

Red Hat OpenShift Container Platform 4.6 for Hybrid-Multicloud and NFV Workloads

If you're looking for a scalable, flexible and high-performance platform for enterprise multicloud and NFV workloads, this reference architecture for Red Hat OpenShift Container Platform running on 3rd Gen Intel® Xeon® Scalable processors is the answer



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Executive Summary

Currently, hybrid-cloud-capable, cloud-native data center infrastructure is required for databases, AI, machine learning, telecommunications and other workloads. Today's cloud-native applications are distributed across private clouds and one or more public clouds. Eighty-nine percent of enterprises have a multicloud strategy.¹

Infrastructure modernization, automation and cloud-native containers are important aspects of business transformation. The portability and repeatability of containers can help save on costs and resources, as well as enable faster time to market and rapid innovation. Containers have little overhead, which helps to lower hardware, maintenance and licensing costs. They can be implemented quickly and components can be shared among other containers.

Intel and Red Hat co-developed this high-performance reference architecture using Red Hat® OpenShift® Container Platform 4.6 and 3rd Generation Intel® Xeon® Scalable processors. This combination enables the deployment of performant and low-latency container-based workloads onto different footprints, such as bare metal, virtual, private cloud, public cloud or a combination of these, in either a centralized data center or at the edge.

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Hybrid-Multicloud Workload Solution

Easy management and orchestration for containers 	Validated design simplifies design choices and speeds time to deployment 	Scalability from edge to private cloud to public clouds 
High performance for AI, analytics and database workloads		
 3rd Gen Intel® Xeon® Scalable processors	 Intel® Optane™ and NAND-based SSDs	 Intel® Ethernet Network Adapters

Solution Brief

Business Challenge

The amount of data that enterprises must store and analyze has been growing steadily for years. With the spike in digital transformation efforts spurred on by the 2020 global health crisis, even more demands are being made on IT infrastructure. According to IDC, over the next four years the number of applications will double, and data will grow 4-5x.²

To handle their burgeoning data, enterprises are focusing on distributed computing spread across hybrid and multicloud environments. As a result, enterprise IT needs more compute power to handle the proliferation of applications and data. Disparate or legacy technology can create integration challenges and impede progress. For successful digital transformation, enterprises must invest in an infrastructure that can provide the foundation to meet these new demands. They also need to provide IT and developers with the ability to design and move applications consistently across different environments from the data center to the cloud and to the edge. In short, enterprises seek a cohesive collection of technologies that can propel their business into the digital future.

Solution Value

Business transformation requires automation, containers and a modern infrastructure. That's exactly what enterprises obtain when they deploy Intel's reference architecture for Red Hat OpenShift Container Platform 4.6 for hybrid-multicloud workloads. With this reference architecture, enterprises can shift to a modern, cloud-native infrastructure that meets today's IT demands. Here are a few of the benefits of this solution:

- **Take advantage of a validated, yet customizable design.** Whatever the workload, this verified design helps organizations deploy data center infrastructure quickly and efficiently with less tuning—potentially reducing total costs and speeding time to deployment.
- **Accelerate and simplify application development.** Modern applications have a lot of moving parts, and there are many different concepts developers need to be aware of. This complexity can slow down innovation. [OperatorHub](#) is an intuitive catalog of operators (a method of packaging, deploying and managing a Kubernetes-native application) from the Kubernetes community and Red Hat partners.
- **Easily scale your workloads.** The combination of Red Hat OpenShift Container Platform, Red Hat OpenShift Data Foundation, OperatorHub and Intel technology makes it easy to scale a variety of workloads. These include databases, event streaming, video streaming, telecommunications service provider operations, data analytics, AI and machine learning. The modular nature of the architecture enables developers to quickly add capacity, expand clusters and extend capabilities.
- **Meet growing storage needs.** As the amount of data explodes in every industry, storing and managing that data becomes increasingly challenging. Intel® Optane™ SSDs

with OpenShift Data Foundation can store metadata and/or act as data cache to accelerate storage systems based on SATA and NAND SSDs. It can also help eliminate the storage penalty typical of infrastructures that use low-cost, high-capacity drives.

Solution Benefits

- Simple scalability from on-premises to the hybrid cloud helps enterprises easily accommodate additional changes in workload demands.
- High storage performance of Red Hat OpenShift Data Foundation, powered by Intel® Optane™ SSDs, can help enterprises get the most out of their Intel® Xeon® processors running a wide variety of workloads, including AI, analytics and database workloads.
- The validated design is customizable and fully interoperable with existing infrastructure, and helps simplify design choices and accelerate time to deployment.
- Intel architecture-optimized AI libraries and tools for application developers—along with validated, bundled containers—speed innovation and ease development.

Solution Architecture Highlights

This reference architecture provides a turnkey, end-to-end solution using the latest Intel technologies (see Figure 1) to deliver a production-ready foundation. The solution simplifies hybrid-multicloud deployment, shares the latest best practices and provides a stable environment for running production applications. It also helps to provision and deploy a highly available OpenShift Container Platform 4.6 cluster either on-premises or in a hybrid cloud with both the registry and the application pods backed by OpenShift Data Foundation. The solution is powered by highly scalable 3rd Gen Intel® Xeon® Scalable processors and is supported by Intel Optane SSDs and NAND-based SSDs as well as Intel® Ethernet products.

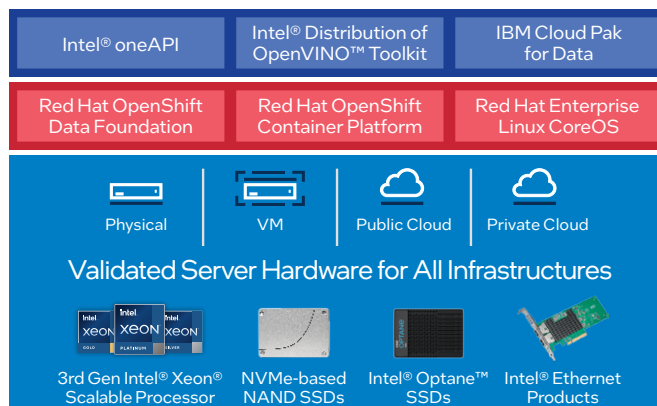


Figure 1. The Red Hat OpenShift Container Platform is optimized for Intel technologies.

A Closer Look at Red Hat OpenShift Container Platform

The Red Hat OpenShift Container Platform provides a consistent and security-enabled Kubernetes cloud-native, hybrid-multicloud experience (see Figure 2). It accommodates a large, scalable mix of microservices-oriented applications and their dependent components. OpenShift Container Platform uses the Container Runtime Interface—Open Container Initiative engine and Kubernetes-based orchestration. It provides Container-as-a-Service (CaaS) and Platform-as-a-Service (PaaS) workflows for developers and existing applications. OpenShift Container Platform uses external data nodes for OpenShift Data Foundation to provide high-performance, scalable storage. The following sections describe a few notable components of the overall platform.

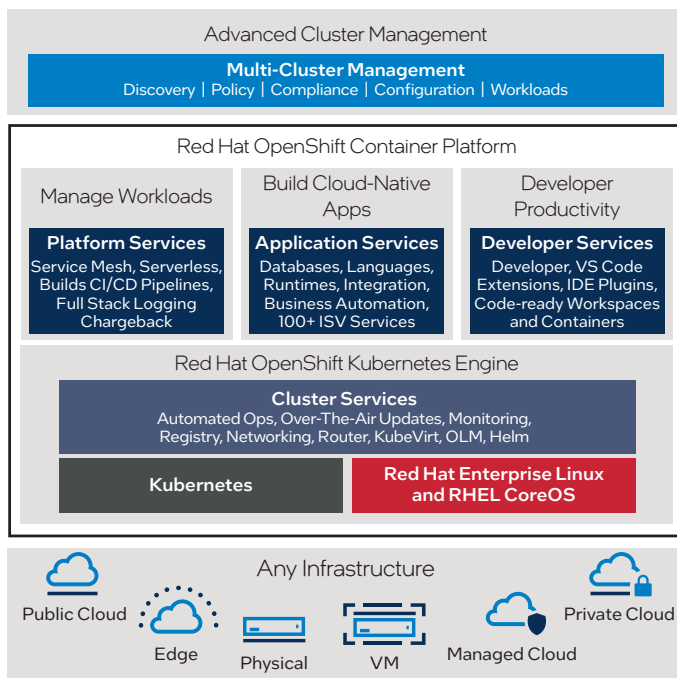


Figure 2. Red Hat OpenShift Container Platform helps enterprises develop, deploy and manage innovative applications at scale.

OpenShift Marketplace

Developers and Kubernetes administrators can use [Red Hat Marketplace](#) to gain automation advantages while enabling the portability of the services across Kubernetes environments. Developers can choose operators for a wide variety of tasks, including AI and machine learning, databases, integration and delivery, logging and tracing, monitoring, networking, security, storage, and streaming and messaging. Once installed on a cluster, operators are listed in the OpenShift Container Platform Developer Catalog, which provides a self-service experience. Developers don't need to be an expert in applications such as Ceph Object Storage, Kubeflow, Jupyterhub, Apache Spark, Seldon, Prometheus, Grafana, Argo, TensorFlow

or Scikit-learn—they just install the operators they need to accomplish their application goals. The result is that teams can spend more time solving critical business needs and less on installing and maintaining infrastructure.

[Open Data Hub](#) is an integration of open-source projects that provide a blueprint for building AI-as-a-Service and SR-IOV on OpenShift Container Platform. Open Data Hub makes it easier for developers to jump in and start writing portable and cloud-native, hybrid AI applications.

Red Hat OpenShift Data Foundation

Red Hat OpenShift Data Foundation offers persistent storage for cloud-native applications that require features such as encryption, replication and availability across the hybrid cloud. Whether data is at rest, on the move or at work, OpenShift Data Foundation provides the portability and scale today's data centers need. These cloud-native infrastructure data services are portable and highly scalable. Application teams can dynamically provision persistent volumes for a wide variety of workload categories including SQL/NoSQL databases, continuous integration/continuous delivery (CI/CD) pipelines and AI and machine learning. OpenShift Data Foundation is based on Ceph block, file and object storage. Ceph is ideal for handling the vast amounts of unstructured data that modern applications analyze.

The benefits of using OpenShift Data Foundation include the following:

- Platform services help manage workloads effectively.
- Application services simplify building cloud-native applications.
- Developer services help increase developer productivity.
- Data services help organizations realize the full value of data.

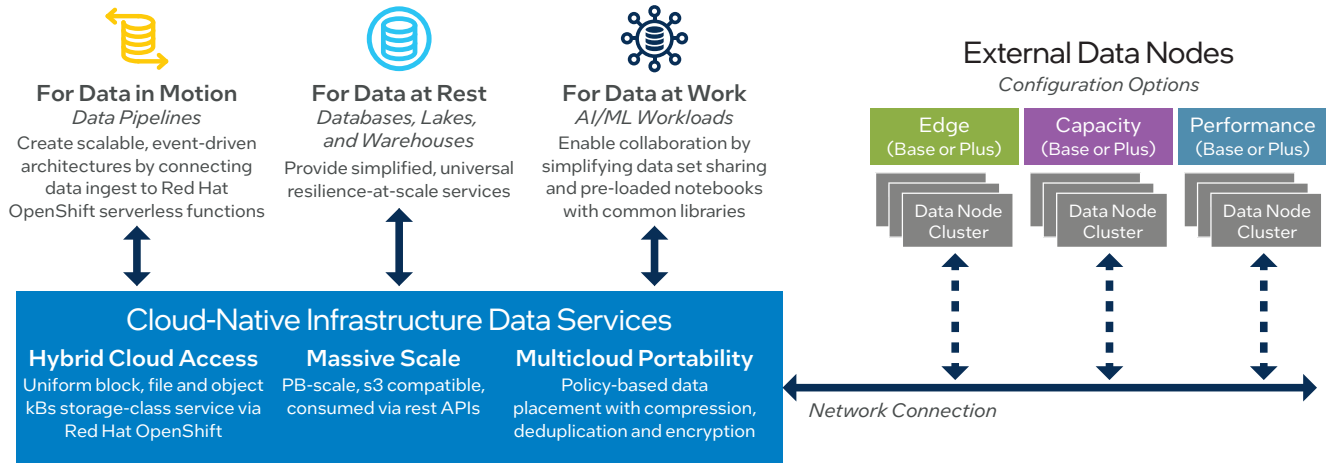
OpenShift Data Foundation provides a trusted, enterprise-grade application development environment that simplifies and enhances the user experience across the application lifecycle in several ways:

- Take advantage of flexible storage options.
- Block storage for databases.
- Shared file storage for continuous integration, messaging and data aggregation.
- Object storage for cloud-first development, archival, backup and media storage.
- Scale applications and data exponentially.
- Attach and detach persistent data volumes quickly.
- Stretch clusters across multiple data centers or availability zones.
- Establish a comprehensive application container registry.
- Support the next generation of OpenShift workloads such as data analytics, AI, machine learning, deep learning and Internet of Things (IoT).
- Dynamically provision not only application containers, but also data service volumes and containers, as well as additional OpenShift Container Platform nodes, Elastic Block Store (EBS) volumes, and other infrastructure services.

Other Deployment Options

The focus of this reference architecture is on internal mode storage, where the Compute/Worker nodes also serve as Storage nodes. However, Red Hat OpenShift Data Foundation also supports an “external mode” storage, where the data nodes are separate from the Compute/Worker nodes. This is the configuration shown in the figure below.

Workload Specialized Data Services



Whether data is at rest, in motion, or at work, Red Hat OpenShift Data Foundation provides the portability and scalability today's data centers need.

Use Case

As mentioned earlier, this reference architecture can be used for a broad variety of enterprise workloads, including databases like Microsoft SQL Server and PostgreSQL; event streaming using Apache Kafka; telecommunications service provider operations like network functions virtualization (NFV); advanced data analytics; and AI and machine-learning workloads.

An interesting example of the latter can be found in the oil and gas (O&G) industry, which generates tremendous amounts of data from all the major operational sectors: upstream, midstream, and downstream.³ Geoscientists are applying deep-learning algorithms in various application workflows, including analyzing seismic and microseismic data, performing asset management, improving occupational safety and optimizing acquisition strategies. In particular, AI algorithms are showing promising results in seismic interpretation. The deep-learning algorithms can aid in processing huge datasets quickly and often spot subtle features that might be overlooked by human scientists. Deep-learning models trained with geological data can provide O&G companies valuable insights to plan their drilling and rigging. The models can assist in accurately determining the availability of natural gas and oil.

For example, salt-bodies are important subsurface structures that are associated with the presence of hydrocarbon accumulation and help seal petroleum reservoirs. However, if salt-bodies are not recognized prior to drilling, they can lead to a number of complications if encountered unexpectedly while drilling the well. A deep-learning algorithm deployed on Intel's reference architecture for OpenShift Container Platform can help O&G companies increase exploration efficiency and avoid costly surprises.

Learn More

You may also find the following resources useful:

- [3rd Gen Intel® Xeon® Scalable processors](#)
- [SSD D7-P5500 Series](#)
- [Intel® Optane™ SSDs](#)
- [Intel® Ethernet products](#)
- [Red Hat OpenShift Container Platform](#)

Find the solution that is right for your organization.
Contact your Intel representative.

Configuration Summary

Introduction

The previous pages discussed the business value of using Intel technology with OpenShift Container Platform, along with a high-level look at the technologies used in the solution. In this section, more detail is provided about those technologies, the seismic interpretation use case and the steps required to run the use case experiment.

Key Technologies

3rd Generation Intel Xeon Scalable Processors

Intel's latest processors for data center workloads are [3rd Gen Intel Xeon Scalable processors](#). They are packed with performance- and security-enhancing features, including the following:

- Enhanced per-core performance, with up to 40 cores in a standard socket.
- Enhanced memory performance with support for up to 3200 MT/s DIMMs (2 DIMMs per channel).
- Database compression with Intel® Vector Byte Manipulation Instructions.
- Increased memory capacity with up to eight channels.
- Support for [Intel Optane PMem 200 series](#).
- Built-in AI acceleration with enhanced performance of [Intel® Deep Learning Boost](#).
- Faster inter-node connections with three Intel® Ultra Path Interconnect links at 11.2 GT/s.
- More, faster I/O with PCI Express 4 and up to 64 lanes (per socket) at 16 GT/s.
- Hardware-enhanced security of [Intel® Crypto Acceleration](#).

3rd Gen Intel Xeon Scalable processors offer new hardware-enhanced security features, in addition to those features available on previous-generation processors:

- [Intel® Platform Firmware Resilience](#) uses an Intel® FPGA to protect, detect, and correct platform firmware.
- [Intel® Secure Hash Algorithm \(SHA\) Extensions](#) are designed to improve the performance of SHA-1 and SHA-256 on Intel® processors.
- [Total Memory Encryption](#) provides full memory encryption to help protect against physical attack.

Intel Optane SSDs

- [Intel Optane SSD P5800X](#) with next-generation Intel Optane storage media and advanced controller delivers “no-compromises” I/O performance—read or write. It also has high endurance, providing unprecedented value over legacy storage in the accelerating world of intelligent data. Intel Optane SSD P5800X delivers 4x greater random 4K mixed read/write IOPS and 67% higher endurance, compared to the previous-generation Intel Optane SSD P4800X, which uses PCIe gen 3.⁴

Intel® Ethernet Products

[Intel Ethernet products](#) are the foundation for server and appliance connectivity. They provide broad interoperability, critical performance optimizations, and increased agility for communications, cloud and enterprise IT network solutions. Intel provides data centers worldwide with innovative Ethernet components and solutions that are extensively tested for network interoperability, reliability and performance. Intel Ethernet controllers, adapters and accessories deliver speeds from 1 to 100 GbE—with versatile capabilities to optimize workload performance.

The [Intel Ethernet 800 Series](#) is the next evolution in Intel's line of Ethernet products. Compared to the Intel Ethernet 700 Series, the 800 Series offers higher bandwidth due to use of PCIe 4.0 and 50 Gb PAM4 SerDes. It also improves application efficiency with Application Device Queues and enhanced Dynamic Device Personalization. The 800 Series is versatile, offering 2x100/50/25/10 GbE, 4x25/10 GbE, or 8x10 GbE connectivity.

AI and Deep-Learning Tools

The [Intel® Distribution of OpenVINO™ toolkit](#) is a comprehensive toolkit for quickly developing applications and solutions that solve a variety of tasks such as emulation of human vision, automatic speech recognition, natural language processing, recommendation systems and many others. Based on latest generations of artificial neural networks—including Convolutional Neural Networks (CNNs), recurrent and attention-based networks—the toolkit extends computer vision and non-vision workloads across Intel® hardware, maximizing performance. It accelerates applications with high-performance, AI and deep-learning inference deployed from edge to cloud.

[Intel® oneAPI](#) products deliver the tools needed to deploy applications and solutions across CPUs, GPUs, and FPGAs. These complementary toolkits—a base kit and domain-specific add-ons—simplify programming and help developers improve efficiency and innovation.

Red Hat OpenShift Container Platform Reference Designs

Tables 1–6 provide a guide for assessing conformance to Intel's reference architecture for OpenShift Container Platform (both the master node and worker node configurations). It is expected that all required resources to implement a software-defined infrastructure reside within each server instance. For a system to conform to the reference architecture, all requirements in these tables must be satisfied, with the exception of Table 2, which provides an alternative deployment option (not referenced in the rest of this document) for use cases that benefit from external data nodes, separate from the Compute/Worker nodes.

Table 1. Required Bill of Materials

Hardware	Hybrid Multi-Cloud	SDN/NFV
3x Control/Master Nodes		
Processor	2x Intel® Xeon® Gold 6252 processor (24 cores, 2.10 GHz)	2x Intel Xeon Gold 5318N processor (20 cores, 2.1 GHz, 135W) or higher number SKU
Memory	192 GB (12x 16 GB)	Option 1: DRAM-only configuration: 256 GB (8x 32 GB DDR4, 2666 MHz) Option 2: DRAM-only configuration: 256 GB (16x 16 GB DDR4, 2666 MHz)
Boot Drive	2x 480 GB SSD D3-S4510 (RAID1 configured)	
Data Network	Intel® Ethernet Controller XXV710 (25 GbE, SFP28)	Option 1: Intel® Ethernet Network Adapter E810-CQDA2 Option 2: Intel Ethernet Network Adapter E810-CQDA2 with Ethernet Port Configuration Tool (EPCT) to break down interface to 4x25G on single port or 8x10G mode (4x10 on single port) Option 3: Intel Ethernet Network Adapter E810-XXVDA2
Management Network	10 GbE Intel Ethernet Network Adapter X722	PXE/OAM: 10 Gbps or 25 Gbps port or Management NIC: 1/10 Gbps port
3x-6x Base Configuration: Compute/Worker/Storage Nodes		
Processor	2x Intel Xeon Gold 6342 processor (24 cores, 2.80 GHz)	2x Intel Xeon Gold 5318N processor (24 cores, 2.1 GHz, 150W) or higher number SKU
Memory	512 GB (16x 32 GB)	Option 1: DRAM-only configuration: 256 GB (8x 32 GB DDR4, 2666 MHz) Option 2: DRAM-only configuration: 256 GB (16x 16 GB DDR4, 2666 MHz)
Boot Drive	2x 480 GB SSD D3-S4510 (RAID1 configured)	
Storage Cache	1x 400 GB Intel® Optane™ SSD P5800X	
Storage Drive	4x 4 TB SSD D7-P5510	
Data Network	Intel Ethernet Controller XXV710 (25 GbE, SFP28)	Option 1: 2x Intel Ethernet Network Adapter E810-CQDA2 Option 2: 2x Intel Ethernet Network Adapter E810-2CQDA2
Management Network	10 GbE Intel Ethernet Network Adapter X722	PXE/OAM: 10 Gbps or 25 Gbps port or Management NIC: 1/10 Gbps port
Intel® QAT	—	1x Intel® QuickAssist Adapter 8960 or 8970 (PCIe) x8 add-in card
3x-6x Plus Configuration: Compute/Worker/Storage Nodes		
Processor	2x Intel Xeon Gold 6342 processor (24 cores, 2.80 GHz)	2x Intel Xeon Gold 5318N processor (24 cores, 2.1 GHz, 150W) or higher number SKU
Memory	512 GB (16x 32 GB)	Option 1: DRAM-only configuration: 256 GB (8x 32 GB DDR4, 2666 MHz) Option 2: DRAM-only configuration: 256 GB (16x 16 GB DDR4, 2666 MHz)
Boot Drive	2x 480 GB SSD D3-S4510 (RAID1 configured)	
Storage Cache	1x 400 GB Intel® Optane™ SSD P5800X	
Storage Drive	4x 4 TB SSD D7-P5510	
Data Network	Intel Ethernet Controller XXV710 (25 GbE, SFP28)	Option 1: 2x Intel Ethernet Network Adapter E810-CQDA2 Option 2: 2x Intel Ethernet Network Adapter E810-2CQDA2
Management Network	10 GbE Intel Ethernet Network Adapter X722	PXE/OAM: 10 Gbps or 25 Gbps port or Management NIC: 1/10 Gbps port
Intel® QAT	—	1x Intel QuickAssist Adapter 8960 or 8970 (PCIe) x16 add-in card

Table 2. Optional External Data Node Configuration (3x-6x Data Nodes for OpenShift Data Foundation - Base Design)

Hardware	Capacity-Optimized for Big Data, AI and ML Workloads (30 TB) ^a	Performance I/O-Optimized for Analytics and Database Workloads (15 TB) ^a
Platform	Dell EMC PowerEdge R740xd	Dell EMC PowerEdge R740xd
Processor	1x Intel® Xeon® Gold 6242R processor (20 cores)	1x Intel Xeon Gold 6242R processor (20 cores)
Memory	96 GB	192 GB
Storage Cache	1x Intel® Optane™ SSD DC P4800X (750 GB)	2x Intel Optane SSD DC P4800X (750 GB)
Storage Drive	8x Intel® SSD DC-S4510 (3.84 TB, 2.5" SATA, TLC)	8x Intel SSD DC-P4610 (1.92 TB, 2.5" U.2 NVMe, TLC)
Data Network	2x 25 GbE Intel® Ethernet Network Adapter XXV710-DA2	2x 50 GbE Intel Ethernet Network Adapter E810-CQDA2
Management Network	1x 10 GbE Intel Ethernet Connection X710-DA2	1x 10 GbE Intel Ethernet Connection X710-DA2

^a OpenShift Data Foundation subscriptions are based on the OpenShift Container Platform nodes that consume the data. For an OpenShift Container Platform subscription on a bare-metal deployment, add RS00421 to each OpenShift Container Platform node (1 to 2 sockets, up to 64 cores). If the OpenShift Container Platform subscription is per core pair, add one MCT4051 per core pair subscription. This addition entitles you to OpenShift Data Foundation Advanced with Premium support.

Table 3. Network Switch

Hardware	Required/Recommended
1x Arista DCS-7170-64C, EOS-4.25.1F	Required

Table 4. Firmware Versions (all required)

Ingredient	Version
BIOS	
2nd Gen Intel® Xeon® Scalable processor platforms	SE5C620.86B.02.01.0013 .121520200651
3rd Gen Intel® Xeon® Scalable processor platforms	SE5C6200.86B.0022.D08 .2103221623
BMC	2.61.1e57a232
Intel® Management Engine	04.04.04.53
SSDD7-P5510	JCV10016
SSDD3-S4510	XCV10132
Intel® SSD P5800X	L0310100
Intel® Ethernet Network Adapter XXV710	3.31
Intel Ethernet Network Adapter E810	1.6.7

Table 5. Software Used

Ingredient	Version	Required/Recommended
Red Hat OpenShift Container Platform	4.6	Required
Red Hat Enterprise Linux CoreOS	4.6	Required
HAProxy	2.1	Recommended
Dnsmasq	2.79	Recommended
Red Hat Enterprise Linux – Compute/Worker Node to support Intel Ethernet Network Adapter E810	7.9	Required
– Bastion/Infrastructure Nodes	8.3	Required
NGINX	1.17.10	Recommended
Intel® QAT	L4.14	Required
DPDK	21.11	Required

Table 6. Workload Requirements for Seismic Use Case

Ingredient	Version	Required/Recommended
IBM Cloud Pak for Data	1.0.7	Required
Watson Studio	3.5.3	Required
IBM Open Data for Industries	2.0.0	Required
OpenVINO™ Toolkit Operator	0.2.0	Recommended
OpenVINO Model Server	2021.4	Required
Red Hat OpenShift Service Mesh	2.0.6-1	Recommended
Python3	3.7	Required
– tensorflow-serving-api	2.5.1	
– segyio	1.9.6	
– scipy	1.4.1	
– tqdm	4.41.1	
– pyvista	0.31.3	
– PVGeo	2.1.0	
– numpy	1.19.2	
– matplotlib	3.2.2	
– Pillow	8.1.1	

Reference Design Key Learnings

This solution simplifies hybrid-multicloud deployment, shares the latest best practices and provides a stable, highly available environment for running production applications. It also helps provision and deploy a highly available Red Hat OpenShift Container Platform 4.6 cluster either on-premises or in a hybrid cloud with both the registry and the application pods backed by Red Hat OpenShift Data Foundation. Throughout the development of this solution, we learned some important lessons:

- Red Hat OpenShift Container Platform, Red Hat OpenShift Data Foundation, OperatorHub and Intel technology are used together to scale a variety of workloads. These include databases, event streaming, video streaming, telecommunications service provider operations, data analytics, AI and machine learning. Intel AI and deep-learning tools like Intel Distribution of OpenVINO toolkit helped us quickly develop applications and solutions for a variety of tasks including emulation of human vision, speech recognition, natural language processing, recommendation systems and others.
- Intel oneAPI products delivered all the tools we needed to deploy applications and solutions across CPUs, GPUs and FPGAs. Its set of complementary toolkits—a base kit and domain-specific add-ons—simplified the programming and helped improve our efficiency and innovation.
- Red Hat OpenShift Container Platform uses the Container Runtime Interface–Open Container Initiative engine and Kubernetes-based orchestration. It provides CaaS and PaaS workflows for developers and existing applications.
- Our developers and Kubernetes administrators used OperatorHub to gain automation advantages while still enabling the portability of the services across our Kubernetes environments. The developers didn't need to be experts in applications such as Ceph Object Storage, the SR-IOV interface, Kafka, KubeFlow, H2O Sparkling Water, Jupyterhub, Apache Spark, Seldon, Prometheus, Grafana, Argo, TensorFlow or Scikit-learn—they just installed the operators they needed to accomplish their application goals. This let teams spend more time solving critical needs and less time installing and maintaining infrastructure.
- Red Hat OpenShift Data Foundation offers persistent storage for cloud-native applications that require features such as encryption, replication and availability across the hybrid cloud.

Revision History

Document Number	Revision Number	Description	Date
	1.0	First Release	August 2021
	2.0	Second Release	July 2022



¹ Flexera, March 21, 2022, "Cloud Computing Trends: 2022 State of the Cloud Report," <https://www.flexera.com/blog/cloud/cloud-computing-trends-2022-state-of-the-cloud-report/>

² IDC, "Today's Trends in Cloud and the Future of Enterprise," December 14, 2020, Matt Eastwood, searchstorage.techtarget.com/post/Todays-Trends-in-Cloud-and-the-Future-Enterprise

³ ScienceDirect, "Big Data analytics in oil and gas industry: An emerging trend," [sciencedirect.com/science/article/pii/S2405656118301421](https://www.sciencedirect.com/science/article/pii/S2405656118301421)

⁴ [2] and [15] at <https://edc.intel.com/content/www/us/en/products/performance/benchmarks/intel-optane-ssd-p5800x-series/>

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