Solutions Reference Architecture
July 2022

# 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

Red Hat OpenShift Container Platform

## Contents




**Authors:**
**Intel Cloud and Enterprise Solutions Group**
**Lokendra Uppuluri,** Software Architect
**Brien Porter,** Enterprise Architect
**Małgorzata Rembas,** Cloud Solutions Architect
**Karol Brejna,** Software Architect
**Kuligowski Maciej,** Cloud Solutions Engineer
**Paweł Kołakowski,** Cloud Solutions Engineer
**Kamil Lipka,** Cloud Solutions Engineer
**Szymon Żebrowski,** Cloud Solutions Engineer

**Other Intel Groups**
**Ravi Panchumarthy,** Machine Learning Engineer, Machine Learning Center
**Ai Bee Lim,** Telco Solution Architect, Network Platform Group
**Shivapriva Hiremath,** Telco Solution Architect, Network Platform Group

**Red Hat Contributor:**
**Mayur Shetty,** Principal Solution Architect

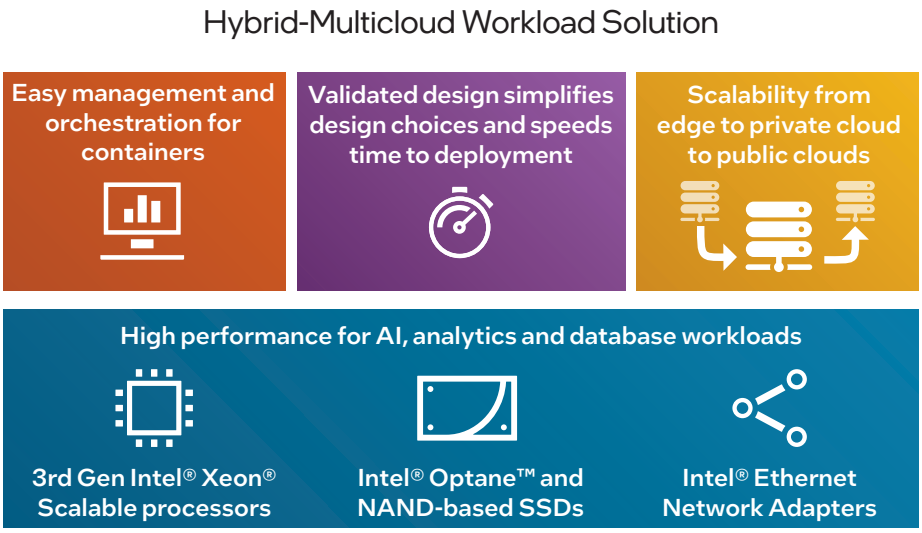
**Reviewers:**
**Jonathan Caplan, Jason Stark**


## 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.

# 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.

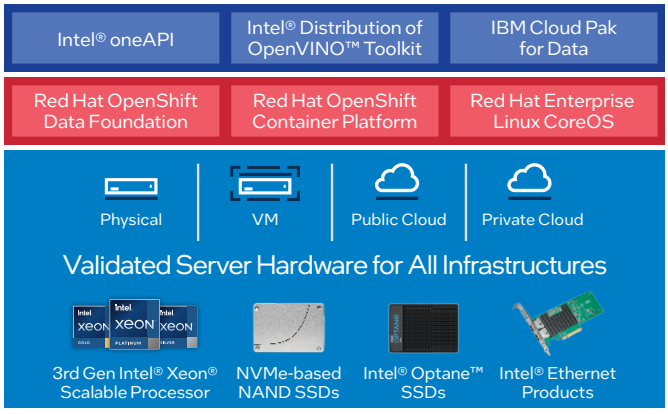



**Figure 1.** The Red Hat OpenShift Container Platform is optimized for Intel technologies.

# 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.

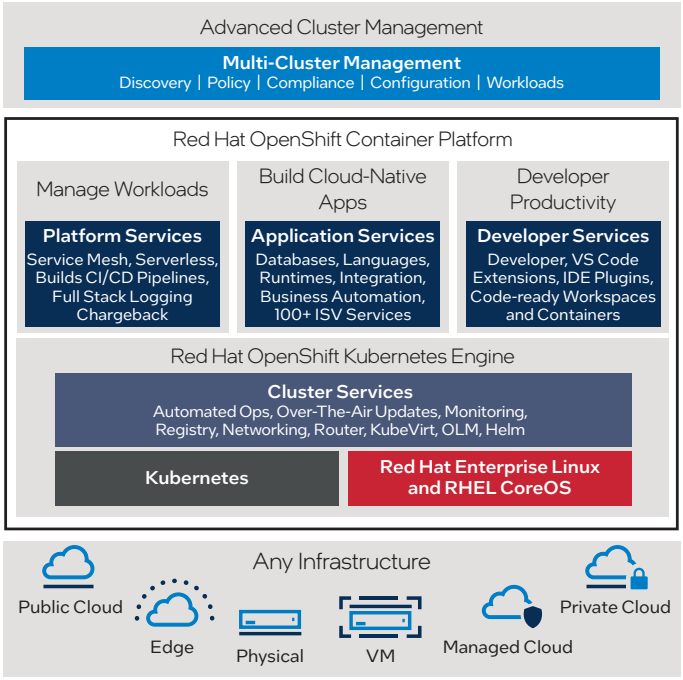



**Figure 2.** Red Hat OpenShift Container Platform helps enterprises develop, deploy and manage innovative applications at scale.

## 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:

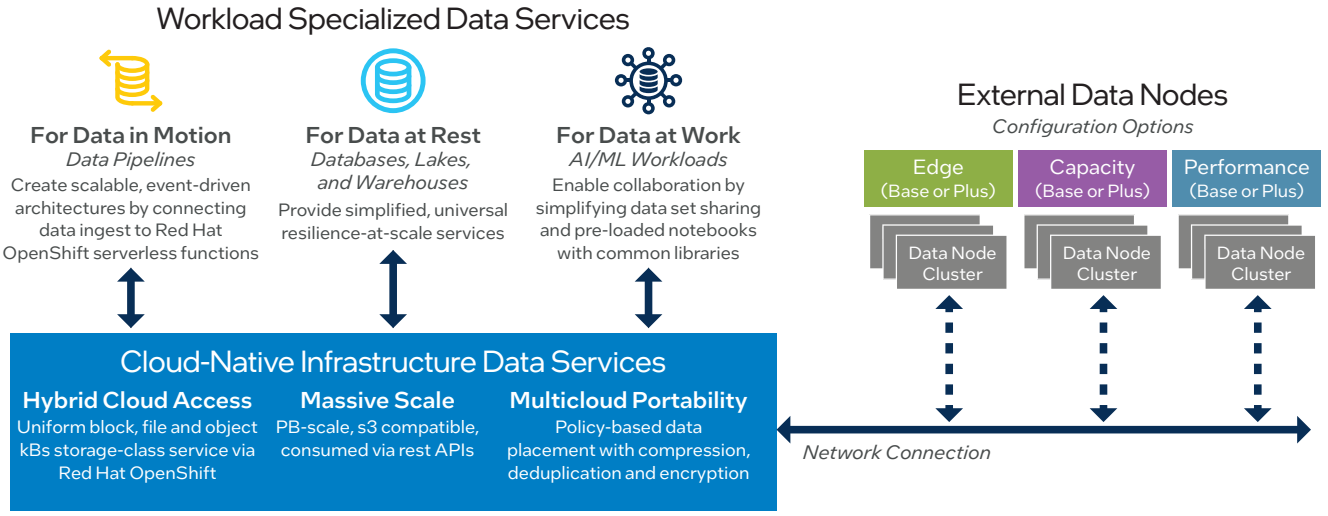
- Platform services help manage workloads effectively.
- Application services simplify building cloud-native applications.
- Developer services help increase developer productivity.
- Data services help organizations realize the full value of data.

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.




**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)<br>**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<br>**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)<br>**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)<br>**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<br>**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)<br>**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<br>**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 |
| SSD D7-P5510 | JCV10016 |
| SSD D3-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<br>– Compute/Worker Node *to support Intel Ethernet Network Adapter E810*<br>– Bastion/Infrastructure Nodes | <br>7.9<br><br>8.3 | <br>Required<br><br>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<br>– tensorflow-serving-api<br>– segyio<br>– scipy<br>– tqdm<br>– pyvista<br>– PVGeo<br>– numpy<br>– matplotlib<br>– Pillow | 3.7<br>2.5.1<br>1.9.6<br>1.4.1<br>4.41.1<br>0.31.3<br>2.1.0<br>1.19.2<br>3.2.2<br>8.1.1 | Required |

## 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

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

Performance varies by use, configuration and other factors. Learn more at intel.com/PerformanceIndex. Performance results are based on testing by Intel as of dates shown and may not reflect all publicly available updates. See configuration disclosures for details. No product or component can be absolutely secure. Your costs and results may vary. Intel technologies may require enabled hardware, software or service activation. Intel does not control or audit third-party data. You should consult other sources to evaluate accuracy. Intel, the Intel logo and other Intel marks are trademarks of Intel Corporation or its subsidiaries. Other names and brands may be claimed as the property of others.