Introduction to Open-Channel Solid State Drives and What's Next!

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Agenda

1. Motivation
2. Interface
3. Eco-system
4. What’s Next? Standardization

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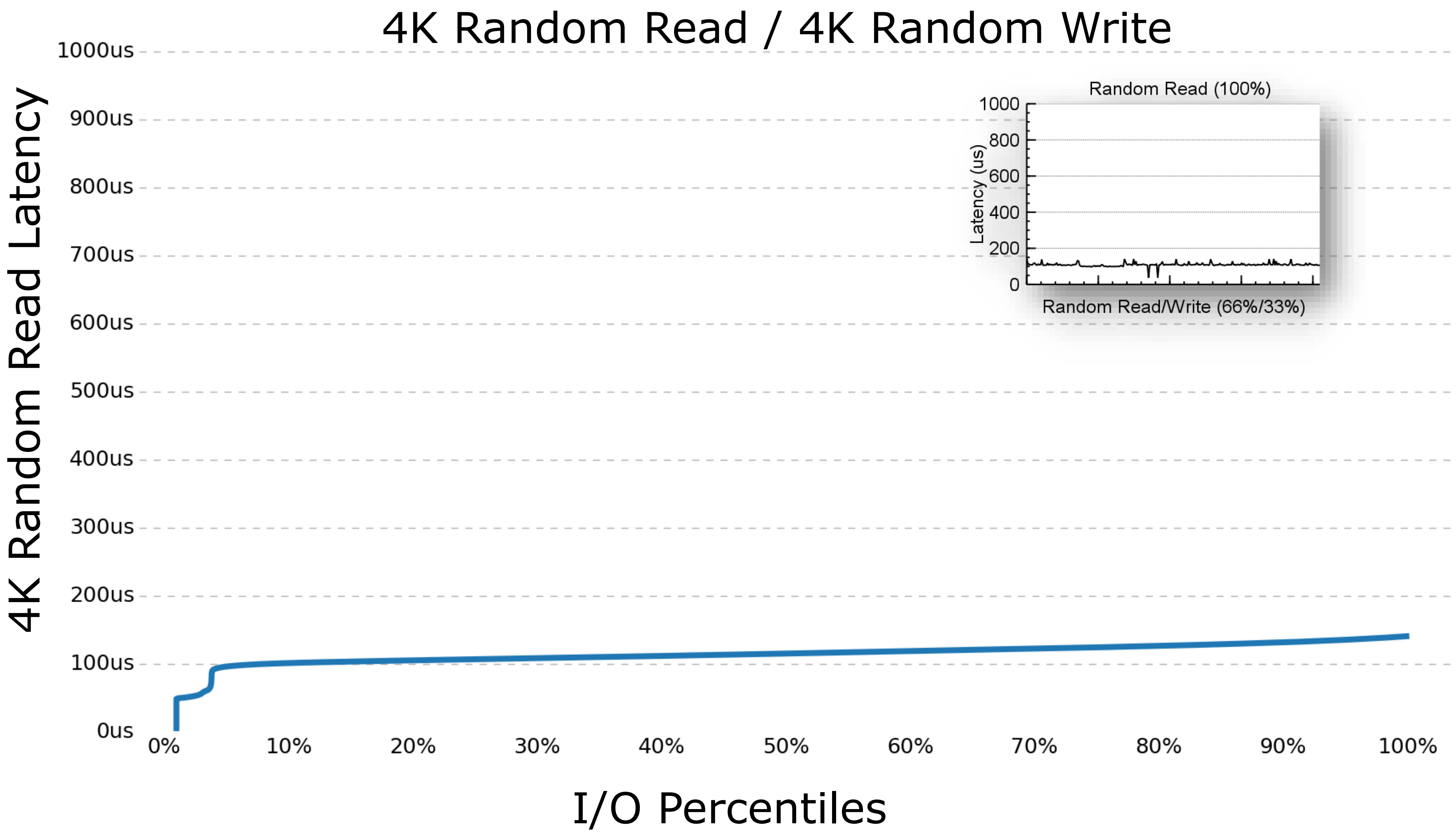
0% Writes - Read Latency



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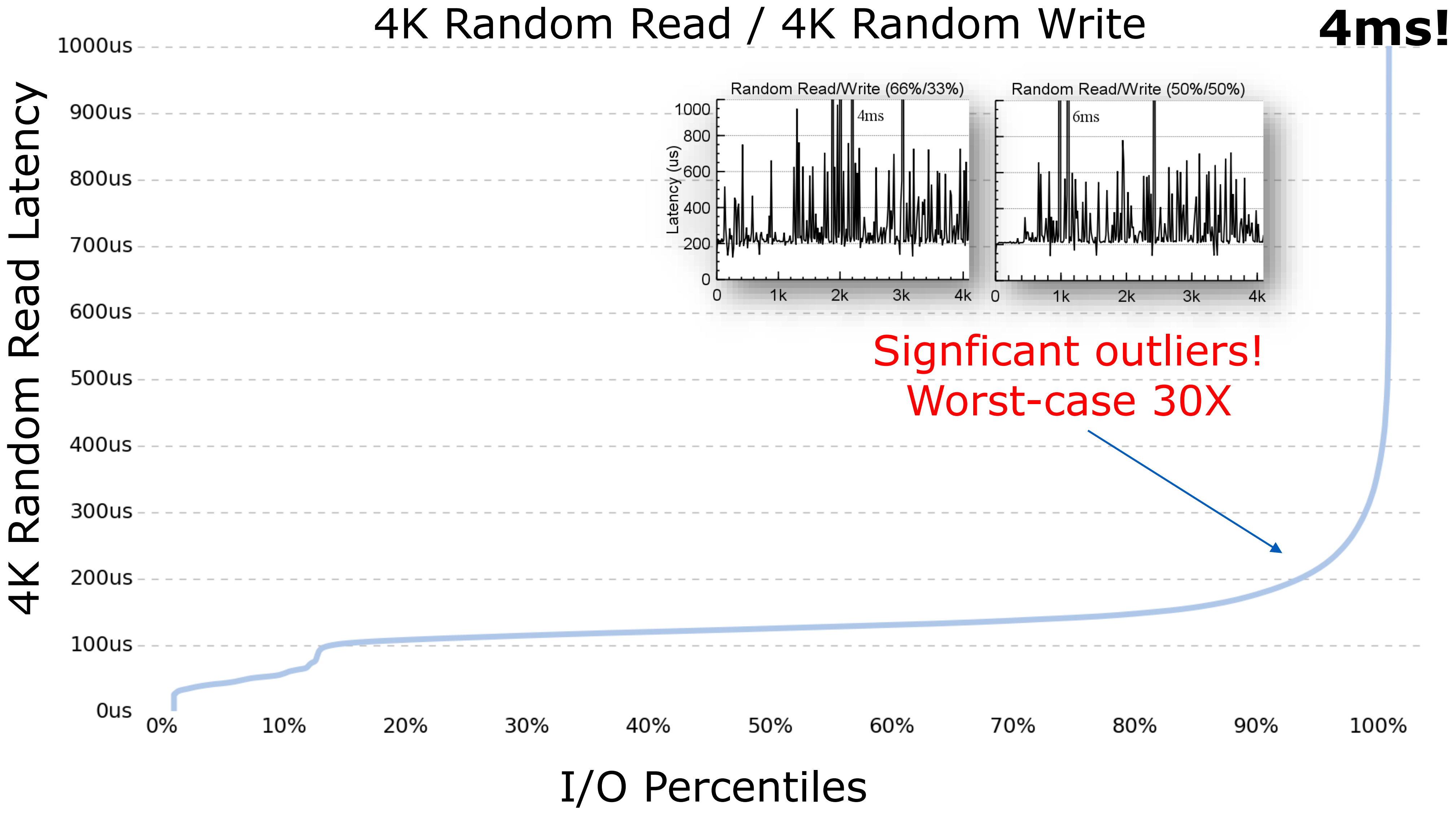
20% Writes - Read Latency



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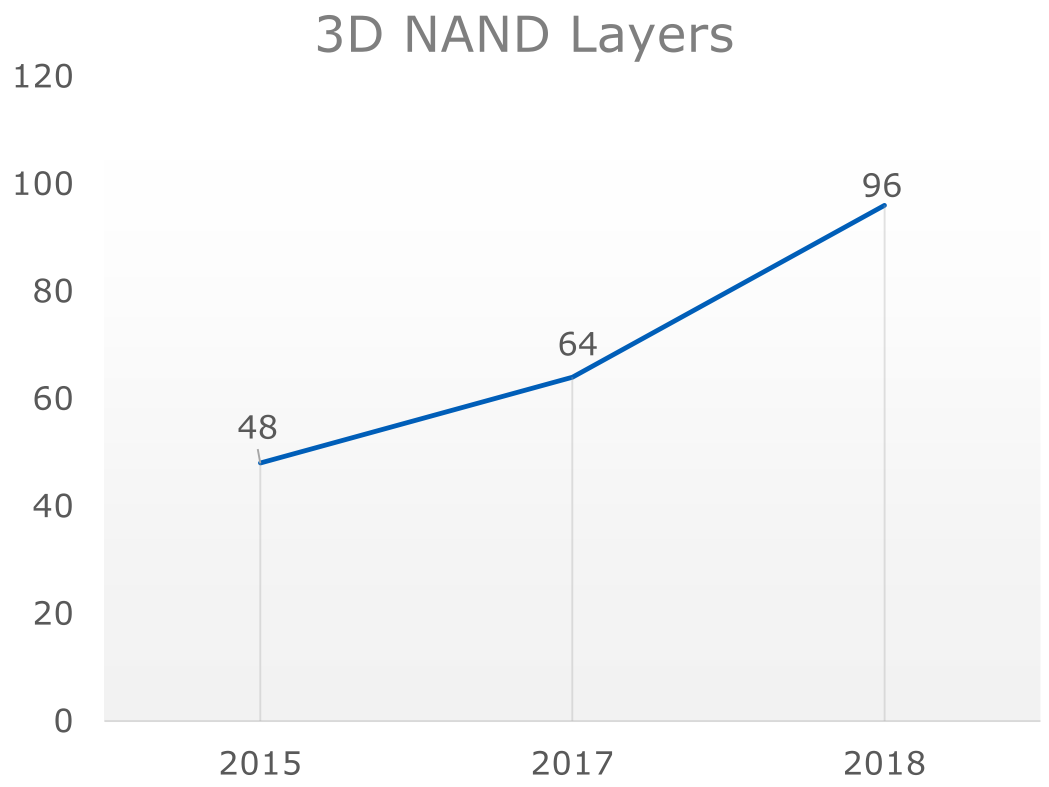
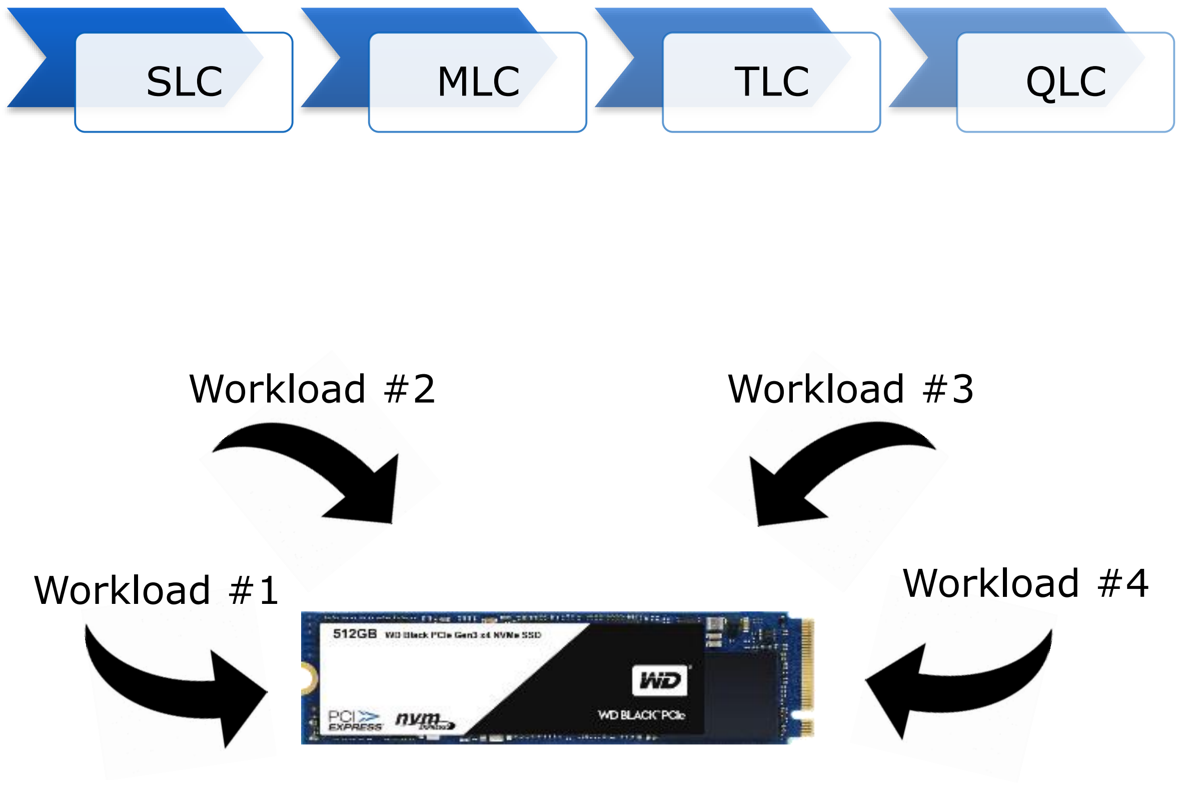
NAND Chip Density Continues to Grow

While Cost/GB decreases





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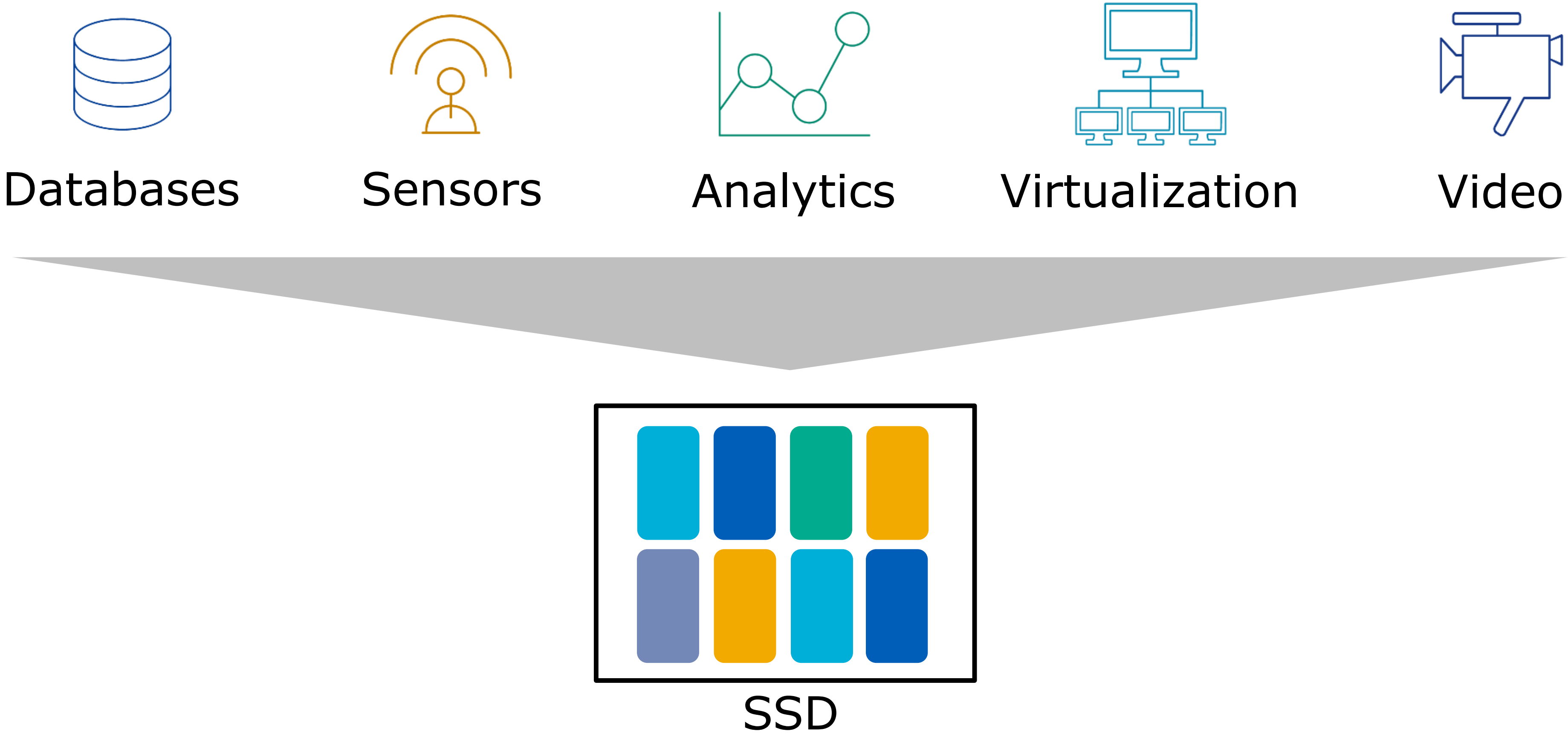
Ubiquitous Workloads

Efficiency of the Cloud requires many different workloads of a single SSD



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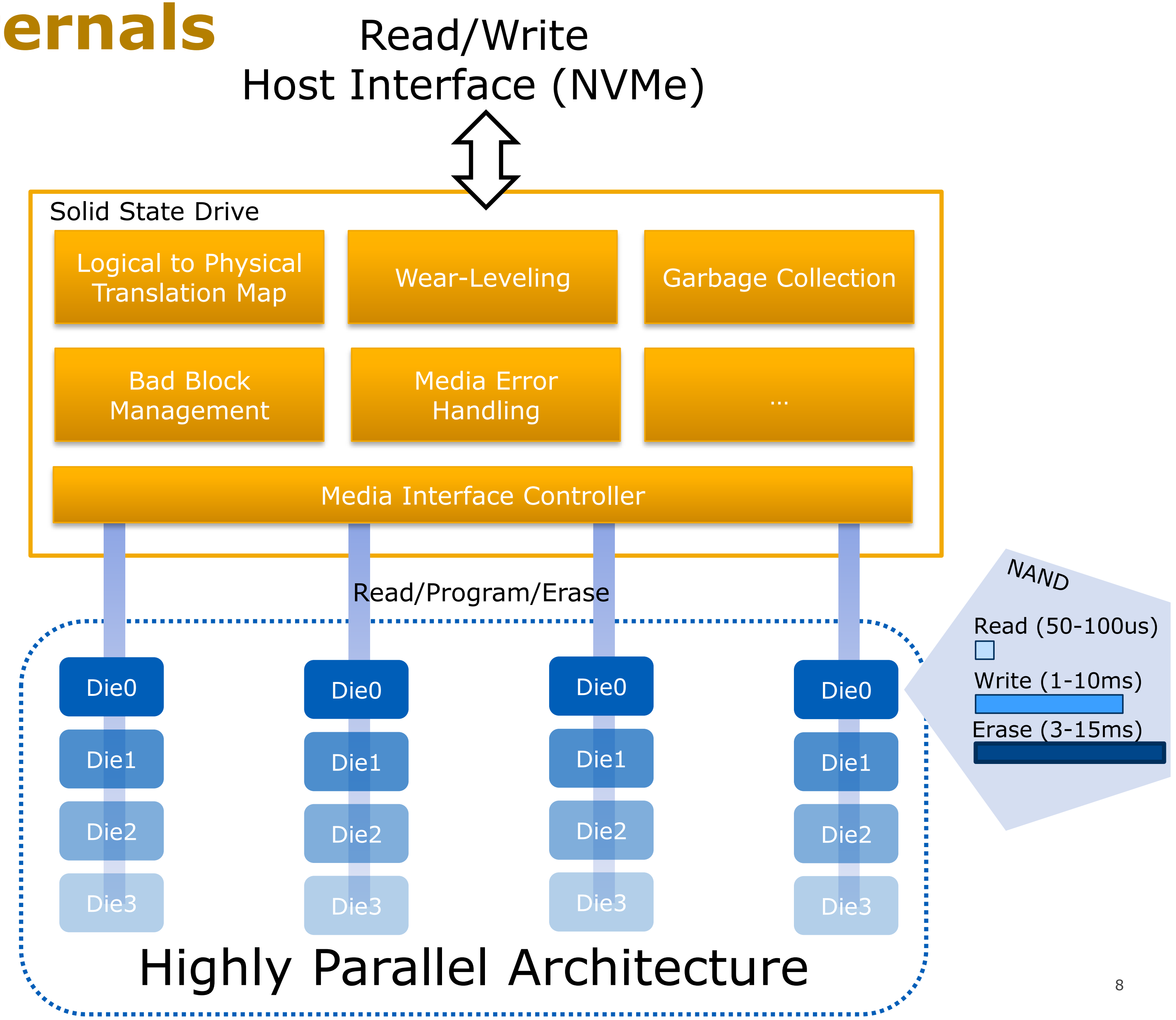
Solid State Drive Internals

- NAND Read/Program/Erase
- Highly Parallel Architecture
  - Tens of Dies
- NAND Access Latencies
- Translation Layer
  - Logical to Physical Translation Layer
  - Wear-leveling
  - Garbage Collection
  - Bad block management
  - Media error handling
  - Etc.
- Read/Write/Erase -> Read/Write



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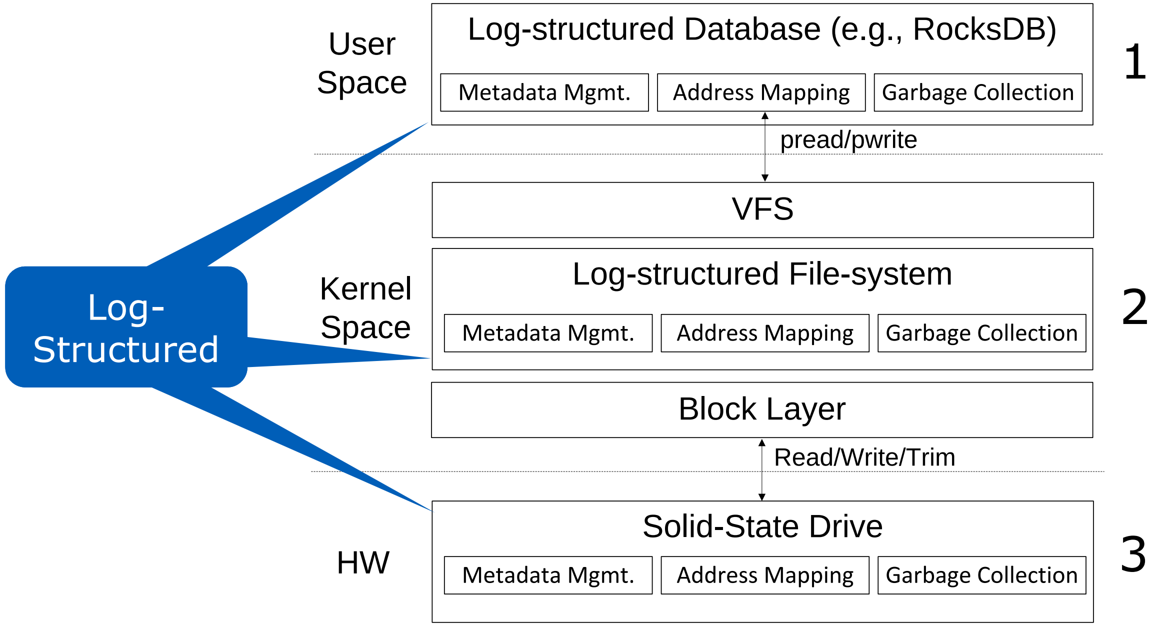
Single-User Workloads

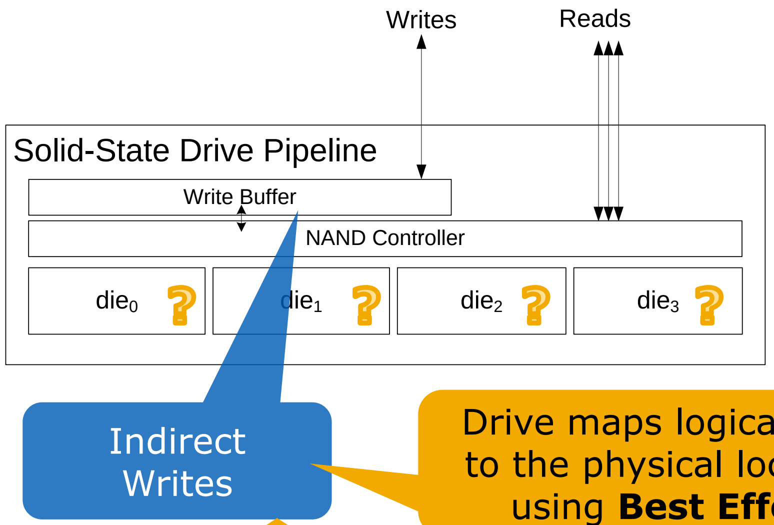
Indirection *and* ***Indirect Writes*** *causes outliers*

Host: Log-on-Log



Unable to align data logically = Write amplification increase + extra GC

Device: Indirect Writes



Drive maps logical data to the physical location using **Best Effort**

Host is oblivious to data placement due to the indirection

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Open-Channel SSDs

I/O Isolation

Predictable Latency

Data Placement &
I/O Scheduling

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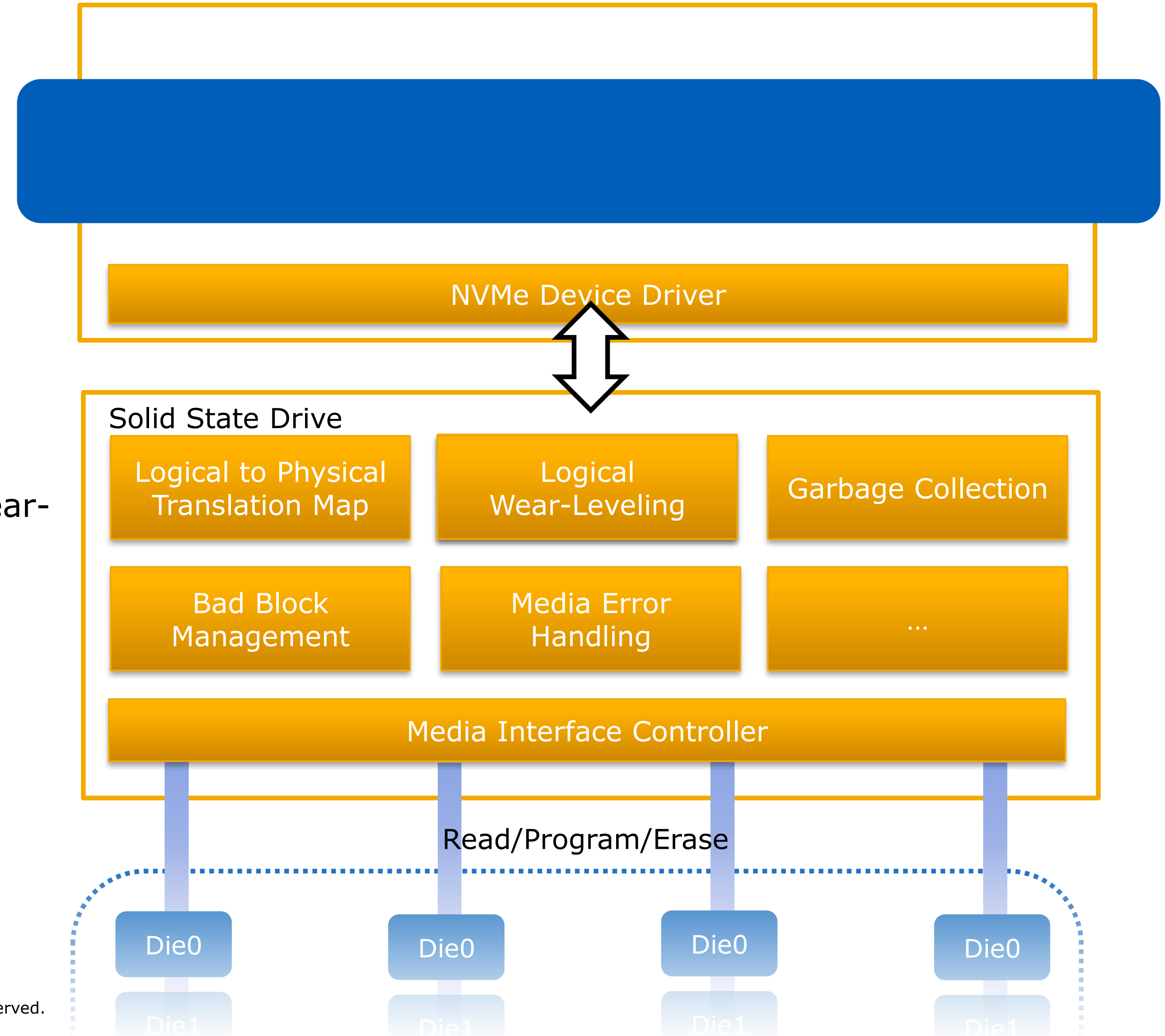
Solid State Drive Internals

- Host Responsibility
  - Logical to Physical Translation Map
  - Garbage Collection
  - Logical Wear-leveling
    - Hint to host to place hot/cold data
- Integration
  - Block device
    - Host-side FTL that does L2P, GC, Logical Wear-leveling
    - Similar overhead to traditional SSDs
  - Applications
    - Databases and File-systems



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Concepts in an Open-Channel SSD

Interface Blocks

- Chunks
  - Sequential write only LBA ranges
  - Align writes to internal block sizes
- Hierarchical addressing
  - A sparse addressing scheme projected onto the NVMe™ LBA address space
- Host-assisted Media Refresh
  - Improve I/O predictability
- Host-assisted Wear-leveling
  - Improve wear-leveling

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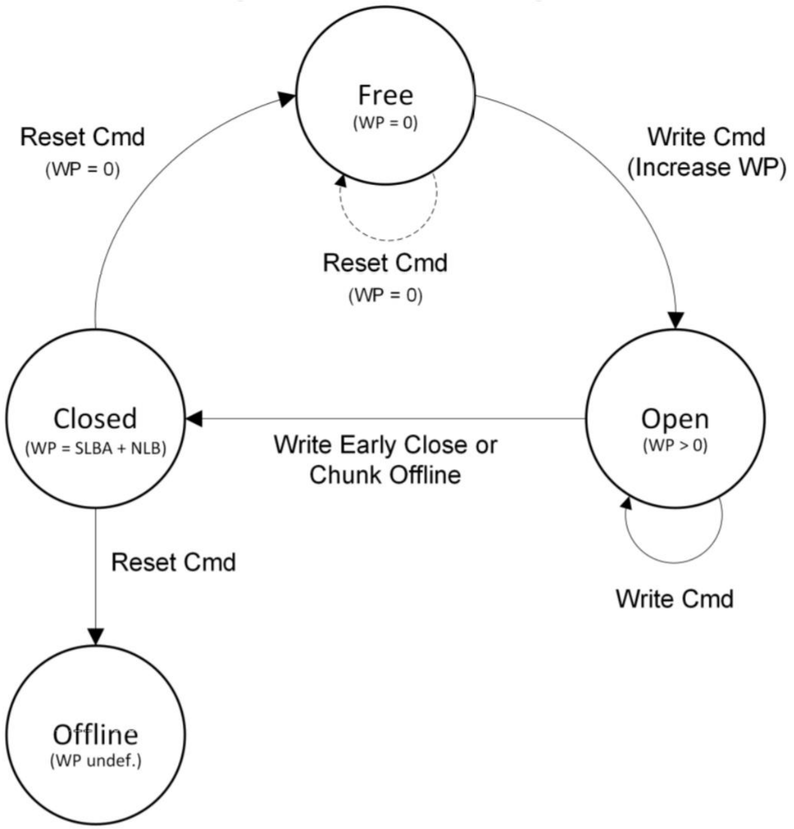
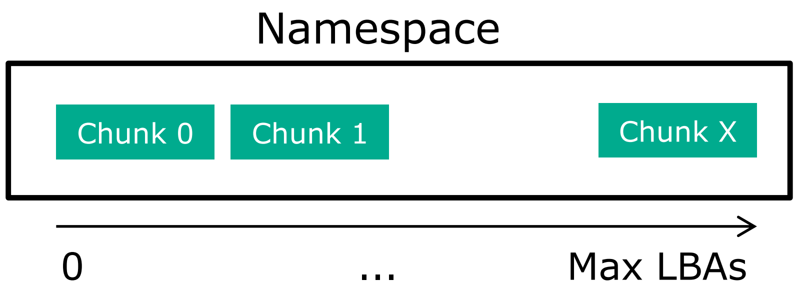
Chunks #1

Enable orders of magnitude reduction of device-side DRAM

- A chunk is a range of LBAs where writes must be sequential.
  - Reduces DRAM for L2P table by orders of magnitude
  - Hot/Cold data separation
- Rewrite requires a reset
  - A chunk can be in one of four states (free/open/closed/offline)
  - If a chunk is open, there is a write pointer associated.
- Same device model as the ZAC/ZBC standards.
- Similar device model to be standardized in NVMe (I'll come back to this)





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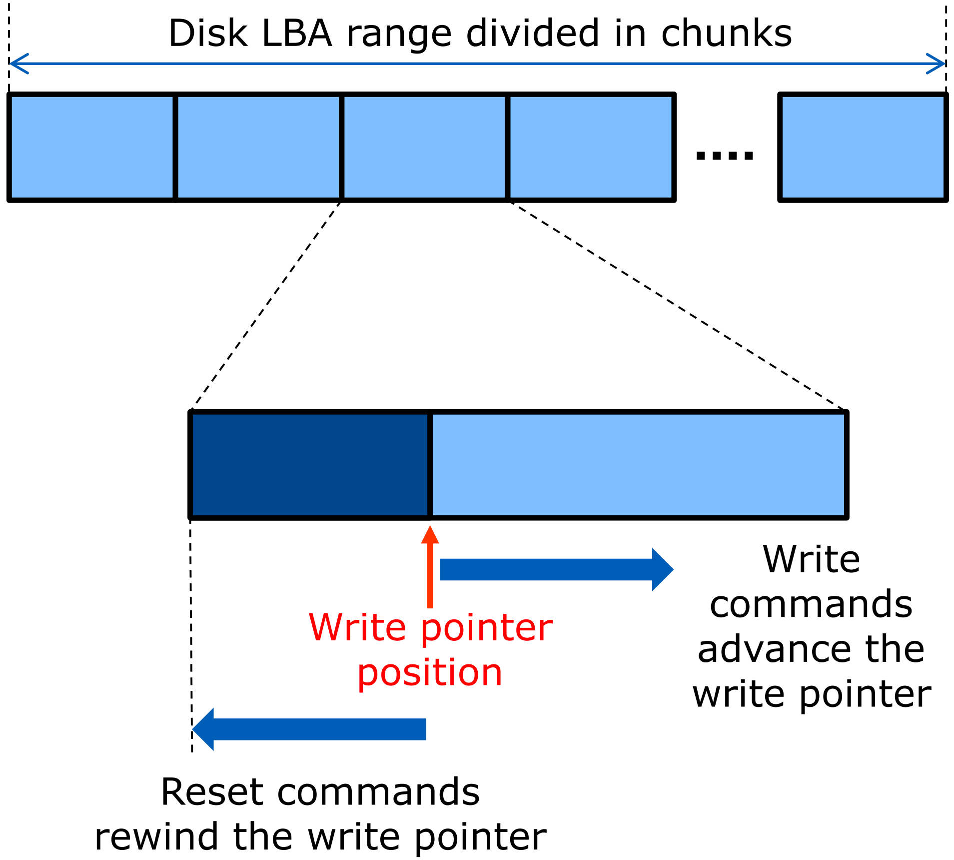
Chunks #2

- Drive capacity divided into chunks
- Chunk types
  - Conventional
    - Random or Sequential
  - Sequential Write Required
    - Chunk must be written sequential only
    - Must be reset entirely before being rewritten



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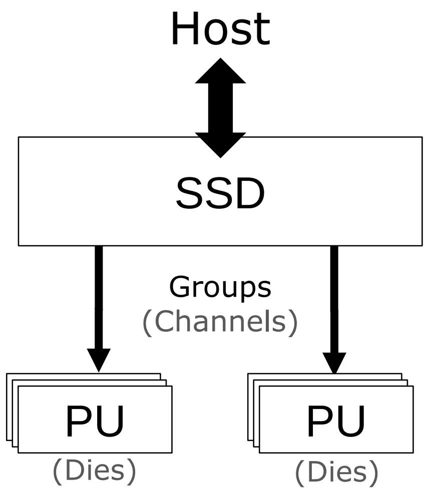
Hierarchical Addressing

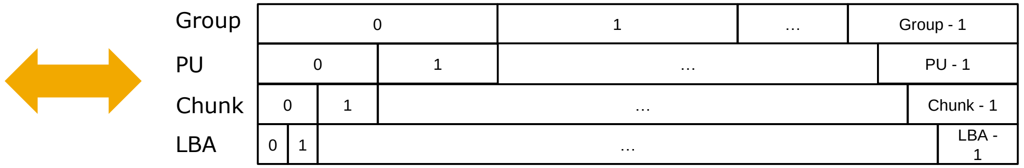
Channels and Dies are mapped to Logical Groups and Parallel Units

- Expose device parallelism through Groups/Parallel Units
  - One or a group of dies are exposed as parallel units to the host
  - Parallel units are a logical representation

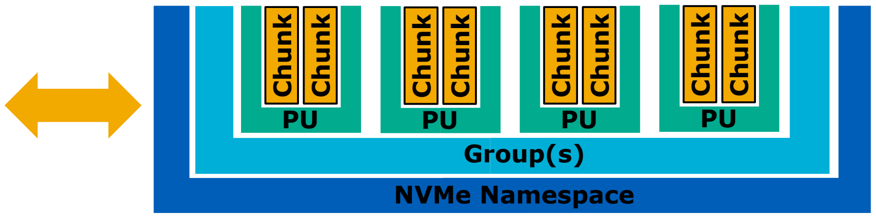
Physical



LBA Address Space



Logical



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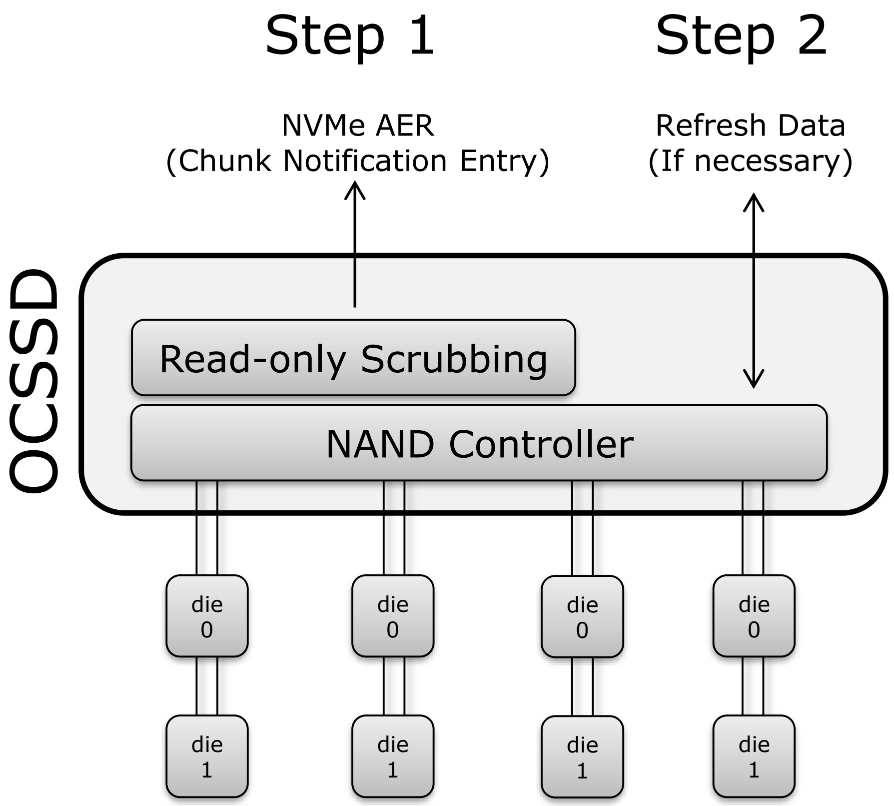
Host-assisted Media Refresh

Enable host to assist SSD data refresh

- SSDs refreshes its data periodically to maintain reliability. It does this through a data scrubbing process
  - Internal read and writes make the drive I/O latencies unpredictable.
  - Writes dominates I/O outliers
- 2-step Data Refresh
  - Device to only perform the data scrubbing read part - Data movement is managed by host
  - Increases predictability of the drive. Host manages refresh strategy
    - Should it refresh? Is there a copy elsewhere?



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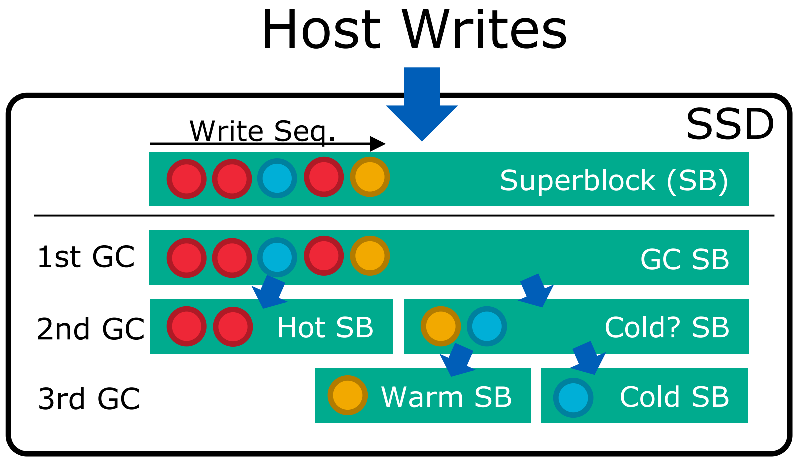
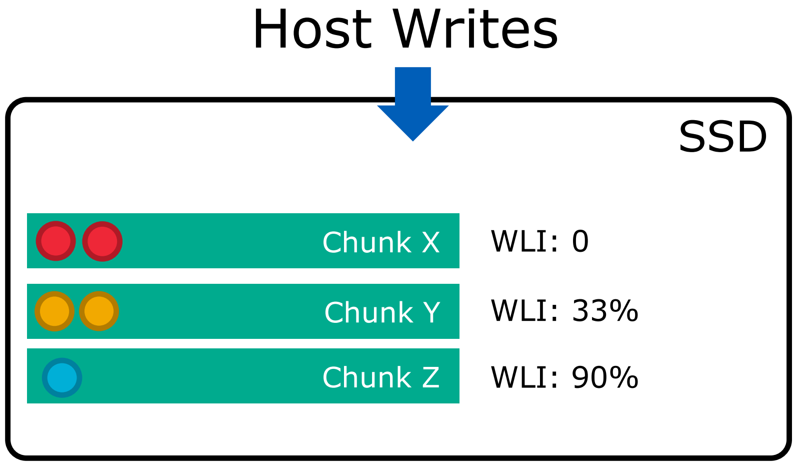
Host-assisted Wear-Leveling

Enable host to separate Hot/Cold data to Chunks depending on wear

- SSDs typically does not know the temperature of newly written data
  - Placing hot and cold data together increases write amplication
  - Write amplication is often 4-5X for SSDs with no optimizations
- Chunk characteristics
  - Limited reset cycles (as NAND blocks has limited erase cycles)
  - Place cold data on chunks that are nearer end-of-life and use younger chunks for hot data
- Approach
  - Introduce per-chunk relative wear-level indicator (WLI)
  - Host knows workload and places data w.r.t. to WLI
  - Reduces garbage collection→ **Increases lifetime, I/O latency, and performance**





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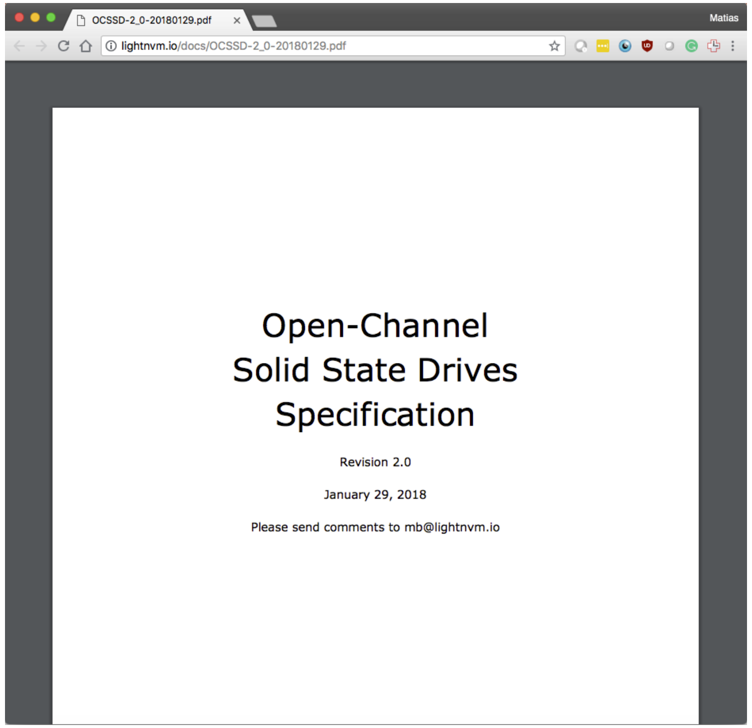
Interface Summary

The concepts together provide

- **I/O Isolation** through the use of Groups & Parallel Units
- **Fine-grained data refresh** managed by the host
- **Reduce write amplification** by enabling host to place hot/cold data efficiently
- **DRAM & Over-provisioning** reduction through append-only Chunks
- Direct-to-media to **avoid expensive internal data movement**



Specification available at http://lightnvm.io

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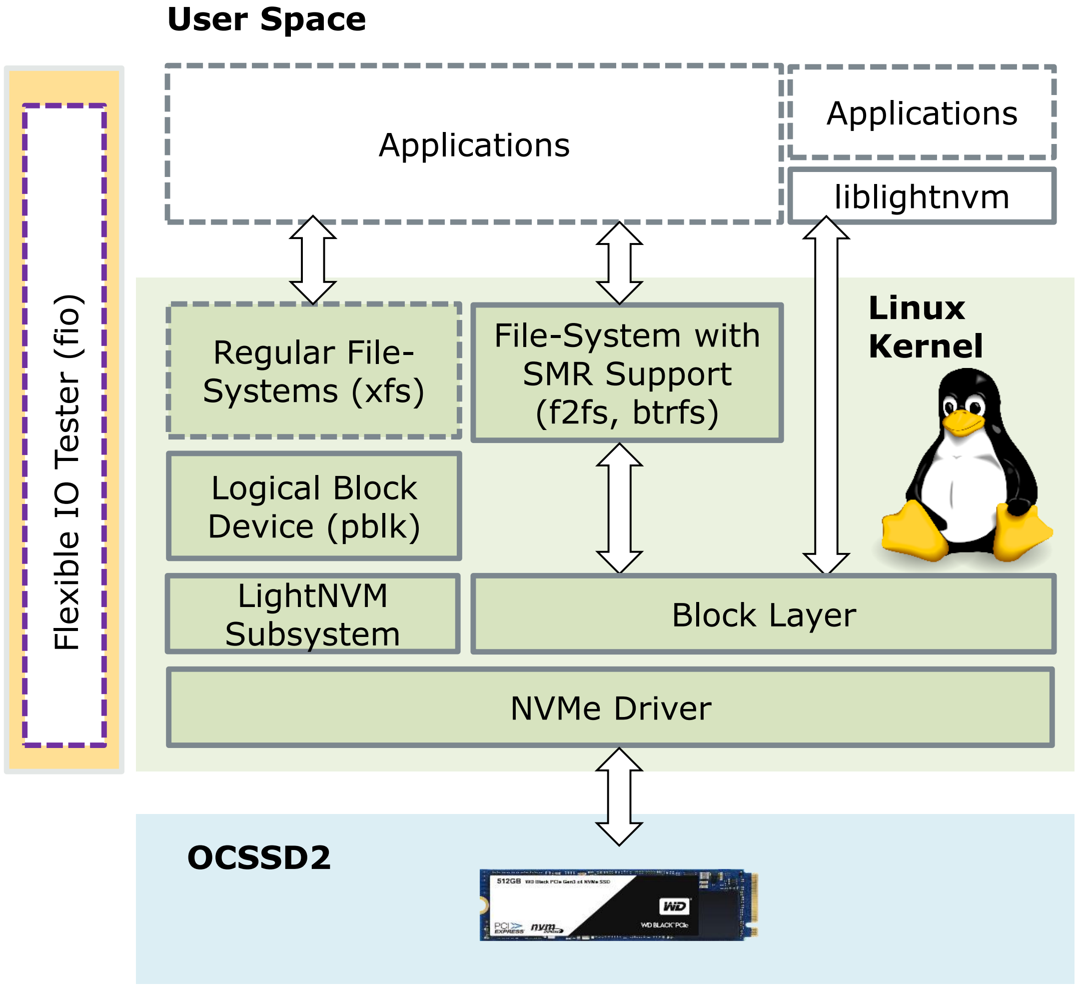
Eco-system

Large eco-system through Zoned Block Devices and OCSSD

- Linux Kernel®
  - NVMe Device Driver
    - Detection of OCSSDs
    - Support for 1.2 and 2.0 specification
    - Register with LightNVM subsystem
    - Register as a Zoned Block Devices (patches available)
  - LightNVM Subsystem
    - Core functionality
    - Target management
  - Target interface
    - Enumerate, get geometry, I/O interface, etc.
    - pblk host-side FTL – Map OCSSD to Block Device
- User-space
  - libzbc, fio (ZBD support), liblightnvm
  - SPDK



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Open-Source Software Contributions

- Initial release of subsystem with Linux kernel 4.4 (January 2016).
- User-space library (liblightnvm) support upstream in Linux kernel 4.11 (April 2017).
- pblk available in Linux kernel 4.12 (July 2017).
- Open-Channel SSD 2.0 specification released (January 2018) and support available from Linux kernel 4.17 (May 2018).
- SPDK Support for OCSSD (June 2018)
- Fio with Zone support (August 2018)
- Upcoming
  - OCSSD as a Zoned Block Device (Patches available)
  - RAIL – XOR support for lower latency
  - 2.0a revision

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Tools and Libraries

LightNVM: The Linux Open-Channel SSD Subsystem

https://www.usenix.org/conference/fast17/technical-sessions/presentation/bjorling

LightNVM

http://lightnvm.io

LightNVM Linux kernel Subsystem

https://github.com/OpenChannelSSD/linux

liblightnvm

https://github.com/OpenChannelSSD/liblightnvm

QEMU NVMe with Open-Channel SSD Support

https://github.com/OpenChannelSSD/qemu-nvme

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