Rethinking the Performance/Cost of Persistent Memory and SSDs

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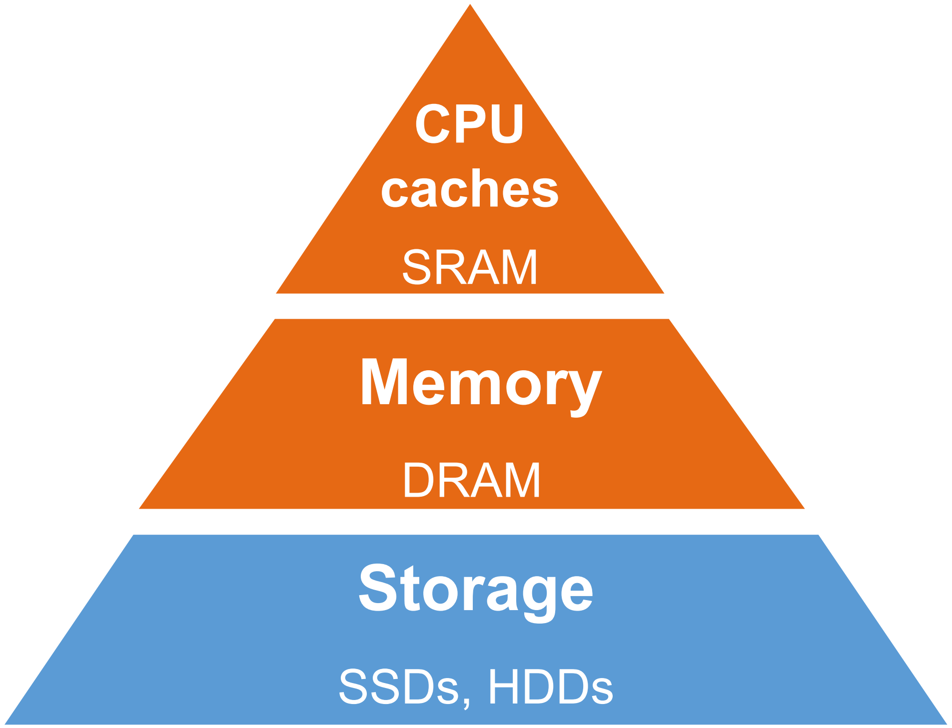
The Storage Hierarchy as We Knew It



Layers with clear boundaries
Memory: fast but volatile
Storage: slower than memory but persistent

Caching stores hugely successful

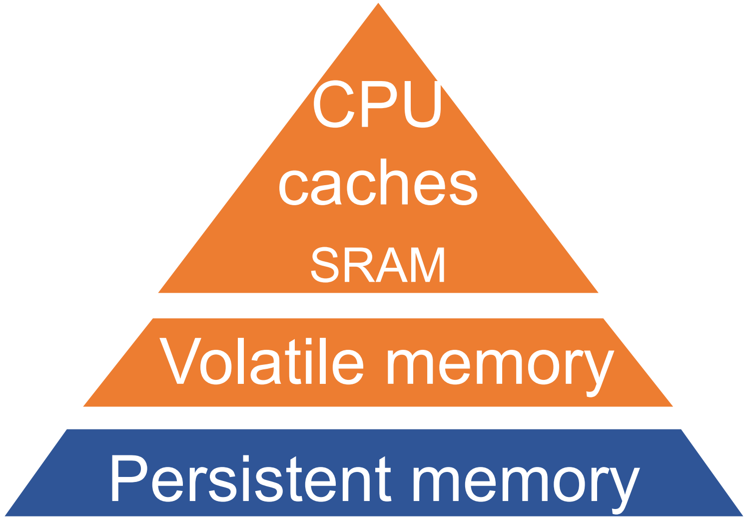
- Hot data in buffer pool (DRAM)
- The whole dataset on drives
- Practical & Cost-effective

…is being disrupted by two trends

Trend 1: (Persistent) Memory Meets Persistence

Persistent memory, generally speaking
- Byte addressable
- Persistence
- Large capacity
- Cheaper than DRAM

Intel Optane Persistent Memory 200 (3D XPoint)
- Peak read: 7.4 GB/s per DIMM
- Peak write: 2.3 GB/s per DIMM
- Capacity: 128/256/512 GB per DIMM



“PM camp”

(a lot of attention)

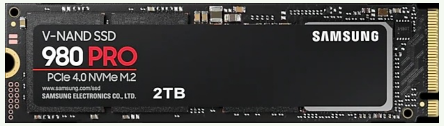
Buffer pool + SSD

Single-level index/store

“SSDs no more, cheaper than DRAM – all in!”

Trend 2: SSD Approaches (Persistent) Memory

- New materials
  - 3D V-NAND Flash or 3D XPoint
- New interconnection
  - PCIe Gen4
- New software stack
  - SPDK, io_uring

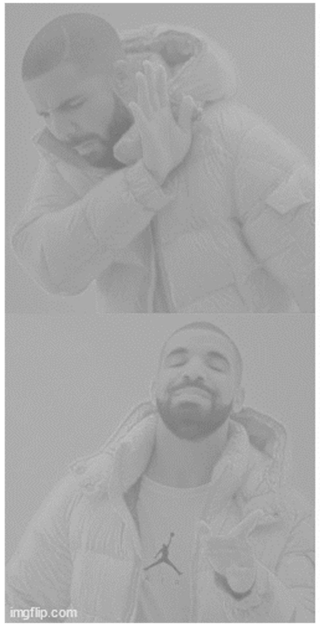


Intel Optane DC SSD P5800X
- Peak read: 7.4 GB/s
- Peak write: 7.4 GB/s
- Capacity: 400/800/1600GB x # drives

vs.

Intel Optane PMem 200 (128GB DIMM)
- Peak read: 7.4 GB/s
- Peak write: 2.3 GB/s
- Capacity: 128GB x # memory channels

"PM camp"
(a lot of attention)



Buffer pool + SSD

Single-level index/store

"SSD camp"
(relatively quieter)

Single-level index/store

~In-memory performance atop SSD

With faster SSDs, match or outperform PM indexes?

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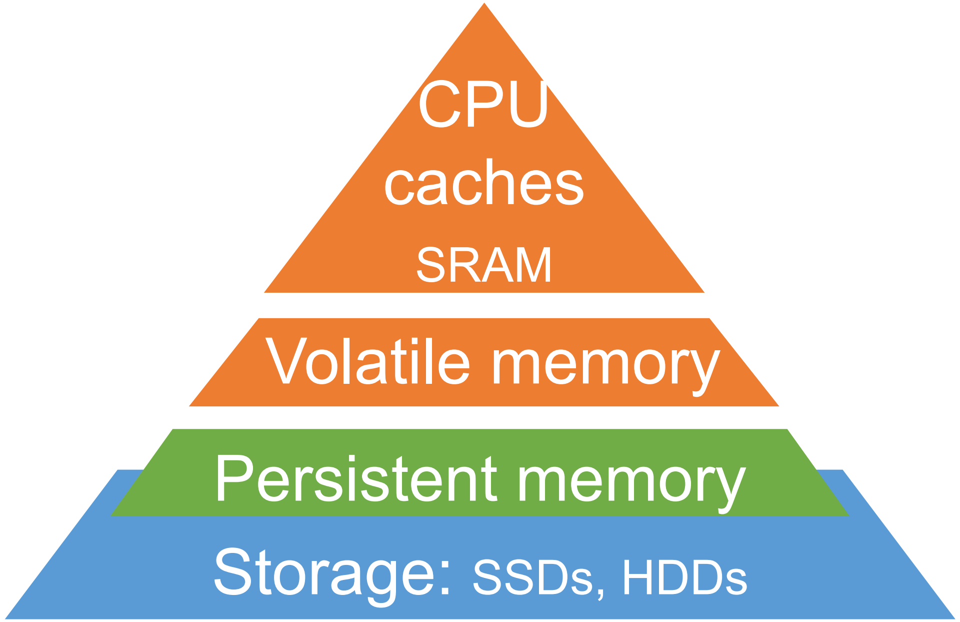
The Storage Jungle



Layers with overlapping properties

Memory not necessarily volatile

Storage not necessarily slower than memory

PM vs. SSD Servers: What to Consider

Rigid installation requirements

- Strict population rules
  - >= 1 DRAM DIMM per controller

→ Overprovisioning

- Clock down frequency

→ Affect overall memory performance

Non-trivial CPU cost

- Synchronous `load/store`

→ High-end CPU cores wasted

Flexible installation requirements

- DRAM requirement decoupled
- Few population rules (e.g., RAID)

→ Nothing overprovisioned

Low CPU cost

- Asynchronous DMA

→ Overlap I/O operations and computing

PM vs. SSD Servers: Costs

$ per GB	PM1 128G	PM6 768G	P4800X 375G
Storage-only	$4.27	$4.27	$2.66
Storage+DRAM	$13.32	$5.78	$5.75
Storage+DRAM+ CPU (minimum)	$18.23	$7.76	$5.92
Storage+DRAM+ CPU (full)	$32.98 (Total: $4,221.69)	$9.06 (Total: $6,955.44)	$12.46 (Total: $4,673.94)

Observations:

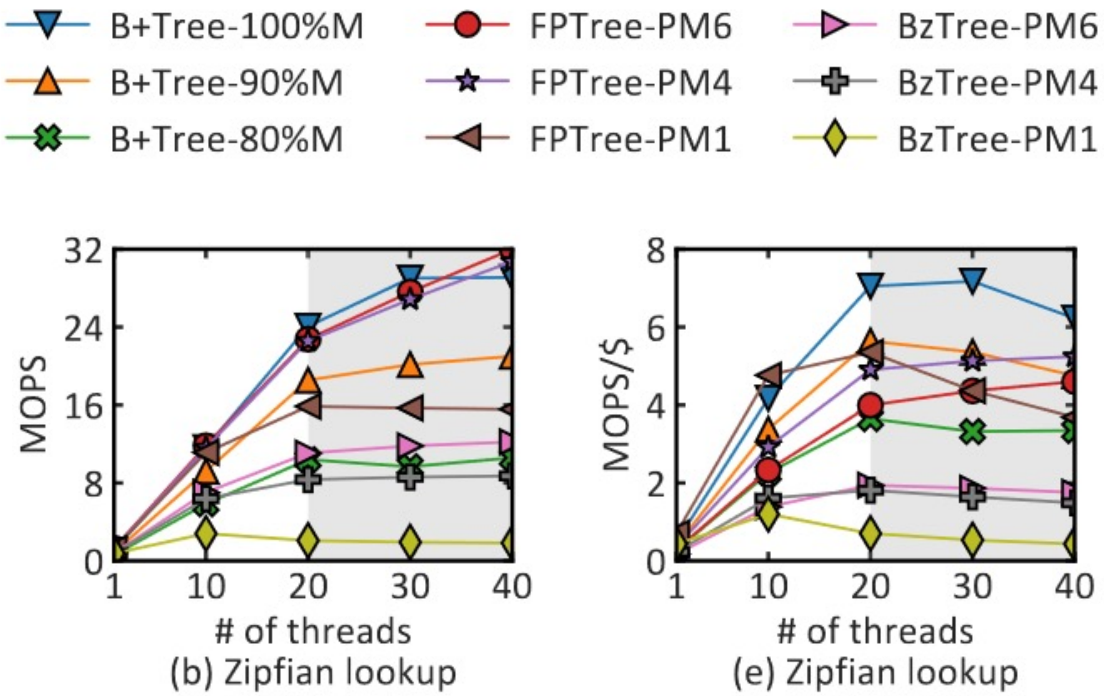
Same material, but PM is more expensive than SSD

DRAM significantly increases the unit prices

10 threads to saturate PM (write bandwidth), 1 thread to saturate SSD

Not fair ☹

PM vs. SSD Servers: Performance



(more details in paper)

FPTree & BzTree:

Tailor-made, optimized for PM

B+Tree:

Coursework-grade (!) atop P4800X

Takeaways:

- Memory-resident? Use SSD + buffer pool
- PM indexes still rely on DRAM to gain performance
- P4800X is very competitive with PM1

Final Thoughts

Before you invest in PM…

- PM hardware is still too expensive;
  - High-end CPU cores for “I/O” + extra DRAM costs
- PM software stack is also “expensive”
  - A steep learning curve, complex programming model

Is SSD a done deal? No.

- SSD is usually more cost-effective
  - Even with suboptimal implementation
- Explore newer storage interfaces (e.g., SPDK)

Full paper at CIDR 2022: SSDs Striking Back: The Storage Jungle and Its Implications on Persistent Indexes

Code: https://github.com/sfu-dis/ssd-vs-pm

Thank you!

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