# Data Scrubbing and Rebuild Using Offload

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Devesh Rai
KIOXIA America, Inc.

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the Future of Memory and Storage



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# Host Orchestrated Compute Offload Building Blocks



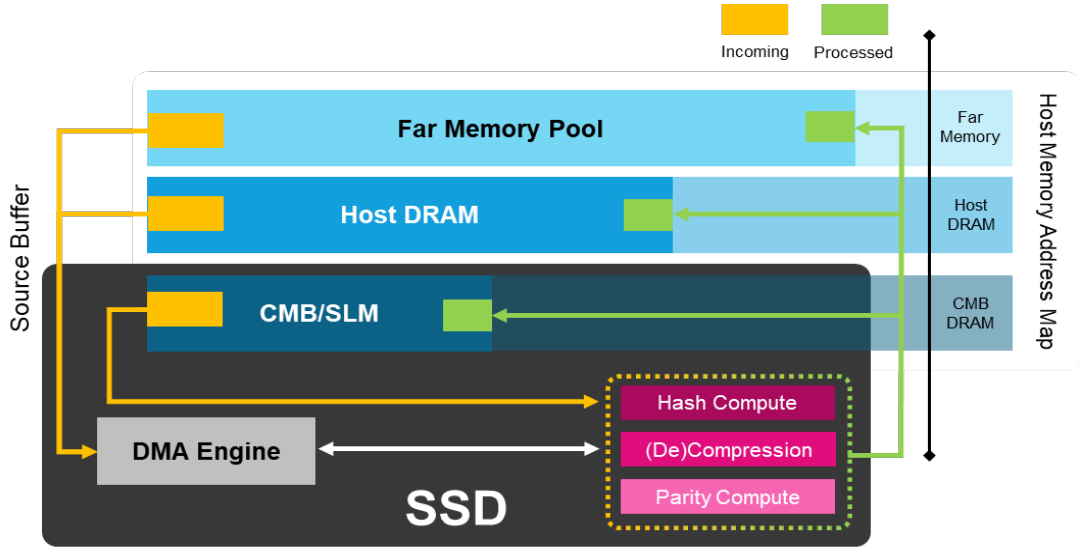
**Power-efficient compute engines**

**DRAM bandwidth saving**

**Host orchestrated standard based**

## Applications of Offload Engines

- **Hash/CRC[3]:** Dedupe, Object/File signature/scrubbing, buffer integrity
- **(De)Compression:** Compression with levels, decompress and filter
- **Parity Compute**: Erasure code (EC), compare, **Data scrubbing, RAID Rebuild**




Host places data in appropriate buffer (host memory/ far memory/ CMB[1]) → Host issues command to the SSD → Compute engine on the SSD executes the command → Processed data is placed into the destination buffer → Command completion returns key attributes

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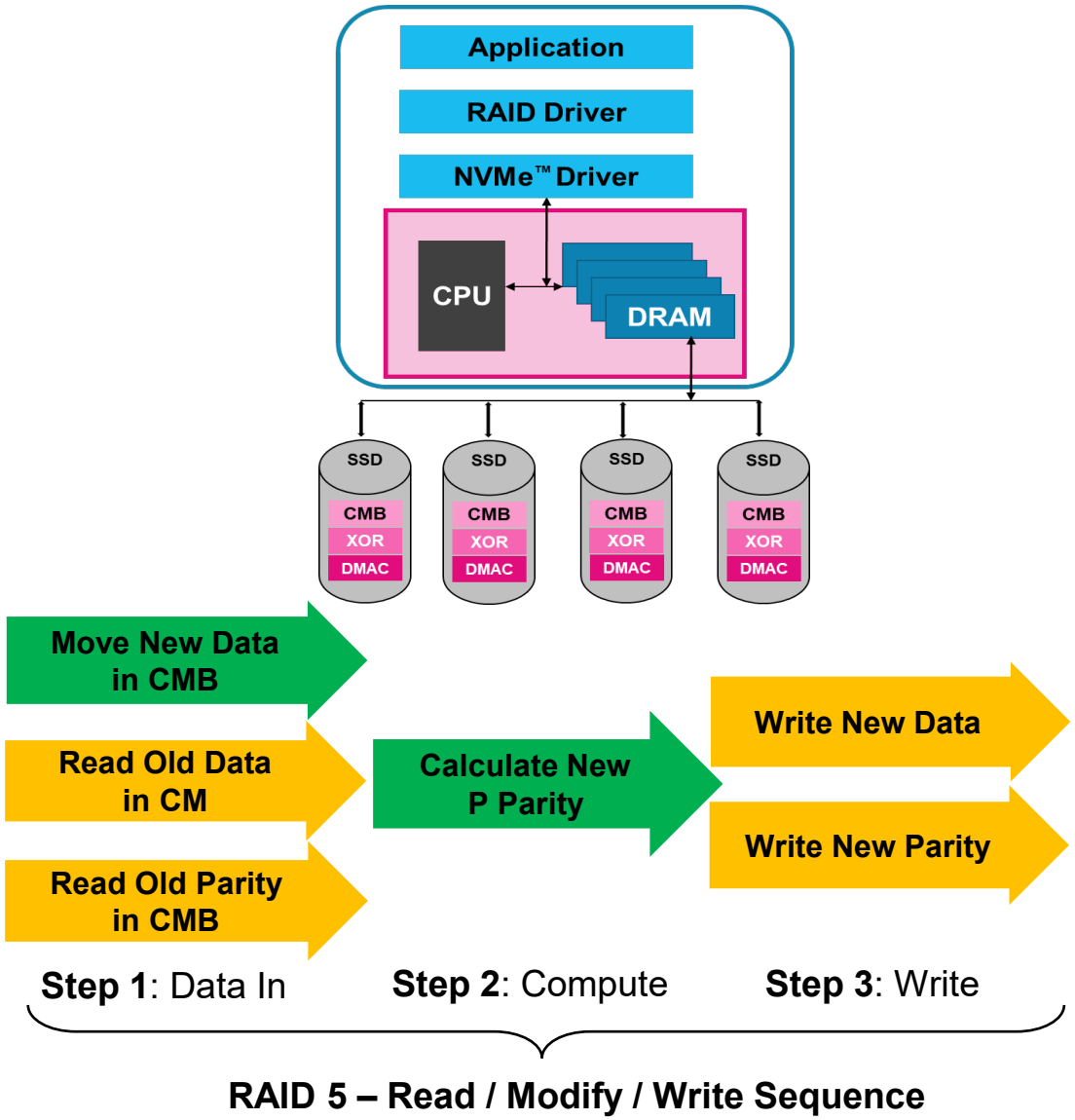
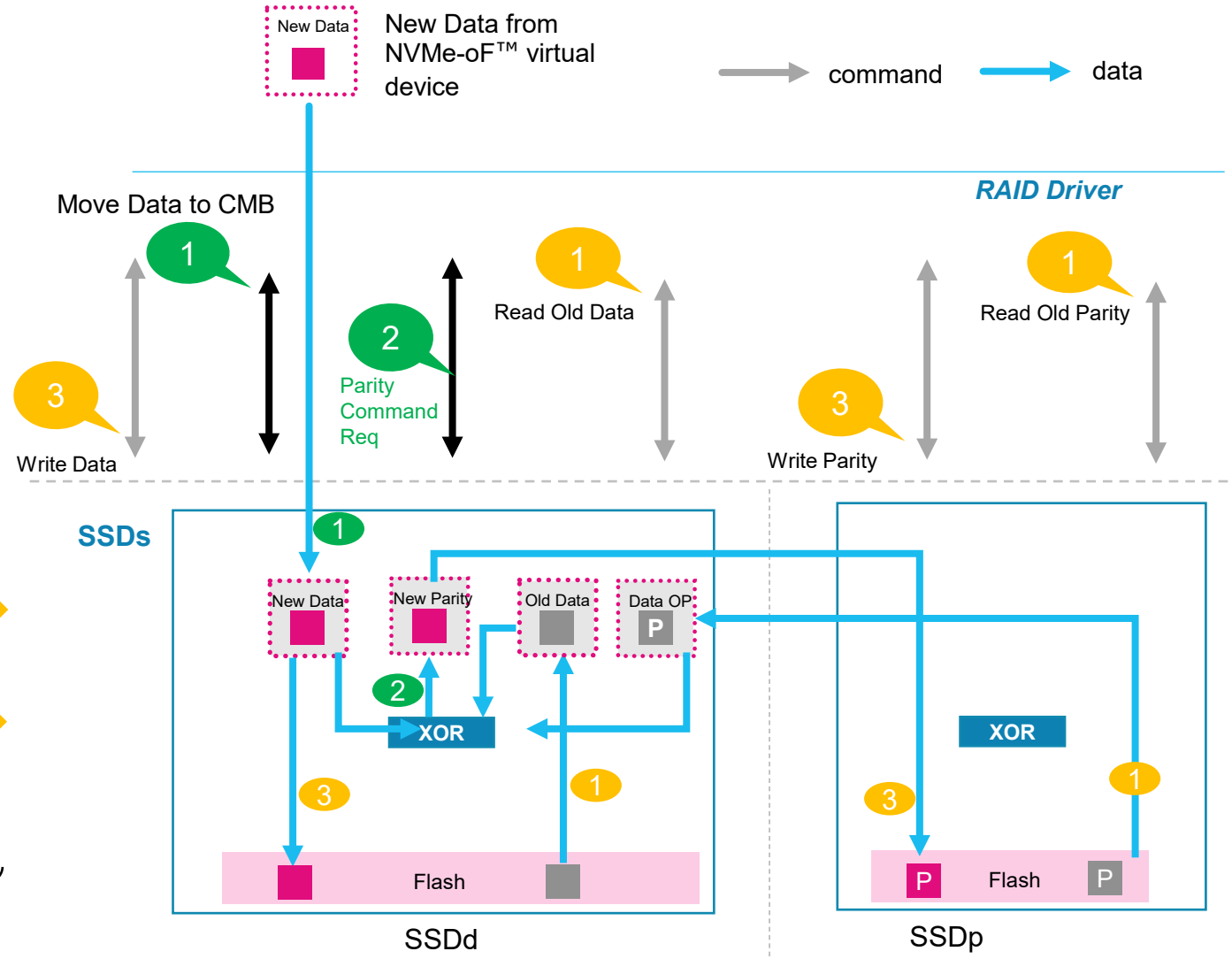
1. Controller memory buffer (CMB). 2. Subsystem local memory (SLM). 3. Cyclic redundancy check (CRC). 

# Command and Data Flow Example for RAID 5 Write



# Fail in Place Mechanism at the SSD Level

# KIOXIA Built-in SSD Level Failure Mitigation



| Failure Mitigation Features | Description |
|---|---|
| **Wear Leveling** | Internally developed “Always on” algorithm to allow even media wearing |
| **Die Fail Tolerance and Recovery** | Enterprise and data center SSDs historically supports die fail tolerance and recovery |
| **Customizable End-of-Life Behavior** | When and what actions to take upon reaching certain thresholds |
| **Overprovisioning (OP) and Available Spare** | Available Spare, critical warning in SMART[1] / health information<br>**Read Only mode if spare capacity falls below threshold** |
| **Dual-Port Functionality in Enterprise SSDs** | Ensures high availability in case of path failure |

**Data verification mechanism still required to ensure data integrity at File/Object/Stripe level.**



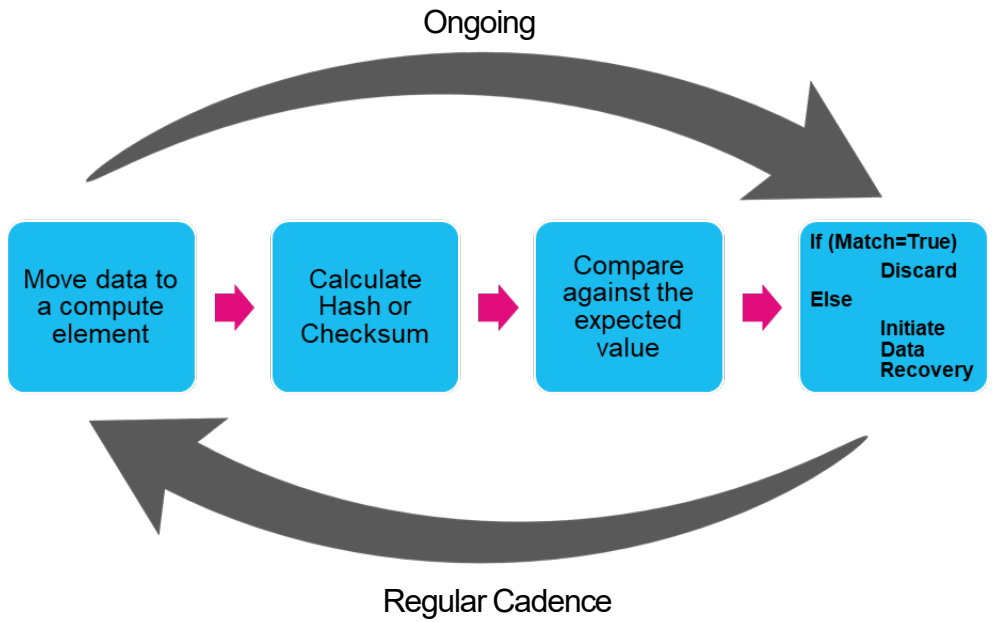
1. Self-Monitoring, Analysis and Reporting Technology (SMART) attributes

# Data Scrubbing Using Offload

# Data verification using Data Scrubbing in Conventional Setup



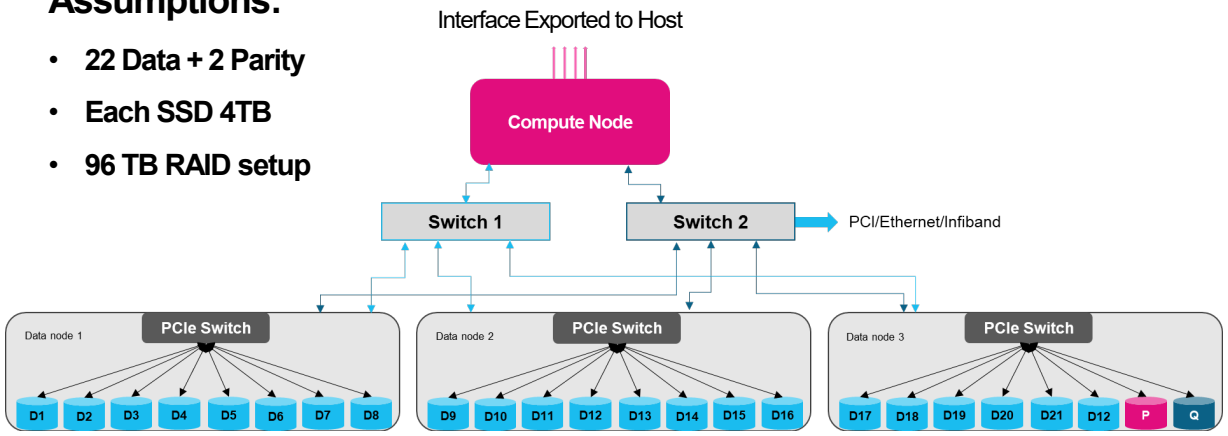
- **Data Scrubbing: Early detection and correction of errors**
- **Method employed : Hash, checksum or RAID technology**
- **Supported Level : File, Object and RAID Stripe**




**All data movement during scrubbing operation is an overhead penalty paid to ensure data integrity**

## Assumptions:

- **22 Data + 2 Parity**
- **Each SSD 4TB**
- **96 TB RAID setup**




**Compute node performing data and parities verification for one stripe using RAID**

1. P + D1 + D2 + D3 + D4 …… + D22 = 0
2. Q + g1.D1 + g2.D2 + g3.D3 + ….. + g22.D22 = 0

**For each Scrubbing Cycle:**

- **96TB data moves over PCIe®, network and CPU**
- **192TB through memory subsystem**

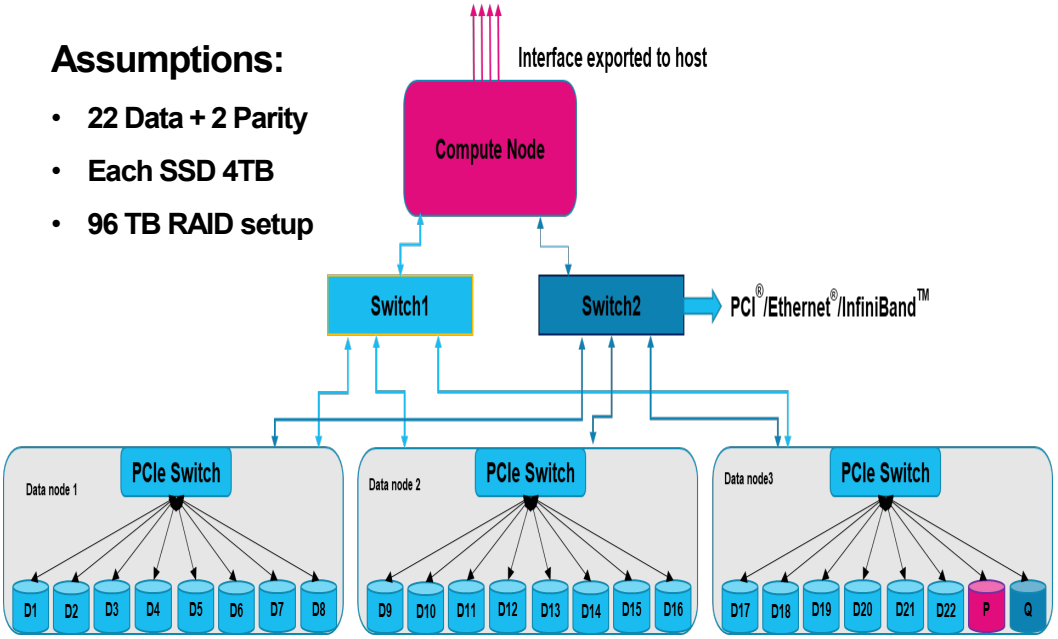
Assumptions created by KIOXIA in-house engineering team.

# Error Detection using Data Scrubbing with RAID/EC Offload

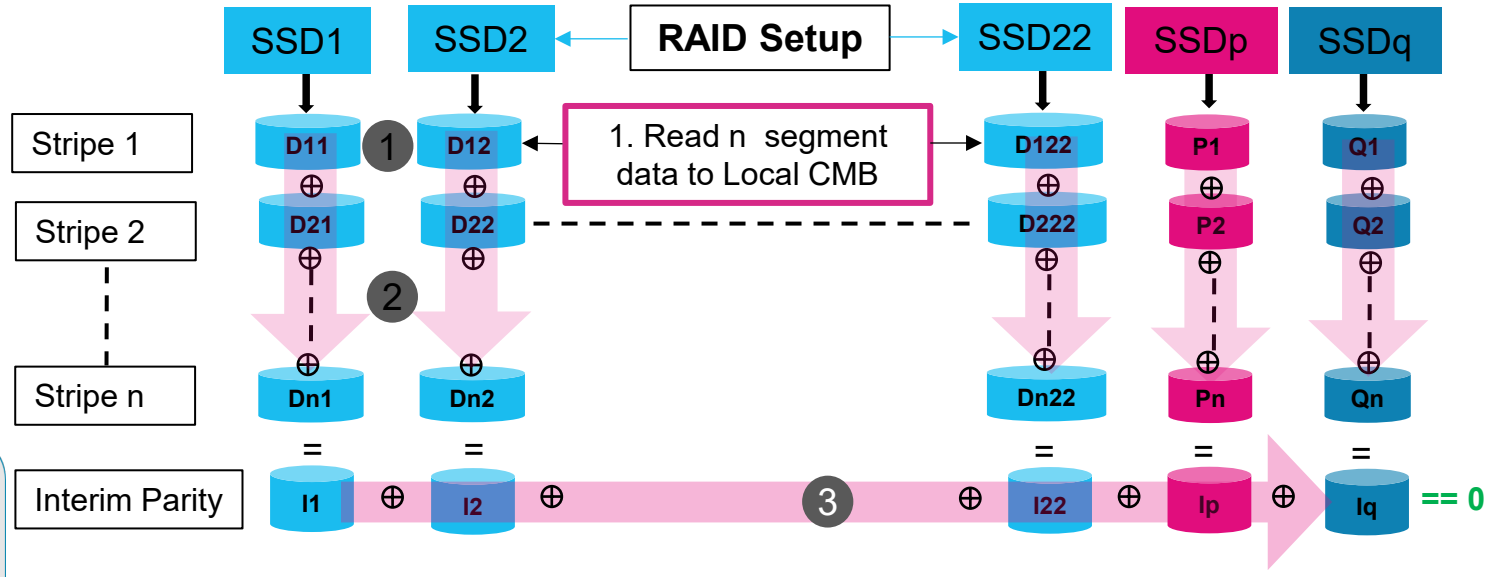


**Assumptions:**

- **22 Data + 2 Parity**
- **Each SSD 4TB**
- **96 TB RAID setup**




Assumptions created by KIOXIA in-house engineering team




2. On each SSD, interim parity by I1 = D11 + g1.D11 + D21 + g2.D21 + ……+ Dn1 + gn.Dn1
3. On any SSD, final parity by I1 + I2 + I3 + ……. + Ip + Iq == 0 ➔ **Success**

- **Using 3 step process, system resource usages reduced by ~99%**
- No data passes through CPU and DRAM on compute node
- For n stripes, only one stripe moves over network and PCIe®
- **A sustainable and scale out solution**
- Dnm=> Data segment D of nth stripe on SSDm

| System Resources to Scrub 96 TB (subject to change) | Conventional Method | KIOXIA Data Scrubbing Offload | % of Savings |
|---|---|---|---|
| Data passes through CPU for parity computation | 96 TB | 0 TB | 100% |
| Data passes through DRAM controller | 192 TB | 0 TB | 100% |
| Data passes through network | 96 TB | 0.4 TB | 99% |
| Data passes through PCIe® interface | 96 TB | 0.4 TB | 99% |

**A very flexible, geometry agnostic and adoptable solution for early error deduction**

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# Rebuild Using RAID Offload

# Efficient Rebuild of 2 SSDs using RAID offload

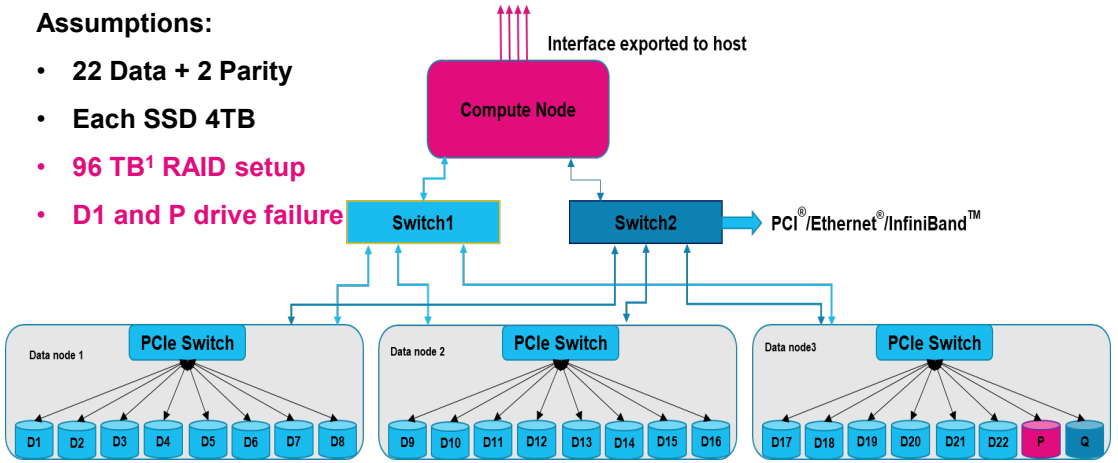


1. *Read good data segments of one RAID strip on compute node*
2. *Compute these two equations in order*
   a. *D1 = (g2.D2 + g3.D3 + ….. + g22.D22 + Q)/g1*
   b. *P = D1 + D2 + D3 + D4 …… + D22*
3. *Write D1 and P to new SSDs on respective stripe*
4. *Repeat steps 1-3 for each RAID stripe generation*

**Without offload**

**Assumptions:**

- **22 Data + 2 Parity**
- **Each SSD 4TB**
- **96 TB[1] RAID setup**
- **D1 and P drive failure**




1. *Read Dm to Dn segments in the CMB of one SSD in each data node*
2. *Calculate node specific intermediate data $D_{in}$ and parity $P_{in}$. For example, on node 1*
   1. *$P_{i1}$ = D2 + …….+ D8*
   2. *$D_{i1}$ = (g2.D2 + …….+g8.D8) / g1*
3. *Read intermediate data $D_{in}$ and parity $P_{in}$ from each data node on compute node and compute D1 followed by P parity*
   1. *$D1 = D_{i1} + D_{i2} + D_{i3}$*
   2. *$P = D1 + P_{i1} + P_{i2} + P_{i3}$*
4. *Write P and D1 to new SSDs on respective stripe*
5. *Repeat steps 1-4 for rebuilding each RAID stripe*

**With offload**

| System Resources to build two drives (subject to change[2]) | Conventional Method | KIOXIA Data Rebuild with Offload | % of Savings |
|---|---|---|---|
| Data passes through CPU for parity computation | 88 TB | 24 TB | 73% |
| Data passes through DRAM controller | 192 TB | 64 TB | 66% |
| Data passes through network | 96 TB | 32TB | 66% |
| Data passes through PCIe® interface | 96 TB | 108TB | -12% |

**Rebuild with offload can saturate write line speed**



System resource usage testing performed in-house by KIOXIA engineers. 1. Definition of capacity: KIOXIA Corporation defines a megabyte (MB) as 1,000,000 bytes, a gigabyte (GB) as 1,000,000,000 bytes, a terabyte (TB) as 1,000,000,000,000 bytes and a petabyte (PB) as 1,000,000,000,000,000 bytes. A computer operating system, however, reports storage capacity using powers of 2 for the definition of 1Gbit = 2^30 bits = 1,073,741,824 bits, 1GB = 2^30 bytes = 1,073,741,824 bytes, 1TB = 2^40 bytes = 1,099,511,627,776 bytes and 1PB = 2^40 bytes = 1,125,899,906,842,624 bytes and therefore shows less storage capacity. Available storage capacity (including examples of various media files) will vary based on file size, formatting, settings, software and operating system, and/or pre-installed software applications, or media content. Actual formatted capacity may vary. 2. Numbers subject to change based on system used and SDD features. PCIe is a registered trademark of PCI-SIG. Ethernet is a registered trademark of Fuji Xerox Co., Ltd. InfiniBand is a trademark of the InfiniBand Trade Association. I Other company and product names may be trademarks of the respective companies with which they are associated. Tables and charts created by KIOXIA engineers. Images and/or graphics within this slide are the property of KIOXIA America, Inc. (KIOXIA) and are reproduced with the permission of KIOXIA.

# Summary

- SSD level data loss mitigation to
  - Avoid rebuild process specially with high-capacity SSDs
  - Recovery of data even in case of die failure
- Efficient data scrubbing method to detect failure early while saving significant system resource cost
- Efficient rebuild process saving significant system resource cost and time
- Data scrubbing and rebuild is based on KIOXIA RAID Offload Technology, and 'Best of Show' award winner at the Future of Memory and Storage (FMS) 2024 conference

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