Reference Architecture: Red Hat OpenShift Container Platform on Lenovo ThinkSystem, ThinkEdge and ThinkAgile HX Servers

Last update: 27 March 2024
Version 3.9

Provides overview of application containers using Lenovo ThinkSystem, ThinkEdge and ThinkAgile HX

Describes container orchestration, virtualization, and security technologies on OpenShift

Describes DevOps and Continuous Integration & Continuous Delivery

Introduces OpenShift site configuration samples and Deployment Ready Solutions

Xiaotong Jiang, Lenovo
Ajay Dholakia, Lenovo
Gareth Jenkins, Red Hat

Table of Contents

1 Introduction

The target audience for this Reference Architecture (RA) is system administrators or system architects. Some experience with Docker and OpenShift technologies may be helpful, but it is not required.

Emerging software applications are making use of containerization to enable rapid prototyping, testing, as well as deployment to the cloud. The microservice revolution introduced container-based service architecture, which offers many benefits when compared to traditional virtualization technologies. Containers provide a more portable and faster way to deploy services on cloud infrastructures compared to virtualization.

While containers themselves provide many benefits, they are not easily manageable in large environments. Hence, many container orchestration tools have increased in momentum and gained popularity. Each orchestration tool is different; hence they should be chosen individually for specific purposes. The Red Hat OpenShift® Container Platform uses Kubernetes which is an orchestration framework based on container-deployment practices. Kubernetes has gained popularity in the cloud community due to its maturity, scalability, performance, and many built-in tools that enable production-level container workload orchestration.

Enterprises are also seeing increasing expansion of their IT infrastructure into edge locations fuelled by the need to enable customer and partner interactions. This growth is being driven by Edge / IoT (Internet of Things) technologies that enable new business opportunities but also pose new challenges. The use of containers has emerged as the de facto mechanism for deploying edge IT infrastructure.

Red Hat OpenShift Container Platform 4.14 is built around a core of application containers powered by CRI-O, with orchestration and management provided by Kubernetes, on a foundation of Red Hat® Enterprise Linux (RHEL) or Red Hat Enterprise Linux CoreOS (RHCOS). It provides many enterprise-ready features like enhanced security, multitenancy, simplified application deployment, and continuous integration/continuous deployment tools. With Lenovo™ servers and Lenovo Open Cloud – Automation (LOC-A) technologies, deployment, provisioning and managing the Red Hat OpenShift Container Platform infrastructure becomes effortless and produces a resilient solution.

This RA describes the system architecture for the Red Hat OpenShift Container Platform 4.14 based on Lenovo ThinkSystem/ThinkEdge/ThinkAgile HX servers. It provides details of the hardware requirements to support various OpenShift node roles and the corresponding configuration of the systems. It also describes the network architecture and details for the switch configurations. The hardware bill of materials is provided for all required components to build the OpenShift cluster.

An example deployment configuration is described for a typical configuration. The hardware bill of materials is provided for all required components to build the OpenShift cluster. A deployment guide is provided to show how to prepare, provision, deploy, and manage the Red Hat OpenShift Container Platform on Lenovo ThinkSystem/ThinkEdge/ThinkAgile HX servers.

2 Business problem and business value

2.1 Business problem

Businesses today want to deliver new features and updates to their products for their internal users as well as external stakeholders quickly and with high quality. Every industry today is seeing a transformation, which is predominantly driven by advances in technology. In order to stay competitive and relevant in their respective industry and marketplace, every business needs to take advantage of new technologies quickly and adopt them to their products and solutions. Today, much of the technology advancement and innovation is driven through a combination of software and hardware. More importantly, emerging technologies such as artificial intelligence (AI) and machine learning (ML) are fuelled by rapid advancements in software. In addition, many of the IT infrastructure and data center advancements are driven through software defined technologies such as software defined storage (SDS) and software defined networking (SDN). Hence software is a key driver in pushing forward various technologies in all industries.

Container technology has picked up momentum in the software development area and enabled developers to take advantage of several benefits from packaging their applications as containers:

- Containers are light-weight application run-time environments compared to virtual machines and are therefore less resource intensive and highly efficient.
- Containers enable developers to package their applications as well as all the library dependencies to properly run them so that a container image provides a completely self-sufficient environment to execute the application code. This also means that multiple application instances requiring different versions of the same libraries can be packaged into different containers and run side-by-side on the same operating system instance without any interference.
- Containers are portable across different platforms (as long as the underlying operating systems are compatible). CRI-O is a modern implementation of the Kubernetes Container Runtime Interface (CRI) which enables using Open Container Initiative (OCI) compatible runtimes. It allows Kubernetes to use any OCI compliant runtime for running pods. It is a lightweight alternative to the legacy docker runtime previously used for containers.
- Containers are now the de facto standard of operation for some of the well-known public cloud environments including Google, Amazon AWS, and Microsoft Azure. Hence, applications packaged as containers can be executed on-prem or on a public cloud without any modifications (other than additional steps to secure the software for use on the public cloud).
- There are many open source tools available now to help developers easily create, test, and deploy containerized applications. In addition, all the well-known protocols for security, authentication, authorization, storage, etc., can be applied to containerized workloads without any modifications to applications. In other words, you can take a legacy application written in a language such as Java and package it, as is, into a container image and run it.
- Containers are now the way to implement a continuous integration/continuous delivery (CI/CD) development pipeline and the DevOps paradigm of combining software development and infrastructure operations.

According to IDC's prediction, over 50% of new Enterprise IT Infrastructure will be deployed at edge sites by 2023. By 2024, 75% of new operational applications deployed at the edge will leverage containerization. Organizations deploy workloads in physical locations that are near the places where data is produced or consumed when they use edge computing. The fast and huge incremental growth of edge sites and edge Apps bring big challenge to IT infrastructures, platforms, and applications.

2.2 Business value

Software development life cycle (SDLC) practices have evolved to achieve high velocity and efficiency of development. Organizations today implement Agile/Scrum as the primary methodology to create cohesive development teams that work close to their customers, gather incremental product requirements, and deliver new features in short development cycles.

2.2.1 DevOps Overview

DevOps is evolving as a standard practice in many organizations to bring together software development and IT operations teams for the goal of eliminating process bottlenecks in development, quality assurance (QA), and delivery cycles, with a goal of providing services to their end customers efficiently. Implementing a proper DevOps process requires careful planning and an assessment of the end-to-end pipeline from development to QA to delivery. Automation is a key aspect of DevOps. Traditional software development processes were handled mostly manually. When developers commit code to the source code repository, the test engineer or a build engineer would then checkout the code and build the project, resolving any conflicts. After the QA iterations, the release engineer would be responsible to take the release branch code and build the final shippable product. Along this pipeline, many of the steps were handled manually by people, which introduced the delays in the release cycles. Agile development now takes advantage of new automation tools that remove the manual steps.

Another core aspect of DevOps is providing the necessary freedom and resources to develop and test code without having to rely on IT operations teams to re-provision or reconfigure hardware every time. With the advances in technologies including virtualization, containers, Cloud multi-tenancy, self-service, and so on, it is now possible to detach applications and end-users from physical hardware and provide the necessary tools for them to create the right virtual environment to run their applications without directly modifying the physical hardware or interfering with other users' applications. With cloud self-service, users can request and provision the hardware to meet their application specific requirements. Cloud administrators create the proper policy and authorization workflows such that the provisioning process does not require manual steps. DevOps essentially combines the role of the software engineer with that of the IT operator so that the end-to-end software pipeline can be implemented with automation.

2.2.2 Monolithic vs Microservices Architecture

Software architecture over the last two to three decades has evolved from a monolithic application that essentially delivered all feature functions in a single package to service-oriented architectures where the application is divided up into multiple tiers with each tier providing programming interfaces (APIs) for its clients to access the features via service calls. Software principles such as modularity, coupling, code reuse, etc., have remained the core principles that people still use, however new programming languages, runtime facilities, mobile versus cloud native techniques, etc., have evolved in the recent years to shift software from the traditional architectures to more of a microservice architecture.

Microservices are software applications that are organized around smaller subsets of functionality of the overall application such that they are much more manageable than a bulky piece of software developed by 10s of developers and coordinated in a complex dev/test process. microservices are software modules that run as services with open APIs. They use open protocols, e.g. HTTP, and expose REST based APIs so that the services can run anywhere - on-premises or on the public cloud, and still be locatable via well-defined service end-points. Due to this design, microservices provide a loosely-coupled architecture that can be maintained by smaller development teams and can be independently updated.

Containers provide a natural mechanism to implement microservices because they allow you to package the application code and all its runtime library dependencies into a single image, which is portable across various platforms. In addition, container orchestration platforms such as Kubernetes provide the mechanisms for service location, routing, service replication, etc., which helps microservices development and runtime. Developers do not need to explicitly write additional code for these types of services because the platform provides these facilities.

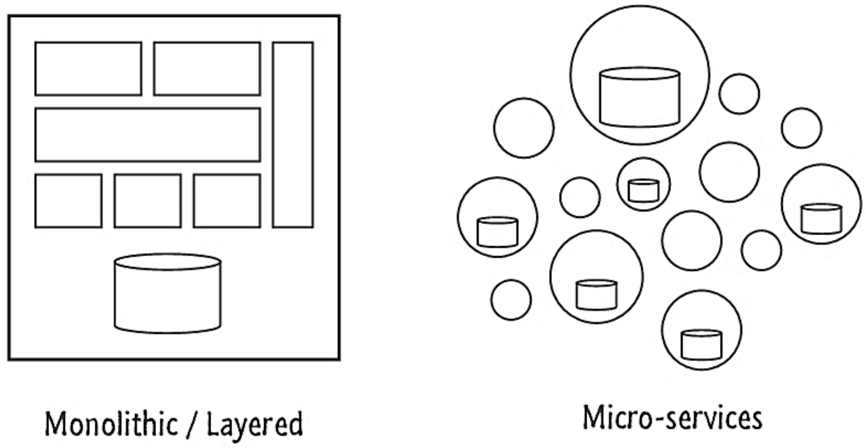


Figure 1. Moving from a Monolithic to Microservices architecture

2.2.3 Continuous Integration/Continuous Delivery (CI/CD)

As discussed in the previous section, successful DevOps practice requires a good amount of automation of the development, test, QA, and delivery pipeline. This is where the CI/CD comes into play.

Continuous integration is the process by which new code development through build, unit testing, QA, and delivery is automated end-to-end using build tools and process workflows. CI enables rapid integration of code being developed by multiple engineers concurrently and committed into a source code repository. CI enables rapid build and test of code so that software bugs and quality issues are identified quickly. Once the code passes the test plan and QA it can then be pushed to the release branches for release integration.

Continuous Delivery (CD) enables automation around delivering code to production systems after performing the necessary functional, quality, security, and performance tests. Continuous delivery enables bringing new features in the software to the end users faster without going through the manual release test and promotion steps.

More information on CI/CD with OpenShift is available in the following online book:

assets.openshift.com/hubfs/pdfs/DevOps_with_OpenShift.pdf

Figure 2 shows a high-level view of DevOps pipeline.

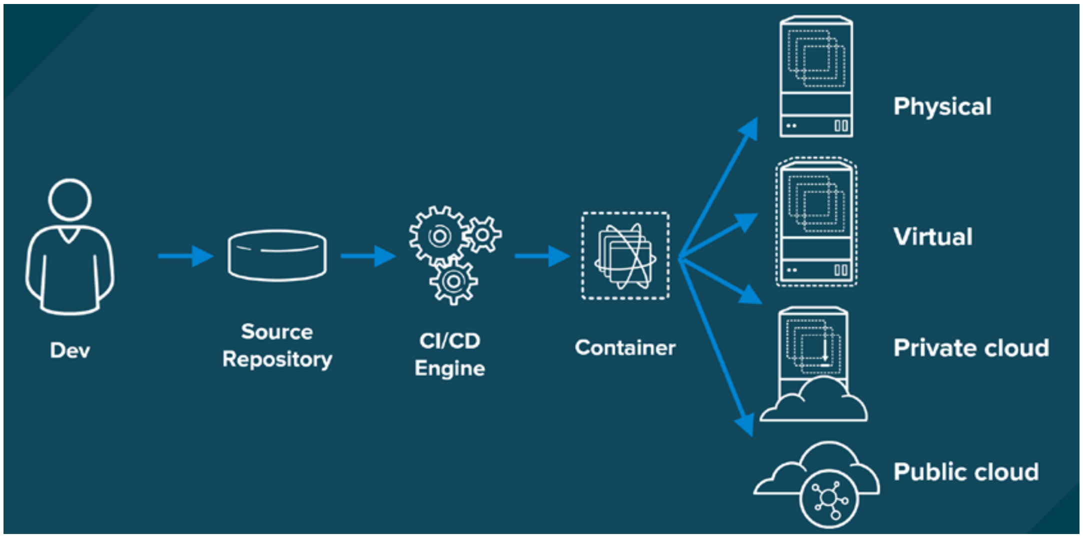


Figure 2. DevOps pipeline from a high-level

As described previously, source code from multiple concurrent developers is integrated, tested, and deployed to production through automation tools. The OpenShift Container Platform provides the mechanisms to implement the CI/CD pipelines with tools such as Jenkins, Tekton, etc. See the following post on how to do this: cloud.redhat.com/blog/cicd-with-openshift.

Note: Latest version of OpenShift Pipelines is Introduced in OpenShift 4.14. See the more detailed description in the link: container-platform/latest/cicd/pipelines/understanding-openshift-pipelines.

2.2.4 Container Orchestration for Edge Infrastructure

As described in the previous section, the expected growth of edge sites to deploy business applications at the edge poses a big challenge to IT infrastructures, platforms, and applications.

Red Hat offers small footprint edge OS (Core OS) and OpenShift edge clusters in their device edge solution. Red Hat OpenShift extends the capabilities of native Kubernetes to edge sites. It supports a flexible edge site configuration, from single node to three nodes, from regional location to far edge, let organization select mixed and matched topology at their edge sites. Red Hat OpenShift can help organizations consistently manage infrastructure at scale, even to the most remote edge locations, without sacrificing security or stability. With Red Hat OpenShift, applications can be developed, deployed and life-cycle managed at scale in a secure, consistent, reliable way of crossing a wide variety of systems.

For Red Hat OpenShift edge computing solution, please see section 6.13.

For Red Hat Edge Device solution and MicroShift component, Please see section 6.23.

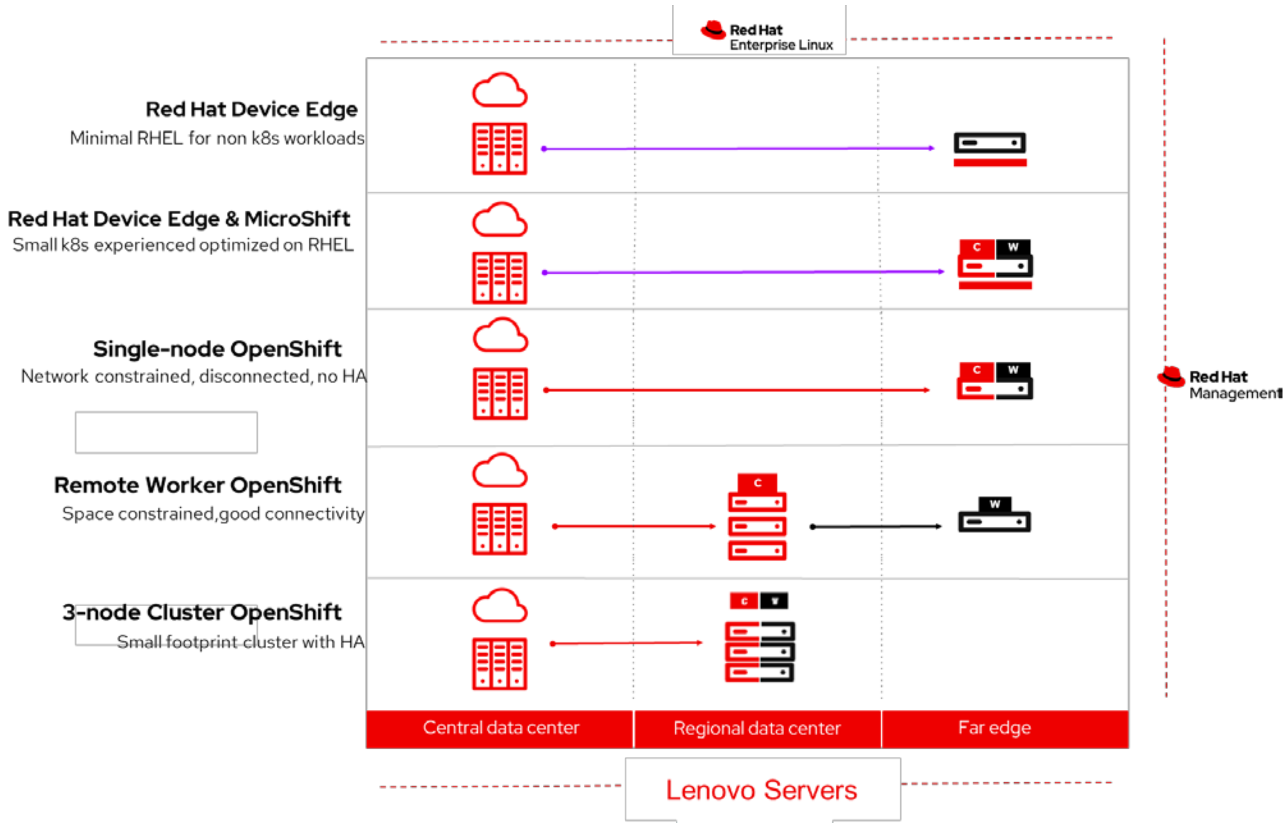


Figure 3. Red Hat Edge solution on Lenovo Servers

Red Hat OpenShift supports hardware acceleration for inference use cases, a broad ecosystem of AI/ML and application development tools, and integrated security and operations management capabilities. AI/ML applications can be deployed at edge sites to gather and analyse data faster, while AI models can be updated frequently to match the case more accurately by integrated DevOps capabilities in OpenShift. Organizations use OpenShift supported edge sites to deliver best delay-sensitive and data-driven application experiences to customers.

3 Requirements

The functional and non-functional requirements for this reference architecture are described below.

3.1 Functional requirements

Table 1 lists the functional requirements.

Table 1. Functional Requirements

Requirement	Description
Container orchestration services	Red Hat OpenShift Container Platform is designed to run workload container images at scale using the Kubernetes container orchestrator, and container runtime interface (CRI-O).
User self-service	OpenShift supports a Web based UI console that allows users to login and manage their containerized workloads.
Policy management	OpenShift allows administrators to configure role-based authorization to manage the system resources such as compute, networking, storage and application workloads.
Cloud integration	OpenShift supports an integrated container registry, the Quay container registry, or public registries which allow users to pull down container images from other places. In addition, building container images on OpenShift platform allows portability to other clouds such as Google container engine.
Network and Storage virtualization	Through built-in OpenShift networking and storage services for Kubernetes, users can access these abstracted resources through their container applications. In addition, OpenShift provides network infrastructure services through open protocols such as VXLAN. A variety of storage facilities can be exposed to container applications via the Kubernetes persistent volume plug-ins and stateful sets.
Command line tools	OpenShift container platform provides CLI tools for almost all cluster operations and for container image operations. In addition, administrators can use Kubernetes CLI tools to directly access its services.
CI/CD tools	A variety of open source and commercial tools are available such as Jenkins build server and integration with GitHub source code repository to implement CI/CD pipelines.
Open source tools	Red Hat container registry and other open container repos such as quay.io and Docker Hub are available to OpenShift users to access open source tools such as nginx, apache httpd, mysql, postgres, Cassandra, etc.
Automation tools	Many tools are available for automation including Ansible, Chef, Puppet, etc.
Service mesh	OpenShift Service Mesh is based on Istio along with the Kiali and Jaeger projects and delivered via Operator. OpenShift Service Mesh provides traffic monitoring, access control, discovery, security, resiliency, tracing, and reporting to a group of services by running as container sidecars.

3.2 Non-functional requirements

Table 2 lists the non-functional requirements that are needed for typical OpenShift deployments

Table 2. Non-functional Requirements

Requirement	Description
Scalability	The OpenShift Container Platform is designed for scale. The platform allows for hundreds of containerized workloads to be scheduled and run without any performance bottlenecks. The physical resources such as compute/worker nodes and storage can be scaled as the workload and user base grows.
Load balancing	OpenShift control plane nodes provide the core API and management services for the Kubernetes cluster. For bare metal/VMware installation, OpenShift 4.14 provides Metal LB as an option. For production environments, Users can use other commercial LB such as F5/A10/etc for their production environment. In addition, Kubernetes handles load-balancing of the workload containers through built-in scheduler features, network routing, replication services, etc.
Fault tolerance	Fault tolerance can be provided to critical container workloads such as databases via Kubernetes built-in mechanisms. In addition, data and configuration settings for container images can be persisted across instances via persistent volume claims and stateful sets.
Physical footprint	OpenShift container platform can be implemented with 3 control plane nodes (for control plane) and 2 compute/worker nodes where all services are consolidated and scaled through multiple physical nodes to distribute services and containers. Hence, the architecture is quite flexible and allows to start small and then scale out.
Ease of installation	Three installation methods for OCP 4, IPI, UPI, and The Assisted Installer. ● IPI (Installer Provisioned Infrastructure) is the automated installer method, where the OpenShift installer provisions the entire infrastructure, including control plane and compute/worker nodes automatically using Red Hat Enterprise Linux CoreOS (RHCOS) and ignition files. IPI is the preferred and best long term method for OCP deployment. ● UPI (User Provisioned Infrastructure) uses pre-existing infrastructure nodes provisioned in advance of OCP installation. ● the Assisted Installer provides a more user friendly and end-to-end deployment experience on bare metal/VMware environment. It provides an interactive experience where you are able to see, modify, and configure the cluster options then boot the nodes to an ISO and let the install run OCP 4 uses RHCOS for the Control Plane nodes in all cases. RHCOS is recommended for worker nodes as well. RHEL is available to be used as worker nodes. Bare metal (or other installations) start by installing RHCOS, only the actual provisioning node usually runs RHEL.
Ease of management/operations	Administrator tools and OpenShift Web console allow day 2 management operations to be performed. In addition, the Lenovo XClarity Administrator tool enables hardware monitoring and management.
Flexibility	OpenShift container platform can be deployed both in a development/test settings and production settings. Various options are available for third party network and storage implementation for OpenShift.
Security	Red Hat OpenShift Container Platform has built-in enterprise grade security, all the way from the operating system layer up to the container registries. Both built-in authentication/authorization facilities and external authentication/authorization integration with tools such as OpenLDAP are supported.
High performance	OpenShift and Kubernetes have achieved wide industry adoption due to the robustness of the platform and high-performance. Enterprises can implement very large-scale OpenShift environments to support hundreds of users and thousands of container workloads with no performance bottlenecks.

4 Architectural overview

The OpenShift Container Platform is a complete container application platform that provides all aspects of the application development process in one consistent solution across multiple infrastructure footprints. OpenShift integrates all of the architecture, processes, platforms, and services needed to help development and operations teams traverse traditional siloed structures and produce applications that help businesses succeed. Figure 4 below shows the high level architecture of the Red Hat OpenShift Container Platform and the core building blocks with Lenovo ThinkSystem/ThinkEdge/ThinkAgile HX servers. OpenShift is a platform designed to orchestrate containerized workloads across a cluster of nodes. The system uses Kubernetes as the core container orchestration engine, which manages the container images and their lifecycle.

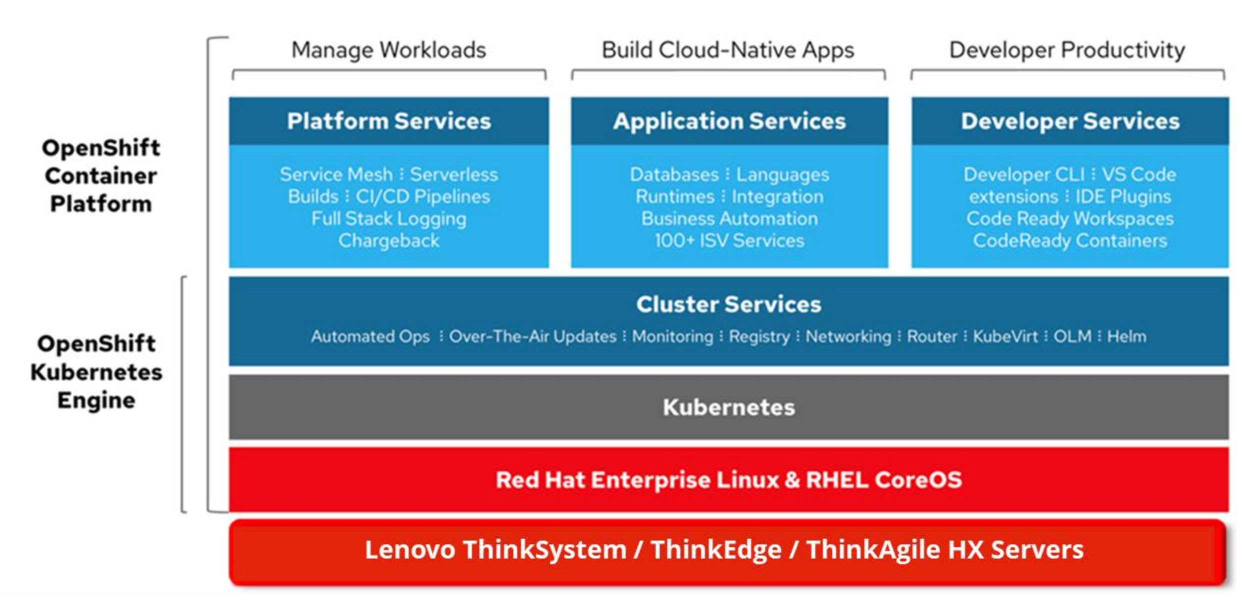


Figure 4. Red Hat OpenShift Container Platform Architecture

The physical configuration of the OpenShift platform with ThinkSystem series is based on the Kubernetes cluster architecture. The control plane node is the primary node on which the Kubernetes scheduler, along with the distributed cluster data store (etcd), the REST API services, and other associated management services run. OpenShift uses three control plane nodes in all clusters except for the single node cluster available for edge deployments. Compute/worker nodes run the users' containerized applications on top of the CRI-O container runtime environment.

ThinkAgile HX Series provides a hyper-converged infrastructure with Nutanix's industry-leading software preloaded on Lenovo platforms. A hyper-converged infrastructure seamlessly pools compute and storage to deliver high performance for the virtual workloads and provides flexibility to combine the local storage using a distributed file system to eliminate shared storage such as SAN or NAS. These factors make the solution cost effective without compromising the performance. They offer the scalability and resilience that enterprise Kubernetes demands, and seamlessly integrate infrastructure layers and cloud-native platform engine.

ThinkAgile HX uses virtualized instances of OpenShift whereas ThinkEdge and ThinkSystem can use either virtualized or bare metal (while bare metal is preferred).

Cloud-native Platform services, Application services, and Developer services are running on top of OpenShift Kubernetes Engine. They provide services to manage workloads, build cloud-native apps, and enhance developer productivity.

5 Component model

As shown in Figure 5, this chapter describes the components and logical architecture of the Red Hat OpenShift solution.

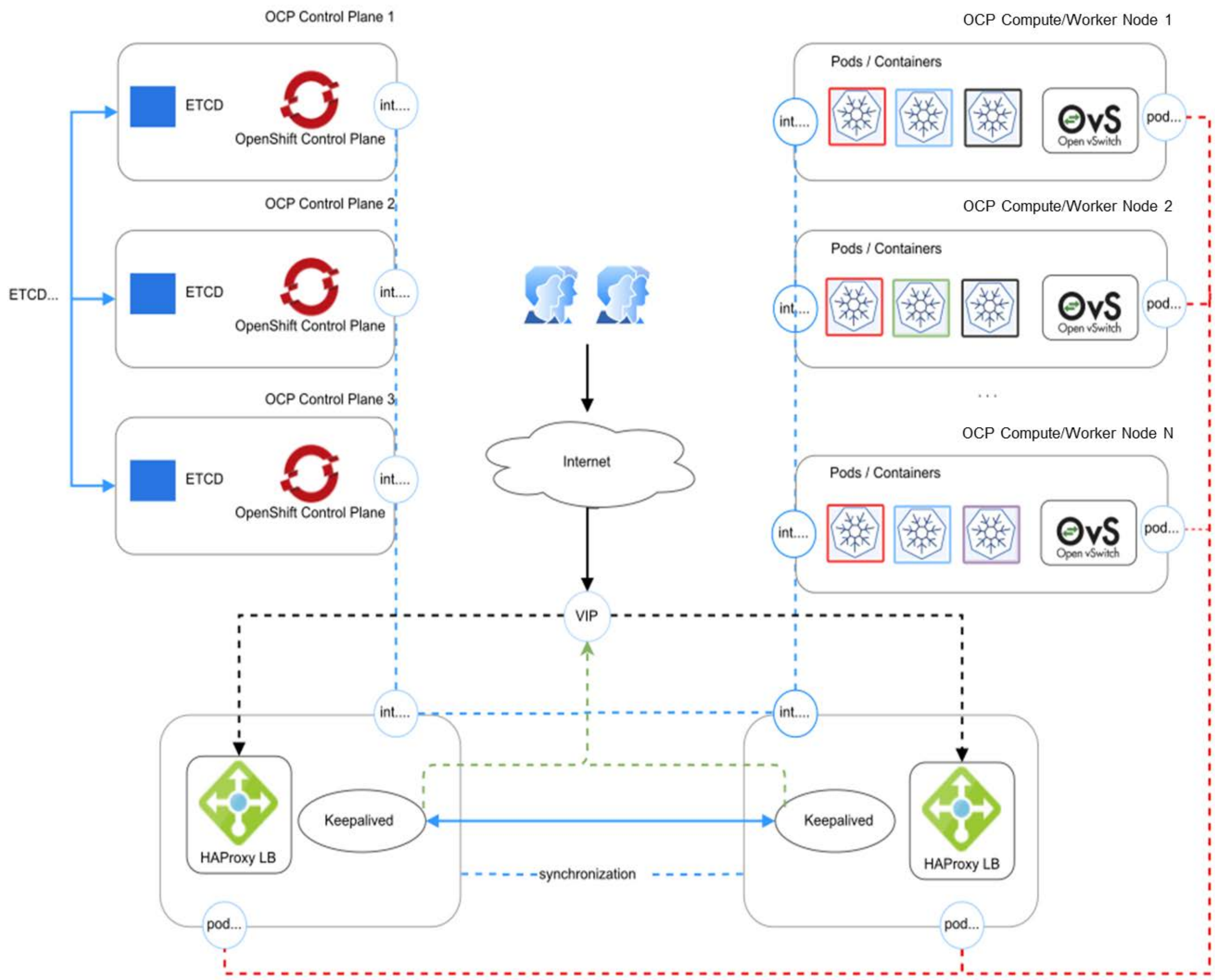


Figure 5. Red Hat OpenShift Container Platform logical architecture

All the OpenShift nodes are connected via the internal network, where they can communicate with each other. Furthermore, OpenShift SDN (based on Open vSwitch) creates its own network for OpenShift pod-to-pod communication. Because of the multi-tenant plugin, Open vSwitch pods can communicate to each other only if they share the same project namespace. There is a virtual IP address managed by *Keepalived* on two *load balance (LB)* hosts for external access to the OpenShift web console and applications. Applications can use local storage operator, storages support CSI interface, OpenShift Data Foundation (ODF), etc. as backend storage in OpenShift cluster. OVN-Kubernetes is available in OCP 4.14, and it is the default network component in OpenShift.

5.1 OpenShift infrastructure components

Figure 6 shows the four types of nodes in an OpenShift cluster deployed on bare-metal server: *bastion, infrastructure, control plane, and compute/worker (or enhanced HCI worker node with OpenShift Data Foundation).* A temporary bootstrap node is not shown in Figure 6. The Bootstrap node can be removed from the cluster after deployment. Bootstrap node introduction is in section 5.1.3. Backend Storage is not listed in this section. Storage introduction is in section 6.7.

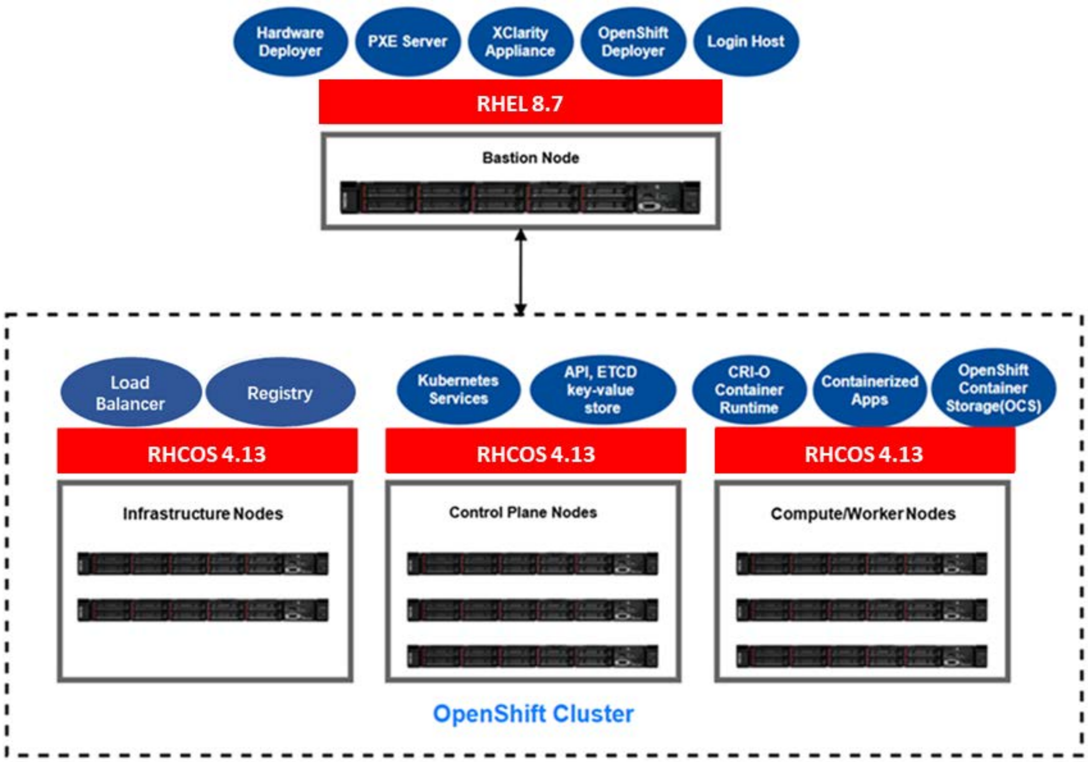


Figure 6. OpenShift Nodes with bare metal deployment

For edge sites, it's recommended to use a lightweight, cost saving and environment adaptation approach to deploy the logical function nodes into physical servers. Find more detailed information in section 6.3, 6.13 and 6.15.2.

Figure 7 shows the three types of nodes in an OpenShift cluster deployed in VMs in Nutanix cluster on Lenovo ThinkAgile HX server: *infrastructure, control plane, and compute/Application node.*

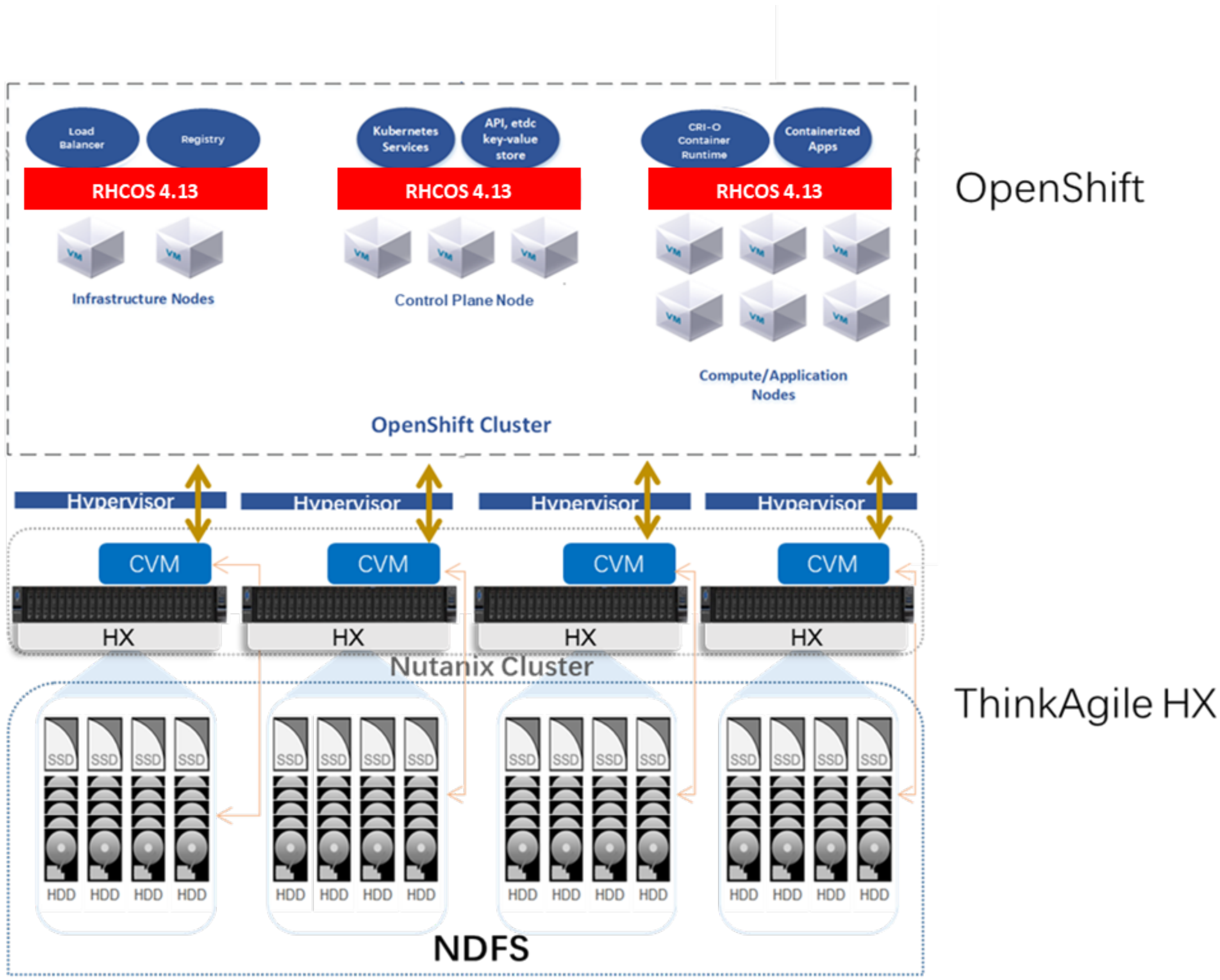


Figure 7. OpenShift Nodes on ThinkAgile HX

5.1.1 Bastion node

This is a dedicated node that serves as the main deployment and management server for the OpenShift cluster. This is used as the logon node for the cluster administrators to perform the system deployment and management operations. OpenShift installation files or Lenovo Open Cloud-Automation (LOC-A) tools are running on the Bastion node for manual deployment or auto-deployment of OpenShift Container Platform. In addition, this node is also used for hardware management via tools such as xCAT and Lenovo XClarity Administrator. The *Bastion* node runs RHEL 8.6 Server with the Linux KVM packages installed.

5.1.2 Infrastructure node

The OpenShift infrastructure node runs load balancing services such as the Keepalived and the HAProxy router. The HAProxy router provides routing functions for OpenShift applications. It currently supports HTTP(S) traffic and TLS-enabled traffic via Server Name Indication (SNI). Additional applications and services like container image registry, and cluster metrics and monitoring, can be deployed on OpenShift infrastructure nodes. The OpenShift infrastructure node runs RHEL Server 8.6. Other commercial load balancers, such as F5/NGINX/Avi networks/Fortinet/etc, can be deployed here in production environment.

5.1.3 Bootstrap node

OpenShift Container Platform uses a temporary bootstrap node during initial configuration to provide the required information to the control plane node. It boots by using an Ignition config file that describes how to create the cluster. The bootstrap node creates the control plane nodes, and control plane nodes create the compute/worker nodes. The control plane nodes install additional services in the form of a set of Operators. The OpenShift *bootstrap* node runs RHCOS 4.14.

5.1.4 Control plane node

The OpenShift Container Platform control plane node is a server that performs control functions for the whole cluster environment. The control plane is responsible for the creation, scheduling, and management of all objects specific to OpenShift. It includes API, controller manager, and scheduler capabilities in one OpenShift binary. Both OpenShift control plane and etcd are running in highly available environments. OpenShift uses the lightweight RHCOS for all control plane nodes, a container-optimized OS based on RHEL 8.

5.1.5 Compute/Worker node

The OpenShift *compute/worker* nodes run containerized applications created and deployed by developers. An OpenShift *compute/worker* node contains the OpenShift node components, including the container engine CRI-O, the node agent Kubelet, and a service proxy, kube-proxy. An OpenShift application node runs RHCOS 4.14 or RHEL 8.6. OpenShift Data Foundation (ODF) can run along with OpenShift components and applications on compute/worker nodes to achieve a hyperconverged-like experience. On ThinkAgile HX platform, Nutanix storage can be used by Applications running on OpenShift via Nutanix CSI.

Lenovo provides a solution to install three-node cluster by leveraging Lenovo Open Cloud Automation (LOC-A). Three-node cluster allows roles of control plane, compute running on the same servers. This small footprint can support customer to extend their IT capabilities to edge locations. Detailed information about Lenovo Open Cloud Automation (LOC-A) can be found in section 6.5.

5.2 OpenShift components architecture

Kubernetes (also known as k8s or simply “kube”) is an open source container orchestration engine that automates many of the manual processes involved in deploying, managing, and scaling containerized applications at massive scale. Kubernetes is designed to take your input on where you want your software to run, and the platform takes care of almost everything else.

Kubernetes was originally developed and designed by engineers at Google. Red Hat was an early adopter, one of the first companies to work alongside Google on Kubernetes, even prior to launch, and is the 2nd leading contributor to the Kubernetes upstream project. Google donated the Kubernetes project to the newly formed Cloud Native Computing Foundation (CNCF) in 2015.”

K8s allows you to cluster together groups of hosts running Linux containers, and helps you easily and efficiently manage those clusters. Kubernetes clusters can span hosts across on-premise, public, private, or hybrid clouds. For this reason, Kubernetes is an ideal platform for hosting cloud-native applications that require rapid scaling.

A Kubernetes cluster is a set of node machines for running containerized applications. At a minimum, a cluster contains a control plane and one or more compute/worker nodes. The control plane is responsible for maintaining the desired state of the cluster, such as which applications are running and which container images they use. Nodes actually run the applications and workloads.

The cluster is the heart of Kubernetes’ key advantage: the ability to schedule and run containers across a group of machines, be they physical or virtual, on premises or in the cloud.

A Kubernetes cluster has a desired state, which defines which applications or other workloads should be running, along with which images they use, which resources should be made available for them, and other such configuration details. Kubernetes provides the orchestration capabilities for containers, including scheduling the container images to nodes in a cluster, managing the container life cycle, availability, replication, persistent and non-persistent storage for containers, policy, multi-tenancy, network virtualization, routing, hierarchical clusters via federation APIs, and so forth.

Note: More Kubernetes introduction can be found in webpages:

What Is Kubernetes?, An Introduction to Enterprise Kubernetes, What is a Kubernetes Cluster?

The Core of Red Hat OpenShift is Kubernetes. A software description of the OpenShift components is described on this website: docs.openshift.com/container-platform/latest/architecture/architecture.html.

Figure 8 shows the OpenShift high-level architecture and components.

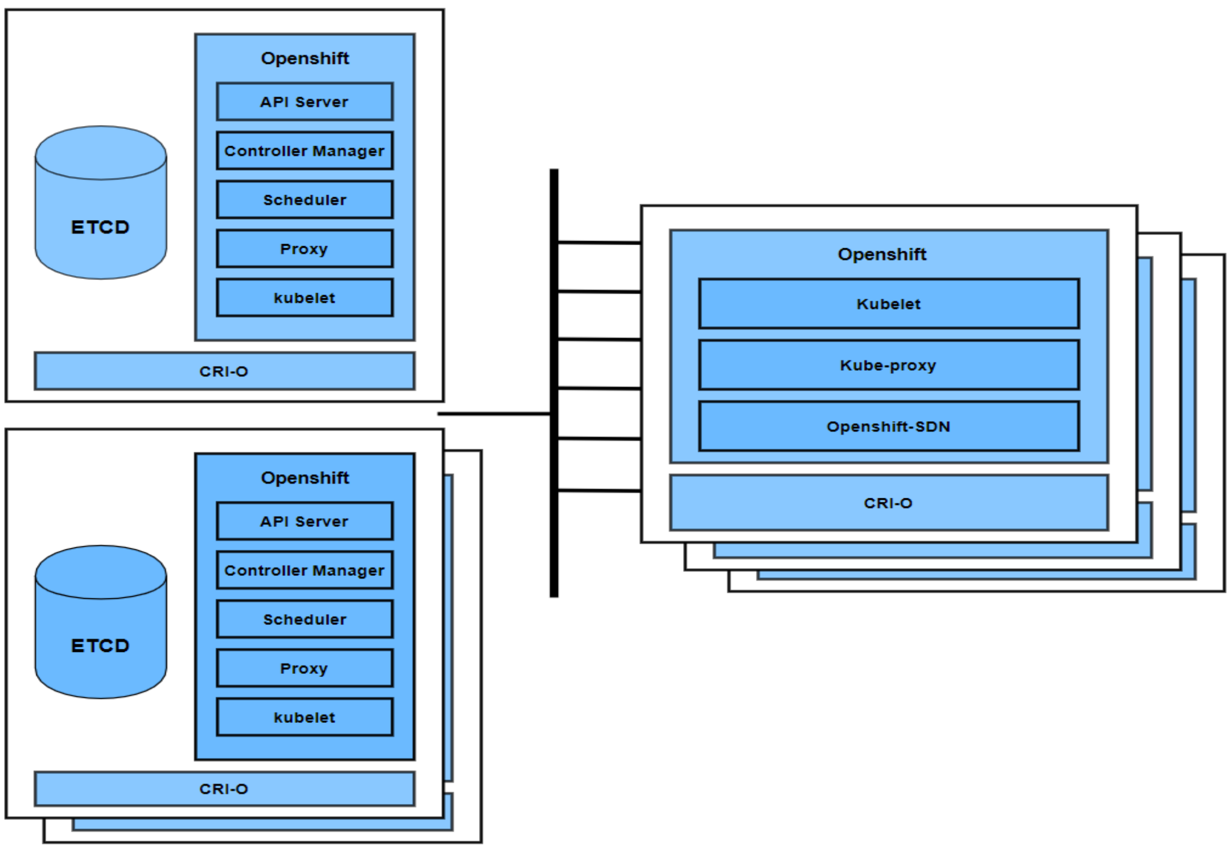


Figure 8. OpenShift component architecture

The control plane nodes, as described previously, form the control plane and are responsible for core services such as API interface, authentication/authorization, container scheduling, controller management, and configuration database. The control plane manages the state of the cluster and the lifecycle of the user container images. For redundancy and high availability, three control plane nodes form a cluster with frontend load-balancers such as HAproxy. (A note on load balancers: “Load balancers deployed to control plane nodes are only for the API. The load balancer(s) used by applications are deployed to compute/worker nodes hosting the Router(s)) The command line interface to OpenShift is implemented via the “oc” command.

The compute/worker nodes are where application container images are executed. In OpenShift terminology the compute/worker nodes run “pods”, each of which manages one or more running containers. Each node implements a “kubelet”, which is the node level controller that manages the pods and interacts with the OpenShift control plane.

In addition to the core OpenShift services, the Red Hat OpenShift platform also includes other features such as the web-based user self-service console, monitoring, logging and metrics, an integrated container registry, storage management, authentication/authorization, automation via Operators, and other administrative tools for managing the container platform.

6 Operational model

This chapter describes the options for mapping the logical components of Red Hat OpenShift onto Lenovo ThinkSystem/ThinkEdge/ThinkAgile HX servers, and storage.

6.1 Hardware components

The following section describes the hardware components that can be used in an OpenShift implementation.

6.1.1 Lenovo ThinkSystem SR630 V3 1U Server

The Lenovo ThinkSystem SR630 V3 is an ideal 2-socket 1U rack server for small businesses up to large enterprises that need industry-leading reliability, management, and security, as well as maximizing performance and flexibility for future growth. The SR630 V3 is designed to handle a wide range of workloads, such as databases, virtualization and cloud computing, virtual desktop infrastructure (VDI), infrastructure security, systems management, enterprise applications, collaboration/email, streaming media, web, and HPC.

- ThinkSystem SR630 V3 supports up to two fourth-generation Intel® Xeon® Scalable Processors with up to 60-core processors, up to 112.5 MB of last level cache (LLC), up to 4800 MHz memory speeds, and up to 4 Ultra Path Interconnect (UPI) links at 16 GT/s.
- Offers flexible and scalable internal storage in a 1U rack form factor with up to 12x 2.5-inch drives or up to 4x 3.5-inch drives or up to 16x EDSFF drives, providing a wide selection of SAS/SATA HDD/SSD and NVMe SSD types and capacities.
- Provides I/O scalability with the OCP slot, PCIe 5.0 slot for an internal storage controller, and up to three PCI Express (PCIe) 5.0 I/O expansion slots in a 1U rack form factor.

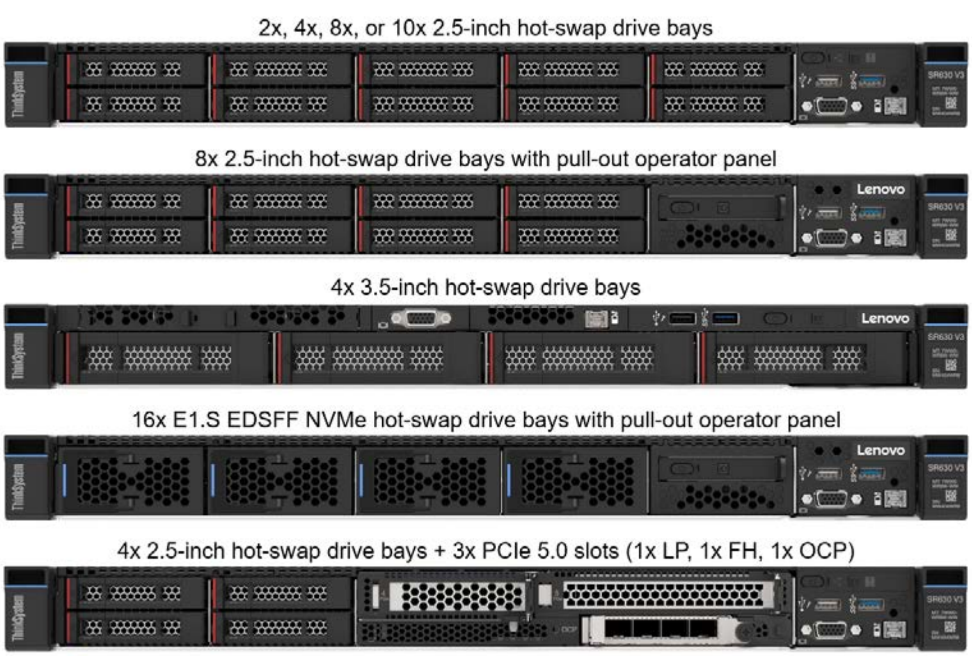


Figure 9. Lenovo ThinkSystem SR630 V3 Server Front Views

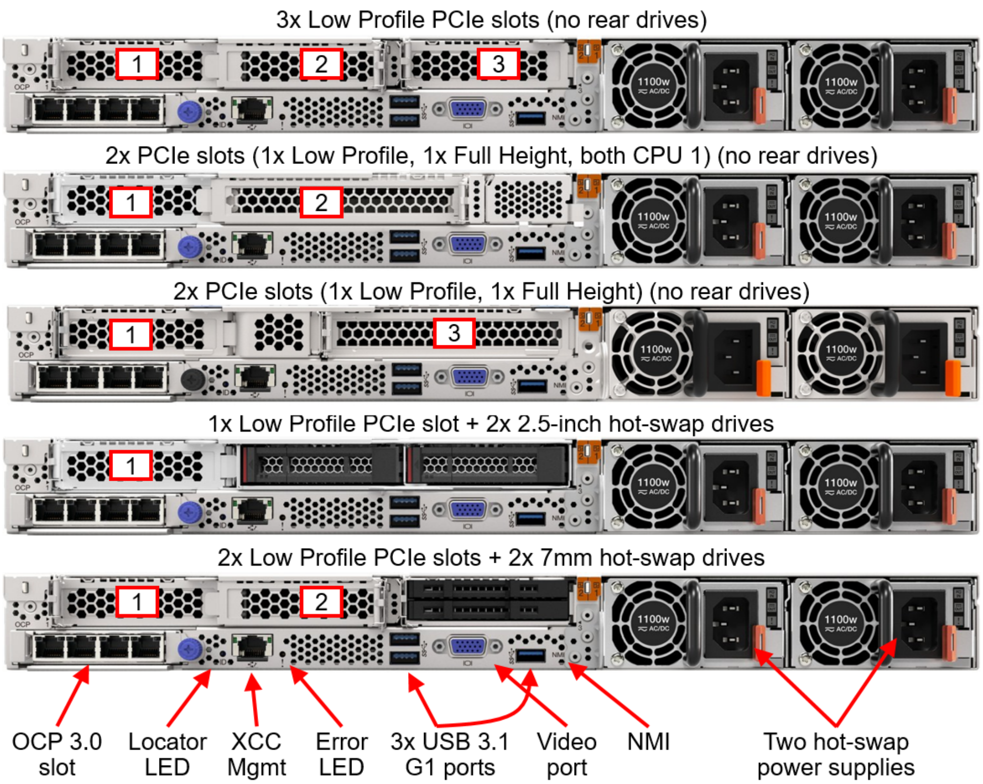


Figure 10. Lenovo ThinkSystem SR630 V3 Server Rear Views

For more information, see the Lenovo ThinkSystem SR630 V3 Product Guide:

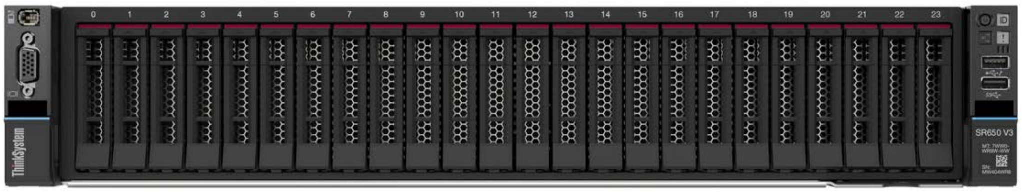
ThinkSystem SR630 V3 Server Product Guide.

6.1.2 Lenovo ThinkSystem SR650 V3 2U Server

The Lenovo ThinkSystem SR650 V3 is an ideal 2-socket 2U rack server for small businesses up to large enterprises that need industry-leading reliability, management, and security, as well as maximizing performance and flexibility for future growth. The SR650 V3 is designed to handle a wide range of workloads, such as databases, virtualization and cloud computing, virtual desktop infrastructure (VDI), infrastructure security, systems management, enterprise applications, collaboration/email, streaming media, web, and HPC.

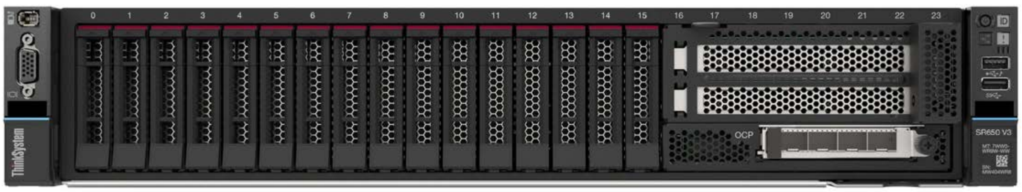
The SR650 V3 server supports:

- Up to two fourth-generation Intel® Xeon® Scalable Processors with up to 60-core processors, up to 112.5 MB of last level cache (LLC), up to 4800 MHz memory speeds, and up to 4 Ultra Path Interconnect (UPI) links at 16GT/s.
- With RDIMMs: Up to 8TB by using 32x 256GB 3DS RDIMMs.
- Up to 40x 2.5-inch or 20x 3.5-inch drive bays with an extensive choice of NVMe PCIe SSDs, SAS/SATA SSDs, and SAS/SATA HDDs.
- Flexible I/O Network expansion options with the OCP slot, the dedicated storage controller slot, and up to 10x PCIe slots, up to 9x slots can be PCIe 5.0.



Up to 24x 2.5-inch (combinations of SAS/SATA, NVMe and AnyBay)

Up to 12x 3.5-inch (combinations of SAS/SATA, NVMe and AnyBay)



Up to 16x 2.5-inch + 3x PCIe slots (2x FH, 1x OCP)

Figure 11. Lenovo ThinkSystem SR650 V3 Server Front Views

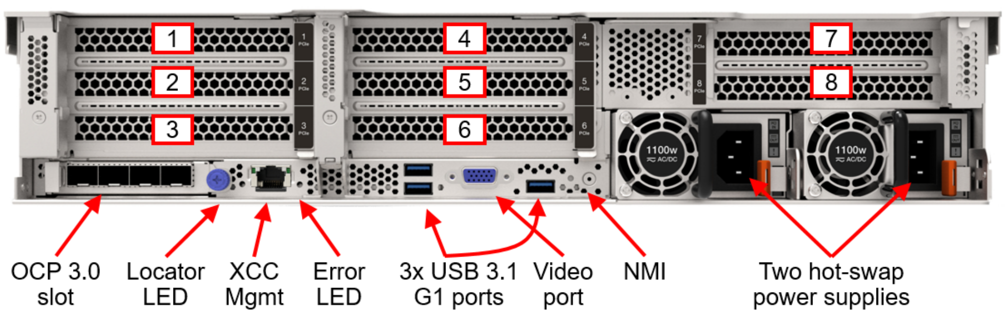


Figure 12. Lenovo ThinkSystem SR650 V3 Server Rear Views

For more information, see the Lenovo ThinkSystem SR650 V3 Product Guide:

[ThinkSystem SR650 V3 Server Product Guide]

6.1.3 Lenovo ThinkSystem SR630 V2 1U Server

Lenovo ThinkSystem SR630 V2 is an ideal 2-socket 1U rack server for small businesses up to large enterprises that need industry-leading reliability, management, and security, as well as maximizing performance and flexibility for future growth. The SR630 V2 is designed to handle a wide range of workloads, such as databases, virtualization and cloud computing, virtual desktop infrastructure (VDI), infrastructure security, systems management, enterprise applications, collaboration/email, streaming media, web, and HPC.

- ThinkSystem SR630 V2 supports two third-generation Intel® Xeon® Scalable Processors with up to 40-core processors, up to 60 MB of last level cache (LLC), up to 3200 MHz memory speeds, and up to 11.2 GT/s Ultra Path Interconnect (UPI) links.
- Offers flexible and scalable internal storage in a 1U rack form factor with up to 12x 2.5-inch drives or up to 4x 3.5-inch drives or up to 16x EDSFF drives, providing a wide selection of SAS/SATA HDD/SSD and NVMe SSD types and capacities.
- Provides I/O scalability with the OCP slot, PCIe 4.0 slot for an internal storage controller, and up to three PCI Express (PCIe) 4.0 I/O expansion slots in a 1U rack form factor.

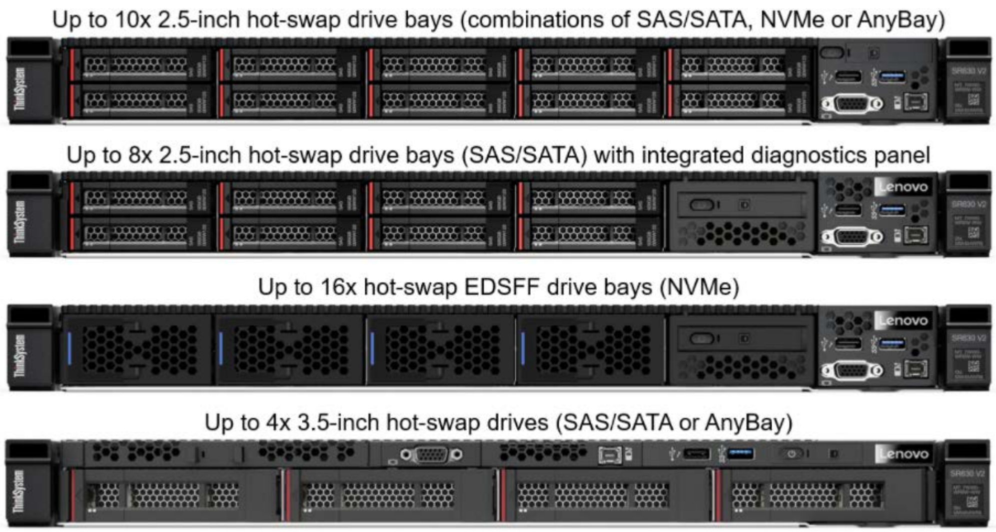


Figure 13. Lenovo ThinkSystem SR630 V2 Server Front Views

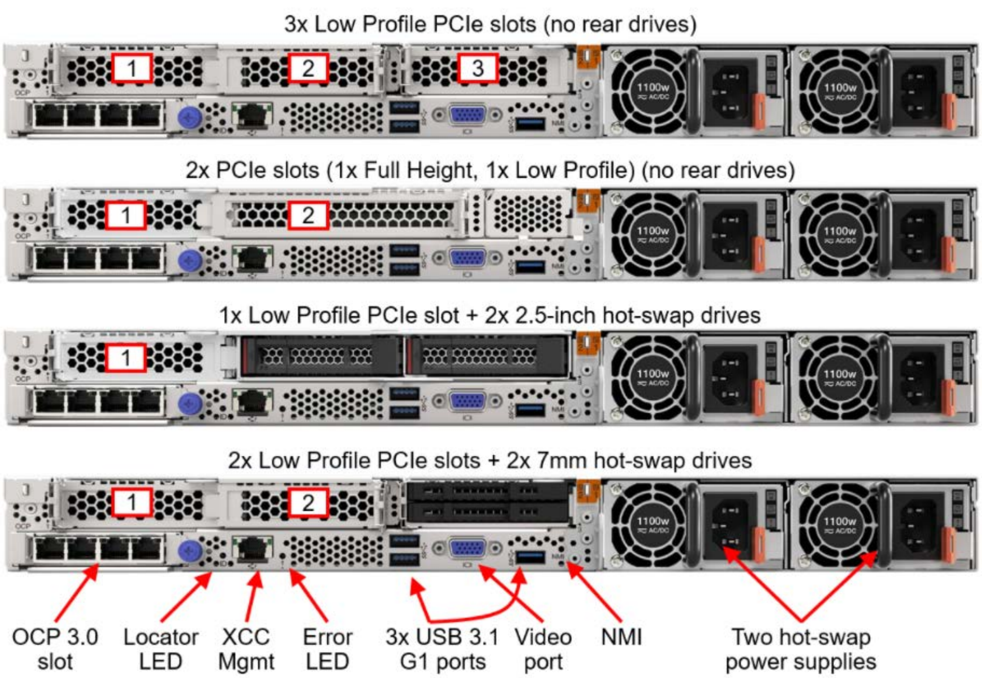


Figure 14. Lenovo ThinkSystem SR630 V2 Server Rear Views

For more information, see the Lenovo ThinkSystem SR630 V2 Product Guide:

ThinkSystem SR630 V2 Server Product Guide.

6.1.4 Lenovo ThinkSystem SR650 V2 2U Server

The Lenovo ThinkSystem SR650 V2 is an ideal 2-socket 2U rack server for small businesses up to large enterprises that need industry-leading reliability, management, and security, as well as maximizing performance and flexibility for future growth. The SR650 V2 is designed to handle a wide range of workloads, such as databases, virtualization and cloud computing, virtual desktop infrastructure (VDI), infrastructure security, systems management, enterprise applications, collaboration/email, streaming media, web, and HPC.

The SR650 V2 server supports:

- Up to two third-generation Intel® Xeon® Scalable Processors with up to 40-core processors, up to 60 MB of last level cache (LLC), up to 3200 MHz memory speeds, and up to 11.2 GT/s Ultra Path Interconnect (UPI) links.
- With RDIMMs: Up to 8TB by using 32x 256GB 3DS RDIMMs
  With Persistent Memory: Up to 6TB by using 16x 128GB 3DS RDIMMs and 16x 256GB Pmem modules
- Up to 40x 2.5-inch or 20x 3.5-inch drive bays with an extensive choice of NVMe PCIe SSDs, SAS/SATA SSDs, and SAS/SATA HDDs
- Flexible I/O Network expansion options with the OCP slot, the dedicated storage controller slot, and up to 8x PCIe slots

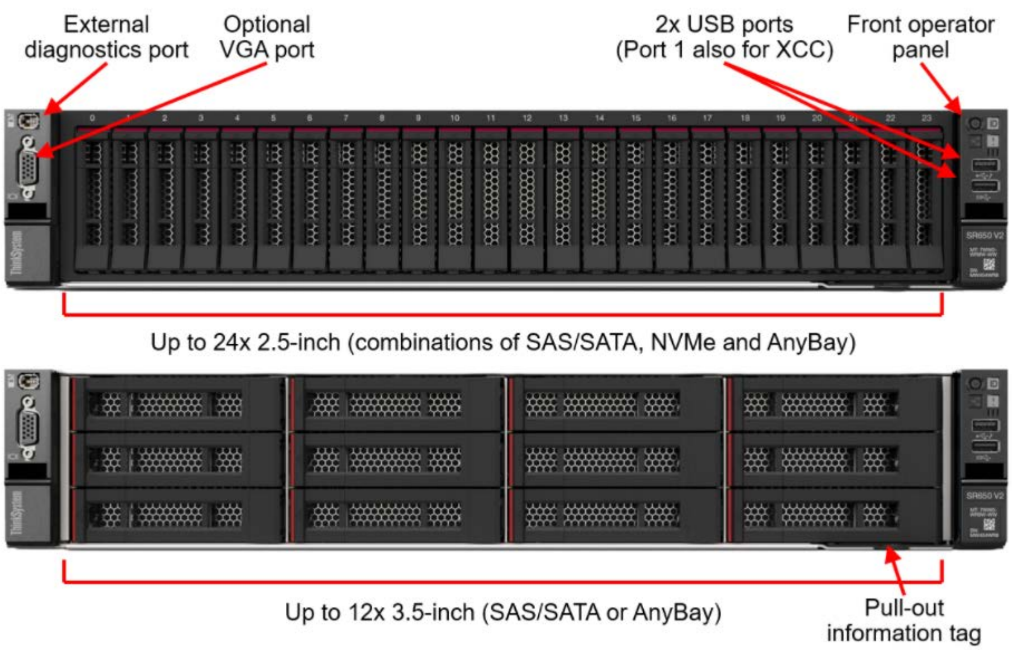


Figure 15. Lenovo ThinkSystem SR650 V2 Server Front Views

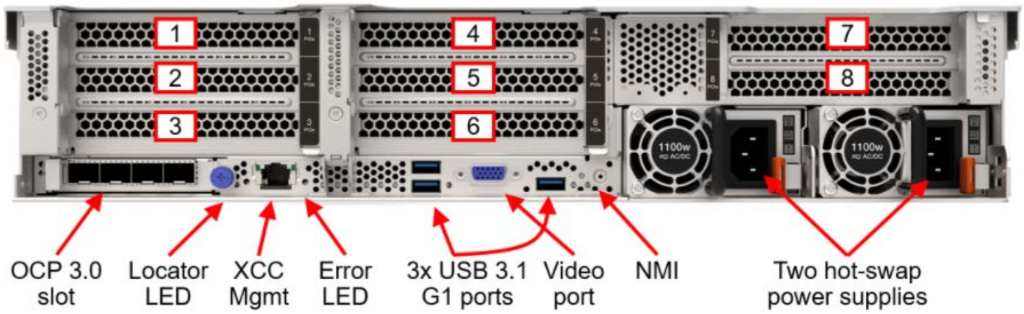


Figure 16. Lenovo ThinkSystem SR650 V2 Server Rear Views

For more information, see the Lenovo ThinkSystem SR650 V2 Product Guide:

ThinkSystem SR650 V2 Server Product Guide

6.1.5 Lenovo ThinkSystem SE350 Edge Server

The ThinkSystem SE350 is a purpose-built server that is half the width and significantly shorter than a traditional server, making it ideal for deployment in tight spaces. It can be mounted on a wall, stacked on a shelf or mounted in a rack.

The ThinkSystem SE350 puts increased processing power, storage and network closer to where data is generated, allowing actions resulting from the analysis of that data to take place more quickly. The server has wired connections up to 10GbE and optionally supports both Wi-Fi and LTE wireless connectivity.

Since these edge servers are typically deployed outside of secure data centers, they include technology that encrypts the data stored on the device if it is tampered with, only enabling authorized users to access it.

The SE350 edge server supports:

- One Intel Xeon D Processor with up to 16-core processors, core speeds of up to 2.2 GHz, and TDP ratings of up to 100W.
- Up to 4 TruDDR4 memory DIMMs an up to 256 GB of memory using 64 GB DIMMs.
- Up to 8 M.2 data drives -- SATA or NVMe -- provide efficient and rugged storage for edge workloads.
- Supports 1 or 2 additional M.2 SATA drives for OS boot and applications, allowing the convenience of separating application code from data.
- Two 10 GbE SFP+ or 10GBASE-T ports standard for high-speed networking to back-end servers.
- Support for the NVIDIA T4 GPU for enhanced workloads at the edge of your network.

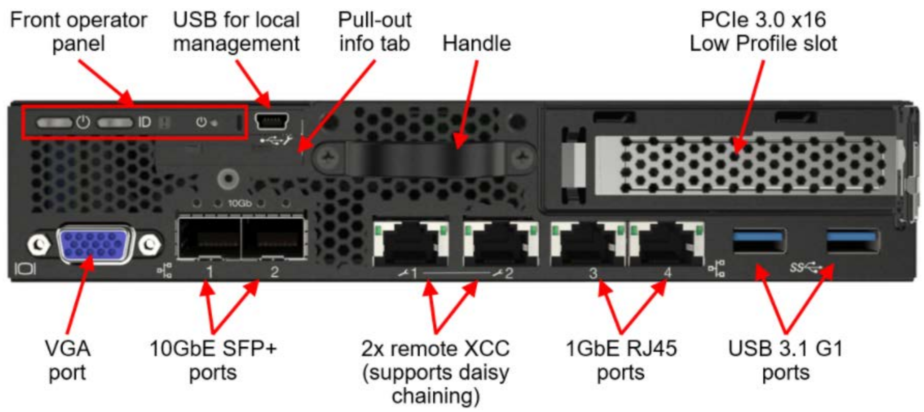


Figure 17. Front view of the Lenovo ThinkSystem SE350 with 10G SFP+ network module

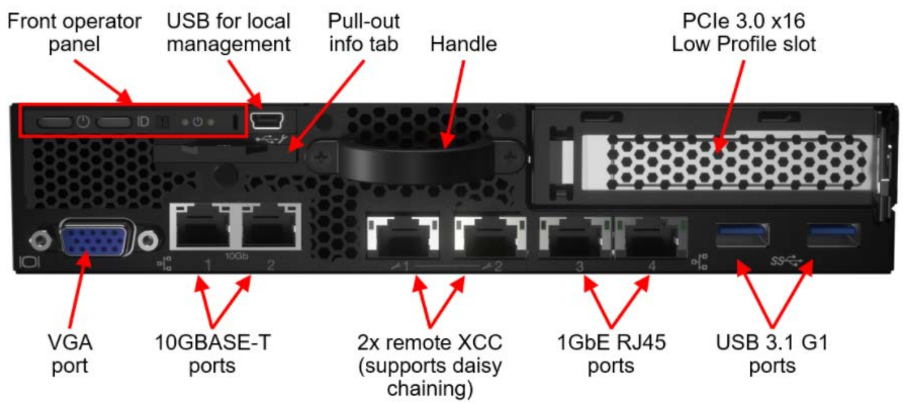


Figure 18. Front view of the Lenovo ThinkSystem SE350 with 10GBASE-T network module

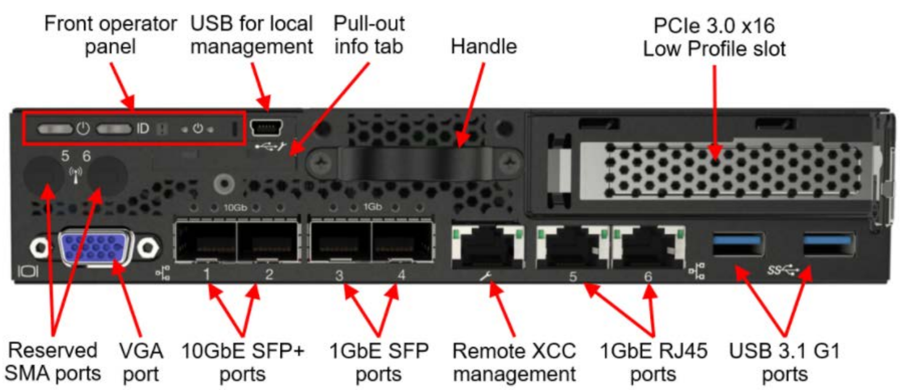


Figure 19. Front view of the Lenovo ThinkSystem SE350 with Wireless network module

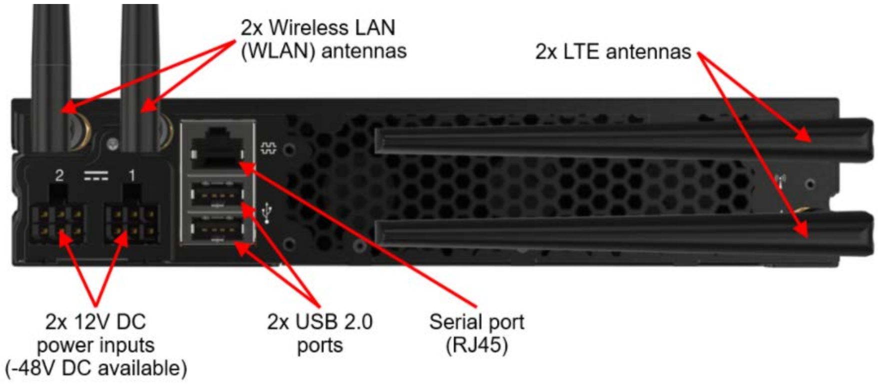


Figure 20. Rear view of the Lenovo ThinkSystem SE350

Figure 21. View of the Lenovo ThinkSystem SE350

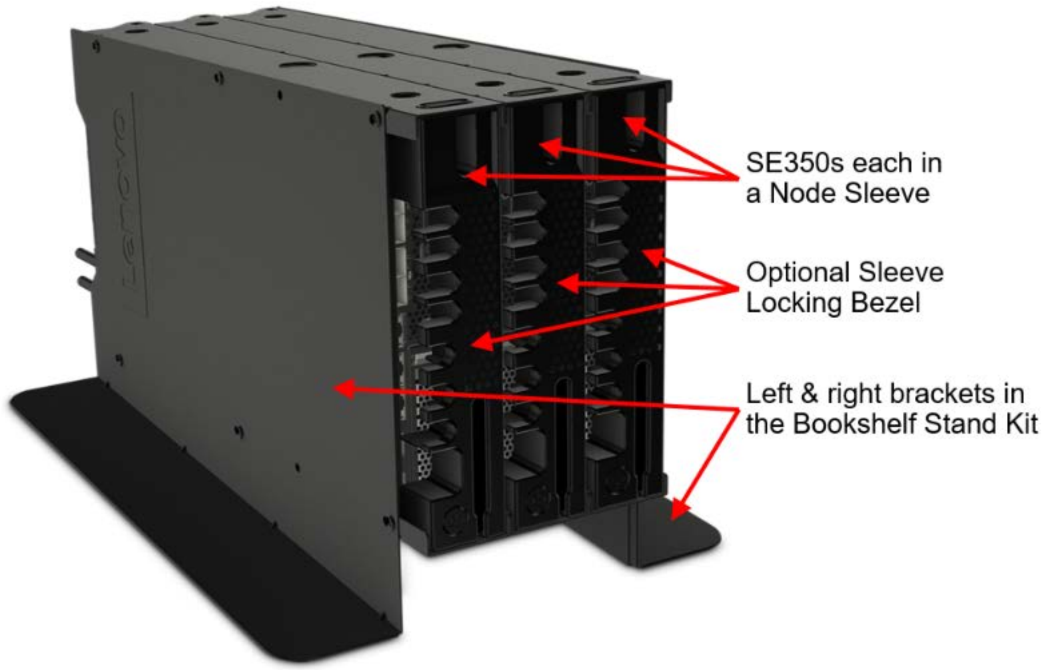


Figure 22. Bookshelf mount (with optional locking bezels)

For more information, see the Lenovo ThinkSystem SE350 Product Guide:

ThinkSystem SE350 Server Product Guide

6.1.6 Lenovo ThinkEdge SE360 V2 Server

The SE360 V2 is a purpose-built server that is a 2U high and half width making it significantly smaller than a traditional server, ideal for deployment in tight spaces. It can be mounted on a wall, ceiling, placed on a desk or mounted in a rack.

The ThinkEdge SE360 V2 server puts increased processing power, storage and network closer to where data is generated, allowing actions resulting from the analysis of that data to take place more quickly. The server has wired connections for 1GbE, 10GbE/25GbE and optionally supporting wireless LAN (WLAN) to enable connectivity to Wi-Fi clients.

Since these edge servers are typically deployed outside of secure data centers, they include technology that encrypts the data stored on the device if it is tampered with, only enabling authorized users to access it.

The ThinkEdge SE360 server supports:

- One Intel Xeon D Processor with up to 16-core processors, core speeds of up to 2.1 GHz, and TDP ratings of up to 100W.
- Up to 4 TruDDR4 memory DIMMs an up to 256 GB of memory using 64 GB DIMMs.
- Up to 8 M.2 data drives -- NVMe -- provide efficient and rugged storage for edge workloads.
- Supports 1 or 2 additional M.2 NVMe drives for OS boot and applications, allowing the convenience of separating application code from data.
- 1GbE I/O board or 10GbE/25GbE SFP28 I/O board to support low and high-speed networking to back-end servers.
- Support for the NVIDIA A2, NVIDIA L4 or Qualcomm Cloud AI 100 for enhanced workloads at the edge of your network.

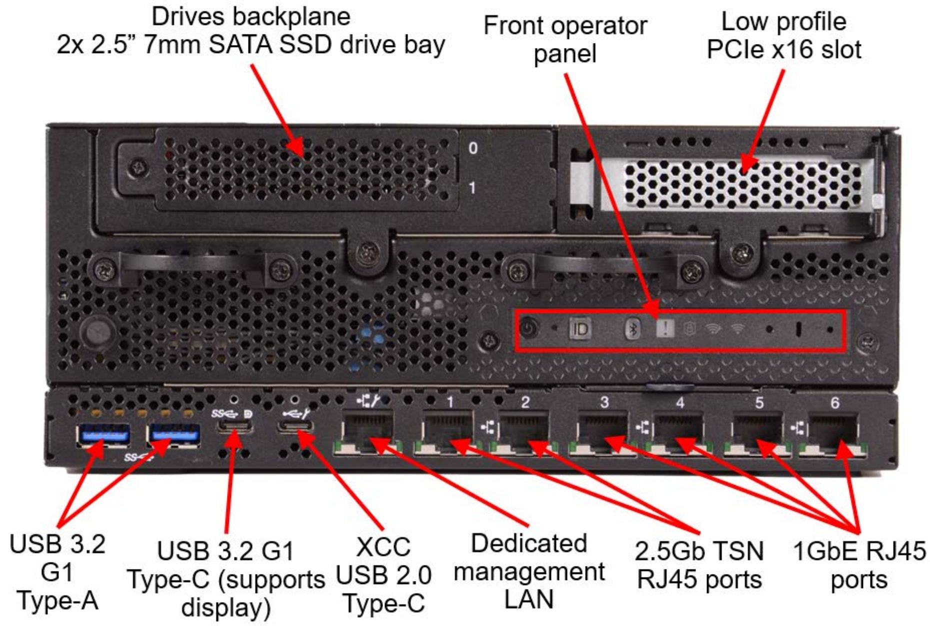


Figure 23. Front view of the Lenovo ThinkEdge SE360 V2 server with 1GbE network module

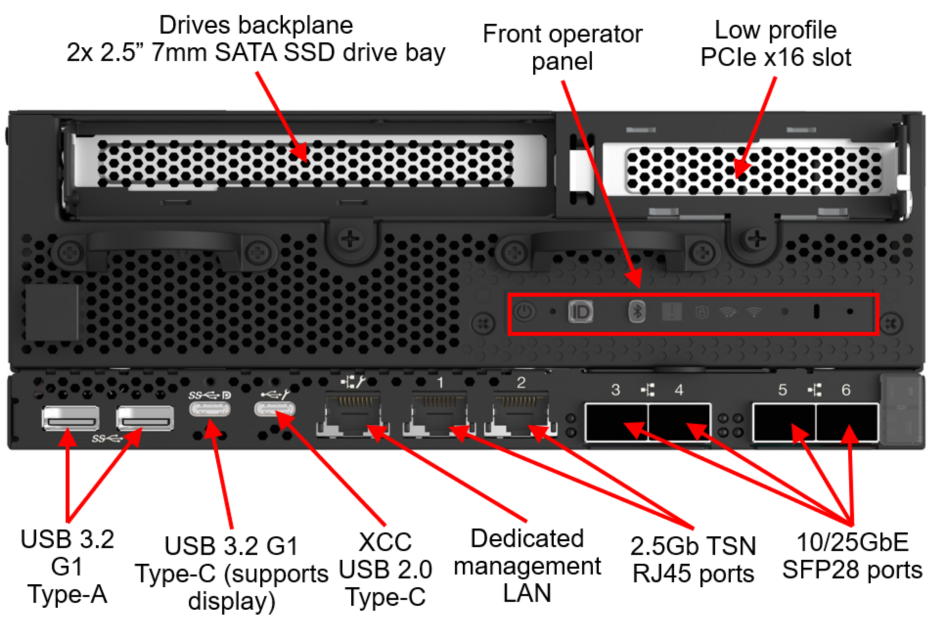


Figure 24. Front view of the Lenovo ThinkEdge SE360 V2 server with 10/25GbE network module

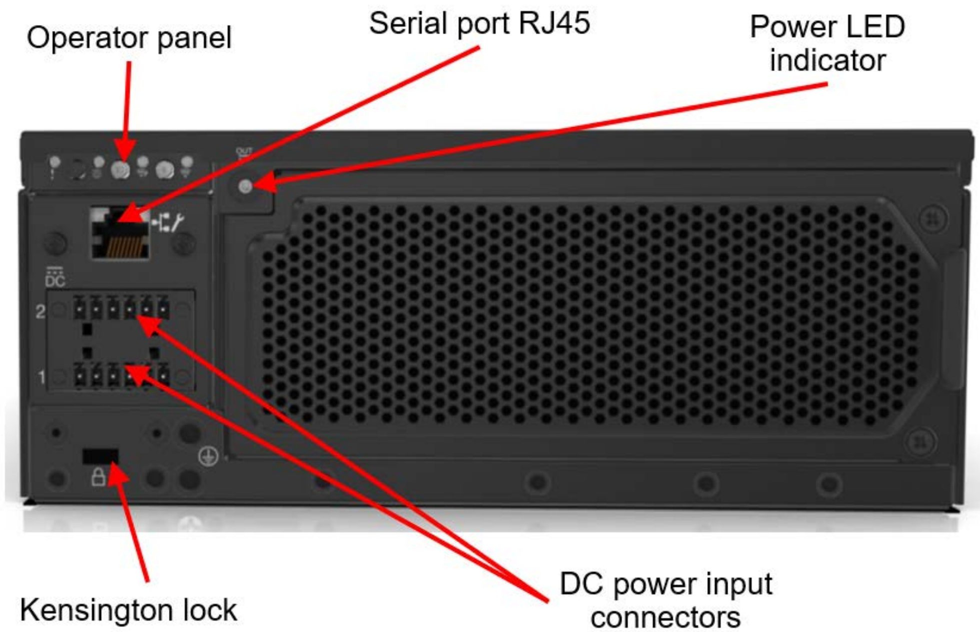


Figure 25. Rear view of the Lenovo ThinkEdge SE360 V2 with DC input connector

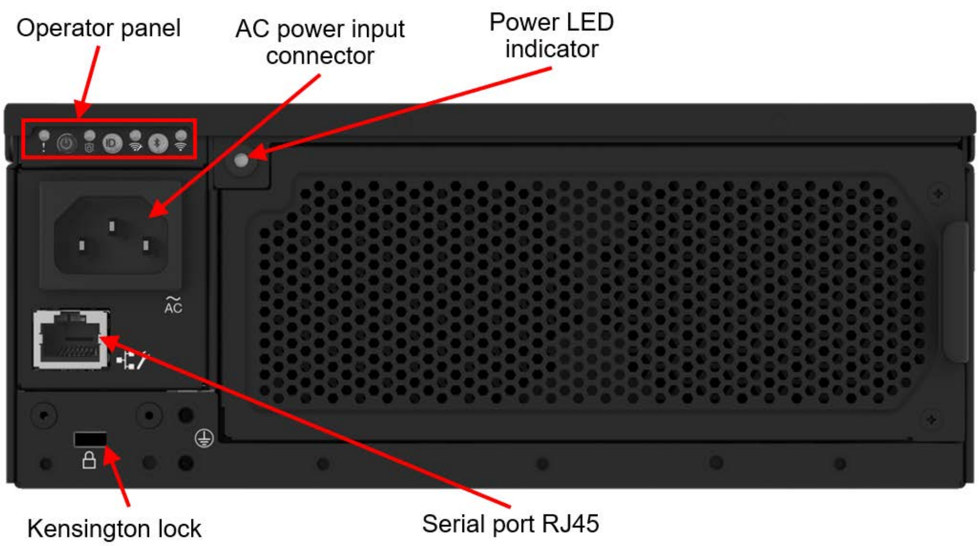


Figure 26. Rear view of the Lenovo ThinkEdge SE360 V2 with AC input connector

Figure 27. View of the Lenovo ThinkSystem SE360 V2

For more information, see the Lenovo ThinkEdge SE360 V2 Product Guide:

ThinkEdge SE360 V2 Server Product Guide

6.1.7 Lenovo ThinkEdge SE450 Server

The ThinkEdge SE450 is a single-socket server with a 2U height and short depth case, making it suitable for deployment in shallow cabinets. It can be mounted on a wall, stacked on a shelf, or mounted in a rack.

The SE450 puts increased processing power, storage, and network closer to where data is generated, allowing actions resulting from the analysis of that data to take place more quickly. The server is also designed for Wireless LAN (WLAN) connectivity for even great flexibility in deployment options.

Since these edge servers are typically deployed outside of secure data centers, they include technology that encrypts the data stored on the device if it is tampered with, only enabling authorized users to access it.

The ThinkEdge SE450 server supports:

- One Intel Xeon Scalable "Ice Lake" processor with up to 36-core processors, core speeds of up to 3.0 GHz, and TDP ratings of up to 205W.
- Up to 8 TruDDR4 memory DIMMs and up to 1 TB of memory using 128 GB DIMMs.
- Up to 4x internal SSD drive bays supporting non-hot-swap trayless NVMe or SATA SSD drives. Up to 2x 2.5-inch hot-swap drive bays, front accessible, supporting SAS or SATA SSD drives (mutually exclusive with slots 3 and 4 in Riser 2). Up to 2x M.2 drives for boot functions, supporting SATA or NVMe drives.
- Support four network adapters, up to 100 Gb Ethernet or HDR100 InfiniBand, for high-speed networking to back-end servers.
- Up to 4x single-wide GPUs or up to 2x double-wide GPUs.

Figure 28. Front view of the Lenovo ThinkEdge SE450

Figure 29. Rear view of the Lenovo ThinkEdge SE450

Figure 30. View of the ThinkEdge SE450 with security bezel attached

Figure 31. SE450 installed on a wall in a manufacturing environment

For more information, see the Lenovo ThinkEdge SE450 Product Guide:

[ThinkEdge SE450 Server Product Guide]

6.1.8 Lenovo ThinkEdge SE455 V3 Server

The ThinkEdge SE455 V3 is a single-socket server with a 2U height and short depth case, making it suitable for deployment in shallow cabinets. It can be mounted in a 2-post or 4-post rack. The SE455 V3 uses the new AMD EPYC 8004 Series "Siena" processors for an ideal mix of performance and power efficiency. The SE455 V3 puts processing power, storage and network closer to where data is generated, allowing actions resulting from the analysis of that data to take place more quickly.

The ThinkEdge SE455 V3 is a purpose-built server that is significantly shorter than a traditional server, making it ideal for deployment in tight spaces. The ThinkEdge SE455 V3 puts increased processing power, storage and network closer to where data is generated, allowing actions resulting from the analysis of that data to take place more quickly.

Since these edge servers are typically deployed outside of secure data centers, they include technology that encrypts the data stored on the device, protecting the data if the system is tampered with, only enabling authorized users to access it.

The ThinkEdge SE455 V3 server supports:

- One AMD EPYC 8004 ("Siena") processor with up to 64-core processors, core speeds of up to 2.65 GHz, and TDP ratings of up to 225W.
- Up to 6 TruDDR5 memory DIMMs and up to 576 GB of memory using 96 GB DIMMs.
- Support for up to 8x 2.5-inch drive bays, 4x hot-swap drives at the front of the server, and 4x non-hot swap drives internal to the server. Optional RAID with the addition of a RAID adapter installed in a slot.
- Supports M.2 drives for convenient operating system boot functions. Available M.2 adapters support either one M.2 drive or two M.2 drives. M.2 with RAID is available now using a PCIe RAID adapter; support for an M.2 adapter with integrated RAID is planned for 1Q/2024.
- The server offers PCI Express 5.0 (PCIe Gen 5) I/O expansion capabilities that doubles the theoretical maximum bandwidth of PCIe 4.0 (32GT/s in each direction for PCIe 5.0, compared to 16 GT/s with PCIe 4.0). A PCIe 5.0 x16 slot provides 128 GB/s bandwidth, enough to support a 400GbE network connection.
- Supports up to 6x single-width GPUs or 2x double-wide GPUs, for substantial processing power in an edge system.
- Supports up to 6x AMD Alveo V70 Datacenter Accelerator adapters, tuned for video analytics and natural language processing workloads.

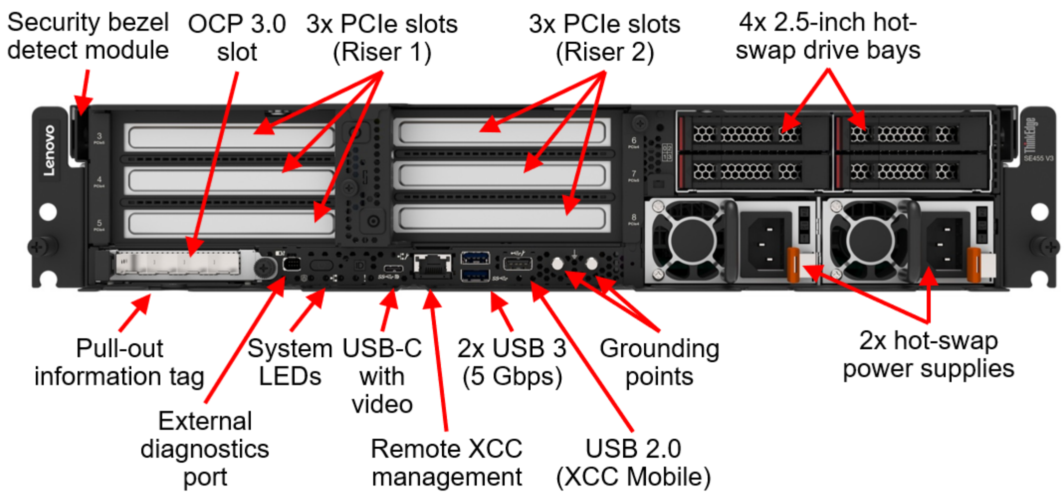


Figure 32. Front view of the ThinkEdge SE455 V3

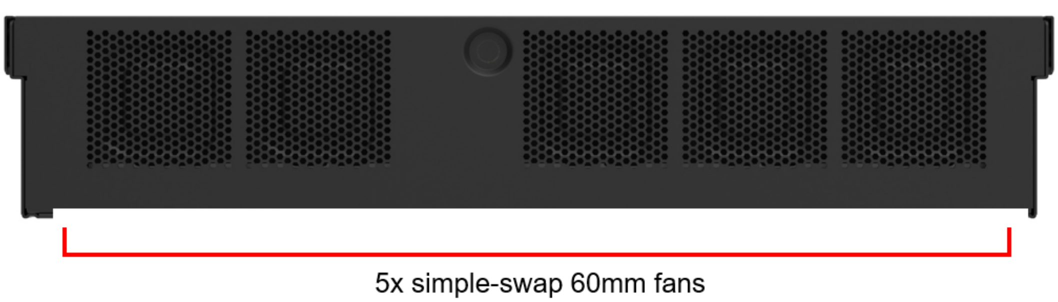


Figure 33. Rear view of the ThinkEdge SE455 V3

Figure 34. View of the ThinkEdge SE455 V3 with security bezel attached

For more information, see the Lenovo ThinkEdge SE455 V3 Product Guide:

ThinkEdge SE455 V3 Server Product Guide

6.1.9 Lenovo ThinkSystem SR645 V3 1U Server

The Lenovo ThinkSystem SR645 V3 is a dense, high performance, 2-socket 1U rack server. It is suitable for small businesses to large enterprises, and especially cloud service providers. The server features the AMD EPYC 9004 "Genoa" family of processors and support for the new PCIe 5.0 standard for I/O. It is designed to handle a wide range of workloads such as cloud computing, virtualization, VDI, enterprise applications, and database management.

- ThinkSystem SR645 V3 supports up to two fourth-generation AMD EPYC 9004 processors with up to 96-core processors, up to 384 MB of L3 cache, up to 4800 MHz memory speeds, and 4x dedicated xGMI x16 interprocessor links.
- Offers flexible and scalable internal storage in a 1U rack form factor with up to 12x 2.5-inch drives or up to 4x 3.5-inch drives or up to 16x E1.S EDSFF drives, providing a wide selection of SAS/SATA HDD/SSD and NVMe SSD types and capacities.
- Provides I/O scalability with the OCP slot, PCIe 5.0 slot for an internal storage controller, and up to three PCI Express (PCIe) expansion slots (2x PCIe 5.0, 1x PCIe 4.0) in a 1U rack form factor.

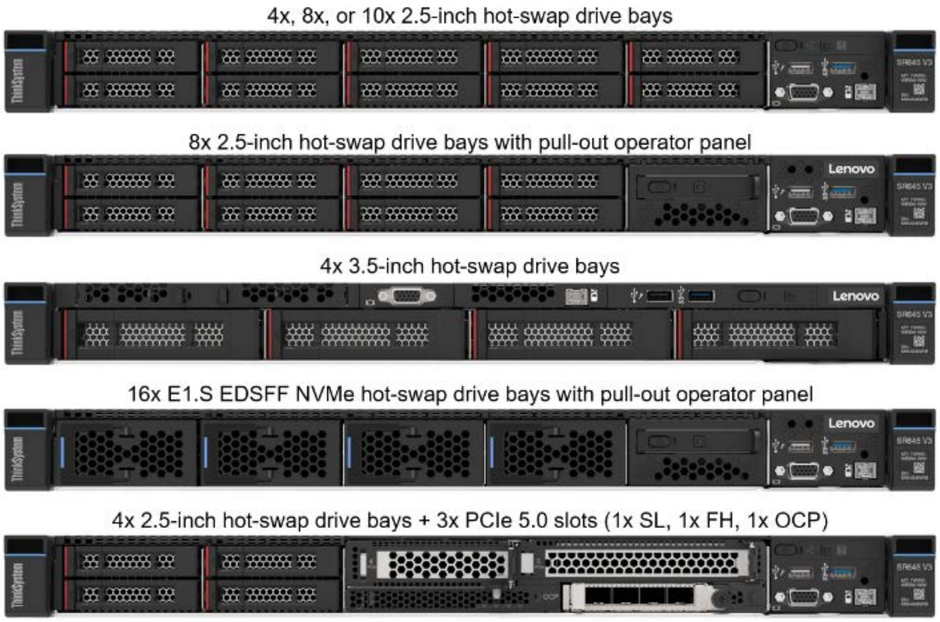


Figure 35. Lenovo ThinkSystem SR645 V3 Server Front Views

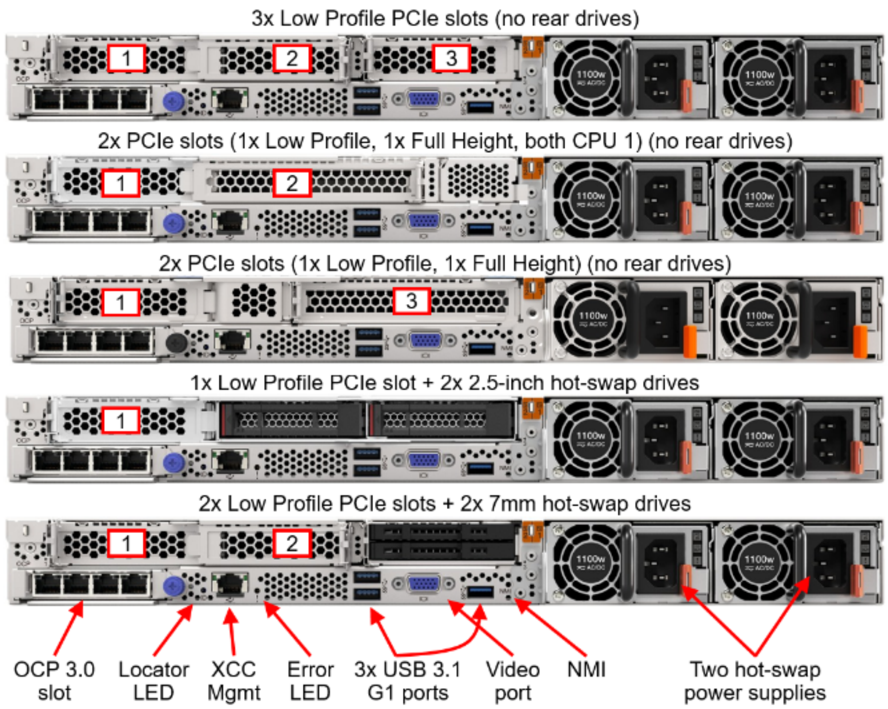


Figure 36. Lenovo ThinkSystem SR645 V3 Server Rear Views

For more information, see the Lenovo ThinkSystem SR645 V3 Product Guide:

ThinkSystem SR645 V3 Server Product Guide.

6.1.10 Lenovo ThinkSystem SR665 V3 2U Server

The Lenovo ThinkSystem SR665 V3 is a 2-socket 2U server that features the AMD EPYC 9004 "Genoa" family of processors. With up to 96 cores per processor and support for the new PCIe 5.0 standard for I/O, the SR665 V3 offers the ultimate in two-socket server performance in a 2U form factor. The server is ideal for dense workloads that can take advantage of GPU processing and high-performance NVMe drives. The SR655 V3 is designed to handle a wide range of workloads, such as Inference, virtualization, VDI, HPC, Hyperconverged infrastructure.

The SR665 V3 server supports:

- Up to 2-socket 2U server that features the AMD EPYC 9004 "Genoa" family of processors, with up to 96-core per processor, up to 384 MB of L3 cache, up to 4800 MHz memory speeds, and up to 4x xGMI x16 interprocessor links, 1 of which can be used for an additional 16 PCIe 5.0 lanes.
- Up to 6TB of system memory.
- Up to 40x 2.5-inch or 20x 3.5-inch drive bays with an extensive choice of NVMe PCIe SSDs, SAS/SATA SSDs, and SAS/SATA HDDs.
- Flexible I/O Network expansion options with the OCP slot, the dedicated storage controller slot, and up to 10x PCIe slots, up to 9x slots can be PCIe 5.0.

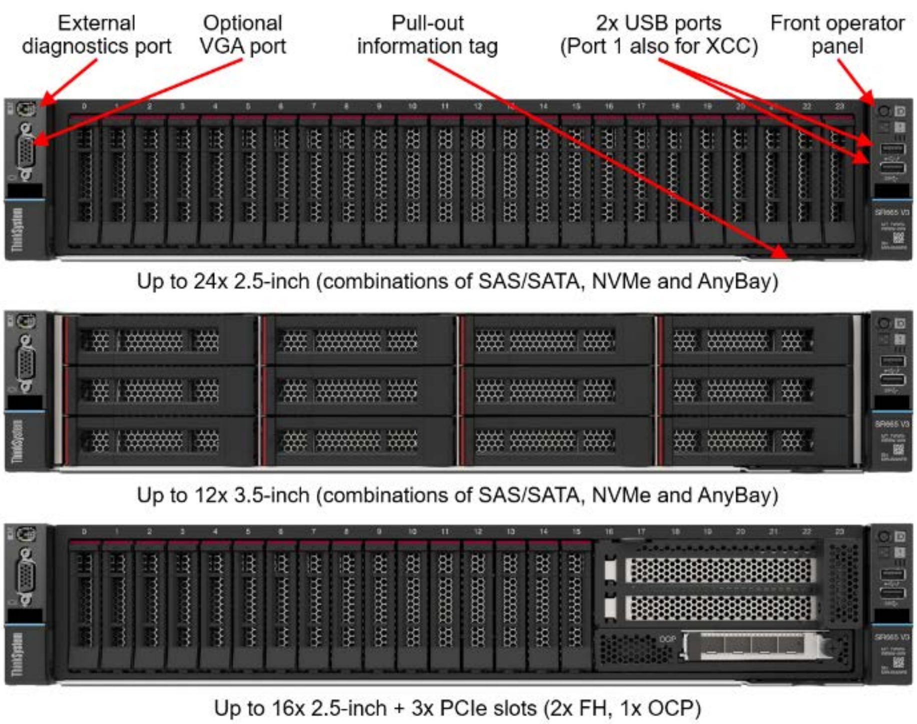


Figure 37. Lenovo ThinkSystem SR665 V3 Server Front Views

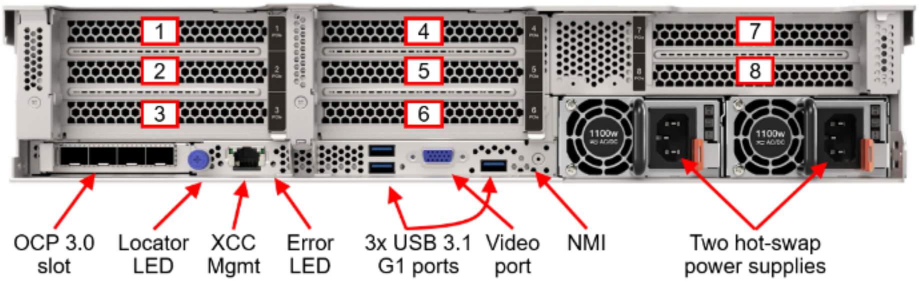


Figure 38. Lenovo ThinkSystem SR665 V3 Server Rear Views

For more information, see the Lenovo ThinkSystem SR665 V3 Product Guide:

[ThinkSystem SR665 V3 Server Product Guide]

6.1.11 Lenovo ThinkSystem SR635 V3 1U Server

The Lenovo ThinkSystem SR635 V3 is a 1-socket 1U server that features the AMD EPYC 9004 "Genoa" family of processors. With up to 96 processor cores and support for the new PCIe 5.0 standard for I/O, the SR635 V3 offers the ultimate in one-socket server performance in a 1U form factor. The server is ideal for dense workloads that can take advantage of GPU processing and high-performance NVMe drives. It is designed to handle a wide range of workloads such as AI Inference, VDI, OLTP, Analytics, HPC, software-defined storage.

- ThinkSystem SR635 V3 supports up to one fourth-generation AMD EPYC 9004 processors with up to 96-core processors, up to 384 MB of L3 cache, up to 4800 MHz memory speeds, and 128x PCIe 5.0 lanes per processor.
- Offers flexible and scalable internal storage in a 1U rack form factor with up to 12x 2.5-inch drives or up to 16x E1.S EDSFF drives, providing a wide selection of SAS/SATA HDD/SSD and NVMe SSD types and capacities.
- Provides I/O scalability with the OCP slot, PCIe 5.0 slot for an internal storage controller, and up to five PCI Express (PCIe) slots (3 rear, 2 front) in a 1U rack form factor.

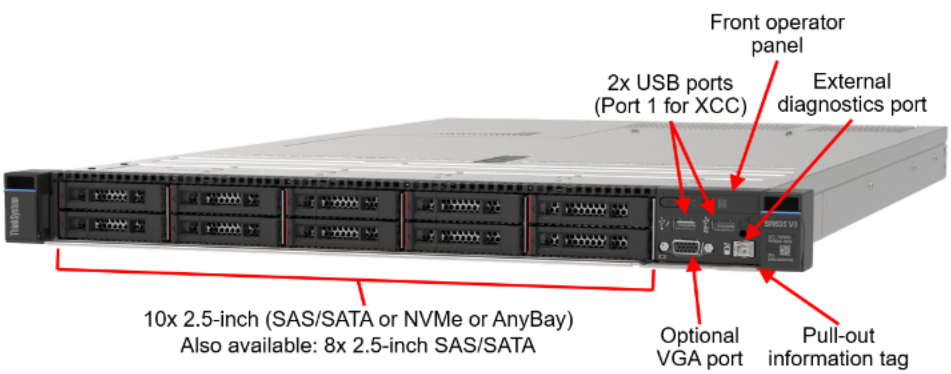


Figure 39. Lenovo ThinkSystem SR635 V3 Server Front Views

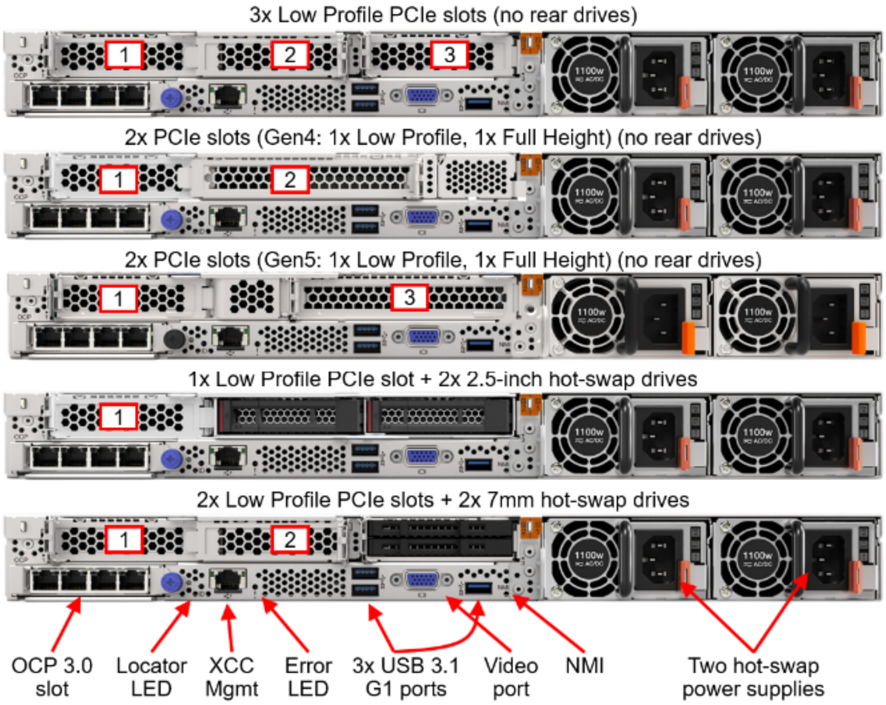


Figure 40. Lenovo ThinkSystem SR635 V3 Server Rear Views

For more information, see the Lenovo ThinkSystem SR635 V3 Product Guide:

ThinkSystem SR635 V3 Server Product Guide.

6.1.12 Lenovo ThinkSystem SR655 V3 2U Server

The Lenovo ThinkSystem SR655 V3 is a 1-socket 2U server that features the AMD EPYC 9004 "Genoa" family of processors. With up to 96 cores per processor and support for the new PCIe 5.0 standard for I/O, the SR655 V3 offers the ultimate in one-socket server performance in a 2U form factor. The server is ideal for dense workloads that can take advantage of GPU processing and high-performance NVMe drives. The SR655 V3 is designed to handle a wide range of workloads, such as AI Inference, VDI, OLTP, Analytics, software-defined storage.

The SR655 V3 server supports:

- Up to 1-socket 2U server that features the AMD EPYC 9004 "Genoa" family of processors, with up to 96-core per processor, up to 384 MB of L3 cache, up to 4800 MHz memory speeds, and up to 64x PCIe 5.0 lanes per processor.
- Up to 1.5TB of system memory.
- Up to 40x 2.5-inch or 20x 3.5-inch drive bays with an extensive choice of NVMe PCIe SSDs, SAS/SATA SSDs, and SAS/SATA HDDs.
- Flexible I/O Network expansion options with the OCP slot, the dedicated storage controller slot, and up to 10x PCIe slots, up to 9x slots can be PCIe 5.0.

Figure 41. Lenovo ThinkSystem SR655 V3 Server Front Views

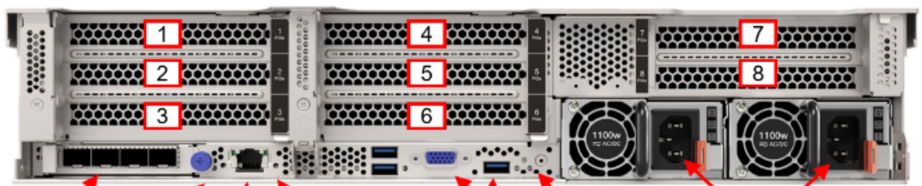


Figure 42. Lenovo ThinkSystem SR655 V3 Server Rear Views

For more information, see the Lenovo ThinkSystem SR655 V3 Product Guide:

[ThinkSystem SR655 V3 Server Product Guide]()

6.1.13Lenovo ThinkAgile HX series

Lenovo ThinkAgile HX Series appliances and certified nodes are designed to help you simplify IT infrastructure, reduce costs, and accelerate time to value. These hyper-converged appliances from Lenovo combine industry-leading hyper-convergence software from Nutanix with Lenovo enterprise platforms. Several common uses are:

- Enterprise workloads
- Private and hybrid clouds
- Remote office and branch office (ROBO)
- Server virtualization
- Virtual desktop infrastructure (VDI)
- Small-medium business (SMB) workloads

Starting with as few as three nodes to keep your acquisition costs down, the Lenovo ThinkAgile HX Series appliances and certified nodes are capable of immense scalability as your needs grow.

Lenovo ThinkAgile HX Series appliances and certified nodes are available in five families that can be tailored to your needs:

- Lenovo ThinkAgile HX1000 Series: optimized for ROBO environments
- Lenovo ThinkAgile HX2000 Series: optimized for SMB environments
- Lenovo ThinkAgile HX3000 Series: optimized for compute-heavy environments

- Lenovo ThinkAgile HX5000 Series: optimized for storage-heavy workloads
- Lenovo ThinkAgile HX7000 Series: optimized for high-performance workloads

Table 3 shows the similarities and differences between ThinkAgile HX Series appliances and certified nodes.

Table 3: Comparison of ThinkAgile HX Series appliances and certified nodes

Feature	HX Series Appliances	HX Series certified nodes
Validated and integrated hardware and firmware	Yes	Yes
Certified and preloaded with Nutanix software	Yes	Yes
Includes Nutanix licenses	Yes	No
ThinkAgile Advantage Single Point of Support for quick 24/7 problem reporting and resolution	Yes	Yes
Includes deployment services	Optional	Optional
Supports ThinkAgile HX2000 Series	Yes	No

For more information about the system specifications and supported configurations, refer to the product guides for the Lenovo ThinkAgile HX Series appliances and certified nodes based on the Intel Xeon Scalable processor. For appliances see:

- Lenovo ThinkAgile HX1000 Series: lenovopress.com/lp0726
- Lenovo ThinkAgile HX2000 Series: lenovopress.com/lp0727
- Lenovo ThinkAgile HX3000 Series: lenovopress.com/lp0728
- Lenovo ThinkAgile HX5500 Series: lenovopress.com/lp0729
- Lenovo ThinkAgile HX7500 Series: lenovopress.com/lp0730
- Lenovo ThinkAgile HX7800 Series: lenovopress.com/lp0950

For certified nodes see:

- Lenovo ThinkAgile HX1001 Series: lenovopress.com/lp0887
- Lenovo ThinkAgile HX3001 Series: lenovopress.com/lp0888
- Lenovo ThinkAgile HX5501 Series: lenovopress.com/lp0889
- Lenovo ThinkAgile HX7501 Series: lenovopress.com/lp0890
- Lenovo ThinkAgile HX7800 Series: lenovopress.com/lp0951

For appliances and certified nodes with Intel Xeon Scalable processor Gen 2 see

https://lenovopress.com/lp1521-thinkagile-hx1320-hx1321-hx2320-hx2321-hx3320-hx3321-1u

For appliances and certified nodes with Intel Xeon Scalable processor Gen 3 see
https://lenovopress.com/lp1481-thinkagile-hx-1u-appliances-certified-nodes-whitley

The diagrams below show the Intel Xeon Scalable processor-based ThinkAgile HX Series appliances and certified nodes.

Figure 43. HX1320 or HX1321

Figure 44. HX2320-E

Figure 45. HX2720-E

Figure 46. HX3320 or HX3321

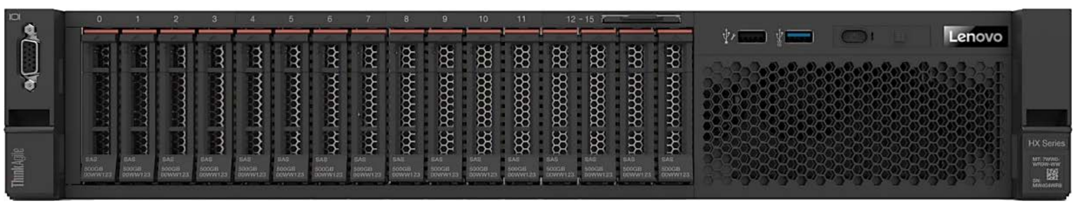


Figure 47. HX3520-G or HX3521-G

Figure 48. HX3720 or HX3721

Figure 49. HX1520-R, HX1521-R, HX5520, HX5521, HX5520-C, or HX5521-C

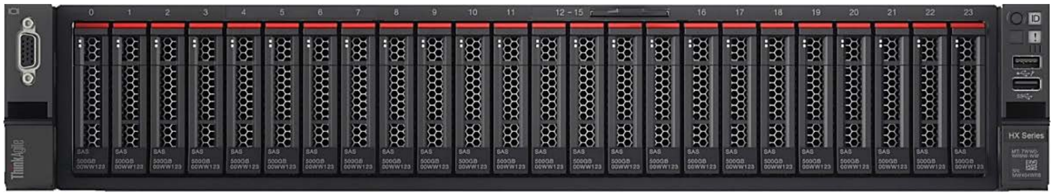


Figure 50. HX7520 or HX7521

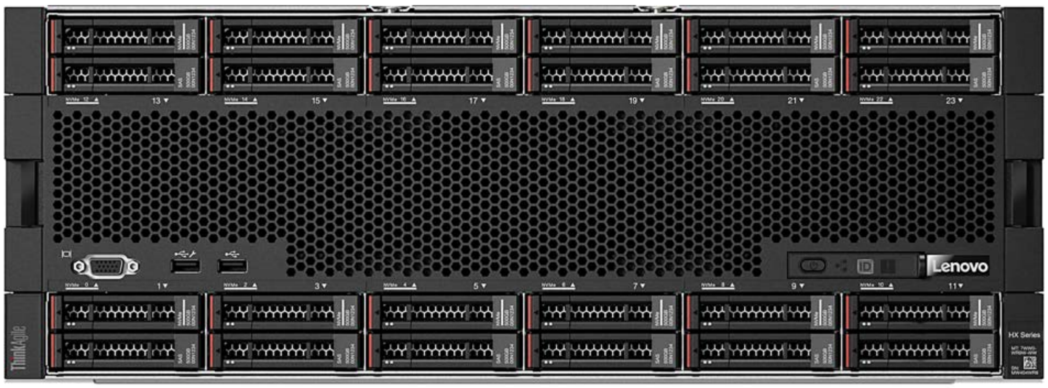


Figure 51. HX7820 or HX7821

For best recipes of supported firmware and software, please see: https://datacentersupport.lenovo.com/us/en/products/solutions-and-software/thinkagile-hx/hx3320/7x83/solutions/ht505413.

6.2 Hypervisor supported by ThinkAgile HX

The ThinkAgile HX Series appliances and certified nodes (generally) support the following hypervisors:

- Nutanix Acropolis Hypervisor based on KVM (AHV)
- VMware ESXi 6.7
- VMware ESXi 7.0

The HX1520-R, HX5520-C, HX7820, and all SAP HANA models support only the following hypervisor:

- Nutanix Acropolis Hypervisor based on KVM (AHV)

The HX Series appliances come standard with the hypervisor preloaded in the factory. This software is optional for the ThinkAgile HX Series certified nodes.

6.3 Deployment models

The OpenShift Container Platform can be implemented in development/test, staging, and production settings. Each node role has its own dedicated servers for performance and availability. However, in a non-production environment, a minimal environment can be provided to test applications before moving them to a staging or production environment.

For a production OpenShift deployment on bare metal, all of the core services such as the API servers, Kubernetes scheduler, etcd, etc., need to be highly available. The table below shows the recommended configuration for a production deployment with external enterprise storage.

Node type	Quantity	Node role
Bastion	1	Deployment of the environment, LOC-A Ansible playbooks, hardware management, etc.
Infrastructure	2	HAProxy, Keepalive, routing, logging, metrics.
Bootstrap	1	OpenShift bootstrap node. It can be a VM.
Control plane	3	OpenShift API, etcd, pod scheduler.
Compute/worker	2+	Runs the application containers.
Storage	1+	External 3rd Party Enterprise Storage as OpenShift platform's backend storage.

The table below shows the recommended configuration for a production deployment on bare metal with OpenShift Data Foundation (ODF).

Node type	Quantity	Node role
Bastion	1	Deployment of the environment, LOC-A Ansible playbooks, hardware management, etc.
Infrastructure	2	HAProxy, Keepalive, routing, logging, metrics.
Bootstrap	1	OpenShift bootstrap node. It can be a VM.
Control plane	3	OpenShift API, etcd, pod scheduler.
Compute/worker (enhanced node with ODF)	3+	Runs the application containers and ODF pods.

For production OpenShift deployment on bare metal environments, it is recommended to build an OpenShift platform with external storage supporting CSI interface, or to build an OpenShift platform with OpenShift Data Foundation (ODF).

Red Hat offers three kinds of OpenShift edge cluster deployment approaches in edge sites.

Cluster type	Node Quantity	Logical Node Type
Single-node edge cluster	1	Control plane, Worker node.
Remote worker	3+ (1+) + (2+)	3 Control plane, 1+ Remote Worker node, 2+ Local Worker nodes
3-nodes cluster	3	Control plane, Worker node.

For a production OpenShift deployment on ThinkAgile HX platform, all OpenShift nodes are installed in Nutanix VMs, and Nutanix storage can be used by applications running on OpenShift via Nutanix CSI.

Node type	Quantity	Node role
Infrastructure	2	HAProxy, Keepalive, routing, logging, metrics.
Control plane	3	OpenShift API, etcd, pod scheduler.
Compute/worker	2+	Runs the application containers.

6.4 Deployment Ready Solution

Lenovo works closely with software partners to provide high performance, scalable, and cost-effective IT solutions-Deployment Ready Solutions (DRS) to accelerate business advantage. With Red Hat, we provide a series of engineered, tested, and certified OpenShift Deployment Ready Solutions for customers to get fast time to value benefit.

Hardware configurations and Software license are all packaged in Deployment Ready Solutions.

We have 4 categories of OpenShift Deployment Ready Solutions：AI Edge, Datacenter Cluster, Minimum Cluster, and Single Node cluster.

- AI Edge - The DRS accelerates AI/ML workflows and the delivery of AI-powered intelligent applications. It’s a single node solution. It can be deployed from the edge of the network to on-site, virtualized, and private cloud deployments to public clouds. It is based on the SE350/SE360 V2, with GPUs, runs Red Hat OpenShift Platform Plus which includes OpenShift Container Platform (container/VM management), Advanced Cluster Management (multi-cloud/cluster management), Advanced Cluster Security (cluster/container security), Quay (global image registry) and OpenShift Data Foundations (container storage). The DRS can be exported or customized in the AI Edge webpage
- Datacenter Cluster - The DRS provides complete container orchestration needed to deploy and manage containerized applications. It’s a six-node cluster (3 control nodes and 3 worker nodes). It eases the burden of configuring, deploying, managing, and monitoring of the largest-scale deployments. It is based on the SR630 V2/SR630 V3, runs Red Hat OpenShift Platform Plus which includes OpenShift Container Platform (container/VM management), Advanced Cluster Management (multi-cloud/cluster management), Advanced Cluster Security (cluster/container security), Quay (global image registry) and OpenShift Data Foundations (container storage). The DRS can be exported or customized in the Datacenter Cluster webpage
- Minimum Cluster - The DRS is the smallest, fully functional OpenShift cluster offering high availability. It is a 3-node HA cluster configuration (each node is both a control node and a worker node) - HCI capable. This cluster is ideal for HCI, edge sites, or regional data centers that have more restricted space, and power/cooling requirements. It is based on the SR630 V2/SR630 V3, runs Red Hat OpenShift Platform Plus, which includes OpenShift Container Platform (container/VM management), Advanced Cluster Management (multi-cloud/cluster management), Advanced Cluster Security (cluster/container security), Quay (global image registry) and OpenShift Data Foundations (container storage). The DRS can be exported or customized in the Minimum Cluster webpage
- Single Node cluster – The DRS deploys all OpenShift services and end-user applications to a single physical or virtual node. This is ideal for edge use cases that have limited space, low bandwidth, or

have intermittent connectivity between remote and core/central sites. It is based on the SE450/SE455 V3 and runs Red Hat OpenShift Platform Plus which includes OpenShift Container Platform (container/VM management), Advanced Cluster Management (multi-cloud/cluster management), Advanced Cluster Security (cluster/container security), Quay (global image registry) and OpenShift Data Foundations (container storage). The DRS can be exported or customized in the Single Node Cluster webpage

Some configuration samples leveraging DRS can be found in section 6.15

More information about Red Hat OpenShift Deployment Ready Solutions, see:

https://lenovopress.lenovo.com/lp1671-red-hat-openshift-deployment-ready-solutions-on-lenovo-servers

More information about Red Hat OpenShift Platform Plus, see:

https://www.redhat.com/en/technologies/cloud-computing/openshift/platform-plus

6.5 Auto-Deployment by Lenovo Open Cloud Automation

Lenovo Open Cloud Automation (LOC-A) is a Lenovo software solution for simplifying Cloud and Data Center Infrastructure Deployment & Management. LOC-A leverages open software stacks to support rapid deployment, optimization, and management of cloud infrastructures for bare-metal servers, containers and VMs.

Figure 52 shows high-level scope for Lenovo Open Cloud Automation.

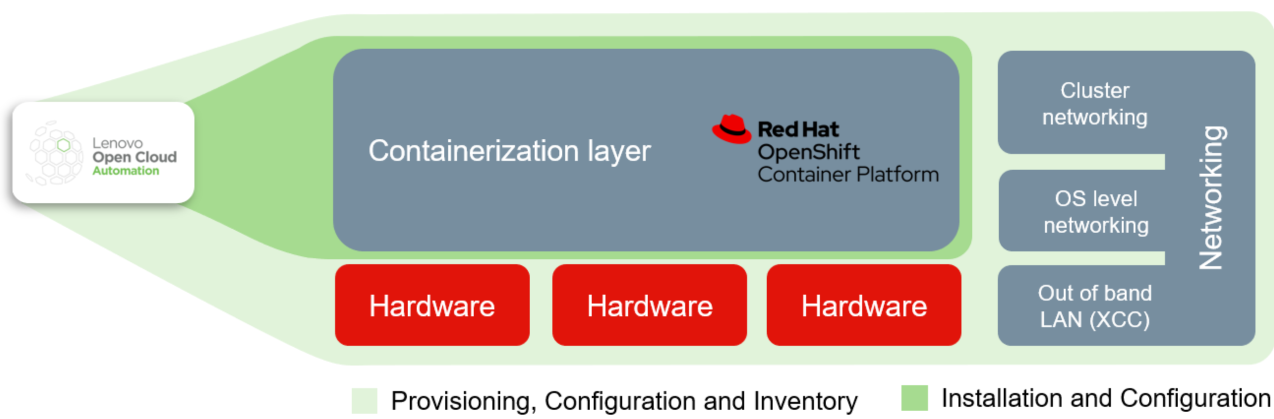


Figure 52. High-level scope of Lenovo Open Cloud Automation

LOC-A provides Red Hat OpenShift Container Platform one-click auto-deployment from scratch by following pre-defined HW configurations and configurable deployment workflows. It supports container cloud infrastructure deployment at edge and data center environments for Enterprises and Cloud Providers. Lenovo Open Cloud Automation has been developed specifically for solving all of the challenges at a diversity of locations and cases.

Figure 53 shows stack components in LOC-A for OpenShift.

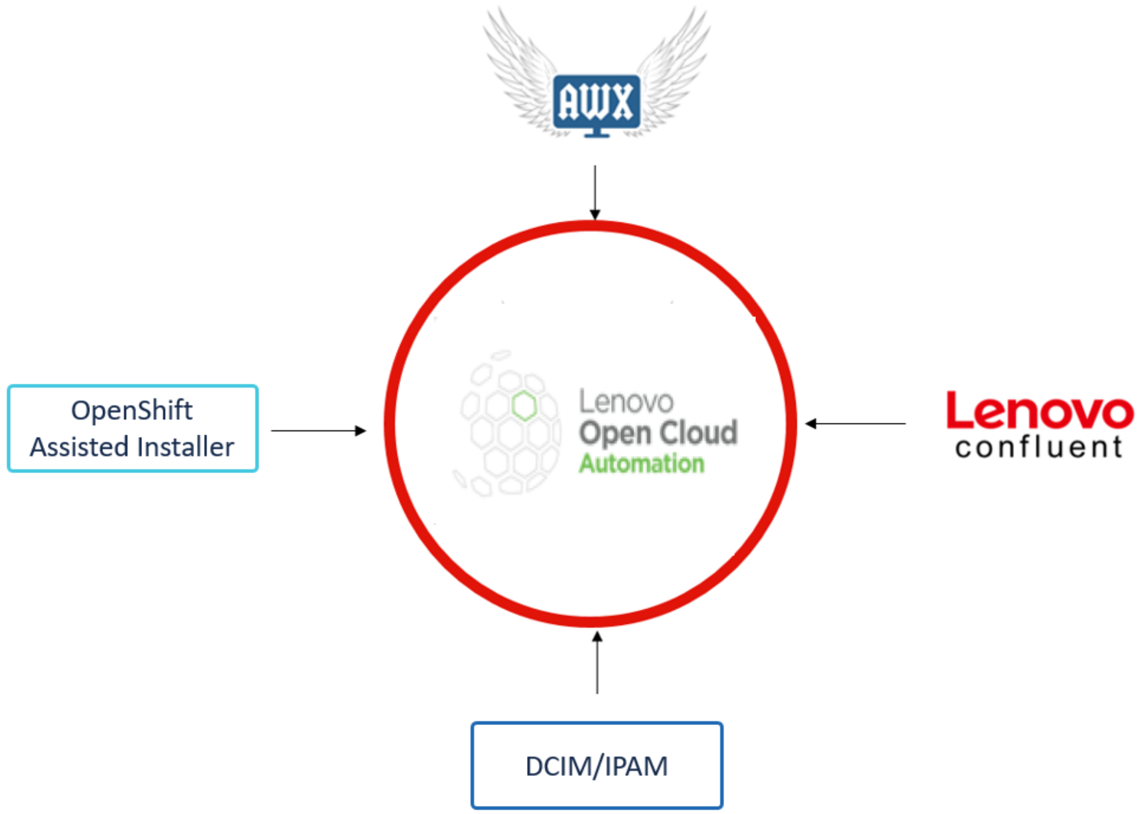


Figure 53. Components of Lenovo Open Cloud-Automation for OpenShift

LOC-A uses ansible and the AWX tool to perform auto-deployment of multiple platforms. Platform inventory/resources are stored in a DCIM. Lenovo Confluent is a discovery engine to find resources on site, and it also supports OS deployment. OpenShift Assisted Installer is a managed service to install OpenShift clusters.

Figure 54 shows a brief workflow when LOC-A deploys OpenShift.

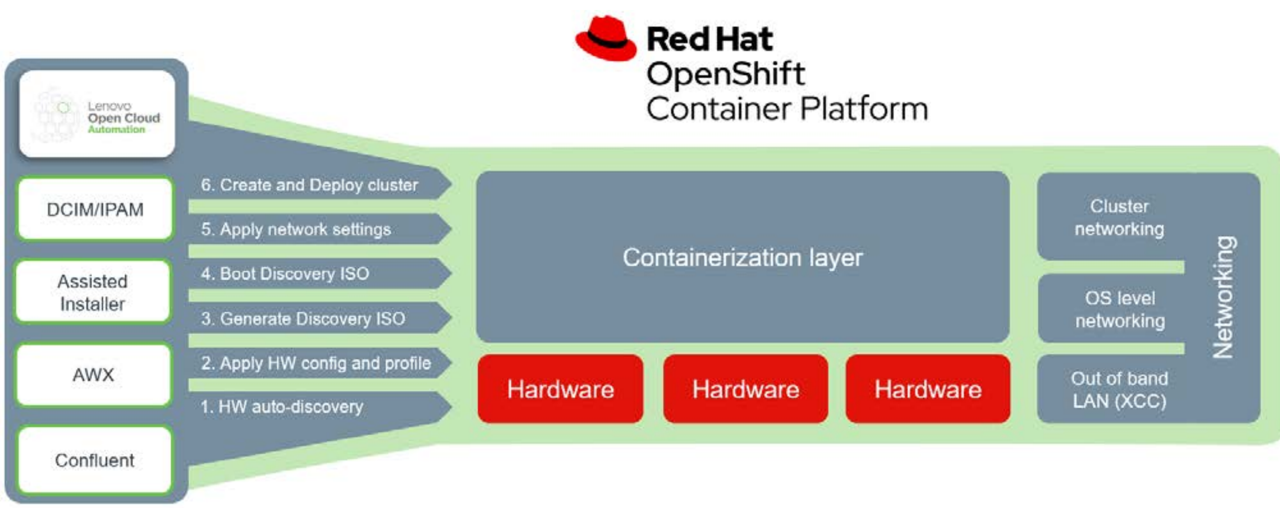


Figure 54. OpenShift Deployed by Lenovo Open Cloud - Automation

LOC-A can be installed on a bastion node/cloud. It discovers hardware automatically, generates a discovery ISO image, install the image, configure network, and deploys OpenShift platform on top of bare-metal HW. More information about licenses, RHOCP versions and configurations is available in Lenovo Open Cloud Automation document: [Lenovo Open Cloud Automation for Red Hat OpenShift datasheet]

Note: Current LOC-A is published in an OVA image. OpenShift deployment on ThinkAgile HX platform hasn't been supported by LOC-A yet.

6.6 Compute/worker node

The OpenShift Container Platform can be implemented on a small footprint of x86 servers/VMs clustered together and scaled as the user workloads grow.

The right choice of servers/VMs and the corresponding configuration for CPUs, memory, and networking will depend upon various factors, including but not limited to:

- Number of concurrent OpenShift users to be supported
- Type and mix of application workloads, which will drive the system resource requirements
- System growth projection
- Development or production use
- Fault-tolerance and availability requirements for applications
- Application performance expectations
- Implementation of hybrid-cloud model, which drives the requirements for on-premises infrastructure

More guidance on sizing and other considerations is available for OpenShift clusters in OpenShift documentation: access.redhat.com/documentation/en-us/openshift_container_platform/4.14/html/scalability_and_performance

Lenovo does not recommend server/VMs configuration specifics for CPU, memory, storage, etc. because it is heavily dependent on the sizing considerations previously listed. However, Lenovo has verified configurations on ThinkSystem/ThinkEdge/ThinkAgile HX servers using both Intel Xeon Scalable Processors gen 2, and gen 3 CPUs. The user is requested to perform a proper sizing assessment for their particular needs and choose the right configurations to meet those requirements.

6.7 Persistent storage for containerized workloads

There are two types of storage consumed by containerized applications – ephemeral (non-persistent) and persistent. As the names suggest, non-persistent storage is created and destroyed along with the container and is only used by applications during their lifetime as a container. Hence, non-persistent storage is used for temporary data. When implementing the OpenShift Container Platform, local disk space on the application nodes can be configured and used for the non-persistent storage volumes.

Persistent storage, on the other hand, is used for data that needs to be persisted across container instantiations. An example is a 2 or 3-tier application that has separate containers for the web and business logic tier and the database tier. The web and business logic tier can be scaled out using multiple containers for high availability. The database that is used in the database tier requires persistent storage that is not destroyed.

OpenShift uses a persistent volume framework that operates on two concepts – persistent storage and persistent volume claim. Persistent storage is the physical storage volumes that are created and managed by the OpenShift cluster administrator. When an application container requires persistent storage, it would create a persistent volume claim (PVC). The PVC is a unique pointer/handle to a persistent volume on the physical storage, except that PVC is not bound to a physical volume. When a container makes a PVC request, OpenShift would allocate the physical disk and bind it to the PVC. When the container image is destroyed, the volume bound to the PVC is not destroyed unless you explicitly destroy that volume. In addition, during the lifecycle of the container if it relocates to another physical server in the cluster, the PVC binding will still be maintained. After the container image is destroyed, the PVC is released, but the persisted storage volume is not deleted. The specific persistent storage policy for the volume will determine when the volume gets deleted.

For more detailed conceptual information on persistent volumes see: access.redhat.com/documentation/en-us/openshift_container_platform/4.14/html/storage

A variety of persistent storage options are available for OpenShift, choices including CSI (Container Storage Interface), ODF (Red Hat OpenShift Data Foundation), NFS, Cinder, iSCSI, Azure File, AWS elastic block storage (EBS), and others. OpenShift deployed on ThinkAgile HX platform can use Nutanix storage via Nutanix CSI. For a complete list of these choices and the corresponding requirements, see the link below: access.redhat.com/documentation/en-us/openshift_container_platform/4.14/html/storage/understanding-persistent-storage#persistent-storage-overview_understanding-persistent-storage

6.7.1 Container Storage Interface (CSI)

The Container Storage Interface (CSI) is a standard for exposing arbitrary block and file storage systems to containerized workloads on Container Orchestration Systems like OpenShift. Using CSI, third-party storage providers can write and deploy plugins exposing new storage systems in OpenShift platform. OpenShift Container Platform can leverage CSI to consume storage from storage backends as persistent storage.

OpenShift platform supports CSI, such as Nutanix storage, Cinder, etc. More CSI drivers can be found in: kubernetes-csi.github.io/docs/drivers.

For more information on Container Storage Interface, see: access.redhat.com/documentation/en-us/openshift_container_platform/4.14/html/storage/using-container-storage-interface-csi#persistent-storage-using-csi

Figure 55 provides a high-level overview about the Container Storage Interface components running in pods in the OpenShift Container Platform cluster. CSI driver needs its own external controllers' deployment and DaemonSet with the driver and CSI registrar.

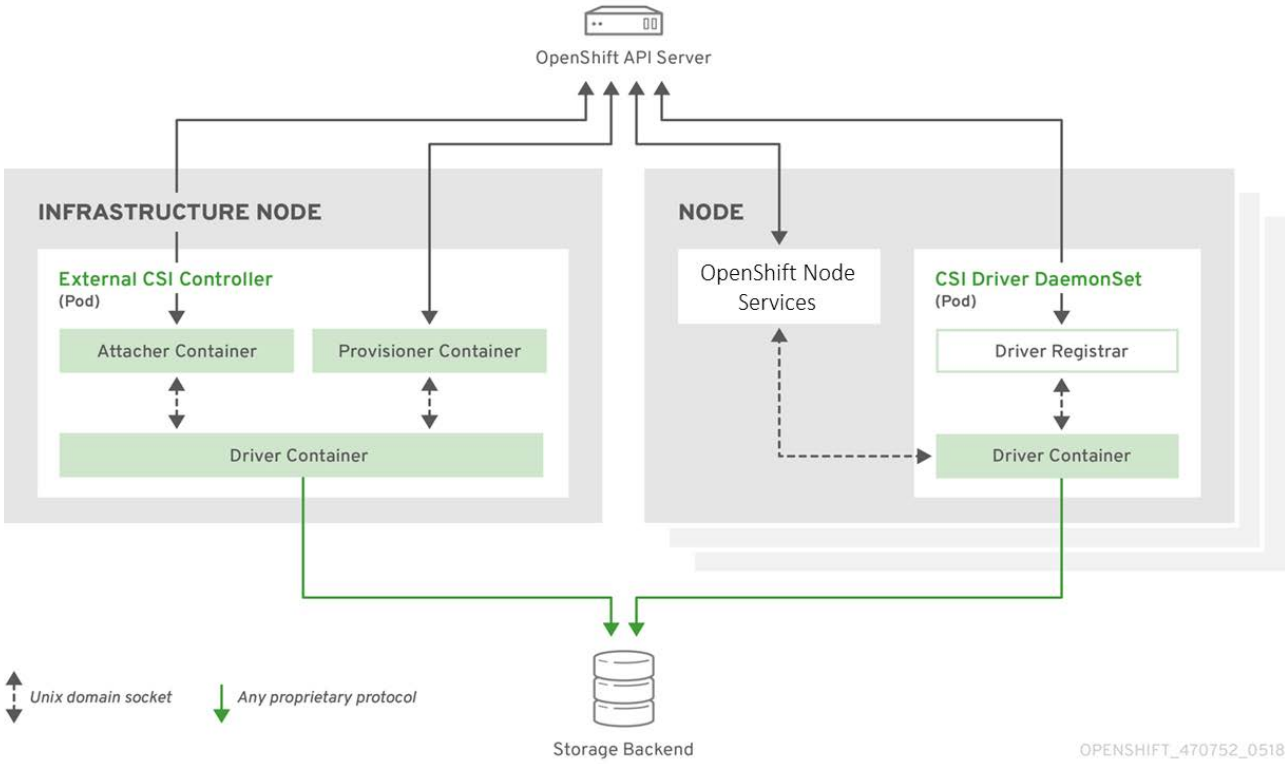


Figure 55. Container Storage Interface Architecture

6.7.2 ThinkSystem DM series

Lenovo ThinkSystem DM Series (Hybrid Flash Array) are unified, hybrid, scalable storage systems. Lenovo ThinkSystem DM Series (All-Flash Array) are all-flash storage systems, available as either unified or SAN. Lenovo ThinkSystem DM Series are designed to provide high performance, simplicity, capacity, security, and high availability for small to large enterprises. Powered by the ONTAP software, Lenovo ThinkSystem DM Series deliver enterprise-class storage management capabilities with a wide choice of host connectivity options, flexible drive configurations, and enhanced data management features.

Figure 56. ThinkSystem DM series

For more information on ThinkSystem DM series, see: [Unified-storage]

Trident is an open source tool used as storage provisioner for Kubernetes based orchestrator. Trident has been purpose-built to address the persistent storage needs of containerized applications. It leverages industry-standard interfaces like the Container Storage Interface (CSI) to ensure seamless integration with OpenShift platform. When deployed in OpenShift clusters, Trident operates as pods and delivers dynamic storage orchestration services for your OpenShift workloads. This empowers your containerized applications to effortlessly access and utilize persistent storage resources managed by ONTAP.

Trident simplifies the dynamic storage orchestration and expedites storage provisioning for your clusters. In OpenShift clusters using the DM Series in conjunction with Trident, you can quickly establish a containerized storage environment that can be easily expanded upon.

Trident installation offers two distinct approaches:

Generic Installation: This method represents the simplest way to install Trident. It is ideal for OpenShift clusters with unrestricted network access, allowing for seamless image retrieval from external sources.

Customized Installation: Alternatively, you have the option to tailor your installation to specific needs. In scenarios where network access is limited (such as air-gapped environments), you can configure Trident to fetch its images from a private repository.

For more information on Trident, see: https://github.com/NetApp/trident

6.7.3 Red Hat OpenShift Data Foundation (ODF)

Red Hat OpenShift Data Foundation is used as the persistent storage backend in this Reference Architecture as it simplifies the overall OpenShift architecture and consolidates the compute and storage components in the same x86 servers. ODF was previously known as OpenShift Container Storage (OCS).

Red Hat OpenShift Data Foundation is an open source distributed, scalable, and high-performance file based storage system. It is used widely for many types of applications. Red Hat OpenShift Data Foundation provides volume plug-ins into OpenShift to support the persistent storage for containers.

Red Hat OpenShift Data Foundation can be implemented for the OpenShift platform in converged mode and external mode.

In the converged mode, ODF is running within the OpenShift cluster

- ODF can be deployed on standard compute/worker nodes, alongside the applications. OCP and ODF subscription will be needed in this case.
- ODF can be deployed on infra nodes, where only an ODF subscription will be needed.

In the external mode, customers can easily set up and operate a stand-alone storage cluster that simultaneously supports block, file, and object access by one or more OpenShift clusters. This feature also enables centralized OpenShift storage administration.

For more information on Red Hat OpenShift Data Foundation, see:
access.redhat.com/documentation/en-us/red_hat_openshift_data_foundation/4.14

Figure 57 gives an overview of persistent storage in an OpenShift Data Foundation cluster.

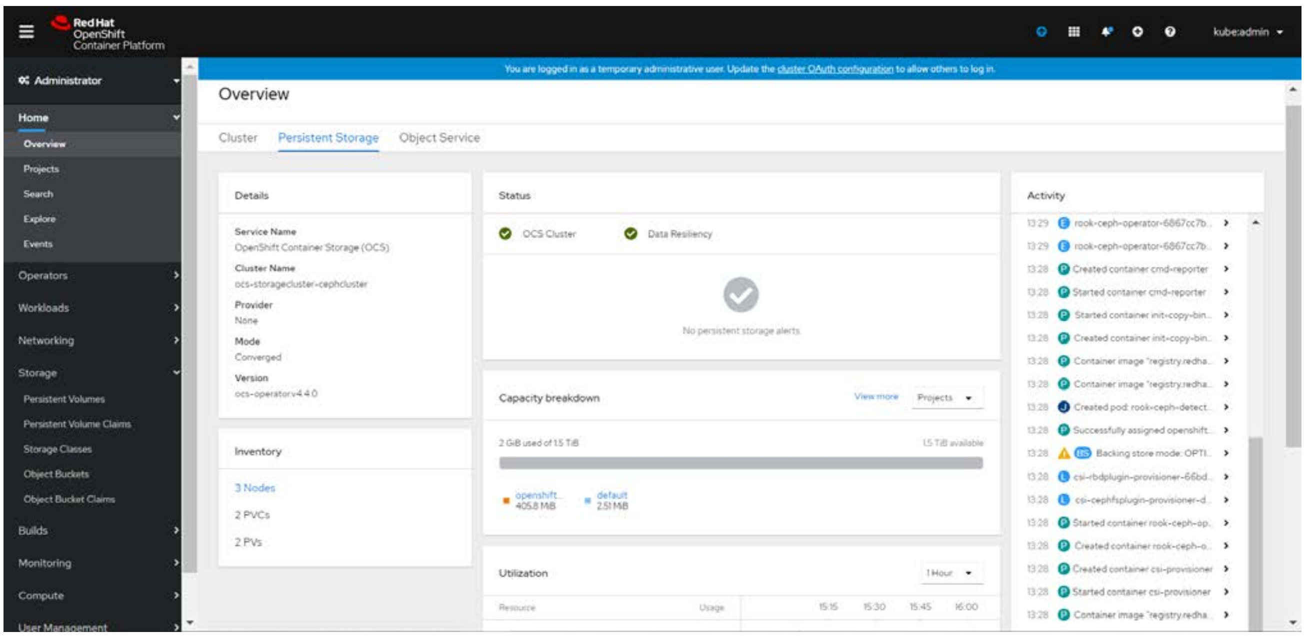


Figure 57. Persistent storage in an OpenShift Data Foundation cluster

Figure 58 gives an overview of object storage service in an OpenShift Data Foundation cluster.

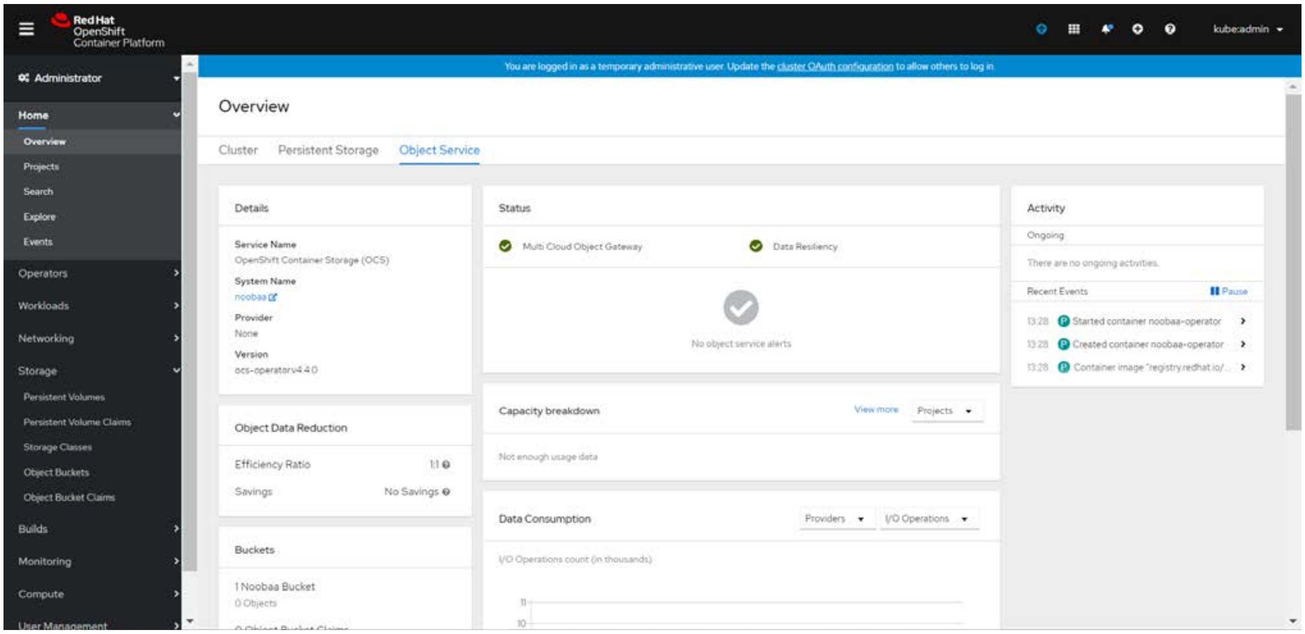


Figure 58. Object storage service in an OpenShift Data Foundation cluster

Note: Subscription method for ODF has changed. Entitlements are based on the number of cores that the worker nodes have just like OpenShift. So, running storage stacked or on dedicated nodes doesn't change the number of subscriptions. Having dedicated nodes simplifies scaling and management.

Note: Red Hat will not provide individual ODF since January 1st, 2023. We can get ODF from OpenShift Platform Plus subscription. Please see section 6.17 for detailed information about subscriptions. For individual ODF license, we can get it from IBM.

6.8 Networking for OpenShift deployment on bare metal

For OpenShift Container Platform deployment on bare metal with ThinkSystem servers, 25Gbps networking is recommended as the choice for all cluster-wide communication for the core OpenShift services, virtual network implementation for container workloads, storage services access, as well as all east-west traffic across the container workloads. In addition, the north-south traffic between the OpenShift environment and uplink into the customer (or campus) network can be implemented over the 25Gbps network. 10GbE switches can be used in test/dev environments as alternative switches to 25GbE switches.

There are three logical networks defined in this RA:

- **External**: The external network is used for the OpenShift Control Plane API, the OpenShift web interface, and exposed applications (services and routes).
- **Internal**: This is the primary, non-routable network used for cluster management and inter-node communication. The same network acts as the layer for server provisioning using PXE and HTTP. Domain Name Servers (DNS) and Dynamic Host Configuration Protocol (DHCP) services also reside on this network to provide the functionality necessary for the deployment process and the cluster to work. Communication with the Internet is provided by NAT configured on the *bastion* node.
- **Out-of-band/IPMI**: This is a secured and isolated network used for switch and server hardware management, such as access to the IMM module and SoL (Serial-over-LAN).

Figure 59 shows the Red Hat OpenShift cluster with Lenovo ThinkSystem servers and the recommended network architecture.

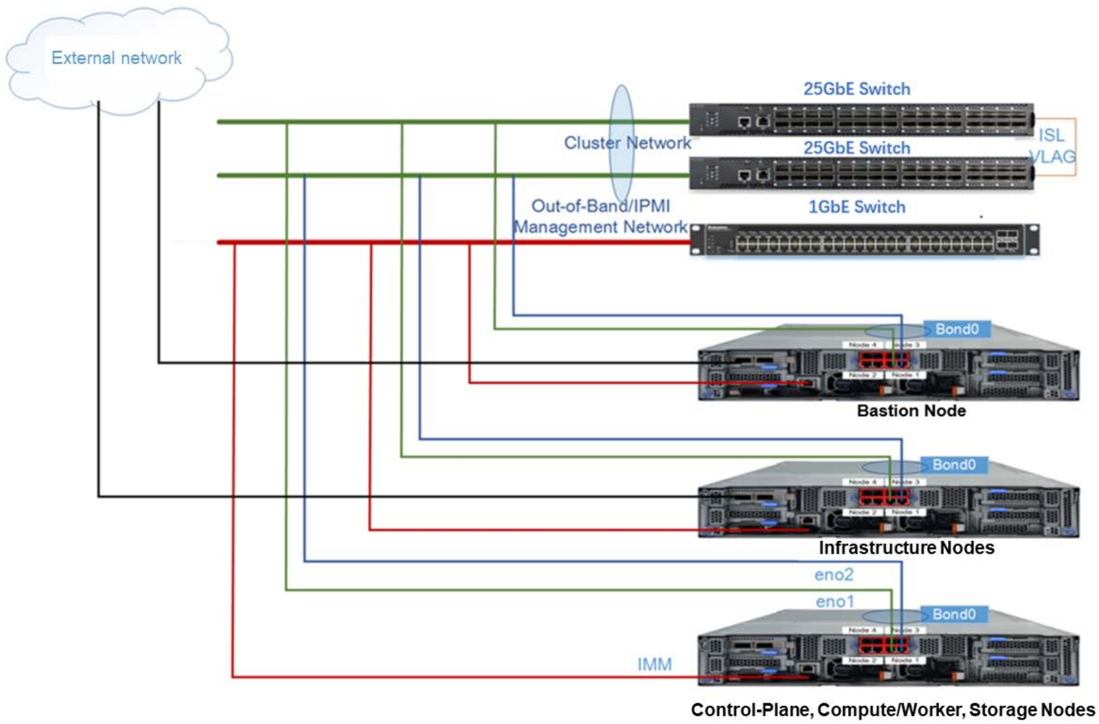


Figure 59. OpenShift Network Connectivity

All OpenShift nodes are connected via the internal network, where they can communicate with each other. Furthermore, OpenShift SDN creates its own network for OpenShift pod-to-pod communication. Because of the multi-tenant plugin, OpenShift SDN pods can communicate to each other only if they share the same project namespace.

6.9 Networking for OpenShift deployment on ThinkAgile HX

For OpenShift Container Platform deployment on Lenovo ThinkAgile HX platform, 3 logical networks are recommended as the choice for all cluster-wide communication for management services, storage services, the core OpenShift services, application container workloads, as well as all east-west traffic and north-south traffic across the container workloads.

Three logical networks:
• **Internal Network**: The Internal network is used for OpenShift internal workload.
• **Management Network**: This is the primary, non-routable network used for cluster management and inter-node communication. The same network acts as the layer for server provisioning using PXE and HTTP. Domain Name Servers (DNS) and Dynamic Host Configuration Protocol (DHCP) services also reside on this network to provide the functionality necessary for the deployment process and the cluster to work. Communication with the Internet can be provided by NAT in this network.
• **Storage Network**: This is network used for Nutanix storage traffic.

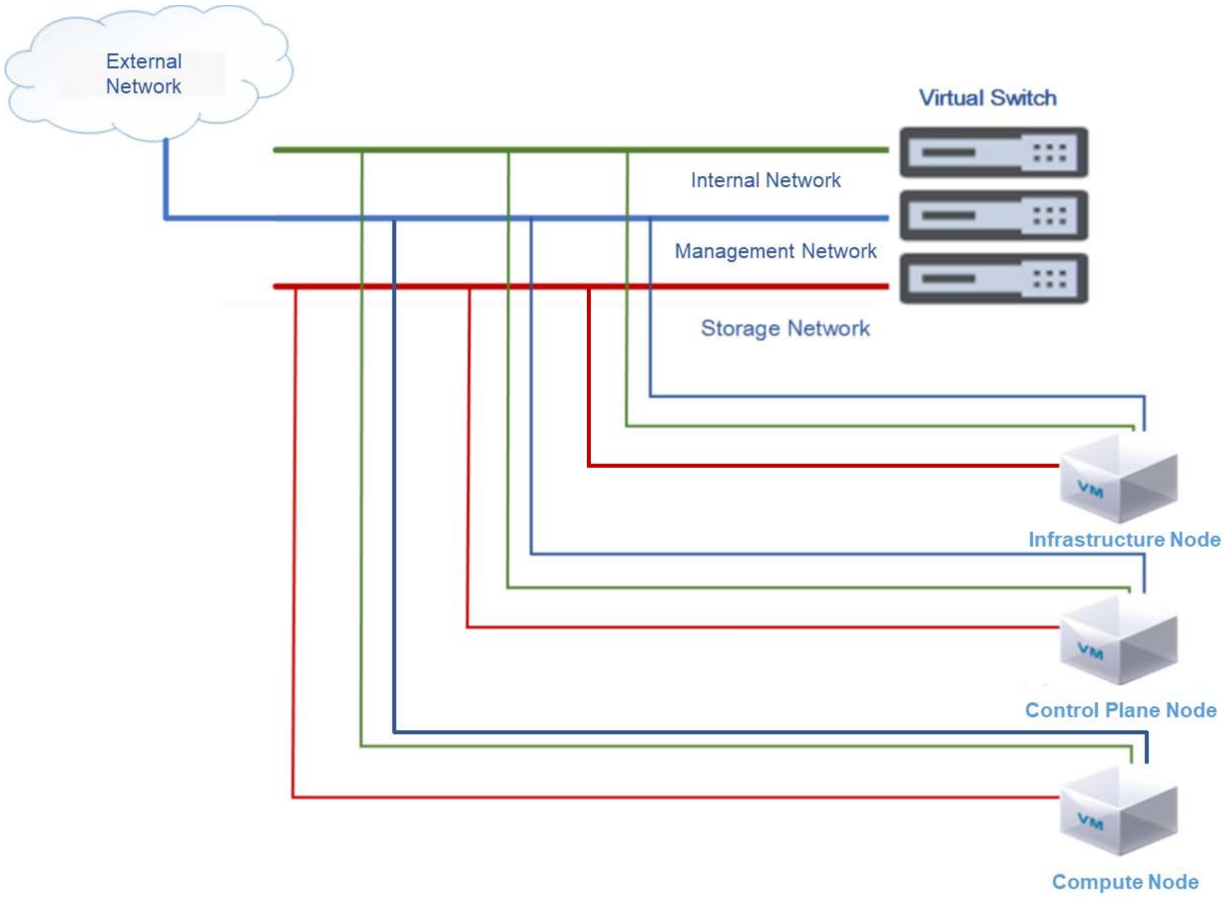


Figure 60. OpenShift Network Connectivity

6.10 Hardware management network

For out-of-band management of the servers and initial cluster deployment over the network from the *bastion* node, use the 1Gbps management fabric via 1 GbE switch. The Lenovo ThinkSystem/ThinkEdge/ThinkAgile HXservers have a dedicated 1GbE network port for the IMM interface. The IMM enables remote-management capabilities for the servers, access to the server’s remote console for troubleshooting, and running the IPMI commands via the embedded baseboard management controller (BMC) module.

6.11 Network redundancy

The Lenovo ThinkSystem/ThinkEdge/ThinkAgile HX platform uses the 10 GbE/25 GbE network as the primary fabric for inter-node communication. Two switches are used to provide redundant data layer communication and deliver maximum availability.

Figure 61 shows the redundant network architecture.

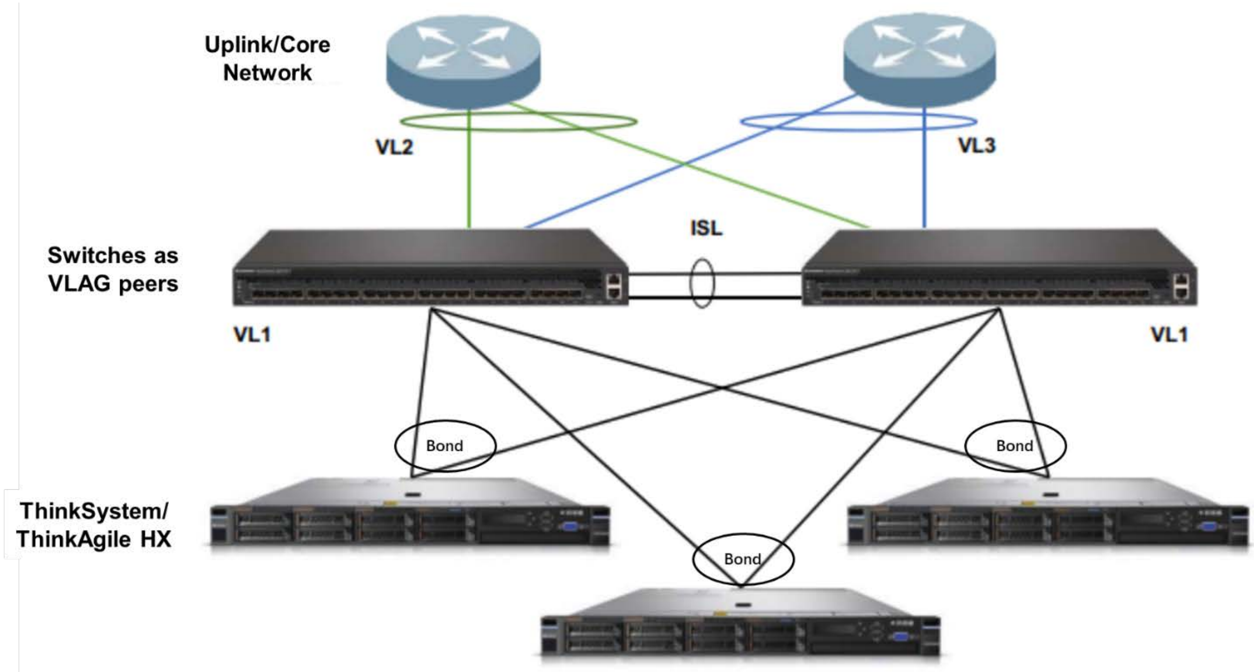


Figure 61. Redundant network architecture

Virtual Link Aggregation Group (VLAG) is a feature that allows a pair of switches to work as a single virtual switch. Each of the cluster nodes has a link to each VLAG peer switch for redundancy. This provides improved high availability (HA) for the nodes using the link aggregation control protocol (LACP) for aggregated bandwidth capacity. Connection to the uplink core network is facilitated by the VLAG peers, which present a logical switch to the uplink network, enabling connectivity with all links active and without a hard requirement for spanning-tree protocol (STP). The link between the two VLAG peers is an inter-switch link (ISL) and provides excellent support of east-west cluster traffic the nodes. The VLAG presents a flexible basis for interconnecting to the uplink/core network, ensures the active usage of all available links, and provides high availability in case of a switch failure or a required maintenance outage.

6.12 Networking switch configurations

This section contains the configurations for network switches. The typical configuration can use 10 or 25 GbE networking. The Intel Select configuration must use 25 GbE networking. The higher end switches (100GbE) are also supported. The management network can use 1 GbE switch.

Following table shows the Switches configurations:

Role	Description
Management network	1 GbE switch
Data network	10/25/100 GbE switch

6.13 Edge computing

Red Hat offers 3 kinds of OpenShift edge cluster deployment approaches for different edge locations and different edge categories. Edge site allows users to extend their services from core data center to remote locations. Edge site is a place to gather, process, and perform on data. Edge can support reliability, low-latency, and high-performance link with computing environments close to customers and devices. Red Hat OpenShift for edge solution allows edge sites deployed in regional edge and far edge at low-cost, even in a constricted environment.

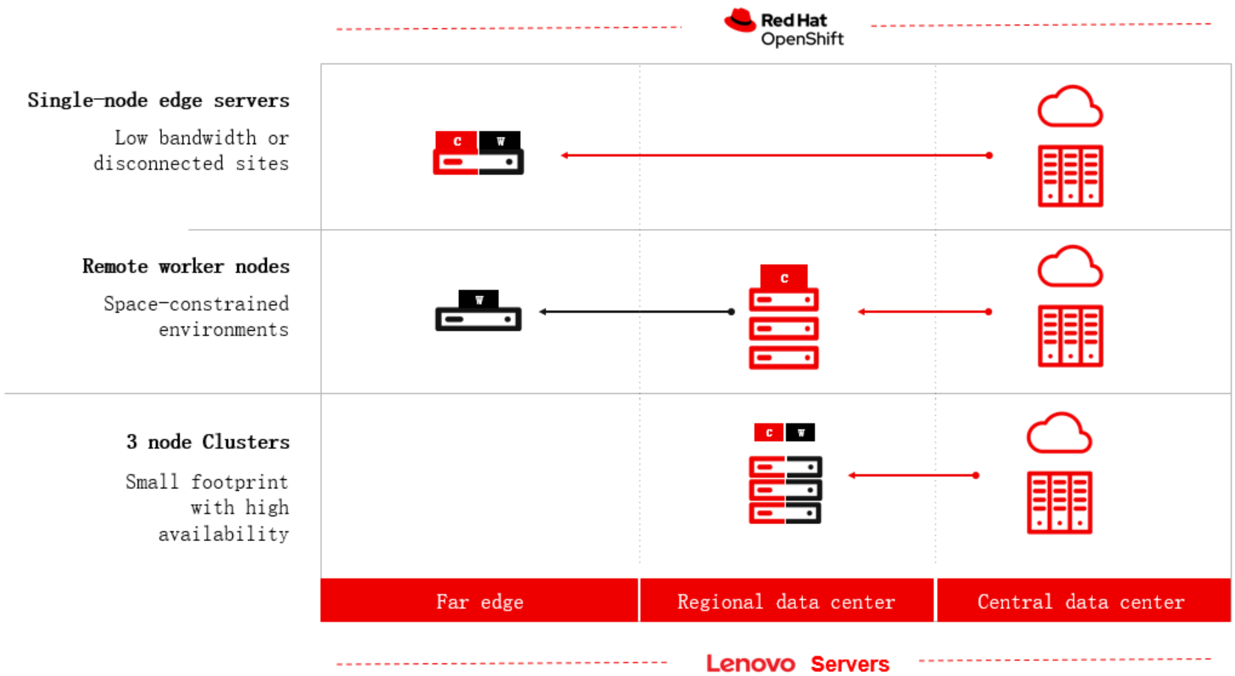


Figure 62. Red Hat OpenShift Edge Cluster solution on Lenovo Servers

For detailed server configuration information for edge sites, please see section 6.15.2.

6.14 Systems management

In addition to in-band management via IPMI, the Lenovo XClarity Administrator software provides centralized resource management that reduces complexity, speeds up response, and enhances the availability of Lenovo® server systems and solutions.

The Lenovo XClarity Administrator provides agent-free hardware management for Lenovo's ThinkSystem® rack servers, System x® rack servers, and Flex System™ compute nodes and components, including the Chassis Management Module (CMM) and Flex System I/O modules. Figure 63 shows the Lenovo XClarity administrator interface, in which Flex System components and rack servers are managed and are seen on the dashboard. Lenovo XClarity Administrator is a virtual appliance that is quickly imported into a virtualized environment server configuration.

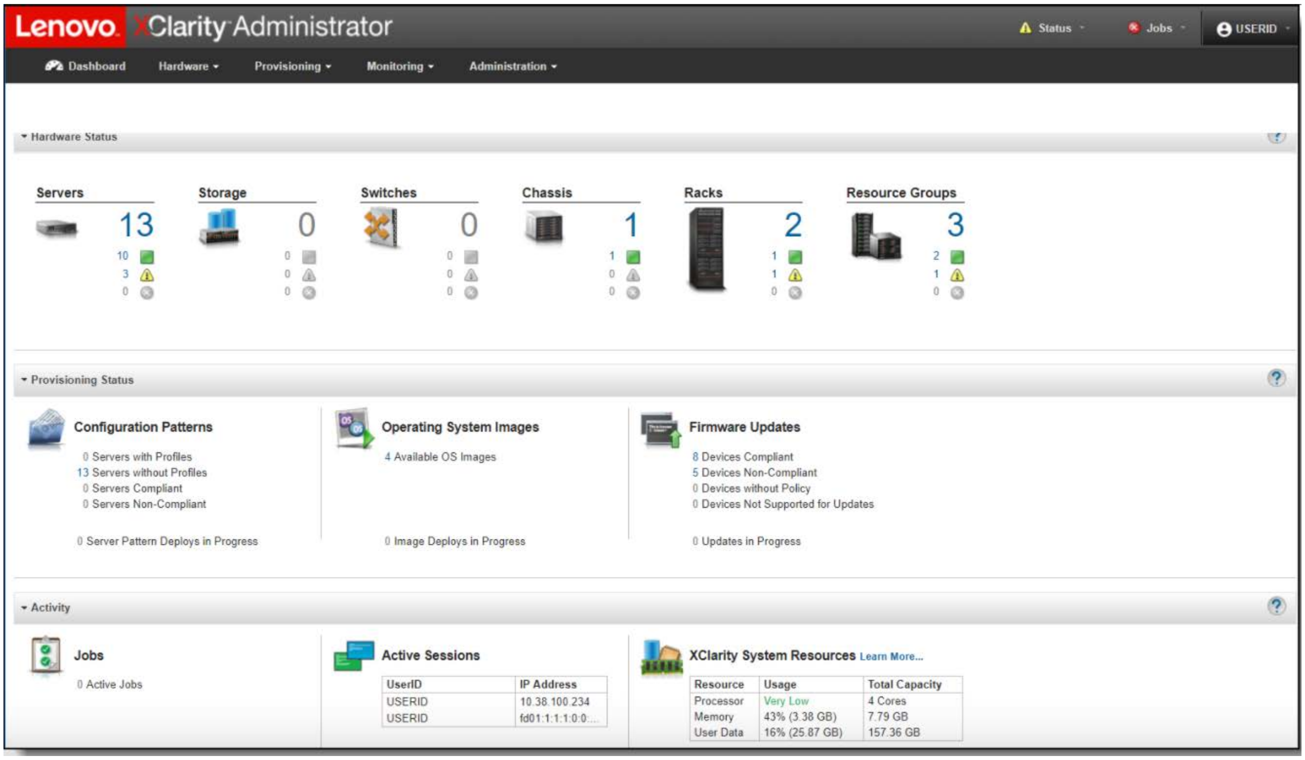


Figure 63. Lenovo XClarity Administrator Dashboard

For more information, see: [Lenovo XClarity Administrator Product Guide]

6.15 Deployment examples with ThinkSystem server

This section describes six example configurations, Three typical and enhanced configurations, and Three edge cluster configurations:

- Compact OpenShift cluster configuration
- Converged OpenShift cluster configuration for
- Typical OpenShift cluster configuration for data center

- Three-node OpenShift cluster configuration for edge
- Three controller nodes and multiple remote worker nodes for edge
- Single node OpenShift cluster for edge

We can configure them from scratch, we can also leverage [OpenShift Deployment Ready solution] to create configurations.

6.15.1 Typical and enhanced OpenShift configurations

The Compact OpenShift configuration uses three nodes, three switches:

- Three Compact nodes (Control plane, Compute/worker, OpenShift Data Foundation)

- 2 25GbE switches for traffic load network
- 1 1GbE switch for management network

We can leverage Minimum Cluster in OpenShift Deployment Ready solution to create a Compact OpenShift cluster with ThinkSystem SR630 V2 servers：

- Minimum Cluster in OpenShift Deployment Ready solution. The configurations can be customized.
- 2 25GbE switches for traffic load network
- 1 1GbE switch for management network

The converged OpenShift configuration with OpenShift Data Foundation (ODF) in converged mode uses 7+ nodes, 1 bootstrap, 2 load balancer, and 3 switches:

- 1 Bastion node
- 2 Infrastructure nodes (Optional. User can use other commercial load balancers, such as F5/NGINX/Avi networks/Fortinet/etc)
- 1 Bootstrap node (Bootstrap node is a temporary node that can be removed after deployment)
- 3 Control plane nodes
- 3+ Converged Compute/worker nodes (Compute/worker, OpenShift Data Foundation)
- 2 25GbE switches for traffic load network
- 1 1GbE switch for management network

We can also leverage DataCenter Cluster in OpenShift Deployment Ready solution to create a converged OpenShift cluster with ThinkSystem SR630 V2 servers：

- 1 Bastion node
- 2 Infrastructure nodes (Optional. User can use other commercial load balancers, such as F5/NGINX/Avi networks/Fortinet/etc)
- 1 Bootstrap node (Bootstrap node is a temporary node that can be removed after deployment)
- DataCenter Cluster in OpenShift Deployment Ready solution. The configurations can be customized. More Converged Compute/worker nodes can be added via Customize entry on DataCenter Cluster .
- 2 25GbE switches for traffic load network
- 1 1GbE switch for management network

The typical OpenShift configuration uses 10+ nodes, 1 bootstrap, 2 load balancer, 3 switches, and external storage as follows:

- 1 Bastion node
- 2 Infrastructure nodes (Optional. User can use other commercial load balancers, such as F5/NGINX/Avi networks/Fortinet/etc)
- 1 Bootstrap node (Bootstrap node is a temporary node that can be removed after deployment)
- 3 Control plane nodes
- 2+ Compute/worker nodes
- 3+ ODF node in external mode/external 3rd Party Enterprise Storage as OpenShift platform's backend storage.
- 2 25GbE switch for traffic load network
- 1 1GbE switch for management network

This configuration represents a production level OpenShift implementation that meets high-availability, redundancy, and scale requirements for enterprises. Additional Application nodes can be added to increase the available compute and storage capacity.

Table 4 provides the hardware configuration summary using Lenovo ThinkSystem SR630/SR650 V2 servers.

Table 4. Node Hardware Configuration for OpenShift Deployment

OpenShift Node Role	ThinkSystem server configuration
Bastion Node Control plane Node Bootstrap Node	2x Intel Xeon Gold 6326 16C 185W 2.9GHz Processor 192GB memory (12x 16 GB) 2x ThinkSystem M.2 5300 480GB SATA 6Gbps Non-Hot Swap SSD 1x ThinkSystem M.2 SATA/NVMe 2-Bay Enablement Kit 1x ThinkSystem 4350-8i SAS/SATA 12Gb HBA 4x ThinkSystem 2.5" S4520 3.84TB Read Intensive SATA 6Gb HS SSD 1x ThinkSystem Mellanox ConnectX-6 Lx 10/25GbE SFP28 2-Port OCP Ethernet Adapter
Compact node Converged Compute/Worker node	2x Intel Xeon Platinum 8362 32C 265W 2.8GHz Processor 512GB memory (12x 32 GB) 2x ThinkSystem M.2 5300 480GB SATA 6Gbps Non-Hot Swap SSD 1x ThinkSystem M.2 SATA/NVMe 2-Bay Enablement Kit 1x ThinkSystem 4350-8i SAS/SATA 12Gb HBA 4x ThinkSystem 2.5" S4520 3.84TB Read Intensive SATA 6Gb HS SSD 1x ThinkSystem Mellanox ConnectX-6 Lx 10/25GbE SFP28 2-Port OCP Ethernet Adapter
Storage (ODF) node	2x Intel Xeon Gold 6326 16C 185W 2.9GHz Processor 192GB memory (12x 32 GB) 2x ThinkSystem M.2 5300 480GB SATA 6Gbps Non-Hot Swap SSD 1x ThinkSystem M.2 SATA/NVMe 2-Bay Enablement Kit 1x ThinkSystem 4350-16i SAS/SATA 12Gb HBA 10x ThinkSystem 2.5" S4520 3.84TB Read Intensive SATA 6Gb HS SSD 1x ThinkSystem Mellanox ConnectX-6 Lx 10/25GbE SFP28 2-Port OCP Ethernet Adapter

The typical server configuration for the Bastion, Control plane and Compute/worker nodes is the same. This allows the role for a server to be easily changed. The Compact node/converged node is an HCI type of node with OpenShift compute and storage workload running on top of it.

We can also select similar configurations with proper capabilities that meet requirements from Lenovo ThinkSystem SR630 V3/ SR650 V3/ SR645 V3/ SR665 V3/ SR635 V3/SR655 V3 servers.

6.15.2 OpenShift configurations for edge computing

Three-node OpenShift cluster configuration for edge use cases uses 3 nodes, 2 switches:

- 3 nodes (Control plane, Remote worker)
- 1 25GbE switch for traffic load network
- 1 1GbE switch for management network

We can leverage Minimum Cluster in OpenShift Deployment Ready solution to create a 3-node edge site with ThinkSystem SR630 V2 servers：

- Minimum Cluster in OpenShift Deployment Ready solution. The configurations can be customized.
- 1 25GbE switches for traffic load network
- 1 1GbE switch for management network

Three controller nodes and multiple remote worker nodes for edge use cases uses 3 nodes and 2 switches for controller nodes, 1+ nodes for remote worker nodes:

- 3 nodes (Control plane)
- 1 25GbE switch for traffic load network
- 1 1GbE switch for management network
- 1+ nodes (Remote worker)

Single node OpenShift cluster for edge uses 1 node:

- 1 node (Control plane, Remote worker)

We can also leverage Single Node or AI Edge in OpenShift Deployment Ready solution to create a single-node edge site for general purpose or AI service with ThinkEdge SE450 server or ThinkEdge SE350 server：

- Single Node or AI Edge in OpenShift Deployment Ready solution. The configurations can be customized.

Table 5 provides the hardware configuration summary using Lenovo ThinkEdge SE350 servers. Lenovo ThinkEdge SE450 and ThinkSystem SR630 are also 2 options for create edge computing sites.

Table 5. Node Hardware Configuration for OpenShift Deployment at Edge Site

Node type samples in Edge cluster	**ThinkEdge server configuration samples**
Single-node edge server in Single-node cluster	**Normal condition:** 1x Intel Xeon D-2183IT 16C 100W 2.20 GHz Processor 128GB memory (4x 32 GB) 2x ThinkSystem M.2 480GB Industrial A600i SATA SED SSD 2x ThinkSystem SE350 M.2 SATA/NVMe 4-bay Data Drive Enablement Kit 8x ThinkSystem M.2 N600Si 1.92TB NVMe PCIe 3.0 x4 Non-Hot Swap SSD (Industrial) 1x ThinkSystem SE350 10GbE SFP+ 2-Port, 1GbE SFP 2-Port Switch, Wireless Capable 1x ThinkSystem M.2 WiFi Module **Extrem shock & vibration condition:** 1x Intel Xeon D-2183IT 16C 100W 2.20 GHz Processor 128GB memory (4x 32 GB) 2x ThinkSystem M.2 480GB Industrial A600i SATA SED SSD 1x On Board SATA Software RAID Mode 2x ThinkSystem SE350 M.2 SATA/NVMe 4-bay Data Drive Enablement Kit (Extreme Shock & Vibe) 8x ThinkSystem M.2 N600Si 1.92TB NVMe PCIe 3.0 x4 Non-Hot Swap SSD (Industrial) 1x ThinkSystem SE350 10GbE SFP+ 2-Port, 1GbE SFP 2-Port Switch, Wireless Capable (Extreme Shock & Vibe) 1x ThinkSystem M.2 WiFi Module
Remote worker in far edge site	1x Intel Xeon D-2163IT 12C 75W 2.10 GHz Processor 128GB memory (4x 32 GB) 2x ThinkSystem M.2 480GB Industrial A600i SATA SED SSD 1x On Board SATA Software RAID Mode 1x ThinkSystem SE350 M.2 SATA/NVMe 4-bay Data Drive Enablement Kit

	4x ThinkSystem M.2 N600Si 1.92TB NVMe PCIe 3.0 x4 Non-Hot Swap SSD (Industrial) 1x ThinkSystem SE350 10GbE SFP+ 2-Port, 1GbE SFP 2-Port Switch, Wireless Capable 1x ThinkSystem M.2 WiFi Module
Node in 3-nodes cluster	1x Intel Xeon D-2183IT 16C 100W 2.20 GHz Processor 128GB memory (4x 32 GB) 2x ThinkSystem M.2 480GB Industrial A600i SATA SED SSD 1x On Board SATA Software RAID Mode 2x ThinkSystem SE350 M.2 SATA/NVMe 4-bay Data Drive Enablement Kit 8x ThinkSystem M.2 N600Si 1.92TB NVMe PCIe 3.0 x4 Non-Hot Swap SSD (Industrial) 1x ThinkSystem SE350 10GbE SFP+ 2-Port, 10/100/1GbE RJ45 2-Port Intel i350

6.16 Deployment examples with ThinkAgile HX server

This section describes 3 Nutanix ThinkAgile HX example configurations:

- Small size Nutanix cluster configuration for OpenShift deployment
- Medium size Nutanix cluster configuration for OpenShift deployment
- Large size Nutanix cluster configuration for OpenShift deployment

Table 6 provides the hardware configuration summary using Lenovo ThinkAgile HX servers.

Table 6. Hardware Configuration for OpenShift Deployment on ThinkAgile HX server

Cluster type	**ThinkAgile HX server configuration sample**
Small size cluster (Sample: 3x HX3320)	2x Intel Xeon Platinum 8276 28C 165W 2.2GHz Processor 24x ThinkSystem 32GB TruDDR4 2933MHz (2Rx4 1.2V) RDIMM 1x ThinkSystem 430-16i SAS/SATA 12Gb HBA 8x ThinkSystem 2.5" PM1645a 800GB Mainstream SAS 12Gb Hot Swap SSD 2x ThinkSystem M.2 5300 480GB SATA 6Gbps Non-Hot Swap SSD 1x Mellanox ConnectX-4 Lx 10/25GbE SFP28 2-port PCIe Ethernet Adapter
Medium size cluster (Sample: 5x HX5530)	2x Intel Xeon Platinum 8352S 32C 205W 2.2GHz Processor 32x ThinkSystem 32GB TruDDR4 3200 MHz (2Rx4 1.2V) RDIMM 1x ThinkSystem 440-16i SAS/SATA PCIe Gen4 12Gb HBA 12x ThinkSystem 3.5" PM1645a 1.6TB Mainstream SAS 12Gb Hot Swap SSD 2x ThinkSystem M.2 5300 480GB SATA 6Gbps Non-Hot Swap SSD 1x ThinkSystem Mellanox ConnectX-6 Lx 10/25GbE SFP28 2-Port OCP Ethernet Adapter
Large size cluster (Sample: 7x HX7820)	4x Intel Xeon Platinum 8276 28C 165W 2.2GHz Processor 48x ThinkSystem 64GB TruDDR4 2933MHz (2Rx4 1.2V) RDIMM 2x ThinkSystem 430-16i SAS/SATA 12Gb HBA 24x ThinkSystem 2.5" PM1645a 1.6TB Mainstream SAS 12Gb Hot Swap SSD 2x ThinkSystem M.2 5300 480GB SATA 6Gbps Non-Hot Swap SSD 2x Mellanox ConnectX-4 Lx 10/25GbE SFP28 2-port PCIe Ethernet Adapter

Single/Multiple OpenShift clusters can be deployed on each type of Nutanix clusters on ThinkAgile HX platform. Applications/services on OpenShift can use Nutanix storages via Nutanix CSI.

Other types of ThinkAgile HX servers can be selected according to varies of cluster requirements.

For more information about OpenShift deployment on Nutanix cluster, see:

https://docs.openshift.com/container-platform/installing/installing_nutanix/

6.17 Software and subscription

For this example, the following software is needed:

- **OpenShift Container Platform**, which adds developer and operation-centric tools to enable rapid application development, easy deployment, scaling, and long-term lifecycle maintenance for small and large teams and applications
- **OpenShift Data Foundation**, which uses Red Hat OpenShift Container Platform as a base, and can provide Block storage, Object storage, and File storage for different workload types.
- **Lenovo XClarity Administrator** for management of the operating systems on bare-metal servers

Additionally, the following OpenShift Container Platform components play a key role in the solution:

- **Kubernetes** to orchestrate and manage containerized applications
- **Etcd***, which is a key-value store for the OpenShift Container Platform cluster
- **OpenShift SDN** to provide software-defined networking (SDN)-specific functions in the OpenShift Container Platform environment
- **Ingress Controller** for routing, load-balancing, and virtual IP management

Note: There is still the expectation placed on the **customer or implementer** that an outside-the-cluster L4 load balancer (F5, NGINX, Avi networks, Fortinet, etc.) is provided for balancing both the API and compute traffic. Those wildcards and API DNS records point to these LB VIPs.

Table 7 lists the software versions used for this example deployment

Table 7. Software versions

Component	**Version**
Red Hat Enterprise Linux	8.8
Red Hat CoreOS	4.14
OpenShift Container Platform	4.14
OpenShift Data Foundation (ODF)	4.14

We can subscribe self-managed OpenShift software features from 3 kinds of offerings:

- **Red Hat OpenShift Kubernetes Engine**, it includes Red Hat OpenShift Kubernetes Runtime(engine), Red Hat Enterprise Linux and Red Hat Enterprise Linux CoreOS, Red Hat OpenShift Virtualization, Red Hat OpenShift administrator console, Red Hat Application Streams.
- **Red Hat OpenShift Container Platform**, it includes Red Hat OpenShift Kubernetes Engine, Red Hat JBoss Web Server, Red Hat's single sign-on (SSO) technology, Log management, Red Hat CodeReady Workspaces, Red Hat build of Quarkus, Web console, Red Hat OpenShift Pipelines, Red Hat OpenShift GitOps, Red Hat OpenShift Serverless, Red Hat OpenShift Service Mesh, Red Hat Insights for OpenShift, IBM Cloud Satellite.
- **Red Hat OpenShift Platform Plus,** it includes Red Hat OpenShift Container Platform, Red Hat Advanced Cluster Management for Kubernetes, Red Hat Advanced Cluster Security for Kubernetes, Red Hat Quay, Red Hat OpenShift Data Foundation Essentials.

Figure 64 shows services and components running on self-managed OpenShift platform with 3 kinds of subscription offerings:

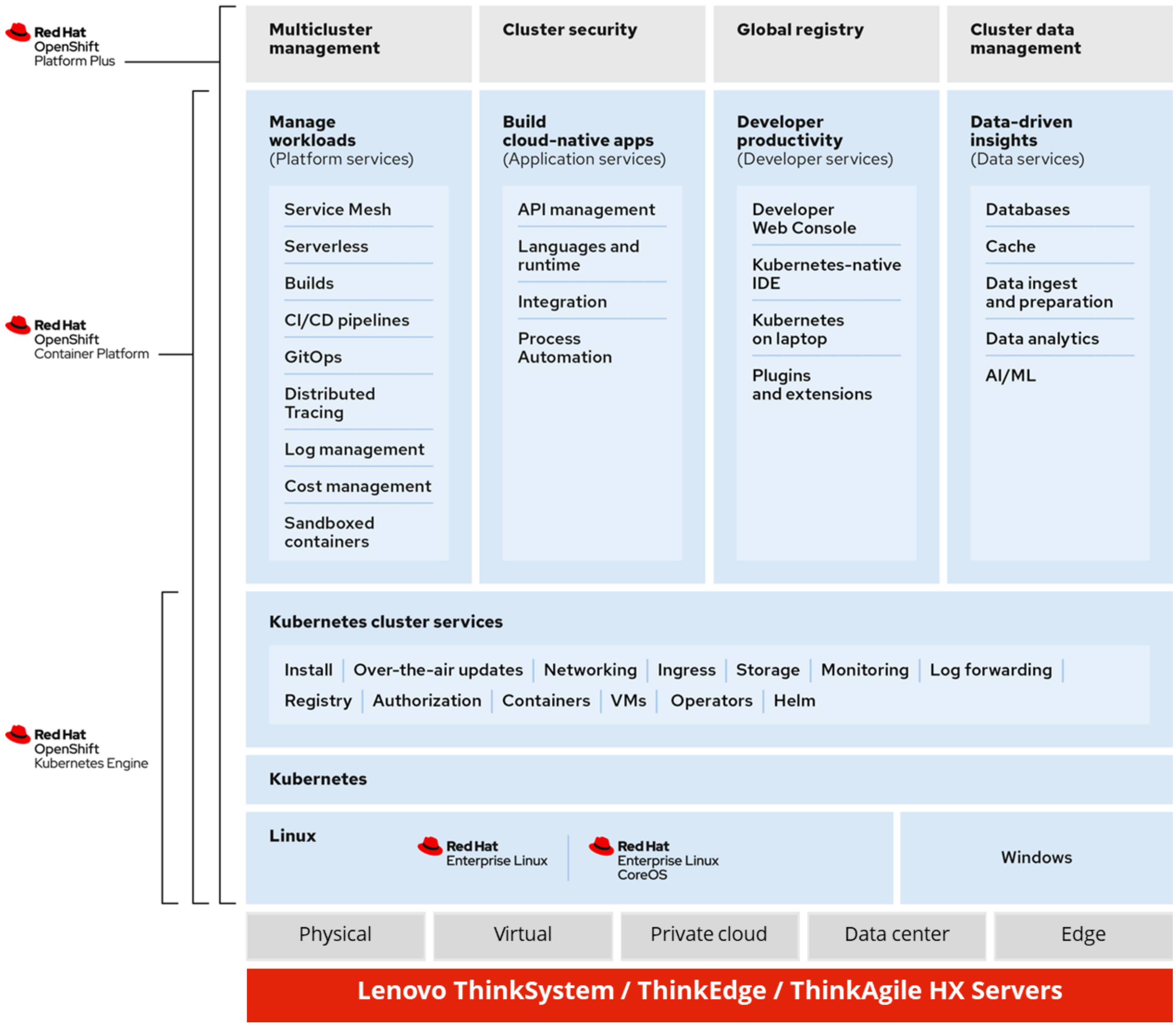


Figure 64. Services and components running on self-managed OpenShift platform with 3 kinds of subscription offerings

More information about Red Hat OpenShift subscriptions, see:

https://www.redhat.com/en/resources/self-managed-openshift-sizing-subscription-guide

Note: Red Hat will not provide individual ODF since January 1st, 2023. We can get ODF from OpenShift Platform Plus subscription. For individual ODF offering, we can get it from IBM.

6.18 Deployment validation

The deployment should be validated before it is used. The OpenShift Container Platform web console provides two perspectives: the Administrator perspective and the Developer perspective. At verification step, log on to the OpenShift Container Platform web console, and display the OpenShift container Administrator perspective.

Figure 65 shows an example.

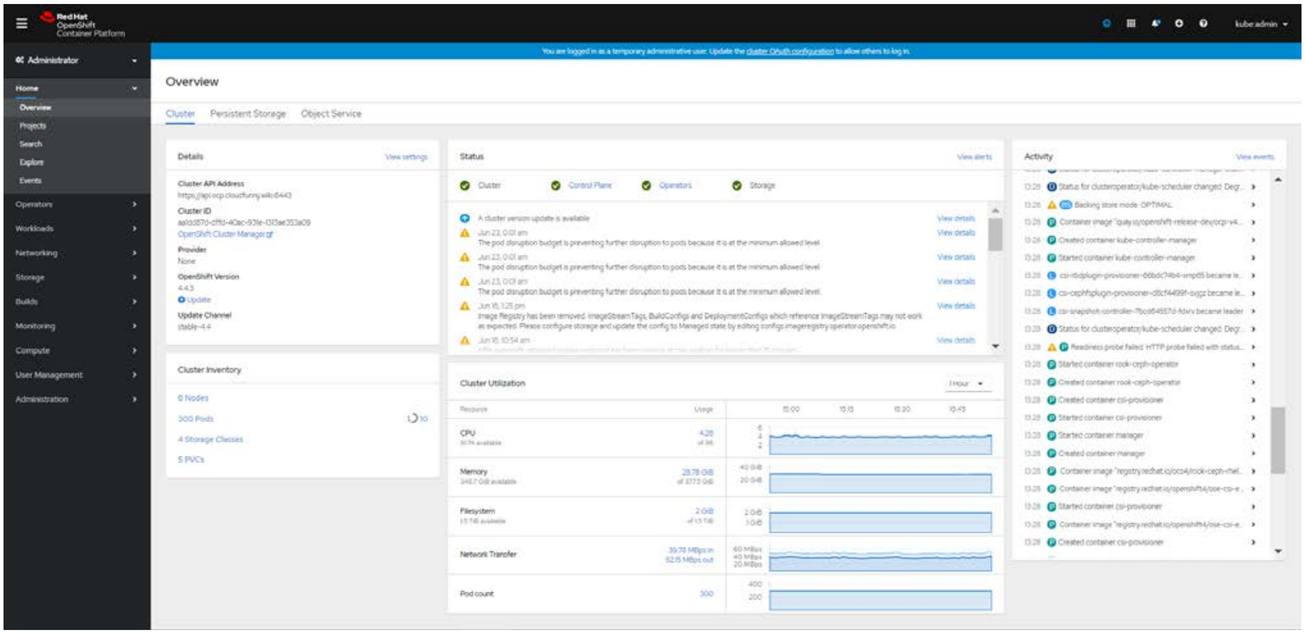


Figure 65. Administrator perspective of OpenShift Container Platform

Figure 66 shows Developer perspective.

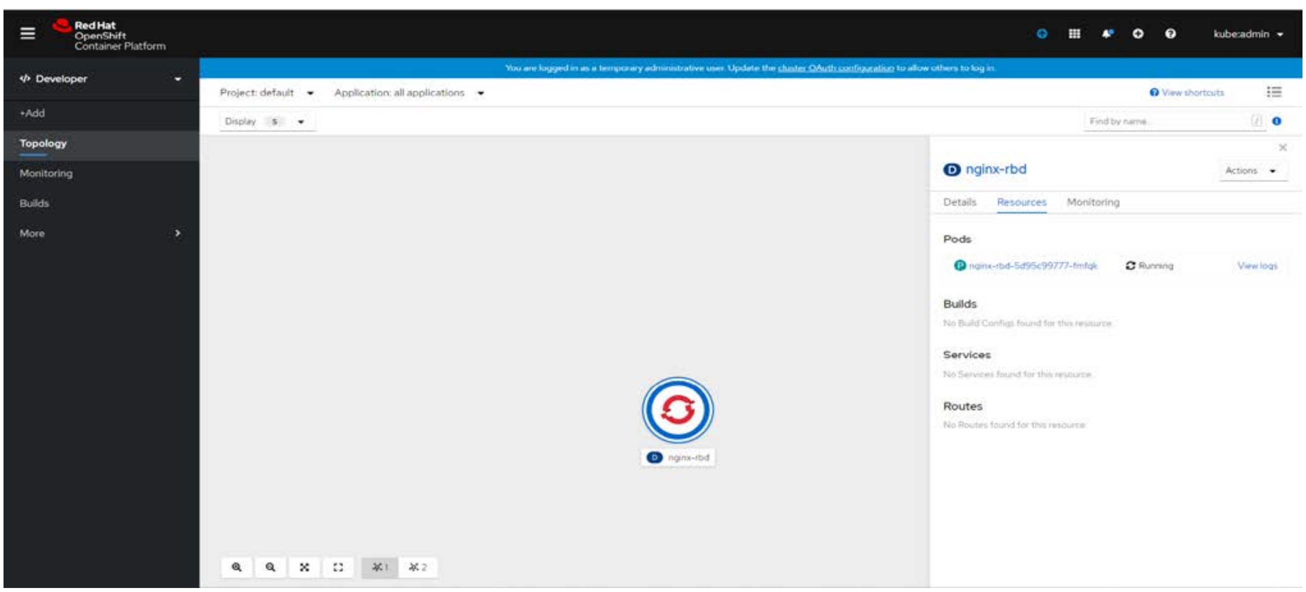


Figure 66. Developer perspective of OpenShift Container Platform

Other important validation steps include:

- Backing the OCP image registry with ODF. This provides validation for the ODF and completes a post install task.
- Also important to add are the Prometheus Metrics collected and having them be backed by ODF, as by default they store to emptydir{}, which is ephemeral storage.

Figure 67 shows a sample of backing OCP image registry with ODF

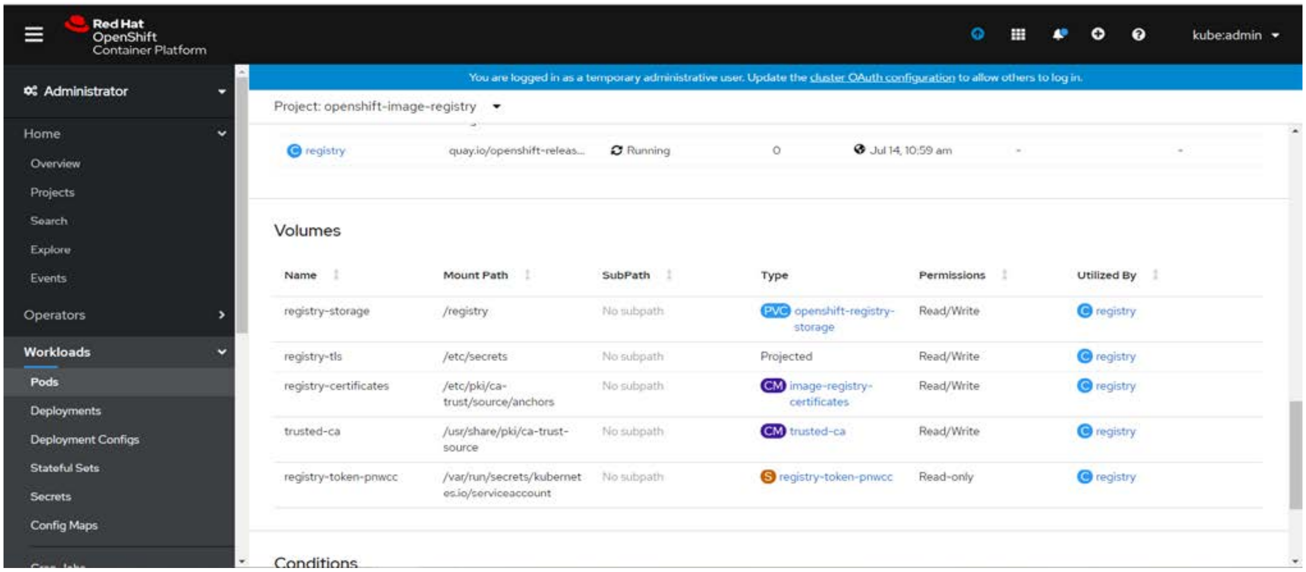


Figure 67. Backing OCP image registry with ODF

6.19 Multi-cluster management

Red Hat OpenShift extends the capabilities of native Kubernetes from data center to edge sites. Red Hat OpenShift clusters are widespread in different regions. Customers want the ability to manage their infrastructure across multi-cloud environments. Multi-cluster topologies and management introduce new challenges and potentials. Multi-cluster topologies can be useful to provide unified access to the infrastructure, and to orchestrate applications across various locations. Multi-cluster management can leverage multi-cluster topologies to bring the possibility of migrating an application from cluster to cluster, transparently and quickly. Workloads shifting can be practical when dealing with cluster disasters or infrastructure upgrading, scaling, or placement optimization.

Red Hat Advanced Cluster Management (RHACM) for Kubernetes has been designed to manage Kubernetes clusters, including Red Hat OpenShift Container Platform, in the cloud and on-premise seamlessly.

Figure 68 shows RHACM components in an infrastructure where multiple OpenShift clusters are managed by RHACM and deployed on Lenovo ThinkSystem/ThinkEdge/ThinkAgile HX platform:

- *Hub cluster.* It defines the central controller that runs in a Red Hat Advanced Cluster Management for Kubernetes cluster.
- *Managed cluster.* It defines additional clusters that are managed by the hub cluster.
- *Cluster lifecycle.* It defines the process of creating, importing, managing, and destroying Kubernetes clusters across various infrastructure cloud providers, private clouds, and on-premises data centers.
- *Application lifecycle.* It defines the processes that are used to manage application resources on your managed clusters.
- *Governance.* It enables admin/super users to define policies that either enforce security compliance, or inform you of changes that violate the configured compliance requirements for your environment.

- *Observability.* It collects and reports the status and health of the OpenShift Container Platform version 4.x, or later, managed clusters to the hub cluster.

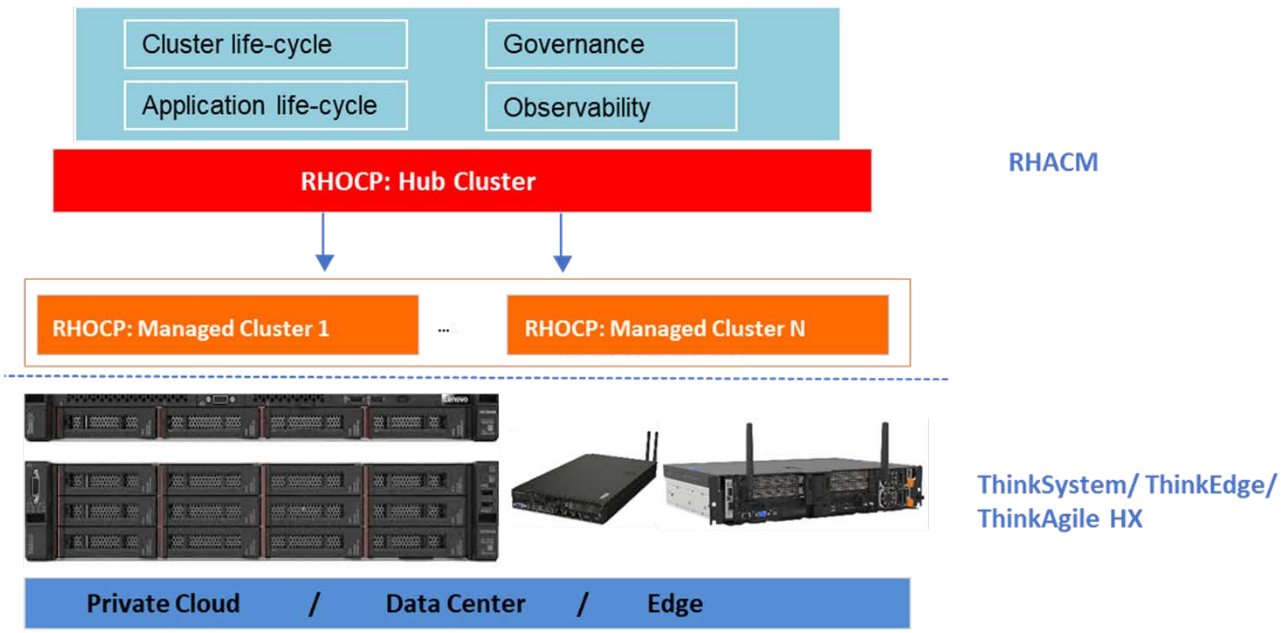


Figure 68. Multiple OpenShift clusters managed by RHACM on ThinkSystem/ThinkEdge/ThinkAgile HX

In order to use RHACM a "hub cluster" is required. From the hub cluster, you can access the console and product components, as well as the Red Hat Advanced Cluster Management APIs. You can also use the console to search resources across clusters and view your topology.

Hub clusters govern "managed clusters". The connection between the two is completed by using the klusterlet, which is the agent that is installed on the managed cluster. The managed cluster receives and applies requests from the hub cluster and enables it to service cluster lifecycle, application lifecycle, governance, and observability on the managed cluster.

RHACM simplifies not only cluster lifecycles but also application lifecycles too. It enhances governance and observability of your managed clusters, regardless of where they are running. There are a dozen (and counting) supported platforms today and the list continues to grow.

More information about RHACM and components, see:

https://access.redhat.com/documentation/en-us/red_hat_advanced_cluster_management_for_kubernetes/2.8/html/about/welcome-to-red-hat-advanced-cluster-management-for-kubernetes#multicluster-architecture

6.20 Virtualization on OpenShift cluster

New application development and deployment is shifting to containers. But organizations and enterprises already have large existing investment on applications running in VMs. Containers and VMs are coexisting to support a variety of services in different industries. For this hybrid environment, we can deploy container clusters in a virtualization environment, such as deploy OpenShift on Nutanix platform (ThinkAgile HX). We can also leverage OpenShift Virtualization to run and manage VMs on OpenShift cluster in a bare-metal environment.

OpenShift Virtualization is based on KubeVirt. KubeVirt supports running VMs within a container. It can manage both Linux VM and Windows VM. It can import and clone existing VMWare VM and Red Hat VM. It supports live migrating VMs between nodes.

Figure 69 shows Cloud-Native/Virtualization applications running on OpenShift cluster.

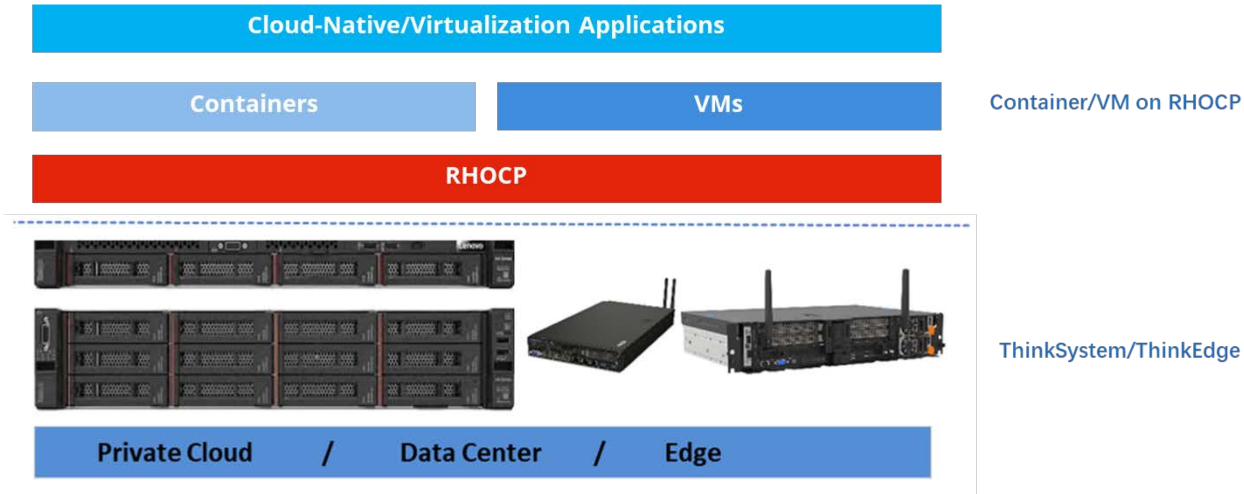


Figure 69. Cloud-Native/Virtualization applications managed by RHOCP on ThinkSystem/ThinkEdge

With OpenShift Virtualization, container and VM technologies can work together, supporting cutting edge and legacy applications, supporting cloud-native and virtualization applications, providing services for customers, all in one OpenShift platform. It delivers a cloud-native virtualization in OpenShift cluster with the advantage of simplicity and speed of container platform.

More information about OpenShift Virtualization and components, see:

https://docs.openshift.com/container-platform/virt/about-virt.html

6.21 OpenShift security

Red Hat OpenShift is a leading container application platform that provides robust security features to ensure the safety and integrity of the applications running on it. The platform offers multiple layers of security, including access control, container security, network security, encryption, and compliance management.

For authentication, OpenShift integrates with various identity and access management solutions, including LDAP, Active Directory, OAuth, etc, to enable secure user authentication and access control. For authorization, the platform provides role-based access control (RBAC) to enable users to manage access control policies efficiently. Users can also use security context constraints (SCCs) to control permissions for the pods in their cluster.

OpenShift includes multiple layers of container security to protect applications from potential security threats. The platform provides features such as image signing and verification, pod security policies, secure build process, and container image vulnerability scanning to ensure the security and integrity of containers.

OpenShift provides several encryption features to secure containerized applications, including secure communication, encrypted etcd data, and local disk encryption. The secure network communication has encrypted links between nodes, platform components, applications, stateful applications and external storage, services and clients, ingress and egress, all using TLS encryption. Etcd data is not encrypted by default, however users can enable etcd encryption to provide an additional layer of data security to further protect against the loss of sensitive data if etcd were ever unexpectedly exposed. Red Hat OpenShift supports encryption for the boot disks on both control plane and compute nodes at installation time. Users can select their preferred encryption approach between Trusted Platform Module (TPM) v2 and Tang encryption modes for different deployment cases like edge site and datacenter.

Red Hat OpenShift Compliance Operator is a tool that helps organizations ensure that their OpenShift clusters meet compliance requirements. The Compliance Operator supports various industry and regulatory compliance standards, such as CIS benchmark, NIST risk management framework, PCI security standard and more. The Compliance Operator uses OpenSCAP, a NIST-certified tool, to scan, identify non-compliant resources and provide recommendations on how to remediate those resources. The Compliance Operator CRDs include ProfileBundle and Profile objects, in which you can define and set the rules for your compliance scan requirements. Users can use ScanSetting and ScanSettingBinding APIs to run compliance scans. Compliance checks are defined by compliance Profiles. The Compliance Operator can be customized via tailored profiles to fit the organization's needs and requirements. A remediation object will be created when a compliance rule can be remediated automatically. It is recommended to check the results and review the remediation achieves the target compliance goal.

For more information about OpenShift security and components, see:

https://docs.openshift.com/container-platform/security/index.html and

https://docs.openshift.com/container-platform/authentication/index.html

Note: Security is a rapidly growing technology area. The topics of DevSecOps, Hybrid cloud security and Red Hat Advanced Cluster Security for Kubernetes (RHACS) are not covered in this document. Also, hardware-based security control technologies, like Intel Software Guard Extensions (Intel SGX), are not introduced in this document.

6.22 OpenShift AI

Red Hat OpenShift AI can be installed on-prem in a self-managed OpenShift Container Platform.

OpenShift AI includes Jupyter and a collection of default notebook images optimized with the tools and libraries required for model development, and the TensorFlow and PyTorch frameworks. Deploy and host your models, integrate models into external applications, and export models to host them in any hybrid cloud environment. You can also accelerate your data science experiments through the use of graphics processing units (GPUs).

OpenShift AI offers a comprehensive set of features tailored to the needs of data scientists:

Containers for Seamless Collaboration: OpenShift AI provides a containerized development environment, including Jupyter notebooks, which allows data scientists to work on their projects without the constraints of individual hardware or software installations. With the use of containers, collaboration becomes effortless as you can easily share your work with team members. This ensures that specialized resources like GPUs and substantial memory are readily available, without the need for expensive personal hardware.

Integration with Third-Party Tools: OpenShift AI promotes flexibility by offering compatibility with a wide range of open source and third-party machine learning tools. Data scientists can seamlessly integrate these tools into their workflow, supporting the entire machine learning lifecycle, from data preprocessing and feature engineering to model deployment and management.

Collaborative Notebooks with Git: The platform enables collaborative coding with the Git interface within Jupyter notebooks. This allows data scientists to work together effectively and keep a record of changes to their code, enhancing version control and facilitating teamwork.

Secure Notebook Images: OpenShift AI offers a selection of secure, pre-configured notebook images equipped with the necessary libraries and tools for model development. These images are thoroughly vetted to ensure reliability and security. Data scientists can start new projects with confidence, avoiding the risk of using unverified and potentially insecure images from external sources.

Custom Notebook Images: In addition to the provided notebook images, data scientists have the flexibility to configure custom notebook images tailored to the specific requirements of their projects. This customization ensures that their development environment aligns perfectly with the demands of their work.

Data Science Pipelines: OpenShift AI supports data science pipelines, allowing for standardized and automated machine learning workflows. This streamlines the process of developing and deploying data science models, enhancing efficiency and maturity in the data science workloads.

Model Serving: Data scientists can deploy their trained machine learning models, making them available as service endpoints for integration into applications and testing. OpenShift AI offers extensive control over how model serving is executed, ensuring that intelligent applications can utilize the deployed models effectively in a production environment.

OpenShift AI empowers data scientists with the tools and capabilities necessary to collaborate, experiment, and deploy machine learning solutions efficiently, all within a secure and customizable development environment.

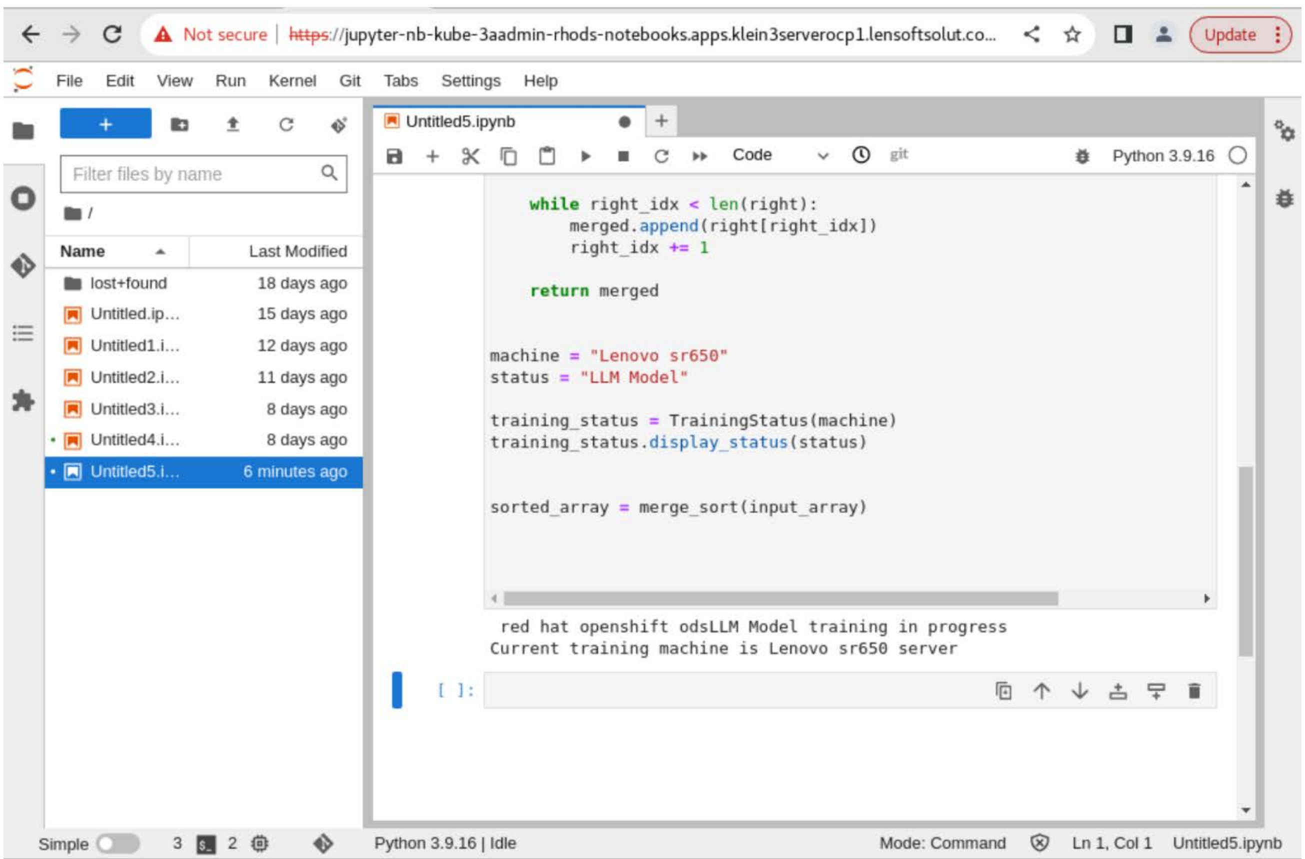


Figure 70. Jupyter notebooks managed by Red Hat OpenShift AI

IT Operations administrators can effectively manage users, data, and resources within OpenShift AI by utilizing the following key features:

User Management with Identity Provider Integration: OpenShift AI seamlessly integrates with the same authentication systems as your OpenShift cluster. By default, all users listed in your identity provider gain access to OpenShift AI without the need for separate credentials. Additionally, administrators have the option to restrict access by creating OpenShift groups, defining specific user subsets. Moreover, administrator access can be granted to a designated group, ensuring control and security.

Resource Management through OpenShift Expertise: IT administrators can leverage their existing OpenShift knowledge to configure and manage resources for OpenShift AI users. This familiar environment simplifies resource allocation and management.

Control over Red Hat Usage Data Collection: Administrators have the choice to enable or disable data collection related to OpenShift AI usage within their cluster. By default, data collection is enabled during the installation of OpenShift AI on the OpenShift cluster, offering flexibility in data privacy.

Cost Optimization through Autoscaling: The cluster autoscaler feature allows administrators to dynamically adjust the cluster size to meet the current resource requirements, optimizing usage costs. This ensures that resources are efficiently allocated to meet user needs while minimizing unnecessary expenditure.

Resource Usage Management by Automatically Stopping Idle Notebooks: OpenShift AI offers the capability to reduce resource consumption by automatically stopping notebook servers that have remained idle for a specified period. This proactive approach helps maintain resource efficiency in the deployment.

Support for Model-Serving Runtimes: OpenShift AI provides native support for model-serving runtimes. This integration facilitates interaction with specific model servers and their supported frameworks. The platform includes the OpenVINO Model Server runtime by default, but administrators can add custom runtimes to address specific model framework requirements.

Installation in Disconnected Environments: OpenShift Data Science's self-managed deployment option supports installation in disconnected environments where clusters are isolated from the internet, typically behind firewalls. In such cases, the OpenShift AI Operator can be deployed to a disconnected environment using a private registry that mirrors relevant images. This ensures that the platform can operate effectively in restricted network environments.

These features empower IT Operations administrators to efficiently manage users, resources, and data while maintaining control, security, and cost-effectiveness within OpenShift Data Science.

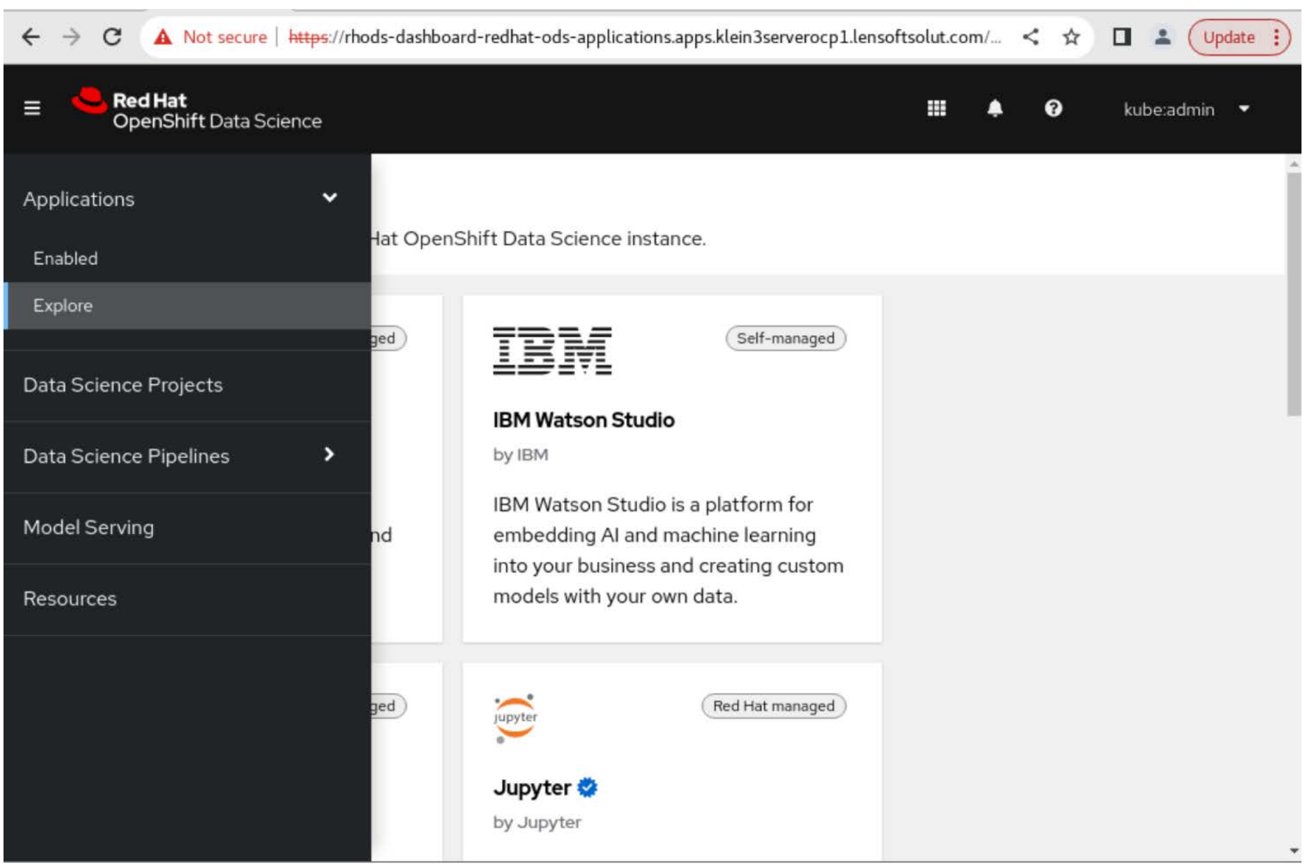


Figure 71. Administrator perspective of of Red Hat OpenShift AI

For more information about OpenShift AI, see:

https://access.redhat.com/documentation/en-us/red_hat_openshift_ai/

6.23 Red Hat Device Edge and MicroShift

At the distant edges of your network, edge devices often have limited computing power, energy supply, cooling capabilities, and connectivity. In addition, they may be inaccessible or located in areas with minimal on-site technical expertise.

To address these challenges, Red Hat introduces Red Hat Device Edge - a versatile platform and solution designed to consistently run various workloads on small, resource-constrained edge devices. Red Hat Device Edge caters to organizations requiring small-form-factor edge devices and support for bare metal, virtualized, or containerized applications.

Red Hat Device Edge is an extension of Red Hat's leading enterprise Linux platform, RHEL. It incorporates Kubernetes features in a lightweight, edge-optimized version with an operating system specifically engineered for edge computing. This allows organizations to manage their edge devices effectively and efficiently using Red Hat Ansible Automation Platform.

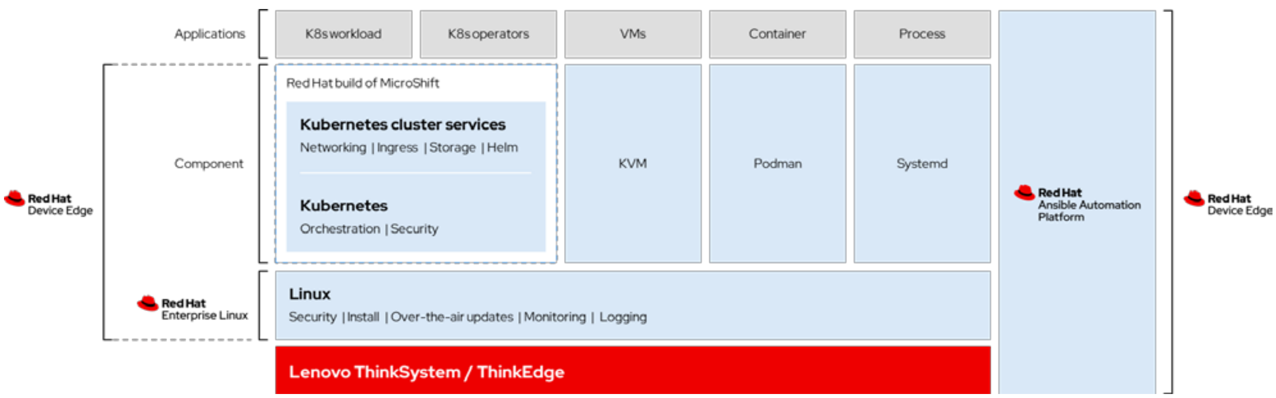


Figure 72. Red Hat Device Edge on Lenovo Servers

MicroShift is a lightweight Kubernetes container orchestration component in Red Hat Device Edge. It is crafted from the edge capabilities of Red Hat® OpenShift® and rooted in the open-source community project bearing the same name. Within the Red Hat Device Edge ecosystem, it boasts a deliberately designed minimal footprint, amalgamating an enterprise-ready distribution of MicroShift that runs seamlessly on an edge-optimized operating system derived from Red Hat Enterprise Linux. MicroShift extends the power and scalability of Kubernetes to the edge, serving as a natural extension of an OpenShift environment. This enables applications to be developed once and deployed precisely where they are needed—adjacent to the data source or end user. Essentially, it encapsulates the capabilities of Kubernetes in a compact form.

MicroShift's primary advantage lies in its compact size. Unlike OpenShift, which can be scaled down, MicroShift is even smaller, making it suitable for deployment in space-constrained environments and on low-power hardware in remote locations. It retains the benefits of Kubernetes, allowing teams to leverage existing tools and processes. MicroShift's consistency facilitates a focus on innovation rather than adapting to new processes and architectures. From core to cloud to edge, MicroShift makes it all Kubernetes.

MicroShift Installation System Requirements:

- Operating System Compatibility:

    A supported version of Red Hat Enterprise Linux (RHEL) or Red Hat Enterprise Linux for Edge.

- Hardware Specifications:

  Minimum of 2 CPU cores.

  2 GB RAM for MicroShift, or 3 GB RAM if using RHEL for network-based HTTPS or FTP installations.

  10 GB of available storage.

- Active MicroShift Subscription:

  Ensure that you have an active MicroShift subscription linked to your Red Hat account. If you do not have a subscription, kindly reach out to your sales representative for detailed information.

- Logical Volume Manager (LVM) Configuration:

  Have a configured Logical Volume Manager (LVM) Volume Group (VG) with ample capacity to accommodate the Persistent Volumes (PVs) required for your workload.

Derived from OpenShift, MicroShift introduces heightened scalability and consistency to cloud-native environments. This flexibility enables applications to operate where they are most beneficial: on-site. In the diverse landscape of edge computing, where considerations range from unique forms, shapes, and sizes to various locations and conditions, MicroShift excels. Whether deployed in traditional data centers, public clouds, or in the field where conditions may vary significantly, MicroShift operates with the resilience of OpenShift on small, efficient hardware, offering reliability across diverse scenarios. Whether near or far, online or off-grid, MicroShift provides a Kubernetes solution tailored to the specifics of each deployment.

For more information about Device Edge, see:

https://www.redhat.com/en/technologies/device-edge

For more information about MicroShift, see:

https://access.redhat.com/documentation/en-us/red_hat_build_of_microshift/

Resources

- Architecture of the Red Hat OpenShift Container Platform
access.redhat.com/documentation/en-us/openshift_container_platform/4.14/html/architecture/architecture

- OpenShift Container Platform
access.redhat.com/documentation/en-us/openshift_container_platform/4.14/

- Kubernetes
kubernetes.io/ and kubernetes.io/docs/tutorials/kubernetes-basics/

- Storage in OpenShift Container Platform
access.redhat.com/documentation/en-us/openshift_container_platform/4.14/html/storage

- OpenShift Data Foundation
access.redhat.com/documentation/en-us/red_hat_openshift_data_foundation/4.14

- Lenovo ThinkSystem Server Comparison
lenovopress.lenovo.com/lp1263-lenovo-thinksystem-server-comparison

- Lenovo Open Cloud Automation DataSheet
lenovo.com/datasheet/ds0129-lenovo-open-cloud-automation-for-red-hat-openshift

- Lenovo ThinkSystem DE Series
lenovo.com/us/en/data-center/storage/storage-area-network/thinksystem-de-series/c/thinksystem-de-series

- Lenovo ThinkSystem DM Series
https://www.lenovo.com/us/en/c/servers-storage/storage/unified-storage/

- Trident
https://github.com/NetApp/trident

- Red Hat OpenShift on Nutanix
https://portal.nutanix.com/page/documents/solutions/details?targetId=TN-2030-Red-Hat-OpenShift-on-Nutanix:architecture

- Lenovo ThinkAgile HX Series
https://lenovopress.lenovo.com/servers/thinkagile/hx-series#sort=relevance

- Red Hat Advanced Cluster Management for Kubernetes
https://access.redhat.com/documentation/en-us/red_hat_advanced_cluster_management_for_kubernetes

- Red Hat OpenShift Virtualization
https://www.redhat.com/en/technologies/cloud-computing/openshift/virtualization
https://docs.openshift.com/container-platform/virt/about-virt.html

- Red Hat OpenShift Deployment Ready Solution
https://lenovopress.lenovo.com/lp1671-red-hat-openshift-deployment-ready-solutions-on-lenovo-servers

- Red Hat OpenShift Deployment Ready Solution
https://lenovopress.lenovo.com/lp1671-red-hat-openshift-deployment-ready-solutions-on-lenovo-servers

- Red Hat OpenShift Security

https://docs.openshift.com/container-platform/security

- Red Hat OpenShift subscription and sizing guide
https://www.redhat.com/en/resources/self-managed-openshift-sizing-subscription-guide

- Red Hat OpenShift AI
https://access.redhat.com/documentation/en-us/red_hat_openshift_ai/

Document History

Version 1.0	1 October 2018	• Initial version
Version 1.1	1 April 2019	• Updated to include the Intel Select Base configuration
Version 1.2	22 April 2019	• Updated configurations to use Intel Xeon Scalable Processor gen 2 CPUs
Version 2.0	22 April 2020	• Update to OpenShift 4.2
Version 2.1	27 June 2020	• Update to OpenShift 4.4 and OpenShift Container Storage 4.4
Version 2.2	17 July 2020	• Updated with Red Hat feedback and markup. Return to Lenovo for review
Version 3.0	16 December 2021	• Updated with ThinkSystem v2 generation HW and Red Hat OCP 4.9 and ODF 4.9
Version 3.1	23 June 2022	• Add more Lenovo Open Cloud Automation (LOC-A) sections
Version 3.2	30 Sept 2022	• Add OpenShift with ThinkAgile HX solution • Upgrade OpenShift version to OCP 4.11. • Add Multi-cluster Management
Version 3.3	15 Dec 2022	• Add OpenShift Deployment Ready Solution • Add OpenShift Virtualization
Version 3.4	13 Jan 2023	• Updated with Red Hat feedback and markup.
Version 3.5	29 March 2023	• Add OpenShift Security • Upgrade OpenShift version to OCP 4.12
Version 3.6	15 June 2023	• Updated with ThinkSystem v3 generation HW.
Version 3.7	18 Sept 2023	• Update with DM storage
Version 3.8	29 Nov 2023	• Update with OpenShift Data Science • Upgrade OpenShift version to OCP 4.13
Version 3.9	27 Mar 2024	• Update with Red hat Device Edge and MicroShift, OpenShift AI • Upgrade OpenShift version to OCP 4.14

Trademarks and special notices

References in this document to Lenovo products or services do not imply that Lenovo intends to make them available in every country.

The following terms are trademarks of Lenovo in the United States, other countries, or both:

Lenovo®, Flex System, System x®, ThinkAgile®, ThinkEdge®, ThinkSystem®, TruDDR4, XClarity®.

The following terms are trademarks of other companies:

Intel® and Xeon® are trademarks of Intel Corporation or its subsidiaries.

Linux® is the trademark of Linus Torvalds in the U.S. and other countries.

Microsoft®, Active Directory®, Azure®, and Windows® are trademarks of Microsoft Corporation in the United States, other countries, or both.

Other company, product, or service names may be trademarks or service marks of others.

Information is provided "AS IS" without warranty of any kind.

All customer examples described are presented as illustrations of how those customers have used Lenovo products and the results they may have achieved. Actual environmental costs and performance characteristics may vary by customer.

Information concerning non-Lenovo products was obtained from a supplier of these products, published announcement material, or other publicly available sources and does not constitute an endorsement of such products by Lenovo. Sources for non-Lenovo list prices and performance numbers are taken from publicly available information, including vendor announcements and vendor worldwide homepages. Lenovo has not tested these products and cannot confirm the accuracy of performance, capability, or any other claims related to non-Lenovo products. Questions on the capability of non-Lenovo products should be addressed to the supplier of those products.

All statements regarding Lenovo future direction and intent are subject to change or withdrawal without notice, and represent goals and objectives only. Contact your local Lenovo office or Lenovo authorized reseller for the full text of the specific Statement of Direction.

Some information addresses anticipated future capabilities. Such information is not intended as a definitive statement of a commitment to specific levels of performance, function or delivery schedules with respect to any future products. Such commitments are only made in Lenovo product announcements. The information is presented here to communicate Lenovo’s current investment and development activities as a good faith effort to help with our customers' future planning.

Performance is based on measurements and projections using standard Lenovo benchmarks in a controlled environment. The actual throughput or performance that any user will experience will vary depending upon considerations such as the amount of multiprogramming in the user's job stream, the I/O configuration, the storage configuration, and the workload processed. Therefore, no assurance can be given that an individual user will achieve throughput or performance improvements equivalent to the ratios stated here.

Photographs shown are of engineering prototypes. Changes may be incorporated in production models.

Any references in this information to non-Lenovo websites are provided for convenience only and do not in any manner serve as an endorsement of those websites. The materials at those websites are not part of the materials for this Lenovo product and use of those websites is at your own risk.