Storage in the DIMM Socket

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Abstract

- As data sets continue to grow, IT managers have begun seeking out new ways for memory technology to be deployed in the data center in order to take greater advantage of the performance and latency benefits.
- Non–Volatile DIMMs, or NVDIMMs, provide a persistent memory solution with the endurance and performance of DRAM coupled with the non–volatility associated with storage.
- This tutorial will provide a general overview of this emerging technology and how it plays in the data center.
- You will learn what an NVDIMM is, how it works, where it fits and why system architects should consider them for their next generation enterprise server and storage designs.
Agenda

- The Memory / Storage Problem (Latency)
- New Memory Technology Roadmap
- NVDIMMs – What they are
- NVDIMMs – How they work
- NVDIMMs – System Considerations
- NVDIMM Performance
- NVDIMM Ecosystem
- Summary
As CPU technology scales with Moore’s Law, memory IO creates significant performance bottlenecks.

The latency gap in memory / storage hierarchy needs to be bridged.

NVDIMM offers a solution today (Storage at DRAM Latency)
Data-Intensive Applications Need Fast Access To Storage
Large Performance Gap Between Main Memory And HDD
SSDs Have Narrowed The Gap, But a Big Gap Still Exists
Until an “SCM” becomes viable for mainstream adoption (2020?)
MAIN MEMORY ROADMAP

- Volatile DRAM
- Non-Volatile Memory

- Scaling Problems
- MFG Concerns <2x nm

- MRAM
- PCM
- ReRAM

2012  2014  2016  2020

SCM

Relative Capability

Volatile DRAM Non-Volatile Memory

DDR3 DDR4 NVDIMM
WHAT THE INDUSTRY WANTS FROM MEMORY (THE HOLY GRAIL)

- Infinite Endurance
- Lowest Latency
- High Capacity
- Non-Volatile
- Low Power
- Scalability
- Low Cost

NVDIMM DOES MOST OF THIS TODAY...
NVDIMMs – What and Why

- Reside on the Memory Channel (DDR3/DDR4)
- Retain data in the event of an unexpected power loss
- Combines mature memory technologies (DRAM and Flash)
- Requires independent power source to ensure persistence
- Fits well with the NVM Programming Model (as precursor to SCM)
- Delivers new levels of storage performance
- Databases can run faster and recover more quickly
- Can enhance both SSD endurance and reliability
HOW IT WORKS

NORMAL OPERATION:

1. During normal operation, the NVDIMM appears like a standard DDR3 DRAM module.
   - DRAM Latency (nanoseconds)
   - DRAM Endurance (practically infinite)
   - DRAM Bandwidth (12GB/s per NVDIMM)
HOW IT WORKS

POWER-FAIL - DRAM SAVE to FLASH:

1. **Power-Fail Event**: The NVDIMM isolated from the BUS. All data (incl. ECC) in the DRAM is SAVED to onboard Flash via the NVDIMM Logic. Super Capacitors provide hold up power to the module during this operation.

2. When the SAVE completes. The NVDIMM module is then shut down.

![Diagram of NVDIMM component including DRAM, NVDIMM Logic, Flash, BUS Isolation, and Supercap]
HOW IT WORKS

POWER RESUME:

1. When power to the system is returned, Super Capacitors are re-charged & the data is RESTORED back from FLASH into the DRAM.
HOW IT WORKS

NORMAL STATE:

1. Once all data is RESTORED back into the DRAM, the NVDIMM is ready for I/O transactions with the host system.
2. Host system finishes BOOT and normal NVDIMM operation continues.
System Considerations

The “Pieces of the Puzzle” that are **required** for NVDIMM Integration

- **System Management** (Power Health)
- **System Support**
  - H/W Trigger (ADR)
- **Mechanical** (Power Source)
- **Application**
- **“NVDIMM –Aware” BIOS**
- **NVDIMM**
THE COST OF HIGH LATENCY

“...every 100ms of latency cost them 1% in sales”

“...an extra 500ms in search page generation time dropped traffic by 20%”

“...a broker could lose $4M per millisecond if their electronic trading platform is 5ms behind the competition”

Source: http://highscalability.com/
Ecosystem performance gap between compute & storage

- Nanoseconds latency (1000x faster than Flash)
- 1.4 million IOPS (3x better)
Example of NVDIMM Performance

(BANDWIDTH – GB/sec)

Benchmark:
VDBENCH, Platform: Intel Sandybridge, Linux, Two DDR3-1333 NVDIMMs as interleaved pair (channel interleaving),
PRAMFS vs. SATA SSD as Linux block device
$ PER I/O : A NEW STORAGE METRIC ?

Performance vs. Cost ($ per I/O) trade-off

*Cost per PB written:
Best in Class SSD: $100.00 / PB versus. NVDIMM: $0.40 (250x cost savings)
Several alternate solutions in the market, all for different usage and applications. Each solution has its purpose, the questions is “finding the right tool for the job”.

<table>
<thead>
<tr>
<th>ATTRIBUTE</th>
<th>HDD</th>
<th>NVDIMM</th>
<th>SATA SSD</th>
<th>PCIe SSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transaction (IOPS)</td>
<td>350</td>
<td>1.4 Million</td>
<td>60K – 250K</td>
<td>70K – 300K</td>
</tr>
<tr>
<td>Capacity</td>
<td>Up to 4TB</td>
<td>2GB – 16GB</td>
<td>60GB - 2TB</td>
<td>400GB – 8TB</td>
</tr>
<tr>
<td>Performance vs. Cost</td>
<td>Highest Cost</td>
<td>Low Cost</td>
<td>Med Cost</td>
<td>High Cost</td>
</tr>
<tr>
<td>Ease of Integration</td>
<td>Plug n’ Play (Low)</td>
<td>NVDIMM enabled Server (High)</td>
<td>Plug n’ Play (Low)</td>
<td>Drivers (Medium)</td>
</tr>
<tr>
<td>Availability</td>
<td>Now</td>
<td>Now</td>
<td>Now</td>
<td>Now</td>
</tr>
<tr>
<td>Scalability</td>
<td>Easy (24 per 2U)</td>
<td>DDR3/4 Socket (Medium)</td>
<td>Drive bays not always available (low – med)</td>
<td>PCIe Sockets (Very Low)</td>
</tr>
<tr>
<td>Market/Audience</td>
<td>All</td>
<td>VARs / Integrators OEMs</td>
<td>All</td>
<td>VARs / Integrators OEMs</td>
</tr>
</tbody>
</table>
NVDIMM ADOPTION

The flow of NVDIMM evolution and adoption

- Standards JEDEC
  - NVDIMM Vendors: Viking, SMART, Agiga, Micron
- BIOS: Intel, AMI, Insyde
  - Motherboard Vendors: Intel, Supermicro, ODM’s, OEM’s
- Platform Integrated Solutions
The NVDIMM-SIG is in the process of developing taxonomy to help the industry distinguish product categories.

- DRAM Modules
- NVDIMM
- MCS (ULLtraDIMM)
- SATADIMM
- HDIMM (Hybrid DIMM)
- MRAM, ReRAM
Options – Flexibility – PRO’s & CON’s

- Flash is cheaper than DRAM $/GB
- NVDIMM has 1000x lower latency than Flash
- DRAM has practically infinite endurance

- Hyperscale want “Dense & Cheap” (WORM)
- Financial want low & predictable latency
- Storage wants higher I/O performance & increased data security
- No individual “BEST” choice – There are OPTIONS….
The Answer – Of Course…Is..

Standard Servers become Highly Flexible
There is a solution for whatever the Application Demands

• Highest Performing Storage - NVDIMM
• High Capacity Flash – PCIe SSD
• Lower Latency SSD – ULLtraDIMM
NVDIMM SIG

NVDIMM Special Interest Group (SIG) formed January 2014
- Organized under the SNIA Solid State Storage Initiative to help:
  - Accelerate awareness and adoption of NVDIMMs
  - Vendors collaborate to broaden industry support and knowledge

SNIA’s history of developing standards and providing education:
- The NVM Programming Model Technical Working Group
- Ideal venue for NVDIMM SIG support

NVDIMM SIG will:
- Educate on how system vendors can design in NVDIMM
- Communicate industry standards as they evolve
- Develop market understanding of NVDIMM technology
- Communicate how new programming models help deliver value
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Authorship History

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