



Operating System Practice

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Flash Memory and Phase Change Memory

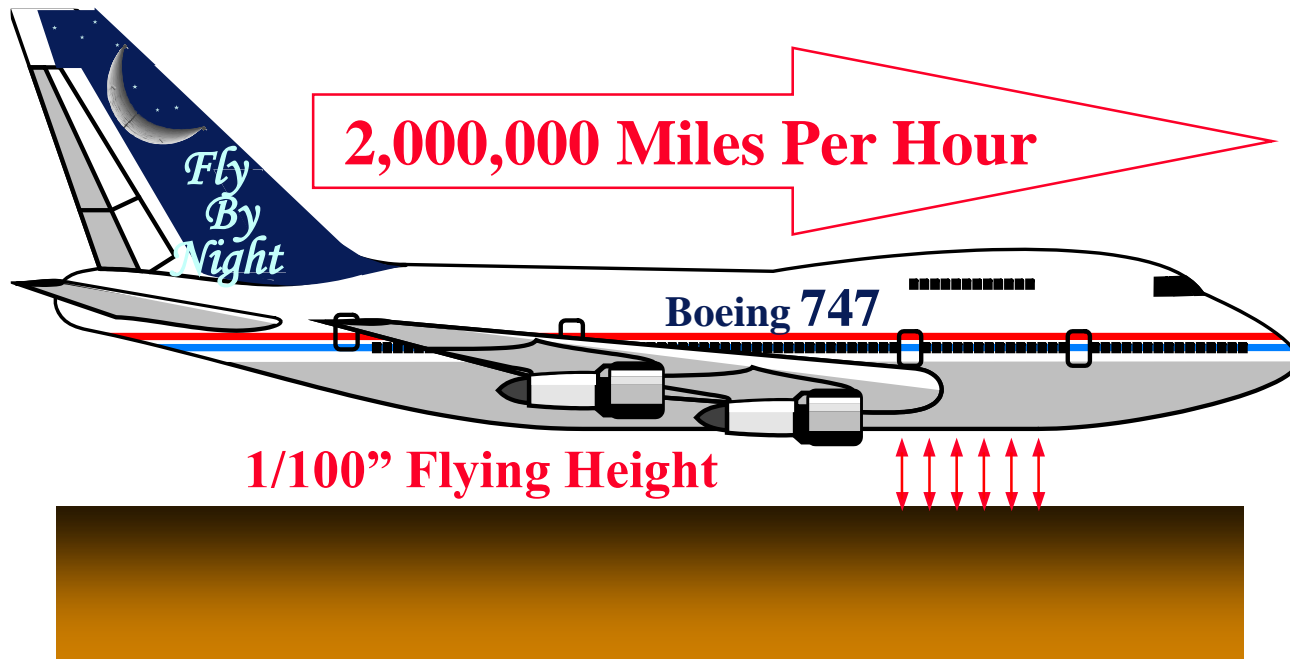
Reference: Prof. Tei-Wei Kuo, NTU and Dr. Yuan-Hao Chang, Academia Sinica

Trends – Market and Technology

- ▶ Diversified Application Domains
 - Portable Storage Devices
 - Consumer Electronics
 - Industrial Applications
- ▶ Competitiveness in the Price
 - Dropping Rate and the Price Gap with HDDs
- ▶ Technology Trend over the Market
 - Improved density
 - Degraded performance
 - Degraded reliability



Trends – Storage Media



VS

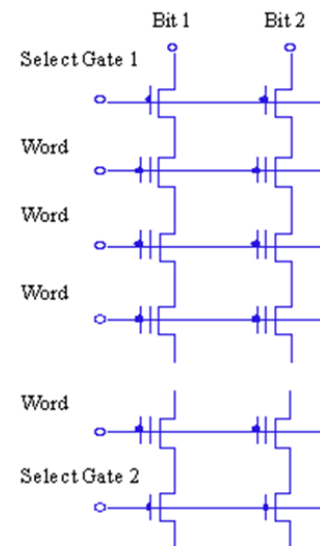
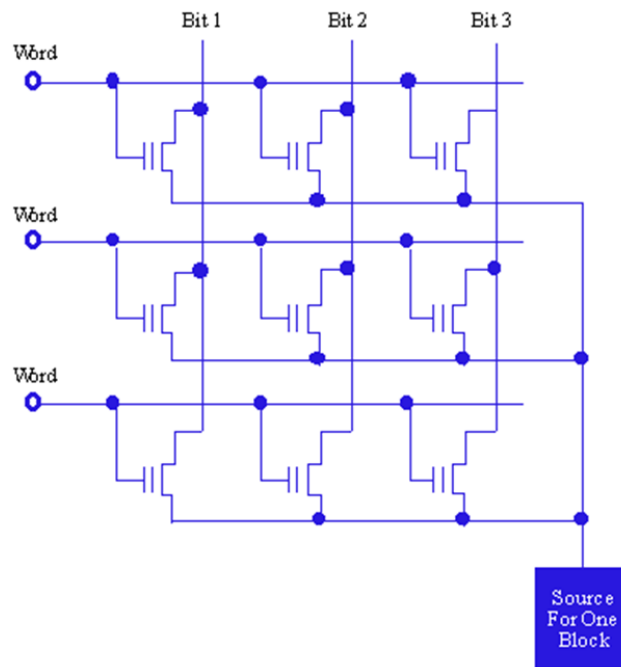


Source: Richard Lary, The New Storage Landscape: Forces shaping the storage economy, 2003.



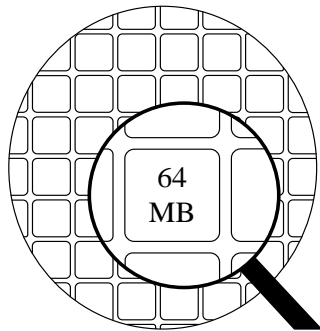
NOR and NAND Flash

- ▶ NAND accesses each cell through adjacent cells, while NOR allows for individual access to each cell
- ▶ The cell size of NAND is almost half the size of a NOR cell



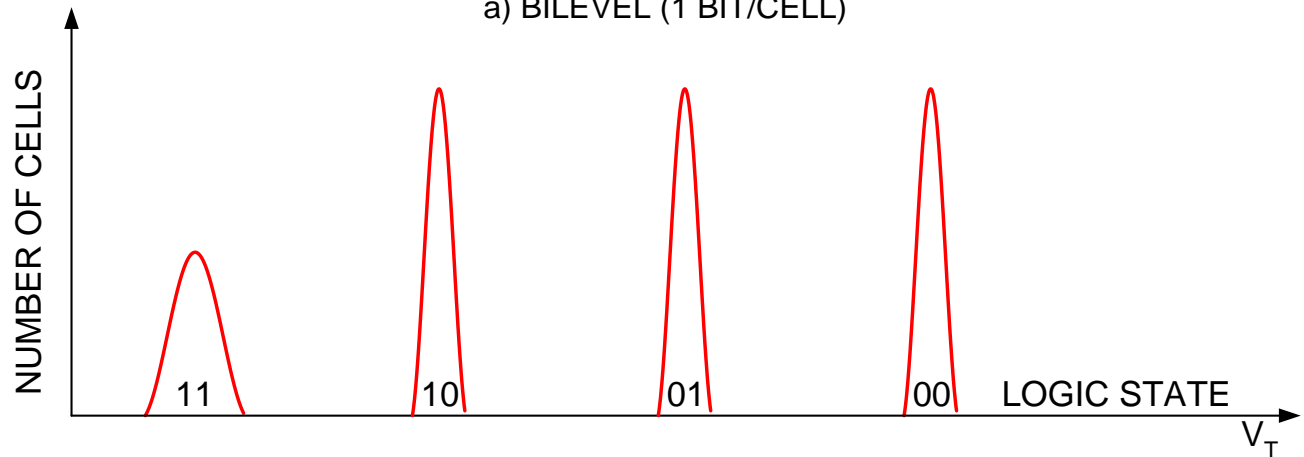
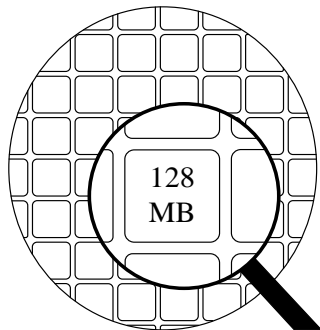
Single-Level Cell (SLC) vs Multi-Level Cell (MLC) Flash

SLC Flash



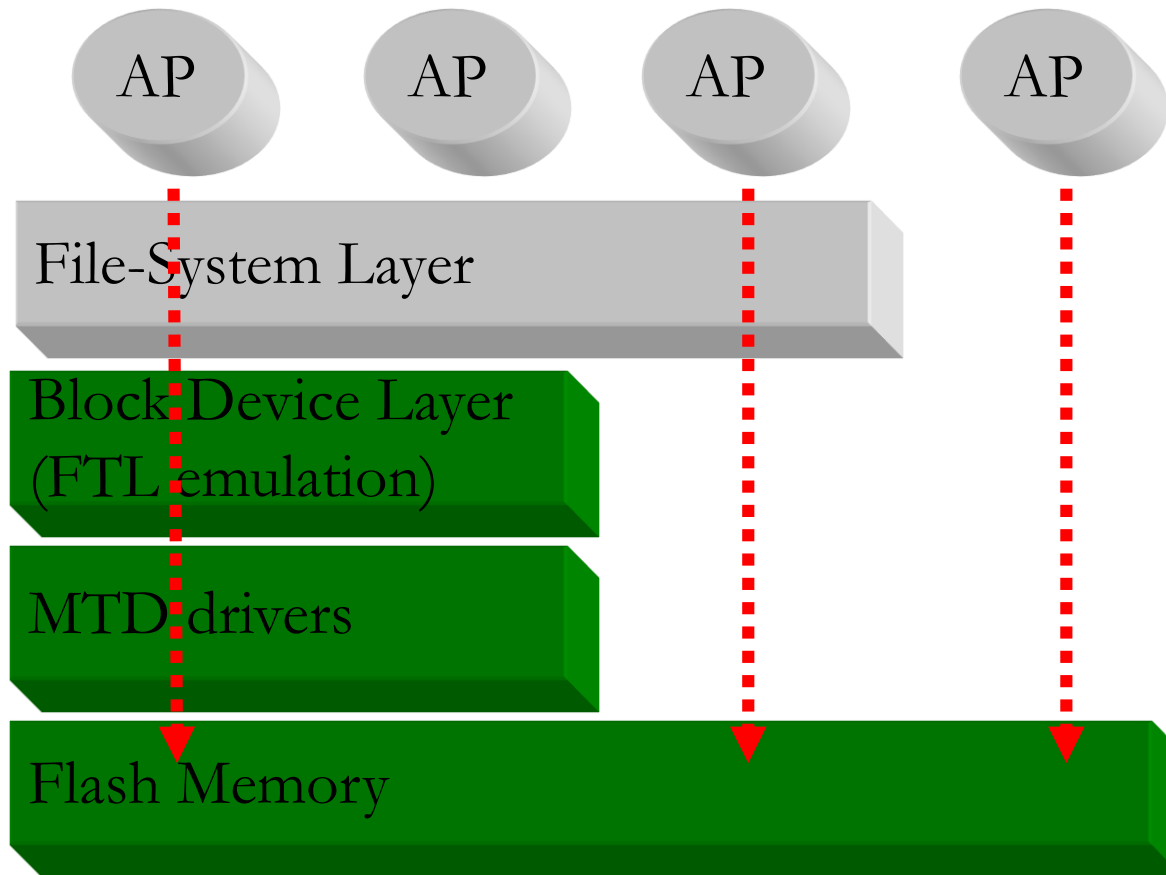
a) BILEVEL (1 BIT/CELL)

MLC Flash



b) MULTILEVEL (2 BIT/CELL)

System Architectures for Flash Management



Flash–Memory Characteristics

► Write-Once

- No writing on the same page unless its residing block is erased
- Pages are classified into valid, invalid, and free pages

► Bulk-Erasing

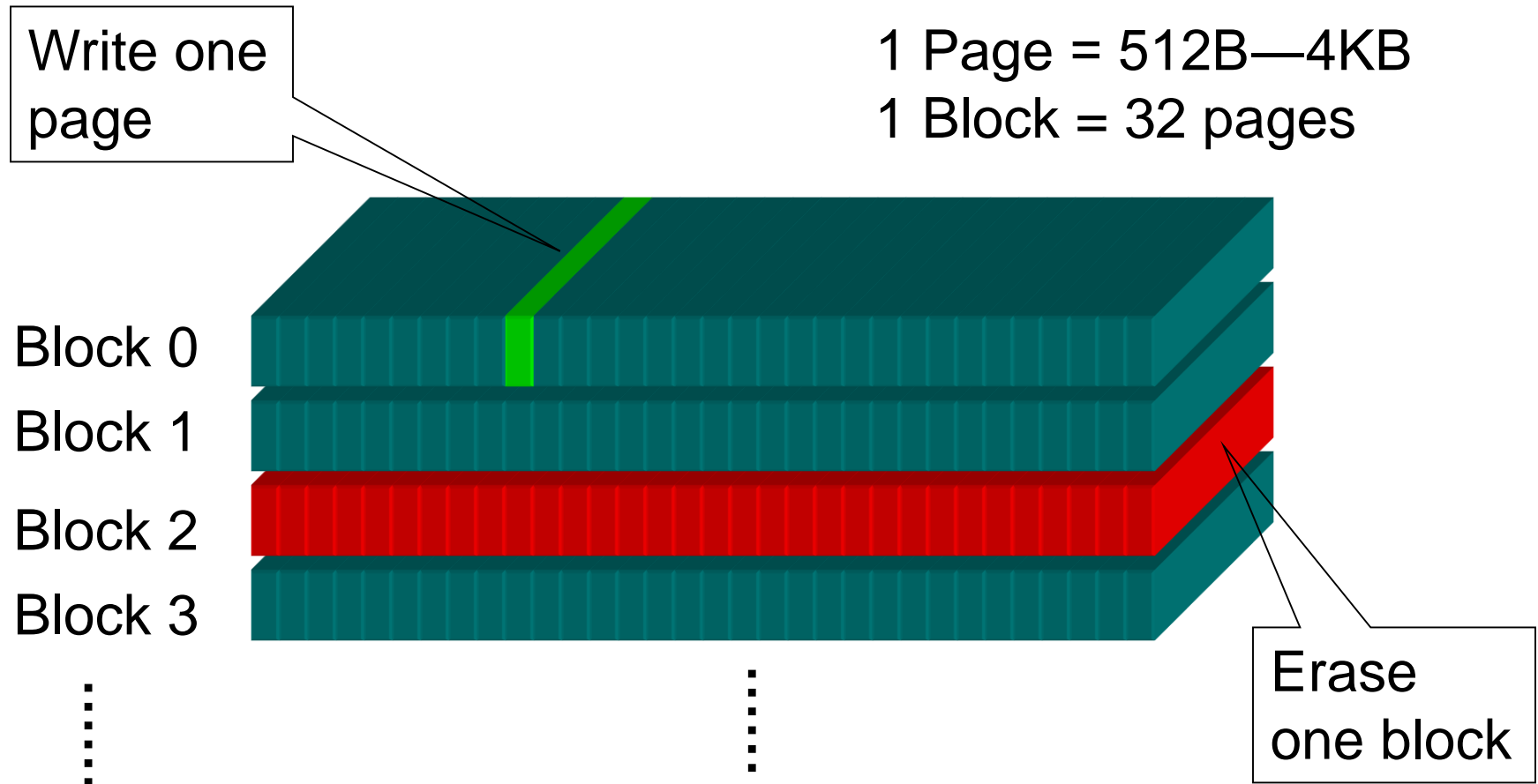
- Pages are erased in a block unit to recycle used but invalid pages



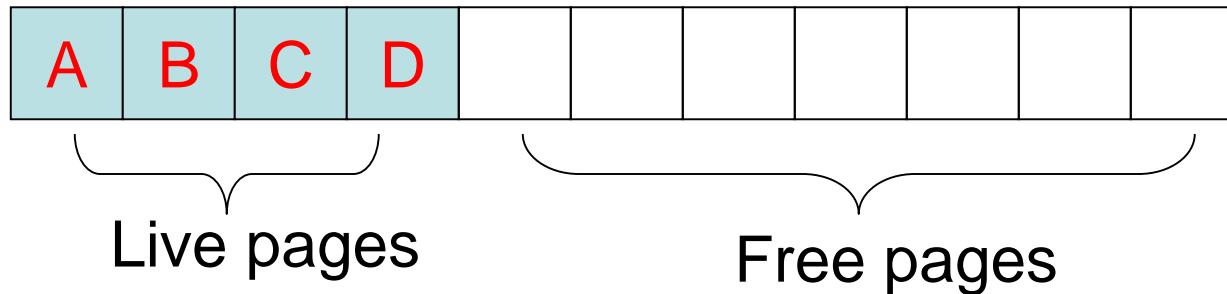
► Wear-Leveling

- Each block has a limited lifetime in erasing counts

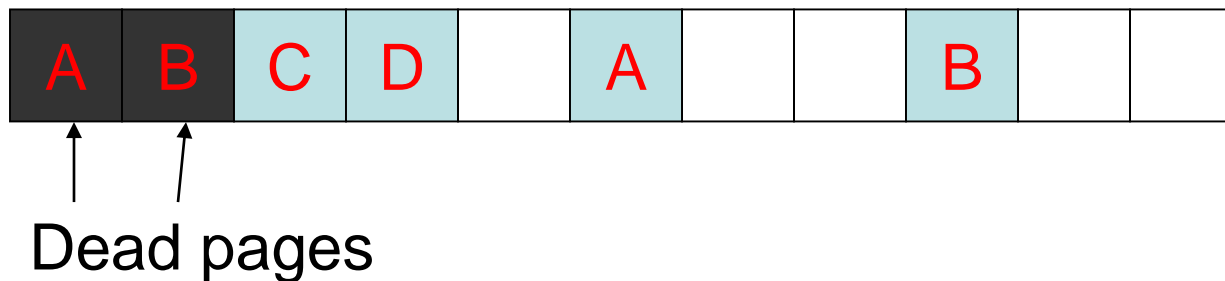
Page Write and Block Erase



Out-Place Update



Suppose that we want to update data A and B...

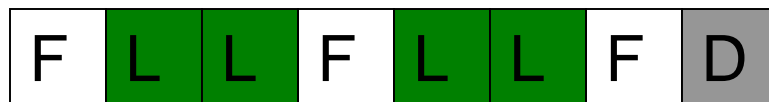
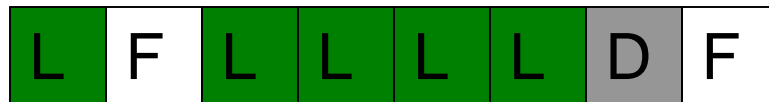





Garbage Collection (1 / 3)



This block is to be recycled

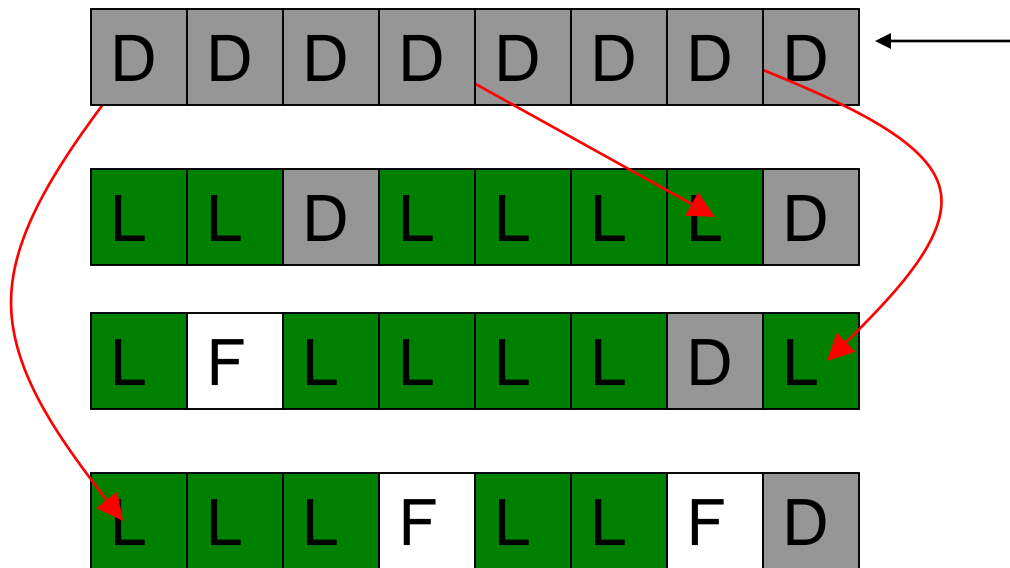
(3 live pages and 5 dead pages)



-  A live page
-  A dead page
-  A free page



Garbage Collection (2/3)



Live data are copied to somewhere else

- A live page
- A dead page
- A free page






Garbage Collection (3 / 3)



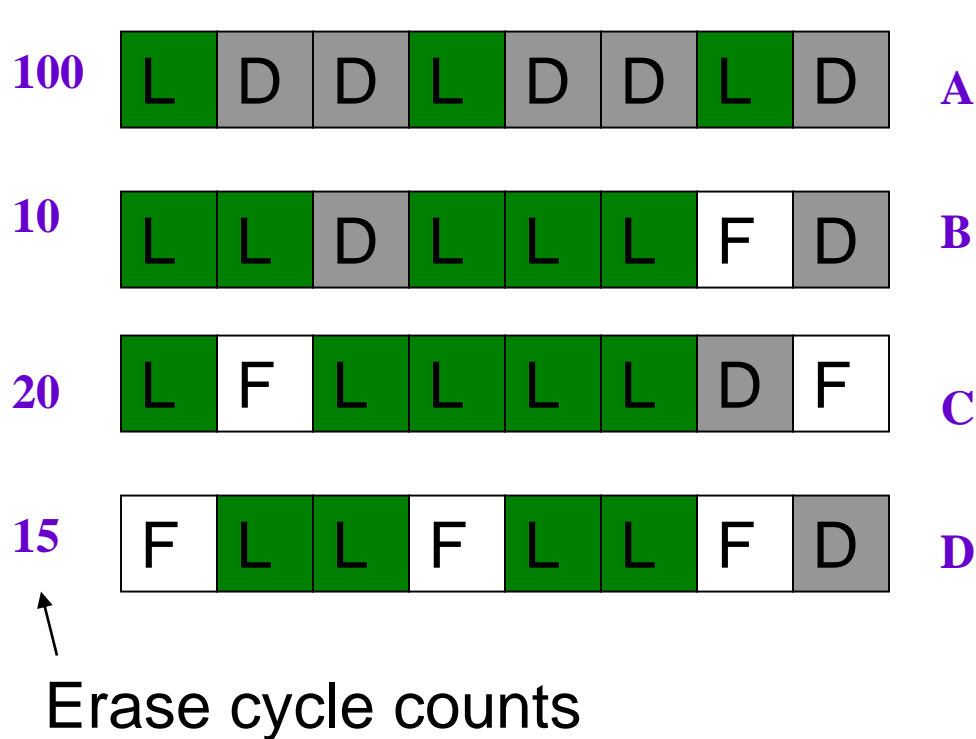
The block is then erased

Overheads:

- live data copying
- block erasing

-  A live page
-  A dead page
-  A free page

Wear-Leveling

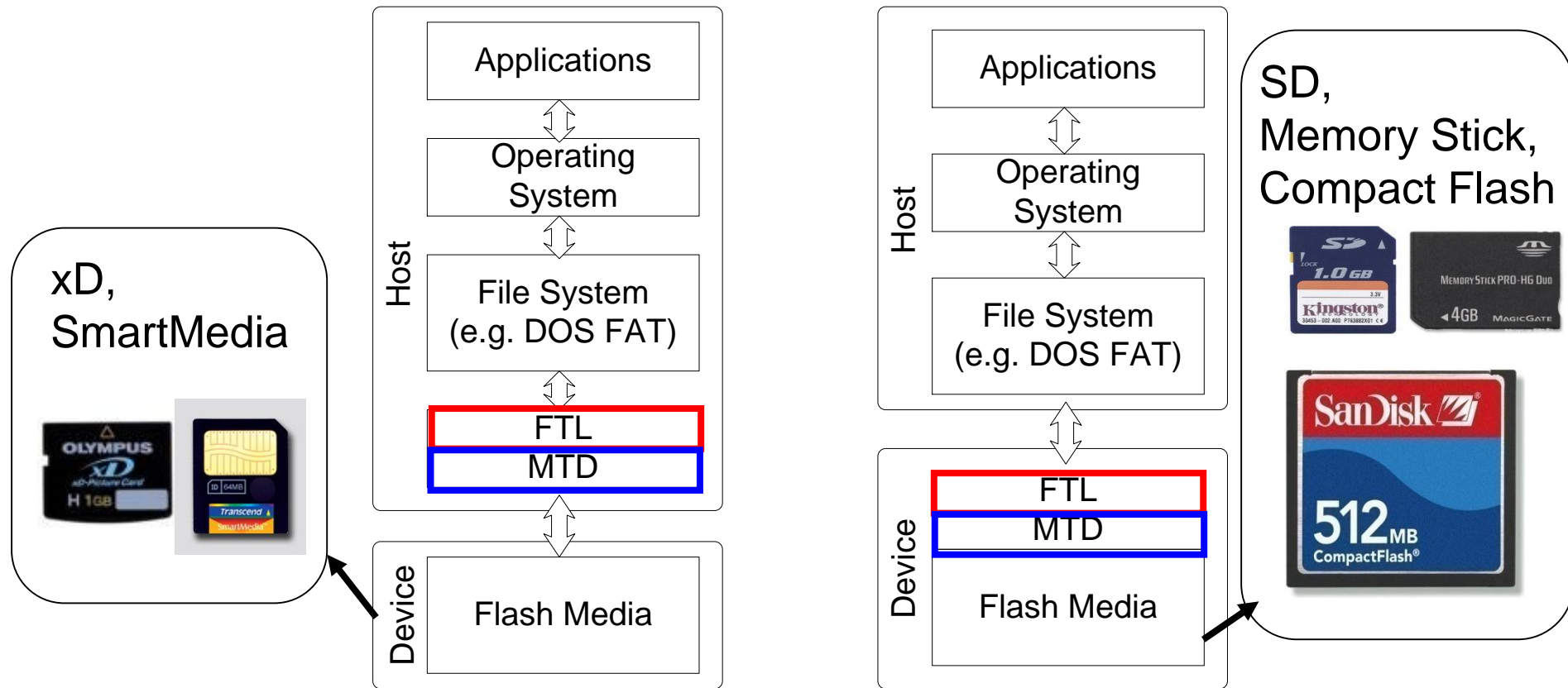


Wear-leveling might interfere with the decisions of the block-recycling policy

- A live page
- A dead page
- A free page



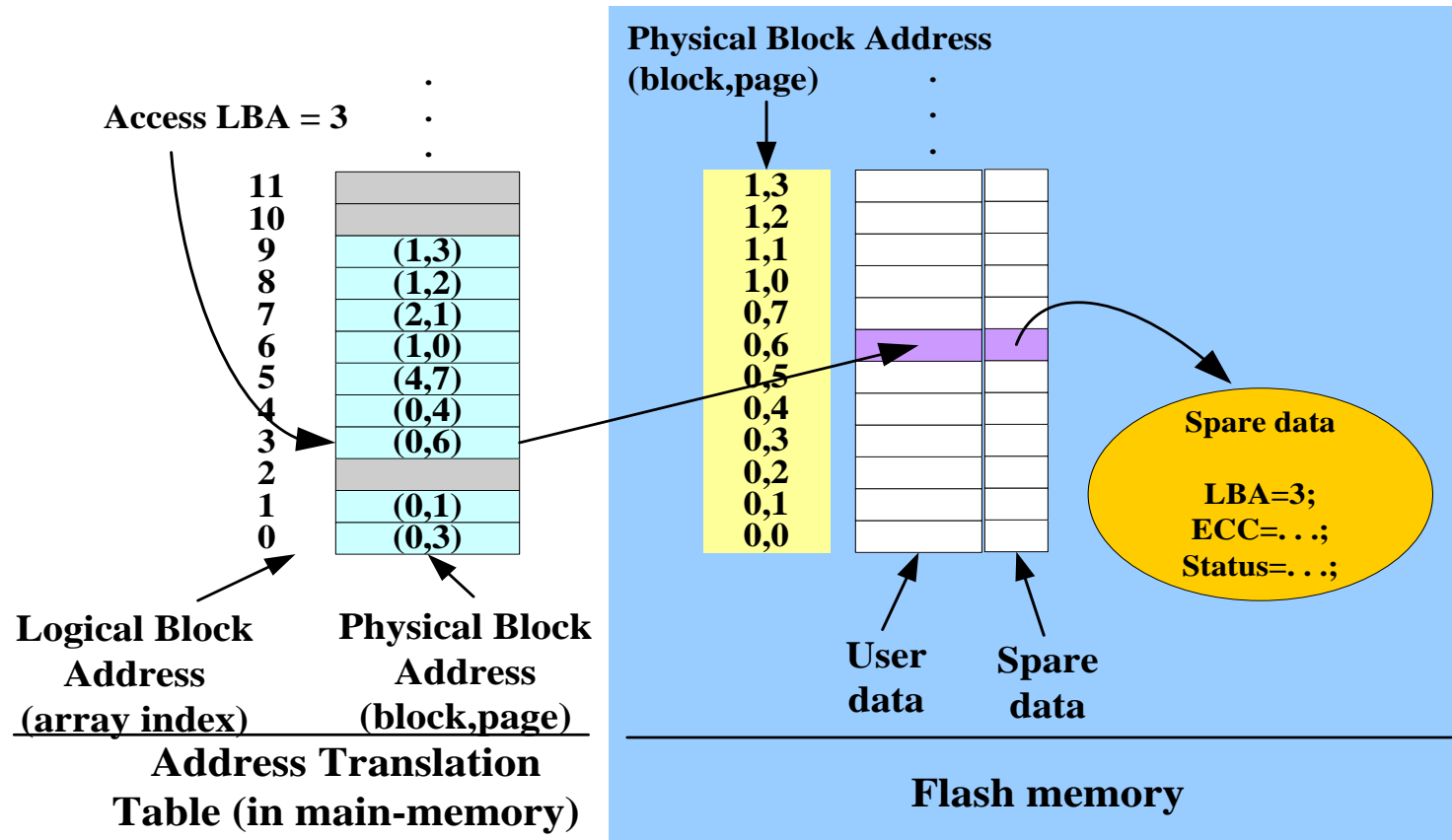
Flash Translation Layer



* **FTL**: Flash Translation Layer, **MTD**: Memory Technology Device

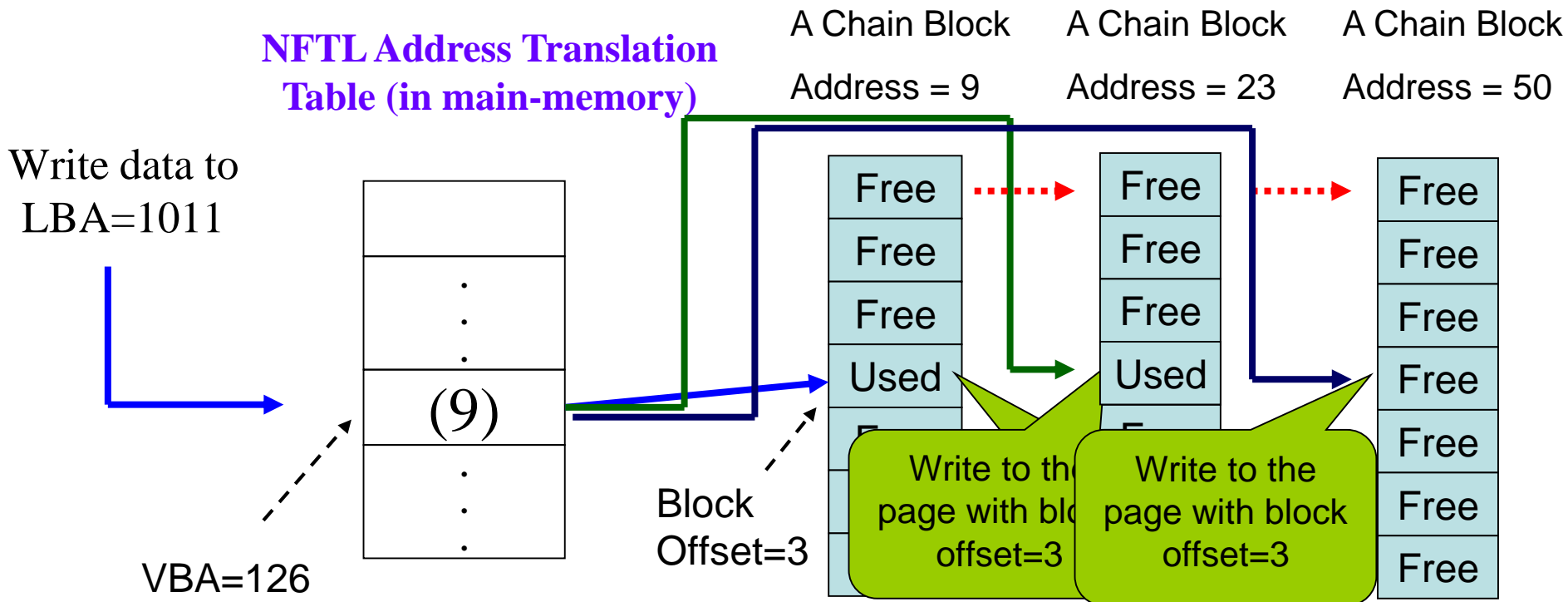
Policies – FTL

- ▶ FTL adopts a page-level address translation mechanism



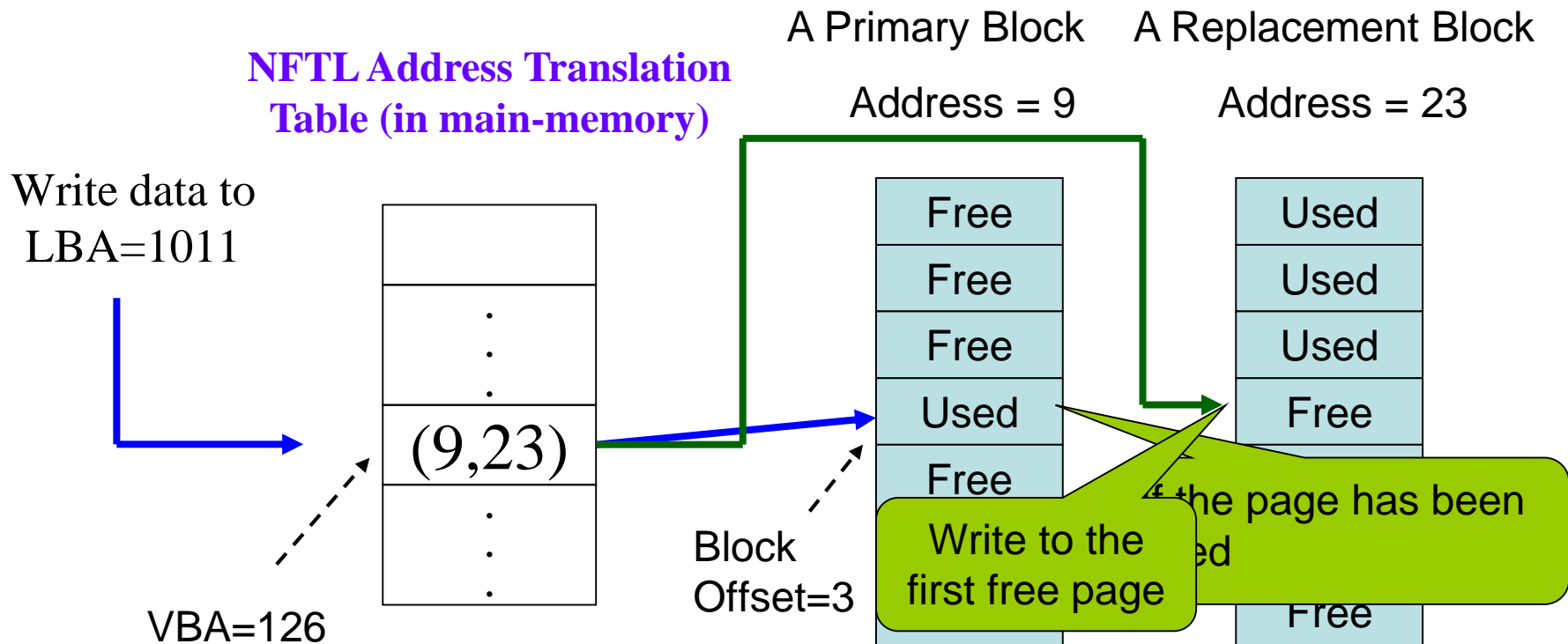
Policies – NFTL (Type 1)

- ▶ A logical address under NFTL is divided into a virtual block address and a block offset, e.g., LBA=1011 => virtual block address (VBA) = $1011 / 8 = 126$ and block offset = $1011 \% 8 = 3$



Policies – NFTL (Type 2)

- ▶ A logical address under NFTL is divided into a virtual block address and a block offset, e.g., LBA=1011 => virtual block address (VBA) = $1011 / 8 = 126$ and block offset = $1011 \% 8 = 3$



Challenges and Research Topics of Flash Memory Designs

► Performance

- Reduce the overheads of Flash management
- Reduce the access time to data
- Reduce the garbage collection time

► Reliability

- Error correcting codes
- Log systems

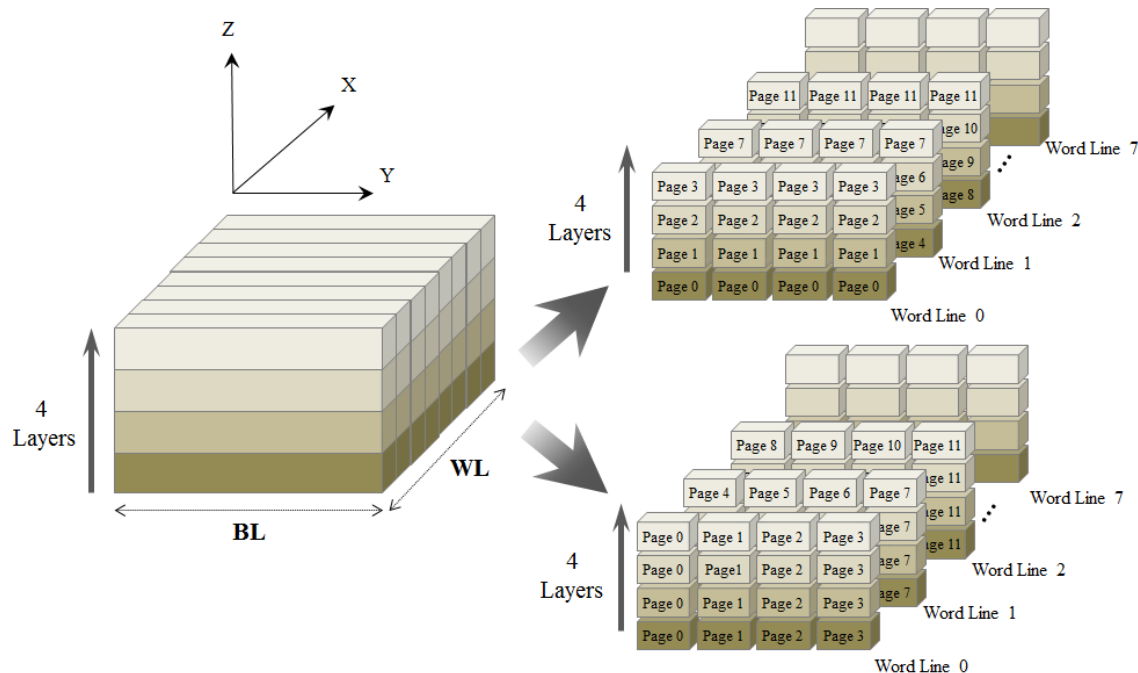
► Endurance

- Dynamic wear-leveling
- Static wear-leveling



3D Flash Memory

- ▶ 3D flash memory provides a good chance to further scale down the feature size and to reduce the bit cost.
 - Deliver very large storage space
 - Worsen program disturbance



Deteriorated Disturb on 3D Flash

