INTEL® OPTANE™ SSD DC P4800X WITH INTEL® MEMORY DRIVE TECHNOLOGY

OVERVIEW

March 2019
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In-memory computing is driving the memory scale-up market.

- Large memory pool
- Analytics/statistics
- Cloud/hyperscale
- In memory database
- Streaming database
- Complex graphs
- Science/engineering

CAGR projected 2017-2022:

30.27%¹

¹Source: Mordor Intelligence; *Global In-Memory Computing Market*, July 2017

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TRADITIONAL OPTIONS FOR IN-MEMORY COMPUTING HAVE DRAWBACKS

“For server DRAM, supply remained tight in Q1 resulting in higher average selling prices (ASPs)” epsnews.com, May 2018

1. **LARGER CAPACITY DRAM**
   - High-capacity DIMMs are expensive

2. **MORE DIMMS PER SERVER**
   - Limited scaling capacity with DIMMs

3. **ADD MORE SYSTEMS**
   - Inefficient to add nodes for memory

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INTRODUCING INTEL® MEMORY DRIVE TECHNOLOGY

SW FOR INTEL® OPTANE™ SSD DC P4800X

- Use Intel® Optane™ SSD DC P4800X transparently as memory
- Grow beyond system DRAM capacity, or replace high-capacity DIMMs for lower-cost alternative, with similar performance
- Leverage storage-class memory today!
  - No change to software: unmodified Linux* OS, applications, and programming
  - No change to hardware: runs bare-metal, loaded before OS from BIOS or UEFI, compatible with Intel® Xeon® processor family (1-8 socket)
- Flexible procurement options:
  1. Software-only (you provide Intel® Optane™ SSD DC P4800X)
  2. Fully-integrated (Intel® Optane™ SSD with preloaded Intel® Memory Drive Technology)

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INTEL® OPTANE™ SSDs WITH INTEL® MEMORY DRIVE TECHNOLOGY DELIVERS BIG, AFFORDABLE MEMORY

EXPAND BEYOND LIMITED DRAM CAPACITY

- Expand Insights with Massive Data Pools
- Intel® Memory Drive Technology supports Linux® x86_64 (64-bit), kernels 2.6.32 or newer.
  *Other names and brands may be claimed as the property of others

DISPLACE DRAM WITH AFFORDABLE SSDs

- Reduce High-capacity DRAM CAPEX Expenditures

Intel® Memory Drive Technology supports Linux® x86_64 (64-bit), kernels 2.6.32 or newer.
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INTEL® OPTANE™ SSDs WITH INTEL® MEMORY DRIVE TECHNOLOGY CAN EXPAND SYSTEM MEMORY CAPACITY

DRAM-ONLY 2-SOCKET MEMORY CAPACITY

Intel® Memory Drive Technology 2-Socket Server Memory Capacity

DRAM-only memory capacity = up to 3TB

Intel® Memory Drive Technology capacity = up to 24TB

1. For example: 128GB DRAM can be expanded up to 1024GB based on the capacity of the non-volatile memory media installed. Higher expansion ratios may be supported, with possibly suboptimal performance.
DISPLACE COSTLY DRAM WITH INTEL® OPTANE™ SSDs AND INTEL® MEMORY DRIVE TECHNOLOGY

COST FOR 3TB OF DRAM-ONLY MEMORY

$45,598

Memory Configuration used:

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>$/ea</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>128GB DDR4-2400 RDIMM</td>
<td>24</td>
<td>$1899</td>
<td>$45,598</td>
</tr>
</tbody>
</table>

COST FOR 3TB OF INTEL® MEMORY DRIVE TECHNOLOGY

$14,240

Memory Configuration used:

<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
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<th>Total</th>
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<tr>
<td>32GB DDR4-2400 RDIMM</td>
<td>8</td>
<td>$273</td>
<td>$2184</td>
</tr>
<tr>
<td>16GB DDR4-2400 RDIMM</td>
<td>8</td>
<td>$147</td>
<td>$1176</td>
</tr>
<tr>
<td>Intel® Memory Drive Technology 640GB</td>
<td>4</td>
<td>$2720</td>
<td>$10880</td>
</tr>
</tbody>
</table>

1 Source – Servers4Less* - Price as of October 26, 2018, Samsung M386AAK40B40-CUC4*
2 128GB PC4-19200 DDR4-2400MHz ECC Registered CL17 288-Pin Load Reduced DIMM
3 Source – Trendforce* - Server DRAM Price as of October 26, 2018 (Market Price)
4 Source – Colfax Direct* - Price as of October 26, 2018. Combined pricing for Intel® Optane™ SSD DC P4800X 750GB and Intel® Memory Drive Technology


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INTELLIGENTLY MANAGE IN-MEMORY DATA TO OPTIMIZE PERFORMANCE

Intel® Memory Drive Technology uses machine-learning to prefetch data to DRAM
## Best Fit Workloads for Intel® Optane™ SSD DC P4800X

### With Intel® Memory Drive Technology

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Workloads</th>
<th>Not a Good Fit</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prefetch</strong></td>
<td>Predictable large memory access patterns</td>
<td>Low-concurrency Workloads</td>
</tr>
<tr>
<td></td>
<td>Enterprise, DBMS, OLTP, OLAP</td>
<td>Serial workloads, single process/threaded</td>
</tr>
<tr>
<td><strong>Asynchronous Memory Load</strong></td>
<td>High-concurrency access patterns; many processes; highly multithreaded</td>
<td>Memory Bandwidth-bound Workloads</td>
</tr>
<tr>
<td></td>
<td>Cloud, Hyperscale, Streaming database, Containers/VMS</td>
<td>NVMe* cannot meet memory controller bandwidth</td>
</tr>
<tr>
<td><strong>HPC</strong></td>
<td>CPU-intensive High Performance Computing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CAE in-core solvers, In-situ workflows, Data analytics, Statistics</td>
<td></td>
</tr>
</tbody>
</table>

* Other names and brands may be claimed as the property of others.
MEMCACHED*: speed up dynamic web apps by alleviating database load

See more at: https://www.intel.com/content/www/us/en/software/memcached-optimization-technology-brief.html

IN-MEMORY DATABASES: leading enterprise in-memory databases for both OLAP and OLTP


REDIS*: in-memory database and caching engine

See more at: https://www.intel.com/content/www/us/en/software/apache-spark-optimization-technology-brief.html

APACHE SPARK*: a fast and general engine for large-scale data processing

See more at: https://www.intel.com/content/www/us/en/software/apache-spark-optimization-technology-brief.html

China Unicom*: http://www.cnii.com.cn/incloud/2017-11/14/content_2012143.htm

Selectel*: https://habrahabr.ru/company/selectel/blog/345306/

KVM*

*Other names and brands may be claimed as the property of others
KVM* + Redis* comparison: Intel® Optane™ SSDs with Intel® Memory Drive Technology vs. Linux* swap

System Configurations
Tested 108 VMs x3.3GB/VM

- **Linux swap on:** 192GB DDR4 DRAM
- **Intel® Memory Drive Technology (no swap):** 192GB DDR4 DRAM + Intel® Optane™ SSD P4800X with Intel® Memory Drive Technology

**Better average latency vs. swap**

- up to 5x

**Better P99 max latency vs. swap**

- up to 10x

**Lower Memory $/VM**

- up to 60%

- add 576GB of Intel® Memory Drive Technology capacity

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1 System configuration: Source – Intel: Server model: 2x Intel® Xeon® Gold 6154 @ 3.0 GHz, 72 hyper threaded cores, Intel system board S2600WF, 192GB installed DDR4 @ 2400Mhz, 2x Intel® Optane™ SSD DC 375GB; CentOS 7.5.1804 (kernel 4.15.12-1.el7.elrepo.x86_64 upgraded), Redis version 4.02 (benchmark and server) in-memory instances given 5.7GB, 3.3 millions key pairs at G=10.

2 Implementation details: System BIOS: 00.01.0013 (Link); Kernel 4.15.12, Mitigation was validated for variants 1 through 3 using a checker script (Link – accessed June 20, 2018).

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Cost advantages derived from memory cost only – DDR4 2400 Server memory @ $11.72/GB (Link) versus bundle channel price of an Intel Memory Drive (any density) of $4.22/GB as of June 25, 2018. (Link), $3.09 for SSD, $1.13 for Software license.
Redis is a well known in-memory data store. The benchmark is using high concurrency SET/GET operations of small (1kB) and large (100kB) messages, comparing 4X memory expansion with Intel® Memory Drive Technology.

**Additional Info**
- Benchmark shown at same system memory capacities
- redis server and client/load systems are connected over 10GbE
- Test maintains one consistent rate of load
- Get more memory per server w/o reducing transaction throughput

**Workload Description**

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1 Source – redis server: 2x Xeon Gold 6154 @ 3.00 Ghz; network topology: 10GigE dedicated back-to-back link; CentOS Linux* release 7.4 (Core); kernel: 3.10.0-693.5.2 (el7.x86_64)
2 Source – DRAMeXchange*: Server DIMM Price Report Feb 2018, 32GB DIMM @ $302.27 average price

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**Performance Chart**

<table>
<thead>
<tr>
<th>Message Size</th>
<th>TPS (Thousands) SET</th>
<th>99th percentile latency: &lt;1 ms</th>
<th>TPS (Thousands) GET</th>
<th>99th percentile latency: &lt;300 µs</th>
</tr>
</thead>
<tbody>
<tr>
<td>100kB</td>
<td>DRAM</td>
<td>Intel Memory Drive Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11.76</td>
<td>11.77</td>
<td>11.78</td>
<td>11.76</td>
<td></td>
</tr>
<tr>
<td>1kB</td>
<td>DRAM</td>
<td>Intel Memory Drive Technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.07</td>
<td>0.93</td>
<td>1.12</td>
<td>0.93</td>
<td></td>
</tr>
</tbody>
</table>

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**System Configuration**

- 2ea Intel® Xeon® Gold 6154 Processor @ 3.00GHz
- 2ea Intel® Memory Drive Technology 64GiB
- Comparing:
  - DRAM-Only with 768GB DDR4
  - 192GB DDR4 augmented with Intel® Memory Drive Technology for a total of 768GB

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**Get Equivalent Performance**

GET EQUIVALENT PERFORMANCE WITH REDUCED MEMORY INVESTMENT

- Deliver 82%-99% of DRAM-only performance for a dataset 4x larger than DRAM

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**System Cost [$]**

- DRAM-only (1.5TB Memory)
- Intel® Memory Drive Technology (256GB)

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**Get More Memory**

GET MORE MEMORY WITHOUT REDUCING TRANSACTION THROUGHPUT

- 11.76 million TPS (Thousands) SET
- 11.77 million TPS (Thousands) GET

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**Intel® Memory Drive Technology + 256GB**

GET MORE MEMORY WITHOUT REDUCING TRANSACTION THROUGHPUT

99 percentile latency: <300 µs
“Spark adoption is booming. Its community is growing, and all major big data platforms make a point of interoperating with Spark.” ZDNet®, Nov 2017

**Six Reasons to Improve Memory with Intel® Optane™ SSDs + Intel® Memory Drive Technology**

### Massive Memory Pool
- Up to 8x expansion versus DRAM-only
- Max capacity of 24TB on dual- or 48TB on quad-Intel® Xeon® systems

### Improved Price/Performance

<table>
<thead>
<tr>
<th>Metric</th>
<th>Baseline</th>
<th>Intel® Memory Drive Technology</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run time</td>
<td></td>
<td></td>
<td>up to 5x</td>
</tr>
<tr>
<td>Run time/$</td>
<td></td>
<td></td>
<td>up to 83.5%</td>
</tr>
</tbody>
</table>

- 3x Intel® Xeon® Servers
- 3x Intel® Xeon® Servers with Intel® Memory Drive Technology

### Innovation Opportunities
- Research larger models and bigger data
- Improve application responsiveness by hosting all data in memory

### Seamless Integration
- Solution loads pre-OS
- No hardware, OS or application changes
- Transparently integrates SSD as memory

### Scale Without Adding CPU Nodes
- Add memory to existing servers, vs. deploying more
- Reduce datacenter space, power, cooling and networking costs

### Reduced Data Center Cost
- CAPEX: lower cost per GB vs. RDIMM
- OPEX: potential for smaller footprint, energy savings, and reduced maintenance costs

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See Appendix A for Footnotes.

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EXPLORE INTEL® MEMORY DRIVE TECHNOLOGY TO:

EXPAND MEMORY CAPACITY

- Increase compute and memory per node
- Greater in-memory compute space

REDUCE COSTS VS DRAM-ONLY

- Reduced memory hardware cost
- Lower ongoing operating expenses

DO THE PREVIOUSLY IMPOSSIBLE

- Consider new usage models
- Consider new business models
Appendix A

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1 Source – Intel, System Configuration for Management Node: S2600WFT Intel White Box, 2 sockets, Intel® Xeon® Gold 6140 CPU @ 2.30GHz, 18 cores per socket / 2 threads per core (total 72 vcores), 192GB DDR4, CentOS 7.4* distribution with 4.15.12 kernel, HortonWorks* Data Platform 2.6.4, Spark 2.2.0*. Performance results are based on testing as of July 30, 2018 and may not reflect all publicly available security updates. See configuration disclosure for details. No product or component can be absolutely secure.

2 Source – Intel, System Configuration for Data Node(s): Same as above plus 2x NVMe* PCIe* Intel® Optane™ SSD DC P4800X 375GB per system, 2x NVMe* PCIe* Intel® SSD DC P4500 3.7 TB per system