# NATIVE OS SUPPORT FOR PERSISTENT MEMORY WITH REGIONS

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# PERSISTENT MEMORY (PM)

❖ Hybrid characteristics of memory and storage

| Memory |
| --- |
| • Volatile<br>• Byte-addressable access<br>• Fast |

| Storage |
| --- |
| • Non-volatile/Persistent<br>• Block I/O access<br>• Slow |

**Read/Write latency**: **4X-10X** of memory

| Persistent Memory |
| --- |
| • Non-Volatile/Persistent<br>• Byte-addressable access<br>• Fast |

# PM CHALLENGES

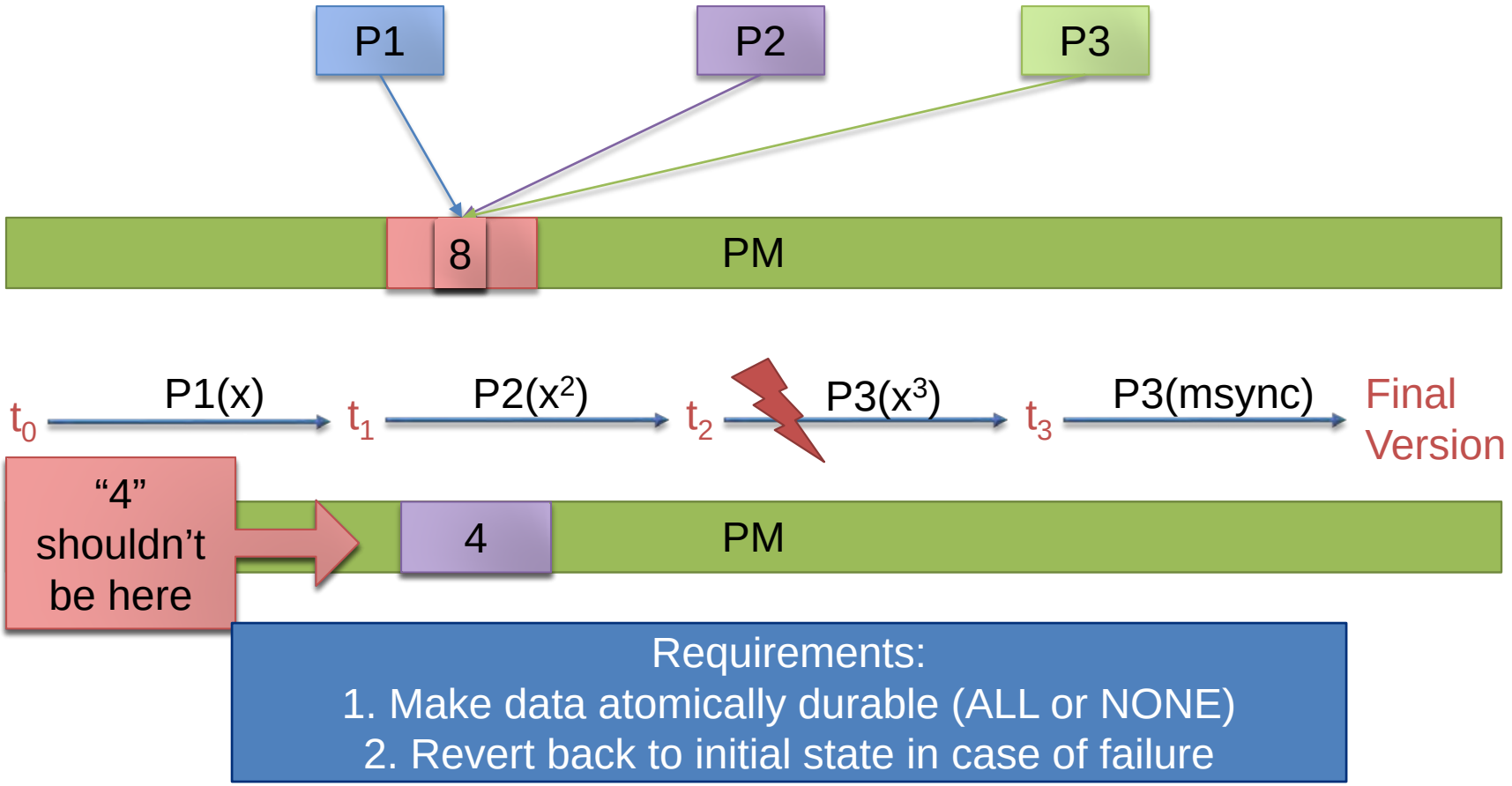
- PM is directly accessible by CPU
- BUT …

PM resident data can be corrupted after a system failure if ordering of updates is violated

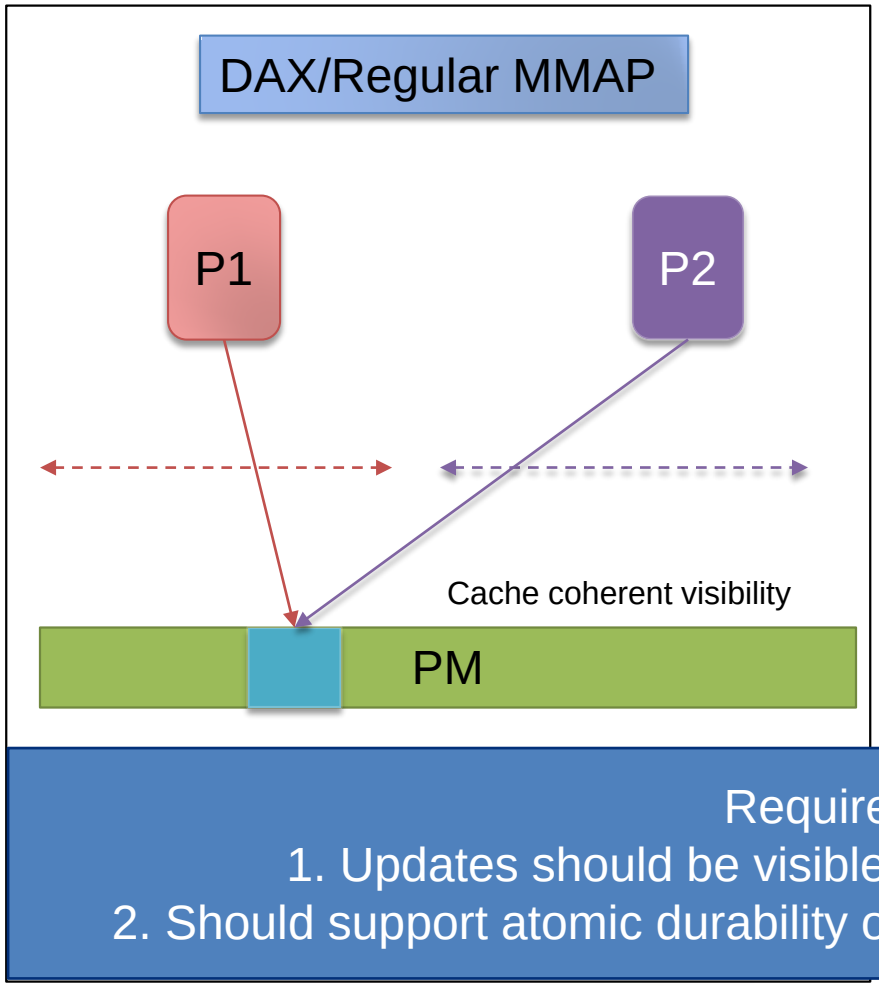
# PM CHALLENGES: THE COSTS OF ORDERING

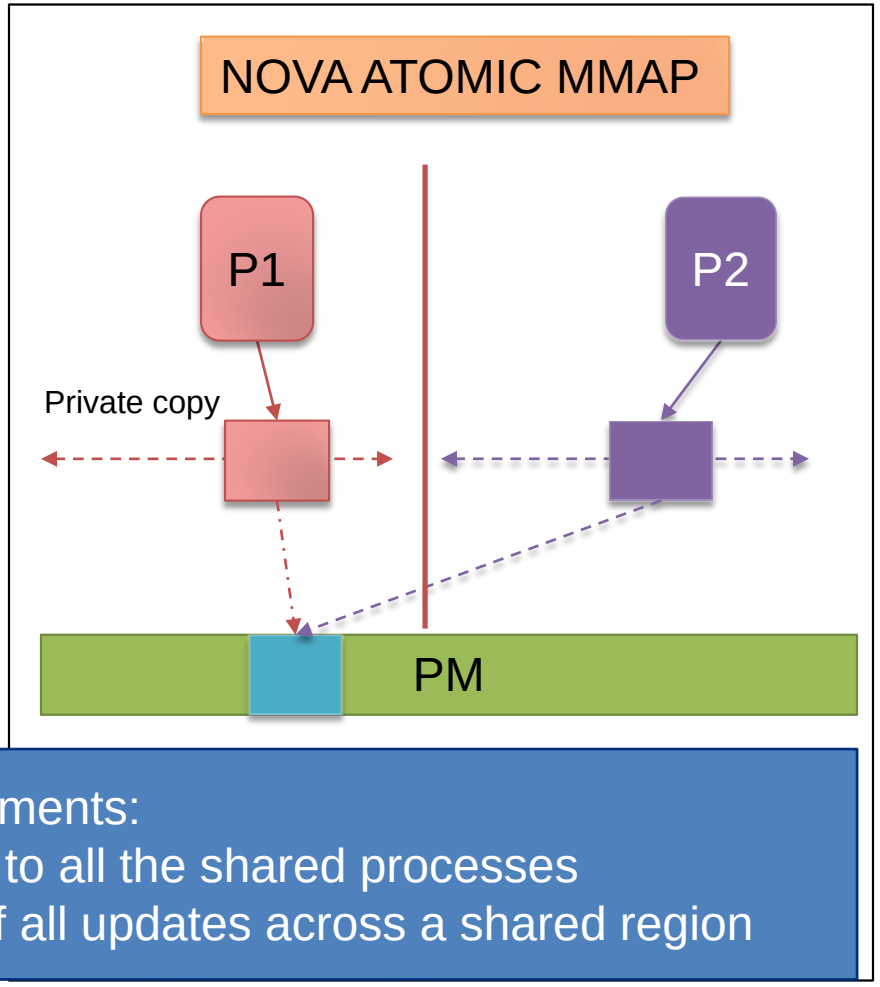
- Ordering requires cache line flushes, barriers, and ADR (asynchronous DRAM refresh)
  - Increased cost of operations
- More redundant metadata → More ordering required
- GOAL→
  - Reduce ordering requirements

# PM CHALLENGES: ATOMIC DATA DURABILITY



# PM OPPORTUNITIES: SHARED CONSISTENCY




Requirements:
1. Updates should be visible to all the shared processes
2. Should support atomic durability of all updates across a shared region

# PM OPPORTUNITIES: SIMPLE MEMORY-LIKE TRANSACTIONS

**Program A**

Allocate persistent Obj1;
Allocate persistent Obj2;

**Begin Transaction**
*Obj1 operations*
**End transaction**

**Begin Transaction**
*Obj2 operations*
**End transactions**

Programmers
1. Must track all updates to persistent objects
2. Must annotate individual transactions

**Program B**

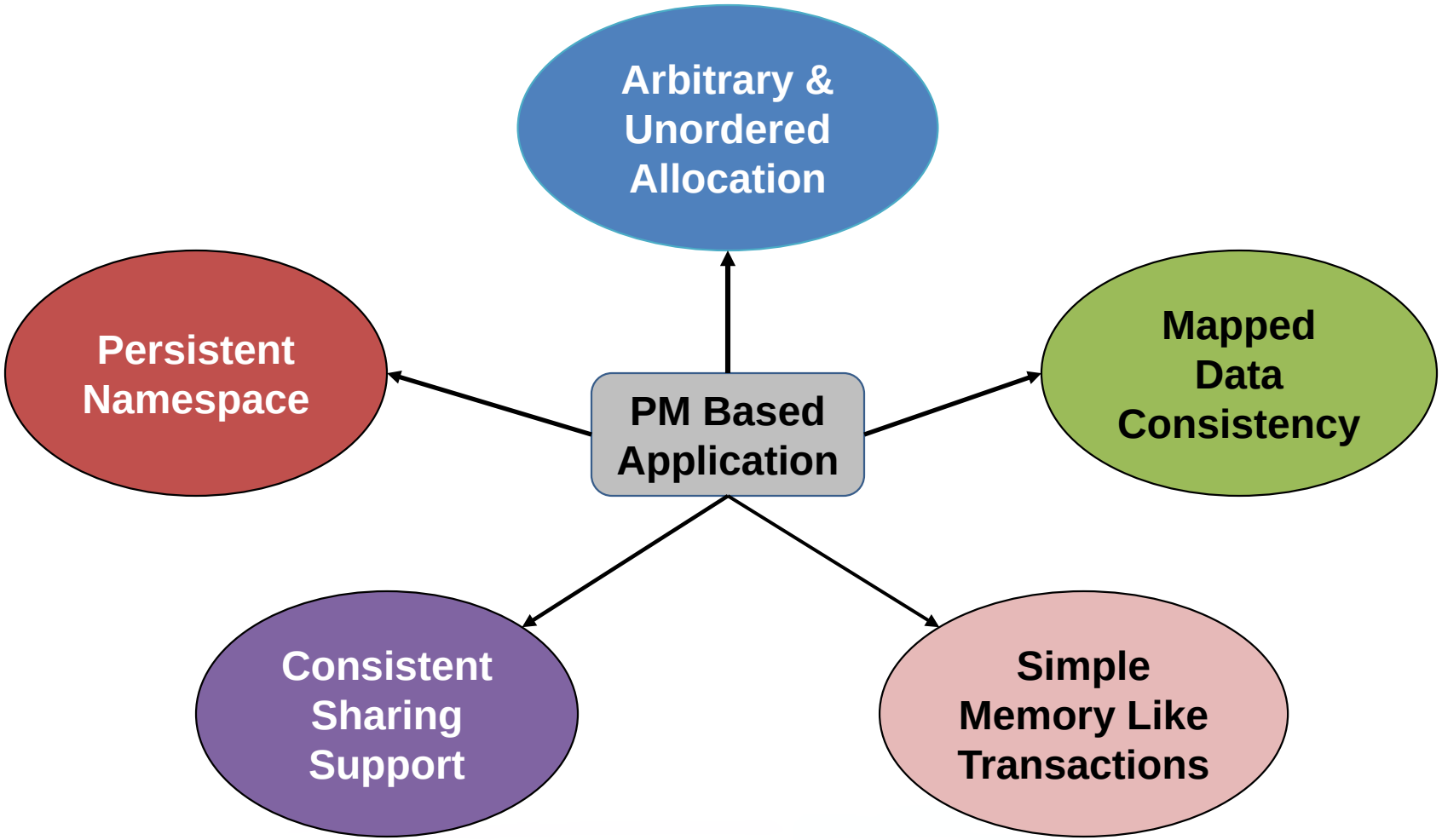
A = mmap(PM);
Allocate objects Obj1,Obj2 from mapped area

Operations involving Obj1, Obj2.
***Sync()***

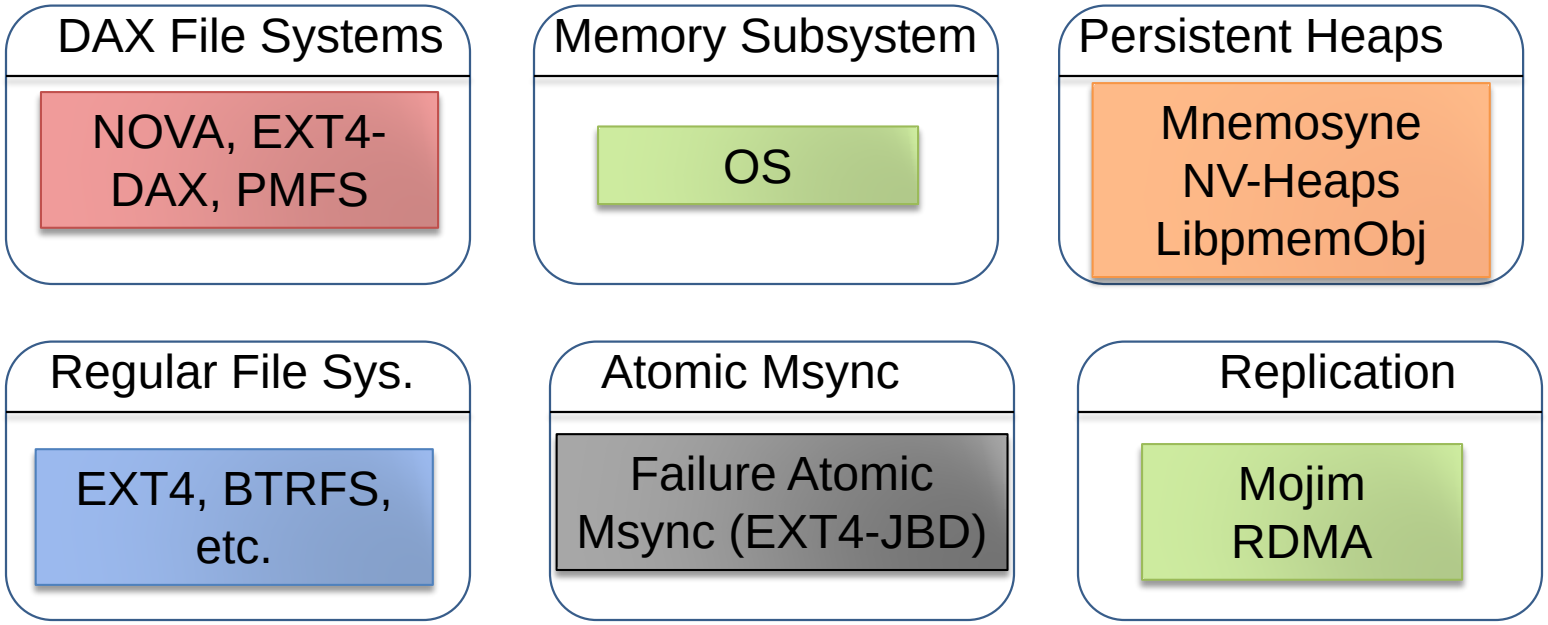
More Operations on both Obj1, Obj2
***Sync()***

**Programmers simply call Sync() to persist all updates in a mapped area**

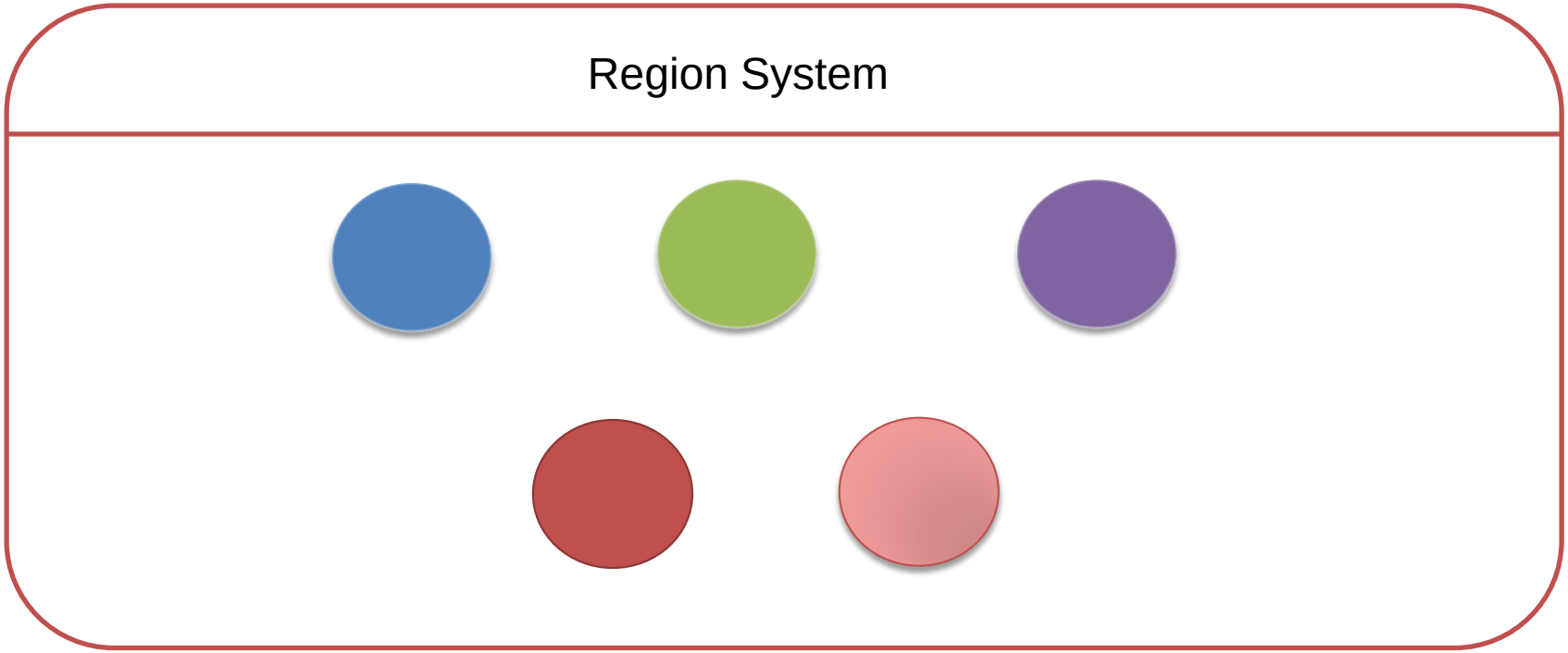
# APPLICATIONS REQUIREMENTS FOR PM



# CONTEMPORARY SOLUTIONS



# CONTEMPORARY SOLUTIONS




**Arbitrary and Unordered Allocation**

**Consistent Sharing Support**

**Simple Memory Like Transactions**

**Mapped Data Consistency**

**Persistent Namespace**

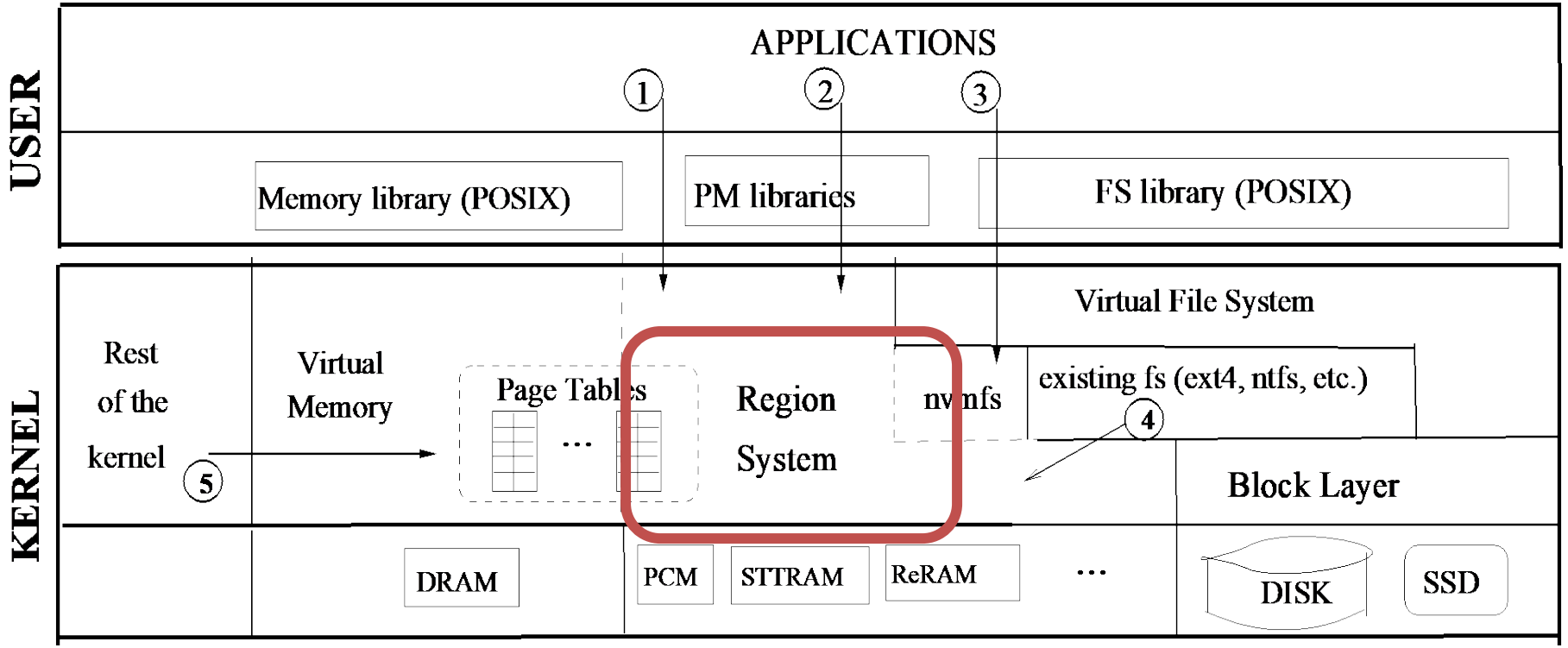
**Mapped Data Consistency (Partial)**

# REGION SYSTEM

We present “Region System”, a kernel subsystem, to support persistent memory to achieve the following goals:

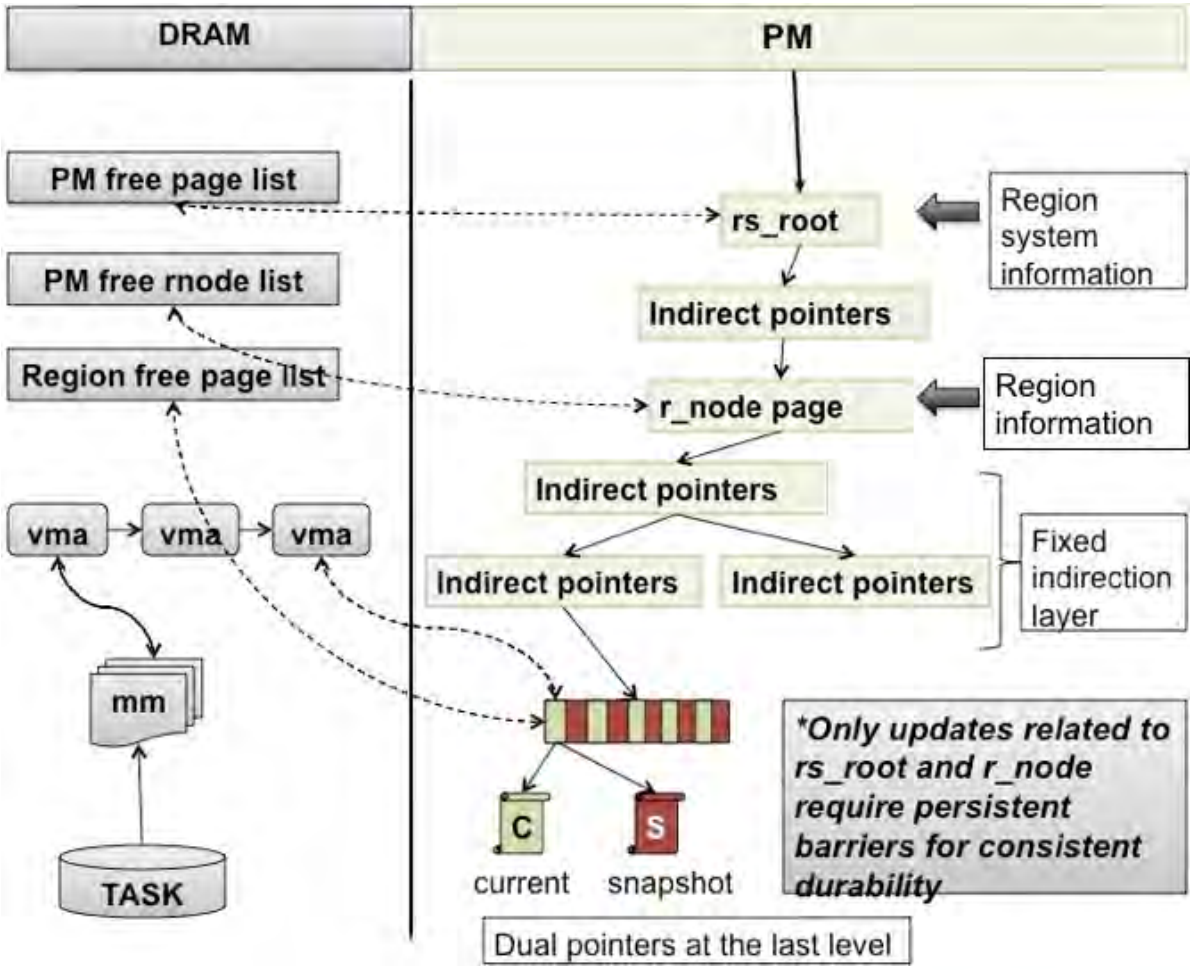
- Minimize unwanted latency in the persistent memory access path;
- Provide users with direct and consistent access to shared persistent memory; and
- Demonstrate modifications of the existing applications for optimized usage.

# REDEFINED OS MEMORY/STORAGE STACK




**NOT** intended as replacement for **File Systems** or **Memory Subsystem**
RS should serve as a core "Persistent Memory Support System" usable by **applications**, **file systems**, and **other kernel subsystems.**

# ARCHITECTURE




**Region**: Collection of persistent pages

**PPAGES**: 4KB PM pages

# CONSISTENCY STATES

| Current | Snapshot | State |
|---|---|---|
| **0** | **0** | No Ppage |
| **0** | **y** | Invalid – There can not be a snapshot without current |
| **x** | **0** | Un-synced page, mapped to the address space |
| **x** | **y** | x == y, page in synced state |
| | | x != y, page in unsynced state, “y” is the consistent version |

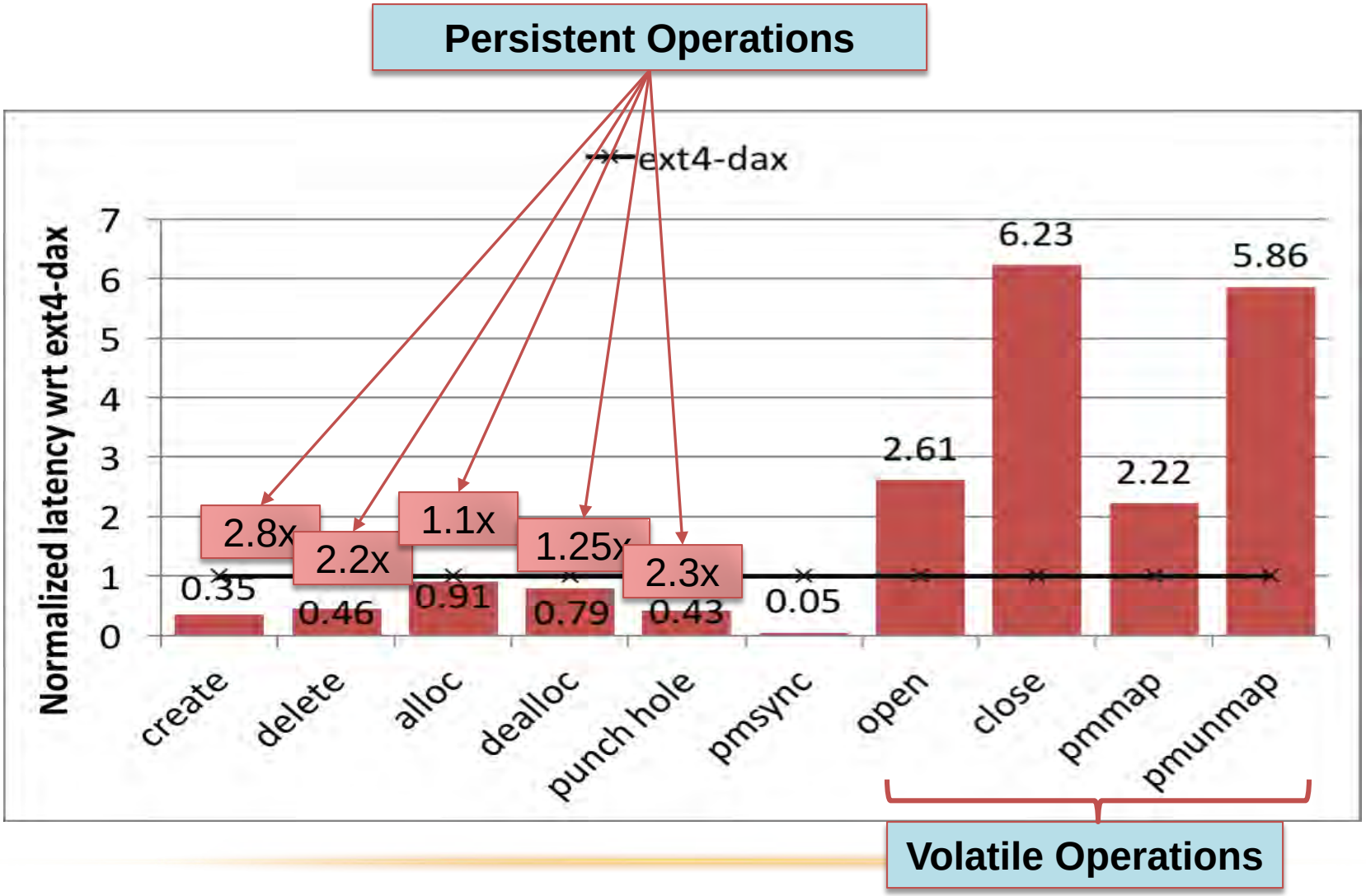
# REGION SYSTEM (RS) INTERFACE

| Class | System Call |
|---|---|
| Namespace | region_d open (char region_name, flags f) |
| | int close (region_d rd ) |
| | int  delete (region_d rd) |
| Allocation | ppage_no alloc_ppage (region_d rd) |
| | int free_ppage (region_d rd, ppage_no ppn) |
| Mapping & Consistency | vaddr pmmap(vaddr va, region_d rd, ppage_no, int nbytes, flags f) |
| | int pmunmap(vaddr va) |
| | pmsync(vaddr va) |

# METADATA OPERATIONS

- Persistent Operations
  - Modifies persistent metadata
- Volatile Operations
  - No updates to persistent metadata
- Persistent operations are designed to achieve atomic durability

# METADATA OPERATION COMPARISON



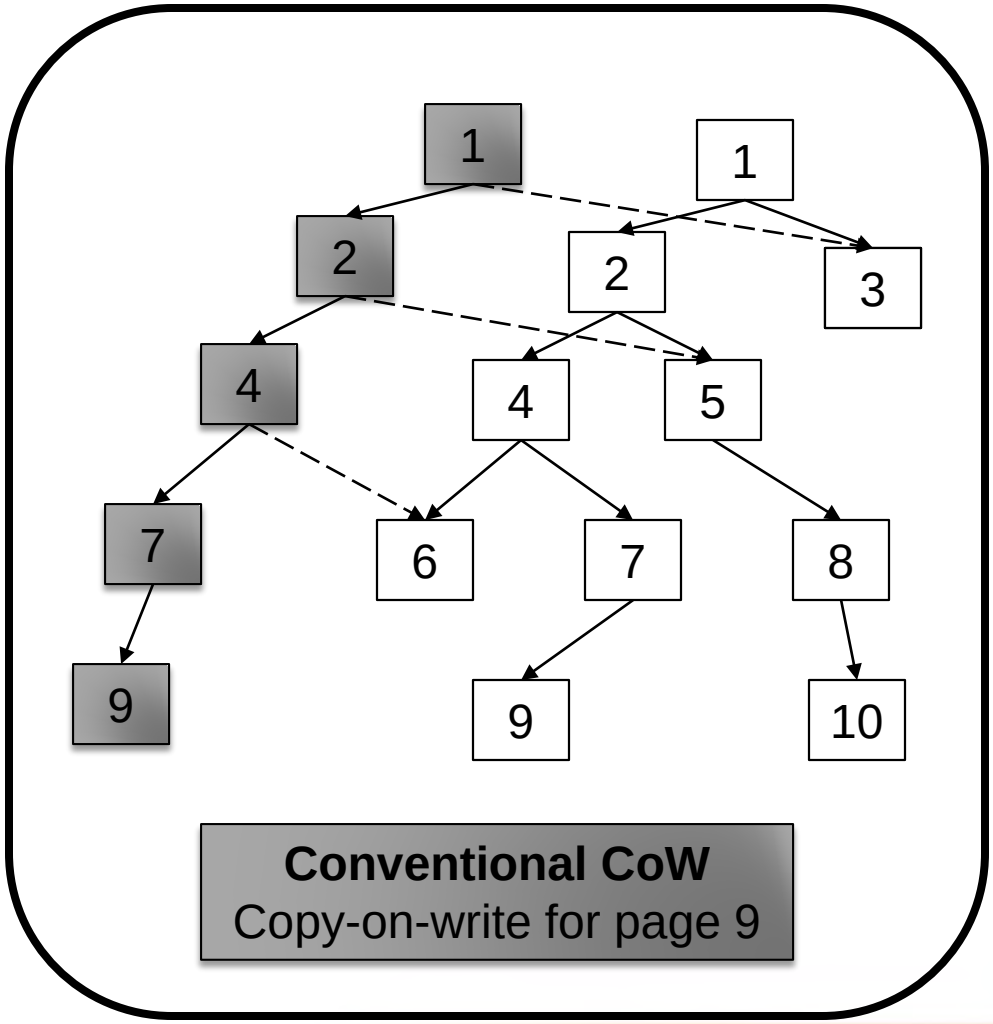
# MAPPED DATA CONSISTENCY CHALLENGES

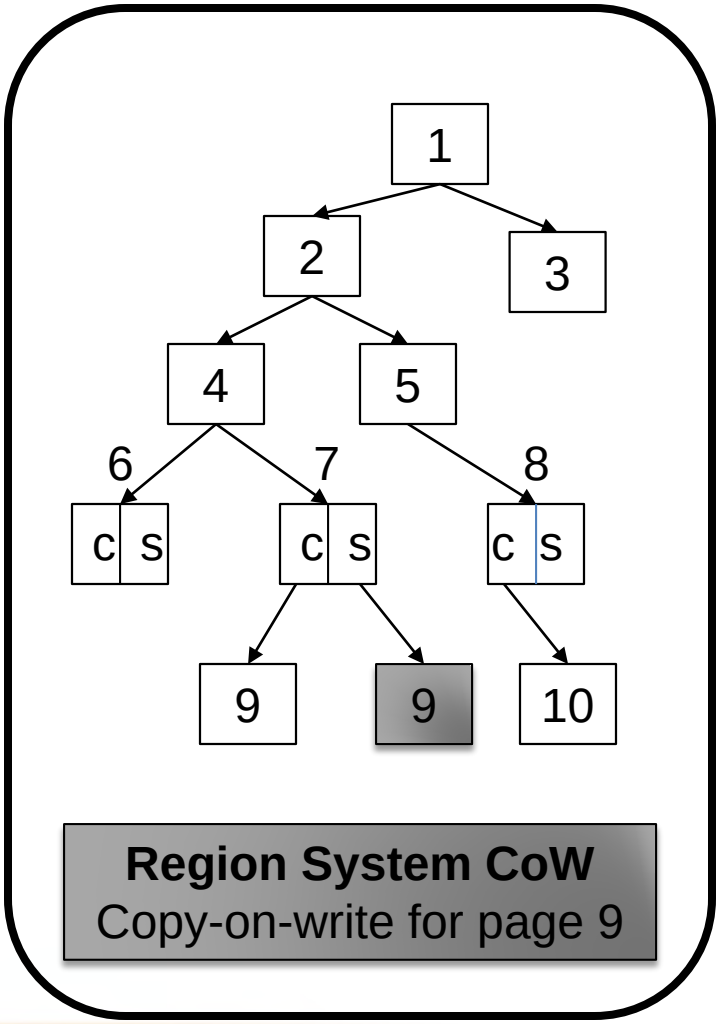
- **Avoid Unwanted Durability**
  - Applications want to make updates durable only updates a msync() invocation.
  - Updates are made durable in PM before a msync call.
  - In case of a failure, the mapped PM area will contain uncommitted data.
- **Protecting the Sync**
  - During sync operation no applications should be allowed to write to mapped PM → difficult to achieve due to direct CPU access.

# ATOMIC DURABILITY WITH PMSYNC

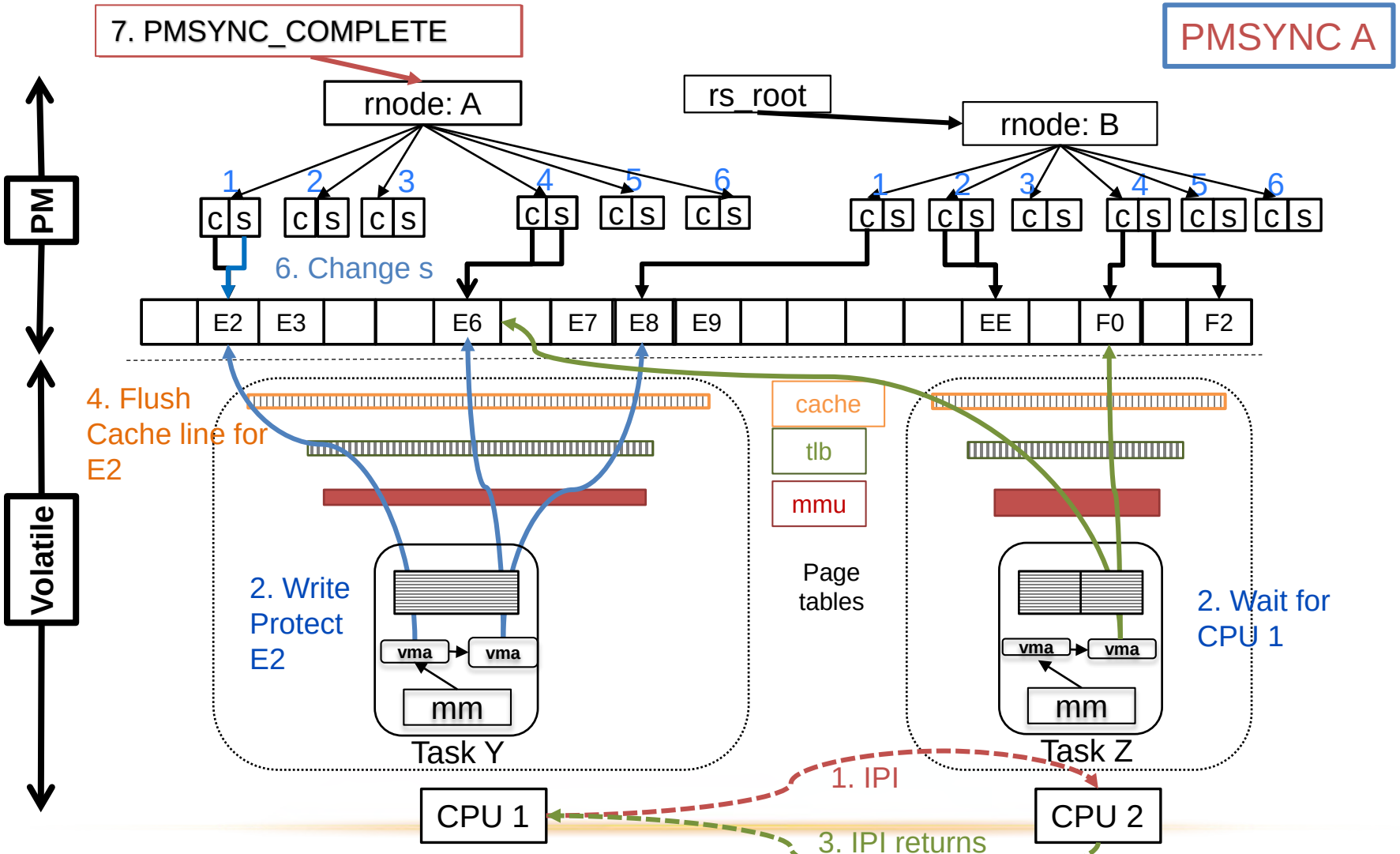
1. Identify the dirty pages
2. Write protect the pages
3. Flush dirty cache lines
4. Copy-on-write protection for future writes to a sync'ed page

# AVOIDING COW PROPAGATION

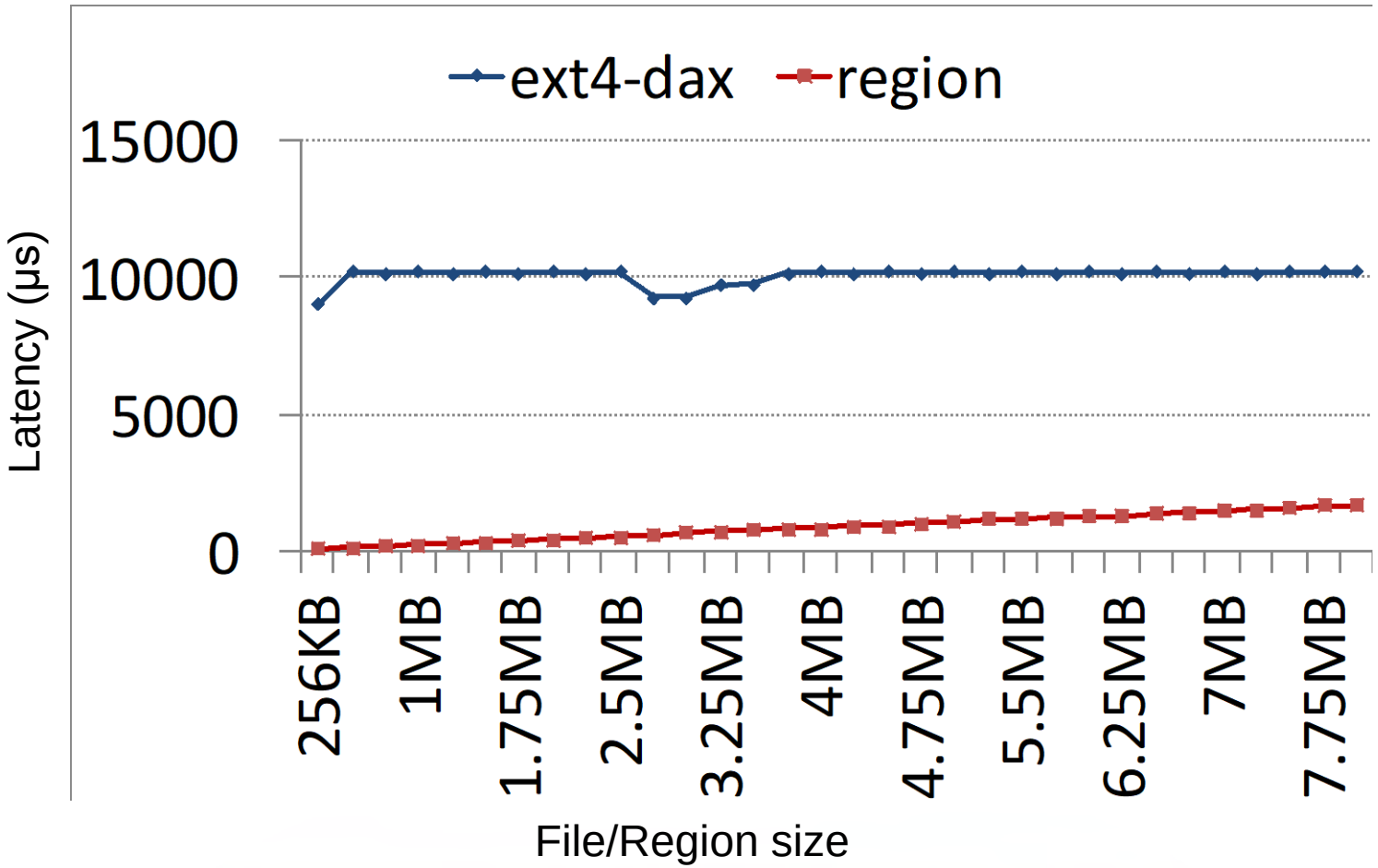


# PMSYNC EXAMPLE



# PMSYNC COMPARISON WITH EXT4-DAX

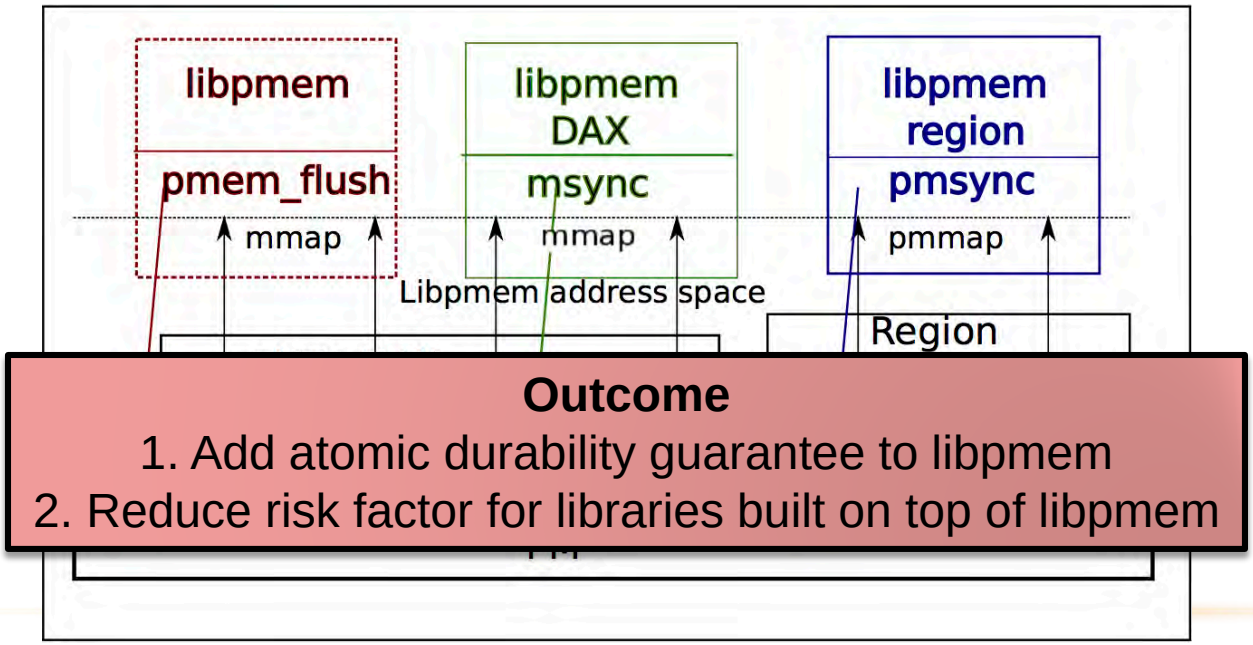


# LIBPMEM-REGION

**Non-transactional pmem-flush**

All or None policy does not work

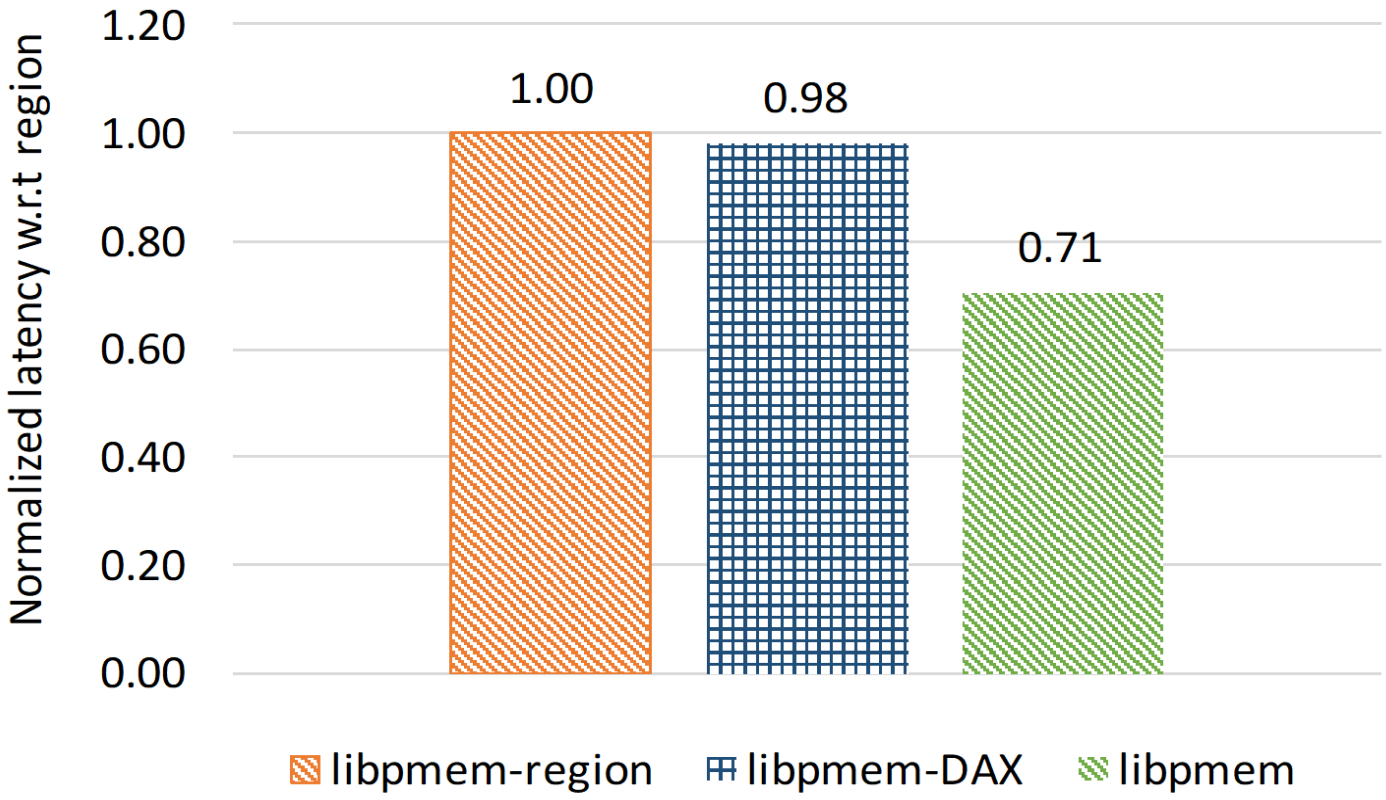
A portion of the updates can be lost



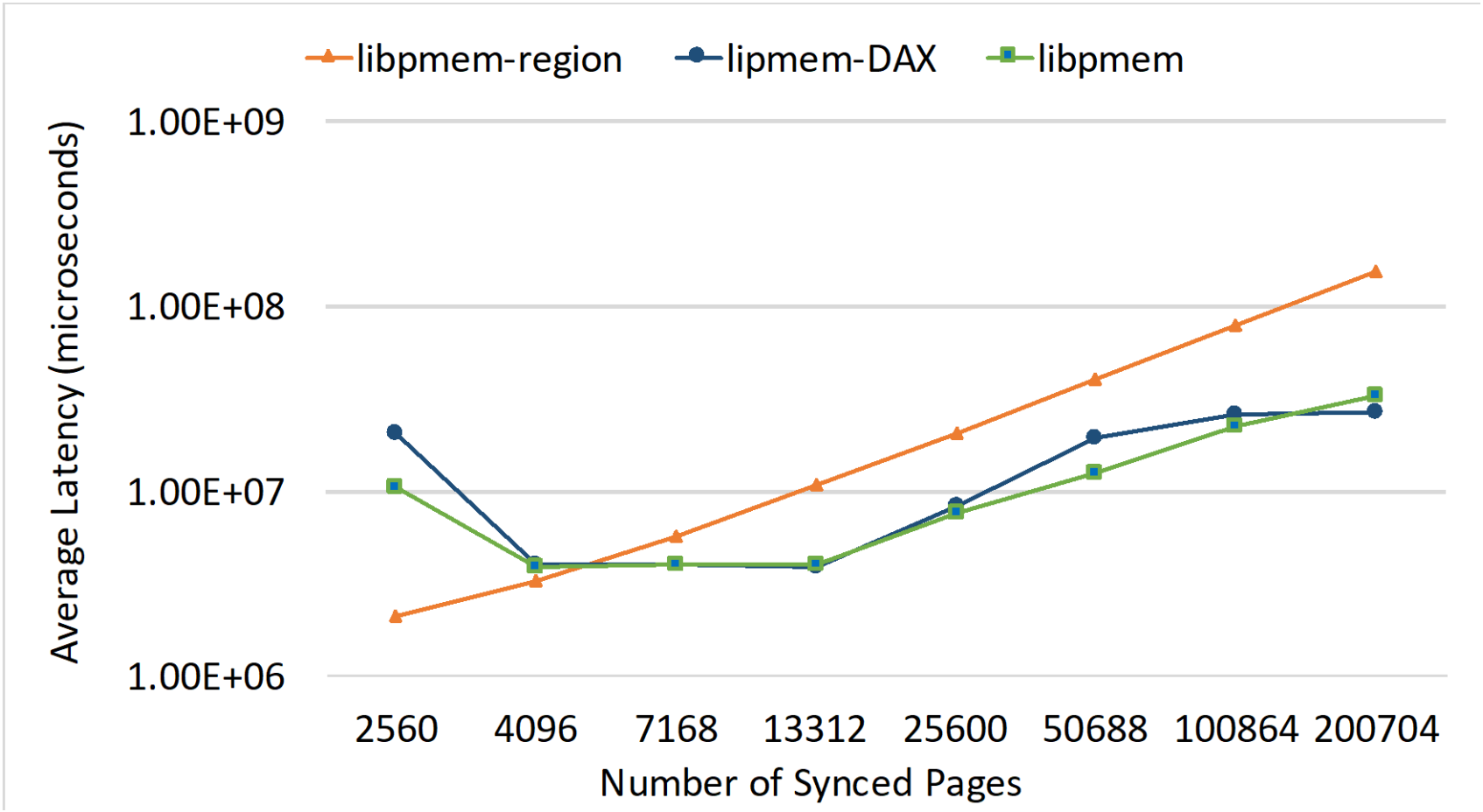

**Outcome**

1. Add atomic durability guarantee to libpmem
2. Reduce risk factor for libraries built on top of libpmem

# LIBPMEM COMPARISONS



# LIBPMEM COMPARISONS



# SUMMARY

- Region System Features
  - Provides **arbitrary** and **unordered** allocation and de-allocation
  - Minimizes ordering requirements by **eliminating redundancy**
  - Provides **transparent sharing** and **atomic durability** of mapped data with competitive performance
  - Usable by **File systems**, **Applications**, **Libraries**, and other kernel subsystems or modules.
  - Source code will be made public soon!

# Thanks!

# QUESTIONS?