Improving SSD Performance Using Restricted Copyback Operations

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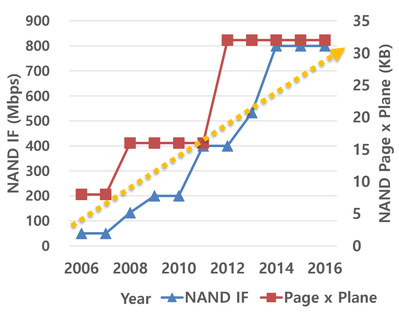
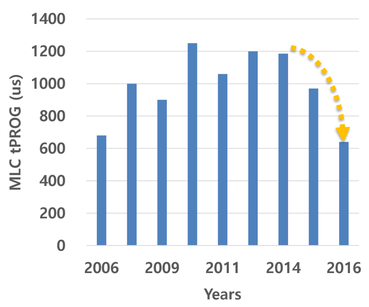
1 Impact and Major Factor of Data Copy

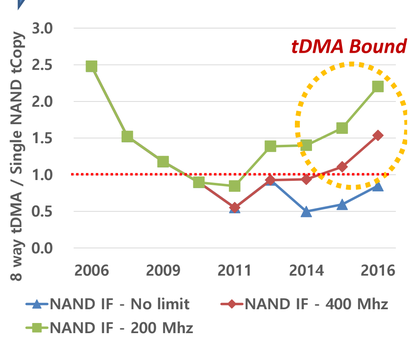
- **Data Copy Operation in SSD**
  - Moving a large amount of data internally → Interfere host I/O
  - E.g. Garbage Collection, Wear-leveling, Read Refresh
- **Data Copy Time, *tCopy* (One Page per plane)**
  - On single NAND : $tCopy = tR + tDMA_{out} + tDMA_{in} + tPROG$
  - Multi way configuration : $tCopy = tR + (tDMA_{out} + tDMA_{in}) \times way + tPROG$
- **Device Parameter Trend and relation with *tCopy***
  - NAND IF Speed (ONFI Spec.) ↑ : Decreasing *tDMA*
  - NAND Page Size ↑ : Increasing *tDMA*
  - NAND tPROG ↓ : Decreasing *tPROG*
  - Device Configuration (ch/way) : Multi ch / way

Compensating each other

tDMA dominates the tCopy

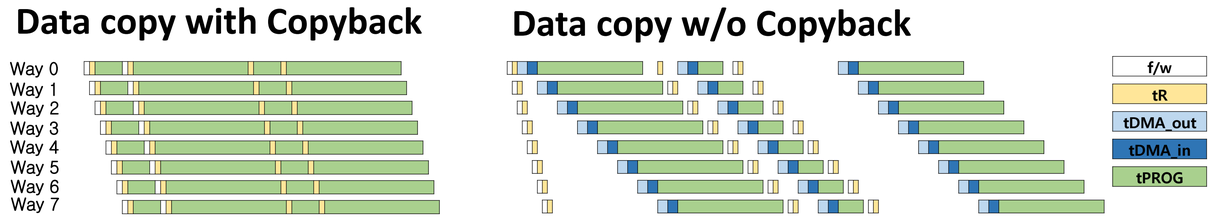






2 Copyback Operation in SSD

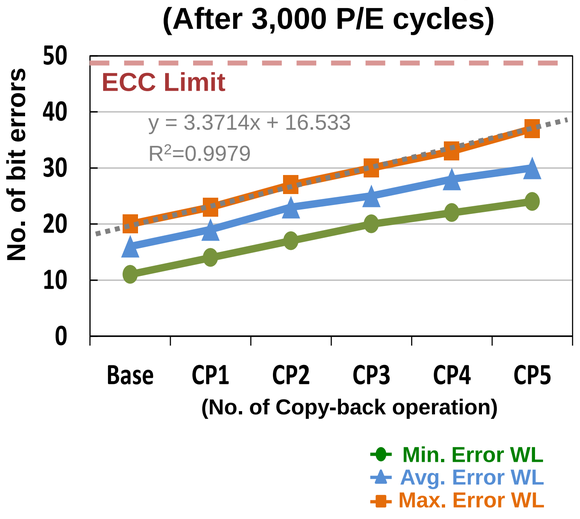
- **Advantage of copyback**
  - DMA time during data copy can be hidden
    - $tDMA_{out}$ and $tDMA_{in}$ are not needed
  - More effective when the number of channel/way is bigger

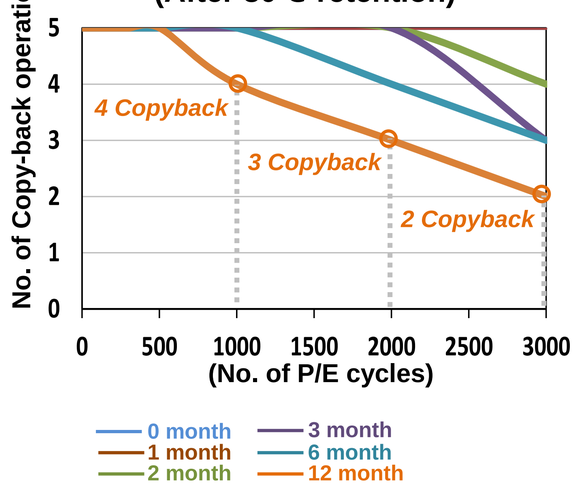


- **Difficulty of applying copyback in SSD**
  - Error Propagation Issue
    - Consecutive copyback can cause *Uncorrectable Error*
  - Same Plane Constraint
    - Src/dst pages should be located in *Same Plane*
  - Partial Invalid Page Management

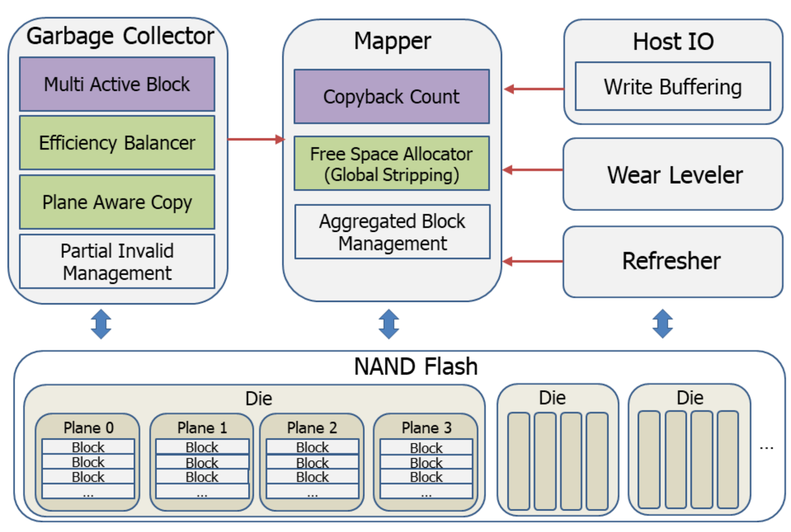
3 Characterization of Copyback Error Propagation

- **Bit Errors are increased by the number of Copyback**
  - 3~4 bits per each Copyback on 1x MLC NAND
- **Minimum two Copyback is allowed at Max P/E cycle**
  - Without sacrificing retention (12 months)



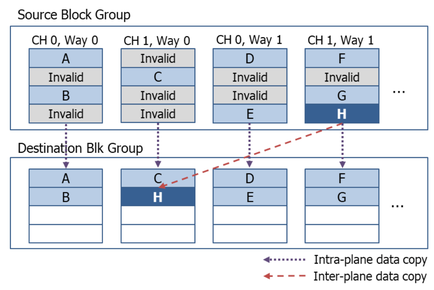


4 rcFTL : Restricted Copyback Aware FTL

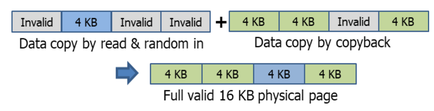


- **G.C Efficiency Balancer**
  - Preventing G.C efficiency difference between planes by managing victim block as a group
- **Plane Aware Copy / Partial Invalid Management**
  - Utilizing copyback maximally, minimizing inter plane data copy.

- **Plane Aware Copy**
  → maximizing copyback usage

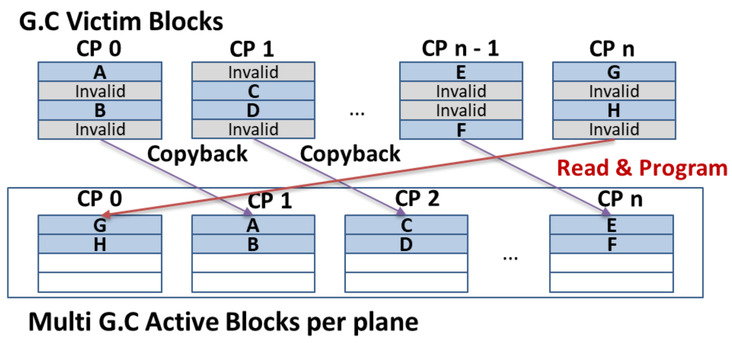


- **Partial Invalid Management**
  (Physical Page > Mapping Size)

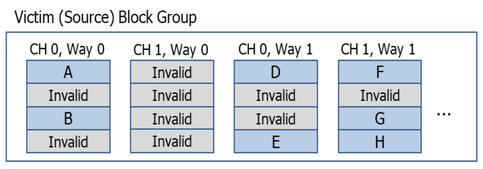


5 Design Requirements of rcFTL

- **Error Propagation Management**
  - R_Copyback : restricted version of copyback, executing error correction using off-chip ECC after *n* consecutive copyback
  - Block based copyback count management to minimize overhead



- **Same Plane Constraint**
  - Global Mapping Scheme
    - Host workload independency, but GC efficiency difference per plane
  - GC Efficiency Balancing
    - Doesn't allocate new victim block for specific plane until all blocks of victim group are invalidated
      → valid page difference management (balancing)



6 Experimental Results

- **Performance improvement: up to 77.6%**
  - 8ch x 8way with Copyback up to 4 times (77.6%), 2 times (54.7%)
  - Improvement of 8ch is higher than 4ch
  - Improvement of 8way is higher than 2/4 way