STORAGE INDUSTRY SUMMIT

The Future of Computing:
The Convergence of Memory and Storage through Non-Volatile Memory (NVM)

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Overview of the NVM Programming Model

SNIA™
Solid State Storage Initiative

Motivation for NVM Programming Models

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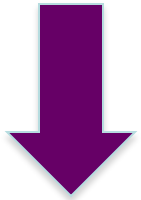
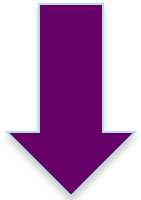


Block Mode Innovations

- Atomics
- Access hints
- NVM-oriented operations



Emerging NVM Technologies

- Performance
- Performance
- Perf… okay Cost!

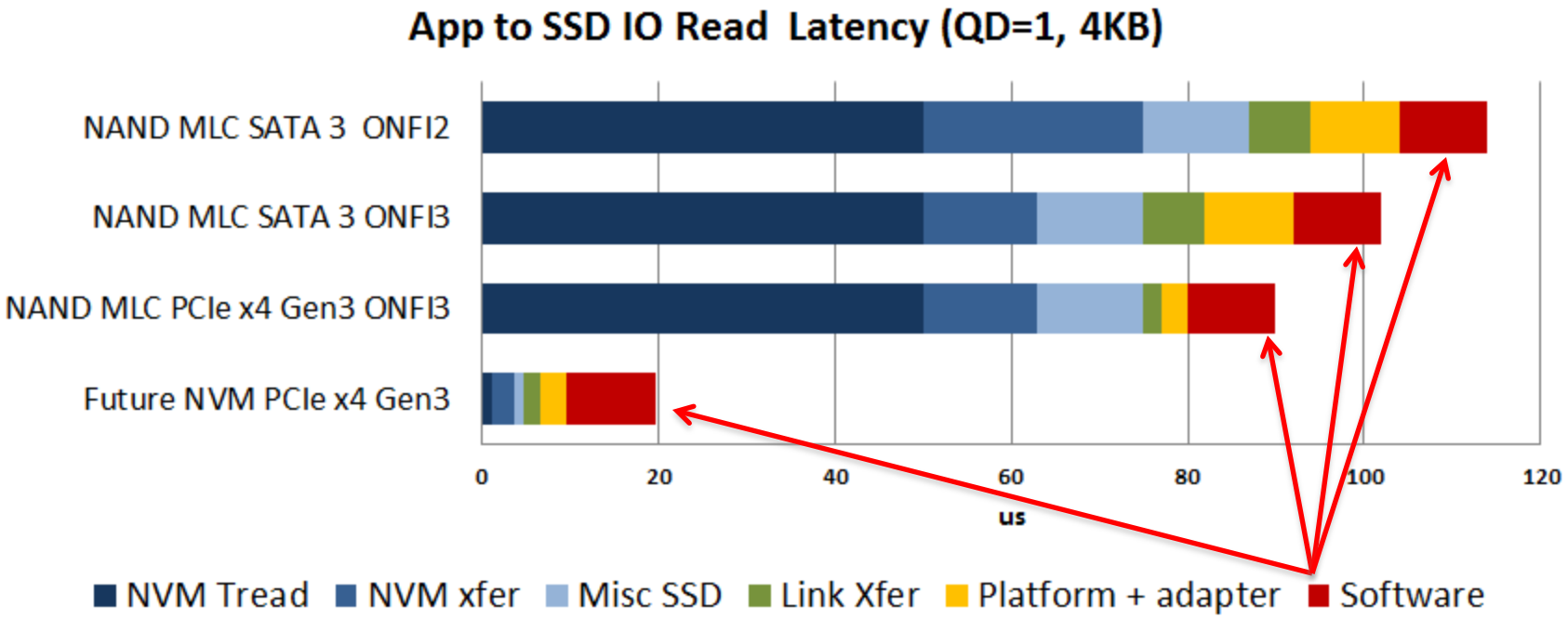
NVM Programming TWG

SNIA™
Solid State Storage Initiative

Members

- EMC, Fujitsu, Fusion-io, HP, HGST, Inphi, Intel, Intuitive Cognition Consulting, LSI, Microsoft, NetApp, PMC-Sierra, Qlogic, Red Hat, Samsung, Seagate, Sony, Symantec, Viking, Virident, VMware
- Calypso Systems, Cisco, Contour Asset Management, Dell, FalconStor, Hitachi, Huawei, IBM, IDT, Marvell, Micron, NEC, OCZ, Oracle, SanDisk, Tata Consultancy Services, Toshiba

The NVM Software Stack



Persistent Memory Definition

- Byte-addressable
  - As far as the programmer is concerned
- Load/Store access
  - Not demand-paged
- Memory-like performance
  - **Would reasonably stall a CPU load waiting for PM**
- Probably DMA-able
  - Including RDMA

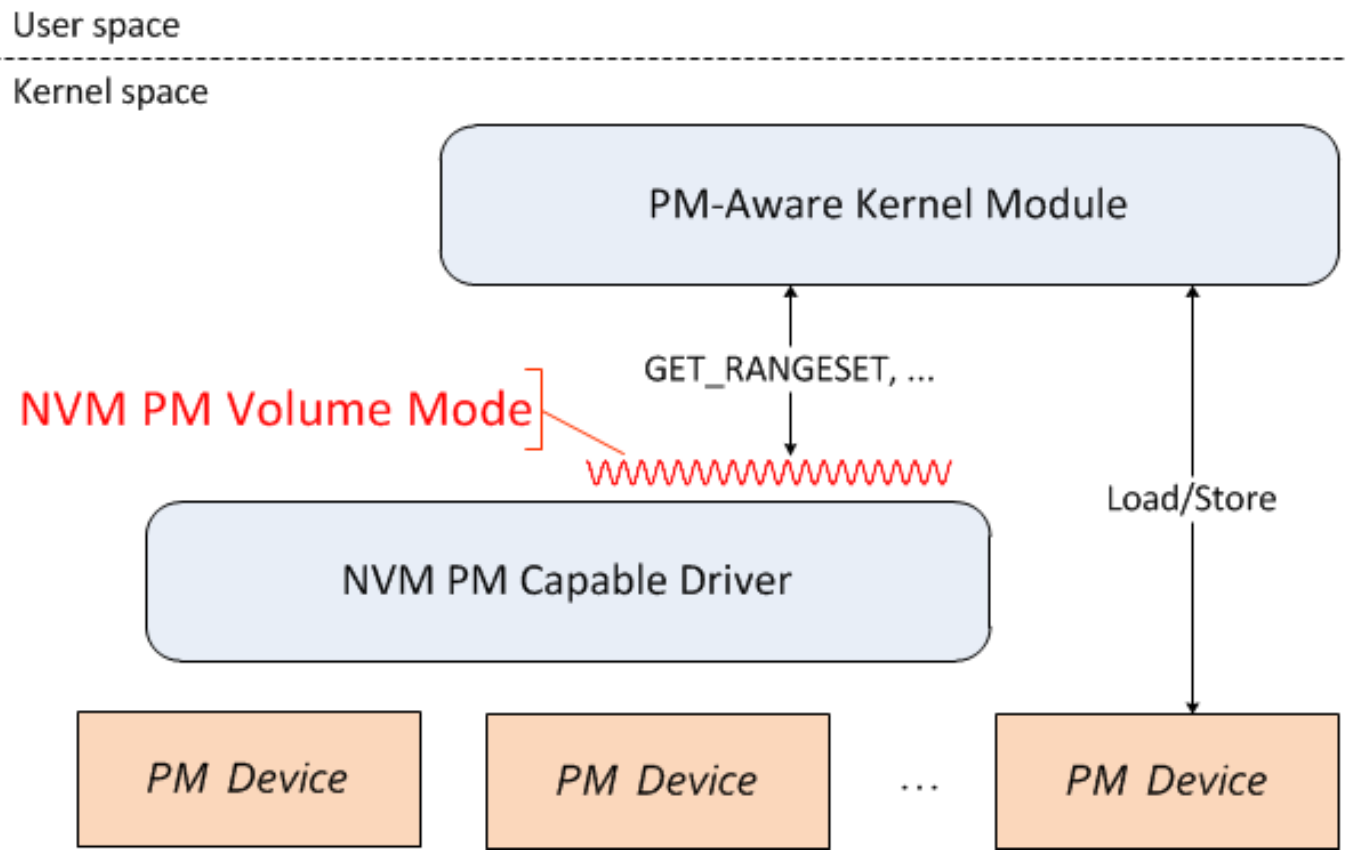
- Think “battery-backed RAM”

Persistent Memory Attributes

- PM does not
  - Surprise the program with unexpected latencies
    - No major page faults
  - Kick other things out of memory
  - Use the page cache unexpectedly
- PM stores aren't durable until data is flushed
  - Is this a new, inconvenient attribute of PM?
  - Or is this something that's been around for decades?
- PM may not always stay at the same address
  - Physically
  - Virtually

PM Volume

- NVM Volumes
  - PM Capable
  - A list of physical ranges of NVM
- Operations
  - GET_RANGESET
  - …

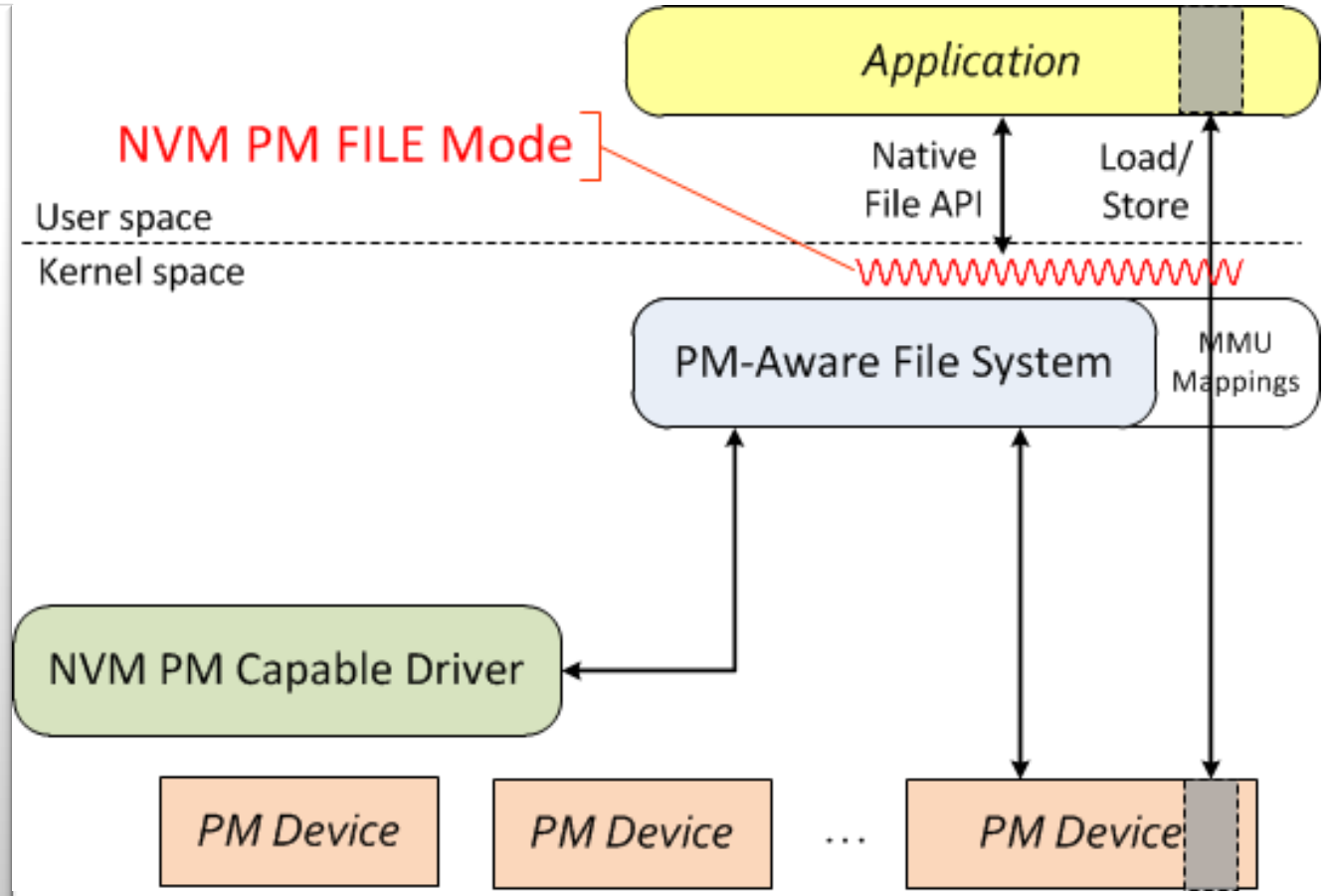


Uses for NVM.PM.VOLUME

- Kernel modules
- File systems
  - Maybe to expose PM
  - Maybe just to use it internally
- Memory management
  - Example: Multi-tiered page cache
- Other storage stack components
  - RAID
  - Caches
  - Clustered I/O
- Future NVM Programming models we haven't thought of yet

PM File

- NVM Files
  - PM Capable
  - Native file APIs and management
- Operations
  - Native open/close read/write
  - NVM.PM.FILE.MAP
  - …

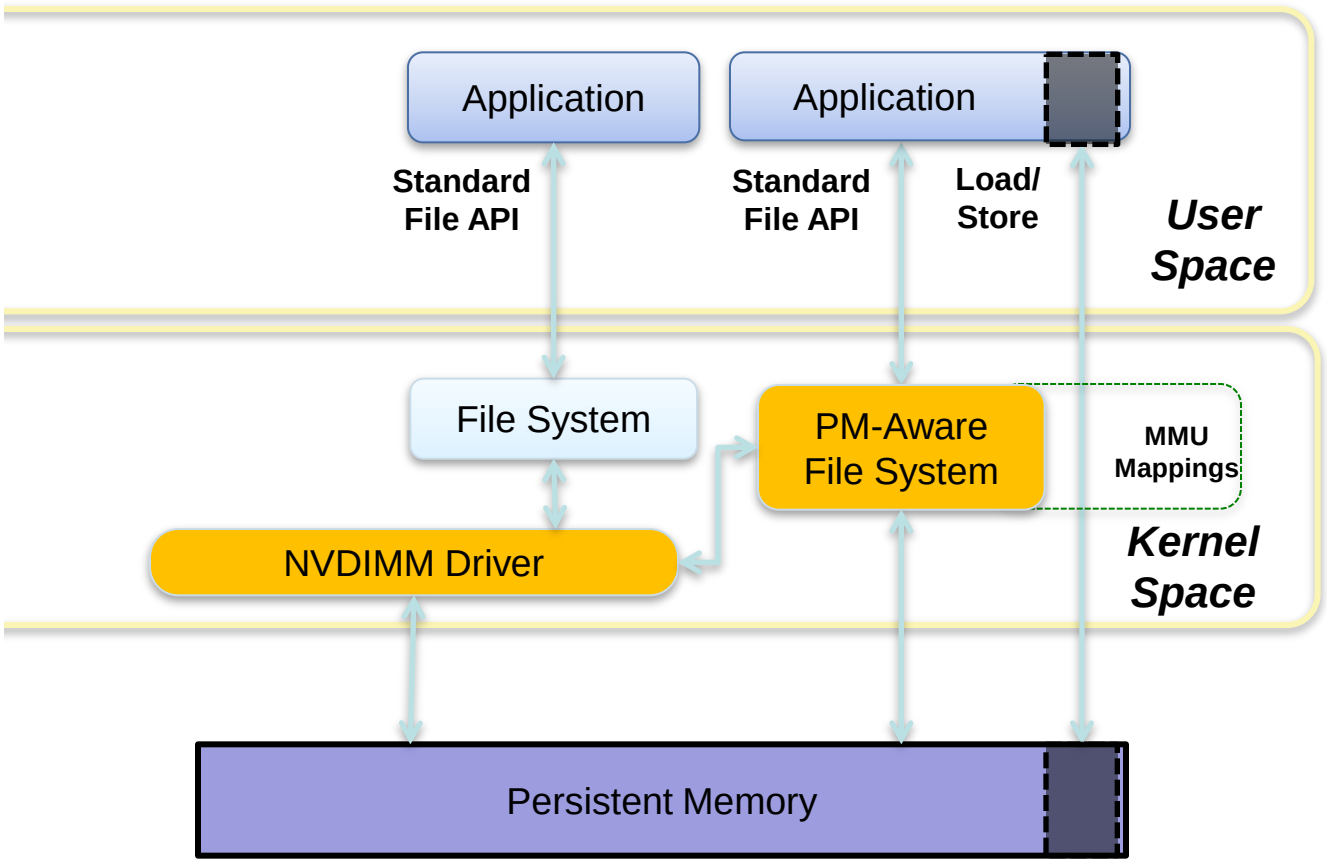


Uses of NVM.PM.FILE

- Applications
  - Persistent data sets, requiring addressability without impacting DRAM footprint
  - Persistent caches
- Usages that must reconnect with blobs of persistence
  - Naming
  - Permissions
- Potentially kernel modules requiring some of the above features

New Components

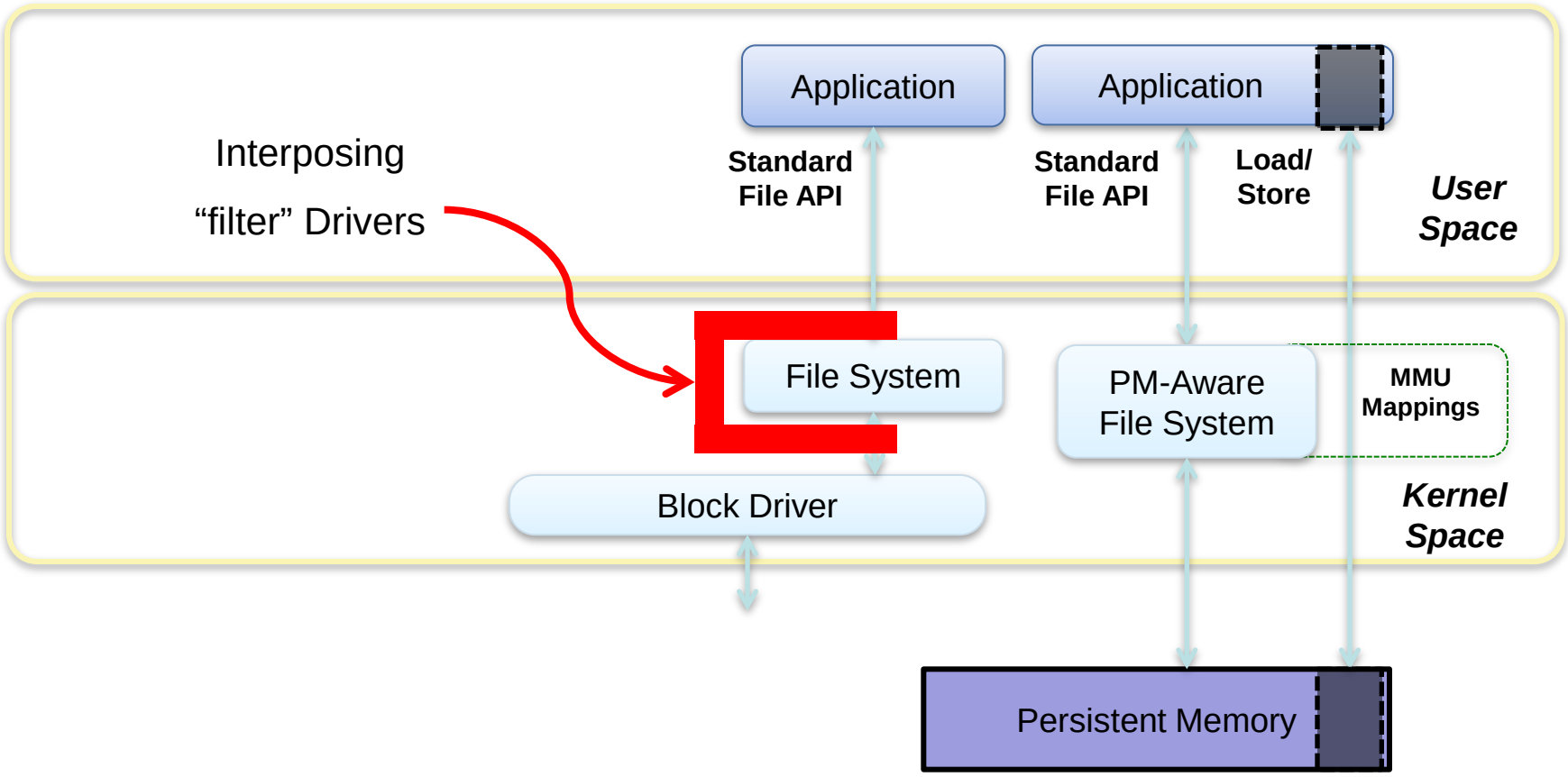
New Components



The Value of Persistent Memory

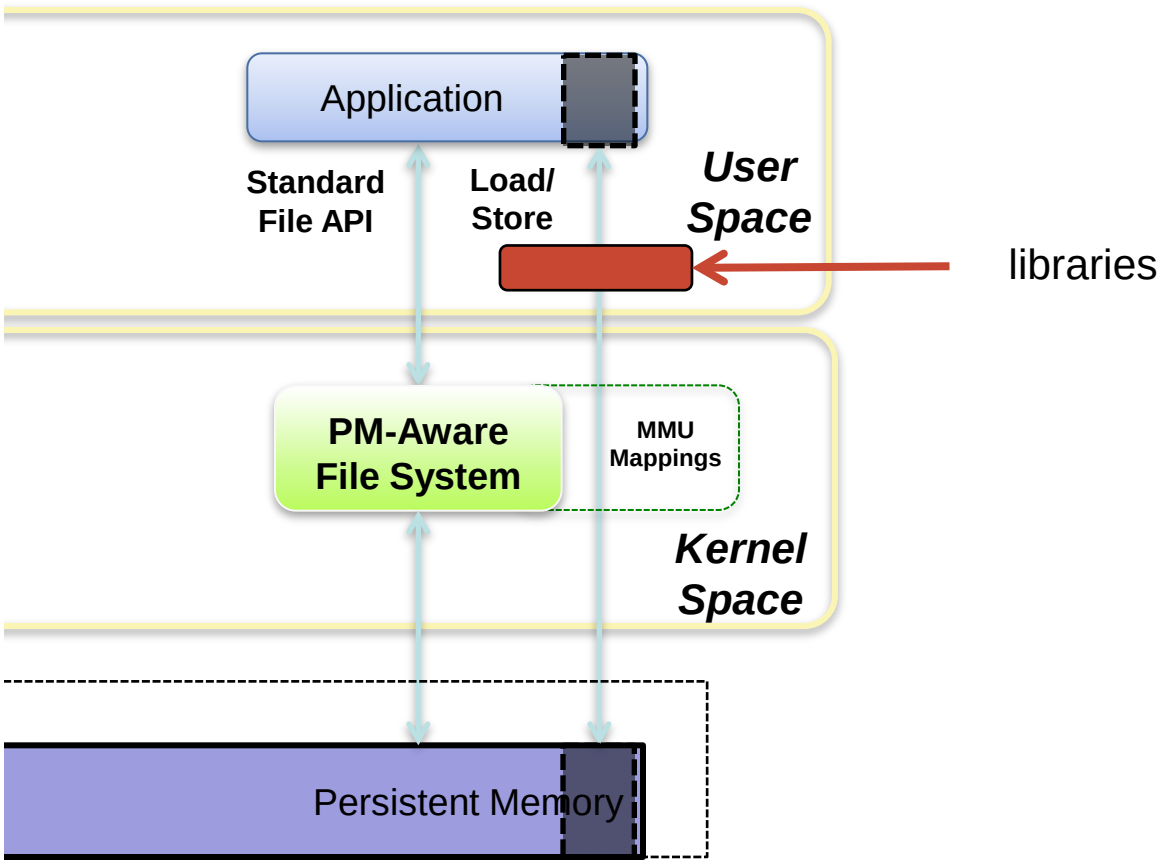
- Data sets addressable with no DRAM footprint
  - At least, up to application if data copied to DRAM
- Typically DMA (and RDMA) to PM works as expected
  - RDMA directly to persistence – no buffer copy required!
- The “Warm Cache” effect
  - No time spend loading up memory
- Byte addressable
- Direct user-mode access
  - No kernel code in data path

Re-thinking the Stack



Building on NVM.PM.FILE

- NVM.PM.FILE programming model "surfaces" PM to application
- Still somewhat raw at that point
- **Build on it with additional libraries**
- Eventually turn to language extensions



Is PM Transparent?

- Totally transparent
  - HW-supported full-system persistence
  - Client first, server much later
- Transparent above a certain level in stack
  - Exactly why we have NVM.PM.VOLUME
  - Also SSDs
- Transparent via library or language run-time
  - JVM seems like an obvious target

Exploring PM Semantics

- Portable, testable code using memory-mapped files
  - Should “just work”
  - Except for performance, of course
- Atomics provided by CPU
  - Typically what can be done in a single store
  - Beyond that, additional HW or SW needed
  - PM atomic requirements for each app is an area of research
- Interaction with CPU caches
  - Analogous to memory-mapped files and page cache

Summary

SNIA™ Solid State Storage Initiative

- The NVM Programming Models are aligning the industry
  - Gaining common terminology
  - Not forcing specific APIs
- Now that we've got it, what do we do with it?
  - PM models expose it
  - New PM models build on existing ones
  - We have not yet found our models to be limiting us
    - "yet"…
- Emerging technologies are going to drive work in this area, increasing as the cost comes down

For More…

- SNIA NVM Programming TWG
  - http://snia.org/forums/sssi/nvmp
- Linux Pmem Examples:
  - https://github.com/pmem/linux-examples
- Linux PMFS:
  - https://github.com/linux-pmfs
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