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Take Advantage of Intel Optane DCPM in Flink

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Contents

目录 >>

1 What’s Intel Optane DC Persistent Memory?

2 Modes and Population

3 How to use it in Flink workload?

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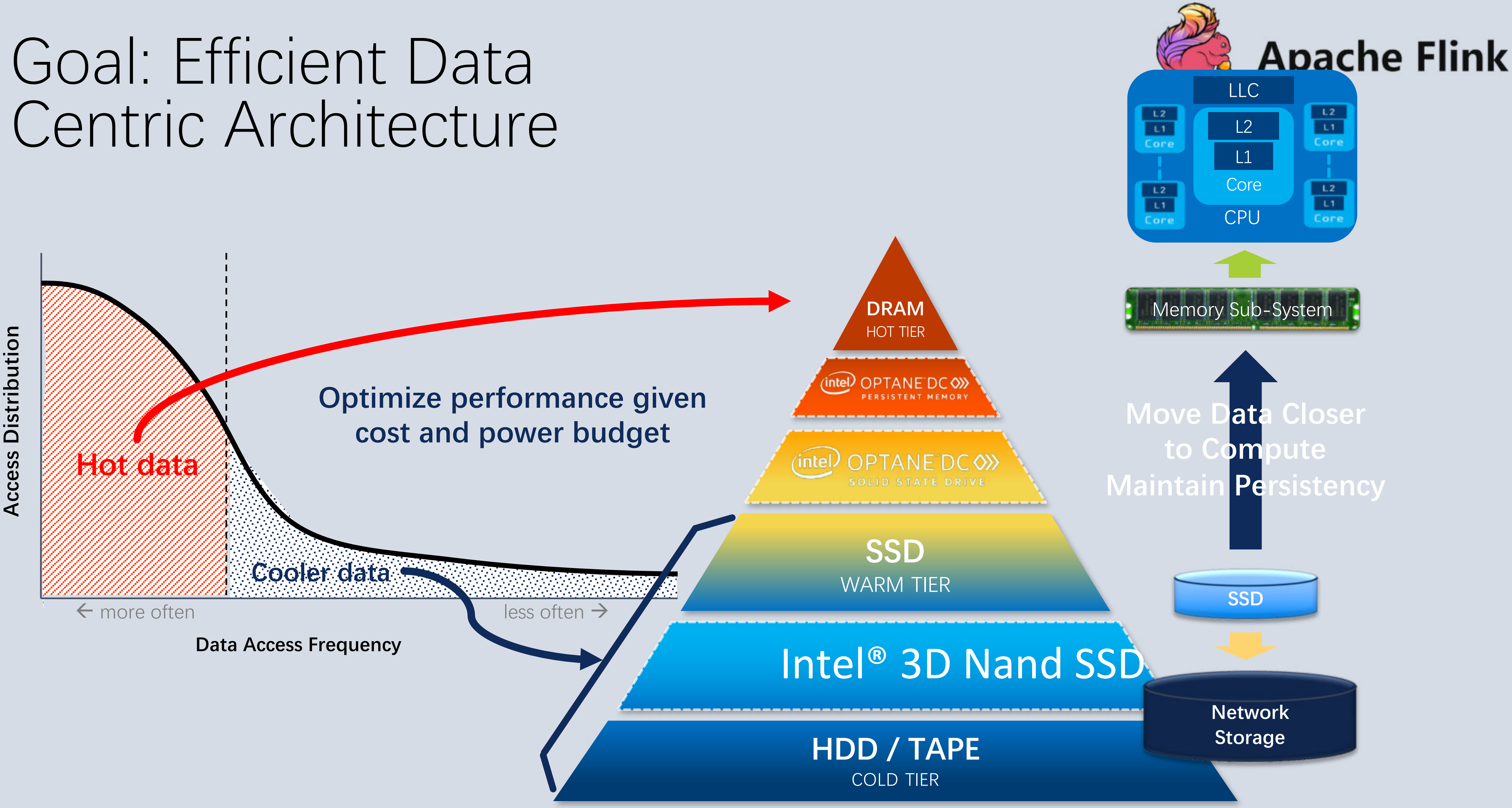
PART 01

What’s Intel Optane DC Persistent Memory?

Goal: Efficient Data Centric Architecture



Optimize performance given cost and power budget

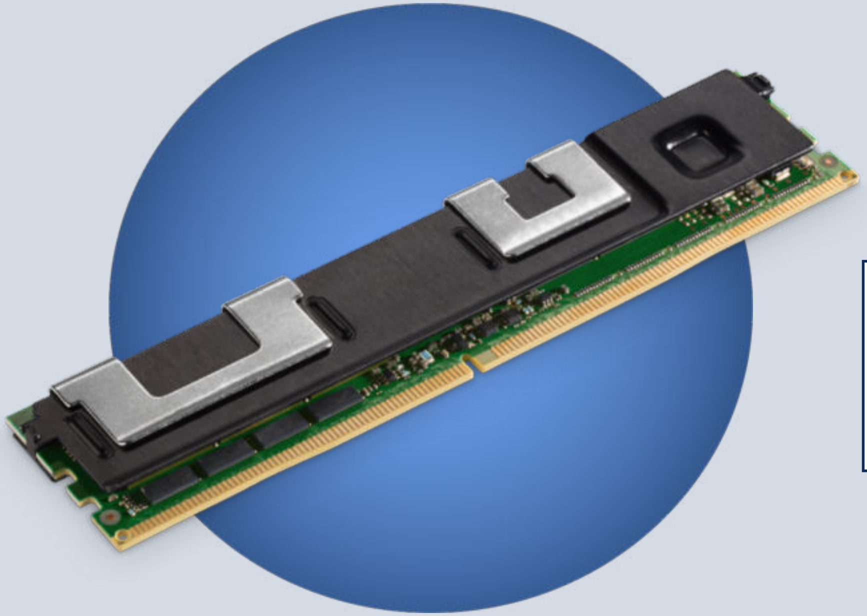
Move Data Closer to Compute

Maintain Persistency

The best of both worlds with Intel® Optane™ DC Persistent Memory

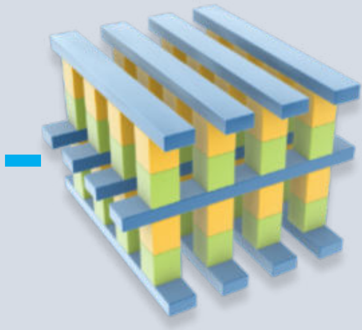
Memory attributes

Performance comparable to DRAM at low latencies[1]



Storage attributes

Data persistence with higher capacity than DRAM[2]



1. *“Fast performance comparable to DRAM”* - Intel persistent memory is expected to perform at latencies near DDR4 DRAM. Benchmarks and proof points forthcoming. *“low latencies”* - Data transferred across the memory bus causes latencies to be orders of magnitude lower when compared to transferring data across PCIe or I/O bus’ to NAND/Hard Disk. Benchmarks and proof points forthcoming.
2. Intel persistent memory offers 3 different capacities – 128GB, 256GB, 512GB. Individual DIMMs of DDR4 DRAM max out at 256GB.

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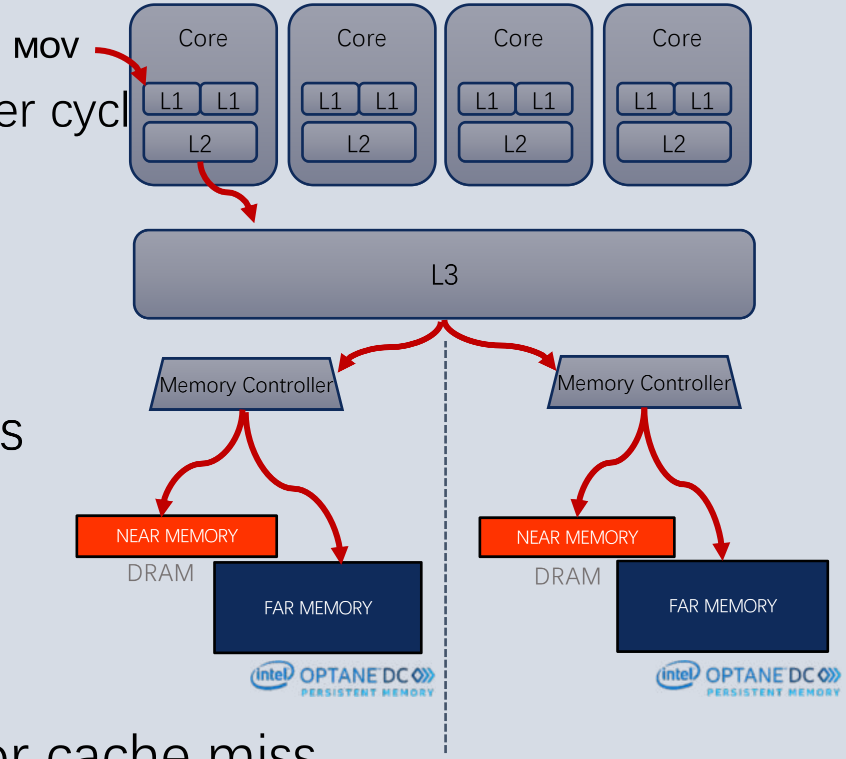
PART 02

Modes and Population

Memory Mode

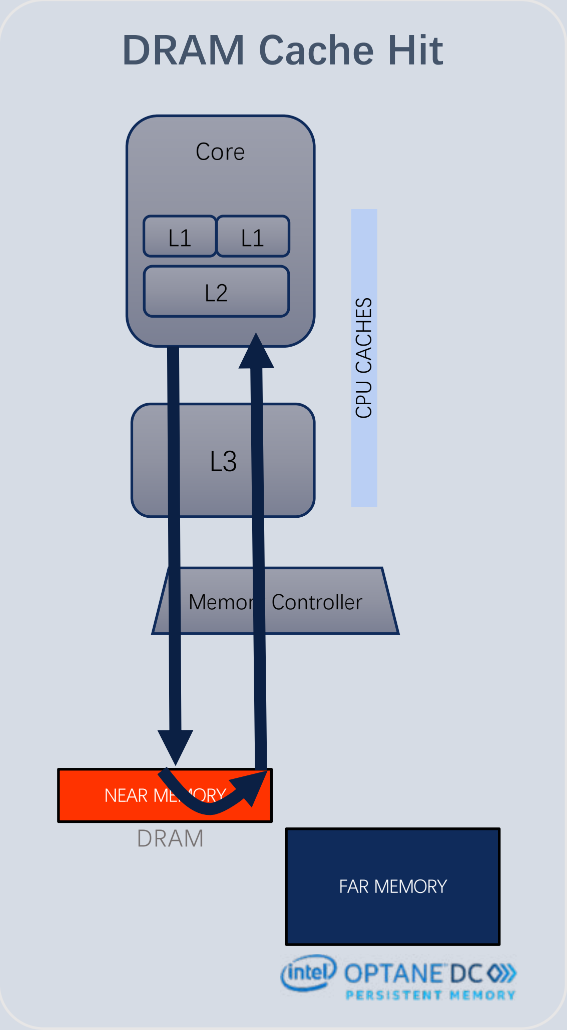
- No software/application changes required
- To mimic traditional memory, data is “volatile”
    - Volatile mode key cleared and regenerated every power cycl
- DRAM is “near memory”
- Used as a write-back cache
- Managed by host memory controller
- Within the same host memory controller, not across
- Ratio of far/near memory (PMEM/DRAM) can vary
- Overall latency
- Same as DRAM for cache hit
- Intel® Optane™ DC persistent memory + DRAM for cache miss

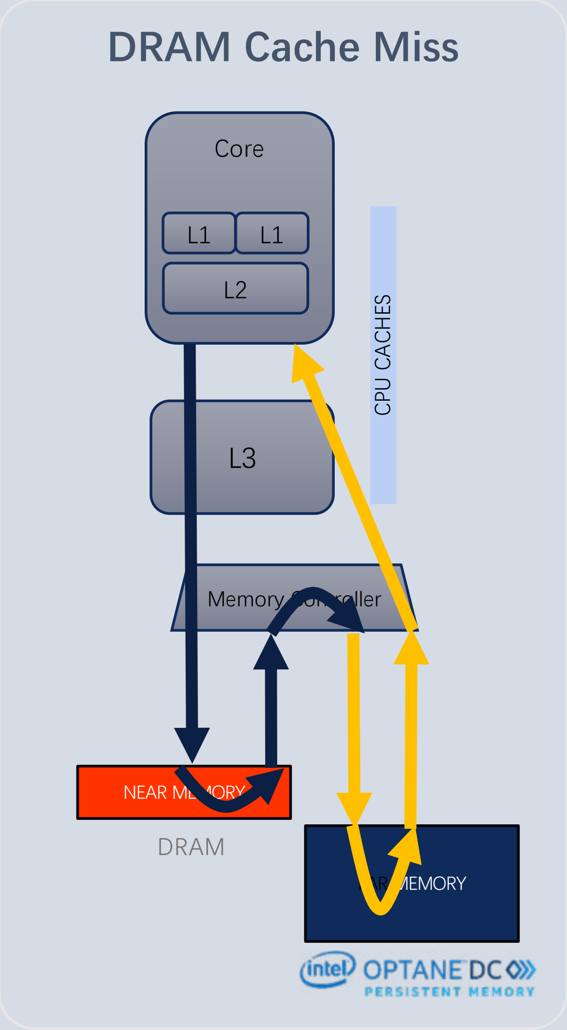


https://itpeernetwork.intel.com/intel-optane-dc-persistent-memory-operating-modes/#gs.qwufar

Memory Mode Transaction Flow

- Good locality means near-DRAM performance
  - Cache hit: latency same as DRAM
  - Cache miss: latency DRAM + Intel® Optane™ DC persistent memory
- Performance varies by workload
  - Best workloads have the following traits:
    - Good locality for high DRAM cache hit rate
    - Low memory bandwidth demand
  - Other factors:
    - #reads > #writes
    - Config vs. Workload size


DRAM Cache Hit


DRAM Cache Miss

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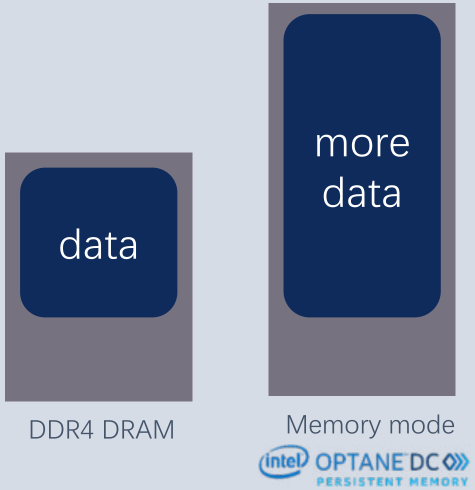
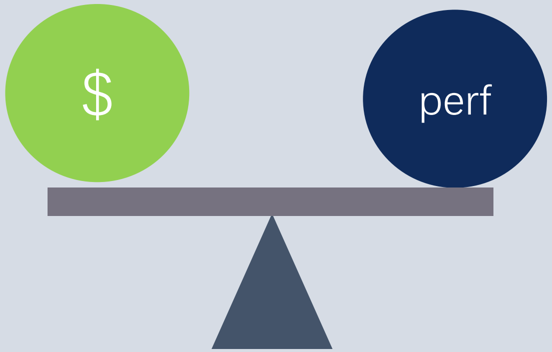
Larger Memory Capacity enables new usages

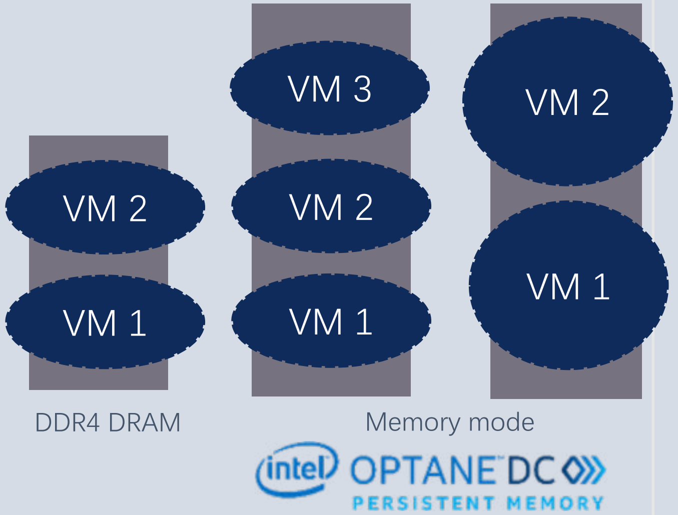
Larger databases and data sets

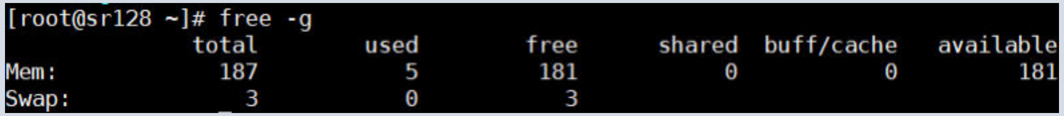


More options for TCO balancing

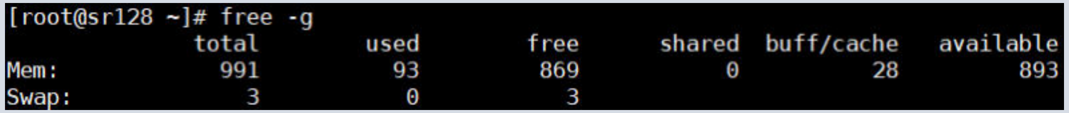


Larger vms, More VMs[1]





```
[root@sr128 ~]# free -g
              total        used        free      shared  buff/cache   available
Mem:            187           5         181           0           0         181
Swap:             3           0           3
```



```
[root@sr128 ~]# free -g
              total        used        free      shared  buff/cache   available
Mem:            991          93         869           0          28         893
Swap:             3           0           3
```

App Direct Mode

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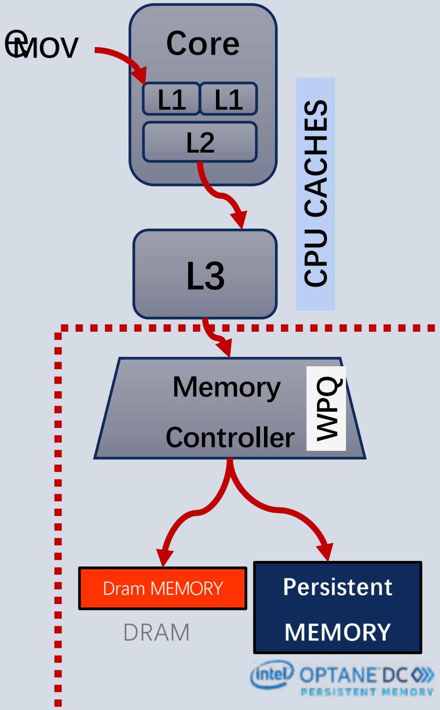
- PMEM-aware software/application required
  - Adds a new tier between DRAM and block storage (SSD/HDD)
  - Industry open standard programming model and Intel PMDK
- In-place persistence
  - No paging, context switching, interrupts, nor kernel code executes
- Byte addressable like memory
  - Load/store access, no page caching
- Cache Coherent
- Ability to do DMA & RDMA



SW makes sure that data is flushed to durability domain using CLFLUSHOPT or CLWB

Minimum required power fail protected domain:
Memory subsystem

Storage Over App Direct

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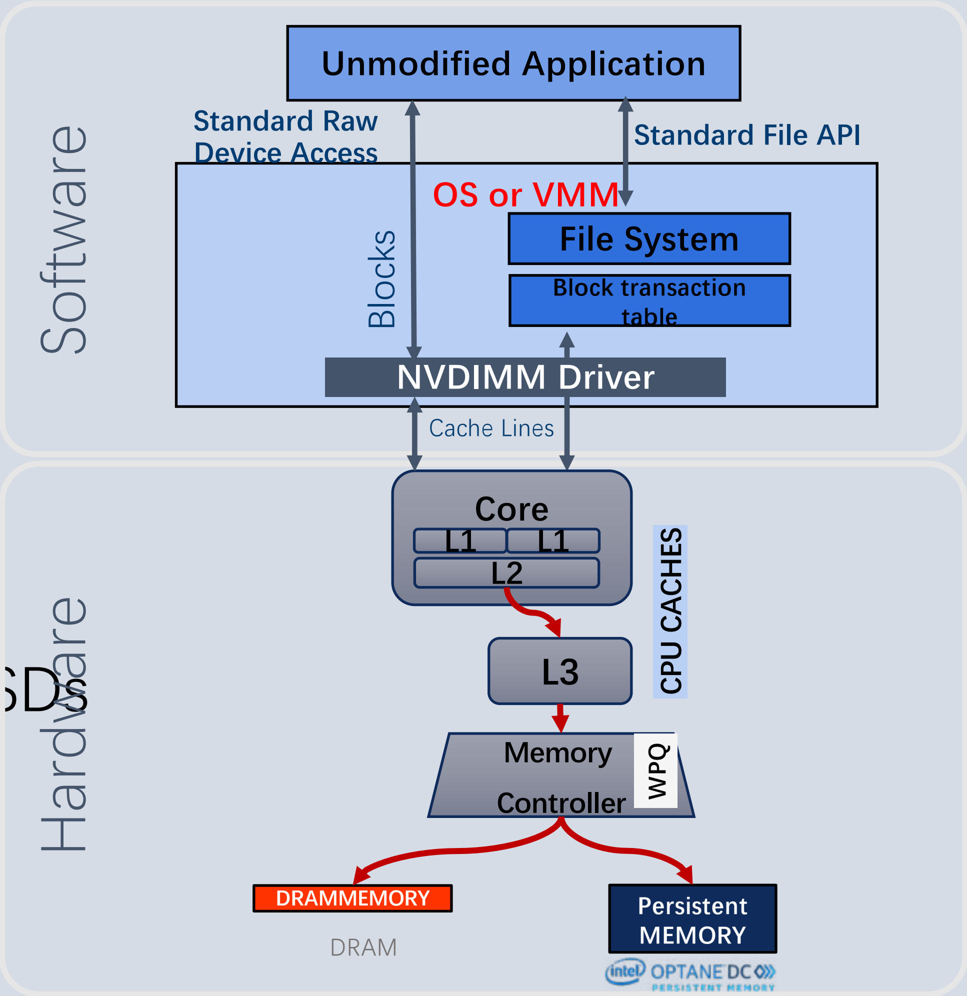
- Operates in blocks like SSD/HDD
  - Traditional read/write instructions
  - Works with existing file systems
  - Atomicity at block level
  - Block size configurable (4K, 512B)
- NVDIMM driver required
  - Support starting kernel 4.2
- Scalable capacity
- Higher endurance than enterprise class SSDs
- High performance block storage
  - Low latency, higher bandwidth, high IOPs



Linux kernel and driver changes: https://www.youtube.com/watch?v=owmN_IcMK2M

App Direct Flexibility for developer to optimize

1. DRAM data and App Direct (Intel® Optane™ DC persistent memory) are separate regions in memory space
   - App Direct region can be used as persistent memory

2. Intel Optane DC persistent memory to enable larger memory data structures. Some example partitioning:
   - Move all in-memory data to persistent memory (AD)
   - Move some in-memory data to persistent memory (AD), leaving most actively accessed data in DRAM

https://software.intel.com/en-us/persistent-memory

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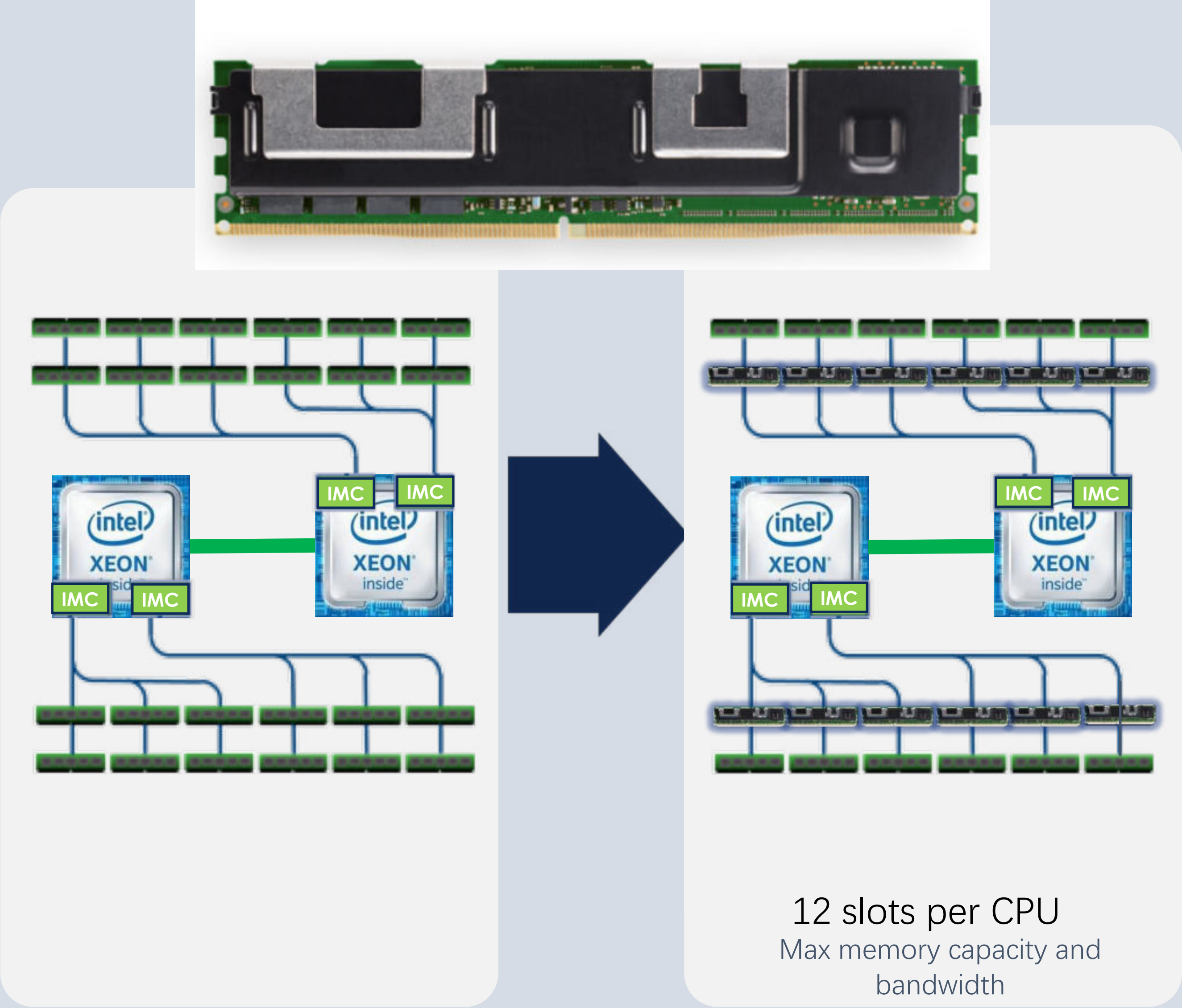
App Direct Flexibility for developer to optimize

- Intel® Optane™ DC persistent memory to accelerate data previously located on disk with significantly lower latency. Some examples:
  - Move data from disk to persistent memory, re-architect data structures from blocks to byte addressable removing software overhead
  - Used as a cache
  - Multiple modules can be interleaved for higher bandwidth
  - Storage Over AD - Mount file system to App Direct (DAX mode to avoid copies) for initial testing

Population examples: 2 socket system



12 slots per CPU

Max memory capacity and bandwidth

- To ensure system configuration flexibility for different population, Intel® Optane™ DC persistent memory can be populated:
    - On the same channel as DRAM
    - On the slot closest to the CPU on each channel
    - Up to 6 modules per CPU
- BIOS can recognize which DDR slot(s) have Intel Optane DC persistent memory and in which mode it is running

* No difference on functionality or performance when 2nd DIMM slot is in channel 0, 1 or 2 for that integrated memory controller (IMC)

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PART 03

How to use Intel Optane Persistent Memory in Flink?

Cluster Configurations

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		Master	Slave
Hardware	Memory	128GB (8x 16GB DDR4)	192GB (16x 12GB DDR4) +1TB DCPM (8 x 128GB)
	DCPMM Mode	N/A	Memory mode/ SoAD mode
	Storage	1TB SSD*5	1.8TB SSD*5
	CPU	Intel(R) Xeon(R) CPU E5-2697 v2 @ 2.70GHz	Intel(R) Xeon(R) Platinum 8280L CPU @ 2.70GHz
Software	Hadoop	hadoop-2.8.5	
	Flink	Flink 1.5.1	
	OS	Fedora release 29 with kernel 5.0.5-200.fc29.x86_64	Fedora release 29 with kernel 4.19.35-600.nvdimm.fc29.x86_64
Workload(TPC-DS)	Data Scale	1TB	
	SQL Queries	Simple query against TPC-DS table web_sales	

Demo

- Set App Direct mode
  - ipmctl create -goal PersistentMemoryType=AppDirect
  - reboot
  - ndctl list -R
  - ndctl create-namespace -m fsdax -r region0
  - ndctl create-namespace -m fsdax -r region1
  - fdisk -l
  - mount -o dax /dev/pmem0 /mnt/pmem0
  - mount -o dax /dev/pmem1 /mnt/pmem1
- Memkind library for AD mode
  - https://github.com/memkind/memkind/blob/master/examples/pmem_malloc.c
- Memcache library for AD mode
  - https://github.com/pmem/vmemcache/blob/master/tests/example.c
- Use DCPM SoAD mode in Flink
  - refer SoAD.cast
- Switch DCPM from App Direct mode to Memory mode
  - umount /mnt/pmem0
  - umount /mnt/pmem1
  - ndctl disable-namespace namespace0.0
  - ndctl destroy-namespace namespace0.0
  - ndctl disable-namespace namespace1.0
  - ndctl destroy-namespace namespace1.0
  - ndctl disable-region region0
  - ndctl disable-region region1
  - ipmctl create -goal MemoryMode=100
  - reboot
- Use DCPM memory mode in Flink
  - refer memory-mode.cast

Reference Link

https://docs.pmem.io/ndctl-users-guide/concepts/libnvdimm-pmem-and-blk-modes
https://software.intel.com/en-us/articles/introduction-to-programming-with-persistent-memory-from-intel
https://software.intel.com/en-us/articles/intel-optane-dc-persistent-memory-a-major-advance-in-memory-and-storage-architecture
ndctl: https://github.com/pmem/ndctl
ipmctl: https://github.com/intel/ipmctl/releases

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