Western Digital®

Zoned Namespaces in Practice

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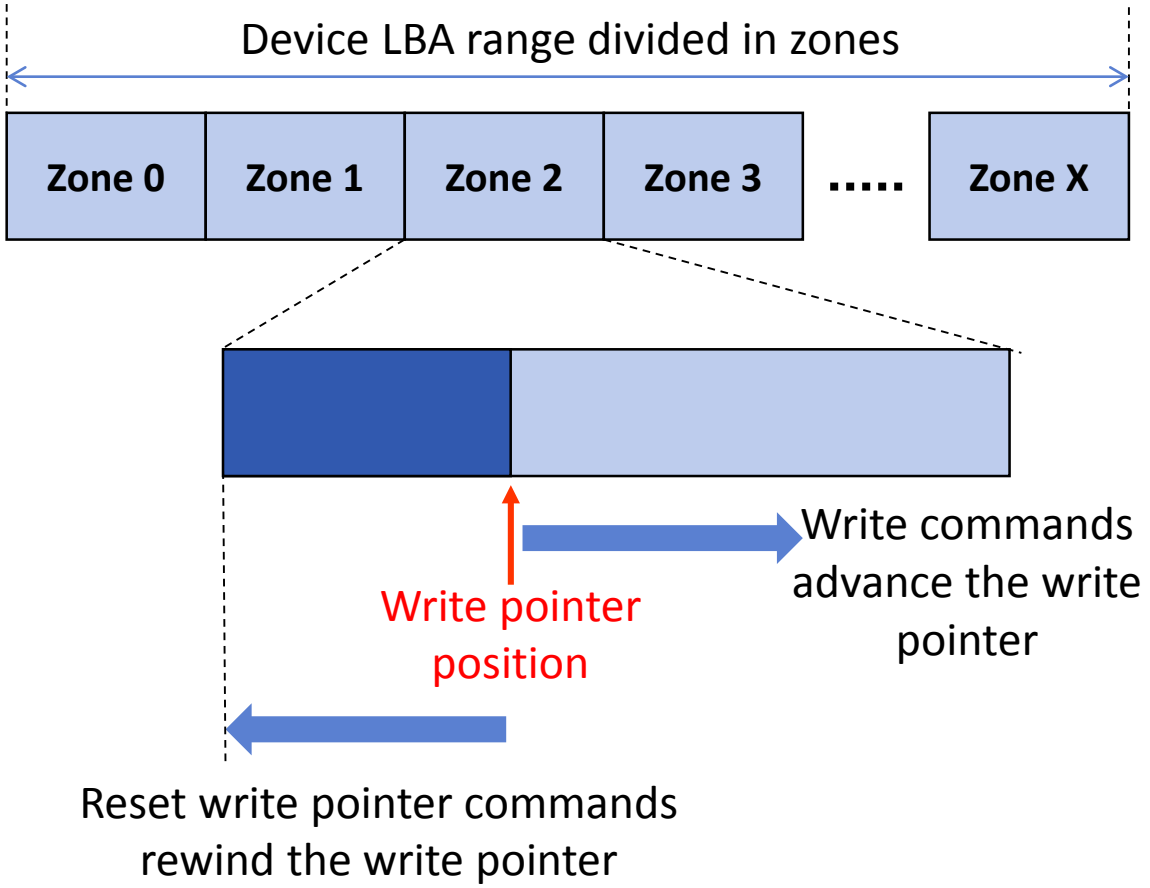
What are Zoned Block Devices?

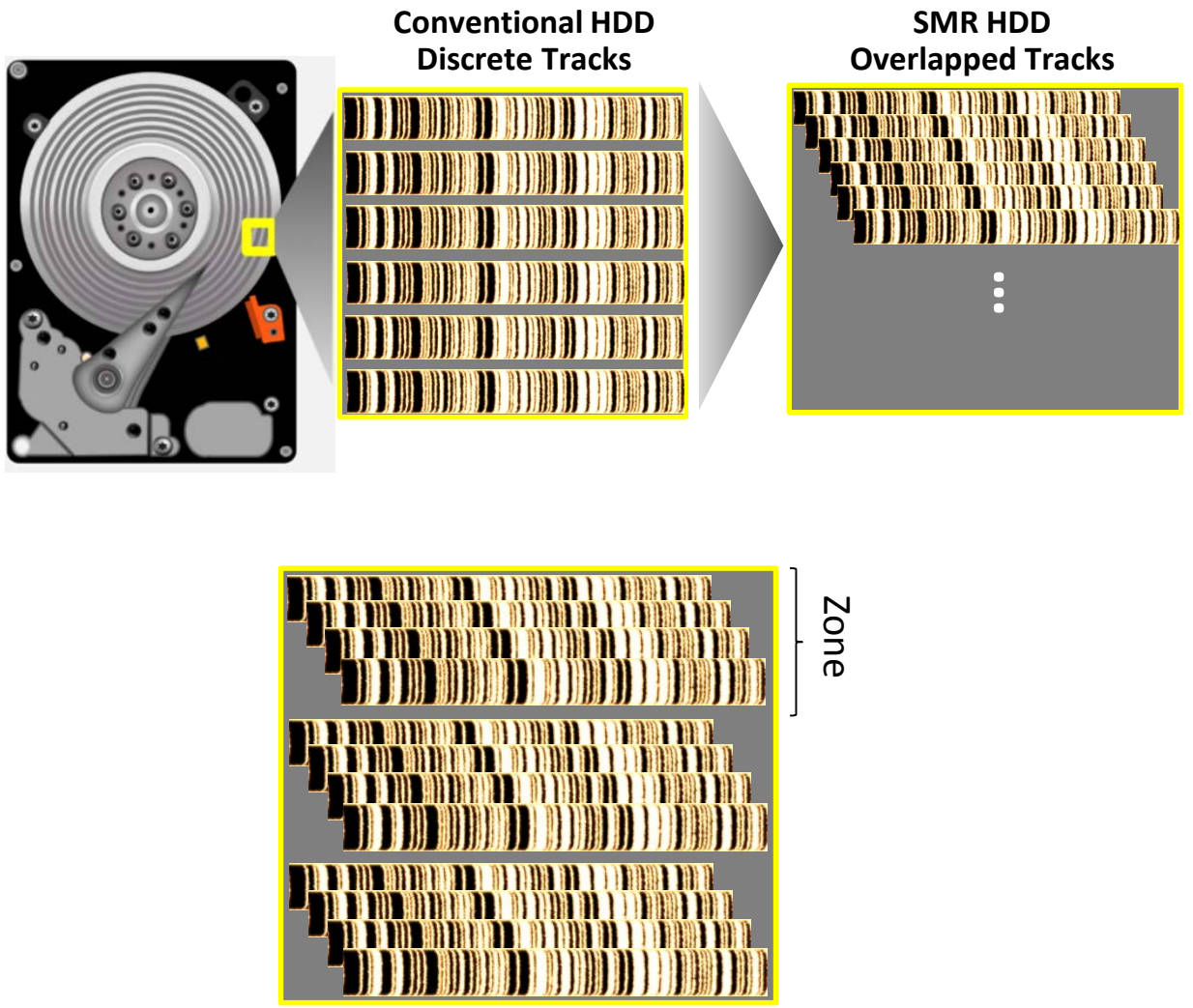
The new paradigm in storage

- The storage device logical block addresses are divided into ranges of zones.
- Writes within a zone must be sequential.
- The zone must be erased before it can be rewritten.



Zoned Storage has already been in HDDs

- SMR (Shingled Magnetic Recording)
  - Enables areal density growth
  - Causes magnetic media to share flash access model
    - Data must be erased to be re-written
- Zoned Access
  - Zoned Block I/F standardized in INCITS
    - Zoned Block Commands (ZBC): SAS
    - Zoned ATA Commands (ZAC): SATA
  - Host/Device cooperate to optimize RMW aspect of SMR by enforcing sequential writes and enabling host FTL model



Why Zoned Storage

Addressing the needs of large-scale data infrastructure

Why Zones for Solid State Drives?

Ubiquitous Workloads

The cloud applies multiple workloads to a single SSD

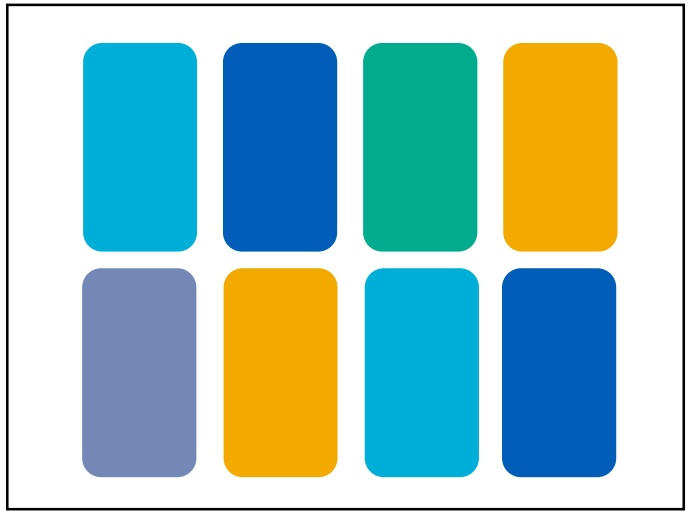
Databases

Sensors

Analytics

Virtualization

Video



Solid-State Drive

SSDs write log-structured to the media that requires garbage collection

Multiplex data streams onto the same garbage collection units

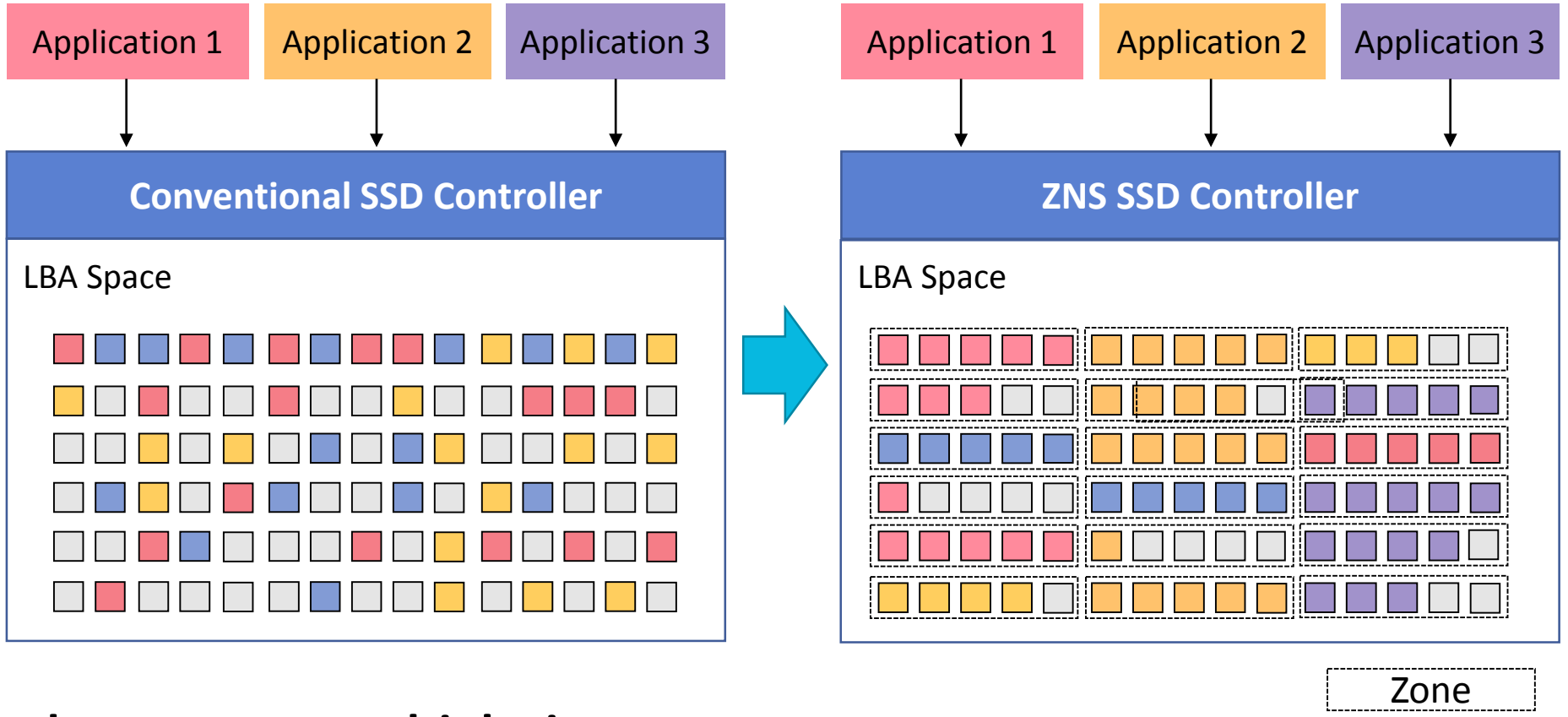
Increases

Write Amplification, Over-Provisioning and thereby Cost

Decreases

throughput and latency predictability

Zones for Solid State Drives



Eliminate data streams multiplexing:

- Significantly decreases **write amplification, over-provisioning and** thereby reduces cost
- Increases throughput and latency predictability

Zoned Namespaces

- **Ongoing Technical Proposal in the NVMe™ working group**
- New Zoned Command Set – Inherits the NVM Command Set and adds zone support.
- Aligns to the existing host-managed models defined in the ZAC/ZBC specifications.
  - Note that it does not map 1:1. Beware of the details.
- Optimized for Solid State Drives
  - Zone Capacity
  - Zone Attributes introduced to optimize for SSD characteristics
  - Zone Append
  - Zone Descriptors

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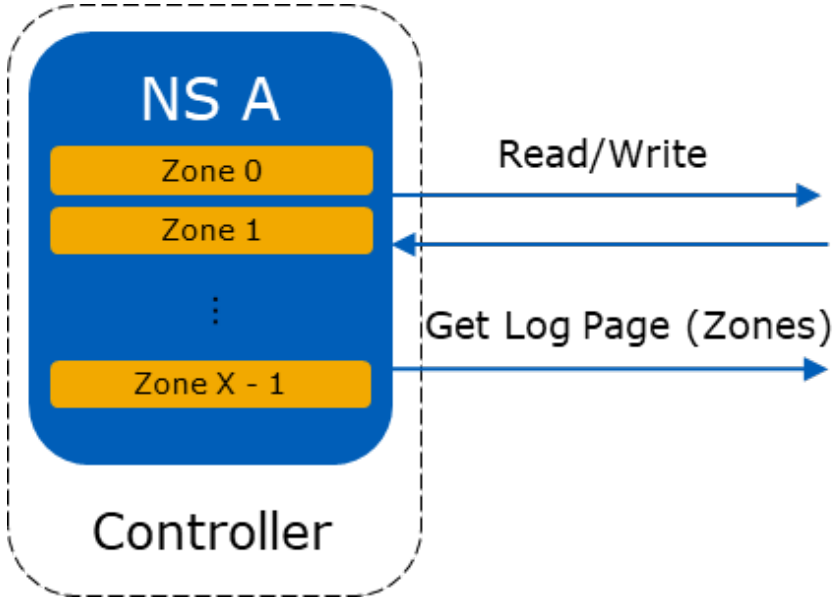
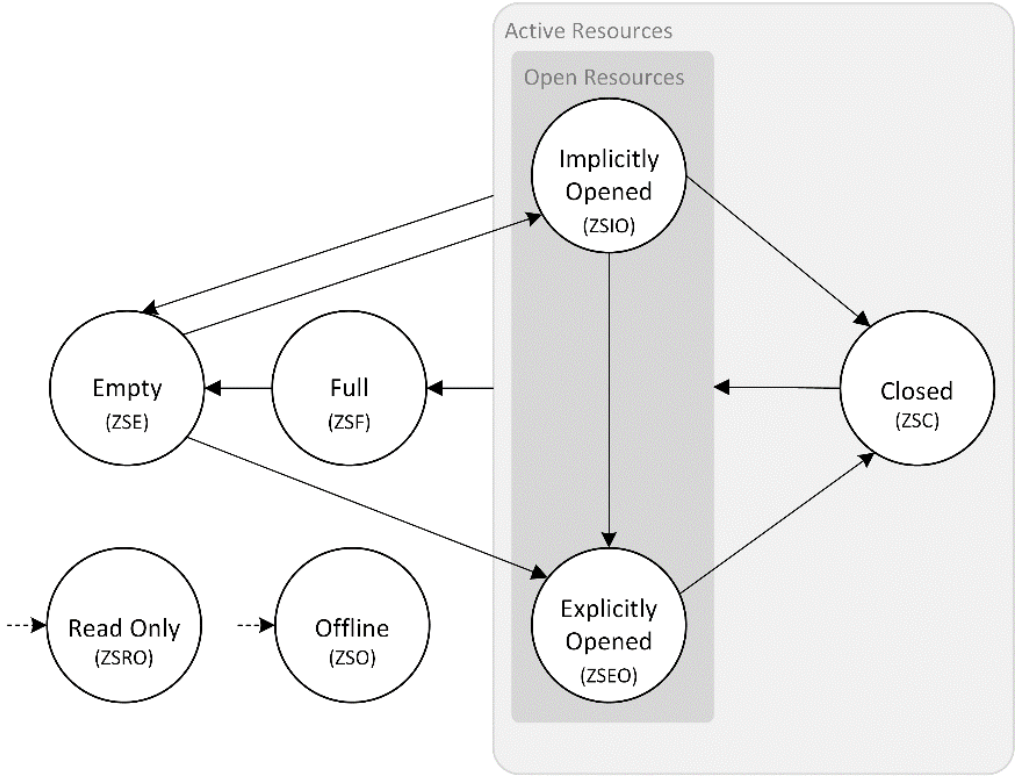
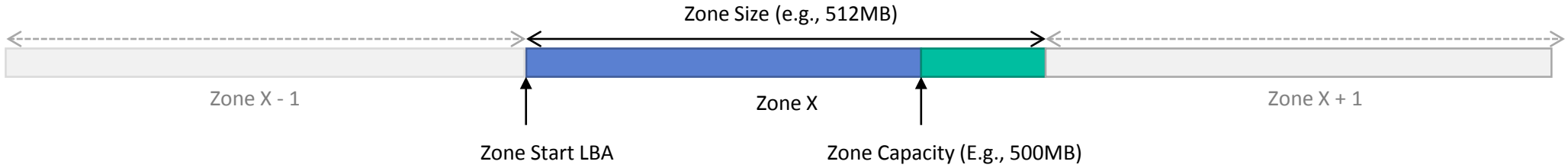
Under review



Host-Managed Zoned Block Devices

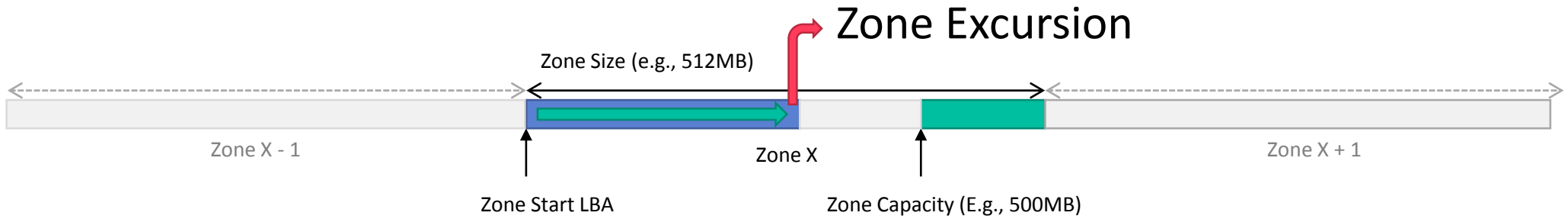
- Zone States
  - Empty, Implicitly Opened, Explicitly Opened, Closed, Full, Read Only, and Offline.
  - Changes state upon writes, zone management commands, and device resets.
- Zone Management
  - Open Zone, Close Zone, Finish Zone, and Reset Zone
- Zone Size & Zone Capacity(NEW)
  - Zone Size is fixed
  - Zone Capacity is the writeable area within a zone





Zone Excursions & Variable Zone Size

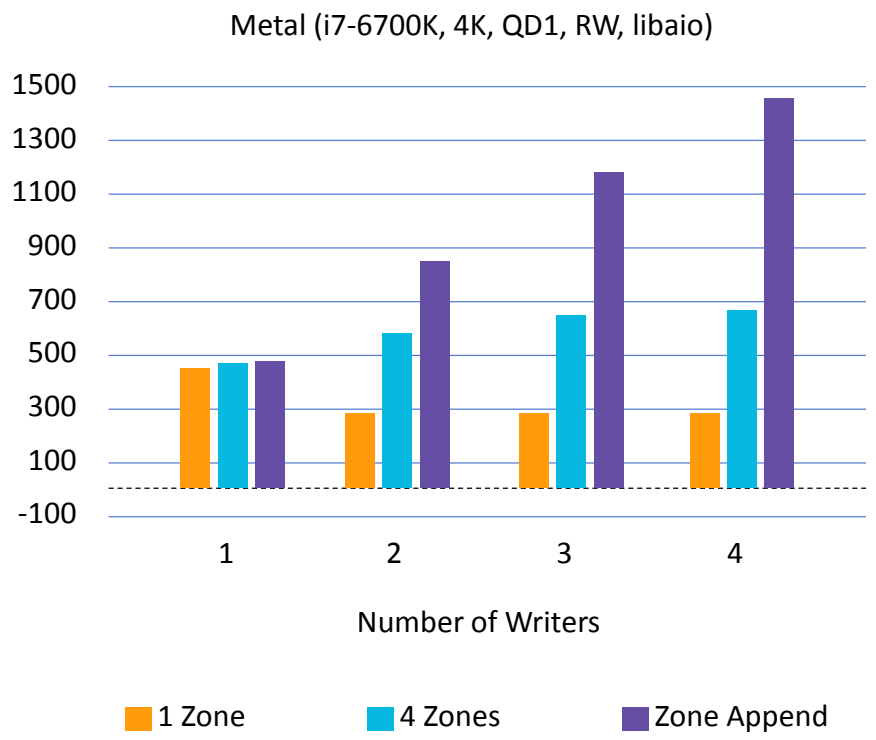
- For NVMe devices that implement the Zoned Command Set, there is optional support for:
  - Variable Zone Capacity
    - The completion of Reset Zone command may result in a notification that zone capacity has changed.
  - Zone Excursions
    - The device can transition a zone to Full before writes reach the Zone Capacity. Host will receive an AEN and write failure if writing after the transition.
- If device implements, the host shall implement as well
  - Incoherent state model if not – Software must be specifically written to understand that zone capacity can change.



Zoned Namespaces TP

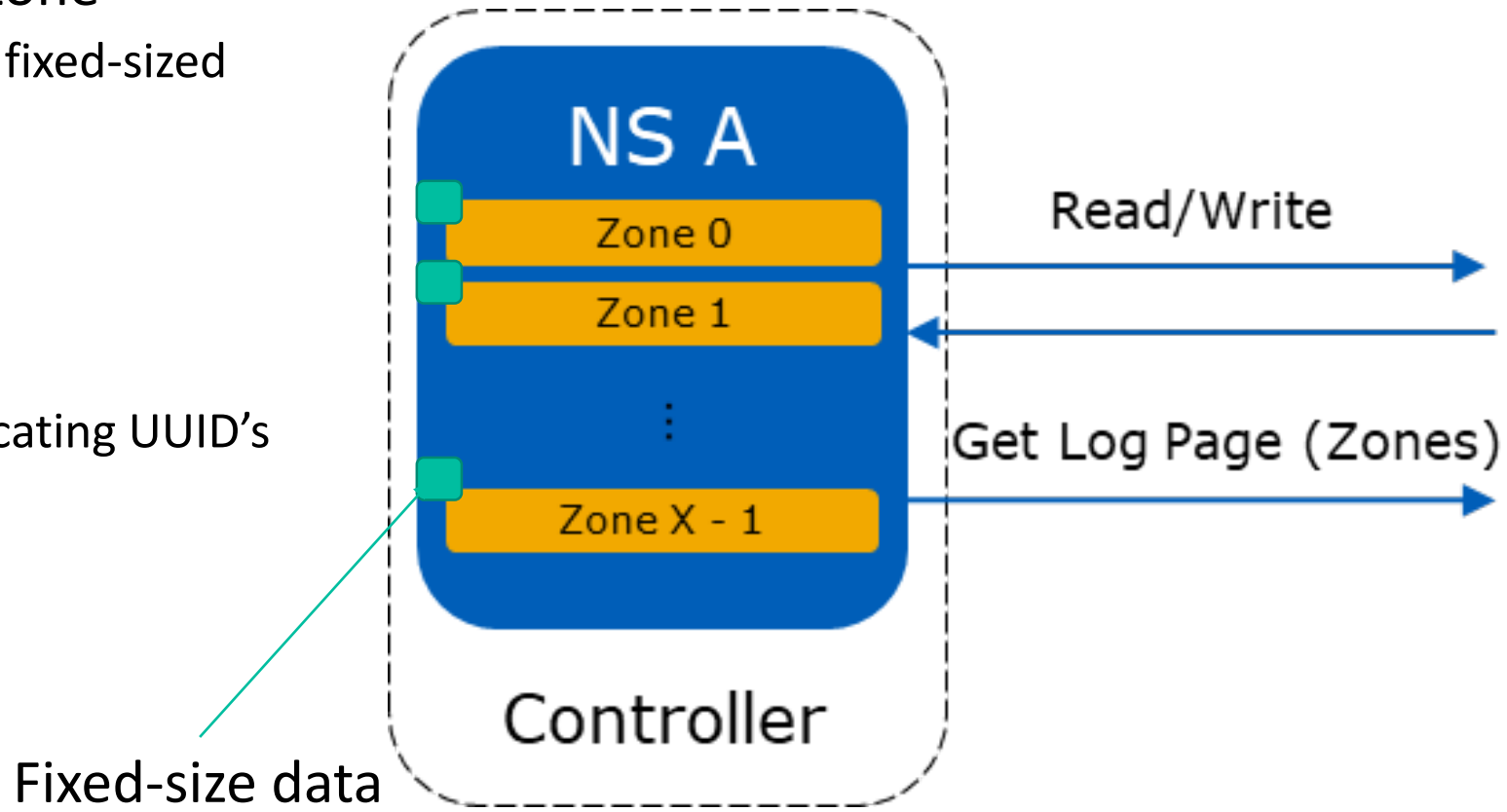
Zone Append

- ZAC/ZBC requires strict write ordering
  - Limits write performance, increases host overhead
- Low scalability with multiple writers to a zone
  - One writer per zone -> Good performance
  - Multiple writers per zone -> Lock contention
- Can improve by writing multiple Zones, but performance is limited
- With Zone Append, we scale
  - Append data to a zone with implicit write pointer
  - Drive returns LBA where data was written in zone



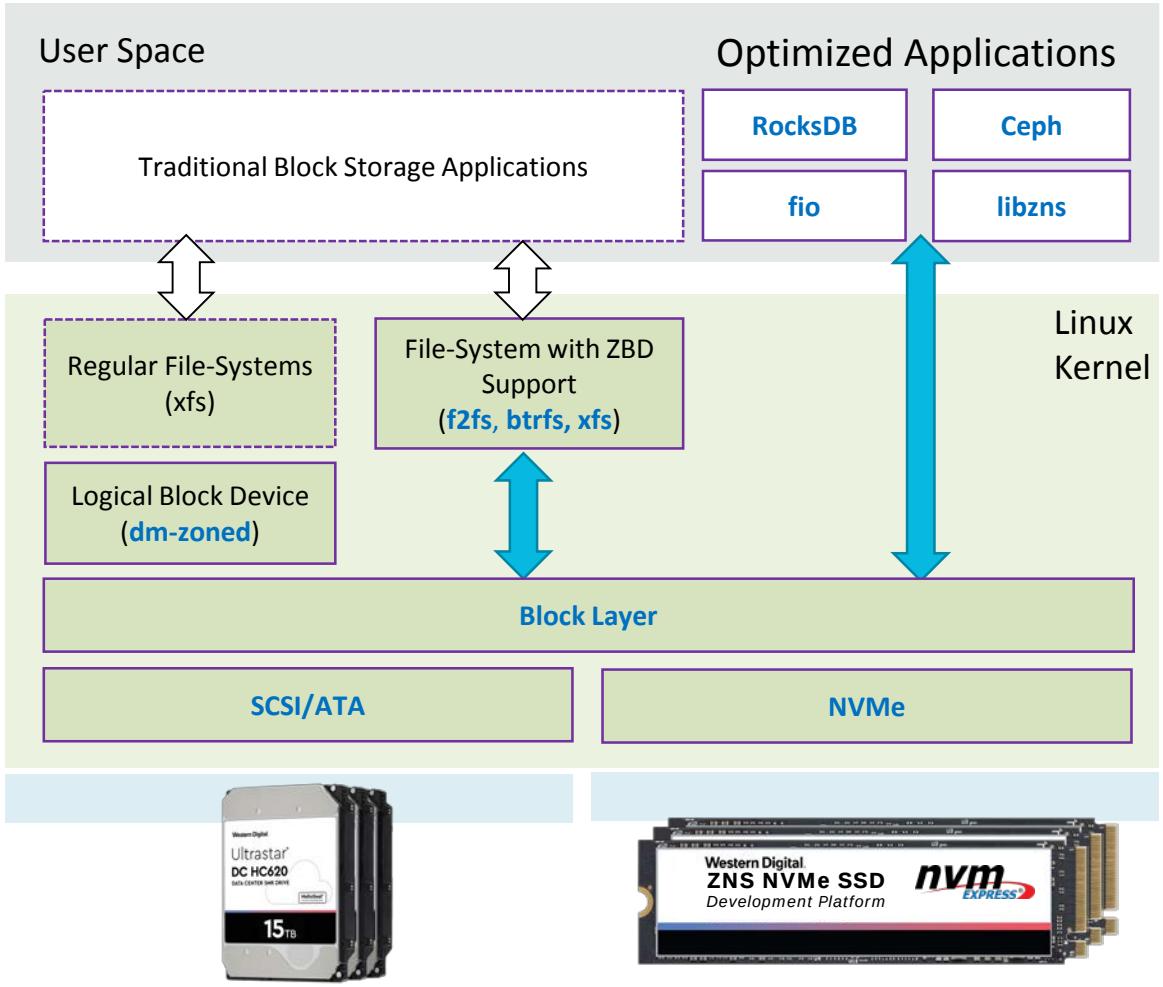
Zone Descriptors

- Fixed-sized data associated to zone
  - Upon opening a zone - associate a fixed-sized amount of data.
  - Invalidated upon zone reset.
  - Same size for all zones.
- Use-case
  - Out-of-band recovery path by allocating UUID's to each zone.
  - Zones can be self-identifying.



ZNS: Synergies w/ ZAC/ZBC software ecosystem

- Exposed as Zoned Block Devices (ZBD)
- Reuse existing work already done for ZAC/ZBC devices
- Existing ZBD-aware file systems & device mappers “just work”
  - Few additions to support to ZNS
- Integrates with file-systems and applications
  - RocksDB, Ceph, fio, libzns, …
- ZAC/ZBC devices are already in production at technology adopters and a mature storage stack is available through the Linux® eco-system.



*= Enhanced data paths for SMR/ZNS drives

ZNS Support in Linux

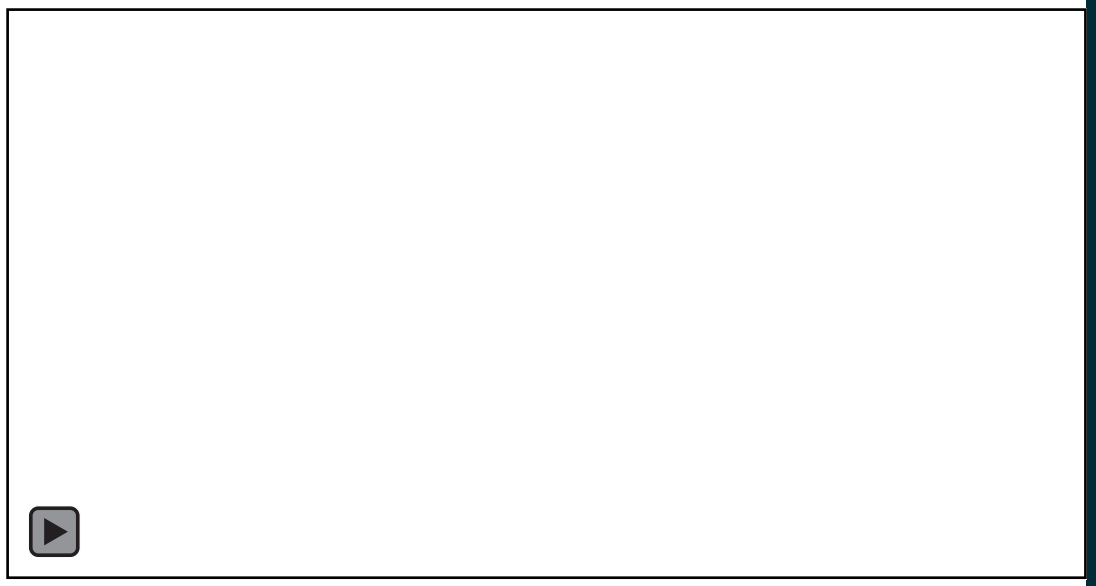
Shows up as a host-managed Zoned Block Device

Fio Workload

Write sequentially to zones

RocksDB Workload – End-to-end Optimized

- Conventional Enterprise Drive: 90% Full – 5x Write Amplification (WA)
- ZNS Drive: 90% Full
  - **1x WA** – 5x more throughput or increase lifetime 5x lifetime



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