additionally, the cost of attention computation grows linearly with the length of the combined input and output sequence for each new token, although this computation is typically not compute-bound. Consistent inter-token latencies indicate efficient memory management, optimal memory bandwidth utilization, and effective attention computation.

Tokens Per Second (TPS)

Total TPS per system represents the total output tokens per seconds throughput, accounting for all the requests happening simultaneously. As the number of requests increases, the total TPS per system increases, until it reaches a saturation point for all the available GPU compute resources, beyond which it might decrease.

Given the following timeline of the entire benchmark with n total requests.

Figure 24. Timeline of events in a benchmarking run



Li : End-to-end latency of i-th request

T_start : start of benchmark

Tx : timestamp of the first request

Ty : timestamp of the last response of the last request

T_end : end of benchmark

GenAI-perf defines the TPS as total output tokens divided by the end-to-end latency between the first request and the last response of the last request.

$$\frac{Total\_output\_tokens}{Ty\ -\ Tx}$$

Requests Per Second (RPS)

This is the average number of requests that can be successfully completed by the system in a 1-second period. It is calculated as:

$$RPS = \frac{total\_completed\_requests}{Ty - Tx}$$

Use Cases

An application’s specific use cases influence sequence lengths - Input Sequence Length(ISL) and Output Sequence Length(OSL), which in turn affect how efficiently a system processes input to form the KV-cache and generate output tokens. Longer ISL increases memory requirements for the prefill stage, thereby extending TTFT, while longer OSL increases memory requirements (both bandwidth and capacity) for the generation stage, thus raising ITL. Understanding the distribution of inputs and outputs in an LLM deployment is crucial for optimizing hardware utilization. Common use cases and their typical ISL/OSL pairs include:

- Translation

  Involves translating between languages and code, characterized by similar ISL and OSL, typically ranging from 200 to 2000 tokens each.

- Generation

  Encompasses generating code, stories, emails, and generic content via search, characterized by an OSL of O(1000) tokens, significantly longer than an ISL of O(100) tokens.

- Classification

  Involves categorizing input data into predefined classes or categories. Usually characterized by an ISL of O(200) tokens and OSL of O(5) tokens.

- Summarization

  Includes retrieval, chain-of-thought prompting, and multi-turn conversations, characterized by an ISL of O(1000) tokens, much longer than an OSL of O(200) tokens.

  Real data can also be used as inputs. GenAI-Perf supports datasets such as HuggingFace OpenOrca and CNN Dailymail.

Load Control

- Concurrency (N)

  Refers to the number of concurrent users, each with one active request, or equivalently, the number of requests being served simultaneously by an LLM service. As soon as a user’s request receives a complete response, another request is sent, ensuring the system always has exactly N active requests.

  LLMperf sends requests in batches of N but includes a draining period where it waits for all requests to complete before sending the next batch. Consequently, the number of concurrent requests gradually reduces to zero towards the end of the batch. This differs from GenAI-perf, which maintains N active requests throughout the benchmarking period.

  Concurrency is primarily used to describe and control the load on the inference system.

- Max Batch Size

A batch is a group of simultaneous requests processed by the inference engine, which may be a subset of the concurrent requests. The maximum batch size parameter defines the maximum number of requests the inference engine can process simultaneously.

If concurrency exceeds the maximum batch size multiplied by the number of active replicas, some requests will queue for later processing, potentially increasing the Time-to-First-Token (TTFT) due to the queuing effect.

- Request Rate

  This parameter controls load by determining the rate at which new requests are sent. A constant (static) request rate (r) means one request is sent every (\frac{1}{r}) seconds, while a Poisson (exponential) request rate determines the average inter-arrival time.

  GenAI-perf supports both concurrency and request rate, but concurrency is recommended. With request rate, the number of outstanding requests may grow unbounded if the requests per second exceed system throughput.

  When specifying concurrencies to test, it is useful to sweep over a range of values, from a minimum of 1 to a maximum not much greater than the max batch size. When concurrency exceeds the max batch size of the engine, some requests will queue, causing system throughput to saturate around the max batch size while latency steadily increases.

Procedure 1. Set up GenAI-Perf

Step 1. Make sure that the NIM for LLM with llama-3.1-8b-instruct service is running with NIM Service:

```
oc get nimcaches.apps.nvidia.com
NAME                          STATUS   PVC                              AGE
llama-3.2-nv-embedqa-1b-v2    Ready    llama-3.2-nv-embedqa-1b-v2-pvc   17d
meta-llama3.1-8b              Ready    meta-llama3.1-8b-pvc             17d
rerankqa                      Ready    rerankqa-pvc                     17d


----


oc get nimservices.apps.nvidia.com
NAME       STATUS   AGE
embedqa    Ready    17d
llm        Ready    17d
rerankqa   Ready    17d
```

Step 2. Observe that the POD is running. The cluster IP of the service is 172.30.73.126 and it's running on Port 8000. It is also exposed as NodePort on Port 30604:

```
            oc get pods
NAME                          READY   STATUS    RESTARTS        AGE
embedqa-5988bf857b-m92cd      1/1     Running   0                              17d
llm-5df9986696-mc7kt          1/1     Running   0               17d
rerankqa-695cc5d6b8-mxl6s     1/1     Running   0               17d




oc get svc
```

```
NAME                        TYPE        CLUSTER-IP       EXTERNAL-IP   PORT(S)
embedqa                     NodePort    172.30.103.111   <none>        8000:30765/TCP
llm                         NodePort    172.30.73.126    <none>        8000:30604/TCP
rerankqa                    NodePort    172.30.160.141   <none>        8000:32630/TCP
```

Step 3. Make a test chat completion to make sure that the LLM endpoint is working:

```
curl -X 'POST' 'http:// 172.30.73.126:8000/v1/completions' -H 'accept: application/json' -H 'Content-Type: application/json' -d '{
"model": "meta/llama-3.1-8b-instruct",
"prompt": "Capital of USA",
"max_tokens": 64
}'



{"id":"cmpl-b0ac03eb587540c1a39cff513cb4d2c3","object":"text_completion","created":1742210493,"model":"meta/llama-3.1-8b-instruct","choices":[{"index":0,"text":":\nA. New York\nB. Washington D.C.\nAnswer: B\nExplanation: The Capitol of United States (USA) is officially called the District of Columbia, Capital Washington D.C. but Commonly referred as Washing-ton. Washington is the capital of the United States. Washington is…\nArea of USA:\nA","logprobs":null,"finish_reason":"length","stop_reason":null,"prompt_logprobs":null}],"usage":{"prompt_tokens":4,"total_tokens":68,"completion_tokens":64}}
```

Note: Once the NIM LLama-3.1 inference service is running, you can set up a benchmarking tool. The easiest way to install GenAI-Perf is by creating a deployment object in OpenShift using the Triton Server SDK container image.

A sample deployment YAML manifest is provided below:

```
[root@aa06-rhel9 genaiperf]# cat deployment.yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: genai-perf
spec:
  strategy:
    type: Recreate
  # Replicas controls the number of instances of the Pod to maintain running at all times
  replicas: 1
  selector:
    matchLabels:
      app: genai-perf
  template:
    metadata:
      labels:
        app: genai-perf
      name: genai-perf-pod
    spec:
      nodeName: worker2.flashstack.local
      imagePullSecrets:
        - name: ngc-secret
      volumes:
      - name: data
        persistentVolumeClaim:
          claimName: genai-perf-data
      containers:
        - name: genai-perf-container
          image: nvcr.io/nvidia/tritonserver:25.01-py3-sdk
          command: [ "/bin/bash", "-c", "--" ]
          args: [ "while true; do sleep 30; done;" ]
          volumeMounts:
            - name: data
              mountPath: /workdir
```

Note: It is recommended to starting a GenAI-perf pod on the same server as NIM to avoid network latency unless you specifically want to factor in the network latency as part of the measurement. Therefore nodeName: worker2.flashstack.local is passed in pod spec.

Step 4. The image pull secret is required with a NGC API key to download the image. It can be created using:

```
oc create secret docker-registry ngc-registry --docker-server=nvcr.io --docker-username=\$oauthtoken --
docker-password=<API Key>
```

Step 5. A repository is required to store the NeMo check points and other temp folders. A sample PVC configuration to provide persistent storage to the pod is provided below:

```
[root@aa06-rhel9 genaiperf]# cat pvc.yaml
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: genai-perf-data
spec:
  accessModes:
    - ReadWriteOnce
  resources:
    requests:
      storage: 50Gi
```

Step 6. Apply the YAML manifests against the OpenShift cluster and make sure all the resources are created

```
oc get pods
NAME                          READY   STATUS    RESTARTS        AGE
embedqa-5988bf857b-m92cd      1/1     Running   1 (5h50m ago)   17d
genai-perf-76f5c958d4-5dcf8   1/1     Running   0               35m
llm-5df9986696-mc7kt          1/1     Running   0               17d
rerankqa-695cc5d6b8-mxl6s     1/1     Running   0               17d
```

Step 7. From the output, you can see that the pod is running. Run the following commands to get access to the pod:

```
oc exec -it genai-perf-76f5c958d4-5dcf8 -- bash
root@genai-perf-76f5c958d4-5dcf8:/workspace#
```

Step 8. Once inside the pod, you can start the GenAI-perf evaluation harness as follows, which runs a warming load test on the NIM backend:

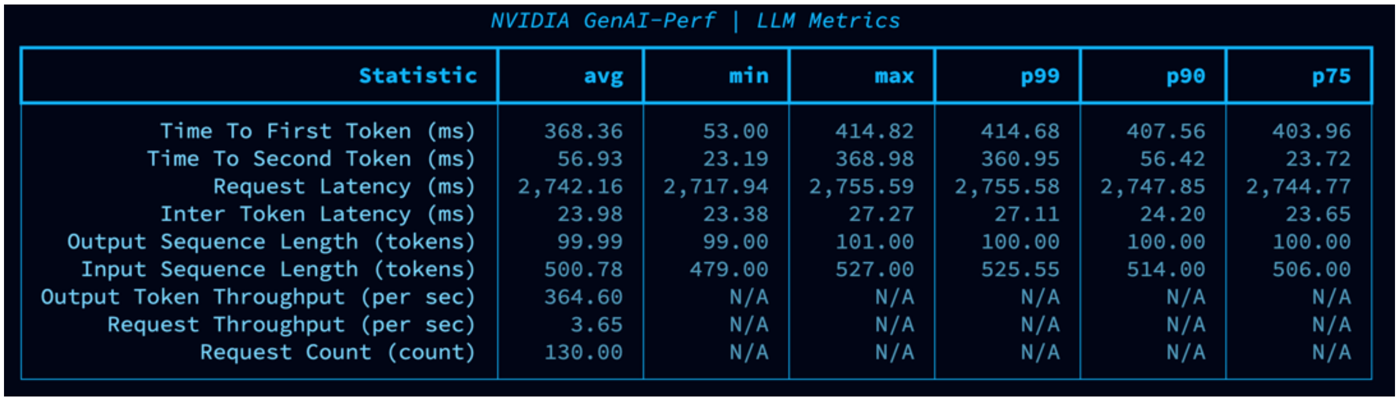
```
export INPUT_SEQUENCE_LENGTH=500
export INPUT_SEQUENCE_STD=10
export OUTPUT_SEQUENCE_LENGTH=100
export CONCURRENCY=10
export MODEL=meta/llama-3.1-8b-instruct



genai-perf \
    profile \
    -m $MODEL \
    --endpoint-type chat \
    --service-kind openai \
    --streaming \
    --url 172.30.73.126:8000 \
    --synthetic-input-tokens-mean $INPUT_SEQUENCE_LENGTH \
    --synthetic-input-tokens-stddev $INPUT_SEQUENCE_STD \
    --concurrency $CONCURRENCY \
    --output-tokens-mean $OUTPUT_SEQUENCE_LENGTH \
    --extra-inputs max_tokens:$OUTPUT_SEQUENCE_LENGTH \
    --extra-inputs min_tokens:$OUTPUT_SEQUENCE_LENGTH \
    --extra-inputs ignore_eos:true \
    --tokenizer meta-llama/Meta-Llama-3-8B-Instruct \
    -- \
    -v \
    --max-threads=256
```

This example specifies the input and output sequence length and a concurrency to test.

Step 9. This test will use the llama-3 tokenizer from HuggingFace, which is a guarded repository. You will need to apply for access, then login with your HF credential:

```
pip install huggingface_hub
huggingface-cli login
```

Step 10. With a successful execution, you will see similar results in the terminal as shown below:



```
                              NVIDIA GenAI-Perf | LLM Metrics
┏━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━┳━━━━━━━━━━┳━━━━━━━━━━┳━━━━━━━━━━┳━━━━━━━━━━┳━━━━━━━━━━┳━━━━━━━━━━┓
┃                          Statistic ┃      avg ┃      min ┃      max ┃      p99 ┃      p90 ┃      p75 ┃
┡━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━━╇━━━━━━━━━━╇━━━━━━━━━━╇━━━━━━━━━━╇━━━━━━━━━━╇━━━━━━━━━━╇━━━━━━━━━━┩
│           Time To First Token (ms) │   368.36 │    53.00 │   414.82 │   414.68 │   407.56 │   403.96 │
│          Time To Second Token (ms) │    56.93 │    23.19 │   368.98 │   360.95 │    56.42 │    23.72 │
│               Request Latency (ms) │ 2,742.16 │ 2,717.94 │ 2,755.59 │ 2,755.58 │ 2,747.85 │ 2,744.77 │
│           Inter Token Latency (ms) │    23.98 │    23.38 │    27.27 │    27.11 │    24.20 │    23.65 │
│     Output Sequence Length (tokens) │    99.99 │    99.00 │   101.00 │   100.00 │   100.00 │   100.00 │
│      Input Sequence Length (tokens) │   500.78 │   479.00 │   527.00 │   525.55 │   514.00 │   506.00 │
│    Output Token Throughput (per sec) │   364.60 │      N/A │      N/A │      N/A │      N/A │      N/A │
│         Request Throughput (per sec) │     3.65 │      N/A │      N/A │      N/A │      N/A │      N/A │
│                Request Count (count) │   130.00 │      N/A │      N/A │      N/A │      N/A │      N/A │
└────────────────────────────────────┴──────────┴──────────┴──────────┴──────────┴──────────┴──────────┘
```

When the tests complete, GenAI-perf generates the structured outputs in a default directory named “artifacts” under your mounted working directory (/workdir in these examples), organized by model name, concurrency, and input/output length. Your results should look similar to the following:

```
root@genai-perf-76f5c958d4-5dcf8:/workspace/artifacts# find .

.

./meta_llama3-8b-instruct-openai-chat-concurrency10

./meta_llama3-8b-instruct-openai-chat-concurrency10/inputs.json

./meta_llama-3.1-8b-instruct-openai-chat-concurrency10

./meta_llama-3.1-8b-instruct-openai-chat-concurrency10/inputs.json

./meta_llama-3.1-8b-instruct-openai-chat-concurrency10/profile_export_genai_perf.json

./meta_llama-3.1-8b-instruct-openai-chat-concurrency10/profile_export_genai_perf.csv

./meta_llama-3.1-8b-instruct-openai-chat-concurrency10/profile_export.json
```

Procedure 2. Sweep through Use Cases

Typically, with benchmarking, a test would be set up to sweep over a number of use cases, such as input/output length combinations, and load scenarios, such as different concurrency values.

Step 1. Use the following bash script to define the parameters so that GenAI-perf executes through all the combinations:

```
#!/usr/bin/bash


declare -A useCases


useCases["Generation"]="100/1000"

useCases["Translation"]="200/200"

useCases["Text classification"]="200/5"

useCases["Text summary"]="1000/200"



runBenchmark() {

    local description="$1"

    local lengths="${useCases[$description]}"

    IFS='/' read -r inputLength outputLength <<< "$lengths"

    echo "Running genAI-perf for $description with input length $inputLength and output length
$outputLength"
    #Runs
    for concurrency in 1 2 5 10 25 50 100; do

        local INPUT_SEQUENCE_LENGTH=$inputLength
        local INPUT_SEQUENCE_STD=0
        local OUTPUT_SEQUENCE_LENGTH=$outputLength
        local CONCURRENCY=$concurrency
        local MODEL=meta/llama-3.1-8b-instruct

        genai-perf \
            profile \
            -m $MODEL \
            --service-kind openai \
            --endpoint-type chat \
            --url 172.30.73.126:8000 \
            --streaming \
            --synthetic-input-tokens-mean $INPUT_SEQUENCE_LENGTH \
            --synthetic-input-tokens-stddev $INPUT_SEQUENCE_STD \
            --concurrency $CONCURRENCY \
            --output-tokens-mean $OUTPUT_SEQUENCE_LENGTH \
            --output-tokens-stddev 0 \
            --extra-inputs max_tokens:$OUTPUT_SEQUENCE_LENGTH \
            --extra-inputs min_tokens:$OUTPUT_SEQUENCE_LENGTH \
            --extra-inputs ignore_eos:true \
            --measurement-interval 60000 \
            --profile-export-file PKOPPA2_${INPUT_SEQUENCE_LENGTH}_${OUTPUT_SEQUENCE_LENGTH}.json \
            -- \
            -v \
            --max-threads=256

    done
}

for description in "${!useCases[@]}"; do
    runBenchmark "$description"
done
```

Step 2. Save this script in a working directory, such as under /workdir/benchmark.sh. You can then execute it with the following command:

```
cd /workdir
bash benchmark.sh
```

The following tables lists the details of performance for three different use cases.

Table 22. NIM for LLM Benchmarking for Classification Use Case (I/O = 200/5)

Number of GPUs	Concurrency	Time to First Token (ms)	Inter-token Latency (ms)	End-to-End Request Latency (ms)	Output Token Throughput (Tokens Per Second)	Request Throughput (Requests Per Second)
1 X L40S	1	19.12	12.9	76.84	72.98	13
	2	33.65	13.34	93.3	120.2	21.43
	5	52.54	14.83	119.11	235.41	41.96
	10	95.69	16.03	167.13	335.84	59.82
	25	179.84	29.49	311.64	447.49	80.17
	50	371.77	44.95	571.87	486.65	87.42
	100	847.02	59.93	1,111.70	500.72	89.89
2 X L40S	1	20.9	7.91	56.42	99.35	17.71
	2	34.14	9.19	75.48	148.52	26.47
	5	66.27	11.05	115.78	242.16	43.17
	10	102.81	16.79	177.85	315.33	56.21
	25	210.76	33.68	360.81	386.26	69.24
	50	477.67	43.39	675.47	415.02	74.01
	100	975.59	74.99	1,315.04	424.2	76.03

Table 23. NIM for LLM Benchmarking for Summarization Use Case (I/O = 1000/200)

Number of GPUs	Concurrency	Time to First Token (ms)	Inter-token Latency (ms)	End-to-End Request Latency (ms)	Output Token Throughput (Tokens Per Second)	Request Throughput (Requests Per Second)
1 X L40S	1	49.78	12.2	2,972.21	81.06	0.34
	2	80.57	12.33	3,039.38	158.95	0.66
	5	203.55	12.9	3,305.13	366.21	1.51
	10	446.78	13.42	3,686.10	659.97	2.71
	25	1,239.95	14.93	4,805.13	1,250.64	5.2
	50	1,916.95	19.6	6,599.43	1,821.36	7.57
	100	2,935.99	32.27	10,645.74	2,229.00	9.27
2 X L40S	1	68.47	7.52	1,889.41	129.07	0.53

Number of GPUs	Concurrency	Time to First Token (ms)	Inter-token Latency (ms)	End-to-End Request Latency (ms)	Output Token Throughput (Tokens Per Second)	Request Throughput (Requests Per Second)
	2	102.29	7.75	1,979.43	246.31	1.01
	5	257.78	8.93	2,420.98	503.9	2.07
	10	547.41	9.69	2,895.52	842.47	3.45
	25	1,359.68	11.48	4,117.37	1,467.60	6.07
	50	2,399.88	15.84	6,230.89	1,953.94	8.02
	100	4,722.26	23.32	10,370.69	2,350.69	9.64

Table 24. NIM for LLM Benchmarking for Translation Use Case (I/O = 200/200)

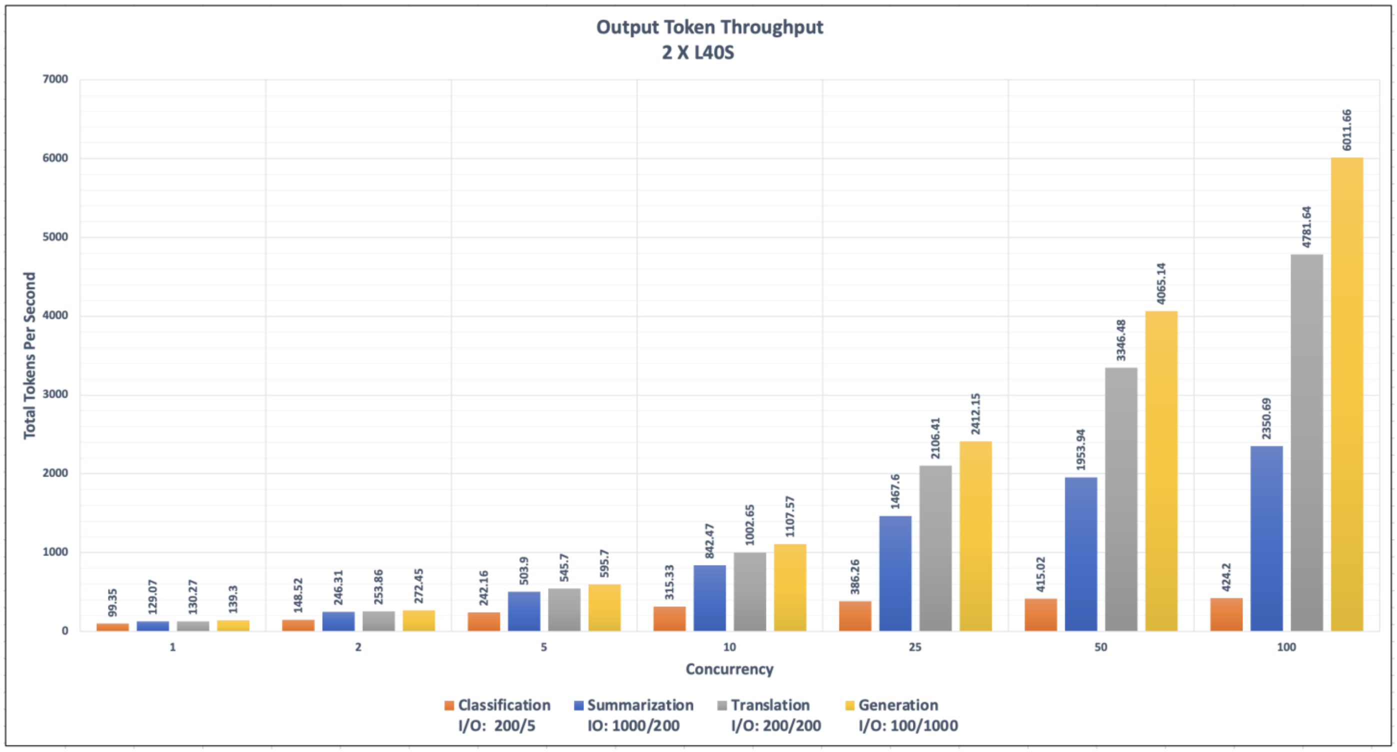
Number of GPUs	Concurrency	Time to First Token (ms)	Inter-token Latency (ms)	End-to-End Request Latency (ms)	Output Token Throughput (Tokens Per Second)	Request Throughput (Requests Per Second)
1 X L40S	1	20.04	12.3	2,900.12	81.18	0.34
	2	33.43	12.35	2,923.17	160.91	0.68
	5	51.78	12.68	3,021.99	389.56	1.65
	10	96.97	12.83	3,109.31	759.27	3.22
	25	188.77	13.74	3,407.33	1,728.73	7.34
	50	256.98	15.19	3,850.02	3,089.05	12.98
	100	804.72	17.47	4,933.87	4,817.75	20.26
2 X L40S	1	21.84	7.62	1,807.43	130.27	0.55
	2	33.98	7.77	1,853.42	253.86	1.08
	5	66.01	8.93	2,154.17	545.7	2.32
	10	124.54	9.49	2,345.32	1,002.65	4.26
	25	259.17	10.83	2,797.69	2,106.41	8.93
	50	417.81	13.24	3,524.02	3,346.48	14.18
	100	1,010.04	16.72	4,935.12	4,781.64	20.25

Table 25. NIM for LLM Benchmarking for Generation Use Case (I/O = 100/1000)

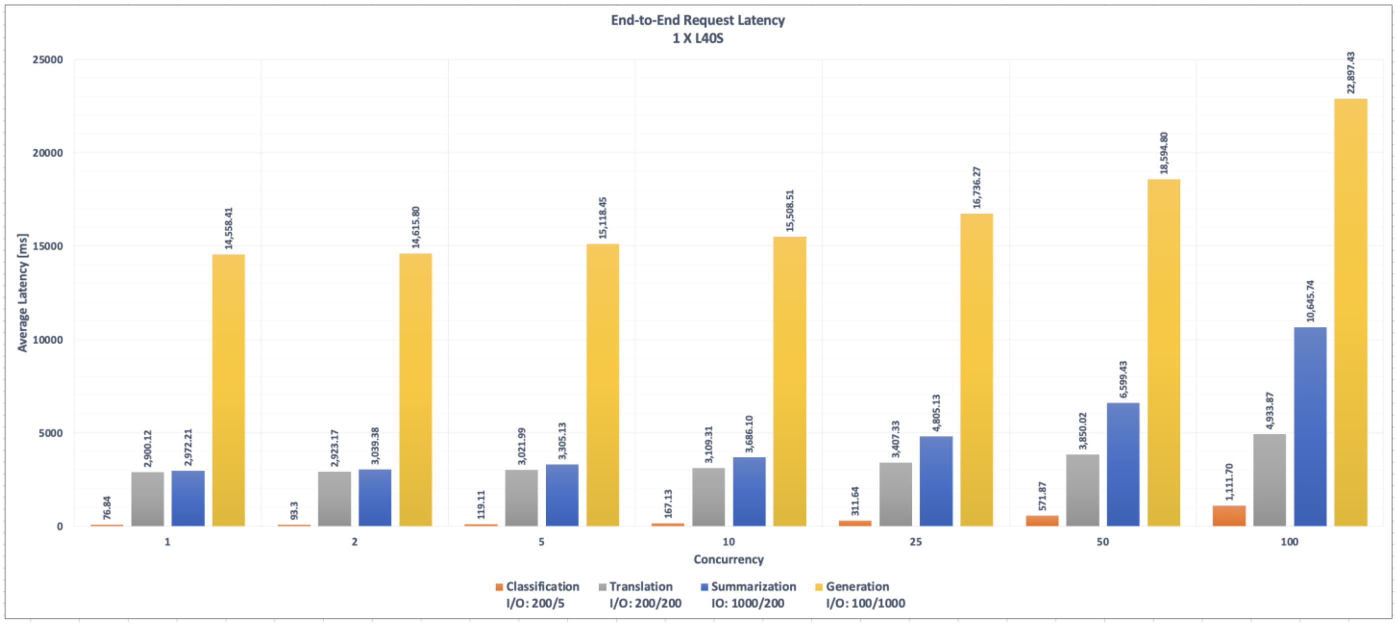
Number of GPUs	Concurrency	Time to First Token (ms)	Inter-token Latency (ms)	End-to-End Request Latency (ms)	Output Token Throughput (Tokens Per Second)	Request Throughput (Requests Per Second)
1 X L40S	1	18.82	11.52	14,558.41	86.81	0.07
	2	30.84	11.58	14,615.80	172.57	0.14
	5	37.3	11.89	15,118.45	420.62	0.33
	10	58.84	12.26	15,508.51	813.84	0.64
	25	112.01	13.16	16,736.27	1,889.62	1.49
	50	192.17	14.55	18,594.80	3,409.86	2.69
	100	358.95	17.9	22,897.43	5,504.94	4.36
2 X L40S	1	17.3	7.18	9067.02	139.3	0.11
	2	26.86	7.33	9220.25	272.45	0.22
	5	42.5	8.38	10578.22	595.7	0.47
	10	73.61	8.99	11383.12	1107.57	0.88
	25	133	10.27	13042.51	2412.15	1.92
	50	294.03	12.08	15475.15	4065.14	3.23
	100	490.22	16.25	20888.17	6011.66	4.78

Analyze the Output

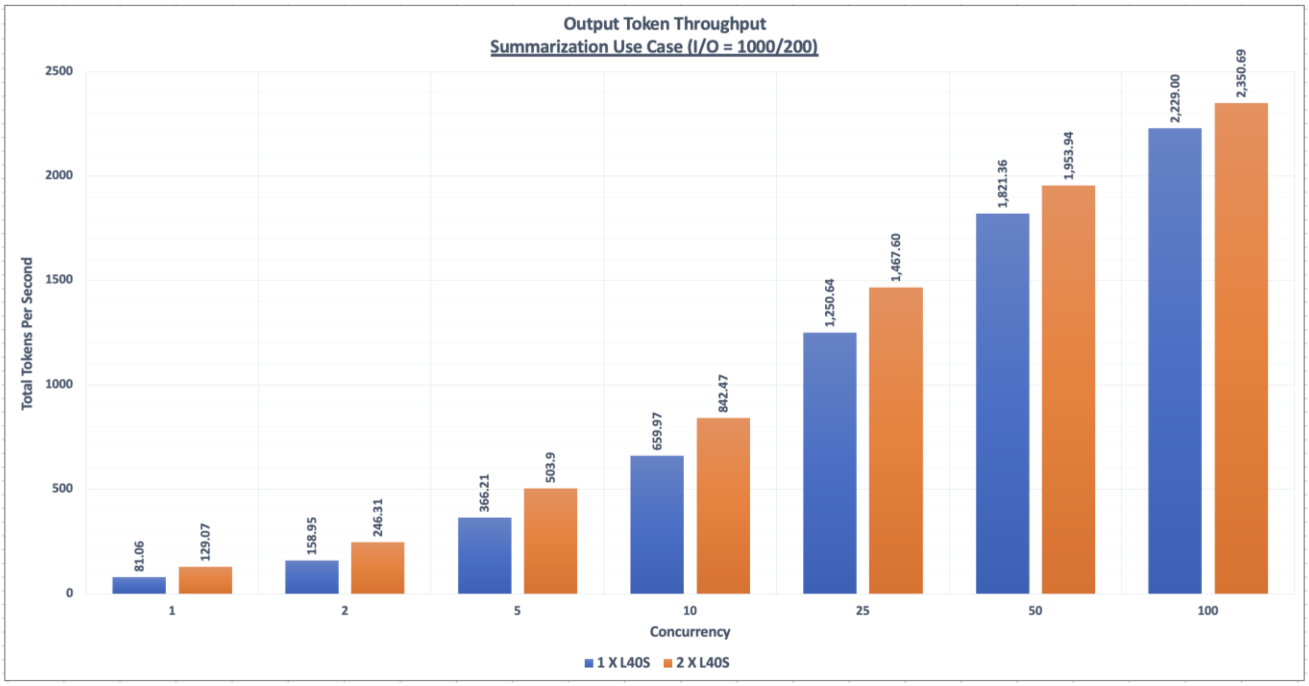
The figure below shows the total output tokens per seconds throughput, accounting for all the requests happening simultaneously from all 4 uses cases.



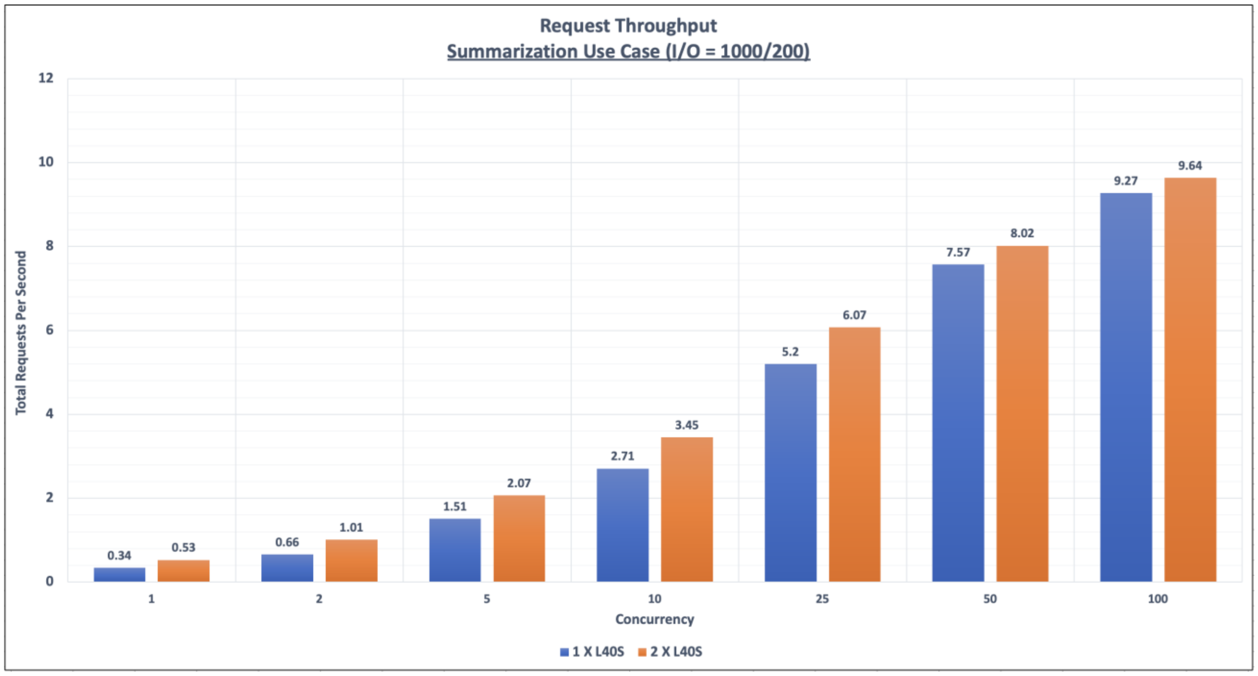
The figure below shows how long it takes from submitting a query to receiving the full response for 4 different use cases.



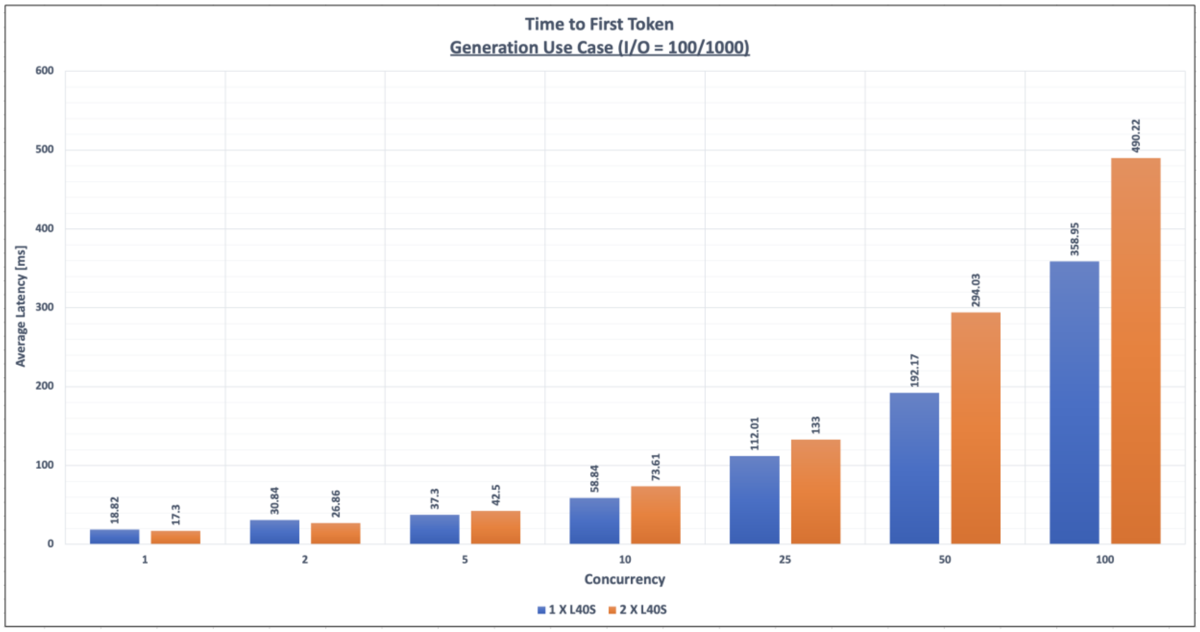
The figure below shows the total output tokens per seconds throughput, accounting for all the requests happening simultaneously with 1 L40S GPU vs 2 X L40S GPU.



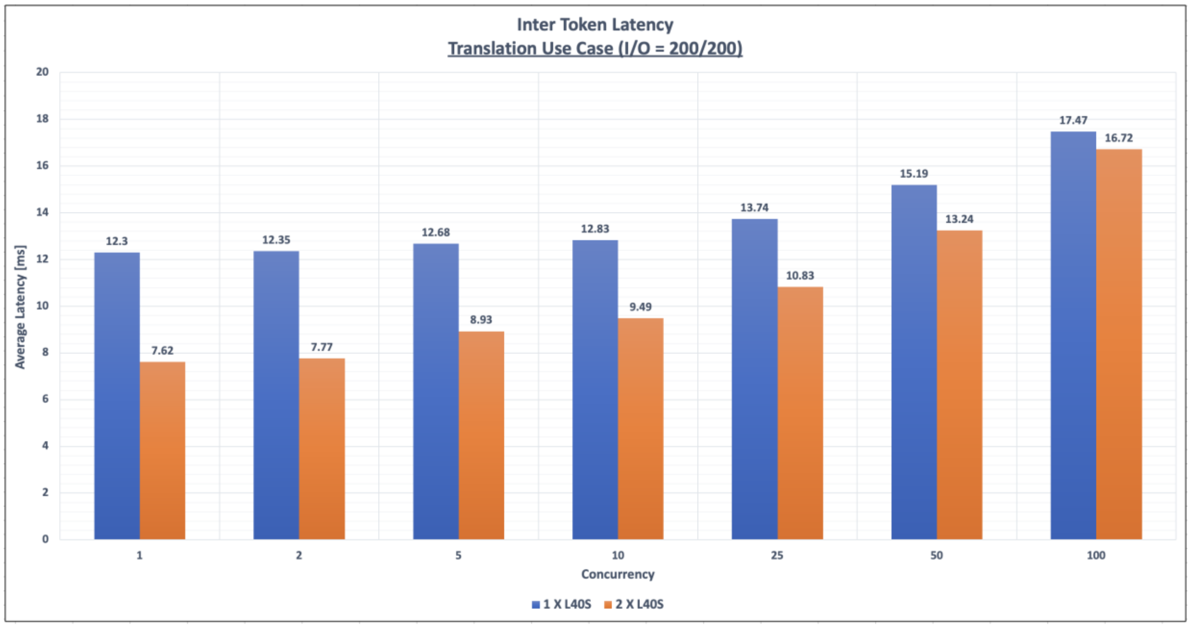
The figure below shows the average number of requests that can be successfully completed by the system in a 1-second period with 1 L40S GPU vs 2 X L40S GPU.



The figure below shows how long a user needs to wait before seeing the model's output with 1 L40S GPU vs 2 X L40S GPU.



The figure below shows the average time between consecutive tokens with 1 L40S GPU vs 2 X L40S GPU.



Interpreting the Results

The following plots illustrate the Latency-Throughput curves for four different use cases with different Input Sequence Length and Output Sequence Lengths.

Summarization (I/O : 1000/200), **Classification** (I/O : 200/5), **Translation** (I/O : 200/200) and **Generation** (I/O : 100/1000) .

Figure 25. Latency-Throughput Curve for Summarization (I/O : 1000/200)

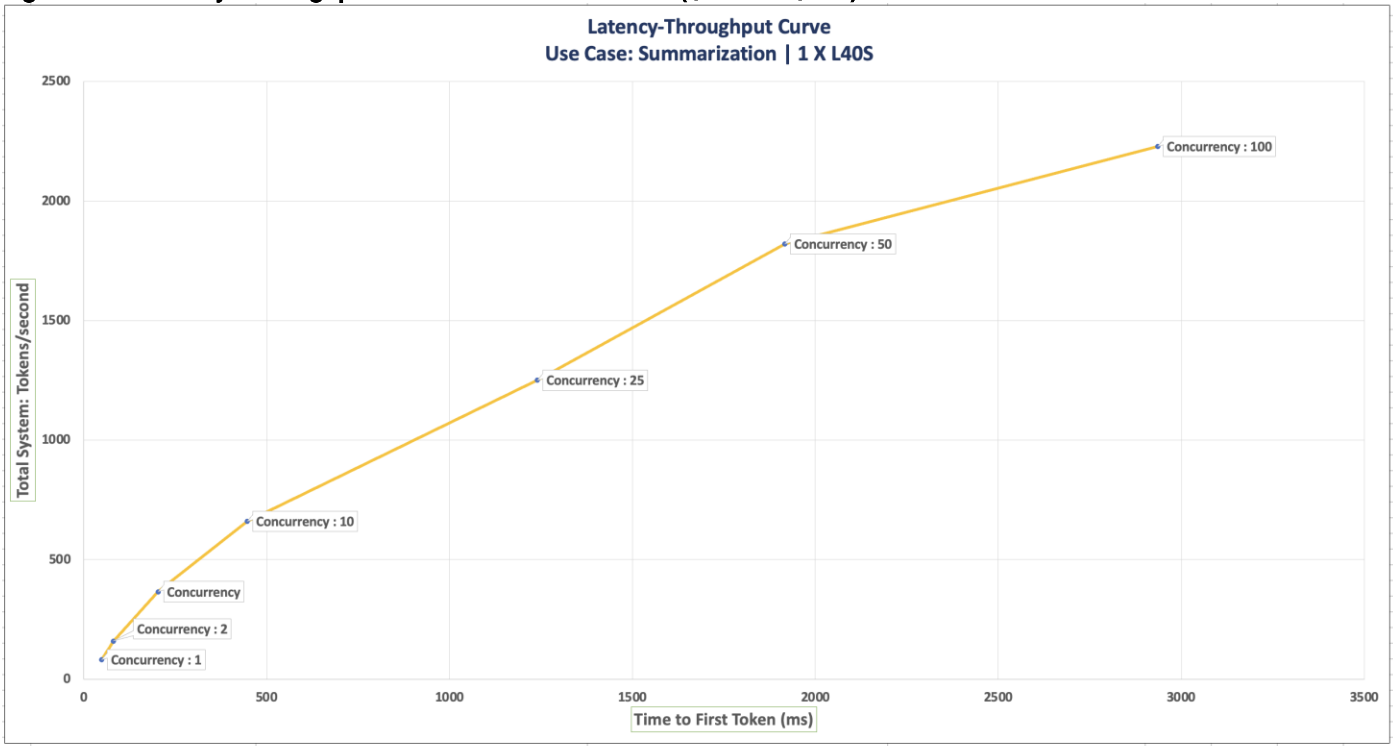


Figure 26. Latency-Throughput Curve for Classification (I/O : 200/5)

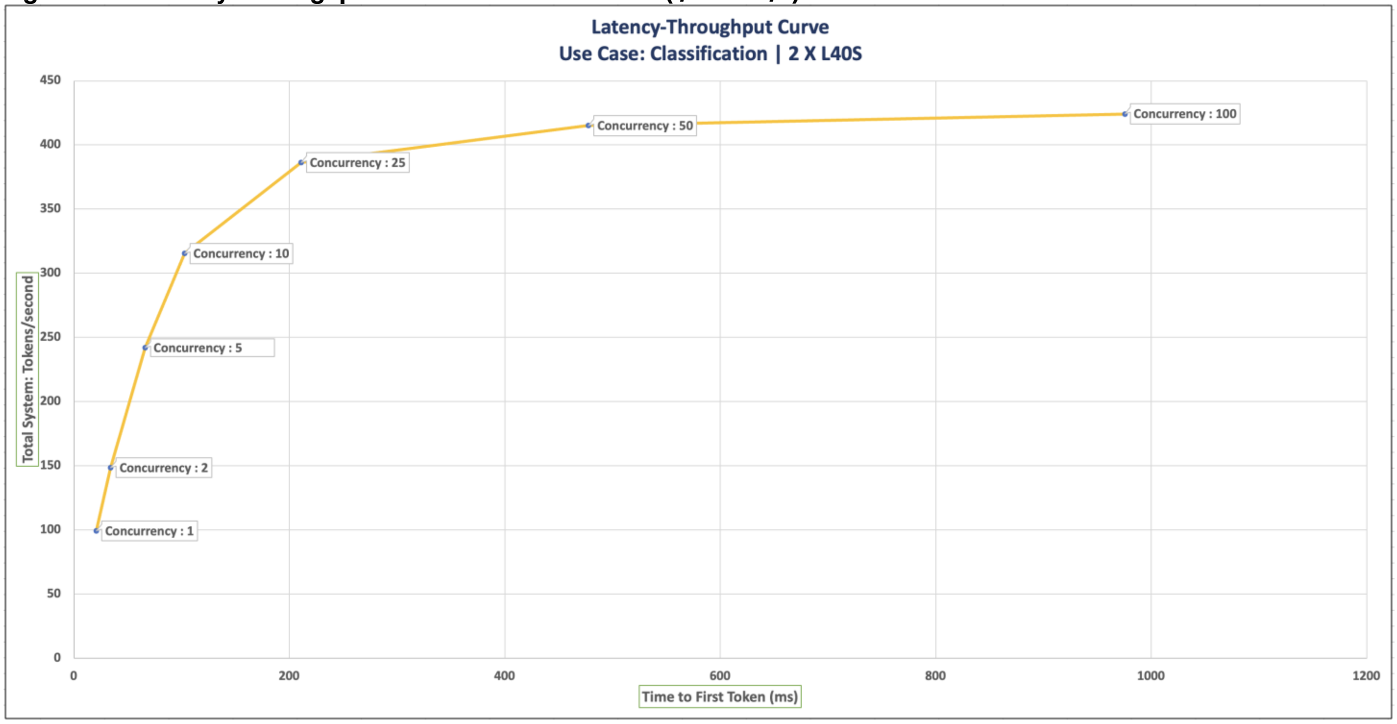
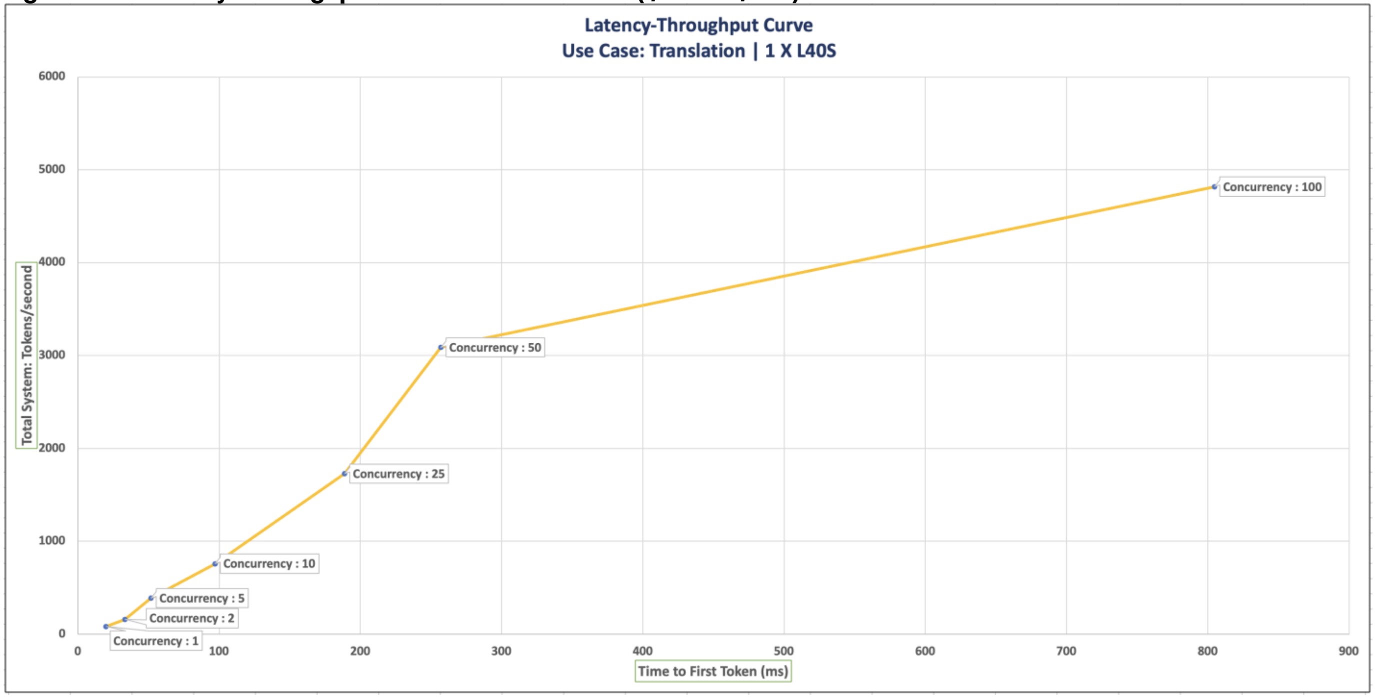


Figure 27. Latency-Throughput Curve for Translation (I/O : 200/200)



- Axes Definitions
  - X-axis: Time to First Token (TTFT) - The duration a user waits before the model starts generating output.
  - Y-axis: Total System Throughput - The total number of output tokens generated per second.
  - Dots: Represent different concurrency levels.

Usage Guidelines

- Latency Budget Approach

  Objective: Determine the highest achievable throughput within a specified latency limit.

  Method: Identify the maximum acceptable TTFT on the X-axis, then find the corresponding Y value and concurrency level. This indicates the highest throughput achievable within the given latency constraint.

- Concurrency-Based Approach

  Objective: Understand the latency and throughput for a specific concurrency level.

  Method: Locate the desired concurrency level on the plot. The intersecting X and Y values represent the latency and throughput for that concurrency.

- Key Observations

  The Latency-Throughput Curve for Classification plot highlights concurrency levels where latency increases significantly with minimal or no throughput gain. Concurrency = 50 is an example of such a point.

- Alternative Metrics

  Similar plots can be generated using different metrics on the X-axis, such as ITL (Inference Time Latency), e2e_latency (End-to-End Latency), or TPS_per_user (Transactions Per Second per User). These plots help visualize the trade-offs between total system throughput and individual user latency.

Sizing

Memory Calculations for LLM Inferencing

Total Memory required is the sum of model memory size and the KV cache.

Calculations for the required total memory are provided below:

```
Model Memory Size = Model Parameters * Precision
```

```
KV Cache Size = 2 x Batch Size x Context Size  x Number of Layers x Model Dimensions x
Precision
```

```
Total Memory Requirements (GB) = Model Memory Size (GB) + KV Cache Size (GB)
```

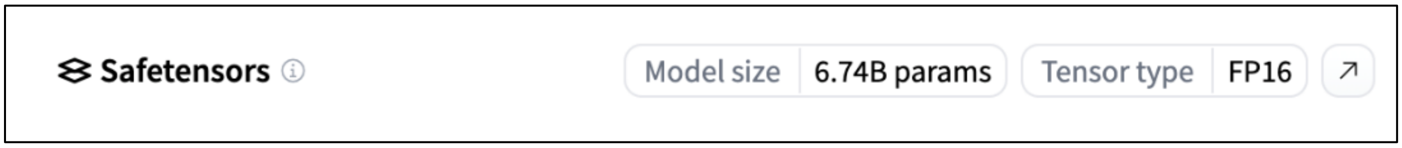
For some models, model dimension data might not be available. In that case, model dimension can be calculated as:

```
Model Dimensions = Attention Head Size X Number of Attention Heads
```

Model Parameters, Precision, Number of layers, Model Dimension are specific to models, and it can be found in the Model card for the model.

Context Size and batch size are input from users.

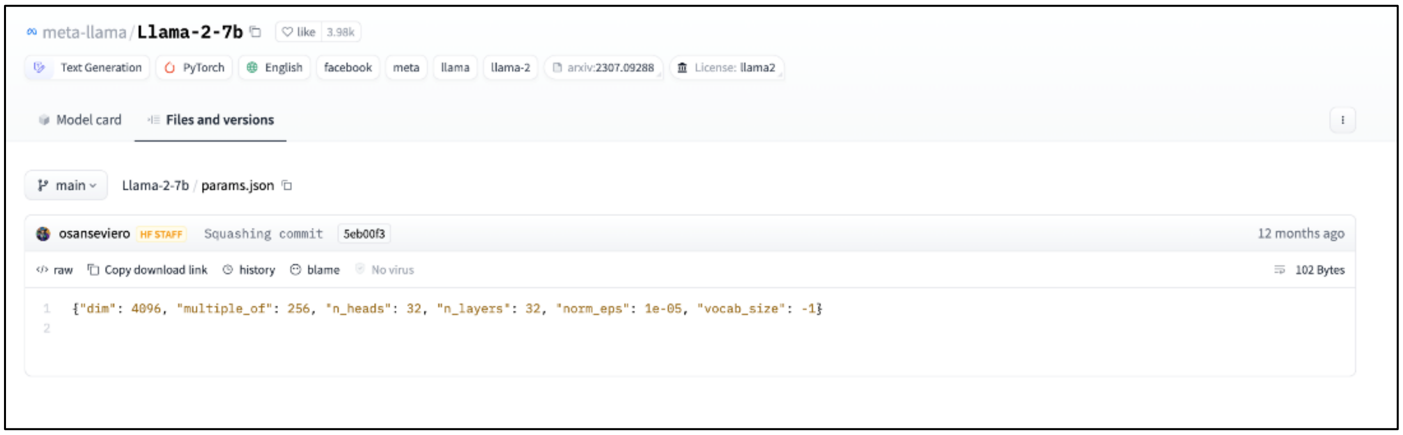
The following is an example memory calculation for Llama 2:



Safetensors

Model size	6.74B params

Tensor type	FP16



meta-llama / Llama-2-7b

like 3.98k

Text Generation · PyTorch · English · facebook · meta · llama · llama-2 · arxiv:2307.09288 · License: llama2

Model card · Files and versions

main · Llama-2-7b / params.json

osanseviero HF STAFF Squashing commit 5eb00f3 · 12 months ago

raw · Copy download link · history · blame · No virus · 102 Bytes

```
{"dim": 4096, "multiple_of": 256, "n_heads": 32, "n_layers": 32, "norm_eps": 1e-05, "vocab_size": -1}
```

For the Llama 2 model:

```
Total model parameters:          6.74B Parameters.
Precision:                       FP16. (2 Bytes)
Number of layers:                32
Model Dimension:                 4096
```

Therefore, the model memory is calculated as shown below:

```
Model Memory Size = Model Parameters * Precision


Model Memory Size for Llama 2    = 6,740,000,000 * 2 Bytes/Parameter
                                 = 13,480,000,000 Bytes
```

```
                                          = 13.48 Giga Bytes
```

Also, considering an example of maximum Input Tokens Length of 1024, Maximum Output Tokens Length of 1024, and the Batch size of 8, below are the calculations for KV Cache Size:

```
KV Cache Size         = 2 x Batch Size x Context Size  x Number of Layers x Model Dimensions
x Precision
KV Cache Size         = 2 x 8 x (1024+1024) x 32 x 4096 x 2 Bytes/Parameter
                      = 8,589,934,592 Bytes
                      =  8.59 Giga Bytes
```

Therefore, Llama2 with maximum Input Tokens Length of 1024, Maximum Output Tokens Length of 1024, and the Batch size of 8, the total memory required is shown below:

```
Total Memory Requirements (GB)   = Model Memory Size (GB) + KV Cache Size (GB)
                                 = 13.48 + 8.59 Giga Bytes
                                 = 22.07 Giga Bytes
```

Performance Calculations

Note: The performance benchmark can be run on model.

Based on the performance requirement, number of users, number of input and output tokens, latency and throughput required, you can choose the appropriate Large Language Model, Inferencing backend, GPUs, and compute infrastructure.

Performance of the model depends on the prefill and decode phases. These two phases have different impacts on the performance of the LLM. While the prefill phase effectively saturates GPU compute at small batch sizes, the decode phase results in low compute utilization as it generates one token at a time per request.

The prefill phase is compute-bound, while the decode phase is memory-bound. So, the following factors need to be considered and measured:

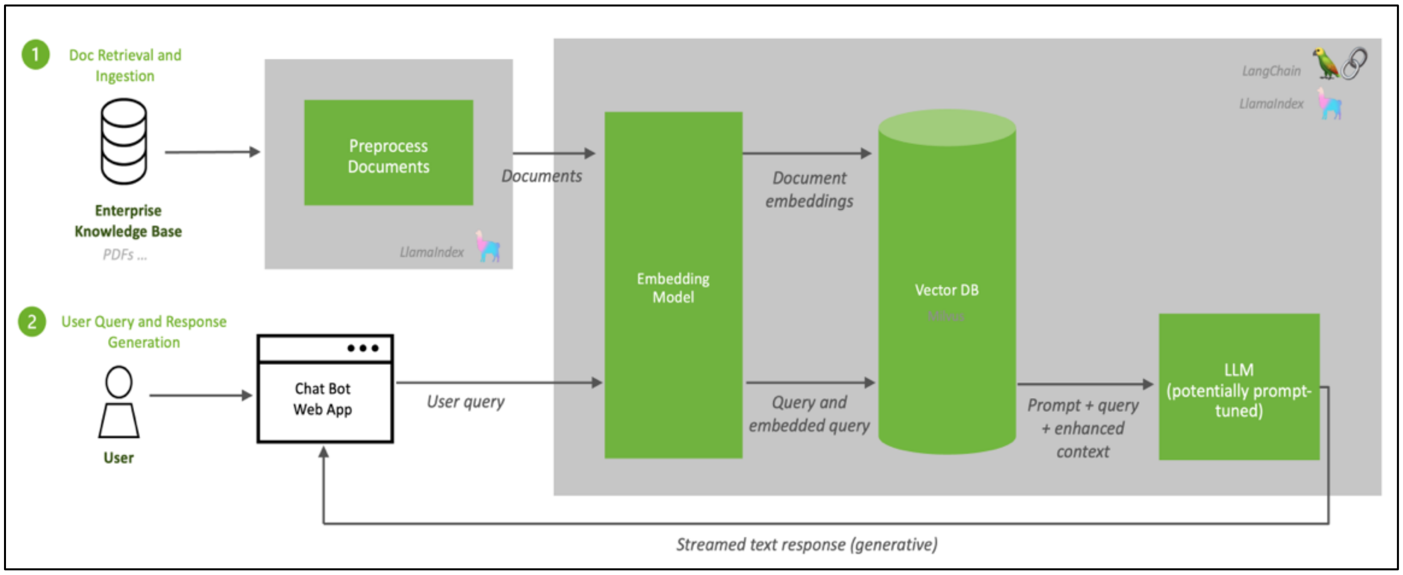
- Prefill Latency
- Prefill Throughput
- Decode Total Latency
- Decode Token Latency
- Decode Throughput

The performance benchmark can be run with different sizes (1,2,4,8,10,25,250, 100 and so on). Also, separate tests can be run focused on performance comparison between 2 different models.

RAG Evaluation

How RAG Works

Retrieval-Augmented Generation (RAG) is a technique used to enrich LLM outputs by using additional relevant information from an external knowledge base. This allows an LLM to generate responses based on context beyond the scope of its training data.


1 Doc Retrieval and Ingestion
Enterprise Knowledge Base
PDFs ...
Preprocess Documents
LlamaIndex
Documents
Embedding Model
Document embeddings
Vector DB
LangChain
LlamaIndex
2 User Query and Response Generation
User
Chat Bot Web App
User query
Query and embedded query
Prompt + query + enhanced context
LLM (potentially prompt-tuned)
Streamed text response (generative)

Why Evaluate RAG?

RAG enhances content generation by leveraging existing information effectively. It can amalgamate specific, relevant details from multiple sources to generate more accurate and relevant query results. This makes RAG potentially invaluable in various domains, including content creation, question & answer applications, and information synthesis. RAG does this by combining the strengths of retrieval, usually using dense vector search, and text generation, but to see what is and isn't working in your RAG system, to refine and optimize, you must evaluate it.

Note: Evaluation is essential to validate and make sure your application does what is expected.

Evaluation Process

Evaluating RAG goes through the following steps:

1. Choose Right Evaluation Framework.
2. Generate Synthetic Dataset.
3. Generate RAG Outputs for the Questions from Synthetic Dataset.
4. Evaluating Using the Generated Dataset.
5. Understanding The Metrics.

Choose the Right Evaluation Framework

RAG evaluation quantifies the accuracy of retrieval phrase by calculating metrics on the top results your system returns, enabling you to programmatically monitor pipeline’s precision, recall ability, and faithfulness to facts.

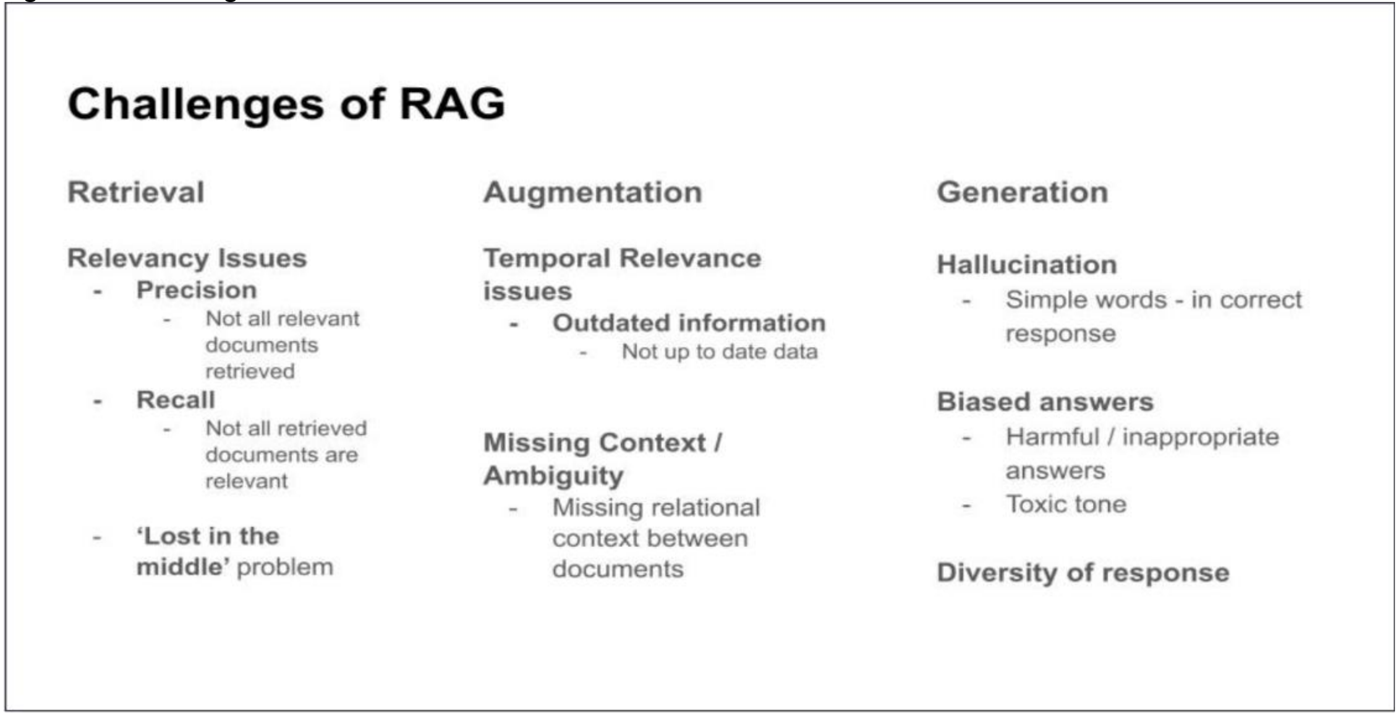
```
If you can't quantify it, you can't improve it
```

It is not only important to have good metrics, but that the ability to measure things separately.

`If you can't retrieve it, you can't generate it.`

To see where things are going well, can be improved, and where errors may originate, it's important to evaluate each component in isolation. The Figure 28 classifies the RAG's components – along with what needs evaluation in each:

Figure 28. Challenges of RAG



Challenges of RAG

Retrieval

Relevancy Issues
- **Precision**
  - Not all relevant documents retrieved
- **Recall**
  - Not all retrieved documents are relevant
- **'Lost in the middle'** problem

Augmentation

Temporal Relevance issues
- **Outdated information**
  - Not up to date data

Missing Context / Ambiguity
- Missing relational context between documents

Generation

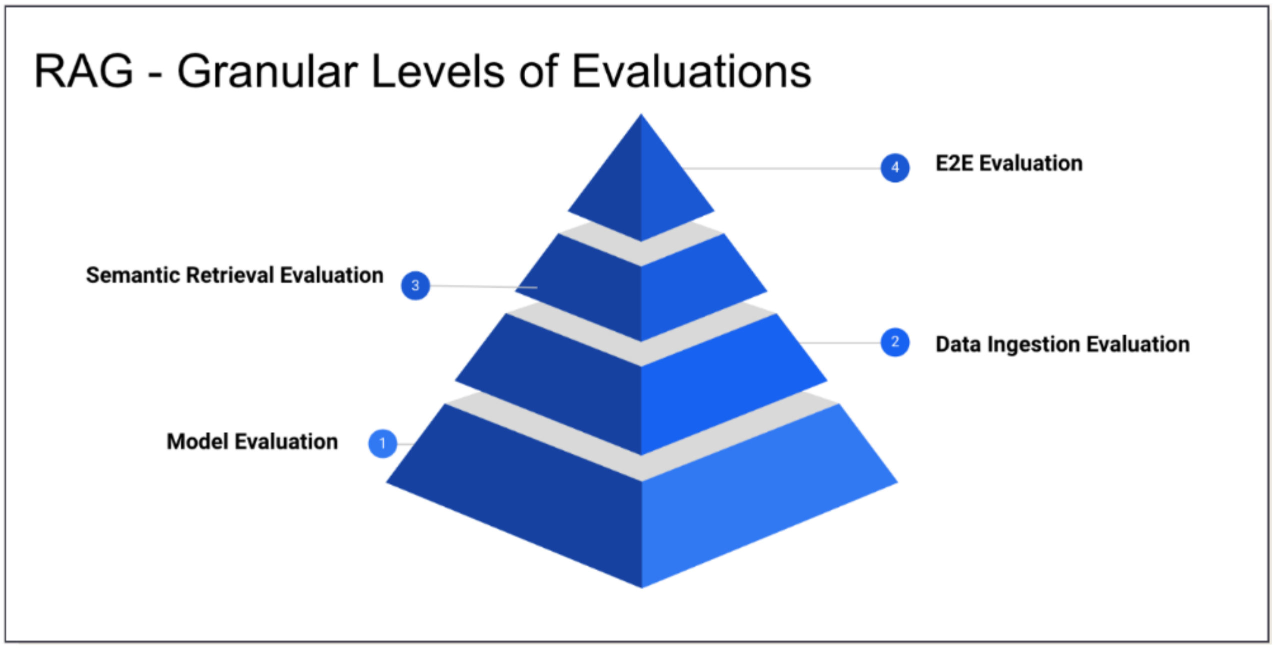
Hallucination
- Simple words - in correct response

Biased answers
- Harmful / inappropriate answers
- Toxic tone

Diversity of response

The Evaluation Framework is meant to ensure granular and thorough measurement, addressing the challenges faced in all three components.

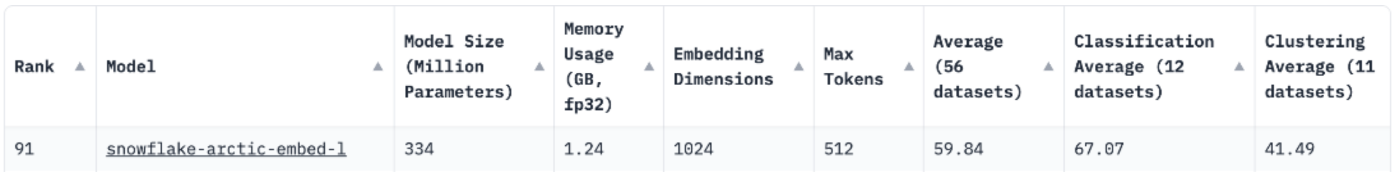
To meet the evaluation challenges systematically, it's a best practice to breakdown evaluation into different levels.


RAG - Granular Levels of Evaluations
4 E2E Evaluation
3 Semantic Retrieval Evaluation
2 Data Ingestion Evaluation
1 Model Evaluation

Embedding Model Evaluation

The [Massive Text Embedding Benchmark (MTEB)]() leverages different public/private datasets to evaluate and report on the different capabilities of individual models. You can use the MTEB to evaluate any model in its list

The Model used in this deployment type is "snowflake-arctic-embed-l" and below is the model's performance listed on leaderboard:



Rank	Model	Model Size (Million Parameters)	Memory Usage (GB, fp32)	Embedding Dimensions	Max Tokens	Average (56 datasets)	Classification Average (12 datasets)	Clustering Average (11 datasets)
91	snowflake-arctic-embed-l	334	1.24	1024	512	59.84	67.07	41.49

Data Ingestion Evaluation

After evaluating model's performance using benchmarks, and (optionally) fine-tune it, then configure data ingestion into semantic retrieval store (vector store).

To evaluate data ingestion, observe and measure how changes in related variables affect ingestion outcomes:

- Chunk Size: The size of each data segment, which depends on the token limit of the embedding model. Chunk size substantially determines data granularity and the contextual understanding of the data, which impacts the precision, recall, and relevancy of results.
- Chunk Overlap: The extent to which data points of events are shared by adjacent data chunks. Overlap helps with retention of context information contained in chunks but should be paired with strategies like deduplication and content normalization to eradicate adverse effects (redundancy or inconsistency).
- Chunking/ Text Splitting Strategy: The process of data splitting and further treatment, based on both data type (for example, html, markdown, code, or pdf, and so on) and nuances of your use case.

Semantic Retrieval Evaluation

In this deployment, the Milvus Vector Database has been deployed, and milvus offers similarity metrics.

Similarity metrics are used to measure similarities among vectors. Choosing a good distance metric helps improve the classification and clustering performance significantly.

Similarity Metrics	Index Type
• Euclidean distance (L2) • Inner Product (IP)	• FLAT • IVF_FLAT • IVF_SQ8 • IVF_PQ • HNSW • IVF_HNSW • RHNSW_FLAT • RHNSW_SQ • RHNSW_PQ • ANNOY

Euclidean distance (L2)—essentially, Euclidean distance measures the length of a segment that connects 2 points.

The formula for Euclidean distance is as follows:

$$d(\mathbf{a},\mathbf{b}) = d(\mathbf{b},\mathbf{a}) = \sqrt{\sum_{i=1}^{n}(b_i - a_i)^2}$$

where a = (a1, a2,..., an) and b = (b1, b2,..., bn) are two points in n-dimensional Euclidean space

It's the most used distance metric and is very useful when the data are continuous.

Inner Product (IP)—The IP distance between two embeddings is defined as follows:

$$p(A,B) = A \cdot B = \sum_{i=1}^{n} a_i \times b_i$$

Where A and B are embeddings, ||A|| and ||B|| are the norms of A and B.

IP is more useful if you are more interested in measuring the orientation but not the magnitude of the vectors.

If you use IP to calculate embeddings similarities, you must normalize your embeddings. After normalization, the inner product equals cosine similarity.

Suppose X’ is normalized from embedding X:

$$\boxed{X' = (x'_1, x'_2, \ldots, x'_n), X' \in {}^{n}}$$

The correlation between the two embeddings is as follows:

$$\boxed{x'_i = \frac{x_i}{\| X \|} = \frac{x_i}{\sqrt{\sum_{i=1}^{n} (x_i)^2}}}$$

End-to-End Evaluation

An end-to-end evaluation of a RAG application assesses the final outputs generated by LLMs in response to given inputs. It requires addressing issues discussed above related to data heterogeneity, domain specificity, and user query and preference diversity. It's impossible to devise a fixed metric or methodology that fits all domains and use cases.

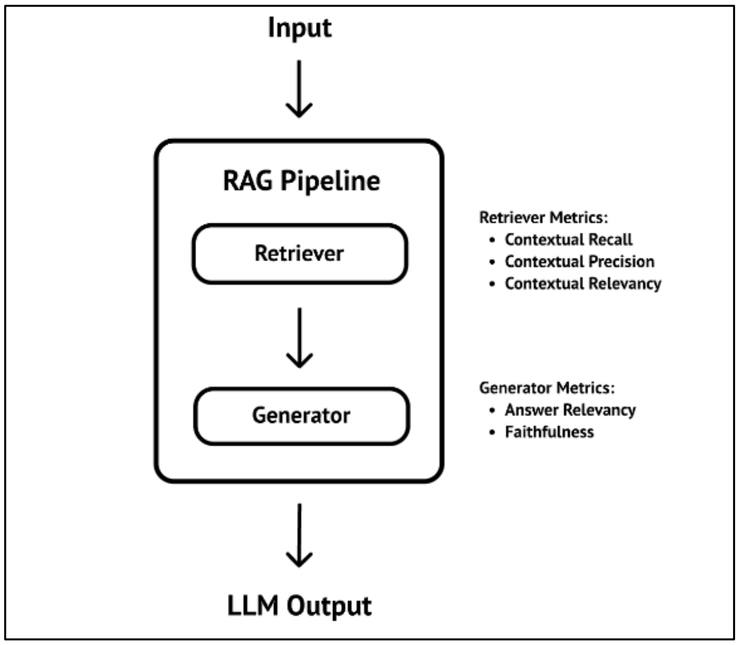
E2E evaluation frameworks range from proprietary solutions to open-source tools. Selecting the right solution requires balancing considerations around ease of maintenance and operational burden, plus how well the metrics observed by the tool map to your Retrieval Augmented Generation pipeline’s use case.

Table 26. Recommended RAG Frameworks based on Use Case

Use Case	Framework	Metrics Used	Reasoning
Initial RAG Evaluations	RAGAS	Average Precision (AP), Faithfulness	RAGAS is ideal for initial evaluations, especially in environments where reference data is scarce. It focuses on precision and how faithfully the response matches the provided context.
Dynamic, Continuous RAG Deployments	ARES	MRR, NDCG	ARES uses synthetic data and LLM judges, which are suitable for environments needing continuous updates and training and focusing on response ranking and relevance.
Full System Traces, Including LLM’s and Vector Storage	TraceLoop	Informational Gain, Factual Consistency, Citation Accuracy	TraceLoop is best suited for applications where tracing the flow and provenance of information used in the generated output is critical, such as academic research or journalism.
Realtime RAG Monitoring	Arize	Precision, Recall, F1	Arize excels in real-time performance monitoring, making

Use Case	Framework	Metrics Used	Reasoning
			it perfect for deployments where immediate feedback on RAG performance is essential
Enterprise Level RAG Applications	Galileo	Custom Metrics, Context Adherence	Galileo provides advanced insights and metrics integration for complex applications, ensuring RAG's adherence to context.
Optimizing RAG for Specific Domains	TruLens	Domain-Specific Accuracy, Precision	TruLens is designed to optimize RAG systems within specific domains, by enhancing the accuracy and precision of domain-relevant responses

Since a satisfactory LLM output depends entirely on the quality of the retriever and generator, RAG evaluation focuses on evaluating the retriever and generator in RAG pipeline separately. This allows for easier debugging and to pinpoint issues on a component level.



This document provides the steps necessary to run RAGAS Evaluation Framework. RAGAS is a framework that helps evaluate Retrieval Augmented Generation (RAG) Initial pipelines.

Generate Synthetic Dataset

To set up RAGAS evaluation Framework, apply ground truth concept. Some ground truth data - a golden set - provides a meaningful context for the metrics to evaluate our RAG pipeline's generated responses.

The first step in setting up RAGAS is creating an evaluation dataset, complete with questions, answers, and ground-truth data, which takes account of relevant context.

Procedure 1. Create an evaluation dataset

Step 1. Create LLM Prompt template:

```
LLM_PROMPT_TEMPLATE = (
    "<s>[INST] <<SYS>>"
    "{system_prompt}"
    "<</SYS>>"
    " "
    "[The Start of the Reference Context]"
    "{ctx_ref}"
    "[The End of Reference Context][/INST]"
)
```

Step 2. Create the System template:

```
SYS_PROMPT = """
    Given the context paragraph, create two very good question answer pairs.
    Your output should be strictly in a json format of individual question answer pairs with keys from
["question","answer"].
    Restrict the question to the context information provided.
    """
```

Step 3. Generate Synthetic Data:

```
def generate_synthetic_data(
    dataset_folder_path,
    qa_generation_file_path,
    text_splitter_params={"chunk_size": 3000, "chunk_overlap": 100},
):
    files=[dataset_folder_path]
    llm = ChatNVIDIA(base_url="http://10.102.2.216:31641/v1", model="meta/llama3-8b-
instruct",nvidia_api_key="not-used", max_tokens=1024)
    json_data = []
    i = 0
    for pdf_file in files:
        i += 1
        try:
            logger.info(f"{i}/{len(files)}")
            # pdf_file = dataset_folder_path +'/'+ pdf_file
            loader = PyPDFLoader(pdf_file)
            data = loader.load()
            text_splitter = RecursiveCharacterTextSplitter(**text_splitter_params)
            all_splits = text_splitter.split_documents(data)
            for split in all_splits:
                context = LLM_PROMPT_TEMPLATE.format(
                        system_prompt=SYS_PROMPT,
                        ctx_ref=split.page_content)
                try:
                    answer = llm.invoke(context).content
                    question_pattern = r'"question":\s*"([^"]*)"'
                    answer_pattern = r'"answer":\s*"([^"]*)"'
                    question_match = re.findall(question_pattern, answer)
                    answer_match = re.findall(answer_pattern, answer)
                    if(len(question_match)==len(answer_match)):
                        for j, _ in enumerate(question_match):
                            my_data = {
                                'question': question_match[j],
                                'ground_truth_answer': answer_match[j],
                                'ground_truth_context': split.page_content,
                                'document': pdf_file,
                            }
                            json_data.append(my_data)

                except Exception as e:
                    logger.info(
                        f"\n PDF: {pdf_file} \n \t Context: {context} \n Exception Occured: {e}"
                    )


        except Exception as e:
            logger.info(f"\n PDF: {pdf_file} \n Exception Occured: {e}")
    with open(qa_generation_file_path, "w", encoding="utf-8") as f:
        json.dump(json_data, f)
```

Step 4. Call this function with path to the document and file name for q&a:

```
generate_synthetic_data('/home/admin/RAG/flashstack_ai_generative_ocp_m7.pdf','/home/admin/RAG/flashstack_qa
_generation.json')
```

This creates a JSON file called “flashstack_qa_generation.json”

Procedure 2. Generate RAG Outputs for the Questions from Synthetic Dataset

Step 1. Load the JSON file and iterate through each question, retrieve context from vector store and ask LLM to generate the response:

```
url_upload = f"http://10.102.2.216:31935/documents"
url_generate = f"http://10.102.2.216:31935/generate"
url_doc_search = f"http://10.102.2.216:31935/search"
f = open('/home/admin/RAG/flashstack_qa_generation.json')
data = json.load(f)

generate_api_params={"use_knowledge_base": True, "temperature":0.2,"top_p":0.7,"max_tokens": 256}

document_search_api_params={"num_docs": 1}

new_data=[]

for entry in data:
    entry_generate = {
        "messages":[
            {
                "role":"user",
                "content":entry["question"]
            }
        ],
        "use_knowledge_base": generate_api_params["use_knowledge_base"],
        "temperature": generate_api_params["temperature"],
        "top_p": generate_api_params["top_p"],
        "max_tokens": generate_api_params["max_tokens"],
        "stop":[
                "string"
        ]
    }
    entry["answer"] = ""
    try:
        with requests.post(url_generate, stream=True, json=entry_generate) as r:
            for chunk in r.iter_lines():
                raw_resp = chunk.decode("UTF-8")
                if not raw_resp:
                    continue
                resp_dict = None
                try:
                    print(raw_resp)
                    resp_dict = json.loads(raw_resp[6:])
                    resp_choices = resp_dict.get("choices", [])
                    if len(resp_choices):
                        resp_str = resp_choices[0].get("message", {}).get("content", "")
                        entry["answer"] += resp_str
                except Exception as e:
                    print(f"Exception Occured: {e}")
    except Exception as e:
        print(f"Exception Occured: {e}")
        entry["answer"] = "Answer couldn't be generated."
    print(entry["answer"])
    entry_doc_search = {
            "query": entry["question"],
            "top_k": document_search_api_params["num_docs"]
        }
    response = requests.post(url_doc_search, json=entry_doc_search).json()
    context_list =typing.cast(typing.List[typing.Dict[str, typing.Union[str, float]]], response)
    contexts = [context.get("content") for context in context_list['chunks']]
    try:
        entry["contexts"] = [contexts[0]]
    except Exception as e:
        print(f"Exception Occured: {e}")
        entry["contexts"] = ""
    new_data.append(entry)
```

Step 2. Once the new list of objects is created, store them on the file system as shown below:

```
with open('/home/admin/RAG/flashstack_eval.json', 'w') as f:
    json.dump(data, f)
```

This creates a JSON file called "flashstack_eval.json"

Procedure 3. Evaluate using the Generated Dataset

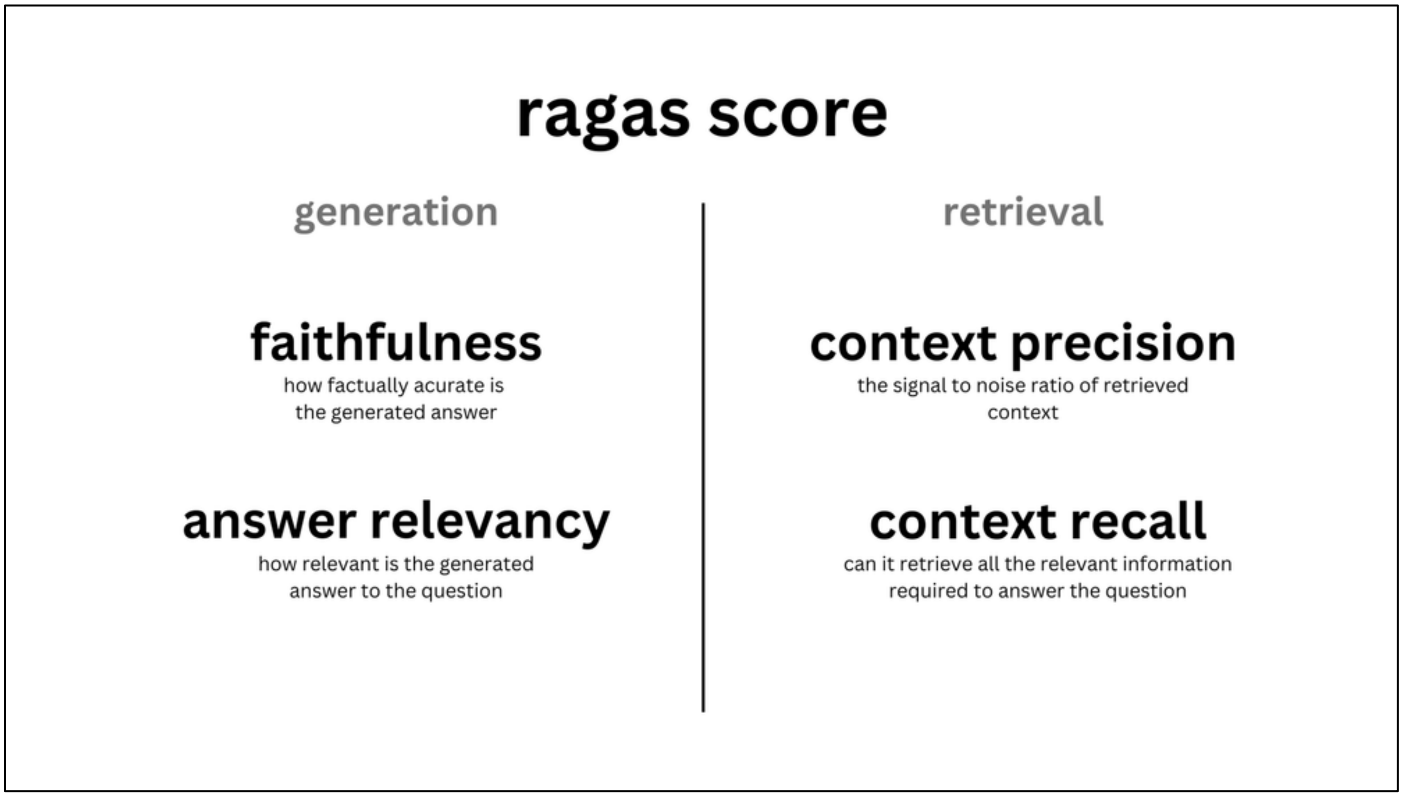
Step 1. Create the Prompt Template:

```
LLAMA_PROMPT_TEMPLATE = (
    "<s>[INST] <<SYS>>"
    "{system_prompt}"
    "<</SYS>>"
    ""
    "Example 1:"
    "[Question]"
    "When did Queen Elizabeth II die?"
    "[The Start of the Reference Context]"
    """On 8 September 2022, Buckingham Palace released a statement which read: "Following further evaluation this morning, the Queen's doctors are concerned for Her Majesty's health and have recommended she remain under medical supervision. The Queen remains comfortable and at Balmoral."[257][258] Her immediate family rushed to Balmoral to be by her side.[259][260] She died peacefully at 15:10 BST at the age of 96, with two of her children, Charles and Anne, by her side;[261][262] Charles immediately succeeded as monarch. Her death was announced to the public at 18:30,[263][264] setting in motion Operation London Bridge and, because she died in Scotland, Operation Unicorn.[265][266] Elizabeth was the first monarch to die in Scotland since James V in 1542.[267] Her death certificate recorded her cause of death as old age"""
    "[The End of Reference Context]"
    "[The Start of the Reference Answer]"
    "Queen Elizabeth II died on September 8, 2022."
    "[The End of Reference Answer]"
    "[The Start of the Assistant's Answer]"
    "She died on September 8, 2022"
    "[The End of Assistant's Answer]"
    '"Rating": 5, "Explanation": "The answer is helpful, relevant, accurate, and concise. It matches the information provided in the reference context and answer."'
    ""
    "Example 2:"
    "[Question]"
    "When did Queen Elizabeth II die?"
    "[The Start of the Reference Context]"
    """On 8 September 2022, Buckingham Palace released a statement which read: "Following further evaluation this morning, the Queen's doctors are concerned for Her Majesty's health and have recommended she remain under medical supervision. The Queen remains comfortable and at Balmoral."[257][258] Her immediate family rushed to Balmoral to be by her side.[259][260] She died peacefully at 15:10 BST at the age of 96, with two of her children, Charles and Anne, by her side;[261][262] Charles immediately succeeded as monarch. Her death was announced to the public at 18:30,[263][264] setting in motion Operation London Bridge and, because she died in Scotland, Operation Unicorn.[265][266] Elizabeth was the first monarch to die in Scotland since James V in 1542.[267] Her death certificate recorded her cause of death as old age"""
    "[The End of Reference Context]"
    "[The Start of the Reference Answer]"

    "Queen Elizabeth II died on September 8, 2022."

    "[The End of Reference Answer]"

    "[The Start of the Assistant's Answer]"

    "Queen Elizabeth II was the longest reigning monarch of the United Kingdom and the Commonwealth."

    "[The End of Assistant's Answer]"

    '"Rating": 1, "Explanation": "The answer is not helpful or relevant. It does not answer the question and
instead goes off topic."'

    ""

    "Follow the exact same format as above. Put Rating first and Explanation second. Rating must be between
1 and 5. What is the rating and explanation for the following assistant's answer"

    "Rating and Explanation should be in JSON format"

    "[Question]"

    "{question}"

    "[The Start of the Reference Context]"

    "{ctx_ref}"

    "[The End of Reference Context]"

    "[The Start of the Reference Answer]"

    "{answer_ref}"

    "[The End of Reference Answer]"

    "[The Start of the Assistant's Answer]"

    "{answer}"

    "[The End of Assistant's Answer][/INST]"

)
```

Step 2. Create System Prompt:

```
SYS_PROMPT = """

    You are an impartial judge that evaluates the quality of an assistant's answer to the question provided.

    You evaluation takes into account helpfullness, relevancy, accuracy, and level of detail of the answer.

    You must use both the reference context and reference answer to guide your evaluation.

    """
```

The performance of individual components within the LLM and RAG pipeline has a significant impact on the overall experience. Ragas offers metrics tailored for evaluating each component of RAG pipeline in isolation.


ragas score
generation
retrieval
faithfulness
how factually acurate is the generated answer
context precision
the signal to noise ratio of retrieved context
answer relevancy
how relevant is the generated answer to the question
context recall
can it retrieve all the relevant information required to answer the question

Step 3. Create a Function to choose the metric types:

```
def calculate_ragas_score(row):
    values = row[['faithfulness', 'context_relevancy', 'answer_relevancy','context_recall']].values
    return statistics.harmonic_mean(values)
```

Step 4. Create a Function to run RAGAS Evaluation from the evaluation json dataset:

```
def eval_ragas(ev_file_path, ev_result_path,llm_model='ai-mixtral-8x7b-instruct'):
    """
    This function evaluates a language model's performance using a dataset and metrics.
    It sets the NVAPI_KEY, initializes a ChatNVIDIA model and LangchainLLM object, loads the
    evaluation dataset, prepares data samples, creates a Dataset object, sets the language model
    for each metric, and evaluates the model with the specified metrics, printing the results.
    """
    llm = ChatNVIDIA(base_url="http://10.102.2.216:31641/v1", model="meta/llama3-8b-
instruct",nvidia_api_key="not-used", max_tokens=1024)
    nvpl_llm = LangchainLLMWrapper(langchain_llm=llm)
    model = "NV-Embed-QA"
    url="http://10.102.2.216:32128/v1/embeddings"
    batch_size=32
    embeddings = NeMoEmbeddings(
    batch_size=batch_size, model=model, api_endpoint_url=url
        )
    nvpl_embeddings = LangchainEmbeddingsWrapper(embeddings)
    try:
        with open(ev_file_path, "r", encoding="utf-8") as file:
            json_data = json.load(file)
    except Exception as e:
        logger.info(f"Error Occured while loading file : {e}")
    eval_questions = []
    eval_answers = []
    ground_truth = []
    vdb_contexts = []
    for entry in json_data:
        eval_questions.append(entry["question"])
        eval_answers.append(entry["answer"])
        vdb_contexts.append(entry['contexts'])
        ground_truth.append(entry["ground_truth_answer"])

    data_samples = {
            'question': eval_questions,
            'answer': eval_answers,
            'contexts': vdb_contexts,
            'ground_truth': ground_truth,
        }
    # print(data_samples)
    dataset = Dataset.from_dict(data_samples)
    print(dataset)
    result = evaluate(
        dataset,
        llm=llm,
        embeddings=nvpl_embeddings,
        metrics=[
            answer_similarity,
            faithfulness,
            context_precision,
            context_relevancy,
            answer_relevancy,
            context_recall
        ],
    )
    df = result.to_pandas()
    df['ragas_score']=df.apply(calculate_ragas_score,axis=1)
    df.to_parquet(ev_result_path+'.parquet')
    result['ragas_score']= statistics.harmonic_mean([result['faithfulness'], result['context_relevancy'],
result['answer_relevancy'], result['context_recall']])
    with open(ev_result_path+'.json', "w", encoding="utf-8") as json_file:
        json.dump(result, json_file, indent=2)
```

The following are the results:

```
eval_ragas('/home/admin/RAG/flashstack_eval.json','/home/admin/RAG/results/flashstack_evaluator')
```

```
{
  "answer_similarity": 0.5262431058841802,
  "faithfulness": 0.7325238095238095,
  "context_precision": 0.9799999999019999,
  "context_relevancy": 0.2949610417961811,
  "answer_relevancy": 0.5797973179159244,
  "context_recall": 0.8744285714285713,
  "ragas_score": 0.5246750611338722
}
```

Understanding the Metrics

- Answer Similarity

  The concept of Answer Semantic Similarity pertains to the assessment of the semantic resemblance between the generated answer and the ground truth. This evaluation is based on the ground truth and the answer, with values falling within the range of 0 to 1. A higher score signifies a better alignment between the generated answer and the ground truth.

  Measuring the semantic similarity between answers can offer valuable insights into the quality of the generated response. This evaluation utilizes a cross-encoder model to calculate the semantic similarity score.

- Faithfulness

  This measures the factual consistency of the generated answer against the given context. It is calculated from answer and retrieved context. The answer is scaled to (0,1) range. Higher the better.

  The generated answer is regarded as faithful if all the claims made in the answer can be inferred from the given context. To calculate this, a set of claims from the generated answer is first identified. Each of these claims is cross-checked with the given context to determine if it can be inferred from the context. The faithfulness score is determined by:

$$\text{Faithfulness score} = \frac{|\text{Number of claims in the generated answer that can be inferred from given context}|}{|\text{Total number of claims in the generated answer}|}$$

- Context Precision

  Context Precision is a metric that evaluates whether all the ground-truth relevant items present in the contexts are ranked higher or not. Ideally all the relevant chunks must appear at the top ranks. This metric is computed using the question, ground_truth and the contexts, with values ranging between 0 and 1, where higher scores indicate better precision.

$$\text{Context Precision@K} = \frac{\sum_{k=1}^{K} (\text{Precision@k} \times v_k)}{\text{Total number of relevant items in the top } K \text{ results}}$$

$$\text{Precision@k} = \frac{\text{true positives@k}}{(\text{true positives@k} + \text{false positives@k})}$$

Where K is the total number of chunks in contexts and vk∈ {0,1} is the relevance indicator at rank k.

- Context Relevancy

This metric gauge the relevancy of the retrieved context, calculated based on both the question and contexts. The values fall within the range of (0, 1), with higher values indicating better relevancy.

Ideally, the retrieved context should exclusively contain essential information to address the provided query. To compute this, we initially estimate the value of |S| by identifying sentences within the retrieved context that are relevant for answering the given question. The final score is determined by the following formula:

$$\text{context relevancy} = \frac{|S|}{|\text{Total number of sentences in retrived context}|}$$

- Answer Relevancy

  The evaluation metric, Answer Relevancy, focuses on assessing how pertinent the generated answer is to the given prompt. A lower score is assigned to answers that are incomplete or contain redundant information and higher scores indicate better relevancy. This metric is computed using the question, the context, and the answer.

  The Answer Relevancy is defined as the mean cosine similarity of the original question to a number of artificial questions, which were generated (reverse engineered) based on the answer:

$$\text{answer relevancy} = \frac{1}{N}\sum_{i=1}^{N} cos(E_{g_i}, E_o)$$

$$\text{answer relevancy} = \frac{1}{N}\sum_{i=1}^{N} \frac{E_{g_i} \cdot E_o}{\|E_{g_i}\|\|E_o\|}$$

Where:

- Egi is the embedding of the generated question i.
- Eo is the embedding of the original question.
- N is the number of generated questions, which is 3 default.

Note: Even though in practice the score will range between 0 and 1 most of the time, this is not mathematically guaranteed, due to the nature of the cosine similarity ranging from -1 to 1.

- Context Recall

  Context recall measures the extent to which the retrieved context aligns with the annotated answer, treated as the ground truth. It is computed using question, ground truth and the retrieved context, and the values range between 0 and 1, with higher values indicating better performance. To estimate context recall from the ground truth answer, each claim in the ground truth answer is analyzed to determine whether it can be attributed to the retrieved context or not. In an ideal scenario, all claims in the ground truth answer should be attributable to the retrieved context. A reference free version of this is available as context_utilization.

  The formula for calculating context recall is as follows:

$$\text{context recall} = \frac{|\text{GT claims that can be attributed to context}|}{|\text{Number of claims in GT}|}$$

- RAGAS Score

  This metric provides a measure of how well the summary captures the important information from the contexts. The intuition behind this metric is that a good summary shall contain all the important information present in the context (or text).

  First extract a set of important key phrases from the context. These key phrases are then used to generate a set of questions. The answers to these questions are always yes (1) for the context. Ask these questions to the summary and calculate the summarization score as the ratio of correctly answered questions to the total number of questions.

  Compute the question-answer score using the answers, which is a list of 1s and 0s. The question-answer score is then calculated as the ratio of correctly answered questions (answer = 1) to the total number of questions.

$$\text{QA score} = \frac{|\text{correctly answered questions}|}{|\text{total questions}|}$$

Milvus Benchmarking with VectorDBBench

Today, the growth of unstructured data and the rise of AI and LLMs have highlighted vector databases as a crucial component of the infrastructure. As the focus shifts to these tools, enterprises need to assess and select the right one for their business. Vector databases manage unstructured data like images, video, text and so on, using vector embeddings. Vector databases specialize in semantic similarity searches using a machine-learning technique called Approximate Nearest Neighbor (ANN). Vector databases are the vector store for RAG applications.

Milvus is a high-performance, highly scalable vector database that runs efficiently across a wide range of environments. Unstructured data varies in format and carries rich underlying semantics, making it challenging to analyze. To manage this complexity, embeddings are used to convert unstructured data into numerical vectors that capture its essential characteristics. These vectors are then stored in a vector database, enabling fast and scalable searches and analytics. Milvus offers robust data modeling capabilities, enabling you to organize your unstructured or multi-modal data into structured collections. Milvus allocates over 80% of its computing resources to its vector databases and search engine. Given the computational demands of high-performance computing, GPUs emerge as a pivotal element of vector database platform, especially within the vector search domain.

NVIDIA’s latest innovation, the GPU-based graph index CAGRA (CUDA ANNs GRAph-based), represents a significant milestone. With NVIDIA’s assistance, Milvus integrated support for CAGRA in its 2.4 version, marking a significant stride toward overcoming the obstacles of efficient GPU implementation in vector search.

The decision to leverage GPU indexes was primarily motivated by performance considerations. We undertook a comprehensive evaluation of Milvus’ performance utilizing the VectorDBBench tool, focusing on CAGRA index and observing key evaluation metrics like QPS (Queries Per Second), latency, and recall.

VectorDBBench is the best performing and cost-effective comparison open-source tool, and it offers more than just benchmark results for popular vector databases and cloud services.

Query Performance Metrics

Assessing the query performance of vector databases typically involves three key metrics: latency, queries per second (QPS), and recall rate.

Latency testing measures the time taken for a single query under serial testing conditions. P99 latency is a commonly used metric representing the duration within which 99% of queries are completed. It offers a more nuanced perspective than average latency and aligns closely with user experience.

Note: While latency testing is straightforward, it's heavily influenced by network conditions, especially for cloud products.

QPS refers to a database's query capability under high concurrency. It is achieved by simultaneously sending multiple requests from the test client to maximize database CPU/ GPU utilization and observe throughput. Unlike latency, QPS is less susceptible to network fluctuations, providing a comprehensive evaluation of a vector database's real-world performance.

Recall is the proportion of the ground truth documents that are represented in the retrieved chunks. This is a measure of the completeness of the results.

$$\text{Recall} = \frac{\text{Number of relevant retrieved items}}{\text{Number of total relevant items}}$$

High recall ensures that the LLM is comprehensive in its responses, capturing all the relevant information necessary for the task.

Procedure 1. Milvus Distributed deployment with FlashBlade//S

Vector database benchmarking is executed with Milvus Distributed vector database with NVIDIA L40S GPUs. For detailed steps on deploying Distributed Milvus vector database, go to section Vector Database.

For detailed information, click the following links:

- https://milvus.io/docs/install_cluster-helm-gpu.md
- https://github.com/milvus-io/milvus

VectorDBBench

VectorDBBench is an open-source benchmarking tool designed for high-performance data storage and retrieval systems. This tool allows users to test and compare different vector database systems' performance to determine their specific use case's most suitable database system. Using VectorDBBench, users can make informed decisions based on the actual vector database performance of the systems they are evaluating.

VectorDBBench is written in Python and licensed under the MIT open-source license, The tool is actively maintained by a community of developers committed to improving its features and performance.

Procedure 1. Install and run the VectorDBBench tool

Step 1. Prerequisite:

```
Python >= 3.11
```

Step 2. Create a virtual python environment “milvus” and activate it:

```
python -m venv milvus
source milvus/bin/activate
cd milvus
```

Step 3. Install vectordb-bench:

```
pip install vectordb-bench==0.0.22
```

Step 4. Run vectordb-bench:

```
python -m vectordb_bench
```

OR

```
init_bench
```

After completion, the tool is up and running and can access the streamlit web application using the network URL.

Step 5. After completion of the benchmark testing with vectordb-bench tool, to come out of the python virtual environment, run the following script:

```
deactivate
```

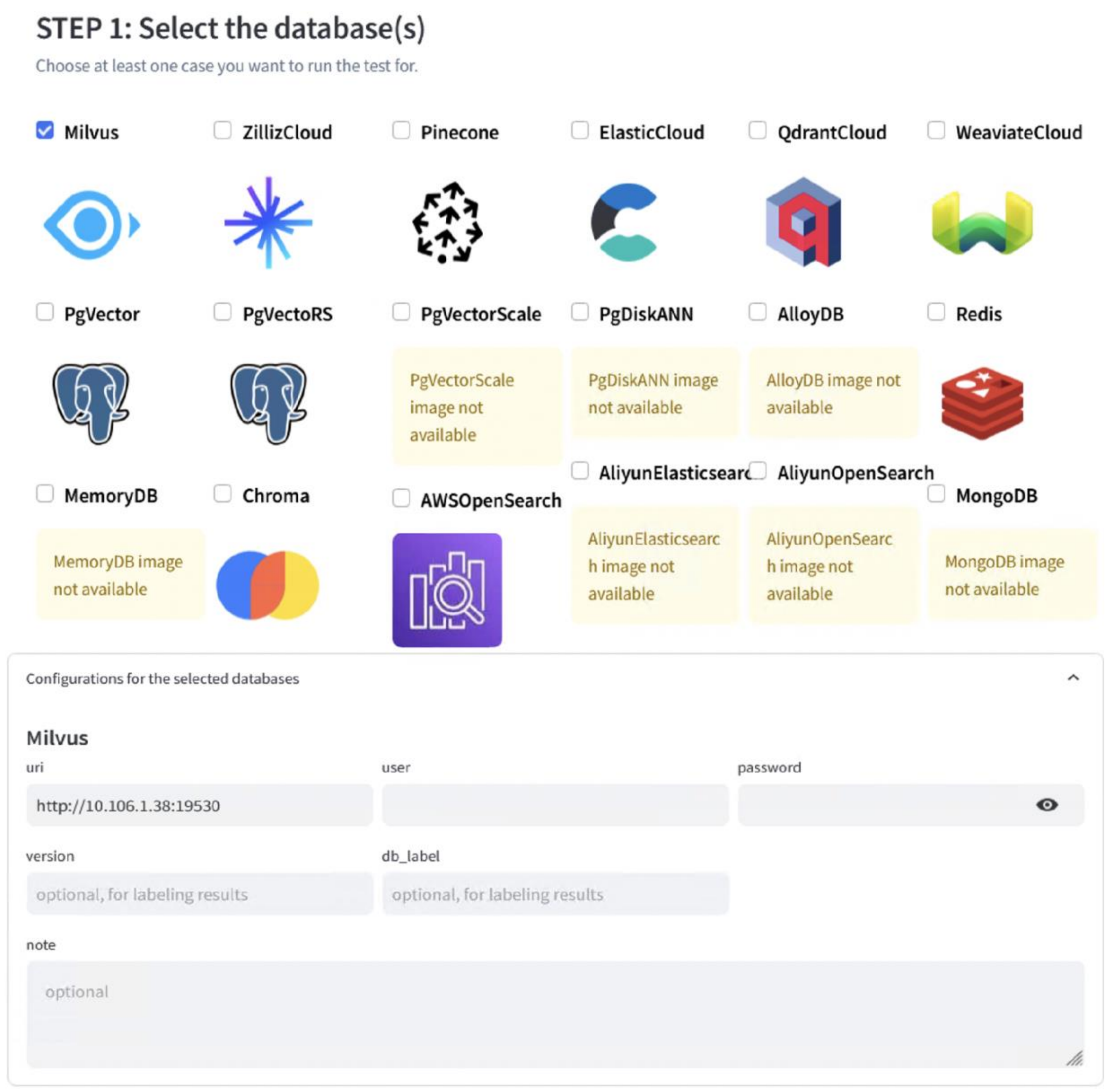
For more information, see: https://github.com/zilliztech/VectorDBBench

Procedure 2. Run the Test

Step 1. Select the database(s). There are various options available for vector databases like Milvus, Pinecone, PgVector, and so on.

Note: In our tests, we used Milvus.

Step 2. Provide the required configuration information for the selected database:


STEP 1: Select the database(s)

Choose at least one case you want to run the test for.

[✓ Milvus] ZillizCloud Pinecone ElasticCloud QdrantCloud WeaviateCloud

PgVector PgVectoRS PgVectorScale PgDiskANN AlloyDB Redis

PgVectorScale image not available

PgDiskANN image not available

AlloyDB image not available

MemoryDB Chroma AWSOpenSearch AliyunElasticsearc AliyunOpenSearch MongoDB

MemoryDB image not available

AliyunElasticsearch image not available

AliyunOpenSearch image not available

MongoDB image not available

Configurations for the selected databases

Milvus

uri	user	password
http://10.106.1.38:19530		
version	db_label	
optional, for labeling results	optional, for labeling results	
note		
optional		

Step 3. Select the test case to run the benchmarking test.

Note: We ran a Search Performance Test case with a medium dataset (Cohere 1M vectors, 768 dimensions)

Step 4. Select the index type. You can select the index type depending upon their deployment characteristics and datasets. Some of the options provided by vectordbbench are DISKANN, HNSW, GPU_IVF_FLAT, GPU_IVF_PQ and so on. There is a flexibility provided to change the test parameters pertaining to a particular index type.

Note: We used GPU_CAGRA and HSNW indexes with default parameters for running the tests.

- HSNW index type (CPU based):

  The HNSW index is a graph-based indexing algorithm that can improve performance when searching for high-dimensional floating vectors. It offers excellent search accuracy and low latency but with the tradeoff of long index build time and it requires high memory overhead to maintain its hierarchical graph structure. For more details on this index type, refer: https://milvus.io/docs/hnsw.md

- GPU_CAGRA Index Type (GPU-based)

GPU_CAGRA is a graph-based index optimized for GPUs. Using inference-grade GPUs to run the Milvus GPU version can be more cost-effective compared to using expensive training-grade GPUs.

Note: For more information about index building and search parameters, go to: https://milvus.io/docs/gpu_index.md.

Note: For detailed information about the integration of milvus with CAGRA, go to: https://zilliz.com/blog/Milvus-introduces-GPU-index-CAGRA

Step 5. You can provide your custom task label or go by default as provided by the tool.

Benchmarking Test Details

In this solution, we executed Search Performance test of Milvus vectorstore DB with Cohere 1M dataset size and 768 dimensions and varied the batch size for the ML model. Latencyp99, recall, load-duration, and QPS (Queries Per Second) are the few KPIs used to validate the test results. These tests were executed for both HSNW and GPU_CAGRA index types.

To update the batch size between test iterations, update the NUM_PER_BATCH variable in the __init__.py file which is stored under python3.12/site-packages/vectordb_bench/ directory.

Note: We used batch sizes of 1, 10, 50, and 100 in the test iterations.

Note: The dataset gets downloaded on the client machine where vectordb_bench is running. Therefore, make sure there is sufficient disk space on the system.

Since these tests are executed with HSNW (CPU based) and GPU_CAGRA (GPU based) indexes, CPU utilization for HSNW and GPU utilization for GPU_CAGRA index were captured during the tests.

Test Results

This chapter contains the following:

- Test Results for HSNW Index Search Performance
- Test Results for GPU_CAGRA Index Search Performance

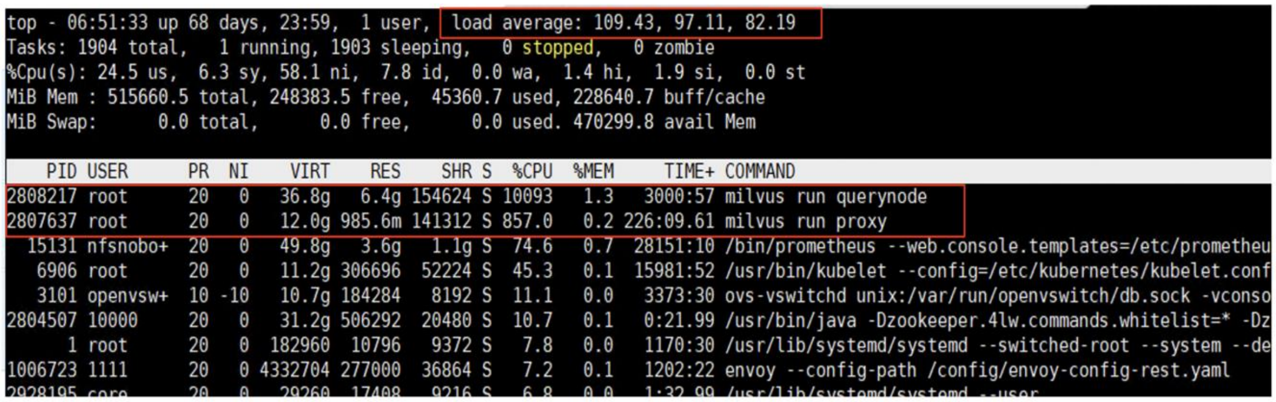
While running the test, we noticed that the CPU and GPU were being utilized during various stages of the test execution like data ingestion, query execution , and so on. The CPU and GPU utilizations are captured during Search Performance test execution with linux top and nvidia-smi tool.

Test Results for HSNW Index Search Performance

The following table lists the performance metrics for various batch sizes with Search Performance test executed with HSNW index type.

Batch size	Recall	serial_latency_p99 (ms)	QPS (Query per second)
1	0.9767	2.9	5082
10	0.9704	2.9	6003
50	0.9704	2.9	6144
100	0.9704	2.9	6527

The following screenshot shows the CPU utilization by the query node during the Search Performance test execution. Milvus query node has consumed all the compute resources available on the worker node.



```
top - 06:51:33 up 68 days, 23:59,  1 user,  load average: 109.43, 97.11, 82.19
Tasks: 1904 total,   1 running, 1903 sleeping,   0 stopped,   0 zombie
%Cpu(s): 24.5 us,  6.3 sy, 58.1 ni,  7.8 id,  0.0 wa,  1.4 hi,  1.9 si,  0.0 st
MiB Mem : 515660.5 total, 248383.5 free,  45360.7 used, 228640.7 buff/cache
MiB Swap:      0.0 total,      0.0 free,      0.0 used. 470299.8 avail Mem

    PID USER      PR  NI    VIRT    RES    SHR S  %CPU  %MEM     TIME+ COMMAND
2808217 root      20   0   36.8g   6.4g 154624 S 10093   1.3   3000:57 milvus run querynode
2807637 root      20   0   12.0g 985.6m 141312 S 857.0   0.2 226:09.61 milvus run proxy
  15131 nfsnobo+  20   0   49.8g   3.6g   1.1g S  74.6   0.7  28151:10 /bin/prometheus --web.console.templates=/etc/prometheu
   6906 root      20   0   11.2g 306696  52224 S  45.3   0.1  15981:52 /usr/bin/kubelet --config=/etc/kubernetes/kubelet.conf
   3101 openvsw+  10 -10   10.7g 184284   8192 S  11.1   0.0   3373:30 ovs-vswitchd unix:/var/run/openvswitch/db.sock -vconso
2804507 10000     20   0   31.2g 506292  20480 S  10.7   0.1   0:21.99 /usr/bin/java -Dzookeeper.4lw.commands.whitelist=* -Dz
      1 root      20   0  182960  10796   9372 S   7.8   0.0   1170:30 /usr/lib/systemd/systemd --switched-root --system --de
1006723 1111      20   0 4332704 277000  36864 S   7.2   0.1   1202:22 envoy --config-path /config/envoy-config-rest.yaml
2928195 core      20   0   29260  17408   9216 S   6.8   0.0   1:32.99 /usr/lib/systemd/systemd --user
```

The HSNW index Search Performance numbers would vary and depend on the resources available on the underlying worker node where the query node is hosted.

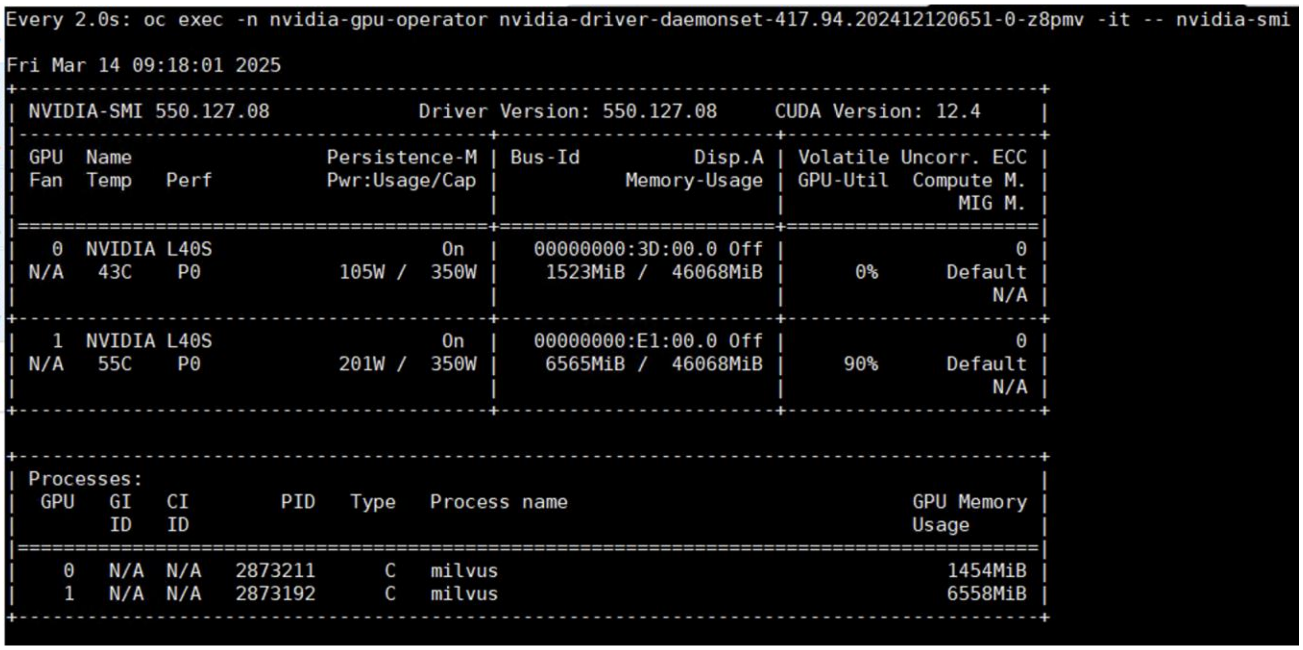
Test Results for GPU_CAGRA Index Search Performance

The following table lists the performance metrics for various batch sizes with Search Performance test executed with GPU_CAGRA index type with one NVIDIA L40S GPU assigned to the milvus query node.

Batch size	Recall	serial_latency_p99 (ms)	QPS (Query per second)
1	0.960	2.4	13229

Batch size	Recall	serial_latency_p99 (ms)	QPS (Query per second)
10	0.9589	2.4	13250
50	0.9598	2.4	13276
100	0.9592	2.5	13291

The following screenshot shows the GPU utilization by the query node during the Search Performance test execution.



```
Every 2.0s: oc exec -n nvidia-gpu-operator nvidia-driver-daemonset-417.94.202412120651-0-z8pmv -it -- nvidia-smi

Fri Mar 14 09:18:01 2025
+-----------------------------------------------------------------------------------------+
| NVIDIA-SMI 550.127.08             Driver Version: 550.127.08     CUDA Version: 12.4     |
|-----------------------------------------+------------------------+----------------------+
| 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 L40S                    On  |   00000000:3D:00.0 Off |                    0 |
| N/A   43C    P0            105W /  350W |    1523MiB /  46068MiB |      0%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+
|   1  NVIDIA L40S                    On  |   00000000:E1:00.0 Off |                    0 |
| N/A   55C    P0            201W /  350W |    6565MiB /  46068MiB |     90%      Default |
|                                         |                        |                  N/A |
+-----------------------------------------+------------------------+----------------------+

+-----------------------------------------------------------------------------------------+
| Processes:                                                                              |
|  GPU   GI   CI        PID   Type   Process name                              GPU Memory |
|        ID   ID                                                               Usage      |
|=========================================================================================|
|    0   N/A  N/A   2873211      C   milvus                                       1454MiB |
|    1   N/A  N/A   2873192      C   milvus                                       6558MiB |
+-----------------------------------------------------------------------------------------+
```

From these results, we can infer that as the batch size increases, the Multi Modal RAG performs better, that is validated by the trend in the output KPIs with Milvus vector store using VectorDBBench tool.

Note: Our test results are in agreement with the observations made by Zilliz as explained here: https://zilliz.com/blog/Milvus-introduces-GPU-index-CAGRA

QPS of GPU_CAGRA index is more than two times as that of HSNW index type. As explained earlier, the performance differences would vary depending on the type of GPU and CPUs used on the worker node.

The benchmark results underscore the substantial performance benefits of adopting GPU-accelerated indexes like CAGRA in Milvus. Not only does it excel in accelerating search tasks across batch sizes, but it also significantly enhances index construction speed, affirming the value of GPUs in optimizing vector database performance.

Conclusion

This Cisco Validated Design presents a robust and meticulously tested solution for deploying enterprise-grade Retrieval Augmented Generation (RAG) pipelines. By synergistically integrating the high-performance Cisco UCS X-Series based FlashStack infrastructure with the advanced capabilities of NVIDIA AI Enterprise software, including the RAG Blueprint and NVIDIA Inference Microservices (NIM), this architecture provides a streamlined path for leveraging generative AI with proprietary data.

The infrastructure is designed using the Cisco UCS X-Series modular platform based FlashStack Datacenter, managed through Cisco Intersight. Deployment involves Red Hat OpenShift Container Platform clusters running on Cisco UCS X210c M7 bare metal compute nodes equipped with NVIDIA GPUs. The NVIDIA AI Enterprise software powers the inferencing workflow, while Portworx Enterprise Storage, backed by Pure Storage FlashArray and FlashBlade, ensures cloud-native storage for model repositories and other services.

Automation facilitated by Red Hat Ansible, provides Infrastructure as Code (IaC) for accelerating deployments.

The FlashStack solution is a validated approach for deploying Cisco and Pure Storage technologies in an enterprise data center. This release of the FlashStack VSI solution brings the following capabilities:

- Fourth generation Intel Xeon Scalable processors with Cisco UCS X210 M7, C220 M7 and C240 M7 servers, enabling up to 60 cores per processor and 8TB of DDR-4800 DIMMs.
- Sustainability monitoring and optimizations to meet Enterprise ESG targets that include power usage monitoring features across all layers of the stack and utilizing the Cisco UCS X-Series advanced power and cooling policies.
- Pure Storage FlashArray Unified Block and File consisting of FC-SCSI, FC-NVMe, iSCSI, NVMe-TCP, NVMe-RoCEv2 as well as NFS and SMB storage.
- Pure Storage FlashBlade//S, a high-performance consolidated storage platform for both file (with native SMB and NFS support) and object (S3) workloads, delivering a simplified experience for infrastructure and data management.
- Red Hat Openshift innovations.
- Cisco Intersight continues to deliver features that simplify enterprise IT operations, with services and workflows that provide complete visibility and operations across all elements of FlashStack datacenter. Also, Cisco Intersight integration with VMware vCenter and Pure Storage FlashArray extends these capabilities and enable workload optimization to all layers of the FlashStack infrastructure.

Ultimately, this validated solution stands as a foundational reference architecture, significantly mitigating the complexities and risks associated with deploying sophisticated RAG workloads. It empowers enterprises to confidently build, manage, and scale secure, high-throughput private RAG applications, accelerating time-to-value for critical AI initiatives.

About the Authors

Paniraja Koppa, Technical Marketing Engineer, Cisco Systems, Inc.

Paniraja Koppa is a member of the Cisco Unified Computing System (Cisco UCS) solutions team. He has over 15 years of experience designing, implementing, and operating solutions in the data center. In his current role, he works on design and development, best practices, optimization, automation and technical content creation of compute and hybrid cloud solutions. He also worked as technical consulting engineer in the data center virtualization space. Paniraja holds a master's degree in computer science. He has presented several papers at international conferences and speaker at events like Cisco Live US and Europe, Open Infrastructure Summit, and other partner events. Paniraja's current focus is on Generative AI solutions.

Gopu Narasimha Reddy, Technical Marketing Engineer, Cisco Systems, Inc.

Gopu Narasimha Reddy is a Technical Marketing engineer with the UCS Solutions team at Cisco. He is currently focused on validating and developing Cisco UCS infrastructure solutions for enterprise workloads with different operating environments including Windows, VMware, Linux, and Kubernetes. Gopu is also involved in publishing database benchmarks on Cisco UCS servers. His areas of interest include building and validating reference architectures, and development of sizing tools in addition to assisting customers in database deployments.

Mahesh Pabba, Customer Delivery Architect, Cisco Systems, Inc.

Mahesh Pabba is a seasoned technology professional with vast experience in the IT industry. With a strong foundation in enterprise applications, he has successfully navigated various domains, excelling in automation and development using cutting-edge technologies. As a skilled Solution Architect, he has designed and implemented numerous innovative solutions throughout his career. Additionally, he possesses expertise in artificial intelligence, specializing in training, inferencing, and deploying AI solutions on Cisco hardware, encompassing compute, network, and storage environments. His unique blend of technical acumen and solution-oriented approach positions him as a valuable contributor to any AI design initiative.

Hang Yu, NVIDIA

Hang Yu is a Solutions Architect with expertise in AI/ML development and production. He focuses on the full-stack AI software, building and deploying enterprise-grade AI solutions, leading projects from initial design to production deployment. He has been working closely with Cisco on enabling this validated design.

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- Robert Alvarez, AI Solutions Architect, Pure Storage, Inc.
- Unnikrishnan R, Senior Solutions Architect, Pure Storage, Inc.

Appendix

This appendix contains the following

- Appendix A – References used in this guide

Appendix A – References used in this guide

Compute

Cisco Intersight: https://www.intersight.com

Cisco Intersight Managed Mode: https://www.cisco.com/c/en/us/td/docs/unified_computing/Intersight/b_Intersight_Managed_Mode_Configuration_Guide.html

Cisco Unified Computing System X-Series Modular System: https://www.cisco.com/go/ucsx

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

AI-ready infrastructure - Cisco Validated Design Zone: https://www.cisco.com/c/en/us/solutions/design-zone/ai-ready-infrastructure.html

Cisco AI native infrastructure for Data Center: https://www.cisco.com/site/us/en/solutions/artificial-intelligence/infrastructure/index.html

Cisco Unified Compute System automation repositories for Cisco Validate Designs (CVD) and white papers: https://github.com/ucs-compute-solutions

Network

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

Pure Storage

Pure Storage FlashArray//XL: https://www.purestorage.com/products/unified-block-file-storage/flasharray-xl.html

Pure Storage FlashBlade//S: https://www.purestorage.com/products/unstructured-data-storage/flashblade-s.html

Portworx by Pure Storage: https://docs.portworx.com/

FlashStack

FlashStack Design Guides: https://www.cisco.com/c/en/us/solutions/design-zone/data-center-design-guides/data-center-design-guides-all.html#FlashStack

FlashStack with Red Hat OCP and Virtualization platform CVD (Base CVD): https://www.cisco.com/c/en/us/td/docs/unified_computing/ucs/UCS_CVDs/flashstack_ocp_baremetal_imm.html

Red Hat OpenShift

Documentation: https://docs.openshift.com/

Red Hat OpenShift Container Platform: https://www.redhat.com/en/technologies/cloud-computing/openshift/container-platform

Red Hat Hybrid Cloud Console: https://cloud.redhat.com/

NVIDIA Enterprise

GitHub page for NVIDIA Blueprints: https://github.com/NVIDIA-AI-Blueprints

NVIDIA NIM Operator: https://docs.nvidia.com/nim-operator/latest/index.html

NVIDIA NIM Catalog: https://catalog.ngc.nvidia.com/

Interoperability Matrix

Cisco UCS Hardware Compatibility Matrix: https://ucshcltool.cloudapps.cisco.com/public/

Pure Storage FlashStack Compatibility Matrix. Note, this interoperability list will require a support login from Pure: https://support.purestorage.com/FlashStack/Product_Information/FlashStack_Compatibility_Matrix

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