Solutions Reference Architecture
December 2022

Red Hat® OpenShift® Container Platform 4.11 for Secure and Sustainable Hybrid-Multicloud Workloads

On-premises or in the cloud, Intel's reference architecture for Red Hat OpenShift Container Platform can help you meet your performance, security and sustainability objectives

Red Hat OpenShift Container Platform

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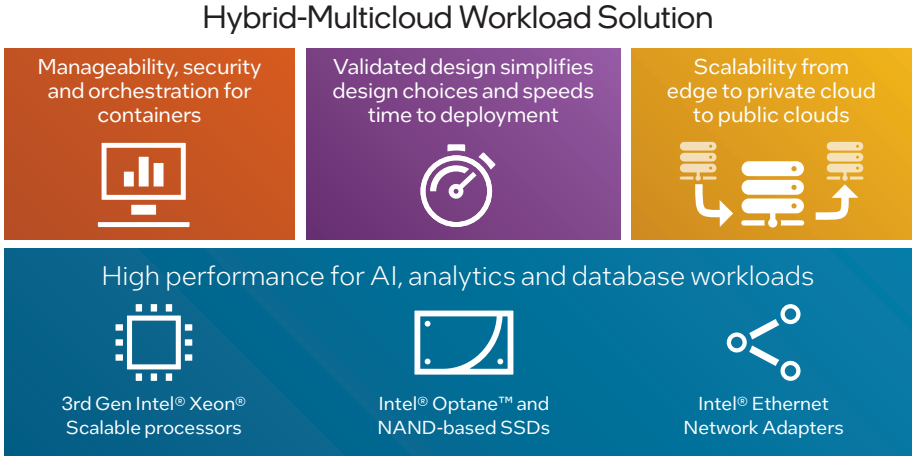
Executive Summary

Currently, hybrid-cloud-capable, cloud-native infrastructure is a major part of data center deployments, whether it involves databases, artificial intelligence (AI), machine learning or telecommunications workloads. Today's cloud-native applications use a distributed cloud approach, with some workloads running in private clouds and others running in one or another public cloud. Over 90% of enterprises have a multicloud strategy.[1]

Intel and Red Hat are working together to combine software and hardware components into a customized infrastructure that is tuned to the needs of achieving transformation, security and sustainability goals. This reference architecture delivers a cloud-native architecture that enables DevOps and IT to accelerate application deployment and easily scale across any cloud environment from on-premises, to hybrid, to the public cloud and edge. The result is an open, interoperable infrastructure that flexibly and securely handles high volumes of applications and data to support fast innovation for a competitive advantage.

This reference implementation includes Intel® Xeon® processors with Intel® Speed Select Technology (Intel® SST) and Intel® Software Guard Extensions (Intel® SGX) to achieve high performance and meet security and sustainability objectives. Other Intel technologies include Intel® Ethernet Network Adapters and Intel® Optane™ Solid State Drives (SSDs). Additional open-source components help accelerate time to value for AI projects. The audience for this reference architecture includes enterprise infrastructure companies, network operators, communications service providers, and cloud service providers.



Solution Brief

Business Challenge

The amount of data that enterprises must store and analyze has been rising steadily for years, putting pressure on enterprises to modernize IT infrastructure that can handle growing workloads. 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 and 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.

But data growth isn't the only concern when choosing hardware and software. An increasingly complex cybersecurity landscape makes it more important than ever to deploy solutions that can help protect data. And environmental issues such as carbon footprint and energy consumption are also top-of-mind for IT executives, leading them to seek solutions that enable customizations that can support sustainability efforts.

Solution Value

Business transformation requires automation and containers as well as a modern, secure and sustainable infrastructure. That's exactly what enterprises obtain when they deploy Intel's reference architecture for Red Hat® OpenShift® Container Platform 4.11 for hybrid-multicloud workloads. This reference architecture can help enterprises move to a cloud-native infrastructure that meets today's IT demands. This solution integrates enterprise-level validated services and components with several hardware features of 3rd Generation Intel® Xeon® Scalable processors that can enhance security, performance and sustainability, along with components that provide real-time continuous software optimization.

Solution Benefits

- **Accelerate time to deployment** with validated enablement of specialized components.
- Through **real-time continuous optimization,** improve server throughput by up to 5x, reduce latency by up to 40% and cut cloud compute costs by up to 60% with no code changes required.[2]
- Easily **tailor CPU usage to specific performance and sustainability scenarios,** such as controlling core frequency and distributing power among cores in power-constrained scenarios.
- **Improve data security** by isolating data and code in Intel® SGX enclaves, without changing underlying software applications.
- **Speed innovation and ease application development** through the use of Intel® architecture-optimized AI libraries and tools for developers, along with validated, bundled containers.

Here are a few of the benefits of this solution:

- **Performance.** Achieve high throughput for AI workloads with Intel® Deep Learning Boost (Intel® DL Boost) and Intel® Advanced Vector Extensions 512 (Intel® AVX-512), combined with the Intel® Optimization for TensorFlow and Intel® Distribution of OpenVINO™ toolkit. Maximize machine-learning training throughput and efficiency with Gaudi® accelerators from Habana Labs.
- **Cost reduction**. The Granulate real-time software optimization solution creates an average of 30-60% cost reduction per customer workload or service, while increasing server throughput by up to 5x and lowering latency by up to 40%. This solution helps lower cloud costs while maintaining high quality of service to meet service-level agreements.
- **Sustainability features.** Optimize energy usage of middleware with Intel® Speed Select Technology (Intel® SST) accessed through the Kubernetes Power Manager Operator, the Intel Power Optimization library and Kepler (Kubernetes-based Efficient Power Level Exporter) sustainability computing.
- **Time to market.** This reference architecture provides a validated solution with containerized tools and sample workloads—making deployment simple and reducing time to market.

Solution Architecture Highlights

This reference architecture (see Figure 1) provides a turnkey, end-to-end solution using Intel® technologies and open-source components to deliver an accelerated production-ready platform suitable for a number of use cases including AI and machine learning. Ask your Intel account representative for the Implementation Guide, which provides best and validated practices and all necessary scripts to enable the various processor features and deploy production applications.

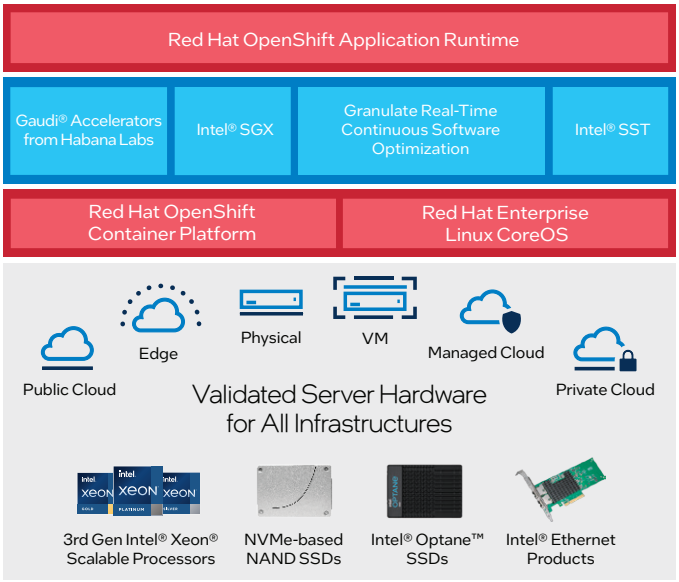


Figure 1. The Red Hat® OpenShift® Container Platform is optimized for Intel® technologies.

The key features of this reference architecture, which spans on-premises, hybrid cloud and multicloud, are as follows:

- Performance acceleration instances powered by Gaudi accelerators.
- Security enclaves for confidential AI, enabled by Intel® Software Guard Extensions (Intel® SGX) with Fortanix Confidential Computing Manager.
- Autonomous, real-time optimization by gAgent from Granulate (certified by Red Hat) for production workloads.
- Kubernetes Power Manager Operator, which simplifies access to Intel® architecture-specific power management technologies such Intel SST, which allows controlling core frequency and distributing power among cores in power-constrained scenarios. The operator provides observability and dynamic power management profile enhancements scaled to production pods with workload services.

Users can also take advantage of Kepler sustainability computing, which uses eBPF to probe energy-related system statistics and exports as Prometheus metrics.

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. Red Hat 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. The following sections describe a few notable components of the overall platform.

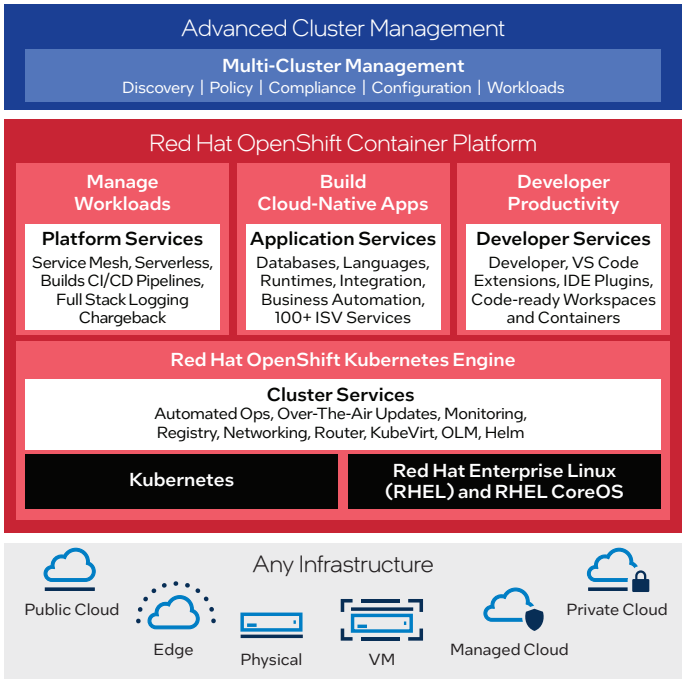


Figure 2. Red Hat® OpenShift® Container Platform helps enterprises develop, deploy and manage innovative applications at scale.

Operators and Red Hat OpenShift Container Platform

Developers and Kubernetes administrators can use the 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 Red Hat 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.

Use Cases

Use Cases for Gaudi® Accelerators from Habana Labs

Gaudi accelerators are custom-designed for machine-learning training and are optimized for TensorFlow and PyTorch workloads. These accelerators are a key component of scalable, cost-effective and easy-to-build architecture. Developers can seamlessly migrate existing GPU-based AI and deep-learning models to systems equipped with Gaudi accelerators. Specific use cases include natural language processing, object detection and image recognition (also known as computer vision).

Get More Out of Your Infrastructure with Granulate Optimization

Granulate operates at the underlying level of the OS, and is therefore agnostic to system architecture and environment:

- **OS:** multiple versions of Linux (such as SUSE Linux, CentOS, Fedora, Red Hat Enterprise Linux and so on).
- **Architecture:** on-premises, public cloud, multicloud or hybrid cloud.
- **Environments and workloads:** Docker, Kubernetes, OpenShift, VMware Tanzu, OpenStack, Google Cloud Platform and others.

Developers can use Granulate's continuous software optimization to help reduce costs for many workflows, including the following (see Figure 3):

- Custom applications like Java, Scala; Clojure; Kotlin; in many cloud-based Kubernetes environments like Amazon Elastic Kubernetes Service and Amazon Elastic Container Service; Azure Kubernetes Service; and Google Kubernetes Engine, as well as for traditional monolithic applications.
- Big data workloads like Apache Spark, PySpark, Hadoop, Dataproc, ElasticSearch, HDInsight and Amazon Elastic MapReduce.
- Stream processing workloads like Kafka, ActiveMQ and RabbitMQ.

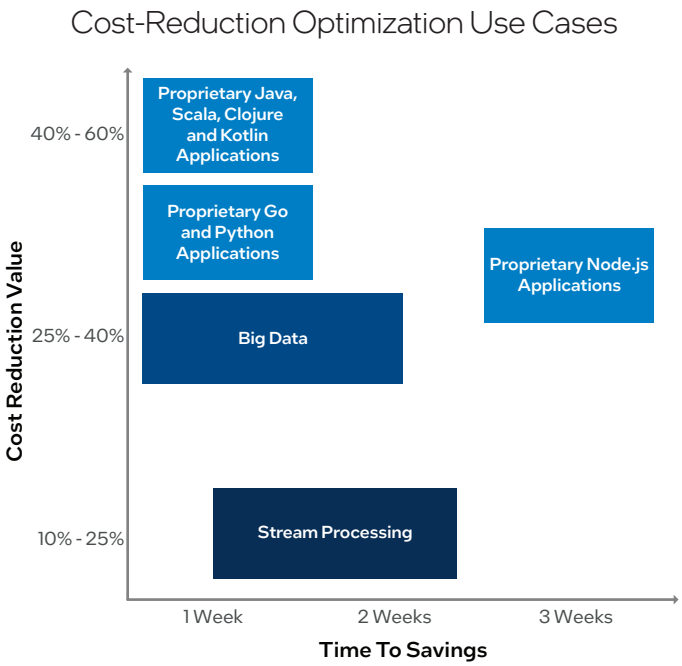


Figure 3. Achieve cost reductions with Granulate optimization.
Source: docs.granulate.io/granulate-the-basics/relevant-use-cases

Use Cases for Kubernetes Power Manager Operator

Use the Kubernetes Power Manager Operator to fine-tune the allocation of CPU resources in scenarios such as the following:

- High-performance workload with known peak times. Pre-schedule nodes to use a performance profile during peak times to minimize core spin up. At non-peak-times, change the nodes' setting to a power-saving profile.
- Unpredictable workload demand. Use machine learning to analyze workload-monitoring data to determine profiles that predict a peak need for compute resources; cores can be spun up ahead of time using the correct performance profile.
- Power optimization over performance. Certain applications may not need the fastest possible response time in all situations; so cores can be spun up with a performance profile on-demand, but remain in power-saving mode the rest of the time.

Use Cases for Intel® SGX with Fortanix Confidential Computing Manager

When enterprises need strong data security, they can turn to Intel SGX and the Fortanix Confidential Computing Manager:

- **Secure containers.** Run unmodified applications within an Intel SGX enclave.
- **Encrypted databases.** Increase security with encrypted database operations.
- **Blockchain.** Increase privacy and security for transaction processing, consensus, smart contracts and key storage.

Learn More

You may also find the following resources useful:

- 3rd Gen Intel® Xeon® Scalable processors
- Intel® Optane™ SSDs
- Intel® Ethernet products
- Intel® SGX
- Gaudi® accelerators from Habana Labs
- Red Hat® OpenShift® Container Platform

Configuration Summary

Introduction

The previous pages provided a high-level discussion of the business value for Red Hat OpenShift Container Platform and the technologies used in the solution. In this section, more detail is provided about those technologies.

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
- 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® SSD Data Center Family

Intel Optane SSDs help remove data bottlenecks to accelerate transactions and time to insights, so users get what they need, when they need it. Intel Optane SSDs deliver fast, predictable performance—even in the most demanding environments. With high quality of service and at least 6x faster 4KB block bandwidth with bi-directional read/write capability than NAND SSDs at low queue depths,[3] the Intel Optane SSD P5800X is the world's fastest SSD.[4]

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 DC P4800X, which uses PCIe gen 3.[5]

Intel® Ethernet 800 Series

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. It also supports RDMA for both iWARP and RoCE v2, which gives enterprises a choice when designing their hyperconverged networks.

Intel® Speed Select Technology

Intel Speed Select Technology (Intel SST) provides granular control over CPU power and performance on specialized 3rd Gen Intel Xeon Scalable processors SKUs. It includes a collection of features that aims to improve performance and optimize total cost of ownership by providing more control over CPU performance.

- **Intel SST – Performance Profile (Intel SST-PP).** Intel SST-PP helps improve server utilization and reduce server qualification test costs by enabling configuration of a single server (not several) to match fluctuating workloads. One flexible server, multiple "configurations-optimized," total cost of ownership is the natural result.
- **Intel SST – Base Frequency (Intel SST-BF).** Intel SST-BF lets the user control base frequency. If some critical workload threads demand constant high guaranteed performance, then this feature can be used to execute the threads at higher base frequency on specific sets of CPUs (high-priority CPUs) at the cost of lower base frequency (low-priority CPUs) on other CPUs.
- **Intel SST – Turbo Frequency (Intel SST-TF).** Intel SST-TF provides the ability to assign prioritization on turbo frequency to specific cores. By using this feature, some cores can be configured to get higher turbo frequency by designating them as high priority at the cost of lower or no turbo frequency on the low-priority cores.
- **Intel SST – Core Power (Intel SST-CP).** Intel SST-CP allows users to define per-core priority. This technology provides a mechanism to distribute power among cores when there is a power-constrained scenario.

Intel® SGX

Intel SGX on Intel Xeon Scalable processors help secure data for confidential computing solutions. For example, many AI models are proprietary and are considered intellectual property. Enterprises want to protect their data and their models, and can do so using Intel SGX.

Going beyond the concepts of protecting data in transit and in use, Intel SGX creates trusted execution environments—called encrypted enclaves. These enclaves protect data and applications while in use by using memory encryption and hardware-enforced access controls to change how data is accessed. This provides enclaves of protected memory in which to run applications and data. Up to 1 TB of enclave capacity for code and data is available to Intel SGX on dual-socket 3rd Gen Intel Xeon Scalable processors-based servers.

Gaudi® Accelerator

Designed to optimize AI performance and deliver higher AI efficiency than traditional CPUs and GPUs, Gaudi accelerators are based on the fully programmable Tensor Processing Core (TPC) 2.0 architecture designed by Habana. These TPCs accelerate matrix multiplication, which is crucial to AI training performance.

In addition to the TPCs, each Gaudi accelerator incorporates several features on the silicon that help accelerate deep-learning workloads:

- Eight clustered, programmable cores that incorporate static random-access memory (SRAM), which acts as local memory for each individual core.
- Four high-bandwidth memory (HBM) devices that provide 32 GB of capacity and memory bandwidth of 1 TBps.
- A dedicated General Matrix to Matrix Multiplication (GEMM) engine that lets Gaudi accelerators increase the performance of multiplying large matrices.

Red Hat OpenShift Container Platform Reference Designs

Tables 1–4 provide a guide for assessing conformance to Intel's reference architecture for the Red Hat OpenShift Container Platform 4.11 (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. Customers must use firmware with the latest microcode.

Table 1. Hardware Bill of Materials

Component	Description	Required or Recommended	Quantity per Node
3x Control Plane Nodes			
Platform	Intel® Server Board M50CYP2SBSTD		
Processor	Intel® Xeon® Gold 6330 processor (28 cores, 2.0 GHz)	Required	2
Memory	256 GB: DDR4 @ 3200 MT/s (2933 MT/s for some processors)	Required	16x 16 GB
Boot Drive	SSD D3-S4510 240 GB	Required	2
Storage Drive	SSD DC-P4610 3.2 TB	Recommended	2
Network	Intel® Ethernet Controller E810-C for QSFP	Required	1
3x-6x Compute/Worker Nodes			
Platform	Intel Server Board M50CYP2SBSTD		
Processor	Intel Xeon Gold 6338 processor (32 cores, 2.0 GHz)	Required	2
Memory	512 GB: DDR4 @3200 MT/s (2933 MT/s for some processors)	Required	16x 32 GB
Boot Drive	SSD D3-S4510 240 GB	Required	2
Storage Cache	Intel® Optane™ SSD P5800X 400 GB	Recommended	1
Storage Drive	SSD D7-P5510 7.68 TB	Required	4
Network	Intel® Ethernet Network Adapter E810-CQDA2 for OCP 3.0	Required	1

Table 2. Firmware Versions (all required)

Ingredient	Version
BIOS	SE5C620.86B.01.01 .0004.2110190142
BMC	2.87.be6beeae
Intel® Management Engine	04.04.04.58
Intel® Ethernet Network Adapter E810-CQDA2 for OCP 3.0	3.0
Intel® Ethernet Controller E810-C for QSFP	3.0
Intel® SSD D3-S4510 240 GB	XC311132
SSD DC P4610 3.2 TB	VDV10170
SSD D7-P5510 3.84 TB	JCV10100
Intel® Optane™ SSD P5800X 400 GB	L0310100

Table 3. Software Requirements (all required)

Software	Description
Red Hat® OpenShift® Container Platform	4.11
Red Hat Enterprise Linux CoreOS	4.11
Red Hat Enterprise Linux	8.6
Fortanix Operator	0.0.2
TensorFlow (used with Intel® SGX)	2.9.1
TensorFlow (used with Gaudi® accelerators from Habana Labs)	2.10.1
Intel® Distribution of OpenVINO™ toolkit	2022.2.0
Intel Distribution of OpenVINO toolkit Docker runtime image based on Red Hat Universal Base Images (UBI) 8	2022.2.0
Kubernetes Power Manager	latest, current: v2.0.0
Kepler	latest, current: v0.3
StressNG	latest, current: 0.13.12-2

Table 4. Amazon Web Services (AWS) CSP Details

Instance Types	More Details (optional)
3x master M6i.xlarge	▪ 4 vCPUs, 8 GB memory ▪ EBS 120 GB volume size
2x worker C6i.xlarge	▪ 4 vCPUs, 8 GB memory ▪ EBS 120 GB volume size
1x worker DL1.24xlarge	▪ 96 vCPUs, 768 GB instance memory ▪ 8x Gaudi® accelerators from Habana Labs ▪ 400 Gbps network bandwidth ▪ 4x 1000 GB NVMe SSD instance storage

Reference Design Key Learnings

As we developed this reference architecture, we garnered the following knowledge that hopefully can help guide others as they pursue digital transformation and infrastructure modernization:

- **Red Hat OpenShift Container Platform and Intel® technology are used together to scale a variety of workloads.** These include databases, data analytics, AI and machine learning. Intel's AI and deep-learning tools like the Intel® Distribution of OpenVINO™ toolkit and the Intel® Optimization of TensorFlow 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.
- **Many workloads running unoptimized can cost organizations in terms of efficiency and energy consumption.** When we implemented Granulate's solution, it helped us to improve operations per cycle, throughput and energy savings.
- **Many enterprises want to be sustainable and to use less energy—to save the planet and our environment and in the face of growing global resource shortages.** Sustainability is a huge topic on everyone's mind. In this solution we highlight the benefits of using Intel Kubernetes Power Manager on OpenShift 4.11, as well as showcase power usage vs. performance drop using Kepler (Kubernetes Efficient Power Level Exporter) and the Intel Power Optimization Library.
- **There is a growing need for secure infrastructure.** We demonstrate Intel SGX together with the Confidential Computing with Fortanix Operator, demonstrating how to run mission-critical workloads in secure enclaves.
- **Our solution includes cost-effective and highly performant deep learning Gaudi accelerators** as a training alternative to existing GPUs, on AWS DL1 instances running a Red Hat OpenShift 4.11 cloud implementation performing inference and training.
- 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.

Revision History

Document Number	Revision Number	Description	Date
	3.0	Third Release: Red Hat OpenShift Container Platform 4.11	December 2022

[1] Krusche & Company GmbH, November 2022, "Do you actually need a multi-cloud strategy?"
[2] Granulate Docs, "Granulate 101," https://docs.granulate.io
[3] Claim [4] at https://edc.intel.com/content/www/us/en/products/performance/benchmarks/intel-optane-ssd-p5800x-series/
[4] Claim [14] at https://edc.intel.com/content/www/us/en/products/performance/benchmarks/intel-optane-ssd-p5800x-series/
[5] [2] and [15] at https://edc.intel.com/content/www/us/en/products/performance/benchmarks/intel-optane-ssd-p5800x-series/

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