Flash Memory Summit

# Increasing Ceph Performance Cost-Effectively with New Non-Volatile Technologies

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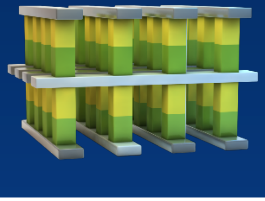
# Agenda

- Ceph* with Intel® Non-Volatile Memory Technologies
- 2.8M IOPS Ceph* cluster with Intel® Optane™ SSDs + Intel® 3D TLC SSDs
- Ceph* Performance analysis on Intel® Optane™ SSDs based all-flash array
- Summary

# Intel® 3D NAND SSDs and OPTANE SSD Transform Storage

## Optimized STORAGE Solutions

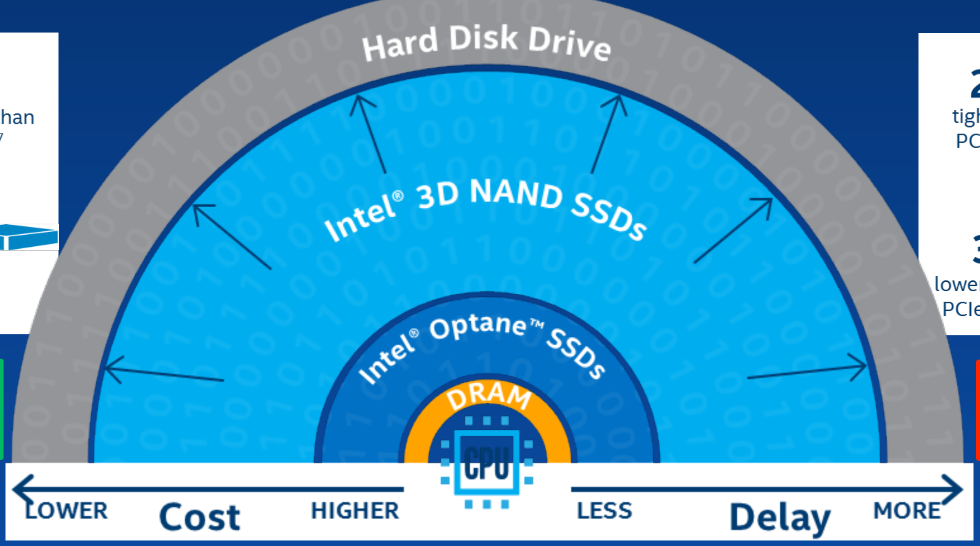


Up to **359x** more IOPS/$ than 10K HDD[6]

**>2X** higher endurance than 2D NAND SSDs[7]

Up to **217x** more IOPS/W than 10K HDD[6]

**More capacity** per rack unit[11]



Up to **200x** tighter QoS than PCIe NAND SSD

**>3X** higher endurance than PCIe NAND SSD

Up to **30%** lower power than PCIe ANND SSD

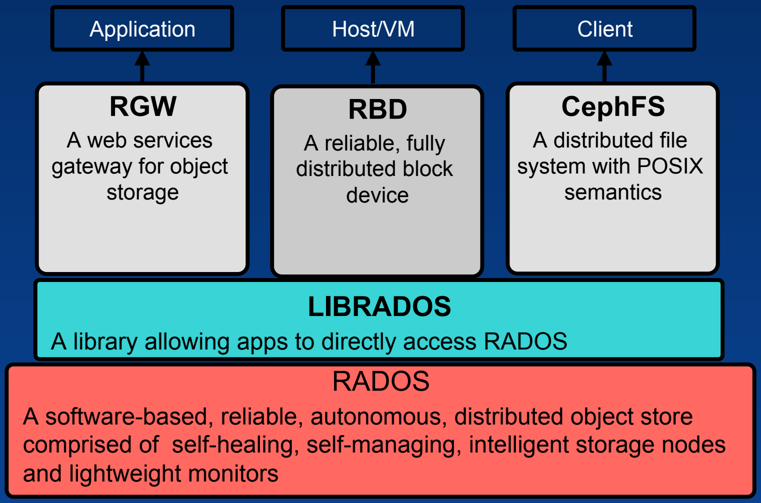
**More VMs, Same QoS** per rack

**Capacity** for Less

**Performance** for Less

Refer to appendix for footnotes

# A Brief Ceph Introduction



Application

Host/VM

Client

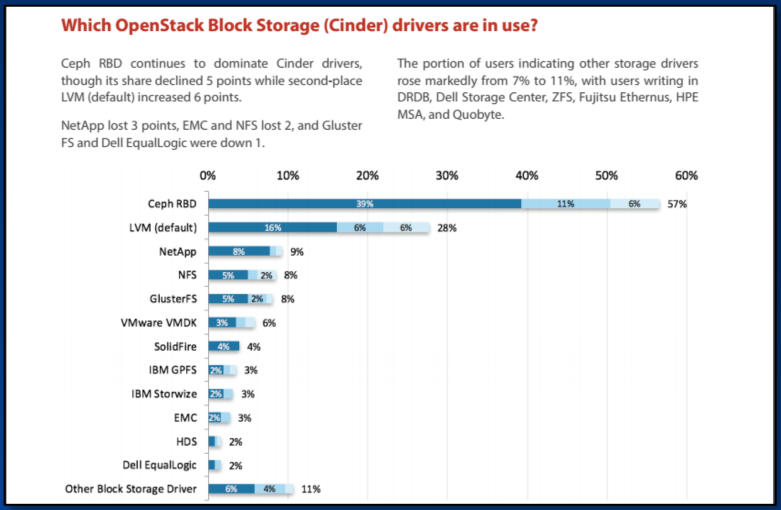
**RGW**
A web services gateway for object storage

**RBD**
A reliable, fully distributed block device

**CephFS**
A distributed file system with POSIX semantics

**LIBRADOS**
A library allowing apps to directly access RADOS

RADOS
A software-based, reliable, autonomous, distributed object store comprised of self-healing, self-managing, intelligent storage nodes and lightweight monitors



**Which OpenStack Block Storage (Cinder) drivers are in use?**

Ceph RBD continues to dominate Cinder drivers, though its share declined 5 points while second-place LVM (default) increased 6 points.

NetApp lost 3 points, EMC and NFS lost 2, and Gluster FS and Dell EqualLogic were down 1.

The portion of users indicating other storage drivers rose markedly from 7% to 11%, with users writing in DRDB, Dell Storage Center, ZFS, Fujitsu Ethernus, HPE MSA, and Quobyte.

- Open-source, object-based scale-out storage
- Object, Block and File in single unified storage cluster
- Highly durable, available – replication, erasure coding
- Runs on economical commodity hardware
- 10 years of hardening, vibrant community

- Scalability – CRUSH data placement, no single POF
- Replicates and re-balances dynamically
- Enterprise features – snapshots, cloning, mirroring
- Most popular block storage for Openstack use cases
- Commercial support from Red Hat

References: http://ceph.com/ceph-storage, http://thenewstack.io/software-defined-storage-ceph-way,

# Who is using Ceph?

Telcom

CISCO

TIVIT synapsis

China unicom中国联通

中国电信 CHINA TELECOM

américa móvil

CSP/IPDC

YAHOO!

ebay

DigitalOcean

Ctrip

360

Letv

SHANDA 盛大集团

OEM/ODM

H3C

QCT Quanta CLOUD TECHNOLOGY

Hewlett Packard Enterprise

DELL

Enterprise, FSI, Healthcare, Retailers

AMX

Walmart

GE imagination at work

Adobe

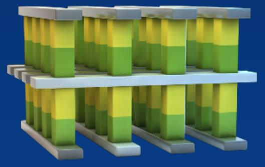
TARGET

Bloomberg

Searchable Examples: http://www.slideshare.net/inktank_ceph

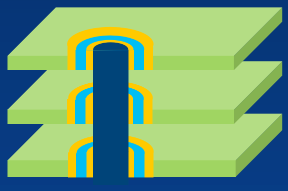
# Innovation for Cloud STORAGE : Intel® Optane™ + Intel® 3D NAND SSDs

- New Storage Infrastructure: enable high performance and cost effective storage:



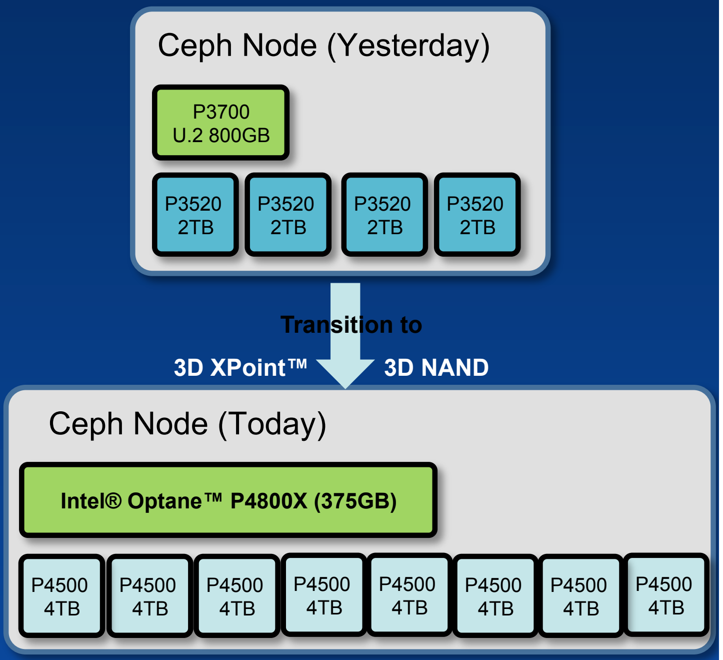
Journal/Log/Cache

+



Data

- Openstack/Ceph:
  - Intel Optane™ as Journal/Metadata/WAL (**Best** write performance, **Lowest** latency and **Best** QoS)
  - Intel 3D NAND TLC SSD as data store (cost effective storage)
  - **Best IOPS/$, IOPS/TB and TB/Rack**



Ceph Node (Yesterday)

P3700 U.2 800GB

P3520 2TB | P3520 2TB | P3520 2TB | P3520 2TB

**Transition to**

**3D XPoint™** **3D NAND**

Ceph Node (Today)

**Intel® Optane™ P4800X (375GB)**

P4500 4TB | P4500 4TB | P4500 4TB | P4500 4TB | P4500 4TB | P4500 4TB | P4500 4TB | P4500 4TB

# Suggested Configurations for Ceph Storage Node

- **Standard/good (baseline):**
- ***Use cases/Applications:*** *that need high capacity storage with high throughput performance*
  - **NVMe*/PCIe* SSD for Journal + Caching, HDDs as OSD data drive**
- **Better IOPS**
- ***Use cases/Applications:*** *that need higher performance especially for throughput,  IOPS and SLAs with medium storage capacity requirements*
  - **NVMe/PCIe SSD as Journal, High capacity SATA SSD for data drive**
- **Best Performance**
- ***Use cases/Applications****: that need highest performance (throughput  and IOPS) and low latency/QoS (Quality of Service).*
  - **All NVMe/PCIe SSDs**

| Ceph* storage node --Good | |
|---|---|
| CPU | Intel(R) Xeon(R) CPU E5-2650v4 |
| Memory | 64 GB |
| NIC | 10GbE |
| Disks | 1x 1.6TB P3700 + 12 x 4TB HDDs (1:12 ratio)<br>P3700 as Journal and caching |
| Caching software | Intel(R) CAS 3.0, option: Intel(R) RSTe/MD4.3 |

| Ceph* Storage node --Better | |
|---|---|
| CPU | Intel(R) Xeon(R) CPU E5-2690v4 |
| Memory | 128 GB |
| NIC | Duel 10GbE |
| Disks | 1x Intel(R) DC P3700(800G) + 4x Intel(R) DC S3510 1.6TB<br>Or 1xIntel P4800X (375GB) + 8x Intel® DC S3520 1.6TB |

| Ceph* Storage node --Best | |
|---|---|
| CPU | Intel(R) Xeon(R) CPU E5-2699v4 |
| Memory | >= 128 GB |
| NIC | 2x 40GbE, 4x dual 10GbE |
| Disks | 1xIntel P4800X (375GB) + 6x Intel® DC P4500 4TB |

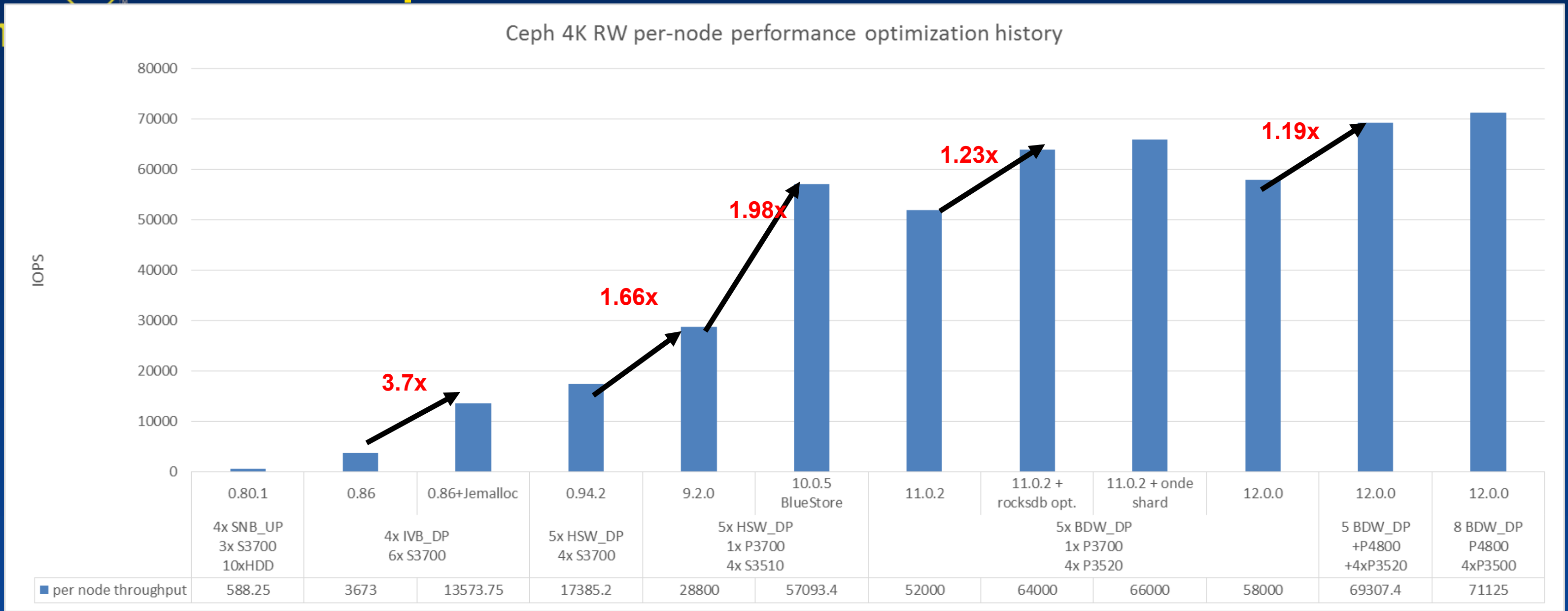
*Other names and brands may be claimed as the property of others. **More information at Ceph.com  (new RAs update soon!)**
http://tracker.ceph.com/projects/ceph/wiki/Tuning_for_All_Flash_Deployments

# Drivers for Ceph on All-Flash Arrays

- Storage providers are struggling to achieve the required high performance
  - There is a growing trend for cloud providers to adopt SSD
    - CSP who wants to build Amazon EBS like services for their OpenStack* based public/private cloud
- Strong demands to run enterprise applications
  - OLTP workloads running on Ceph, tail latency is critical
  - high performance multi-purpose Ceph cluster is a key advantage
  - Performance is still an important factor
- SSD performance continue to increase while price continue to decrease

*Other names and brands may be claimed as the property of others.

# Ceph Performance Trends with SSD



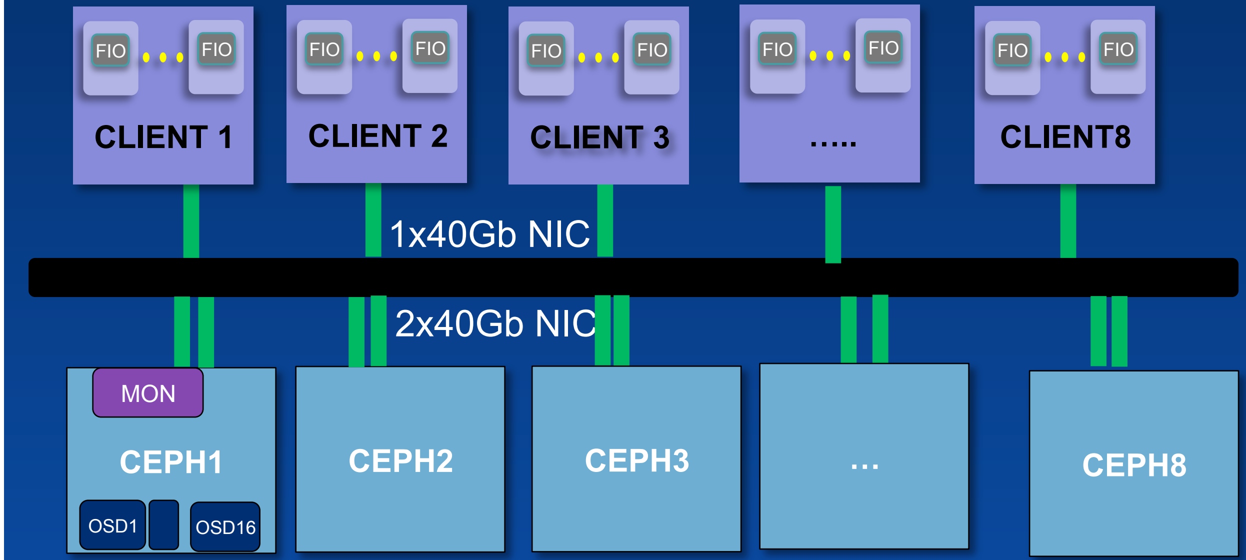
| | 0.80.1 | 0.86 | 0.86+Jemalloc | 0.94.2 | 9.2.0 | 10.0.5 BlueStore | 11.0.2 | 11.0.2 + rocksdb opt. | 11.0.2 + onde shard | 12.0.0 | 12.0.0 | 12.0.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4x SNB_UP<br>3x S3700<br>10xHDD | 4x IVB_DP<br>6x S3700 | | 5x HSW_DP<br>4x S3700 | 5x HSW_DP<br>1x P3700<br>4x S3510 | | 5x BDW_DP<br>1x P3700<br>4x P3520 | | | | 5 BDW_DP<br>+P4800<br>+4xP3520 | 8 BDW_DP<br>P4800<br>4xP3500 |
| ■ per node throughput | 588.25 | 3673 | 13573.75 | 17385.2 | 28800 | 57093.4 | 52000 | 64000 | 66000 | 58000 | 69307.4 | 71125 |

- 18x performance improvement in Ceph on all-flash array!

*Refer to backup section for detail cluster configuration

# Ceph All-Flash Optane Configuration

## Test Environment



Workloads
- Fio with librbd
- 20x 30 GB volumes each client
- 4 test cases: 4K random read & write; 64K Sequential read & write

8x Client Node
- Intel® Xeon™ processor E5-2699 v4 @ 2.3GHz, 64GB mem
- 1x X710 40Gb NIC

8x Storage Node
- Intel Xeon processor E5-2699 v4 @ 2.3 GHz
- 256GB Memory
- 1x 400G SSD for OS
- 1x Intel® DC P4800 375G SSD as WAL and DB
- 8x 2.0TB Intel® SSD DC P4500 as data drive
- 2 OSD instances one each P4500 SSD
- Ceph 12.0.0 with Ubuntu 16.10

*Other names and brands may be claimed as the property of others.

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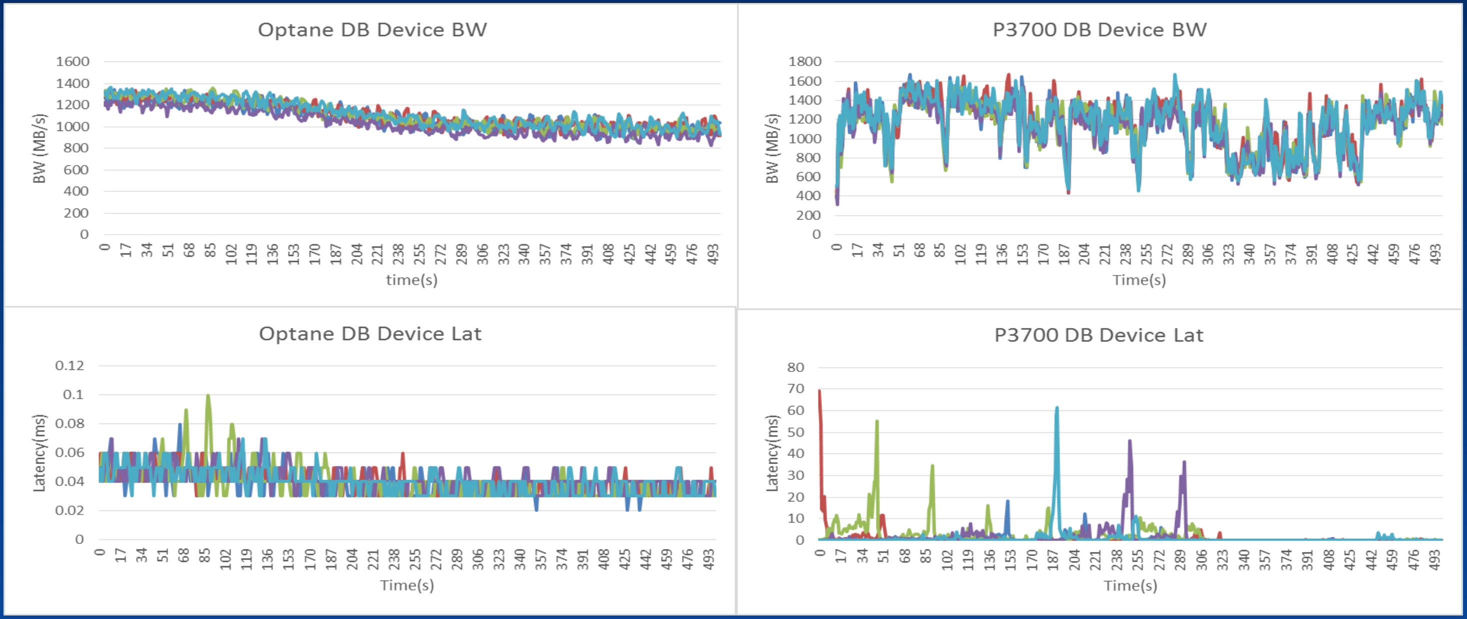
# Ceph Optane Performance Overview

| | Throughput | Latency (avg.) | 99.99% latency (ms) |
|---|---|---|---|
| 4K Random Read | 2876K IOPS | 0.9 ms | 2.25 |
| 4K Random Write | 610K IOPS | 4.0 ms | 25.435 |
| 64K Sequential Read | 27.5 GB/s | 7.6 ms | 13.744 |
| 64K Sequential Write | 13.2 GB/s | 11.9 ms | 215 |

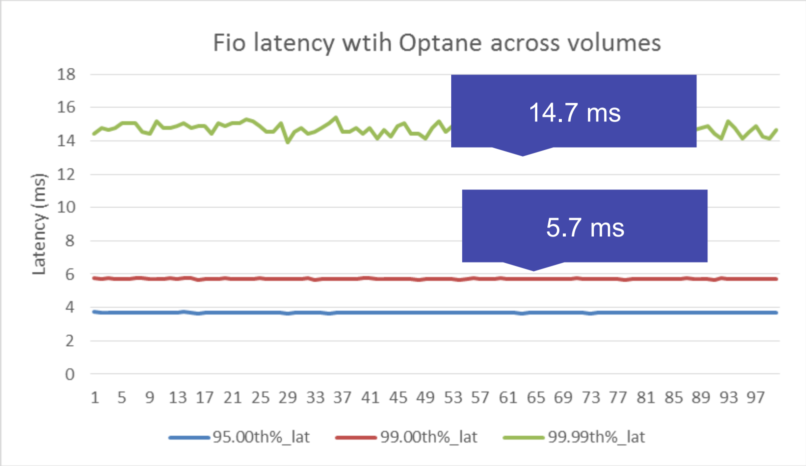
- Excellent performance on Optane cluster
  - random read & write hit CPU bottleneck

# Ceph Optane Performance Improvement



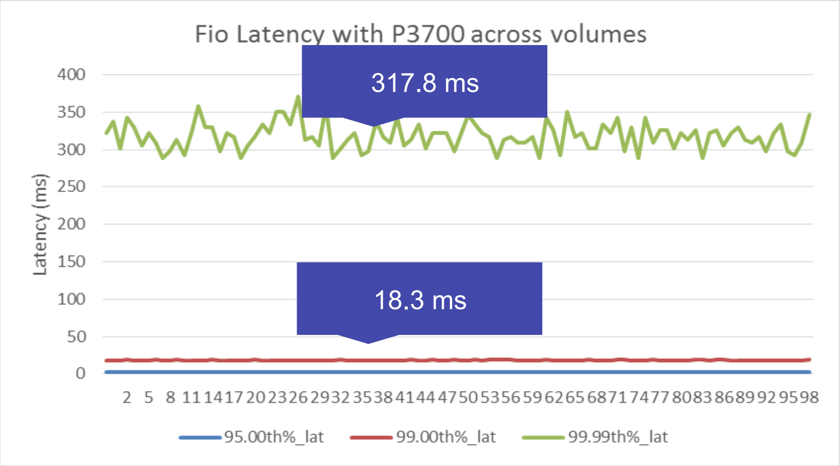
- The breakthrough high performance of Optane eliminated the WAL & rocksdb bottleneck
  - 1 P4800X or P3700 covers up to 8x P4500 data drivers as both WAL and rocksdb

# Ceph Optane Latency Improvement


Fio latency wtih Optane across volumes

14.7 ms

5.7 ms

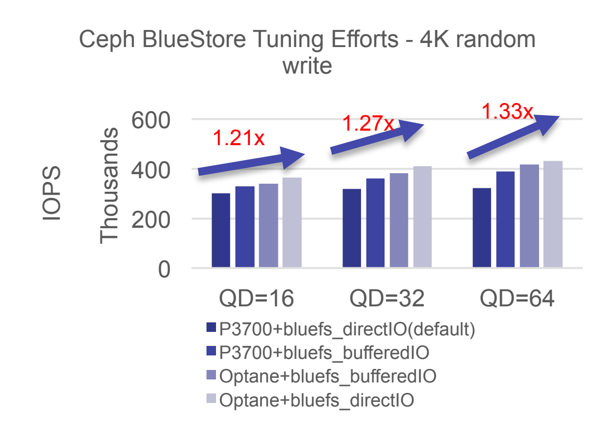

Fio Latency with P3700 across volumes

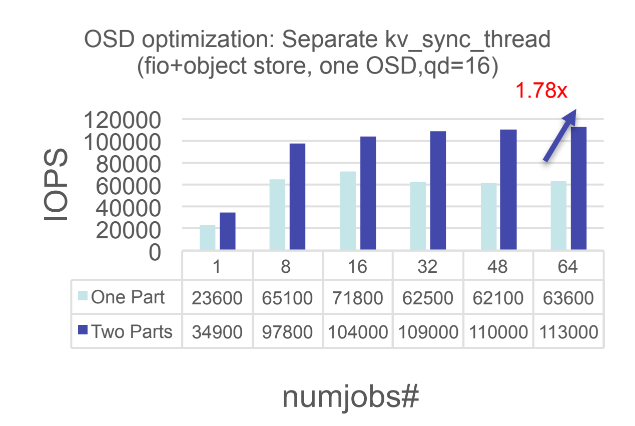
317.8 ms

18.3 ms

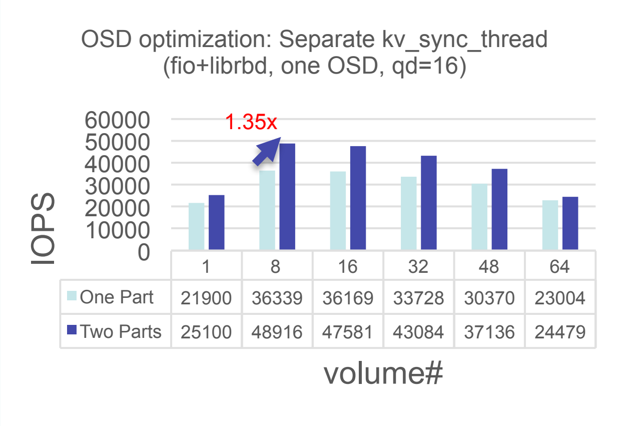
- Significant tail latency improvement with Optane
  - 20x latency reduction for 99.99% latency

# Ceph Performance Optimization on Optane





| | 1 | 8 | 16 | 32 | 48 | 64 |
|---|---|---|---|---|---|---|
| One Part | 23600 | 65100 | 71800 | 62500 | 62100 | 63600 |
| Two Parts | 34900 | 97800 | 104000 | 109000 | 110000 | 113000 |



| | 1 | 8 | 16 | 32 | 48 | 64 |
|---|---|---|---|---|---|---|
| One Part | 21900 | 36339 | 36169 | 33728 | 30370 | 23004 |
| Two Parts | 25100 | 48916 | 47581 | 43084 | 37136 | 24479 |

Optane Performance advantage over P3700 increased from 7% to 33% with tunings (bufferIO)

Optane Optimizations with separate kv_sync_thread

- Separate the thread to feed KV as much as possible. (#PR13943, merged)
- 1.77x performance boost with OSD side optimization on Optane, 1.3x with librbd interface
- Need to further optimize OSD layer

# Summary & Next

- Summary
  - Ceph* is awesome!
  - Strong demands for all-flash array Ceph* solutions
  - Optane based all-flash array Ceph* cluster is capable of delivering over 2.8M IOPS with very low latency!
  - Let’s work together to make Ceph* more efficient with all-flash array!
- Next
  - Improving Ceph network messenger performance with RDMA.
  - Ceph NVMeOF solutions
  - Client side cache on Optane with SQL workloads!

*Other names and brands may be claimed as the property of others.

# Acknowledgements

- This is a joint effort
- Thanks for the contributions of Haodong, Tang, Jianpeng Ma of our Intel Shanghai development team

# Backup

# Ceph All Flash Tunings

```
[global]
 pid_path = /var/run/ceph
    auth_service_required = none
    auth_cluster_required = none
    auth_client_required = none
    mon_data = /var/lib/ceph/ceph.$id
    osd_pool_default_pg_num = 2048
    osd_pool_default_pgp_num = 2048
    osd_objectstore = bluestore
    public_network = 172.16.0.0/16
    cluster_network = 172.18.0.0/16
    enable experimental unrecoverable data corrupting features = *
    bluestore_bluefs = true
    bluestore_block_create = false
    bluestore_block_db_create = false
    bluestore_block_wal_create = false
    mon_allow_pool_delete = true
    bluestore_block_wal_separate = false
 debug objectcacher = 0/0
    debug paxos = 0/0
    debug journal = 0/0
    mutex_perf_counter = True
    rbd_op_threads = 4
    debug ms = 0/0
    debug mds = 0/0
    mon_pg_warn_max_per_osd = 10000
    debug lockdep = 0/0
    debug auth = 0/0
    ms_crc_data = False
    debug mon = 0/0
    debug perfcounter = 0/0
    perf = True
    debug monc = 0/0
    debug throttle = 0/0
    debug mds_migrator = 0/0
    debug mds_locker = 0/0
```

```
debug rgw = 0/0
   debug finisher = 0/0
   debug osd = 0/0
   debug mds_balancer = 0/0
   rocksdb_collect_extended_stats = True
   debug hadoop = 0/0
   debug client = 0/0
   debug zs = 0/0
   debug mds_log = 0/0
   debug context = 0/0
   rocksdb_perf = True
   debug bluestore = 0/0
   debug bluefs = 0/0
   debug objclass = 0/0
   debug objecter = 0/0
   debug log = 0
   ms_crc_header = False
   debug filer = 0/0
   debug rocksdb = 0/0
   rocksdb_collect_memory_stats = True
   debug mds_log_expire = 0/0
   debug crush = 0/0
   debug optracker = 0/0
   osd_pool_default_size = 2
   debug tp = 0/0
   cephx require signatures = False
   cephx sign messages = False
   debug rados = 0/0
   debug journaler = 0/0
   debug heartbeatmap = 0/0
   debug buffer = 0/0
   debug asok = 0/0
   debug rbd = 0/0
   rocksdb_collect_compaction_stats = False
   debug filestore = 0/0
   debug timer = 0/0
   rbd_cache = False
   throttler_perf_counter = False
```

```
▪     [mon]
▪        mon_data = /var/lib/ceph/mon.$id
▪        mon_max_pool_pg_num = 166496
▪        mon_osd_max_split_count = 10000
▪        mon_pg_warn_max_per_osd = 10000
▪     [osd]
▪        osd_data = /var/lib/ceph/mnt/osd-device-$id-data
▪        osd_mkfs_type = xfs
▪        osd_mount_options_xfs = rw,noatime,inode64,logbsize=256k
▪        bluestore_extent_map_shard_min_size = 50
▪        bluefs_buffered_io = true
▪        mon_osd_full_ratio = 0.97
▪        mon_osd_nearfull_ratio = 0.95
▪        bluestore_rocksdb_options =
      compression=kNoCompression,max_write_buffer_number=32,min_write_buffer_number
      _to_merge=2,recycle_log_file_num=32,compaction_style=kCompactionStyleLevel,write
      _buffer_size=67108864,target_file_size_base=67108864,max_background_compaction
      s=31,level0_file_num_compaction_trigger=8,level0_slowdown_writes_trigger=32,level0_
      stop_writes_trigger=64,num_levels=7,max_bytes_for_level_base=536870912,max_byte
      s_for_level_multiplier=8,compaction_threads=32,flusher_threads=8
▪        bluestore_min_alloc_size = 65536
▪        osd_op_num_threads_per_shard = 2
▪        osd_op_num_shards = 8
▪        bluestore_extent_map_shard_max_size = 200
▪        bluestore_extent_map_shard_target_size = 100
▪        bluestore_csum_type = none
▪        bluestore_max_bytes = 1073741824
▪        bluestore_wal_max_bytes = 2147483648
▪        bluestore_max_ops = 8192
▪        bluestore_wal_max_ops = 8192
▪
```

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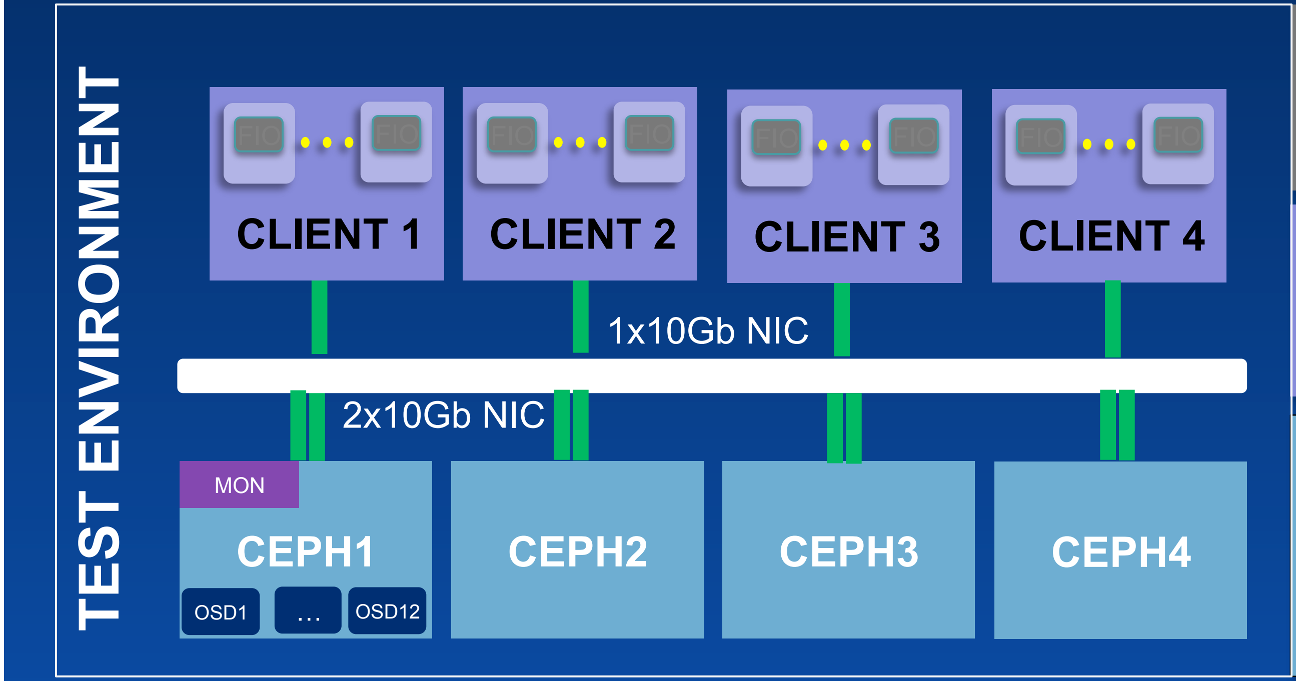
# Ceph* All Flash SATA configuration - IVB (E5 -2680 V2) + 6X S3700



TEST ENVIRONMENT

FIO • • • FIO

CLIENT 1

FIO • • • FIO

CLIENT 2

FIO • • • FIO

CLIENT 3

FIO • • • FIO

CLIENT 4

1x10Gb NIC

2x10Gb NIC

MON

CEPH1

OSD1 … OSD12

CEPH2

CEPH3

CEPH4

**WORKLOADS**

- Fio with librbd
- 20x 30 GB volumes each client
- 4 test cases: 4K random read & write; 64K Sequential read & write

**COMPUTE NODE**

2 nodes with Intel® Xeon™ processor x5570 @ 2.93GHz, 128GB mem
1 node with Intel Xeon processor E5 2680 @2.8GHz, 56GB mem

**STORAGE NODE**

Intel Xeon processor E5-2680 v2
32GB Memory
1xSSD for OS
6x 200GB Intel® SSD DC S3700
2 OSD instances each Drive

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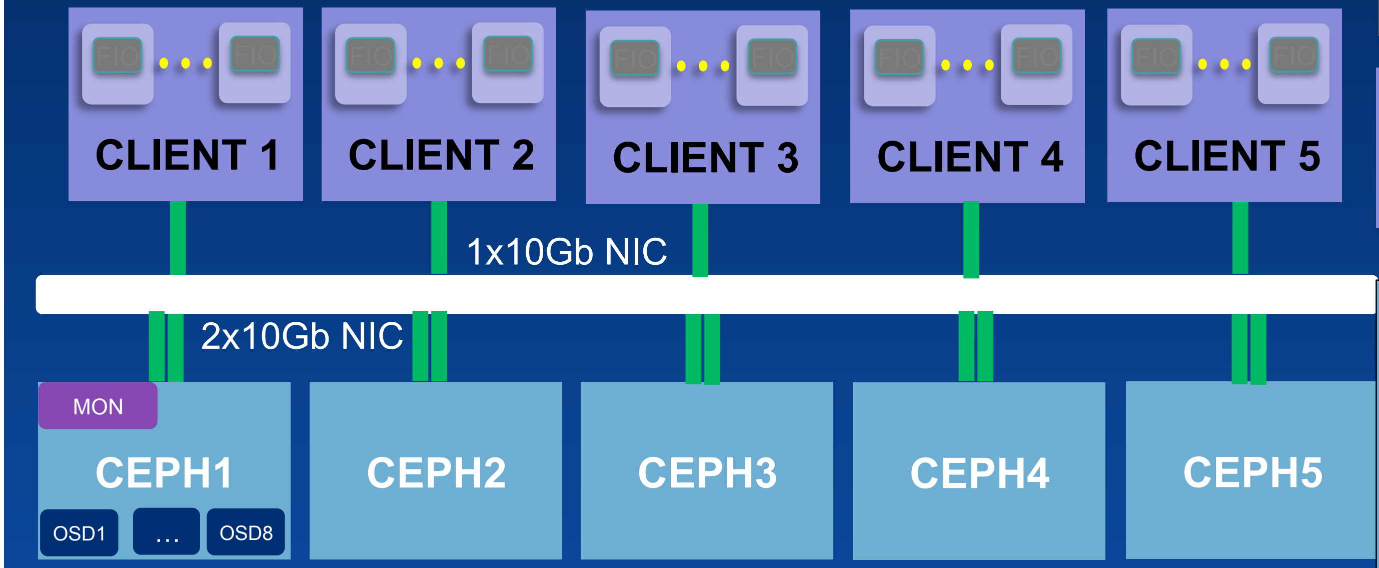
# Ceph* All Flash SATA configuration - HSW (E5 -2699 v3) + P3700 + S3510

## Test Environment



Workloads

- Fio with librbd
- 20x 30 GB volumes each client
- 4 test cases: 4K random read & write; 64K Sequential read & write

5x Client Node
Intel® Xeon® processor E5-2699 v3 @ 2.3GHz, 64GB memory
10Gb NIC

5x Storage Node
Intel Xeon processor E5-2699 v3 @ 2.3GHz, 64GB memory
1x Intel® DC P3700 800G SSD for Journal (U.2)
4x 1.6TB Intel® SSD DC S3510 as data drive
2 OSDs on single S3510 SSD

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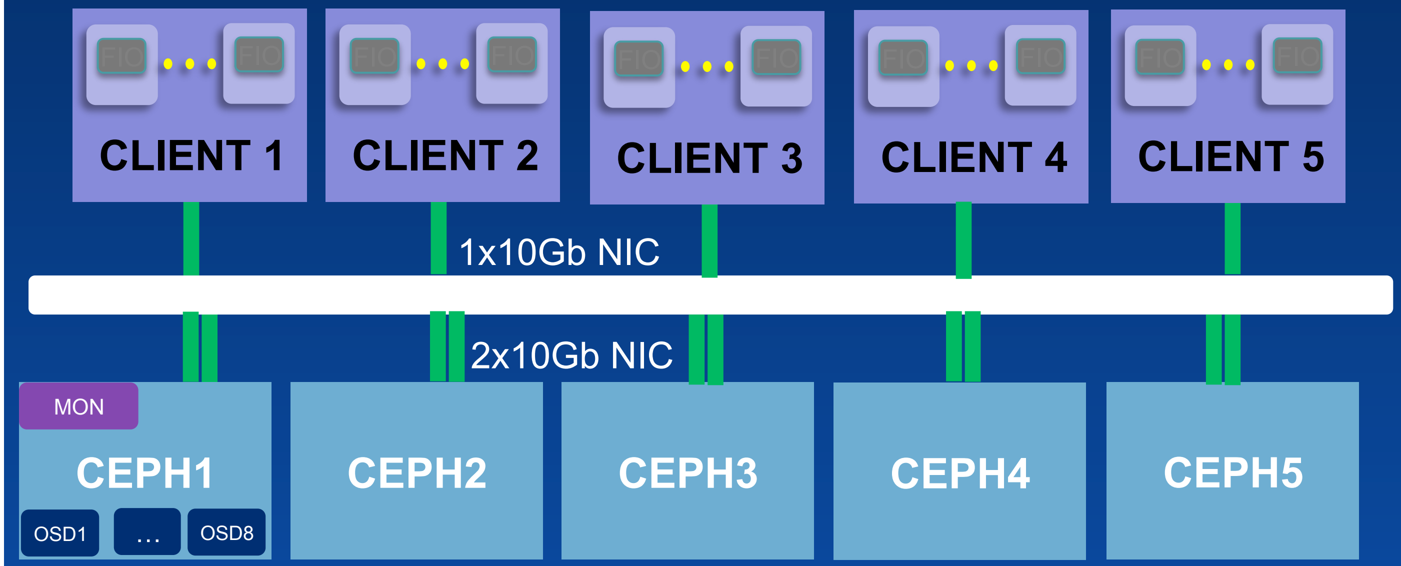
# Ceph* All Flash 3D NAND configuration - HSW (E5 -2699 v3) + P3700 + P3520

## Test Environment



Workloads

- Fio with librbd
- 20x 30 GB volumes each client
- 4 test cases: 4K random read & write; 64K Sequential read & write

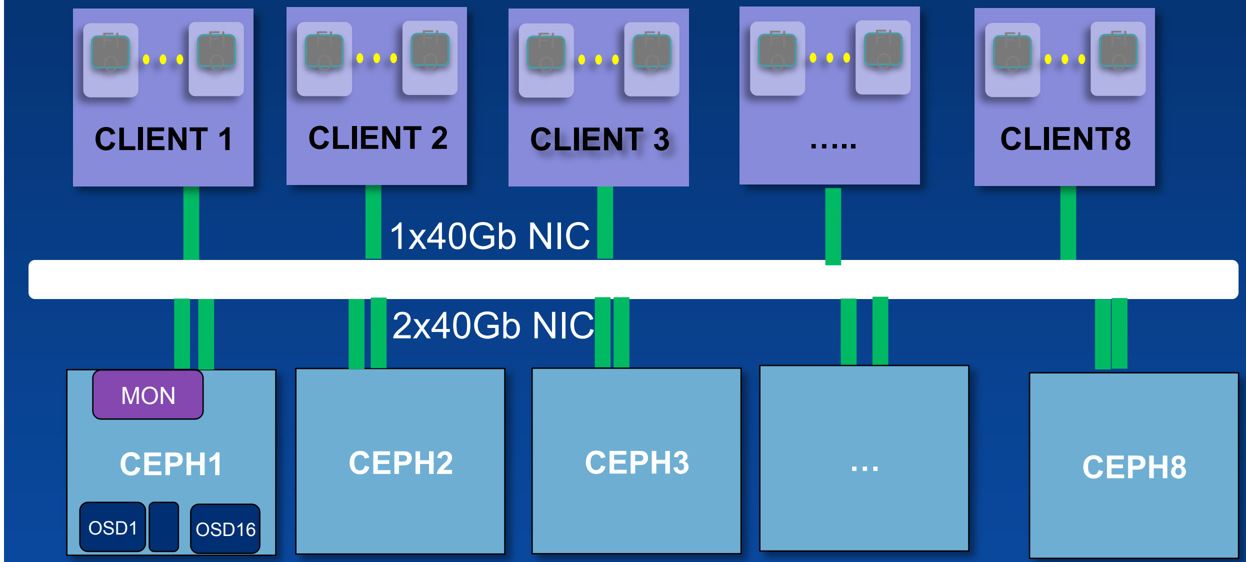
5x Client Node
Intel® Xeon™ processor E5-2699 v3 @ 2.3GHz, 64GB mem
10Gb NIC

5x Storage Node
Intel Xeon processor E5-2699 v3 @ 2.3 GHz
128GB Memory
1x 400G SSD for OS
1x Intel® DC P3700 800G SSD for journal (U.2)
4x 2.0TB Intel® SSD DC P3520 as data drive
2 OSD instances one each P3520 SSD

*Other names and brands may be claimed as the property of others.

# Ceph* All Flash Optane configuration
# - BDW (E5-2699 v4) + Optane + P4500

## Test Environment



Workloads
- Fio with librbd
- 20x 30 GB volumes each client
- 4 test cases: 4K random read & write; 64K Sequential read & write

8x Client Node
- Intel® Xeon™ processor E5-2699 v4 @ 2.3GHz, 64GB mem
- 1x X710 40Gb NIC

8x Storage Node
- Intel Xeon processor E5-2699 v4 @ 2.3 GHz
- 256GB Memory
- 1x 400G SSD for OS
- 1x Intel® DC P4800 375G SSD as WAL and rocksdb
- 8x 2.0TB Intel® SSD DC P4500 as data drive
- 2 OSD instances one each P4500 SSD
- Ceph 12.0.0 with Ubuntu 14.01

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