Addressing Performance Challenges with Persistent Memory

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Agenda

• Overview of Persistent Memory
• NVDIMM use cases
• NVDIMM performance
• Application Access Levels: Direct, OS, Virtualized
• Summary
Convergence of Memory and Storage

Bringing Memory & Storage Closer to Compute

- NVMe™ SSD (NVM)
- NVDIMM-P (NVM)
- RDIMM/LRDIMM (DRAM)
- NVDIMM-N (DRAM/NAND)

Latency:
- Nanoseconds
- Microseconds
- Milliseconds

$/Bit
- Performance Optimized Persistent Memory
- Cost Optimized Persistent Memory

Optimized Persistent Memory
Persistent Memory Adds Value Across Diverse Applications

Relational Database
- MSFT SQL
- MySQL
- Maria DB
- Oracle

Scale-out Storage
- VMware
- VSAN
- MSFT Azure
- Store Virtual

Virtual Desktop Infrastructure
- VMware VDI
- Citrix HDI

Virtual Desktop Infrastructure
- Higher VM consolidation

Big Data
- MongoDB
- Cloudera
- HortonWorks
- Hadoop
- Cassandra
- MSFT SQL Hadoop
- Higher performance

In Memory Database
- SAP HANA
- MSFT SQL
- Hekaton
- XAP Gigaspace

Middleware
- Java
- .NET

HPC
- HPC

Log acceleration: write combining and caching
Tiering, caching, write buffering, meta-data storage
Direct Access to NVDIMM-N

Proprietary driver and APIs include utilities to Read/Write, trigger, and access status of NVDIMM.

Motherboard BIOS uses MRC to identify/configure NVDIMM, and perform backup/restore.

On-module FW controls command/status interaction with MRC/BIOS/Driver/application.

**JEDEC BAEBI Register Set**
(Location and Function)

- **Application**
- **NVDIMM Driver**
- **SMB (I2C)**
  - NVDIMM
  - Save Trigger (Save_n)
  - DIMM Interface
  - CPU/Memory Controller

**Backup Up Power**
(Tethered Ultracap or 12V Pin persistent supply)

**NVDIMM-N module**

**Platform HW**

**Power Supply**
OS Level Access to Persistent Memory

**SNIA NVM Programming Model**

**Linux**

**Windows 2016**

Source: SNIA

Source: MSFT FMS - 2017
## Windows Server 2016: Performance Improved by 10x to 75X

NVDIMM leveraged for Log Storage in SQL server DB Transactions

- **Block Mode Access - 10x**
  - Persistent ramdisk
  - Raw disc
  - Supported by SCM driver

- **Direct Access - 75X**
  - Memory-mapping semantics
  - DAX file system
  - No SW overhead
  - Byte Addressable
  - Filter drivers may require modification

### Performance Comparison

<table>
<thead>
<tr>
<th>4K Random write, QD=1</th>
<th>IOPS</th>
<th>Avg Latency (ns)</th>
<th>MB / Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>NVMe SSD</td>
<td>14,553</td>
<td>66,632</td>
<td>56.85</td>
</tr>
<tr>
<td>Block Mode NVDIMM</td>
<td>148,567</td>
<td>6,418</td>
<td>580.34</td>
</tr>
<tr>
<td>DAX Mode NVDIMM</td>
<td>1,112,007</td>
<td>828</td>
<td>4,343.78</td>
</tr>
</tbody>
</table>

MSFT FMS - 2017
Virtualization Level Access to Persistent Memory

FMS Persistent Memory Track

VMware vSphere 6.7

Enmotus Fuze Drive

Source: VMware VWworld - 2017

Source: Enmotus SNIA - 2018

FMS Persistent Memory Track Presented by:
Virtualization Performance

**FMS Persistent Memory Track**

**Vmware vSphere (Block and Byte Mode)**  
Source: VMware VMWorld - 2017

**Enmotus Fuze Drive (Block Mode)**  
Source: Enmotus SNIA - 2018

**Sysbench Result**

- Up to 1.8x better throughput
- Up to 2.3x better latency

**Microsoft Exchange DB Performance (Throughput)**

- 1.7x increase in Transactional IOPS
- Exchange DB I/O Performance

**IOPS**

- Average IOPS
  - FtsWrite vs. Write: 1,844,986 vs. 676,925
  - Average Bandwidth
    - FtsWrite vs. Write: 7.1Gbps vs. 2.7Gbps
  - Average Latency
    - FtsWrite vs. Write: 139µs vs. 371µs

**Latency**

- (Lower is better)

**Enmotus Fuze Drive** is a technology developed by Enmotus. Their solution identifies the active data set of applications and dynamically allocates the appropriate storage resources in order to optimize performance.

**Micron** is using the Enmotus software, FTSVM, and NVMe to give you the highest density, fastest storage solution. The FTSVM is made up of Micron M5530 and 1.8TB of NVMe.
NVDIMM Virtual Disk

Micron Booth – FMS 2018

- NVDIMM Virtualized
  - Significant Performance improvement using PM with SSD
    - Enmotus Virtualized Storage on Linux
    - 192GB Persistent Memory