



Red Hat Ceph Storage 3

Red Hat Ceph Storage Hardware Selection Guide

Hardware selection recommendations for Red Hat Ceph Storage

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Abstract

This document provides high level guidance on selecting hardware for use with Red Hat Ceph Storage.

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CHAPTER 1. EXECUTIVE SUMMARY

Many hardware vendors now offer both Ceph-optimized servers and rack-level solutions designed for distinct workload profiles. To simplify the hardware selection process and reduce risk for organizations, Red Hat has worked with multiple storage server vendors to test and evaluate specific cluster options for different cluster sizes and workload profiles. Red Hat's exacting methodology combines performance testing with proven guidance for a broad range of cluster capabilities and sizes. With appropriate storage servers and rack-level solutions, Red Hat® Ceph Storage can provide storage pools serving variety of workloads—from throughput-sensitive and cost and capacity-focused workloads to emerging IOPS-intensive workloads.

CHAPTER 2. INTRODUCTION

Red Hat Ceph Storage significantly lowers the cost of storing enterprise data and helps organizations manage exponential data growth. The software is a robust and modern petabyte-scale storage platform for public or private cloud deployments. Red Hat Ceph Storage offers mature interfaces for enterprise block and object storage, making it an optimal solution for active archive, rich media, and cloud infrastructure workloads characterized by tenant-agnostic OpenStack® environments ^[1]. Delivered as a unified, software-defined, scale-out storage platform, Red Hat Ceph Storage lets businesses focus on improving application innovation and availability by offering capabilities such as:

- Scaling to hundreds of petabytes ^[2].
- No single point of failure in the cluster.
- Lower capital expenses (CapEx) by running on commodity server hardware.
- Lower operational expenses (OpEx) with self-managing and self-healing properties.

Red Hat Ceph Storage can run on myriad industry-standard hardware configurations to satisfy diverse needs. To simplify and accelerate the cluster design process, Red Hat conducts extensive performance and suitability testing with participating hardware vendors. This testing allows evaluation of selected hardware under load and generates essential performance and sizing data for diverse workloads—ultimately simplifying Ceph storage cluster hardware selection. As discussed in this guide, multiple hardware vendors now provide server and rack-level solutions optimized for Red Hat Ceph Storage deployments with IOPS-, throughput-, and cost and capacity-optimized solutions as available options.

[1] Ceph is and has been the leading storage for OpenStack according to several semi-annual OpenStack user surveys.

[2] See [Yahoo Cloud Object Store - Object Storage at Exabyte Scale](#) for details.

CHAPTER 3. GENERAL PRINCIPLES

When selecting hardware for Red Hat Ceph Storage, examine the following general principles. These principles will help save time, avoid common mistakes, save money and achieve a more effective solution.

3.1. IDENTIFYING A PERFORMANCE USE CASE

One of the most important steps in a successful Ceph deployment is identifying a price-to-performance profile suitable for the cluster's use case and workload. It is important to choose the right hardware for the use case. For example, choosing IOPS-optimized hardware for a cold storage application increases hardware costs unnecessarily. Whereas, choosing capacity-optimized hardware for its more attractive price point in an IOPS-intensive workload will likely lead to unhappy users complaining about slow performance.

The primary use cases for Ceph are:

- **IOPS optimized:** IOPS optimized deployments are suitable for cloud computing operations, such as running MYSQL or MariaDB instances as virtual machines on OpenStack. IOPS optimized deployments require higher performance storage such as 15k RPM SAS drives and separate SSD journals to handle frequent write operations. Some high IOPS scenarios use all flash storage to improve IOPS and total throughput.
- **Throughput optimized:** Throughput-optimized deployments are suitable for serving up significant amounts of data, such as graphic, audio and video content. Throughput-optimized deployments require networking hardware, controllers and hard disk drives with acceptable total throughput characteristics. In cases where write performance is a requirement, SSD journals will substantially improve write performance.
- **Capacity-optimized:** Capacity-optimized deployments are suitable for storing significant amounts of data as inexpensively as possible. Capacity-optimized deployments typically trade performance for a more attractive price point. For example, capacity-optimized deployments often use slower and less expensive SATA drives and co-locate journals rather than using SSDs for journaling.

This document provides examples of Red Hat tested hardware suitable for these use cases.

3.2. CONSIDERING STORAGE DENSITY

Hardware planning should include distributing Ceph daemons and other processes that use Ceph across many hosts to maintain high availability in the event of hardware faults. Balance storage density considerations with the need to rebalance the cluster in the event of hardware faults. A common hardware selection mistake is to use very high storage density in small clusters, which can overload networking during backfill and recovery operations.

3.3. USE IDENTICAL HARDWARE

Create pools and define CRUSH hierarchies such that the OSD hardware within the pool is identical. That is:

- Same controller.
- Same drive size.
- Same RPMs.

- Same seek times.
- Same I/O.
- Same network throughput.
- Same journal configuration.

Using the same hardware within a pool provides a consistent performance profile, simplifies provisioning and streamlines troubleshooting.

3.4. USING 10GB ETHERNET AS THE PRODUCTION MINIMUM

Carefully consider bandwidth requirements for the cluster network, be mindful of network link oversubscription, and segregate the intra-cluster traffic from the client-to-cluster traffic.



IMPORTANT

1Gbps isn't suitable for production clusters.

In the case of a drive failure, replicating 1TB of data across a 1Gbps network takes 3 hours, and 3TBs (a typical drive configuration) takes 9 hours. By contrast, with a 10Gbps network, the replication times would be 20 minutes and 1 hour respectively. Remember that when an OSD fails, the cluster will recover by replicating the data it contained to other OSDs within the pool.

```
failed OSD(s)
-----
total OSDs
```

The failure of a larger domain such as a rack means that the cluster will utilize considerably more bandwidth. Administrators usually prefer that a cluster recovers as quickly as possible.

At a **minimum**, a single 10Gbps Ethernet link should be used for storage hardware. If the Ceph nodes have many drives each, add additional 10Gbps Ethernet links for connectivity and throughput.



IMPORTANT

Set up front and backside networks on separate NICs.

Ceph supports a public (front-side) network and a cluster (back-side) network. The public network handles client traffic and communication with Ceph monitors. The cluster (back-side) network handles OSD heartbeats, replication, backfilling and recovery traffic. Red Hat recommends allocating bandwidth to the cluster (back-side) network such that it is a multiple of the front-side network using **osd_pool_default_size** as the basis for your multiple on replicated pools. Red Hat also recommends running the public and cluster networks on separate NICs.

When building a cluster consisting of multiple racks (common for large clusters), consider utilizing as much network bandwidth between switches in a "fat tree" design for optimal performance. A typical 10Gbps Ethernet switch has 48 10Gbps ports and four 40Gbps ports. Use the 40Gbps ports on the spine for maximum throughput. Alternatively, consider aggregating unused 10Gbps ports with QSFP+ and SFP+ cables into more 40Gbps ports to connect to another rack and spine routers.

For network optimization, Red Hat recommends a jumbo frame for a better CPU/bandwidth ratio, and a non-blocking network switch back-plane.

3.5. AVOID RAID

Ceph replicates or erasure codes objects. RAID is redundant and reduces available capacity. Consequently, RAID is an unnecessary expense. Additionally, a degraded RAID will have a **negative** impact on performance. When selecting systems with RAID controllers, configure them for RAID 0 (JBOD).

3.6. SUMMARY

Common mistakes in hardware selection for Ceph include:

- Repurposing underpowered legacy hardware for use with Ceph.
- Using dissimilar hardware in the same pool.
- Using 1Gbps networks instead of 10Gbps or greater.
- Neglecting to setup both public and cluster networks.
- Using RAID instead of JBOD.
- Selecting drives on a price basis without regard to performance or throughput.
- Journaling on OSD data drives when the use case calls for an SSD journal.
- Having a disk controller with insufficient throughput characteristics.

Use the examples in this document of Red Hat tested configurations for different workloads to avoid some of the foregoing hardware selection mistakes.

CHAPTER 4. WORKLOAD-OPTIMIZED PERFORMANCE DOMAINS

One of the key benefits of Ceph storage is the ability to support different types of workloads within the same cluster using Ceph performance domains. Dramatically different hardware configurations can be associated with each performance domain. Ceph system administrators can deploy storage pools on the appropriate performance domain, providing applications with storage tailored to specific performance and cost profiles. Selecting appropriately sized and optimized servers for these performance domains is an essential aspect of designing a Red Hat Ceph Storage cluster.

The following lists provide the criteria Red Hat uses to identify optimal Red Hat Ceph Storage cluster configurations on storage servers. These categories are provided as general guidelines for hardware purchases and configuration decisions, and can be adjusted to satisfy unique workload blends. Actual hardware configurations chosen will vary depending on specific workload mix and vendor capabilities.

IOPS-optimized

An IOPS-optimized cluster typically has the following properties:

- Lowest cost per IOPS.
- Highest IOPS per GB.
- 99th percentile latency consistency.

Example uses include:

- Typically block storage.
- 3x replication for hard disk drives (HDDs) or 2x replication for solid state drives (SSDs).
- MySQL on OpenStack clouds.

Throughput-optimized

A throughput-optimized cluster typically has the following properties:

- Lowest cost per MBps (throughput).
- Highest MBps per TB.
- Highest MBps per BTU.
- Highest MBps per Watt.
- 97th percentile latency consistency.

Example uses include:

- Block or object storage.
- 3x replication.
- Active performance storage for video, audio, and images.
- Streaming media.

Cost and Capacity-optimized

A cost- and capacity-optimized cluster typically has the following properties:

- Lowest cost per TB.
- Lowest BTU per TB.
- Lowest Watts required per TB.

Example uses include:

- Typically object storage.
- Erasure coding common for maximizing usable capacity
- Object archive.
- Video, audio, and image object repositories.

How Performance Domains Work

To the Ceph client interface that reads and writes data, a Ceph cluster appears as a simple pool where the client stores data. However, the storage cluster performs many complex operations in a manner that is completely transparent to the client interface. Ceph clients and Ceph object storage daemons (Ceph OSDs, or simply OSDs) both use the controlled replication under scalable hashing (CRUSH) algorithm for storage and retrieval of objects. OSDs run on OSD hosts—the storage servers within the cluster.

A CRUSH map describes a topography of cluster resources, and the map exists both on client nodes as well as Ceph Monitor (MON) nodes within the cluster. Ceph clients and Ceph OSDs both use the CRUSH map and the CRUSH algorithm. Ceph clients communicate directly with OSDs, eliminating a centralized object lookup and a potential performance bottleneck. With awareness of the CRUSH map and communication with their peers, OSDs can handle replication, backfilling, and recovery—allowing for dynamic failure recovery.

Ceph uses the CRUSH map to implement failure domains. Ceph also uses the CRUSH map to implement performance domains, which simply take the performance profile of the underlying hardware into consideration. The CRUSH map describes how Ceph stores data, and it is implemented as a simple hierarchy (acyclic graph) and a ruleset. The CRUSH map can support multiple hierarchies to separate one type of hardware performance profile from another. In RHCS 2 and earlier, performance domains reside in separate CRUSH hierarchies. In RHCS 3, Ceph implements performance domains with device "classes".

The following examples describe performance domains.

- Hard disk drives (HDDs) are typically appropriate for cost- and capacity-focused workloads.
- Throughput-sensitive workloads typically use HDDs with Ceph write journals on solid state drives (SSDs).
- IOPS-intensive workloads such as MySQL and MariaDB often use SSDs.

All of these performance domains can coexist in a Ceph cluster.

CHAPTER 5. SERVER AND RACK-LEVEL SOLUTIONS

Hardware vendors have responded to the enthusiasm around Ceph by providing both optimized server-level and rack-level solution SKUs. Validated through joint testing with Red Hat, these solutions offer predictable price-to-performance ratios for Ceph deployments, with a convenient modular approach to expand Ceph storage for specific workloads. Typical rack-level solutions include:

- **Network switching:** Redundant network switching interconnects the cluster and provides access to clients.
- **Ceph MON nodes:** The Ceph monitor is a datastore for the health of the entire cluster, and contains the cluster log. A minimum of three monitor nodes are strongly recommended for a cluster quorum in production.
- **Ceph OSD hosts:** Ceph OSD hosts house the storage capacity for the cluster, with one or more OSDs running per individual storage device. OSD hosts are selected and configured differently depending on both workload optimization and the data devices installed: HDDs, SSDs, or NVMe SSDs.
- **Red Hat Ceph Storage:** Many vendors provide a capacity-based subscription for Red Hat Ceph Storage bundled with both server and rack-level solution SKUs.

IOPS-optimized Solutions

With the growing use of flash storage, organizations increasingly host IOPS-intensive workloads on Ceph clusters to let them emulate high-performance public cloud solutions with private cloud storage. These workloads commonly involve structured data from MySQL-, MariaDB-, or PostgreSQL-based applications. NVMe SSDs with co-located Ceph write journals typically host OSDs. Typical servers include the following elements:

- **CPU:** 10 cores per NVMe SSD, assuming a 2 GHz CPU.
- **RAM:** 16GB baseline, plus 2GB per OSD.
- **Networking:** 10 Gigabit Ethernet (GbE) per 12 OSDs (each for client- and cluster-facing networks).
- **OSD media:** High-performance, high-endurance enterprise NVMe SSDs.
- **OSDs:** Four per NVMe SSD.
- **Journal media:** High-performance, high-endurance enterprise NVMe SSD, co-located with OSDs.
- **Controller:** Native PCIe bus.

Table 5.1. Solutions SKUs for IOPS-optimized Ceph Workloads, by cluster size.

| Vendor | Small (250TB) | Medium (1PB) | Large (2PB+) |
|--|--------------------|--------------|--------------|
| SuperMicro [a] | SYS-5038MR-OSD006P | N/A | N/A |
| [a] See Supermicro® Total Solution for Ceph for details. | | | |

See also:

- [Red Hat Ceph Storage on Samsung NVMe SSDs](#)
- [Red Hat Ceph Storage on the InfiniFlash All-Flash Storage System from SanDisk](#)
- [Deploying MySQL Databases on Red Hat Ceph Storage](#)
- [Intel® Data Center Blocks for Cloud – Red Hat OpenStack Platform with Red Hat Ceph Storage](#)

Throughput-optimized Solutions

Throughput-optimized Ceph solutions are usually centered around semi-structured or unstructured data. Large-block sequential I/O is typical. Storage media on OSD hosts is commonly HDDs with write journals on SSD-based volumes. Typical server elements include:

- **CPU:** 0.5 cores per HDD, assuming a 2 GHz CPU.
- **RAM:** 16GB baseline, plus 2GB per OSD.
- **Networking:** 10 GbE per 12 OSDs (each for client- and cluster-facing networks).
- **OSD media:** 7,200 RPM enterprise HDDs.
- **OSDs:** One per HDD.
- **Journal media:** High-endurance, high-performance enterprise serial-attached SCSI (SAS) or NVMe SSDs.
- **OSD-to-journal ratio:** 4-5:1 for an SSD journal, or 12-18:1 for an NVMe journal.
- **Host bus adapter (HBA):** Just a bunch of disks (JBOD).

Several vendors provide pre-configured server and rack-level solutions for throughput-optimized Ceph workloads. Red Hat has conducted extensive testing and evaluation of servers from Supermicro and Quanta Cloud Technologies (QCT).

Table 5.2. Rack-level SKUs for Ceph OSDs, MONs, and top-of-rack (TOR) switches.

| Vendor | Small (250TB) | Medium (1PB) | Large (2PB+) |
|--------------------------------|--------------------|--------------------|--------------------|
| SuperMicro [a] | SRS-42E112-Ceph-03 | SRS-42E136-Ceph-03 | SRS-42E136-Ceph-03 |

Table 5.3. Individual OSD Servers

| Vendor | Small (250TB) | Medium (1PB) | Large (2PB+) |
|--------------------------------|-------------------|------------------|------------------|
| SuperMicro [a] | SSG-6028R-OSD072P | SSG-6048-OSD216P | SSG-6048-OSD216P |
| QCT [a] | QxStor RCT-200 | QxStor RCT-400 | QxStor RCT-400 |

[\[a\]](#) See [QCT: QxStor Red Hat Ceph Storage Edition](#) for details.

See also:

- [Red Hat Ceph Storage on QCT Servers](#)
- [Red Hat Ceph Storage on Servers with Intel Processors and SSDs](#)

Table 5.4. Additional Servers Configurable for Throughput-optimized Ceph OSD Workloads.

| Vendor | Small (250TB) | Medium (1PB) | Large (2PB+) |
|---|----------------------|-------------------------|---------------------|
| Dell | PowerEdge R730XD [a] | DSS 7000 [b], twin node | DSS 7000, twin node |
| Cisco | UCS C240 M4 | UCS C3260 [c] | UCS C3260 [d] |
| Lenovo | System x3650 M5 | System x3650 M5 | N/A |
| <p>[a] See Dell PowerEdge R730xd Performance and Sizing Guide for Red Hat Ceph Storage - A Dell Red Hat Technical White Paper for details.</p> <p>[b] See Dell EMC DSS 7000 Performance & Sizing Guide for Red Hat Ceph Storage for details.</p> <p>[c] See Cisco UCS C3160 Rack Server with Red Hat Ceph Storage for details.</p> <p>[d] See UCS C3260 for details</p> | | | |

Cost and Capacity-optimized Solutions

Cost- and capacity-optimized solutions typically focus on higher capacity, or longer archival scenarios. Data can be either semi-structured or unstructured. Workloads include media archives, big data analytics archives, and machine image backups. Large-block sequential I/O is typical. For greater cost effectiveness, OSDs are usually hosted on HDDs with Ceph write journals co-located on the HDDs. Solutions typically include the following elements:

- **CPU.** 0.5 cores per HDD, assuming a 2 GHz CPU.
- **RAM.** 16GB baseline, plus 2GB per OSD.
- **Networking.** 10 GbE per 12 OSDs (each for client- and cluster-facing networks).
- **OSD media.** 7,200 RPM enterprise HDDs.
- **OSDs.** One per HDD.
- **Journal media.** Co-located on the HDD.
- **HBA.** JBOD.

Supermicro and QCT provide pre-configured server and rack-level solution SKUs for cost- and capacity-focused Ceph workloads.

Table 5.5. Pre-configured Rack-level SKUs for Cost- and Capacity-optimized Workloads

| Vendor | Small (250TB) | Medium (1PB) | Large (2PB+) |
|----------------|---------------|--------------------|--------------------|
| SuperMicro [a] | N/A | SRS-42E136-Ceph-03 | SRS-42E172-Ceph-03 |

Table 5.6. Pre-configured Server-level SKUs for Cost- and Capacity-optimized Workloads

| Vendor | Small (250TB) | Medium (1PB) | Large (2PB+) |
|---|---------------|---------------------------------------|------------------------------------|
| SuperMicro [a] | N/A | SSG-6048R-OSD216P [a] | SSD-6048R-OSD360P |
| QCT | N/A | QxStor RCC-400 [a] | QxStor RCC-400 [a] |
| [a] See Supermicro's Total Solution for Ceph for details. | | | |

See also:

- [Red Hat Ceph Storage on QCT Servers](#)
- [Red Hat Ceph Storage on Servers with Intel Processors and SSDs](#)

Table 5.7. Additional Servers Configurable for Cost- and Capacity-optimized Workloads

| Vendor | Small (250TB) | Medium (1PB) | Large (2PB+) |
|--------|---------------|---------------------|---------------------|
| Dell | N/A | DSS 7000, twin node | DSS 7000, twin node |
| Cisco | N/A | UCS C3260 | UCS C3260 |
| Lenovo | N/A | System x3650 M5 | N/A |

CHAPTER 6. RECOMMENDED MINIMUM HARDWARE

Ceph can run on non-proprietary commodity hardware. Small production clusters and development clusters can run without performance optimization with modest hardware.

| Process | Criteria | Minimum Recommended |
|---------------------|----------------|---|
| ceph-osd | Processor | 1x AMD64 or Intel 64 |
| | RAM | Red Hat typically recommends a baseline of 16GB of RAM per OSD host, with an additional 2 GB of RAM per daemon |
| | OS Disk | 1x OS disk per host |
| | Volume Storage | 1x storage drive per daemon |
| | Journal | 1x SSD partition per daemon (optional) |
| | Network | 2x 1GB Ethernet NICs |
| ceph-mon | Processor | 1x AMD64 or Intel 64 |
| | RAM | 1 GB per daemon |
| | Disk Space | 10 GB per daemon |
| | Monitor Disk | 1x SSD disk for leveldb monitor data (optional). |
| | Network | 2x 1GB Ethernet NICs |
| ceph-radosgw | Processor | 1x AMD64 or Intel 64 |
| | RAM | 1 GB per daemon |
| | Disk Space | 5 GB per daemon |
| | Network | 1x 1GB Ethernet NICs |
| ceph-mds | Processor | 1x AMD64 or Intel 64 |
| | RAM | 2 GB per daemon This number is highly dependent on the configurable MDS cache size. The RAM requirement is typically twice as much as the amount set in the mds_cache_memory_limit configuration setting. Note also that this is the memory for your daemon, not the overall system memory. |
| | | |

| Process | Criteria | Minimum Recommended |
|---------|------------|---|
| | Disk Space | 2 MB per daemon, plus any space required for logging, which might vary depending on the configured log levels |
| | Network | 2x 1GB Ethernet NICs Note that this is the same network as the OSDs. If you have a 10 GB network on your OSDs you should use the same on your MDS so that the MDS is not disadvantaged when it comes to latency. |

CHAPTER 7. RECOMMENDED MINIMUM HARDWARE FOR CONTAINERIZED CEPH CLUSTERS

Ceph can run on non-proprietary commodity hardware. Small production clusters and development clusters can run without performance optimization with modest hardware.

| Process | Criteria | Minimum Recommended |
|-------------------------------|--------------|--|
| ceph-osd-container | Processor | 1x AMD64 or Intel 64 CPU CORE per OSD container |
| | RAM | Minimum of 5 GB of RAM per OSD container |
| | OS Disk | 1x OS disk per host |
| | OSD Storage | 1x storage drive per OSD container. Cannot be shared with OS Disk. |
| | Journal | 1x SSD/NVME partition per daemon if using dedicated device |
| | Network | 2x 1GB Ethernet NICs (10GB Recommended) |
| ceph-mon-container | Processor | 1x AMD64 or Intel 64 CPU CORE per mon-container |
| | RAM | 3 GB per mon-container |
| | Disk Space | 10 GB per mon-container (50GB Recommended) |
| | Monitor Disk | 1x SSD disk for Monitor rocksdb data (optional) |
| | Network | 2x 1GB Ethernet NICs(10GB Recommended) |
| ceph-mgr-container | Processor | 1x AMD64 or Intel 64 CPU CORE per mgr-container |
| | RAM | 3 GB per mgr-container |
| | Network | 2x 1GB Ethernet NICs(10GB Recommended) |
| ceph-radosgw-container | Processor | 1x AMD64 or Intel 64 CPU CORE per radosgw-container |
| | RAM | 1 GB per daemon |
| | Disk Space | 5 GB per daemon |
| | Network | 1x 1GB Ethernet NICs |
| | | |

| Process | Criteria | Minimum Recommended |
|---------------------------|------------|--|
| ceph-mds-container | Processor | 1x AMD64 or Intel 64 CPU CORE per mds-container |
| | RAM | <p>3 GB per mds-container</p> <p>This number is highly dependent on the configurable MDS cache size. The RAM requirement is typically twice as much as the amount set in the mds_cache_memory_limit configuration setting. Note also that this is the memory for your daemon, not the overall system memory.</p> |
| | Disk Space | 2GB per mds-container , plus taking into consideration any additional space required for possible debug logging (20GB is a good start). |
| | Network | <p>2x 1GB Ethernet NICs (10GB Recommended)</p> <p>Note that this is the same network as the OSD containers. If you have a 10 GB network on your OSDs you should use the same on your MDS so that the MDS is not disadvantaged when it comes to latency.</p> |

CHAPTER 8. CONCLUSION

Software-defined storage presents many advantages to organizations seeking scale-out solutions to meet demanding applications and escalating storage needs. With a proven methodology and extensive testing performed with multiple vendors, Red Hat simplifies the process of selecting hardware to meet the demands of any environment. Importantly, the guidelines and example systems listed in this document are not a substitute for quantifying the impact of production workloads on sample systems.

For specific information on configuring servers for running Red Hat Ceph Storage, refer to the methodology and best practices documented in the [Red Hat Ceph Storage Hardware Configuration Guide](#). Detailed information, including Red Hat Ceph Storage test results, can be found in the performance and sizing guides for popular hardware vendors.