Bringing Persistent Memory Technology to SAP HANA: Opportunities and Challenges

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Agenda

Persistent Memory (PM): What’s all the noise about?

Bringing PM to in-memory computing: Opportunities & Challenges

Leveraging Intel DIMM based on 3D XPoint™ technology for SAP HANA

Sample use case: Improved in-memory database restart time

Conclusions
Persistent Memory (PM): An emerging, next-generation non-volatile memory technology

- A true game changer for in-memory computing offering new opportunities for increased performance and scalability and lowering cost

Key business drivers for bringing PM to in-memory computing:

- As data volumes keep growing, in-memory databases like SAP HANA require larger capacities
- DRAM scaling has slowed significantly and will offer lower capacities
  - New solutions needed for cost-efficient store of large data while still providing real-time access
Persistent Memory

- Byte addressable persistence
  - Fast enough to load directly
  - Usually on memory bus
- NVDIMMs available today
- 3D XPoint™ Memory
  - Persistent
  - (up to) 1000X faster than NAND
  - (up to) 1000X endurance
  - 6TB per 2-socket system
  - Cheaper than DRAM
  - SSDs first (demonstrated last year)
  - Intel DIMMs for next gen platform

Source: Persistent Memory: What’s Done, Coming Soon, Expected Long-term by Andy Rudoff, Intel
Opportunities:

- Increased scalability
  - Larger memory modules means more memory available per server
- Significant cost savings
  - PM is cheaper than DRAM
- Improved recovery times

Challenges:

- Higher (than DRAM) latency impacting performance
- New technology, standards still evolving…
  - Means slow, phased implementation with increased complexity and uncertain timelines
Intel DIMM based on 3D XPoint™ technology is fully aligned with the SNIA programming models for NVM and provides support for Block, File, Volume, and Persistent Memory (PM) File mode.

**Persistent Memory Mode (SNIA)**

**Use with memory-like NVM**

**NVM.PM.VOLUME Mode**
- Software abstraction to OS components for Persistent Memory (PM) hardware
- List of physical address ranges for each PM volume
- Thin provisioning management

**NVM.PM.FILE Mode**
- Describes the behavior for applications accessing persistent memory
- Discovery and use of atomic write features
- Mapping PM files (or subsets of files) to virtual memory addresses
- Syncing portions of PM files to the persistence domain

SAP HANA focus is on leveraging memory mapping in NVM.PM.FILE mode which enables direct access to persistent memory using CPU instructions
Sample use case: Reducing in-memory database down-time

Logging, warehousing, processing information: lifeline of companies

Information availability depends on database availability (9s)

Minimize restart time to improve database availability

<table>
<thead>
<tr>
<th>Availability</th>
<th>Annual DownTime</th>
</tr>
</thead>
<tbody>
<tr>
<td>97%</td>
<td>11 days</td>
</tr>
<tr>
<td>98%</td>
<td>7 days</td>
</tr>
<tr>
<td>99%</td>
<td>3 days 15 hrs</td>
</tr>
<tr>
<td>99.9%</td>
<td>8 hrs 48 min</td>
</tr>
<tr>
<td>99.99%</td>
<td>53 min</td>
</tr>
<tr>
<td>99.999%</td>
<td>5 min</td>
</tr>
<tr>
<td>99.9999%</td>
<td>32 sec</td>
</tr>
</tbody>
</table>

- Each restart for an IMDB can take up to 1 hour to load TBs of data to memory.
- Dell study shows millions of dollars lost per hour due to downtime**
- Existing HA solutions increase the price exponentially for every nine

Evolving the HANA SW Architecture to incorporate 3D XPoint™ PM technology

Main Store is the perfect fit for Intel DIMM based on 3D XPoint™ technology!

SAP HANA: Memory Architecture

<table>
<thead>
<tr>
<th>Function</th>
<th>Organization</th>
<th>Access type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scratch pad for intermediate results</td>
<td>Scratch pad space</td>
<td>Reads and writes</td>
</tr>
<tr>
<td>Portions of data that has been modified</td>
<td>~5% of data, light compression</td>
<td>Reads and writes</td>
</tr>
<tr>
<td>Data in memory format</td>
<td>~95% of data, 10-20X compressed</td>
<td>Reads (scans)</td>
</tr>
</tbody>
</table>

Main store contains ~95% of the data in highly compressed format.

Technology differentiators | Why Main is well suited
--- | ---
Large capacity | Since 95% of data contained in main, HANA can scale up to larger datasets due to increased memory capacities
Persistence | Avoid loading data from storage and reduce downtime
Higher latencies | References are in form of scans. Hardware and software prefetchers can hide latencies for such reference patterns
Leveraging 3D XPoint™ PM technology for SAP HANA Main Store: Solution Overview

- Primary data store is data volume (in SAN or local storage)
- Main is in 3D XPoint™ PM instead of DRAM and is now persistent
- On Restart: Main already in 3D XPoint™ PM, no need to load data from SAN
- On HW failure: Backup server loads data from data volume
Initial results from a prototype (that leverages a suite of simulation software and hardware technologies by exploiting NUMA configuration) are very promising:

- Significant improvements in the database restart time
  - >5X improvement measured

- Acceptable performance impact
  - Persistent Memory technology has higher (than DRAM) latencies, resulting in slightly lower performance
    - Measured (simulated) performance degradation was within the expected range for most workloads

The challenge ahead:

- New technology, standards still evolving will slow implementation timelines
## Leveraging 3D XPoint™ PM technology for SAP HANA Main Store: Pros and Cons

### PROS

- Significant improvements in database restart time
  - No need anymore to load data, Main Store is now persistent as it is in 3D XPoint™ PM instead of DRAM

- Increased memory capacity at a lower cost
  - Potentially significant cost benefits in several areas

### CONS

- New approach has two redundant persistent copies
  - Dual-writes to 3D XPoint™ PM and “SAN”/Disks
    - Necessary for Backup and Recovery using traditional persistence; also to safeguard against corruptions in persistent memory DIMMs

- 3D XPoint™ technology is still evolving, making s/w design tricky
  - When to operate directly on “PM” vs “DRAM”? (Data storage vs intermediate data handling)
    - Both storages co-exist in DDR4 form factor, but the capacity ratio is unknown
Conclusions

- A hybrid PM + DRAM approach will provide a large amounts of fast, cost-efficient memory for SAP HANA in-memory computing platform

- Persistent Memory can help with achieving near-instant recovery for main-memory databases

- Early results from bringing 3D XPoint™ PM technology to SAP HANA clearly support the expectations of persistent memory becoming a true game changer for in-memory computing