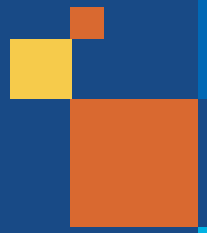
# Intel® Virtual RAID on CPU (Intel® VROC) Detailed Comparison to RAID HBA



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# Notices and Disclaimers

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Performance varies by use, configuration and other factors. Learn more at www.Intel.com/PerformanceIndex.

Performance results are based on testing as of dates shown in configurations and may not reflect all publicly available updates. See backup for configuration 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.

## Purpose:

Broad categorical comparison of Intel VROC (Integrated RAID) vs HW RAID HBAs on features, performance, latency, CPU% and power usage.

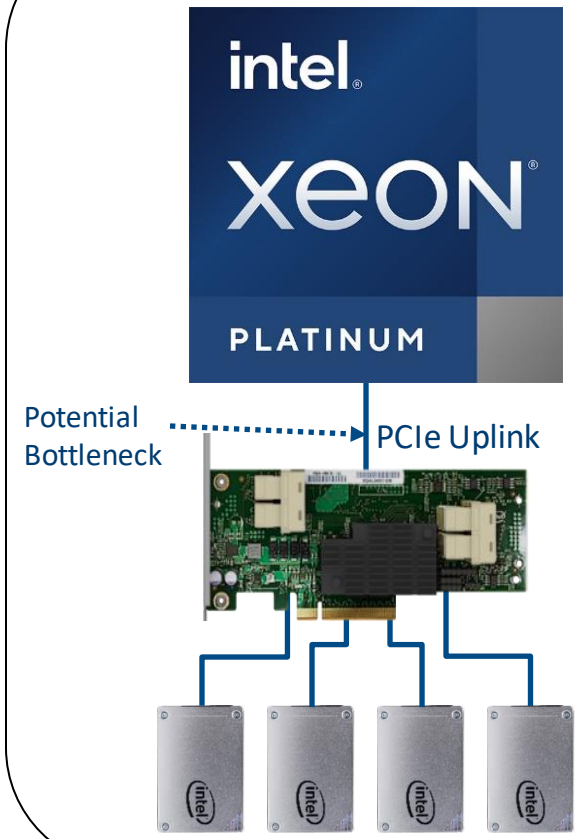
## Agenda:

1. Architecture and Feature Comparison
2. Key findings
3. Intel® Optane™ SSD Comparisons
4. Test Configuration Details
5. Pass-thru Mode (No RAID) Comparison
6. RAID0/1/5/10 Performance Results
7. Detailed RAID0/5 Review (Latency, CPU%, Power)

# Architecture and Feature Comparison

# Intel® VROC vs RAID HBA

## Legacy RAID Architecture




### RAID HBA

Product:
- MegaRAID 9560-16i

Category:
- HW RAID

PCIe Generation:
- Gen. 4

Storage Uplink:
- x8 PCIe Lanes

# Drives:
- 4 SSDs

### Intel VROC

Product:
- Intel VROC

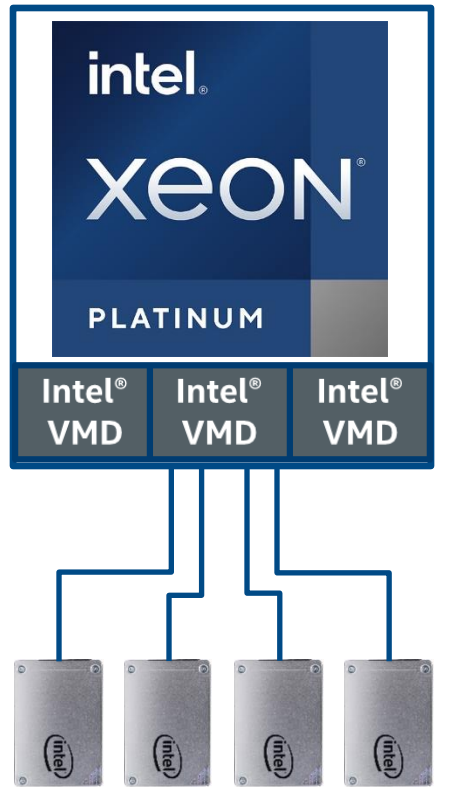
**Category:**
- **Integrated RAID**

PCIe Generation:
- Gen. 4

**Storage Uplink:**
- **X4 PCIe per SSD**

# Drives:
- 4 SSDs

## Intel® Xeon® Scalable Processor




**Intel® VROC onboards RAID HBA functionality onto Intel® Xeon® CPUs[1]**

1-Intel VROC and Intel VMD are available on all generations (Gen. 1, 2 and 3) and SKUs (Bronze, Silver, Gold, and Platinum) of Intel Xeon Scalable Processor

# Intel® VROC vs RAID HBA

| Major RAID Features | HW RAID | VROC | Intel® VROC Comment |
|---|---|---|---|
| Error Handling/Isolation | √ | √ | Both architectures isolates SSD error/event handling to reduce OS crash/reboot |
| Reliable data storage | √ | √ | Enterprise data protection, even when power loss occurs |
| Boot support | √ | √ | Redundant system volume = less down-time/crashes |
| In-band Management Tools | √ | √ | Various UEFI, GUI, and CLI Utilities for each |
| Out-of-band RAID Config. | √ | X | Intel VROC has OOB on roadmap for upcoming releases |
| Full NVMe SSD x4 Bandwidth | X | √ | Intel VROC + Intel VMD allows full x4 access to SSDs, no HW Uplink |
| RAID Processing Location | On HBA | On Intel® Xeon | Uses powerful Intel® Xeon® CPU to RAID the fast NVMe* SSDs. Better scaling for heavy workloads (see Detailed CPU Review) |
| Supported RAID Levels | 0/1/5/6/10/50/60 | 0/1/5/10 | RAID6/50/60 not needed for perf./AFR of NVMe SSDs |
| Write back cache | DRAM + BBU | Integrated Caching + Intel® Optane™ SSD | Replace DRAM WB Cache + BBU with persistent Intel® Optane™ media |
| SED Key Management | On HBA | Platform Integrated | Intel VROC uses platform protocols and remote KMS to manage keys |
| Idle Power[1] | 577W | 562W | Tested 15W reduction in Idle Power Usage with Intel VROC |

See backup for configuration details. For more complete information about performance and benchmark results, visit www.intel.com/benchmarks..

# Key Findings

# Summary (Highlights)[1,2]

1. Intel VROC has **compelling features to replace RAID HBA**, plus a roadmap to fill any gaps (OOB)
2. Intel VROC is the only RAID solution that scales with the Intel Optane SSD solution to deliver extraordinary performance (**Over 5.6M IOPS!**)
3. Intel VROC performance for all RAID levels is equal or better than RAID HBA (**↑ Performance, ↓ Latency**)
4. Intel VROC can improve resource utilization by removing the HBA and related choke points (**↓ CPU Usage, ↓ Power**)
5. Intel VROC has a scalable, integrated design that is better designed for NVMe SSDs (**↑ IOPS/CPU Core, ↑ IOPS/W**)

See backup for configuration details. For more complete information about performance and benchmark results, visit www.intel.com/benchmarks..

# Test Configuration Details

# Test Configuration Details (Optane)

Legacy RAID HBA


## 4 x 400GB Intel Optane P5800X SSDs

- Write Spec: 1,150,000 IOPS
- Read Spec: 1,500,000 IOPS

## Tested Configurations:

- Single Drive Performance
- 4x Drives pass-thru in parallel (no RAID)
- 4x Drive RAID0/5/10
- 2x Drive RAID1

## Workload Details:

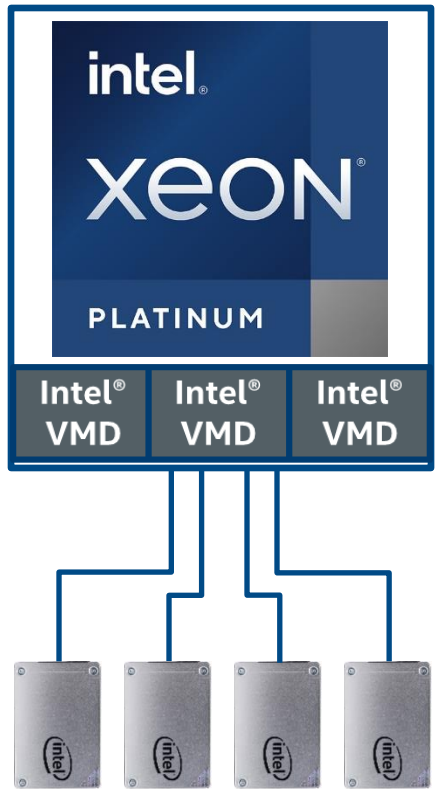
- 4k Random: 70/30 R/W
- 16 Threads, 16 IODepth

## Metrics

- Performance: IOPS
- Bandwidth: MB/sec
- Latency: µsec
- CPU Usage*: Effective Intel Xeon Cores used

## Data on Slides 11-14

**Intel® Xeon® Scalable Processor**




*CPU Usage measured as total platform CPU % consumption, includes workload generation, storage stack (RAID) usage, and background activity
Measured as "Cores Used" = CPU% report out * # cores on system (64 cores)

# Test Configuration Details (NAND)

Legacy RAID HBA


4x 3.84TB Intel D7 P5510 SSDs

- Write Spec: 170,000 IOPS
- Read Spec: 700,000 IOPS

Tested Configurations:

- Single Drive Performance
- 4x Drives pass-thru in parallel (no RAID)
- 4x Drive RAID0/5/10
- 2x Drive RAID1

Workload Details:

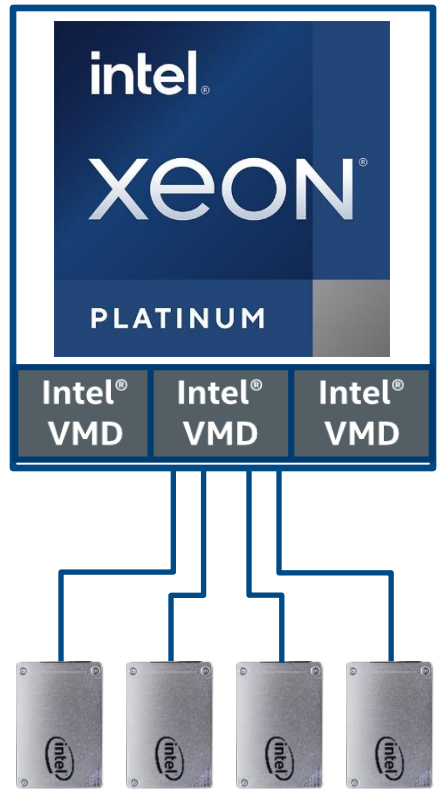
- 4k Random: 100% Reads, 70/30 R/W, 100% Writes
- 1 Threads, 1 IODepth (Isolate Storage Path)
- 16 Threads, 64 and 256 IODepth (Peak performance)

Metrics

- Performance: IOPS
- Power: Watts (Idle and under load)
- Latency: µsec
- CPU Usage*: Effective Intel Xeon Cores used

Data on slides15-28

Intel® Xeon® Scalable Processor




*CPU Usage measured as total platform CPU % consumption, includes workload generation, storage stack (RAID) usage, and background activity
Measured as "Cores Used" = CPU% report out * # cores on system (64 cores)

# Intel Optane Comparisons

# RAID Levels Performance Comparison[1]

Intel® Optane™ SSDs: 16 Thread, 16 IODepth: 70/30 R/W

Intel VROC achieves up to 5.6 million IOPS with RAID0 on mixed workloads

Intel VROC has up to:

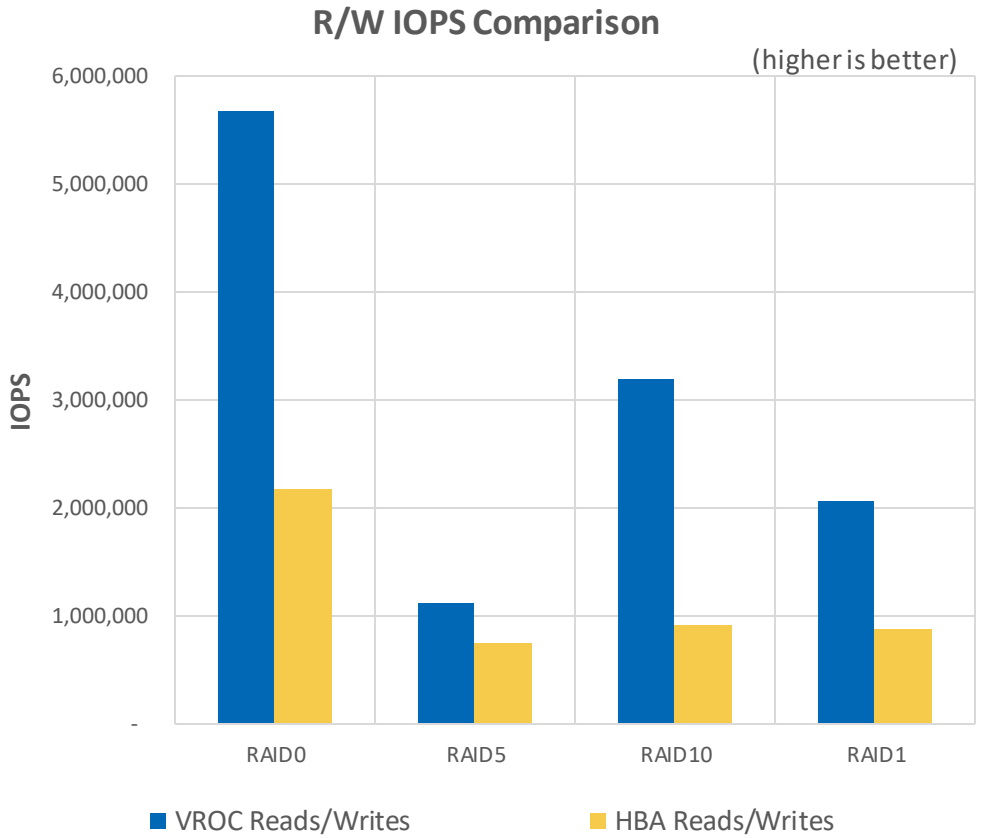
**161% more IOPS on RAID0**

**50% more IOPS on RAID5**

**248% more IOPS on RAID10**

**138% more IOPS on RAID1**

Intel VROC RAID5 > HBA RAID10 performance




See backup for configuration details. Results may vary

# RAID0 Simultaneous Read/Write Comparison[1]

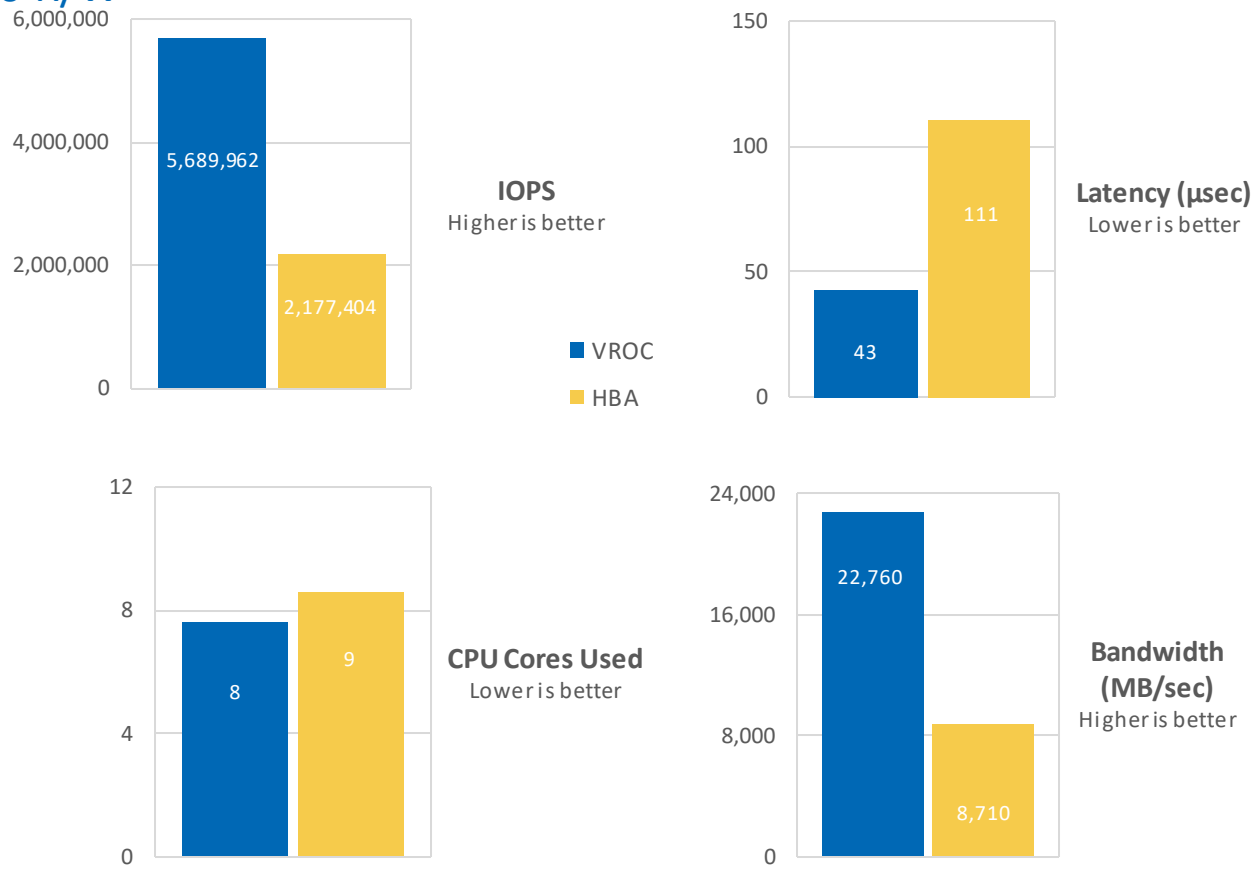
## Intel® Optane™ SSDs: 16 Thread, 16 IODepth: 70/30 R/W

Intel VROC RAID0 reads/writes provides:

- ↑ **IOPS**
- ↓ **Latency**
- ↓ **CPU Usage**
- ↑ **Bandwidth**

RAID0 provides higher performance metrics but with lower resource usage (CPU)

**Up to 161% more Read/Write IOPS**
**Up to 61% lower latency**




See backup for configuration details. Results may vary

# RAID5 Simultaneous Read/Write Comparison[1]

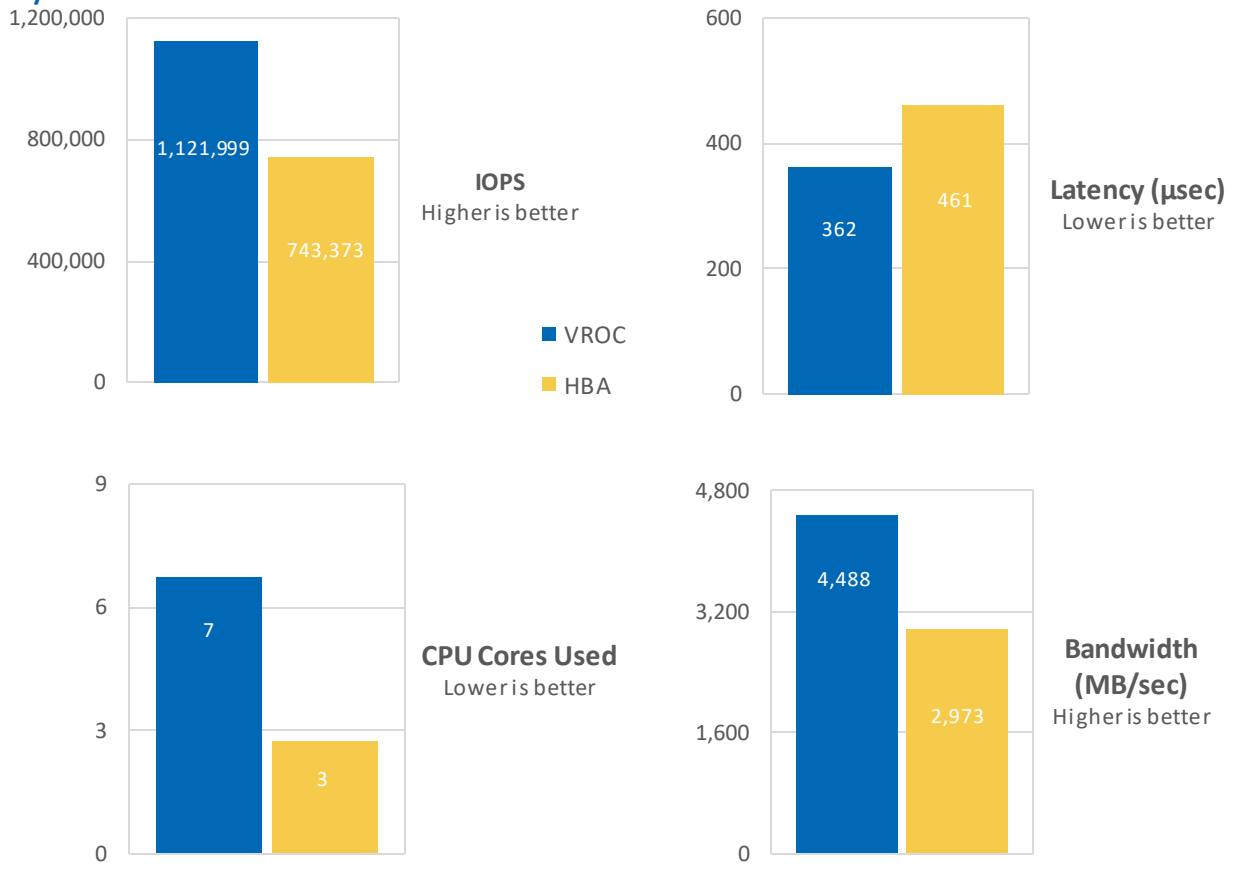
## Intel® Optane™ SSDs: 16 Thread, 16 IODepth: 70/30 R/W

Intel VROC RAID5 reads/write provides:

- **↑ IOPS**
- **↓ Latency**
- ↑ CPU Usage*
- **↓ Bandwidth**

*RAID5 uses 4 more cores but delivers up to 380K additional IOPS

**Up to 50% more Read/Write IOPS**
**Up to 50% more Bandwidth**



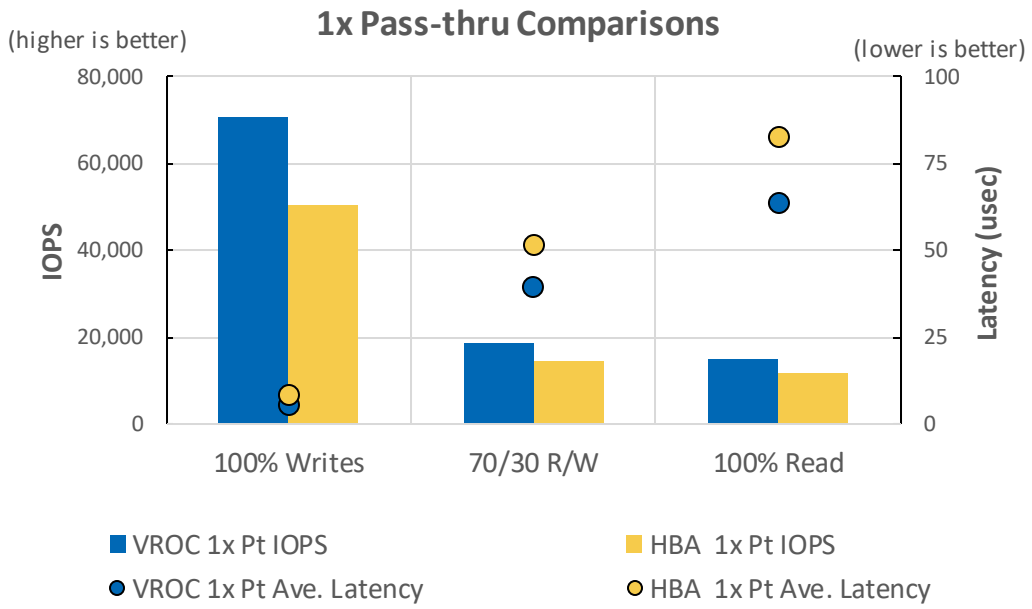

See backup for configuration details. Results may vary

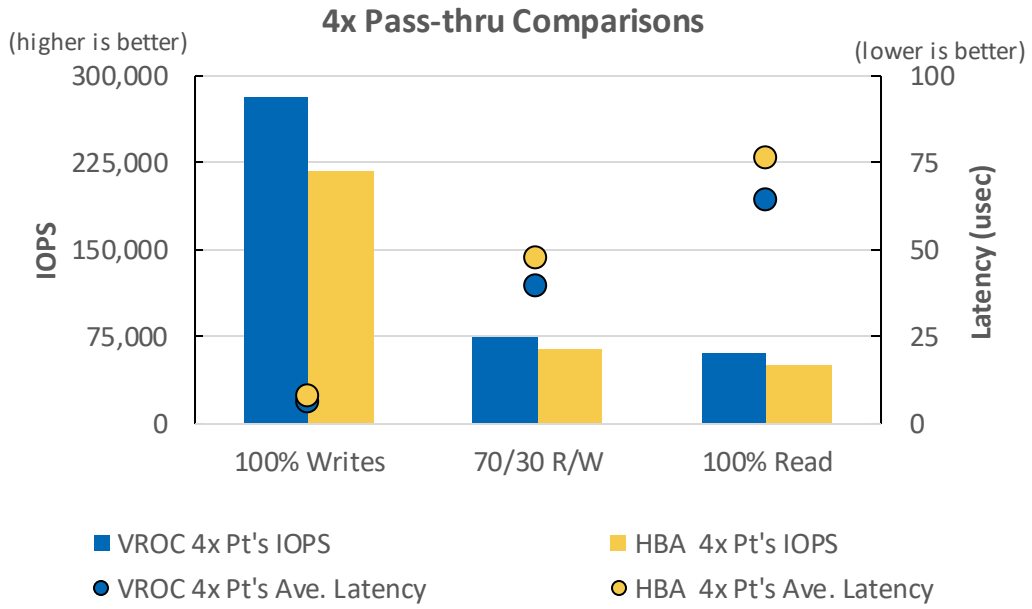
# NAND SSD Comparisons

# Pass-thru Mode (No RAID) Comparison

# Low Workload, Pass-Thru Comparison[2]

## NAND SSDs: 1 Thread, 1 IODepth




**Intel VROC provides unimpeded access to storage for lower latency I/0**

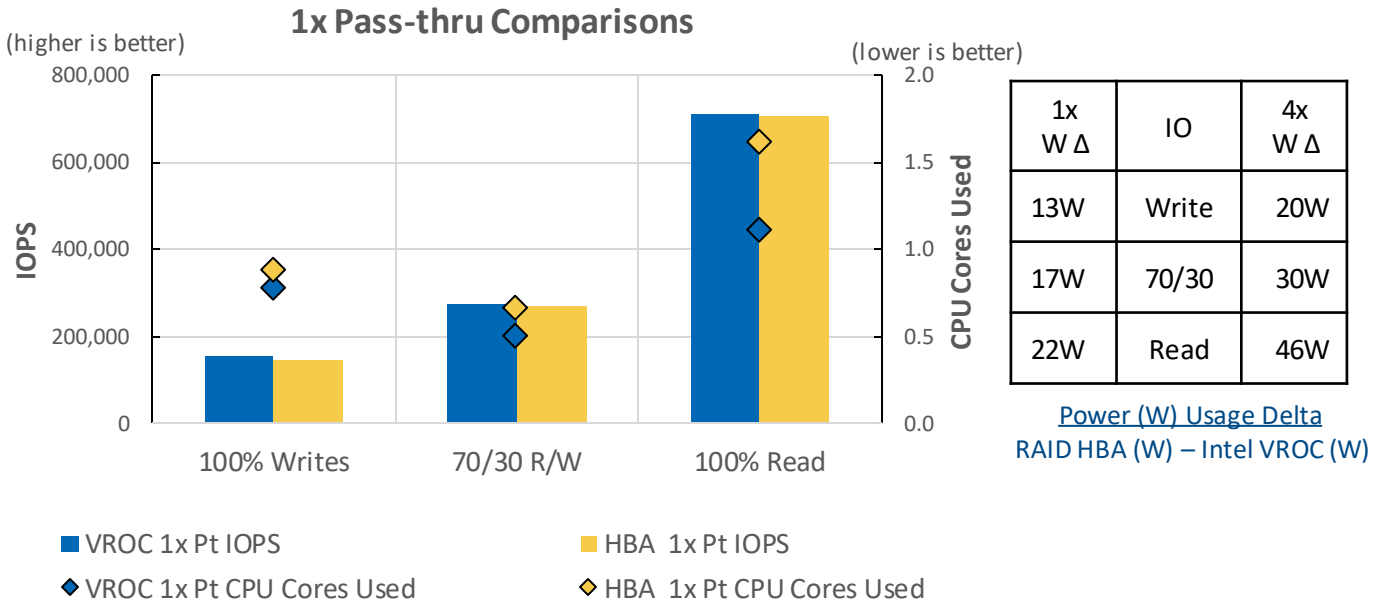
- Single Drive, 100% Write: {**40% IOPS ↑, 32% Latency ↓**}
- Single Drive, 100% Read: {**29% IOPS ↑, 23% Latency ↓**}

Single drive performance improvements scales to multiple drives

See backup for configuration details. Results may vary

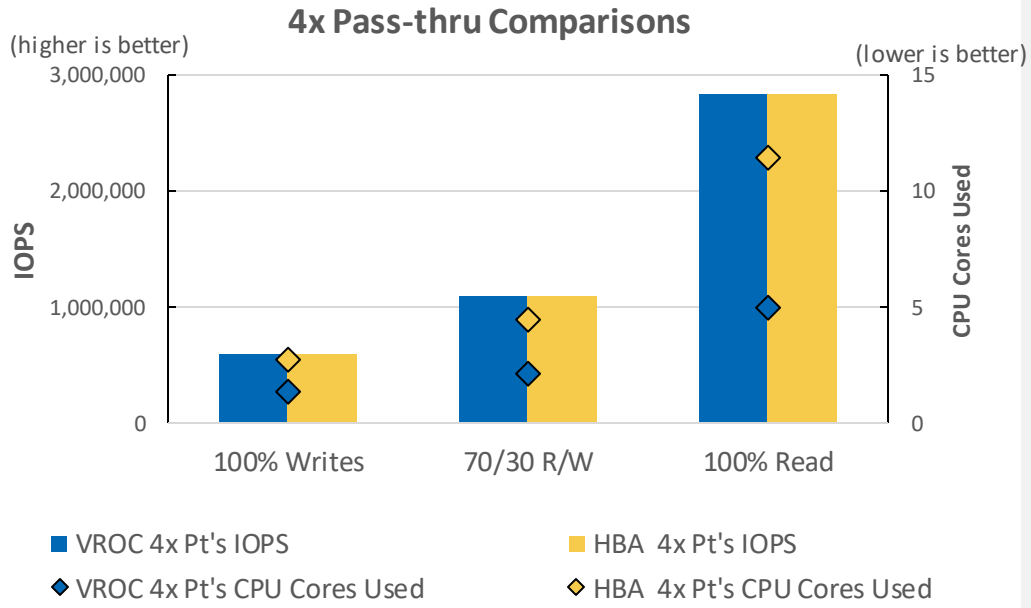
# Peak Performance, Pass-Thru Comparison[2]

## NAND SSDs: 16 Thread, 64 IODepth




| 1x W Δ | IO | 4x W Δ |
|---|---|---|
| 13W | Write | 20W |
| 17W | 70/30 | 30W |
| 22W | Read | 46W |

Power (W) Usage Delta
RAID HBA (W) – Intel VROC (W)




Higher workloads saturate the storage on both solutions

- Latency differences are masked, performance becomes equivalent

Other architecture differences are exposed: Power and CPU usage

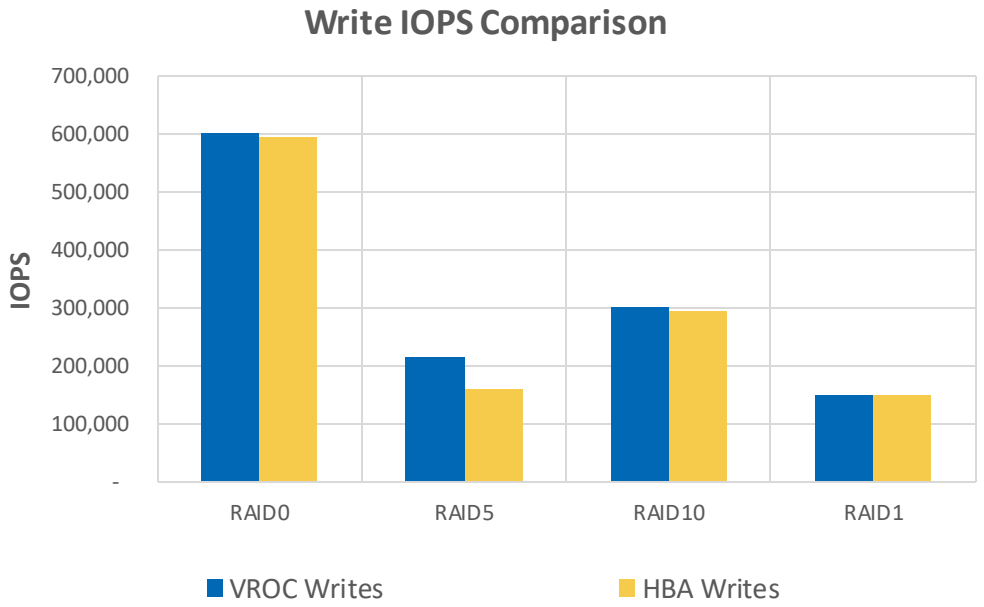
- Additional HBA power draw creates positive WΔ; **Intel VROC ↓ Power**
- RAID HBA on card processing is oversaturated by larger workloads; **Intel VROC ↓ CPU Usage** (See detailed CPU Review)

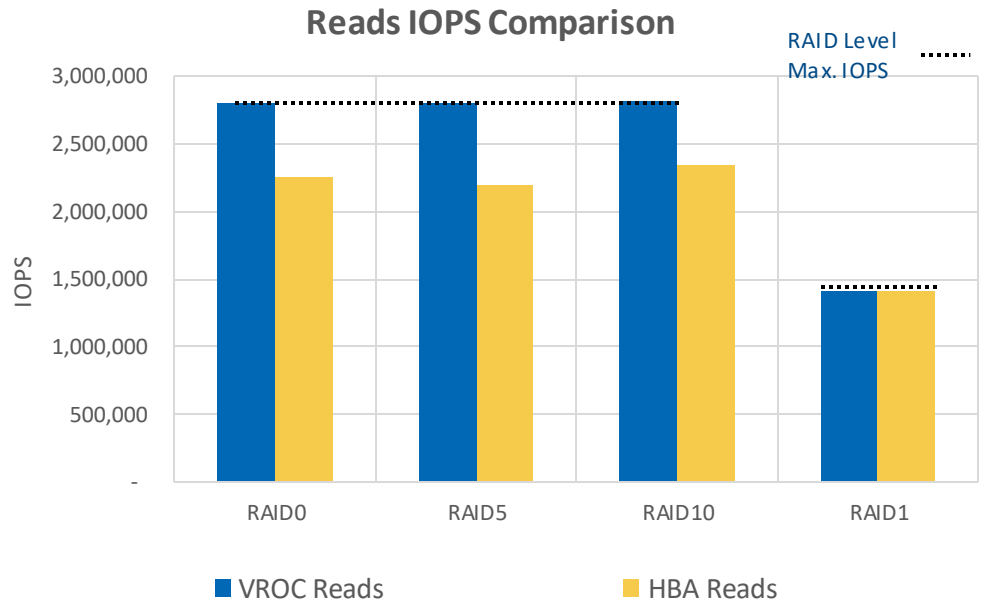
See backup for configuration details. Results may vary

# RAID0/1/5/10 Performance Results

# RAID Levels Performance Comparison[2]

## NAND SSDs: 16 Thread, 64 IODepth




- Intel VROC has **33% more IOPS on RAID5 writes**

Intel VROC Read Performance scales to maximum 4x SSD Spec (~2.8M IOPS RAID0/5/10)

- HBA hits 2.2M IOPS Bottleneck; **Intel VROC delivers up to 27% more IOPS on RAID0/5/10 reads**

See backup for configuration details. Results may vary

# Detailed RAID0/5 Review (Latency, CPU%, Power)

# RAID0/5 Read Comparison[2]

NAND SSDs: 16 Thread, 64 IODepth

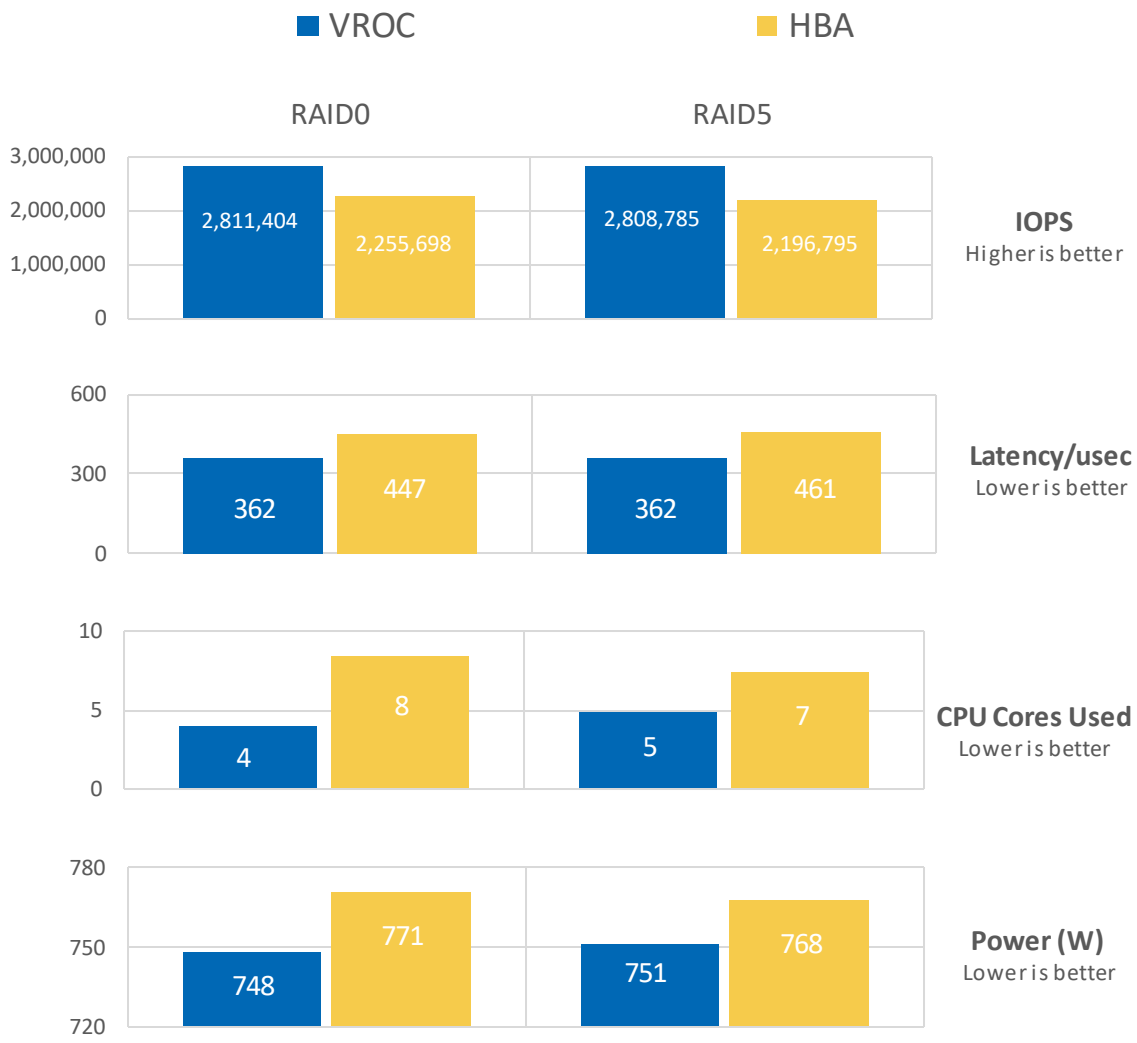
Intel VROC RAID0/5 reads provides:

- ↑ **IOPS**
- ↓ **Latency**
- ↓ **CPU Usage**
- ↓ **Power Consumption**

Integrated RAID is a more effective RAID architecture for NVMe SSDs

**Up to 30% more Read IOPS/W**

**Up to 164% more Read IOPS/CPU Cores Used**




See backup for configuration details. Results may vary

# RAID0/5 Write Comparison[2]

NAND SSDs: 16 Thread, 64 IODepth

Intel VROC RAID0/5 reads provides:

- ↑ **IOPS**
- ↓ **Latency**

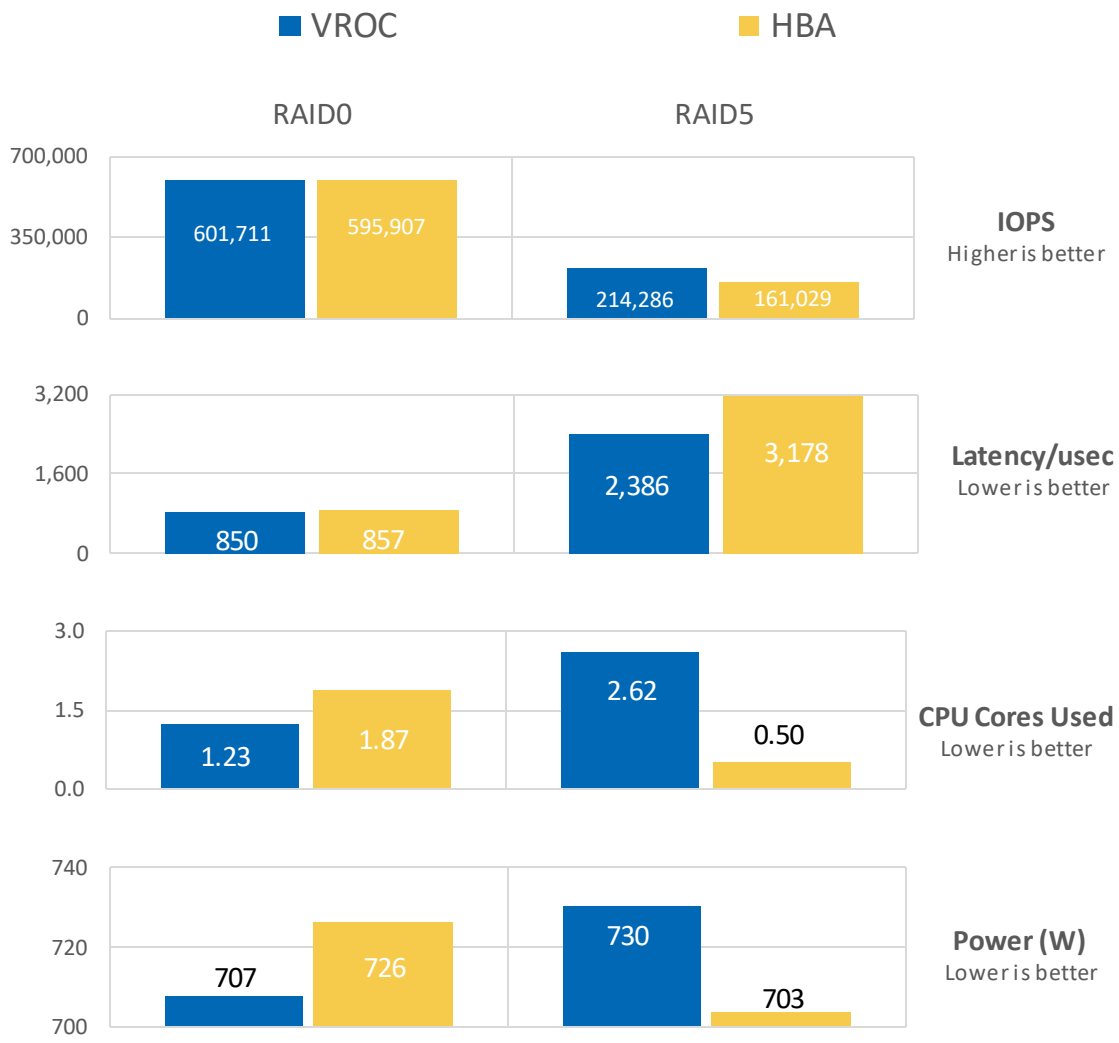
RAID 0 also ↓ **CPU Usage and Power Usage**

RAID5 provides higher performance metrics but with higher resource usage (CPU and Power)....

**This is not the whole story**

**Up to 28% more Write IOPS/W**

**See 'CPU% Usage Explained' for more**



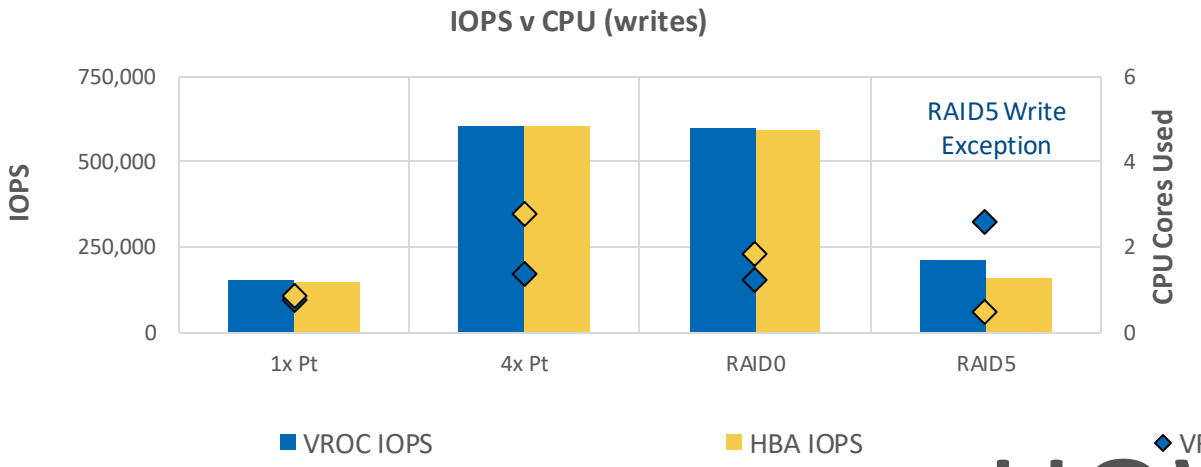

See backup for configuration details. Results may vary

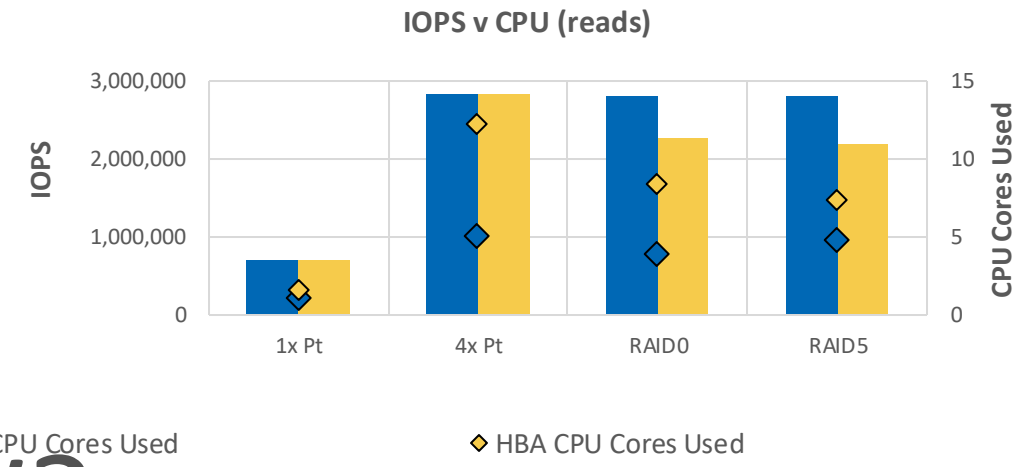
# CPU% Usage Explained

# CPU% Usage-Perception[2]

**Common perception:** RAID HBA consumes less host CPU resources due to HBA offload

**Reality**: **Intel VROC can deliver ↑ performance and consumes ↓ CPU resources!**




HOW?

See backup for configuration details. Results may vary

# CPU% Usage-Reality Explained[2]

## NVMe SSD performance can overwhelm RAID HBA offload design

16 Threads 64 IODepth → 100k's Write IOPS and 1M's Read IOPS

## HBA architecture has choke points that can bottleneck performance:

1. Limited PCIe Uplink (x8 PCIe lanes)
2. Fixed amount of RAID processing
3. SCSi-based RAID stack


Full x4 bandwidth per NVMe SSD

Scaled compute on powerful Intel Xeon

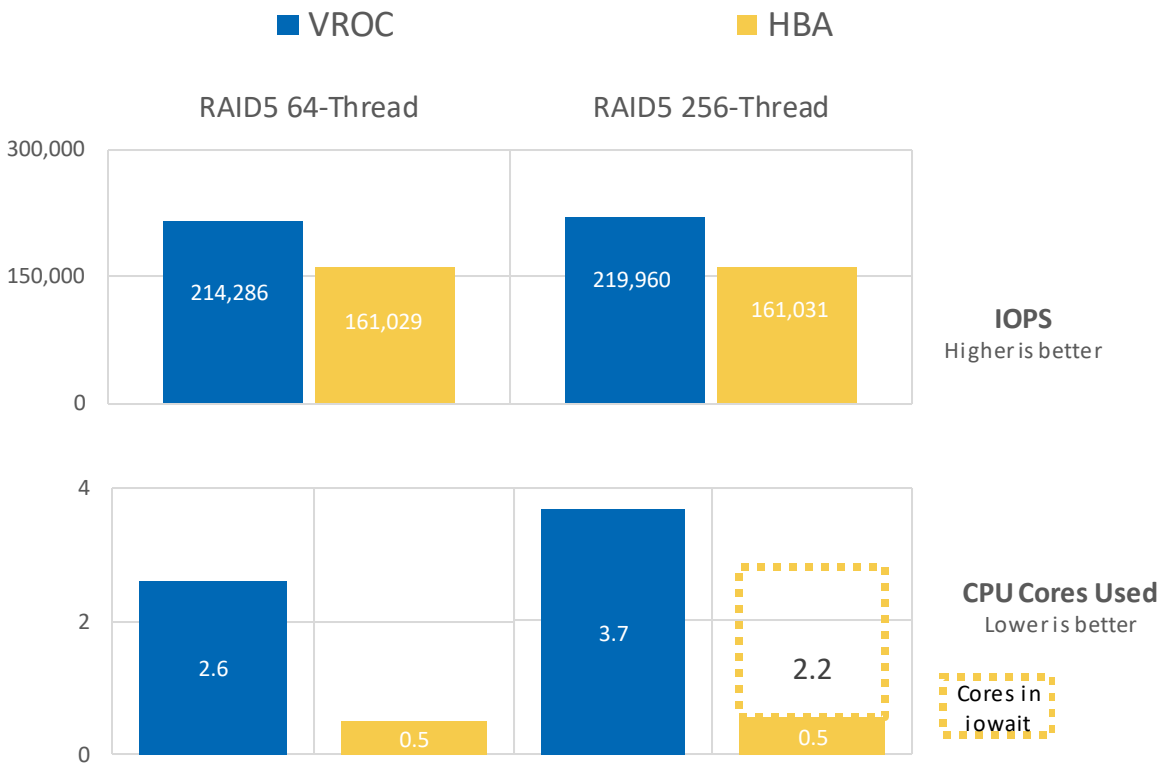
NVMe optimized RAID stack

**These limitations cause thrash on CPU%....and can lead to iowait%**

See backup for configuration details. Results may vary

# iowait% Closer Look[2]

## NAND SSDs: 16 Thread, 64 IODepth → 16 Thread, 256 IODepth




RAID5 writes require high CPU%

- Highest of any Intel VROC supported RAID level per IOP

RAID HBA offload generates iowait at higher workloads:

- If limits of HBA architecture are reached (more IO), host CPU usage ramps up in iowait%
- Iowait could be wasted cycles depending on application

Intel VROC is more efficient for RAID5 writes:

**No ramping of iowait**

**Up to 4% more Write IOPS/CPU Cores Used***

*when accounting for iowait%

See backup for configuration details. Results may vary

# CPU% Usage-Customer Impact

Server design must plan for **Peak Storage Load**

**Peak Storage Load (PSL):** Max. IO during data center operation

| RAID Solution Response to PSL | RAID HBA | Intel VROC |
|---|---|---|
| | • Bottleneck performance<br>• Iowait% ramp and higher latency<br>• Operational Thrash if storage architecture not properly planned | • Scale performance to absorb PSL<br>• Proportionally ramp CPU usage and latency<br>• Mitigate server thrash with fewer CPU cores dedicated for RAID |

**Intel VROC servers often require fewer CPU cores to handle Peak Storage Load**

See backup for configuration details. Results may vary

# Backup

# Configuration Details

**1. Intel VROC vs RADI HBA Comparison (Optane)**
**System configuration**: Beta Coyote Pass M50CYP2SB2U/M50CYP2SBSTD (chassis M50CYP2UR208BPP), 2 x Intel® Xeon® Platinum 8358 CPU @ 2.60GHz, 32 cores each, DRAM 128GB , BIOS Release 04/02/2021, BIOS Version: SE5C6200.86B.0020.P24.2104020811
**OS**: RedHat* Enterprise Linux 8.1, kernel-4.18.0-147.el8.x86_64, mdadm - v4.1 - 2018-10-01, Intel® VROC Pre-OS version 7.5.0.1152
**Storage**: Both configurations used 4 x 400GB Intel Optane P5800X PCIe Gen4 U.2 SSDs (Model: SSDPF21Q400GB, Firmware: L0310100) connected to backplane which is connected via SlimSAS cables directly to a Broadcom 9560-16i (x8) card on Riser 2, PCIe slot 1 on CPU2 **BIOS setting**: SpeedStep(Enabled), Turbo(Enabled), ProcessorC6(Enabled), PackageC-State(C0/C1 State), CPU_PowerAndPerformancePolicy(Performance), HardwareP-States(NativeMode), WorkloadConfiguration(I/O Sensitive)
**RAID Configurations:** 4-Disk RAID0/5/10 and 2-Disk RAID1 with Intel VROC and Broadcom MegaRAID 9560-16i
**Workload Generator**: FIO 3.25, 16-thread 16-IODepth
Performance results are based on testing as of 6/25/2021 and may not reflect all publicly available updates. See configuration disclosure for details. No product can be absolutely secure.

# Configuration Details

**2. Intel VROC vs RADI HBA Comparison (NAND)**
**System configuration**: Beta Coyote Pass M50CYP2SB2U/M50CYP2SBSTD (chassis M50CYP2UR208BPP), 2 x Intel® Xeon® Platinum 8358 CPU @ 2.60GHz, 32 cores each, DRAM 128GB , BIOS Release 03/22/2021, BIOS Version: SE5C6200.86B.0022.D08.2103221623
**OS**: RedHat* Enterprise Linux 8.1, kernel-4.18.0-147.el8.x86_64, mdadm - v4.1 - 2018-10-01, Intel® VROC Pre-OS version 7.5.0.1152
**Storage**: Both configurations used 4x 3.84 TB Intel® D7-P5510 Series SSDs (Model: SSDPF2KX038TZ, Firmware: JCV10016) connected to internal backplane. With Intel VROC config, backplane connect directly to CPU2 via SlimSAS. With RAID HBA, backplane connect to RAID HBA on Riser 2, PCIe slot 1 on CPU2
**BIOS setting**: SpeedStep(Enabled), Turbo(Enabled), ProcessorC6(Enabled), PackageC-State(C0/C1 State), CPU_PowerAndPerformancePolicy(Performance), HardwareP-States(NativeMode), WorkloadConfiguration(I/O Sensitive)
**RAID Configurations:** 4-Disk RAID0/5/10 and 2-Disk RAID1 with Intel VROC and Broadcom MegaRAID 9560-16i
**Workload Generator**: FIO 3.25, 1-thread 1-IODepth, 16 thread 64/256 IODepth
Performance results are based on testing as of 5/3/2020 and may not reflect all publicly available updates. See configuration disclosure for details. No product can be absolutely secure.