Technion – Israel Institute of Technology

Write Once, Get 50% Free:
Saving SSD Erase Costs Using WOM Codes

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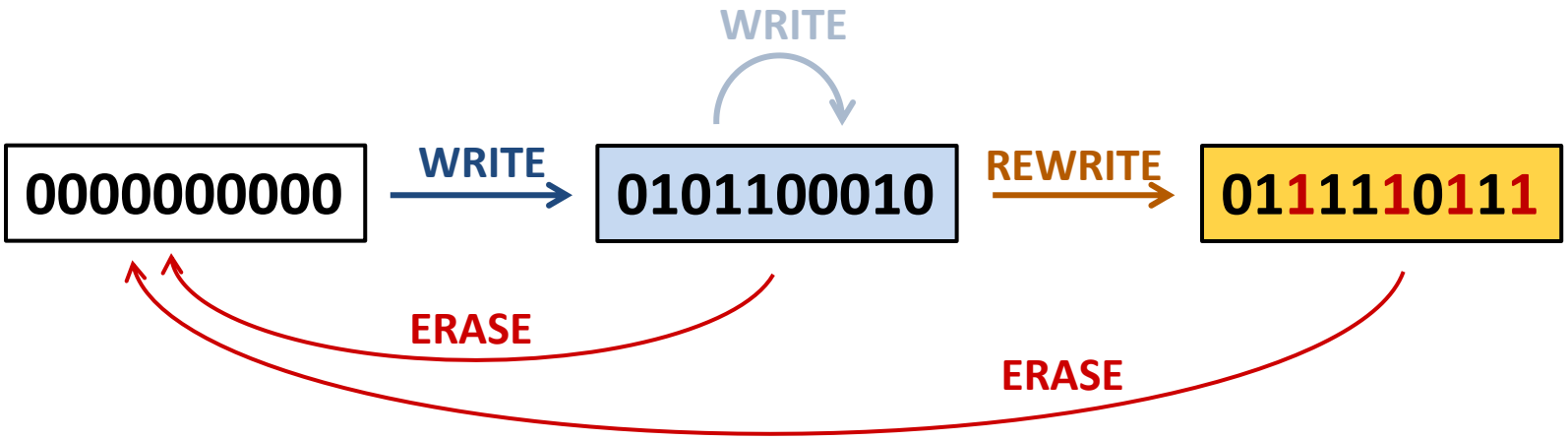
Computer Science

Technion

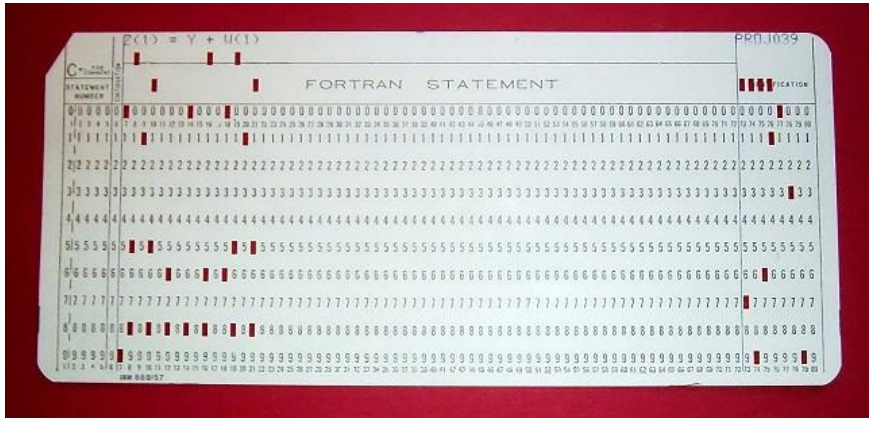
Reusing Flash with WOM Codes



Reusable SSD:

- Perform additional writes before erasure
- Extend **lifetime**
- Improve **performance**
- Preserve **capacity** and **interface**

Write-Once Memory Codes



data	1st write	2nd write
00	000	111
10	100	011
01	010	101
11	001	110

(Rivest and Shamir, 1982)

- $0 \rightarrow 1$ *but* $1 \nrightarrow 0$
- WOM Code: write ***n* bits** of information on ***m* cells**, *n>m*
- Example: **write *11*** and then **write *01***
  - Normally: 

  - WOM code: 

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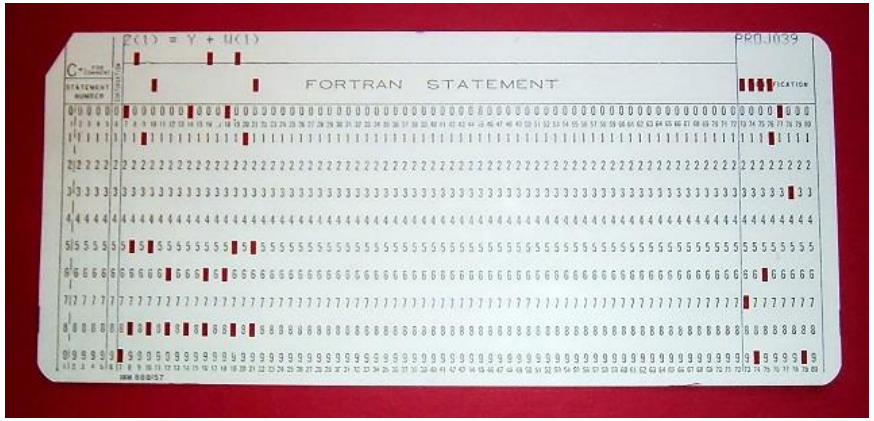

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Typical Use of WOM Codes

- User writes **logical** data pages
- Page size **increases** with encoding
- Invalid pages are 'reused' **without erasing**
- **Read** before the second write

[Grupp et. al., MICRO '09][Jagmohan et.al., MSST '10]
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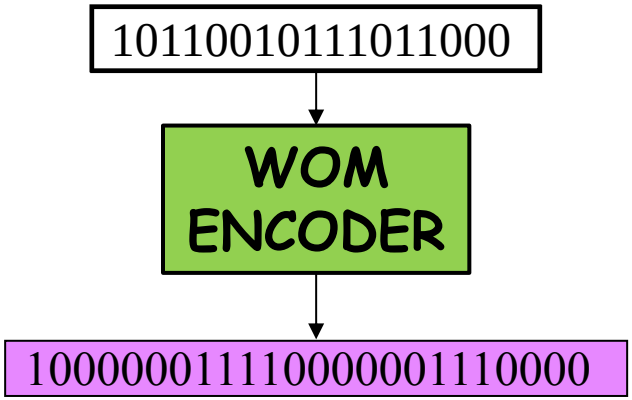

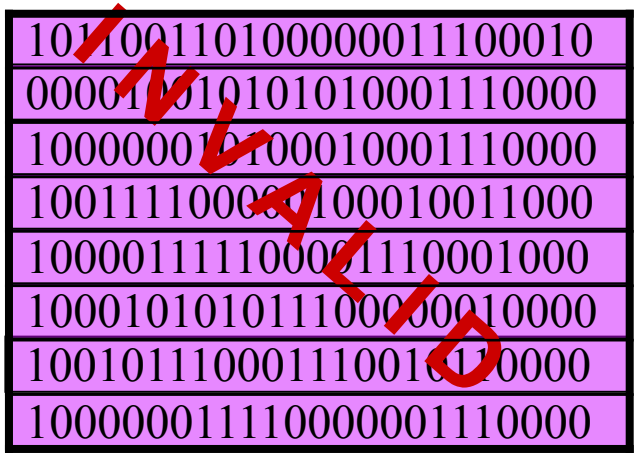

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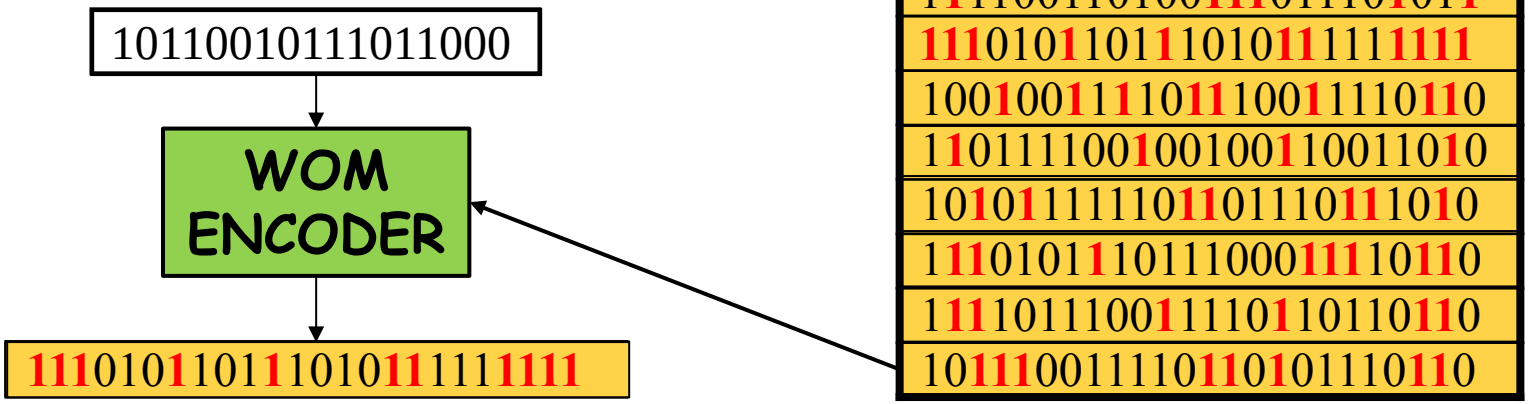
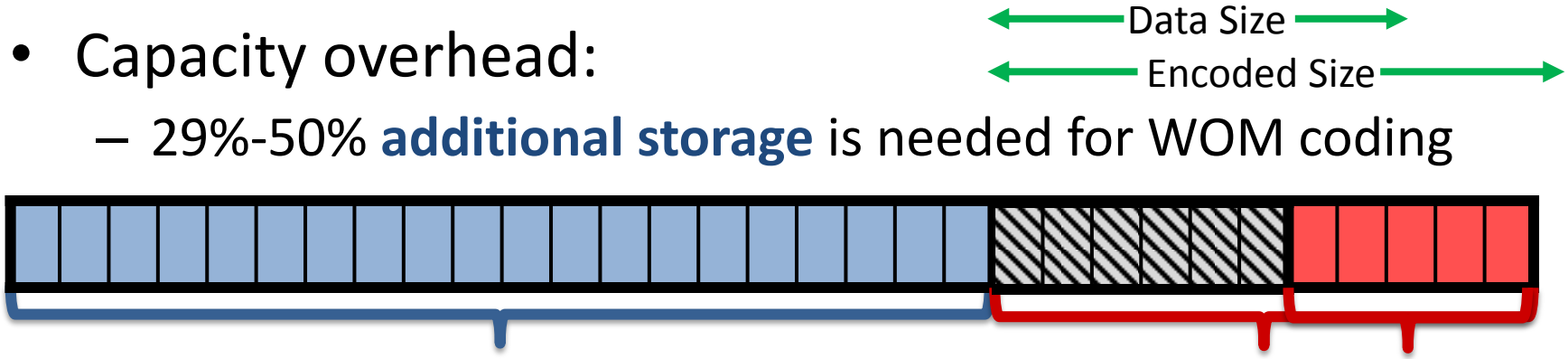
Data Size
Encoded Size



Drawbacks of Typical Use

- Capacity overhead:
  - 29%-50% **additional storage** is needed for WOM coding



- Performance overheads:
  - I/O operations access 29%-50% **more bits**
  - A **read precedes** every second write
- Compatibility:
  - **Requires modification** in physical page size
- Applicbality:
  - High encoding/decoding **complexity**

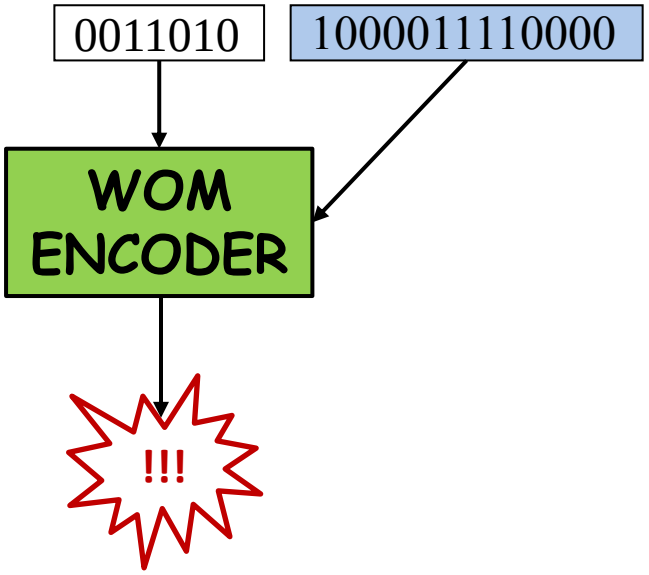
Reusable SSD Design Goals

- Do not touch:
  - Interface
  - Performance
  - Logical capacity

Polar WOM Codes

[Burshtein and Strugatski, IT `13]

- **Efficient**
- **May fail…**



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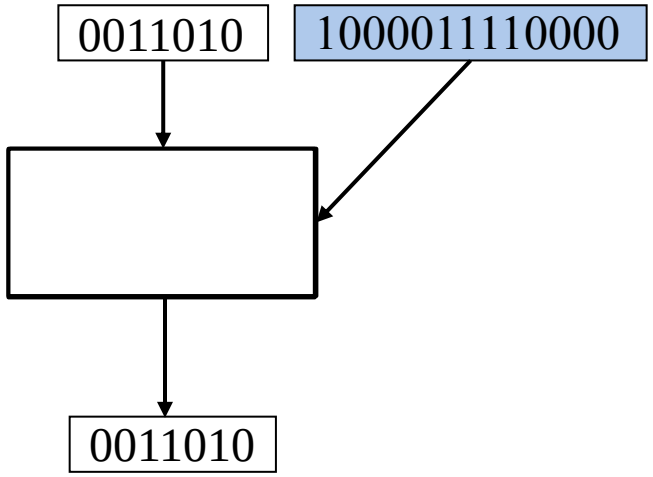
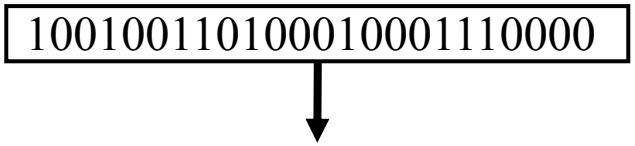
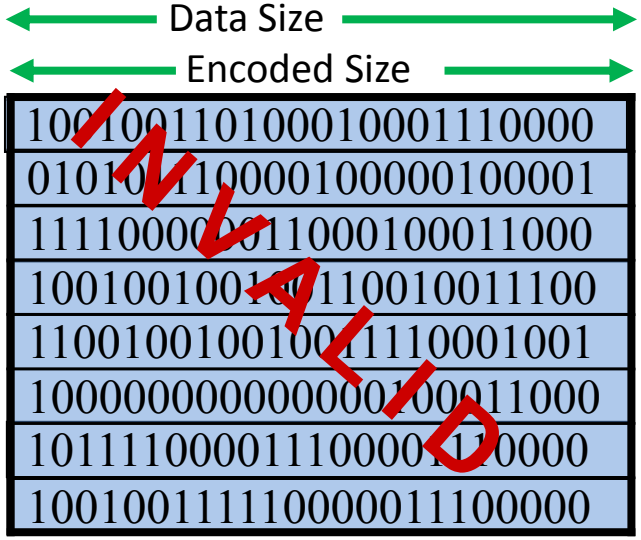


- Avoid **latency** by **parallelizing**
- Handle **failures** by **retrying**
  - 5% of encodings fail
  - 0.25% of encodings fail twice
  - Fall back to 1st write

Reusable SSD

- **1st write**: (almost) unmodified → no overhead
- **2nd write**: one logical page → two physical pages





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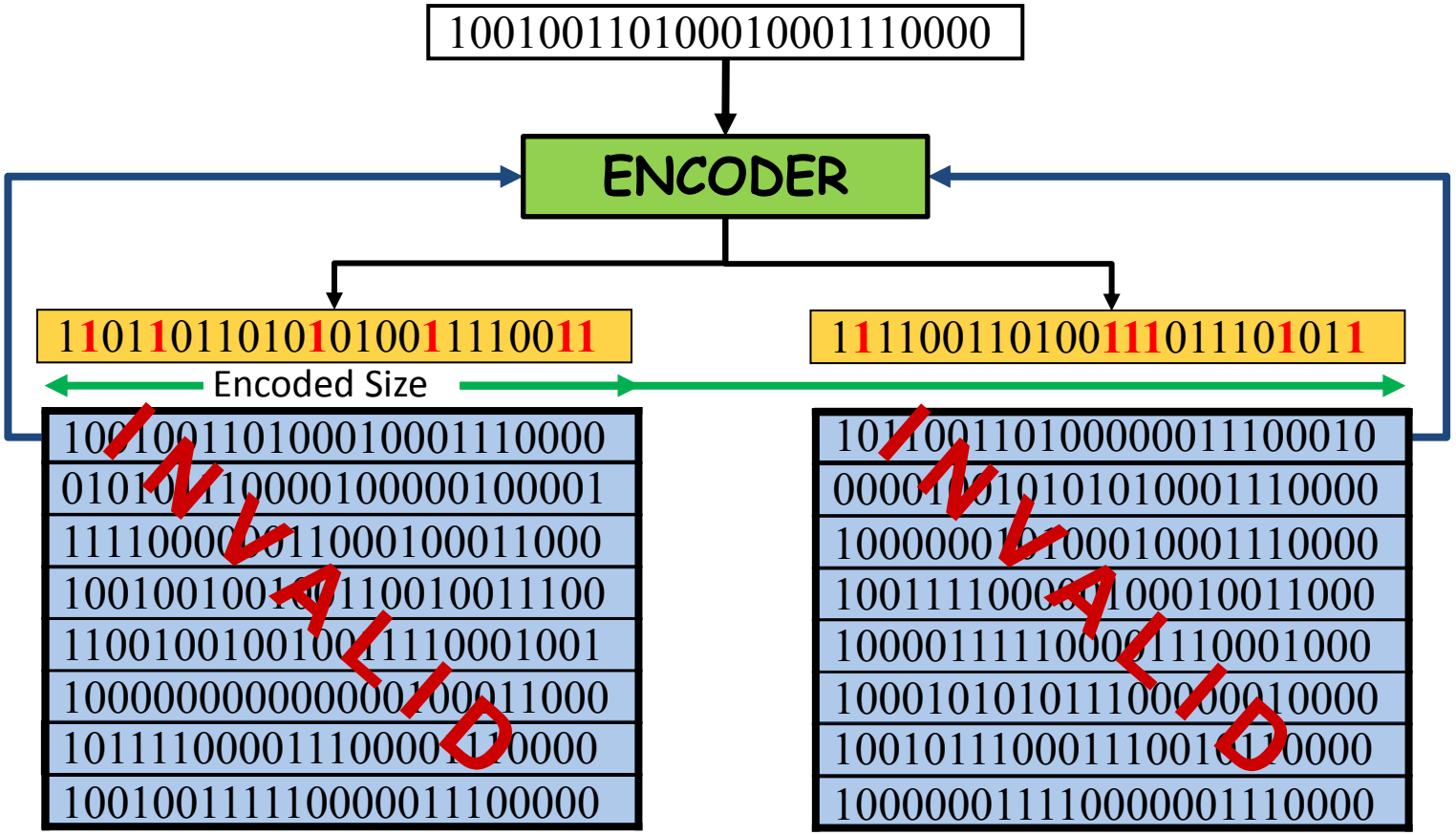

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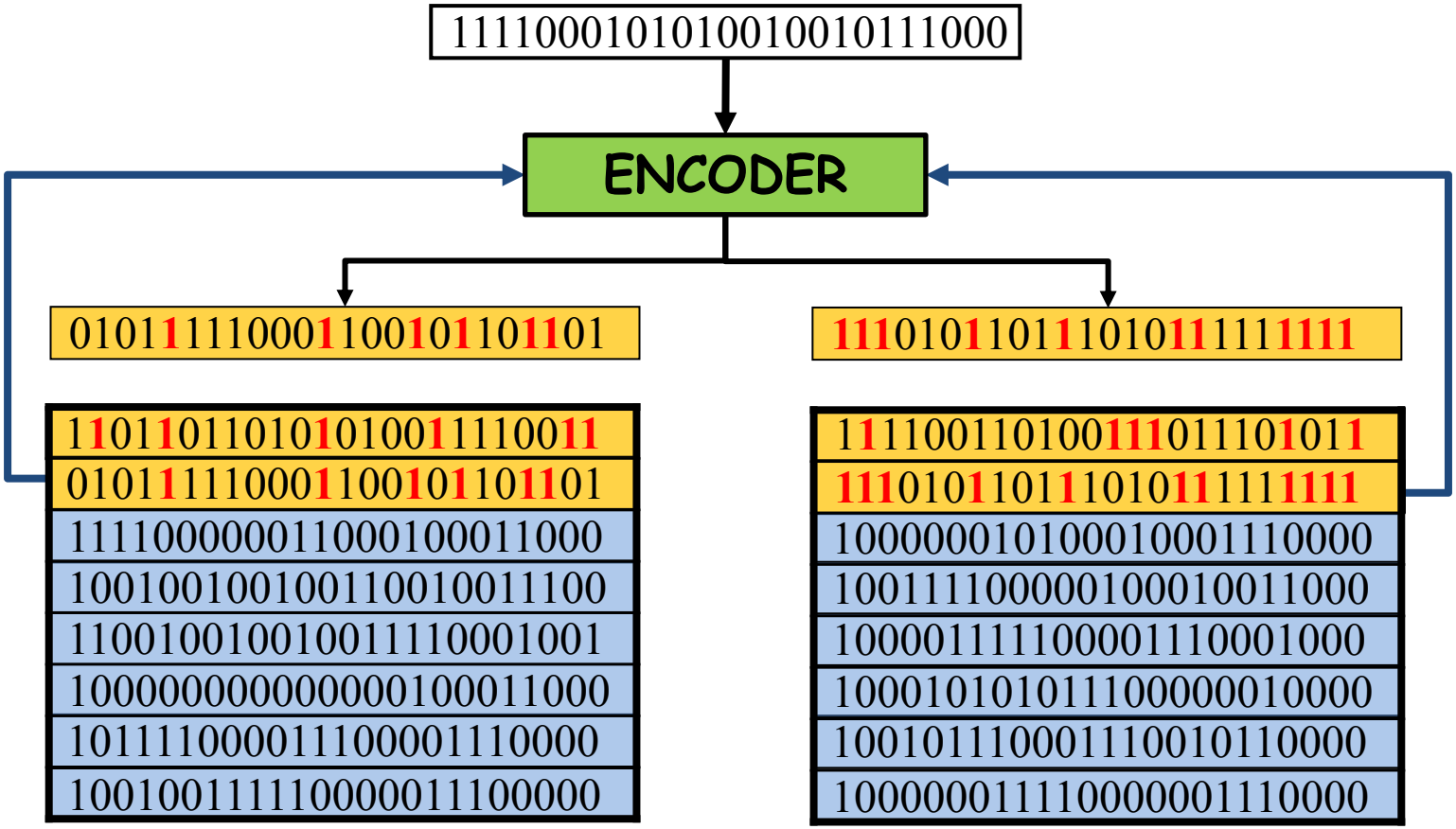

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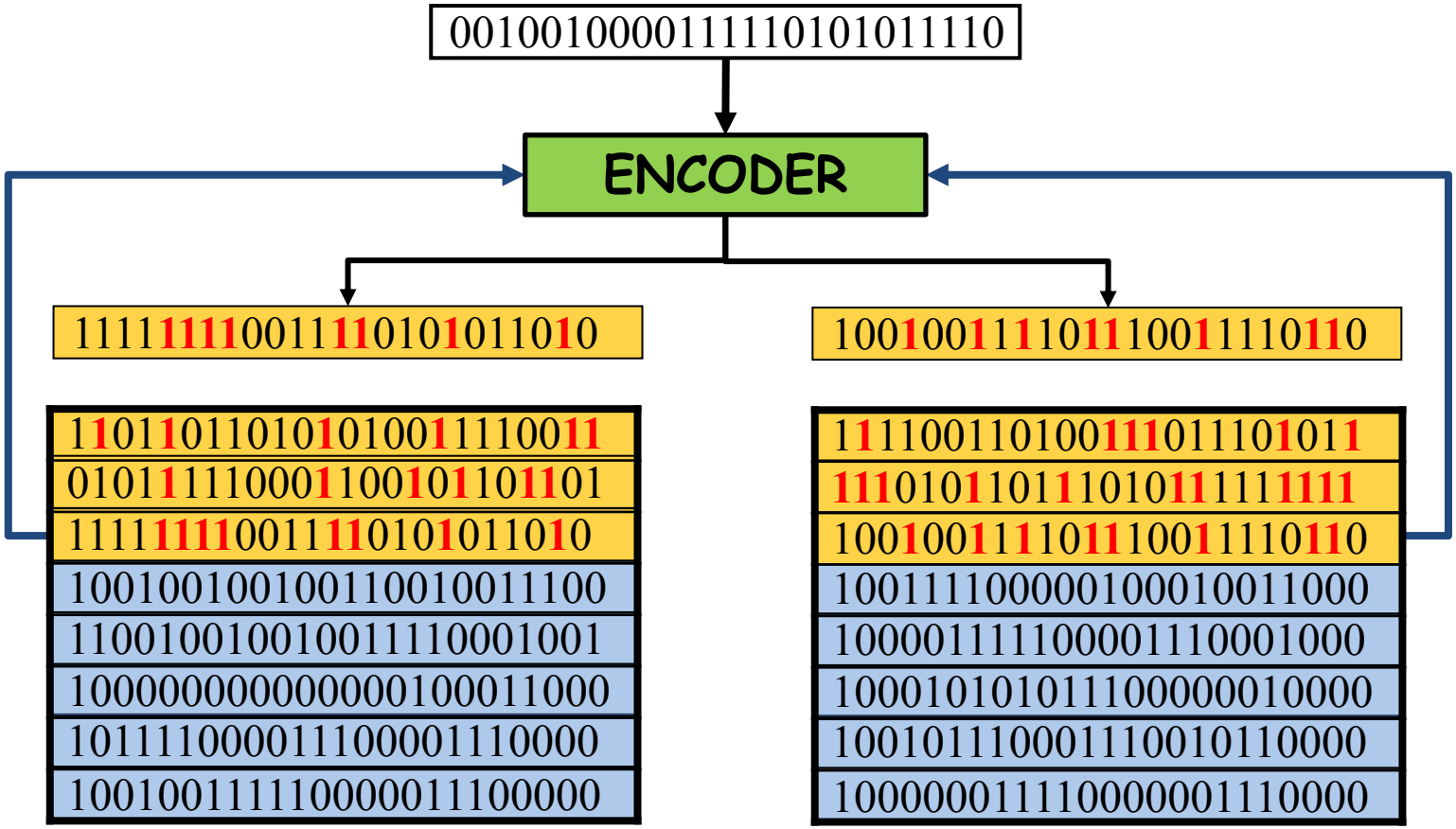

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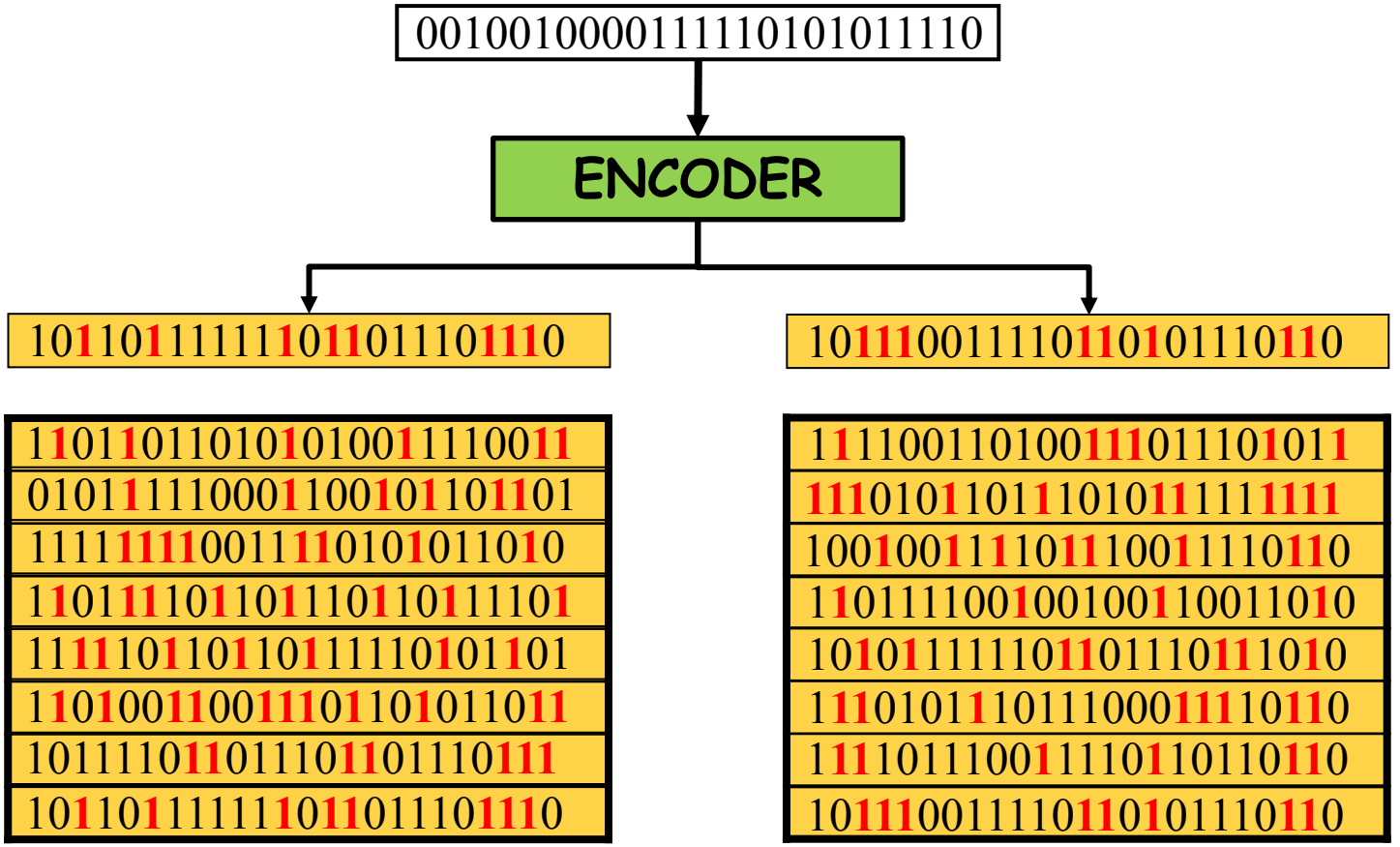
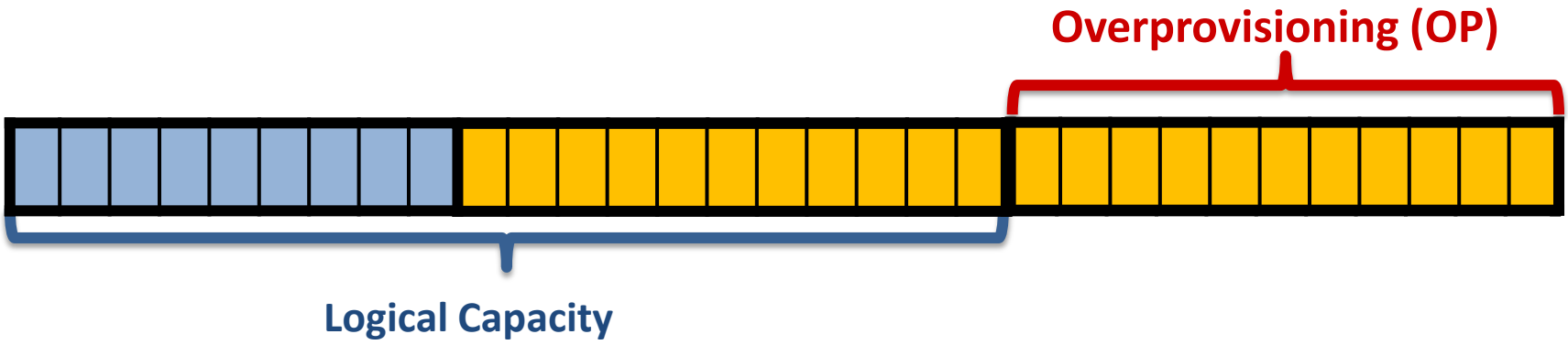


The Benefit of Reusable SSD



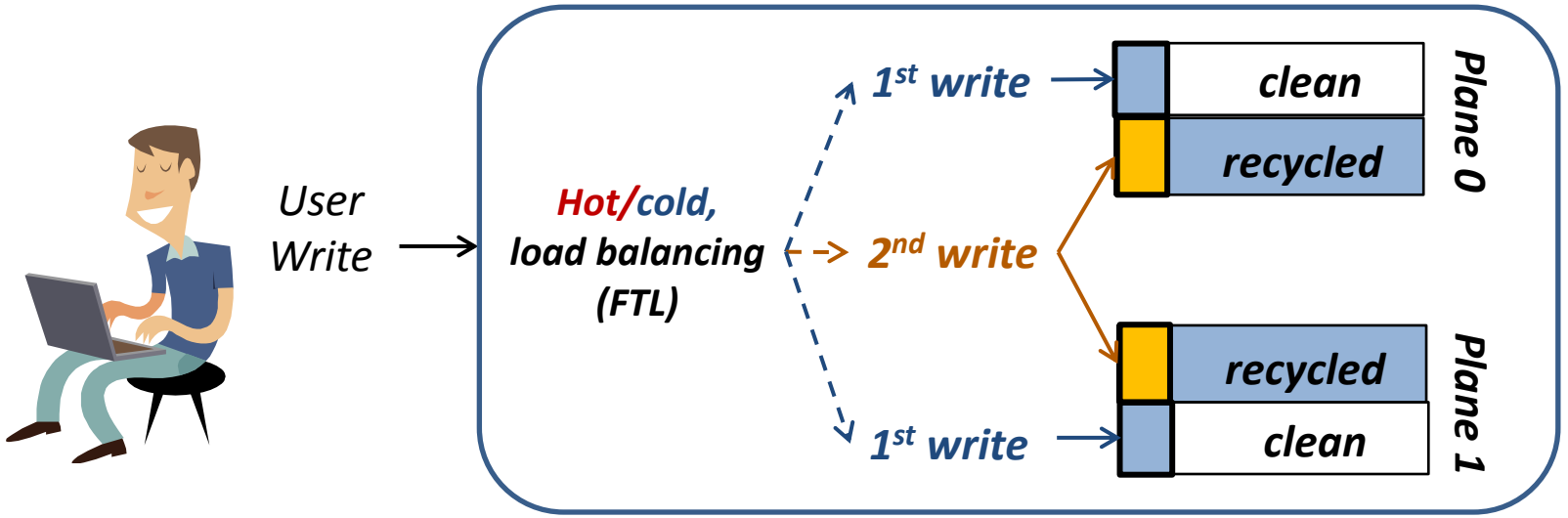
- Standard SSD (best case): $E = \frac{M}{N}$ (*Erasures* = E; M = *Logical pages written*; N = *Pages per block*)

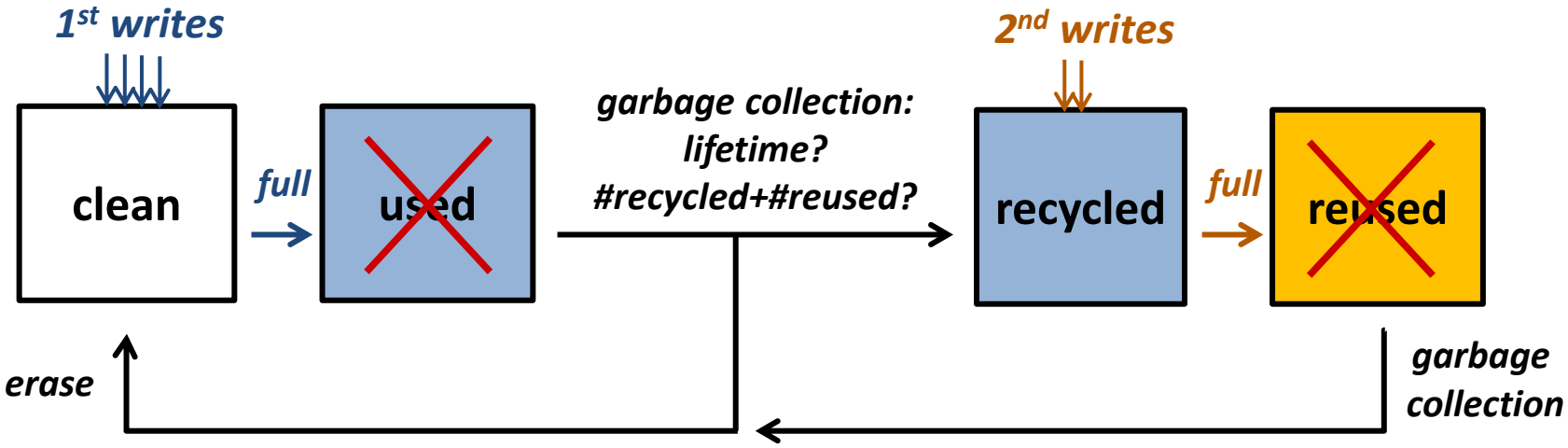
- Reusable SSD (best case): "write once, get 50% free"

$$\mathrm{E}' = \frac{M}{N + {}^{N}/_{2}} = \frac{2}{3}E$$

→ **33% reduction in erasures**

Putting it All Together





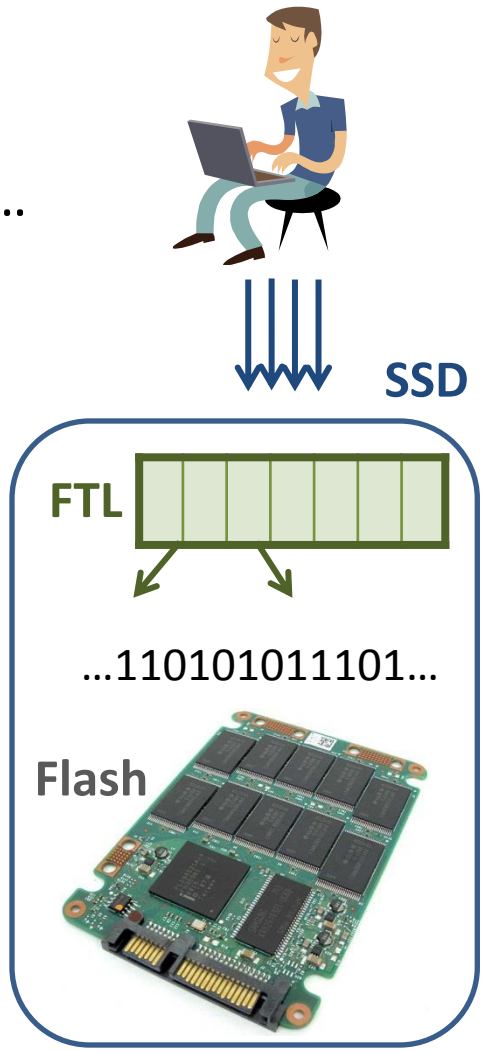
Extending SSD Lifetime

- User level
  - Caching, admission control, specialized FS/DB…

  [Soundararajan et. al., FAST '10][Oh et. al., FAST '12]
  [Li et. al., ATC '14][Marmol et. al., HotStorage '14]
- FTL
  - Wear leveling, throttling, partitioning, buffering, deduplication…

  [Agarwal et. al., ATC '08][Lee et. al., FAST '12]
  [Desnoyers TOS '14][Kim and Ahn, FAST '08]
  [Gupta et. al., FAST '11]
- Code
  - Error correction

  [Cai et. al., DATE '12][Pan et. al., FAST '11][Zhao et. al., FAST '13]
- Flash
  - Write voltage/speed [Jeong et. al., FAST '14]



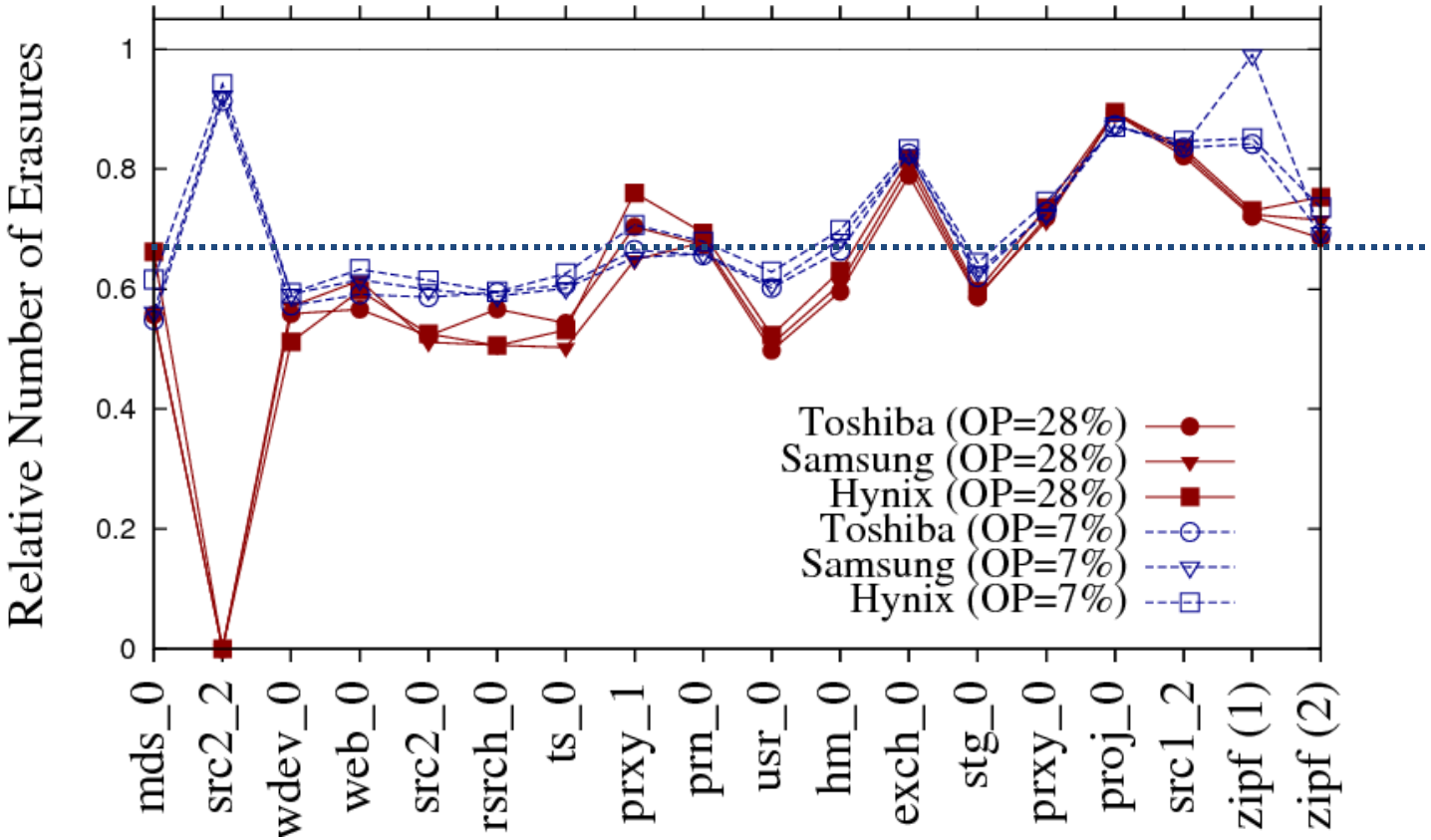
Evaluation

- How many **erasures** saved?
- How is **performance** affected?
- **Sensitivity** to design parameters

Type	Pgs/Blk	R (us)	W (ms)	E (ms)
SLC	64	30	0.3	3
MLC	128	200	1.3	1.5
MLC	256	80	1.5	5

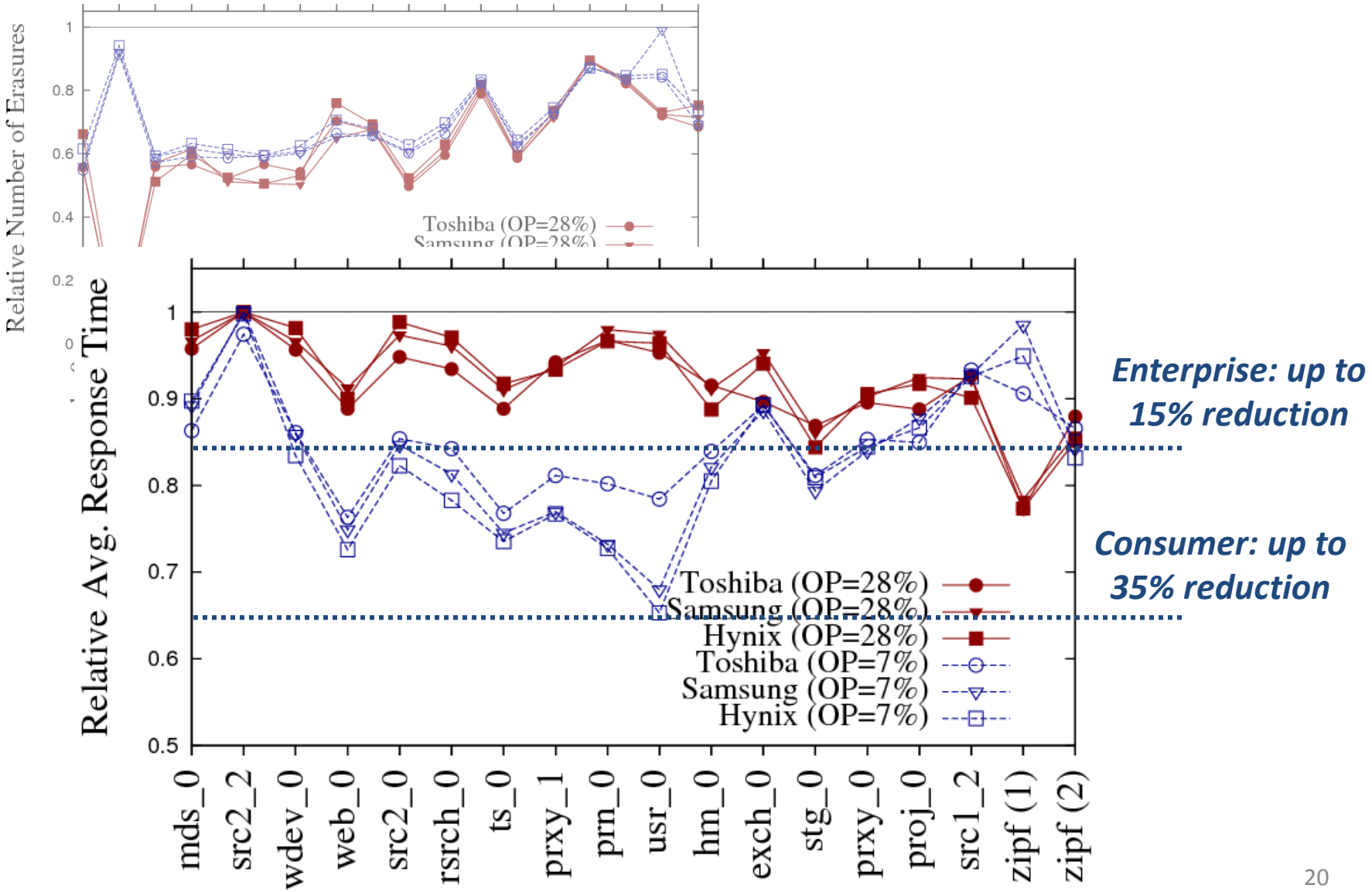
- DiskSim simulator
  - Available SSD extension
  - Modified FTL component
- Trace input:
  - MSR Cambridge + Exchange
  - Synthetic Zipf

Erasures



Expected 33% reduction

Response Time



Enterprise: up to 15% reduction

Consumer: up to 35% reduction

Summary

- First **applicable** design of re-writes in SSD
  - ✓ Unmodified logical capacity
  - ✓ No hardware modification
  - ✓ Efficient computation
- Up to **50% additional free writes**
- Less erasures → improved **performance**
  - ✓ Parallel 2nd writes
  - ✓ Prefetching
  - ✓ Independent retries

Thank you!

- **This is only the beginning!**
  - **Improved codes**
  - **Hardware encoders**