The Need for a New I/O Model

Tarikul Islam Papon
papon@bu.edu

Manos Athanassoulis
mathan@bu.edu

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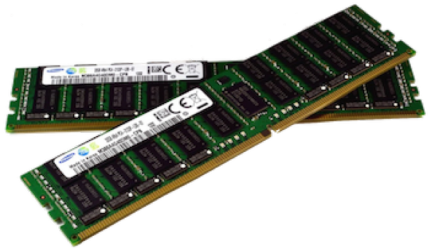
Modeling Performance

"Algorithm/Data Structure **X** has $O(f(N))$ performance, where N is the number of data pages on disk"

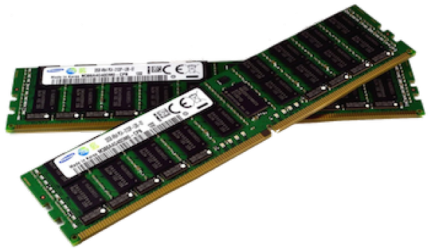
… is probably one of the most commonly read phrases in SIGMOD papers.

Traditional I/O Model



Small, fast main memory
(size M)

Traditional I/O Model



Small, fast main memory
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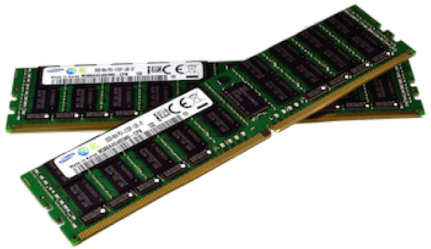
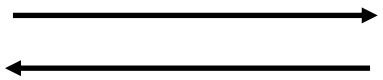
Large, slow external memory

Traditional I/O Model

One I/O at a time





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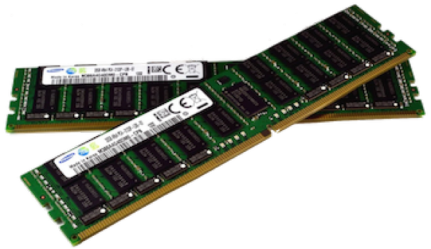
Traditional I/O Model

0 access cost



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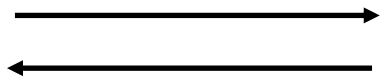

Large, slow external memory

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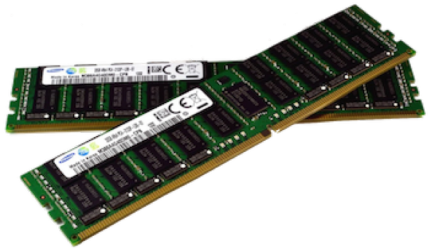


Small, fast main memory
(size M)

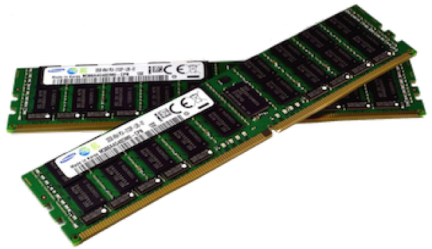
Transfer cost
1 unit

Large, slow external memory

Traditional I/O Model

total cost ≅ total # reads/writes to disk

0 access cost



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Transfer cost
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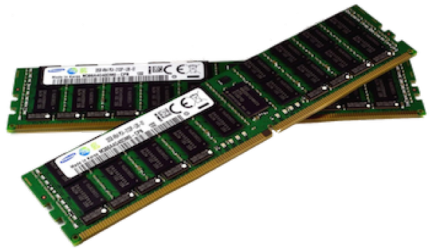
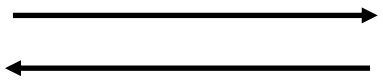
Large, slow external memory

Traditional I/O Model

Two (outdated) assumptions

- **Symmetric** cost for **Read & Write** to disk
- **One I/O** at a time





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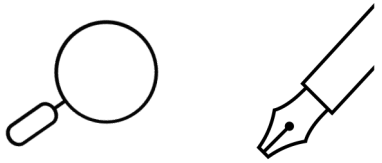
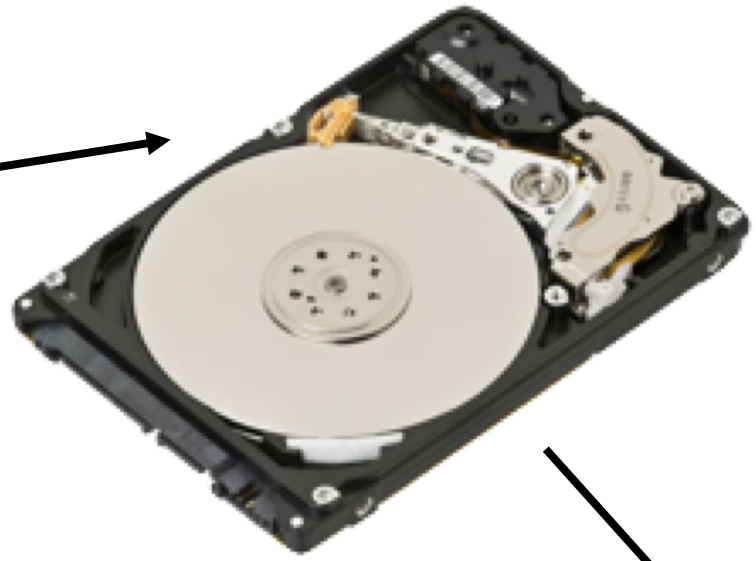
Large, slow external memory

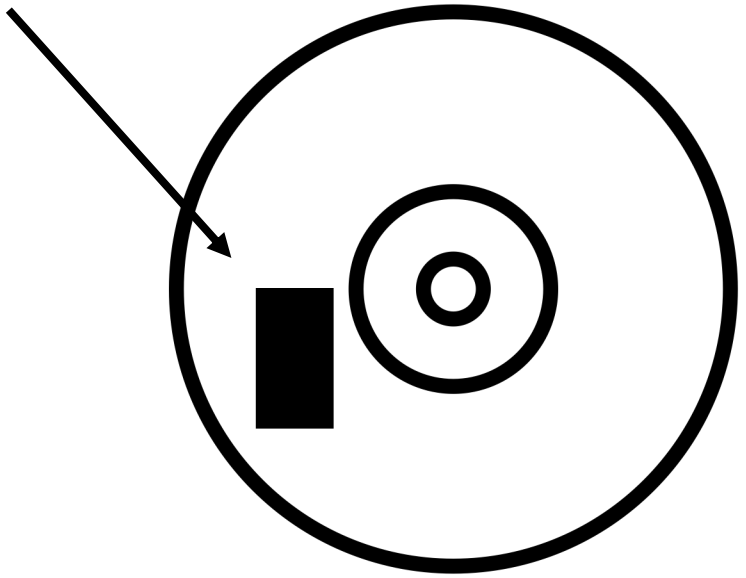
HDD vs. SSD

Read/Write a page from/to HDD

read or write page 5







Accessing a page from SSD

read page 5

Navigate to

- Channel
- Chip
- Die
- Plane
- Block

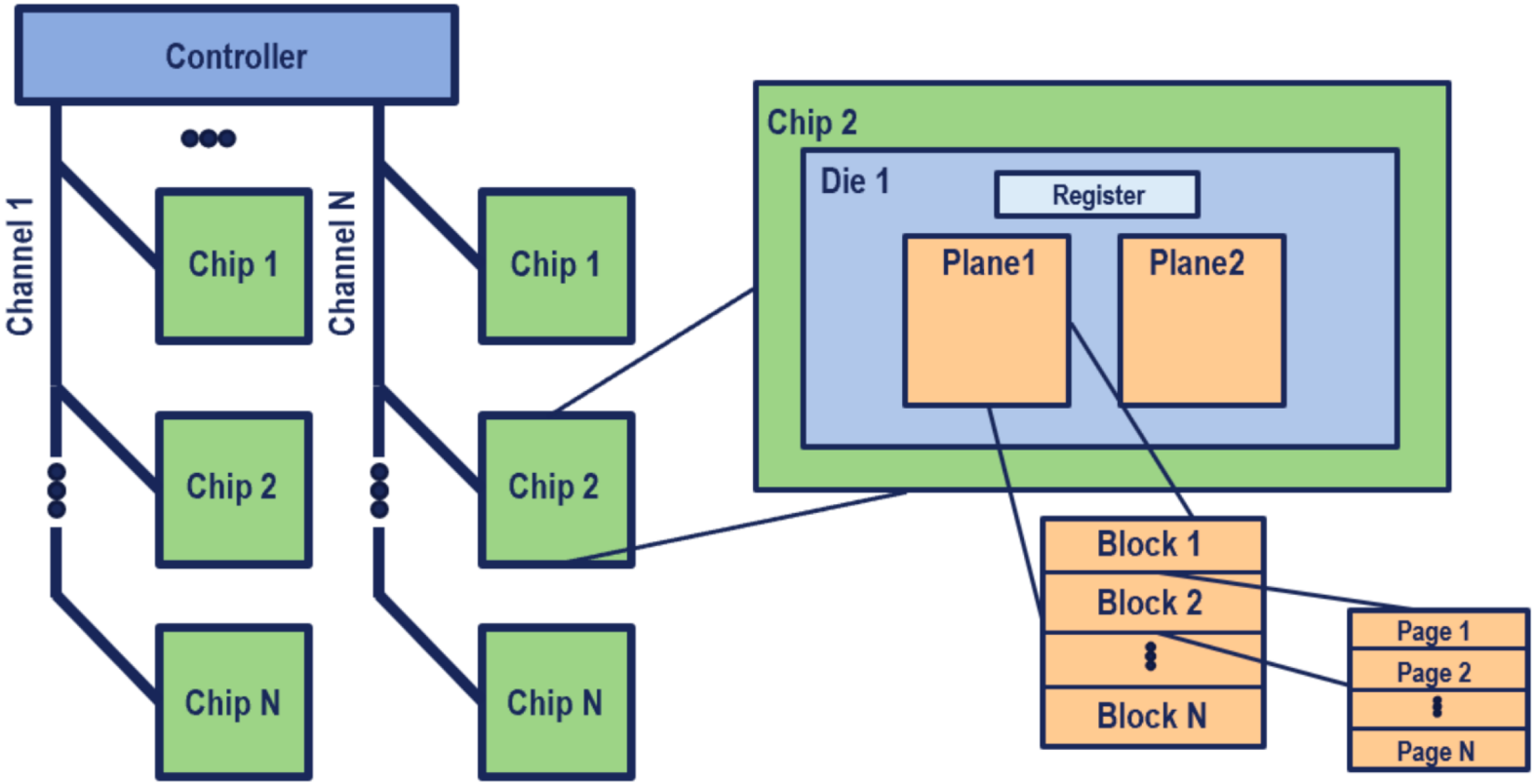


Image Source: Garrett et al. “Enabling Intra-Plane ParallelBlock Erase in NAND Flash to Alleviate the Impact of Garbage Collection”

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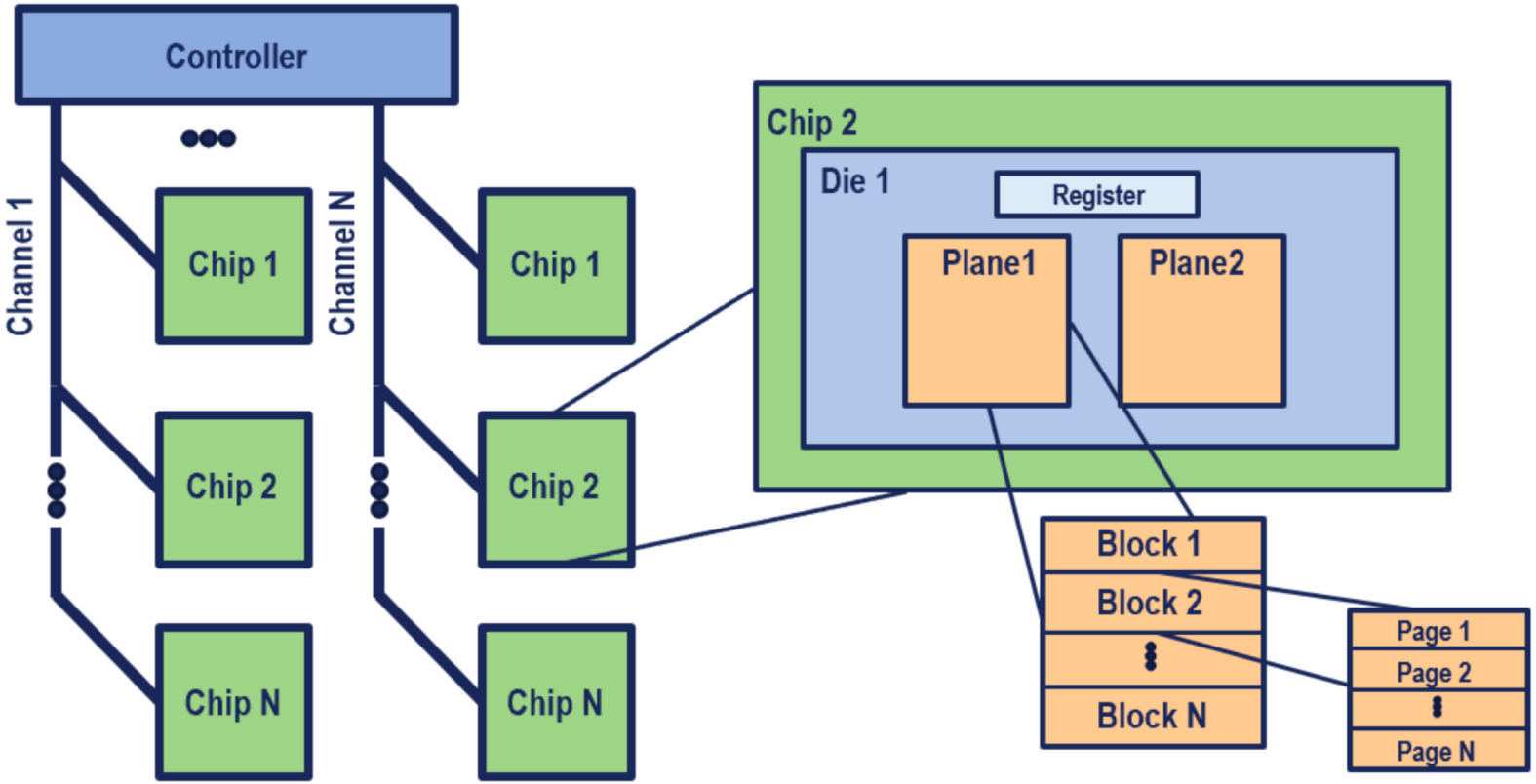


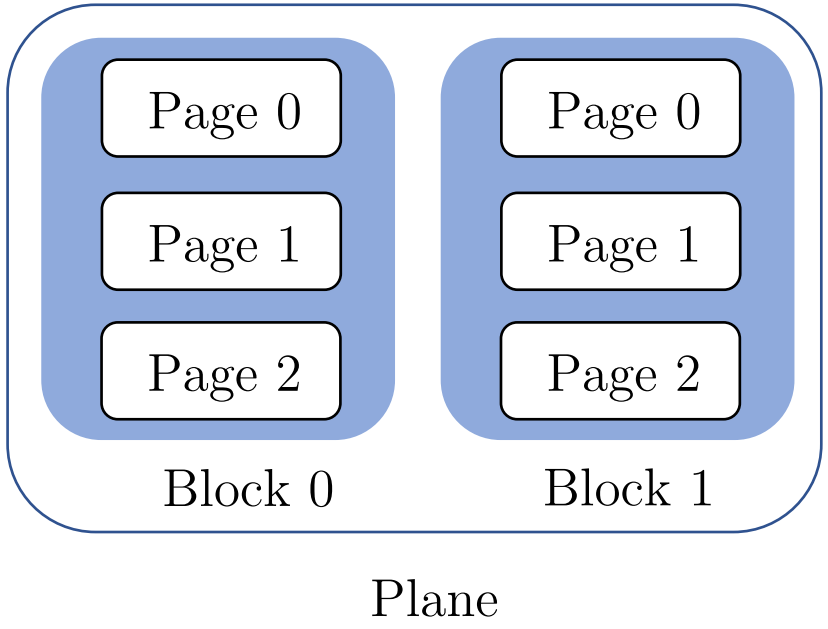
Opportunities for *concurrently* reading or writing multiple pages

Image Source: Garrett et al. “Enabling Intra-Plane ParallelBlock Erase in NAND Flash to Alleviate the Impact of Garbage Collection”

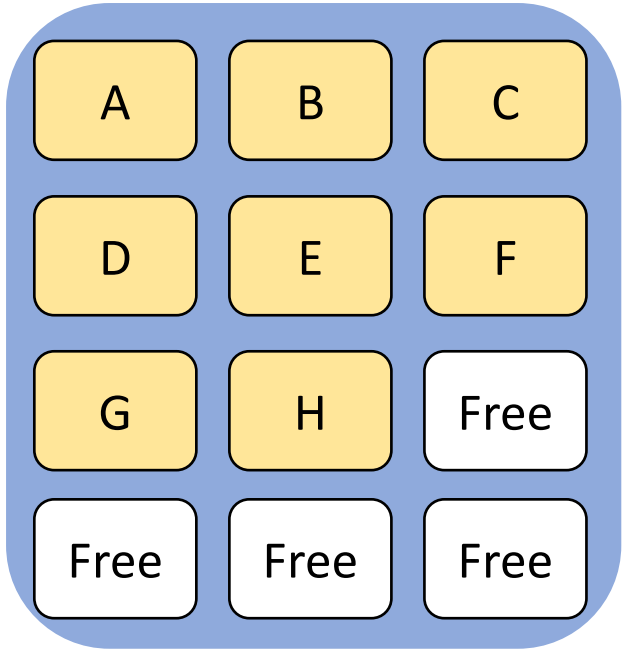
Writes on SSD

Out-of-place updates cause invalidation

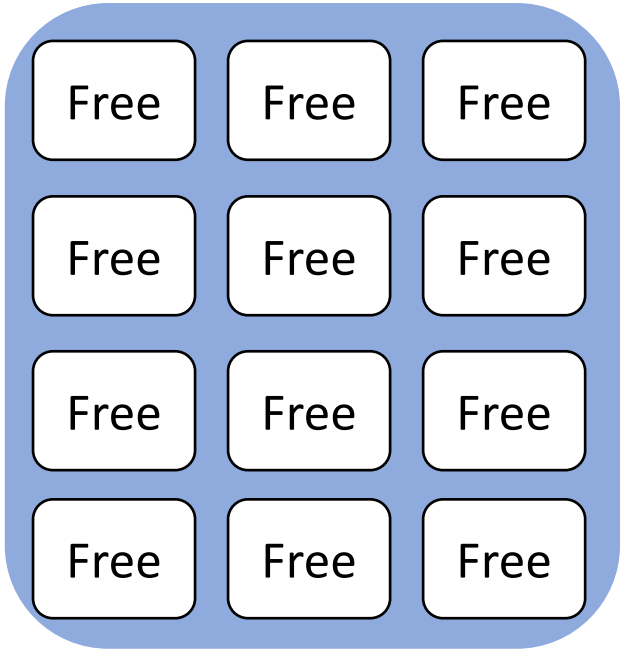
Invalidation causes **garbage collection**



Writes on SSD



Block 0



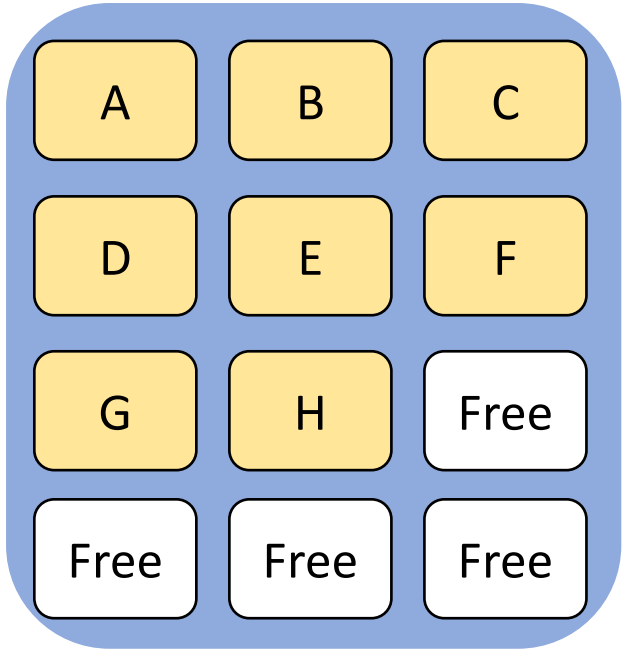
Block 1

Writing in a free page isn't costly!

Writes on SSD

Update

A, B, C, D



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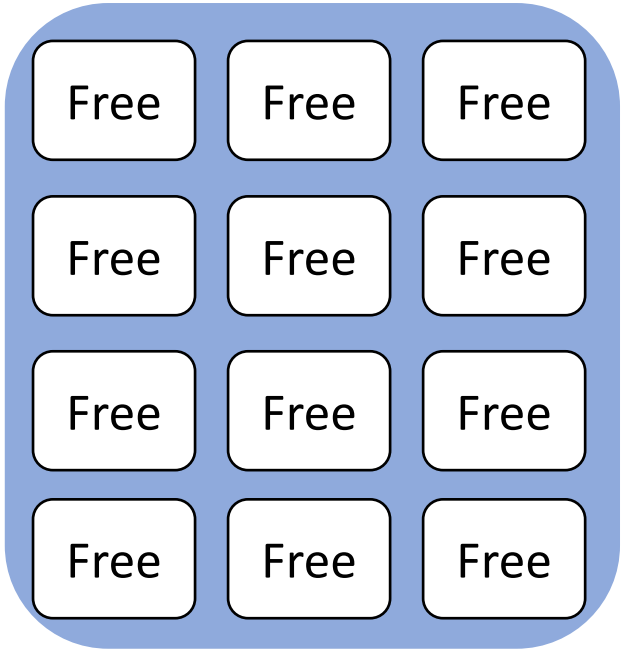

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Writes on SSD

Update

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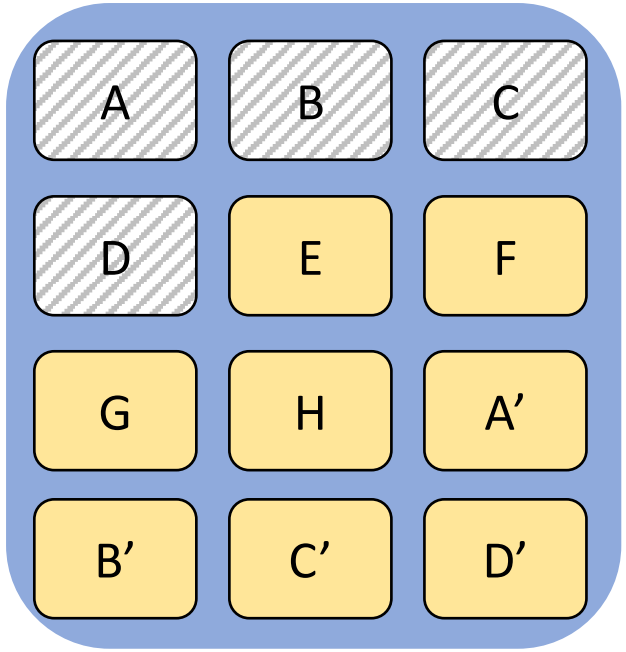

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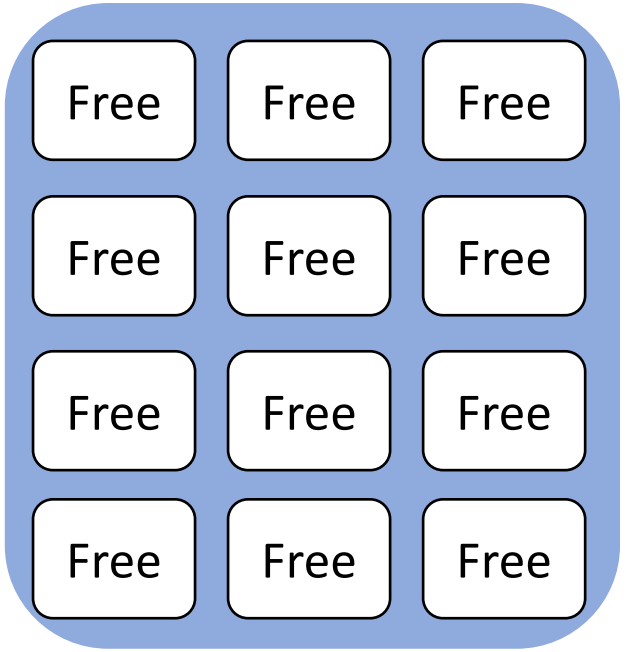
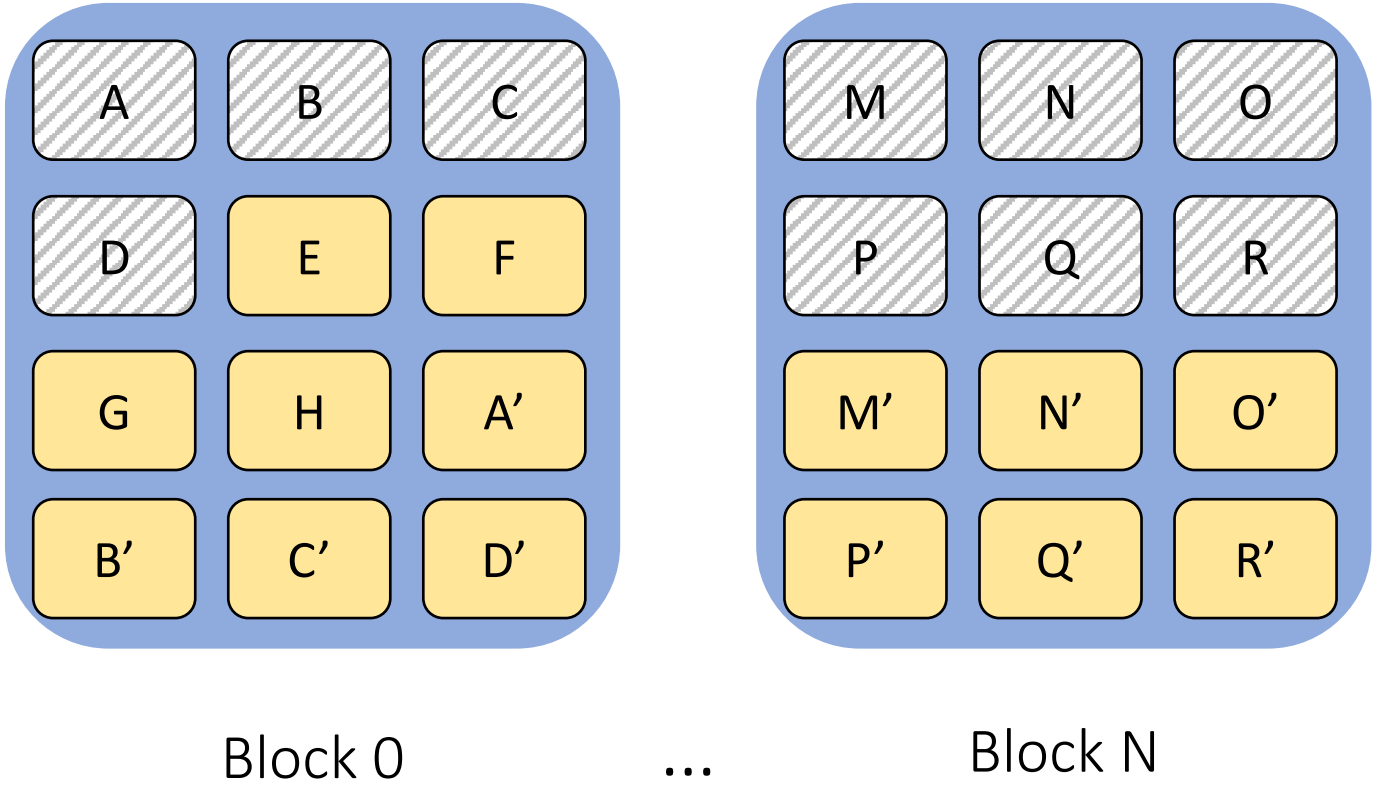


Block 1

Not all updates are costly!

Writes on SSD

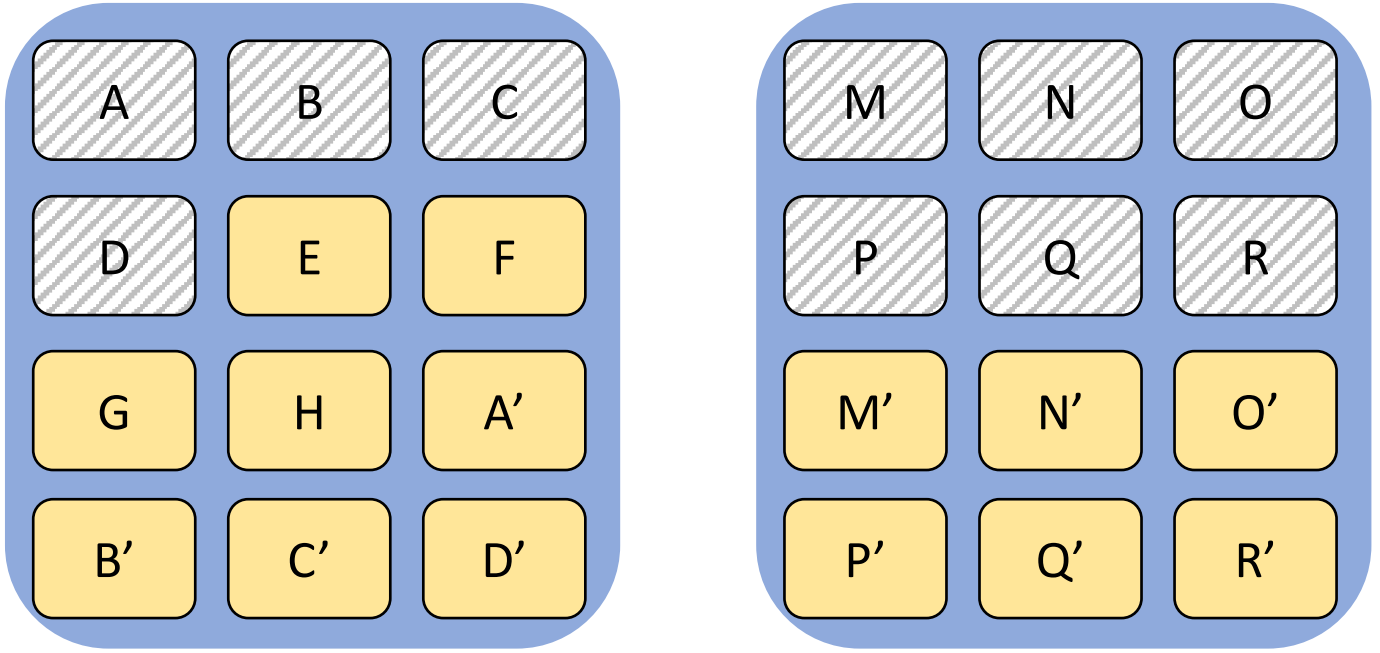
What if there is no space?



Writes on SSD

What if there is no space?

Garbage Collection!



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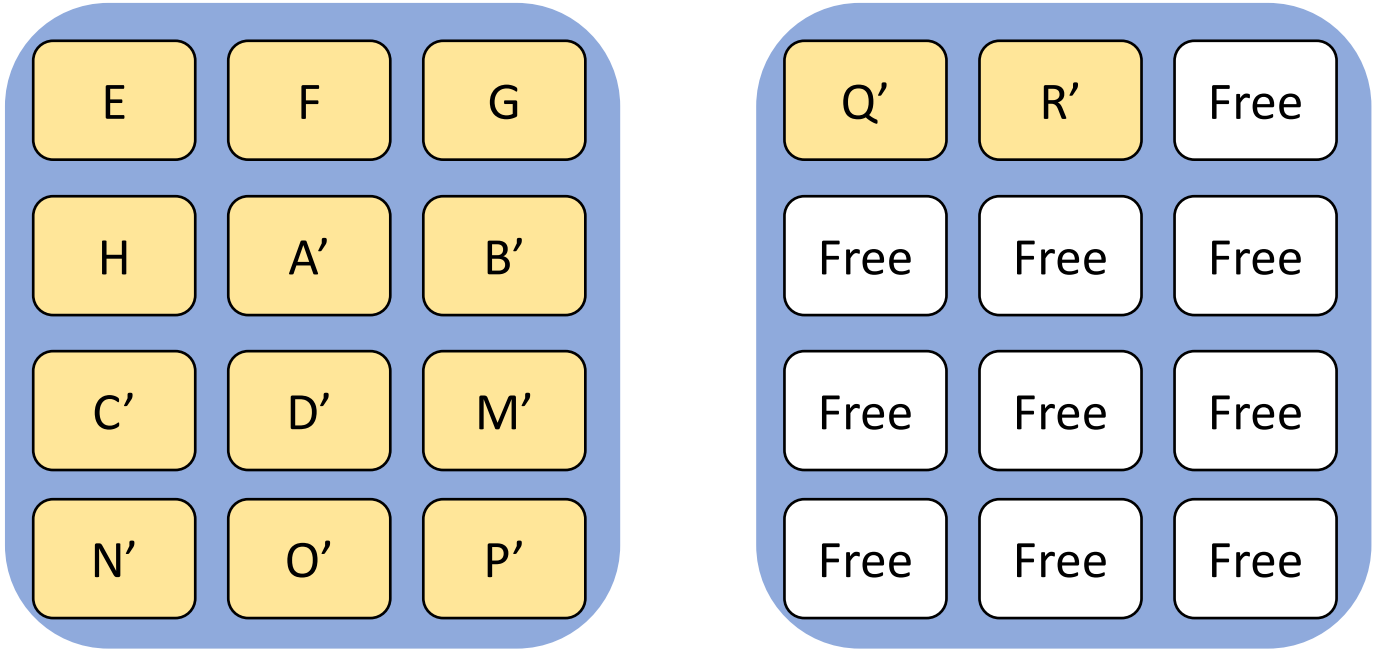

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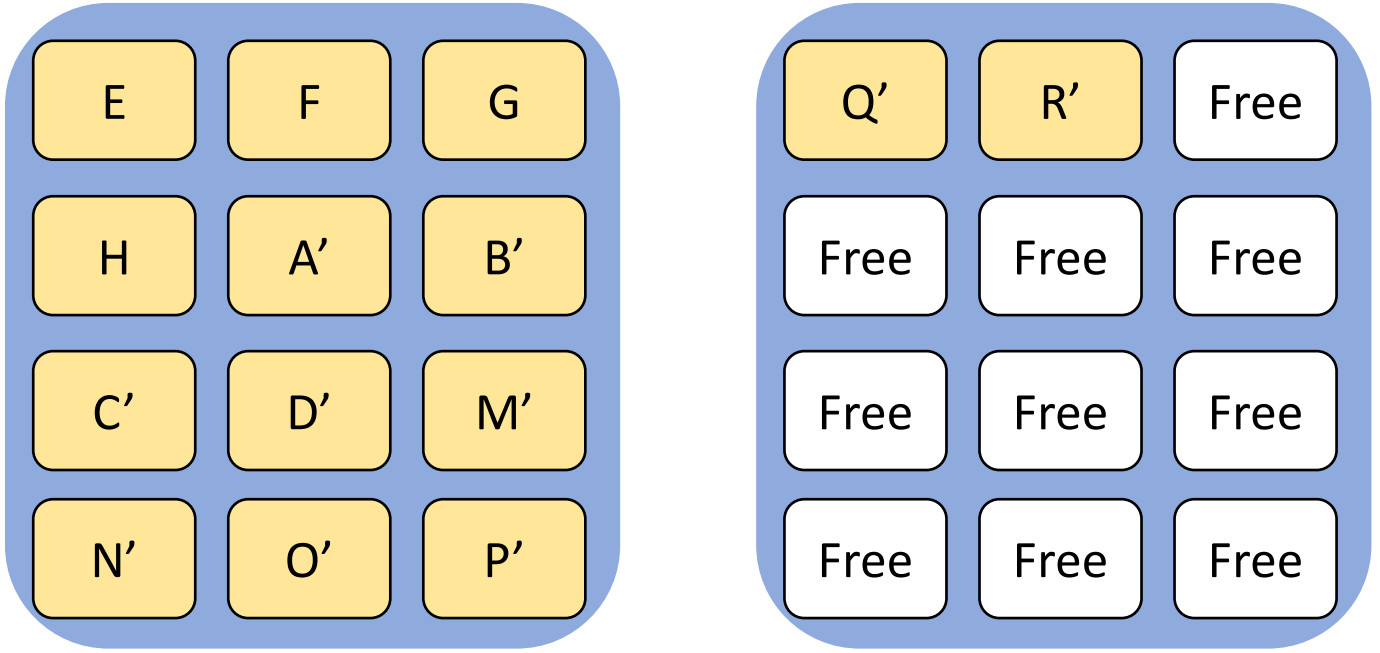
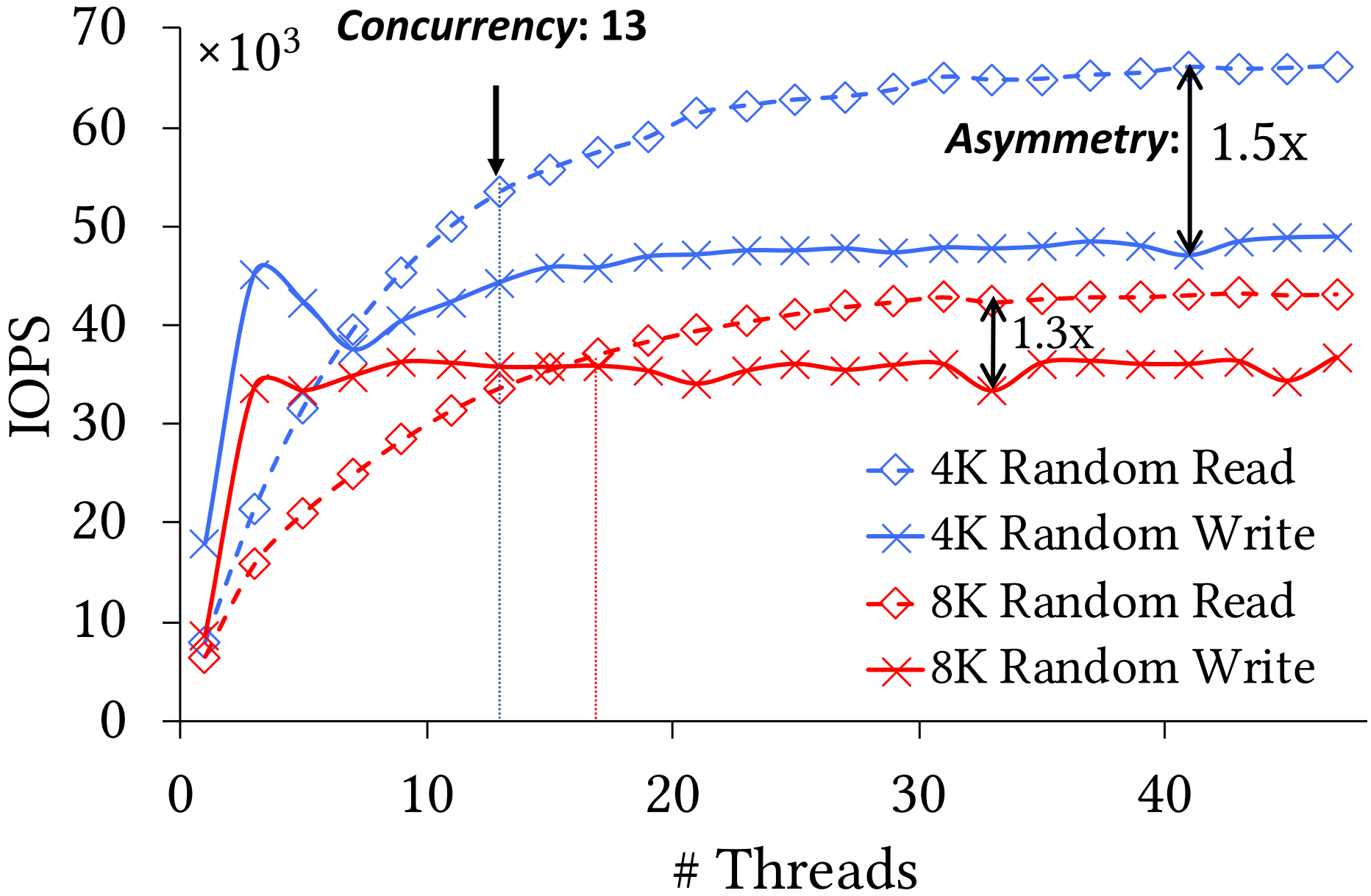
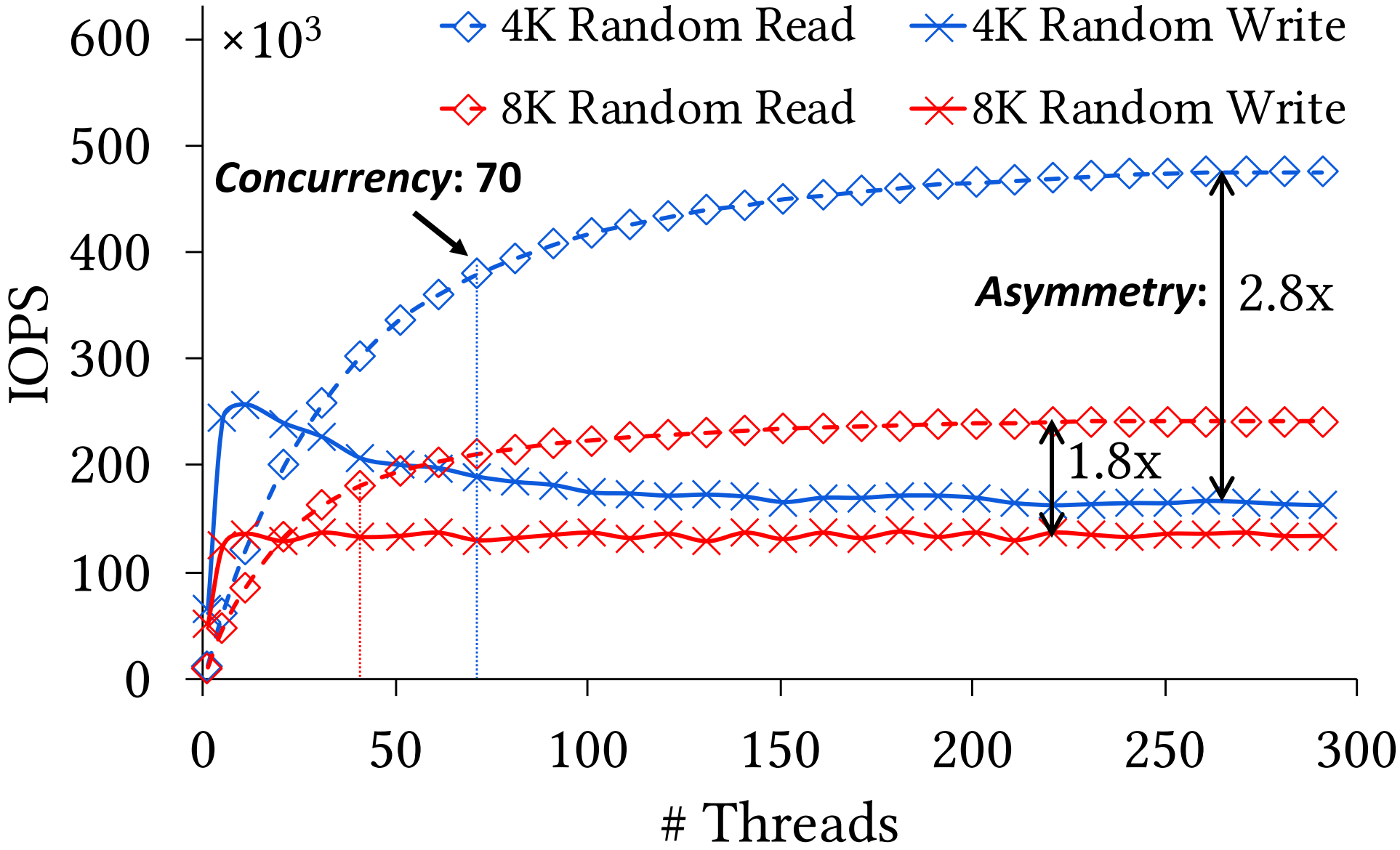


Higher average update cost (due to GC) → ***Read/Write asymmetry***

Measuring Asymmetry/Concurrency in off-the-shelf SSD



Measuring Asymmetry/Concurrency in NVMe SSD

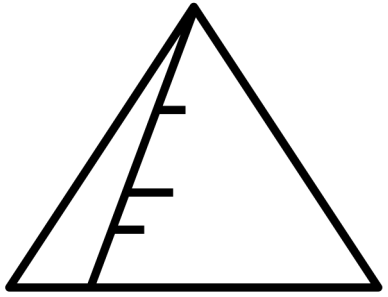


Make *asymmetry and concurrency* part of *algorithm design*

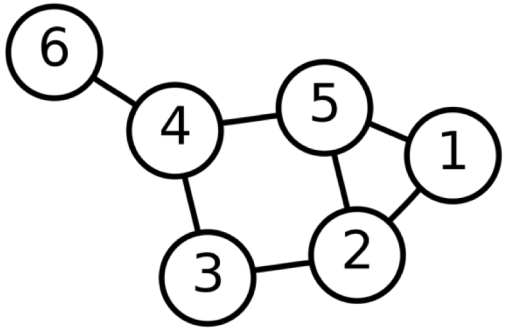
… not simply an engineering optimization

Build algorithms/data structures for storage devices
with asymmetry α and concurrency k

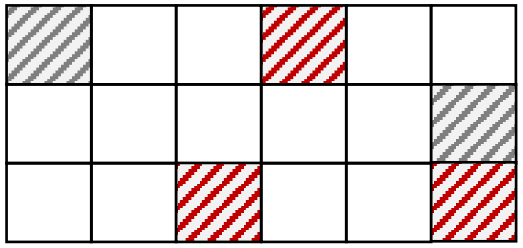
index structures



graph traversal algorithms



bufferpool management



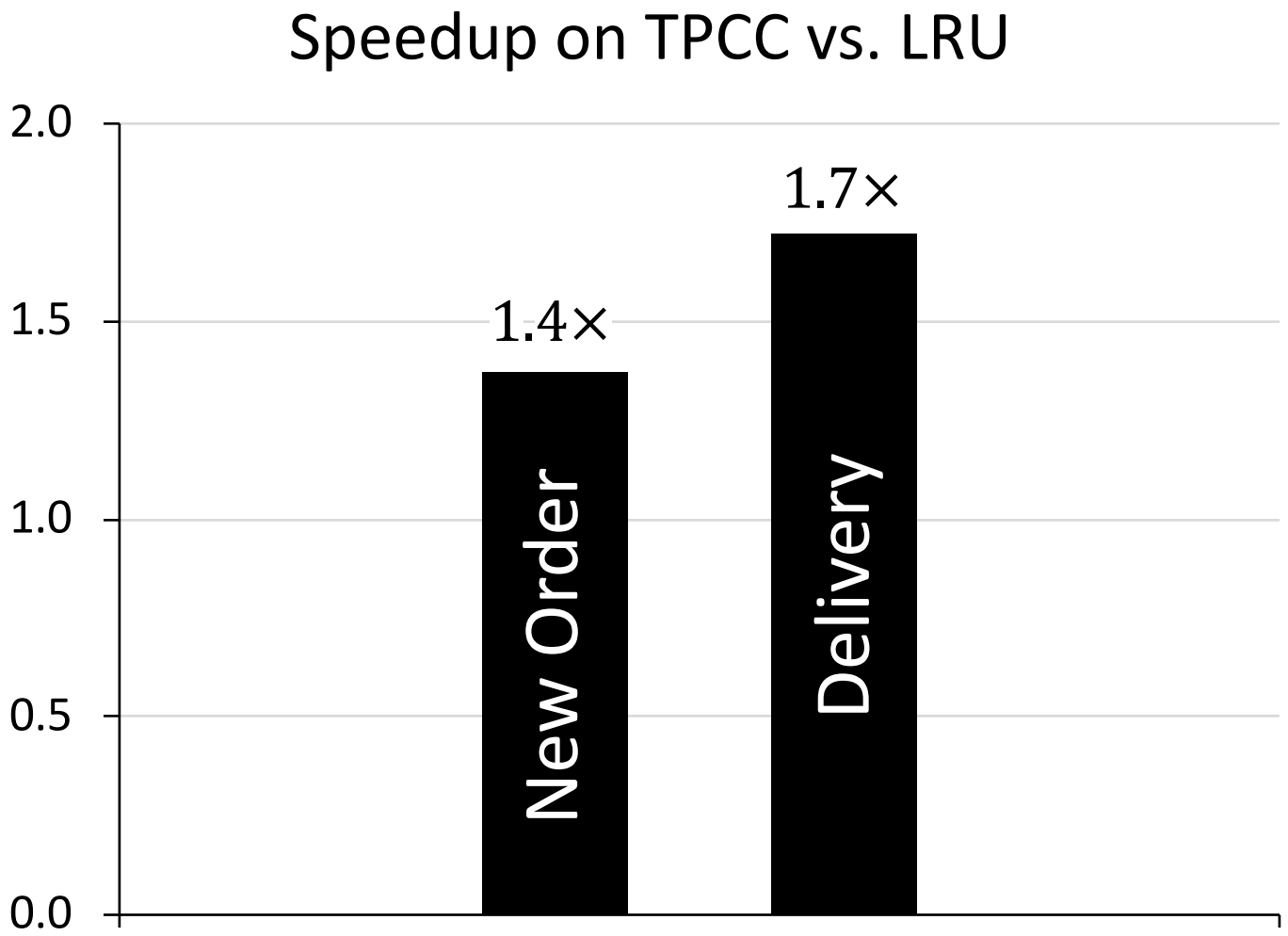
Asymmetry & Concurrency Aware Bufferpool Strategy

exploit **device parallelism**

concurrent write-back without evicting

bridge read/write **asymmetry**

SSD with asymmetry: 1.5x & concurrency: 9



Asymmetry & Concurrency Aware Bufferpool Strategy

exploit **device parallelism**

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Thank you!

DiSC lab

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