Break Through the Bottlenecks With

INTEL® OPTANE™ TECHNOLOGY
And Store More With

INTEL® QLC 3D NAND TECHNOLOGY

Rob Crooke
Senior Vice President, GM
Non-Volatile Memory (NVM) Solutions Group
NSG STRATEGY: ADJACENT, DISRUPTIVE GROWTH

TECHNOLOGY DRIVEN

PLATFORM CONNECTED

CUSTOMER INSPIRED
COMPUTER STORAGE ARCHITECTURE

CAPACITY DATA

Large Capacity

WORKING DATA

Fast Access
INTEL IS A LEADER IN TWO TECHNOLOGIES

INTEL® 3D NAND TECHNOLOGY
LOWER COST AND HIGHER DENSITY
Bulk storage

INTEL® OPTANE™ TECHNOLOGY
HIGHER PERFORMANCE
Working storage and memory

Intel® 3D NAND SSD
Intel® Optane™ SSD
Hard Disk Drive

LOWE R COST  HIGHER  LESS DELAY  MORE
INTEL® OPTANE™ TECHNOLOGY
INTEL® 3D XPOINT™ MEMORY MEDIA

Cross Point Structure
Selectors allow dense packing and individual access to bits

Breakthrough Material Advances
Compatible switch and memory cell materials

Scalability
Memory layers can be stacked in a 3D manner

High Performance
Cell and array architecture that can switch states much faster than NAND
INTEL® OPTANE™ TECHNOLOGY

BUILDING BLOCKS

Intel® 3D XPoint™ Memory Media

Intel Interconnect IP

Inte Software

Intel Memory and Storage Controllers

END-USER VALUE

High Endurance

Responsive under load
Low latency

Predictably fast service
QoS

Breakthrough performance
IOPS

Latency (µS)

Drives

HDD (SAS/SATA)

NAND SSDs (SAS/SATA)

NAND SSDs (NVMe*)

Intel® Optane™ SSDs (NVMe*)

1Source – Intel-tested: Average read latency measured at queue depth 1 during 4K random write workload. Measured using FIO 3.1. Common Configuration – Intel 2U Server System, OS CentOS 7.5, kernel 4.17.6-1.el7.x86_64, CPU 2 x Intel® Xeon® 6154 Gold @ 3.0GHz (18 cores), RAM 256GB DDR4 @ 2666MHz. Configuration – Intel® Optane™ SSD DC P4800X 375GB and Intel® SSD DC P4600 1.6TB. Latency—Average read latency measured at QD1 during 4K Random Write operations using FIO 3.1. Intel Microcode: 0x2000043; System BIOS: 00.01.0013; ME Firmware: 04.02.004; BMC Firmware: 1.43.0f; FRUSDR: 1.43. SSDs tested were commercially available at the time of test. The benchmark results may need to be revised as additional testing is conducted. Performance results are based on testing as of July 24, 2018 and may not reflect all publicly available security updates. No product can be absolutely secure. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations, and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit www.intel.com/benchmarks. *Other names and brands may be claimed as the property of others.
A CLEAR ADVANTAGE: INTEL® XEON® AND INTEL® OPTANE™ TECHNOLOGY

VM Performance (IOmark-VM): 4-Node HCI

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Performance (VM)</th>
<th>Price ($/VM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash+HDD Intel® SSD DC P3700+HDD</td>
<td>88</td>
<td>$2,153</td>
</tr>
<tr>
<td>All-Flash 2D Intel® SSD DC P3700 + Intel® SSD DC S3510</td>
<td>320</td>
<td>$684</td>
</tr>
<tr>
<td>All-Flash 3D Intel® SSD DC P4600 + DC P4500</td>
<td>704</td>
<td>$323</td>
</tr>
<tr>
<td>All-Flash with Intel® Optane™ DC P4800X + Intel® SSD DC P4500</td>
<td>1152</td>
<td>$216</td>
</tr>
</tbody>
</table>

Tests by The Evaluator Group. See config details at https://www.evaluatorgroup.com/document/lab-insight/latest-intel-technologies-power-new-performance-levels-vmware-vsan-2018-update/. Tested using IOmark-VM. Performance results are based on testing as of August 20, 2018 and may not reflect all publicly available security updates. See product configuration disclosure details. No product can be absolutely secure. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit www.intel.com/benchmarks.

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## VMware vSAN* Storage Consolidation vs. 3D NAND SSDs

**Goal:** Achieve about 1000 IOMark VMs*

<table>
<thead>
<tr>
<th># of Nodes Required</th>
<th>CURRENT-GEN ALL-FLASH SOLUTION</th>
<th>INTEL® OPTANE™ DC SSD-BASED SOLUTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 NODE CLUSTER</td>
<td>1056</td>
<td>1152</td>
</tr>
<tr>
<td></td>
<td>~$365,000 USD</td>
<td>~$270,000 USD</td>
</tr>
<tr>
<td>Estimated 3-year Server Costs (lower is better)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Summary:
- **Up to 30%** the storage consolidation
- **60%** the IOMark* VMs per Node
- **25%** Lower 3-year estimated cost

**Same CPU**
- **Swapped in Intel® Optane™ SSD**

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1. Tests by The Evaluator Group. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit www.intel.com/benchmarks. Configuration details available from The Evaluator Group at https://www.evaluatorgroup.com/document/lab-insight-latest-intel-technologies-power-new-performance-levels-vmware-vsan-2018-update/. See Appendix A for server cost estimate details and assumptions.
2. Source – Intel. Estimated HW, SW, MEDIA, MAINT costs = $348,000; Estimated power & infrastructure costs = $17,000. 6-node 3D NAND-based cluster needed to support the approximate same number of VMs vs. 4-Node Intel® Optane™ SSD Configuration.
3. Source – Intel. Estimated HW, SW, MEDIA, MAINT costs = $265,000; Estimated power & infrastructure costs = $15,000.
4. Other names and brands may be claimed as the property of others.
## VMware vSAN* Storage Consolidation Upgrade Scenario

### Prior-Gen All-Flash Solution

- **# of Nodes Required:** 14 Node Cluster
- **IOMark VMs (higher is better):** 1120
- **Estimated 3-year Server Costs (lower is better):** ~$810,000 USD

**CPU:** Intel® Xeon® E5-2699 v4 Processor  
**Cache:** Intel® SSD DC P3700 (PCIe*)  
**Capacity:** Intel® SSD DC S3510 (SATA)  
**Software:** VMware vSAN® 6.2


### Intel® Optane™ DC SSD-Based Solution

- **# of Nodes Required:** 4 Node Cluster
- **IOMark VMs (higher is better):** 1152
- **Estimated 3-year Server Costs (lower is better):** ~$270,000 USD

**CPU:** Intel® Xeon® Gold 6154 Processor  
**Cache:** Intel® Optane™ SSD DC P4800X  
**Capacity:** Intel® SSD DC P4500 (PCIe*)  
**Software:** VMware vSAN® 6.2

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1. Tests by The Evaluator Group. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information visit [www.intel.com/benchmarks](http://www.intel.com/benchmarks).

2. Source – Intel. Estimated HW, SW, MEDIA, MAINT costs = $785,000. Estimated power & infrastructure costs = $25,000. 14-node 2D NAND-based cluster needed to support the approximate same number of VMs vs. 4-node Intel® Optane™ SSD Configuration.


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INTEL® PORTFOLIO FOCUS

CLIENT

INTEL® OPTANE™ MEMORY

INTEL® OPTANE™ SSDs

INTEL® 3D QLC NAND SSDs

DATA CENTER

DRAM

Expanded Memory

Working Data

Capacity Data

HDD

INTEL® OPTANE™ DC PERSISTENT MEMORY

INTEL® OPTANE™ DC SSDs

INTEL® 3D QLC NAND SSDs

Products not shown to scale
NEXT GENERATION DATA CENTER STORAGE
INNOVATIVE FORM FACTORS

1PB IN 42U
w/2 TB HDDs

1PB IN 1U
w/INTEL® 3D NAND SSDs
THE FUTURE OF CLIENT STORAGE & MEMORY
Higher Performance, Lower Cost, Easier Migration

WORKING DATA

OPTIONS FOR CAPACITY DATA

EXPANDABLE
External Card

REMOVABLE
USB / TBT

CLOUD
5G

DISRUPT WITH INTEL® OPTANE™ TECHNOLOGY
DISCIPLINED INVESTMENT

**INTEL® OPTANE™ TECHNOLOGY**

Intel Fab 11X: Rio Rancho, New Mexico

**INTEL® 3D NAND TECHNOLOGY**

Intel Fab 68: China

Based on internal forecasting 2016-2017. Forecasts are Intel estimates, based upon current expectations and available information and are subject to change without notice.
APPENDIX A - VMWare vSAN* SERVER TESTING AND COST ESTIMATES

Source: The Evaluator Group tested. Config details at https://www.evaluatorgroup.com/document/lab-insight-latest-intel-technologies-power-new-performance-levels-vmware-vsan-2018-update/. Tested using IOmark-VM*. System Cost based on publicly available list prices for storage, CPU, memory, networking, chassis, software as of October 16, 2018. Networking switches/cabling costs not considered. Licensing cost included as appropriate. Operating Expenses calculated over 3 year window, factoring in: System Power is sum of the system TDP (CPU TDP and 90/10 read/write active power for SSD as shown at ark.intel.com). A 1.2 (20% inefficiency) Power Usage Effectiveness (PUE) multiplier is applied across total cluster wattage. $0.12 KW/hour price is applied over 3 year 24/7/365 usage. Footprint is estimated cost of solution rack space. $96/sq ft/yr cost is applied with each rack using 25 sq ft. One rack has maximum 24 KW power limit, up to 42U available rack height. Full and partial racks incur same footprint cost. Cluster Size - a target performance metric is chosen based on example customer requirements, and per system performance is applied to estimate number of servers to meet requirement. 100% performance scaling assumed unless otherwise noted. Cost reduction scenarios described are intended as examples of how a given Intel® based product, in the specified circumstances and configurations, may affect future costs and provide cost savings. Circumstances will vary. Intel does not guarantee any costs or cost reduction. Performance results are based on testing as of August 20, 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product can be absolutely secure. Software and workloads used in performance tests may have been optimized for performance only on Intel microprocessors. Performance tests, such as SYSmark and MobileMark, are measured using specific computer systems, components, software, operations and functions. Any change to any of those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products.
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