A Free-Space Adaptive Runtime Zone-Reset Algorithm for Enhanced ZNS Efficiency

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[1)]Sogang University

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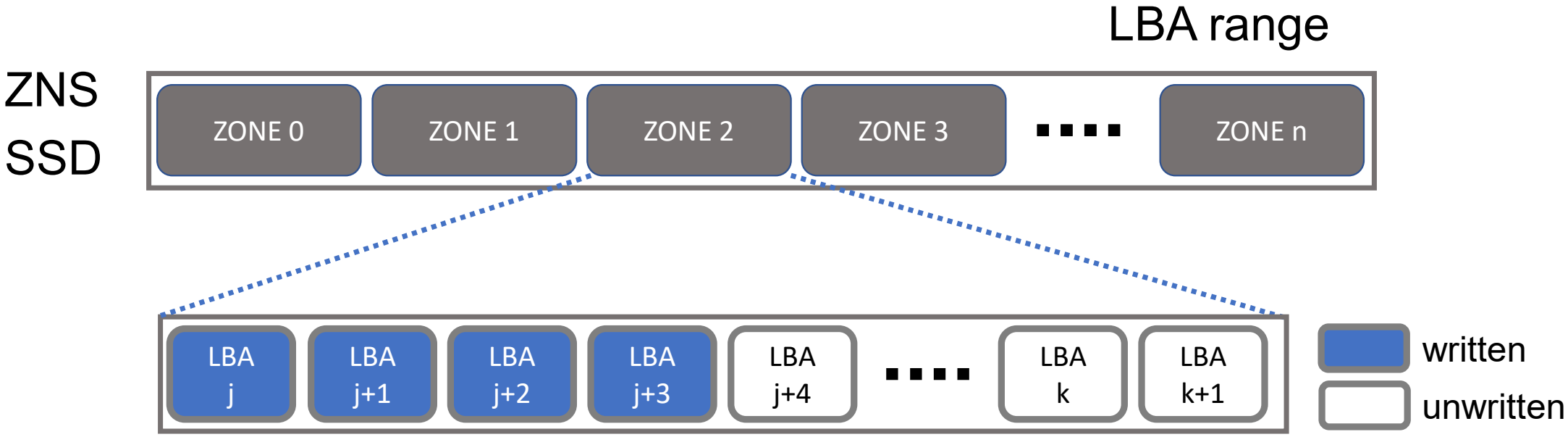
HotStorage 2023

HotStorage '23, July 9, Boston

Contents

Zoned Namespace SSD(ZNS SSD)



- ZNS groups the LBA space into fixed-size zones.

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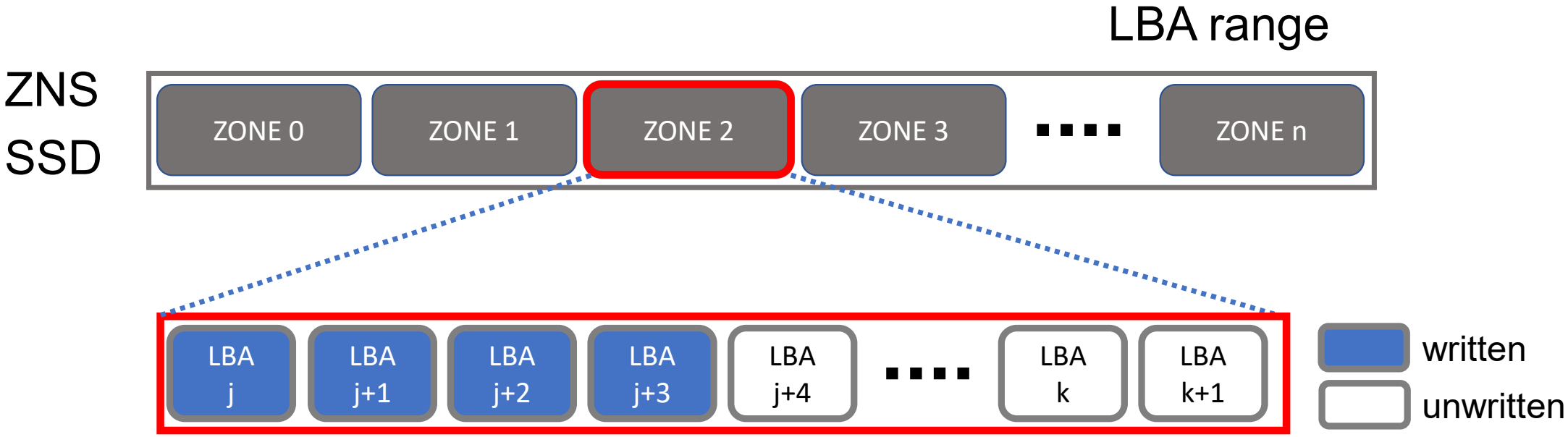

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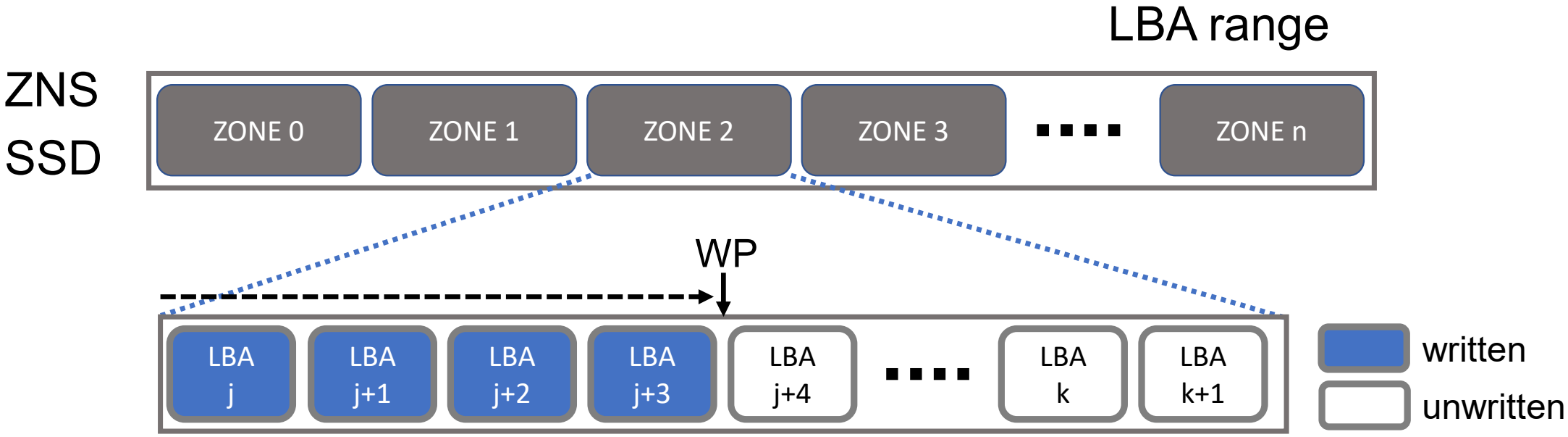

- ZNS groups the LBA space into fixed-size zones.
- Zone is an erase unit of ZNS SSD(zone-reset).
- Each zone must be written sequentially.

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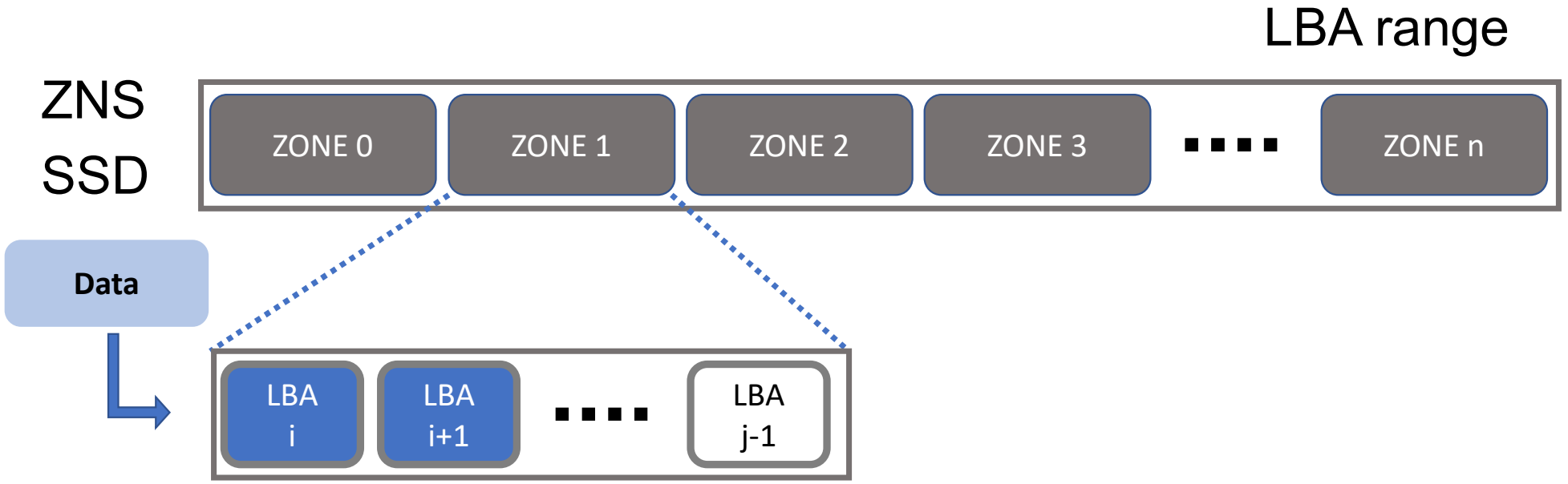

- User applications take over responsibility for
  1) Data placement

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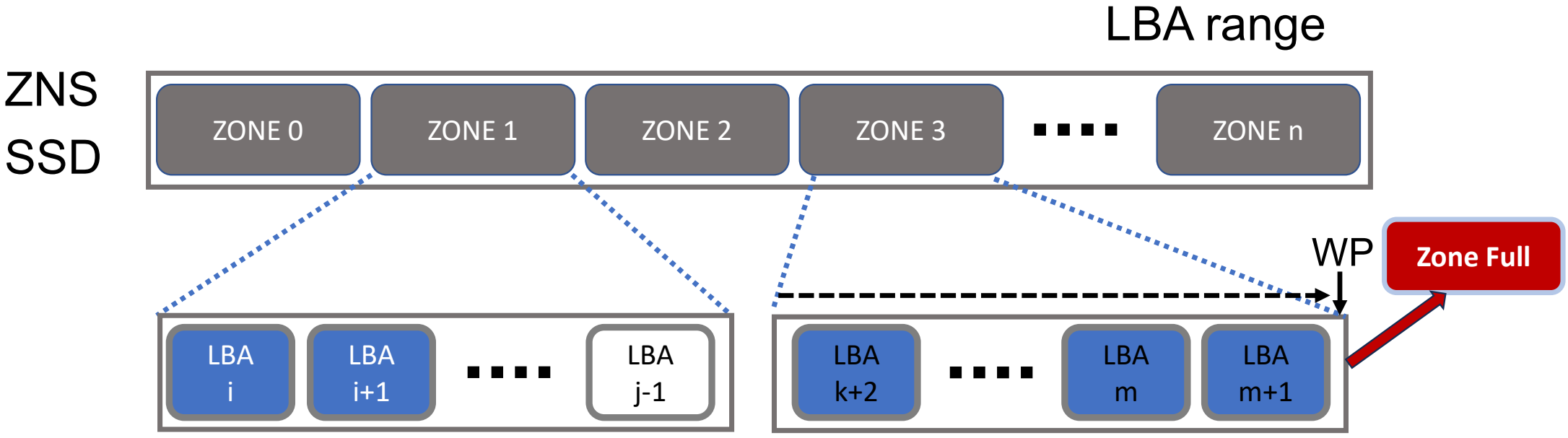


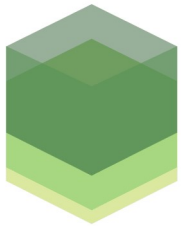
- User applications take over responsibility for
  1) Data placement
  2) **Free space reclamation**

No Garbage Collection in FTL

LSM-based Key-Value Store (LSM-KV)

- Log-structured merge-tree(LSM-tree)
  - Sequential I/O pattern
  - Out-of-place update

RocksDB



LEVELDB

mongoDB®

LSM-based Key-Value Store (LSM-KV)

- Data Update in LSM-tree
- Compaction
  - LSM-tree updates data files (SSTables) through compaction.

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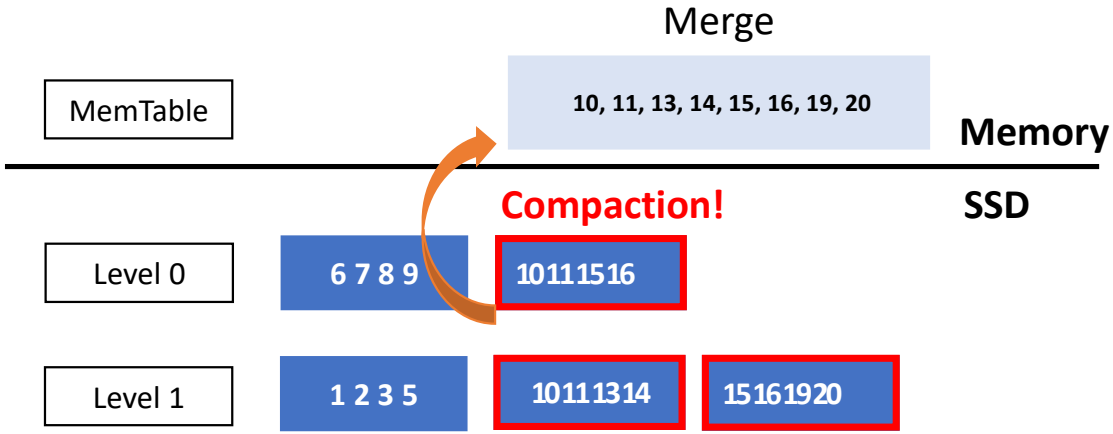

: SSTable

- SSTable size limit : 4 keys
- Level 0 limit : 2 SSTs
- Level 1 limit : 4 SSTs

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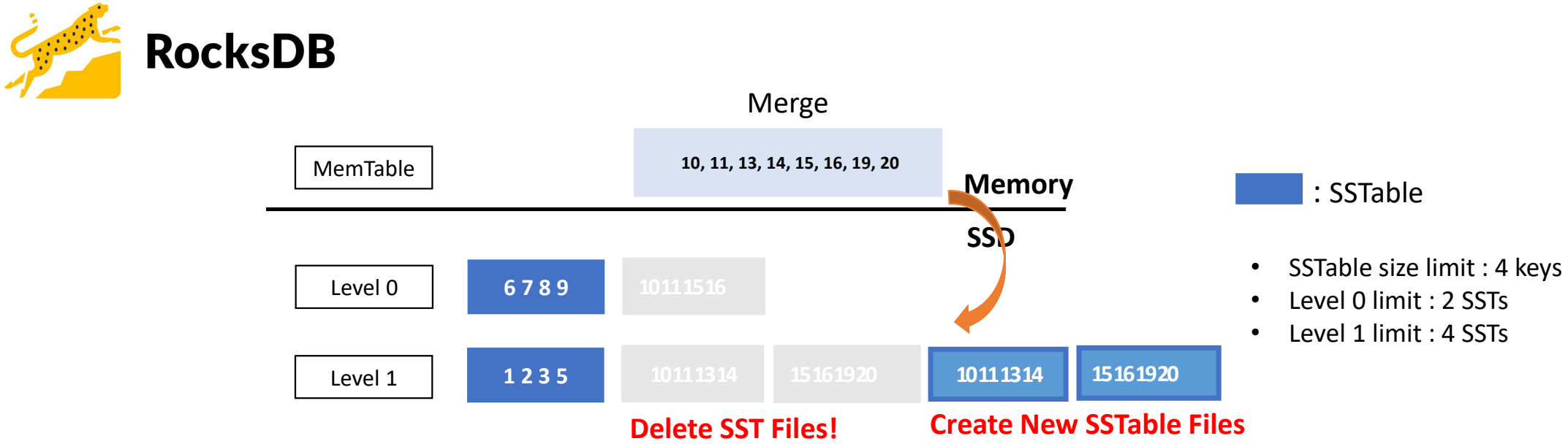

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- User-level file system for LSM-KV
  - Backend module for RocksDB
- Responsible for
  - Zone Allocation (Data placement)
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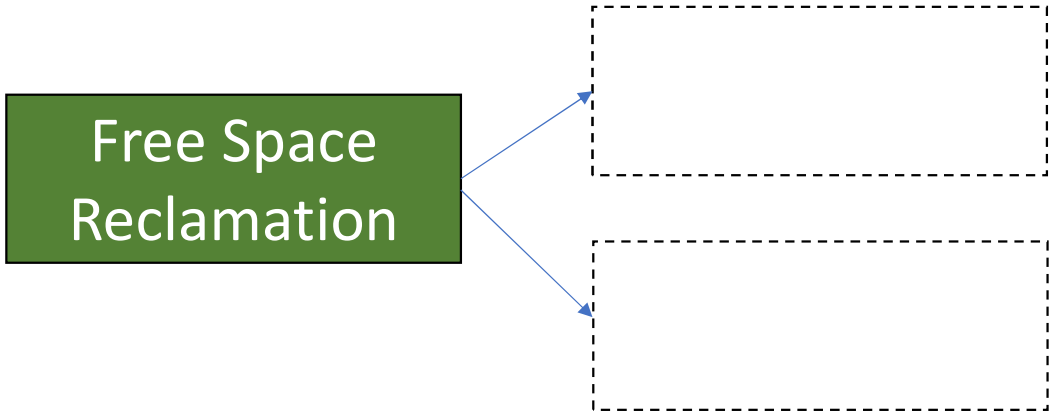

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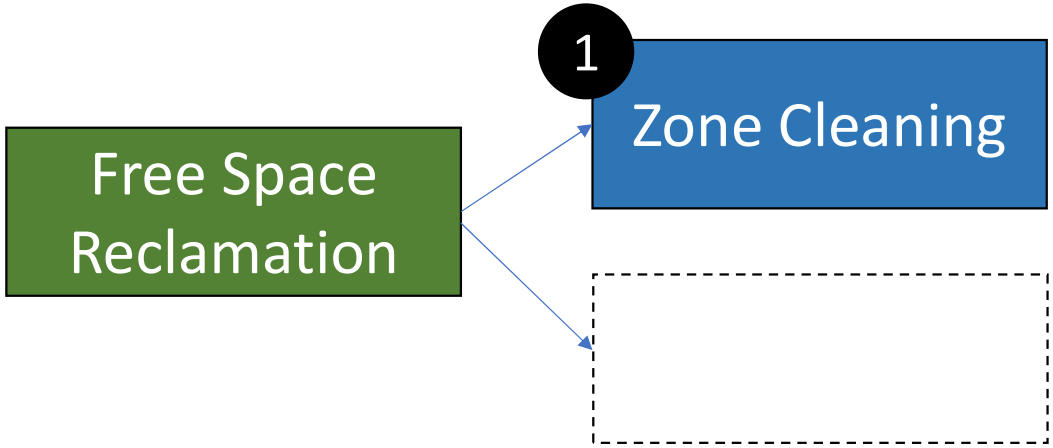

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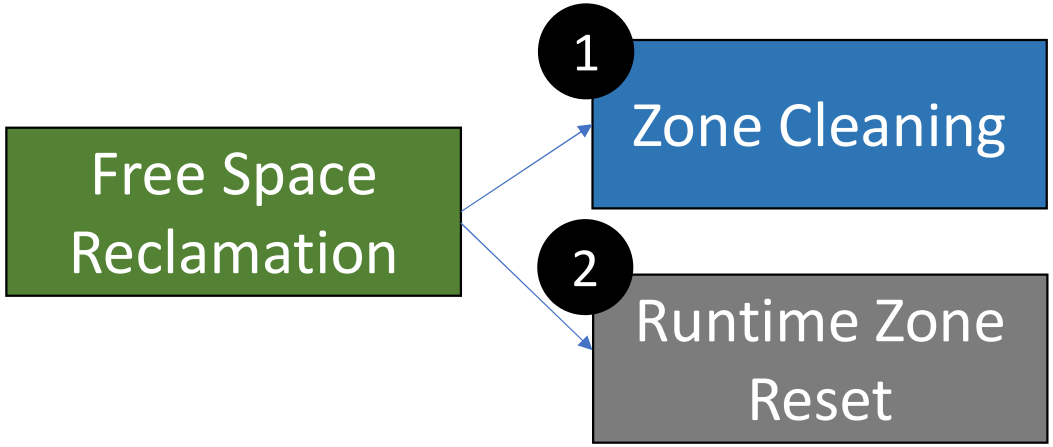

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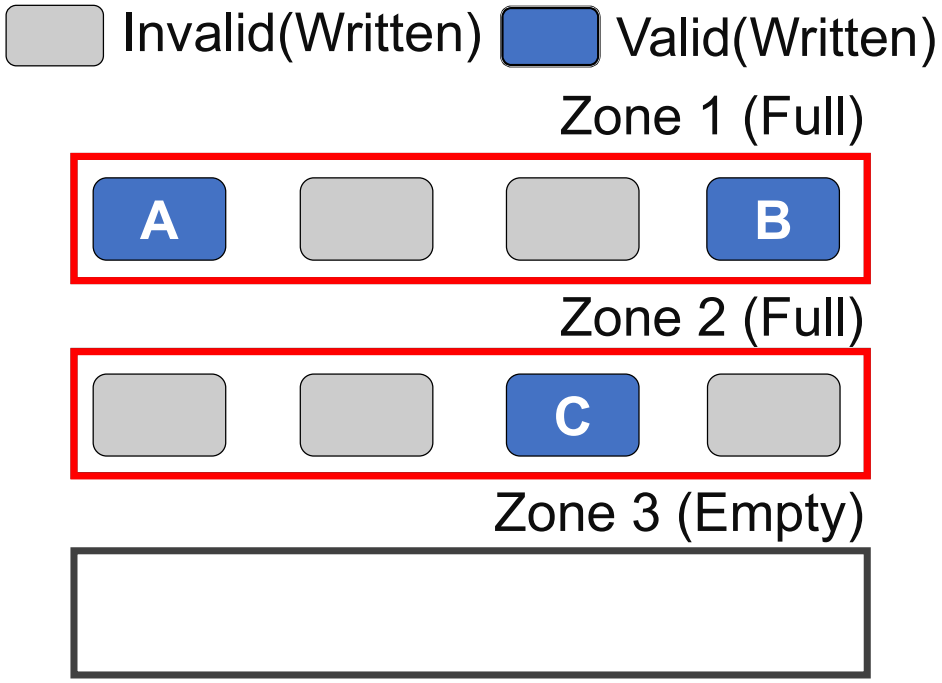
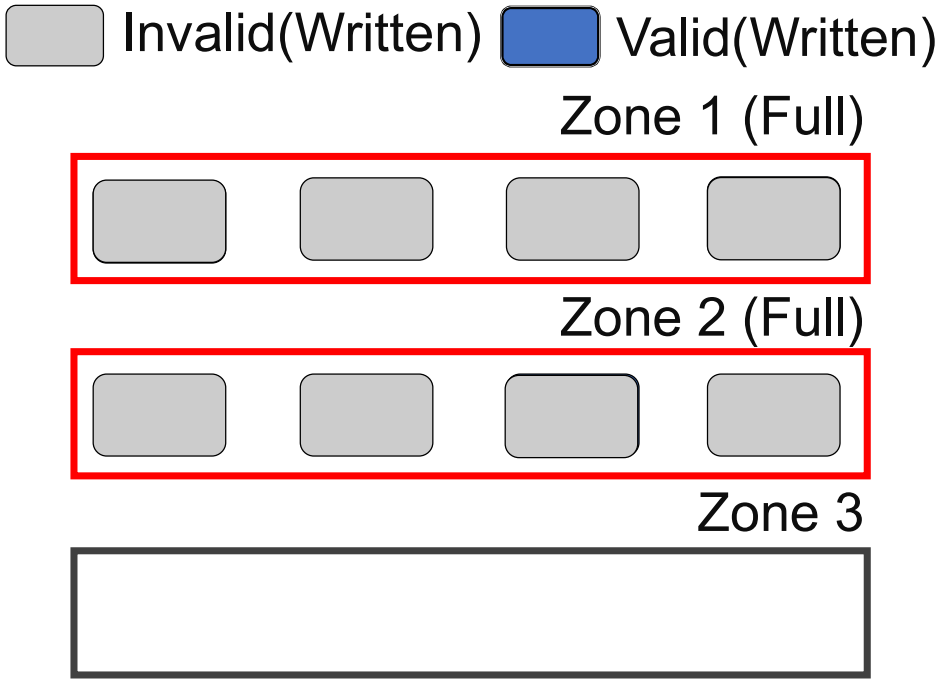


1) Victim Zone(s) Selection

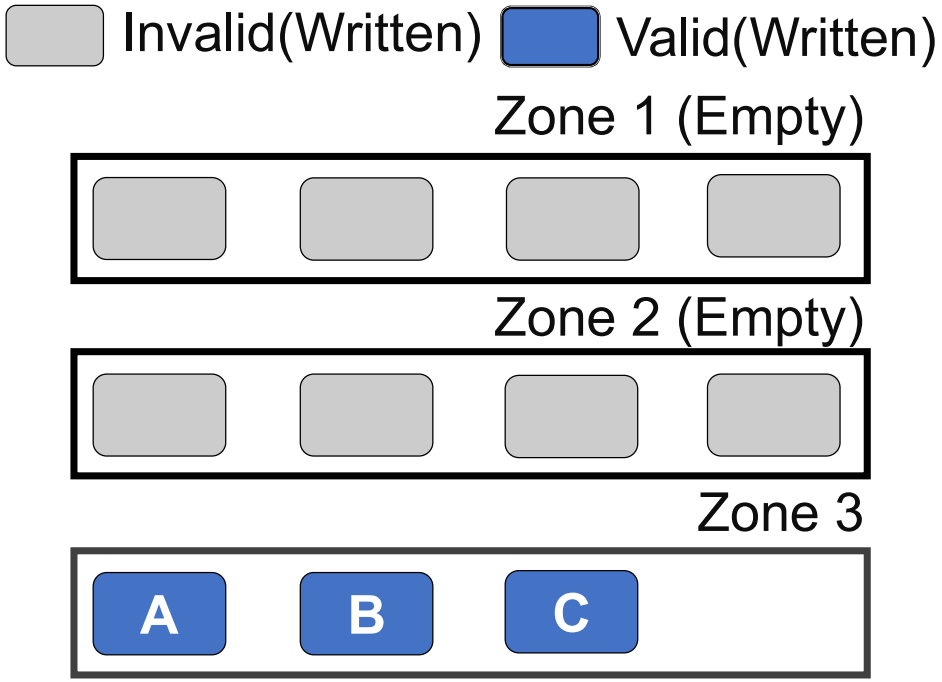
(1) Zone Cleaning



1) Victim Zone(s) Selection

2) Valid Data Copy

(1) Zone Cleaning



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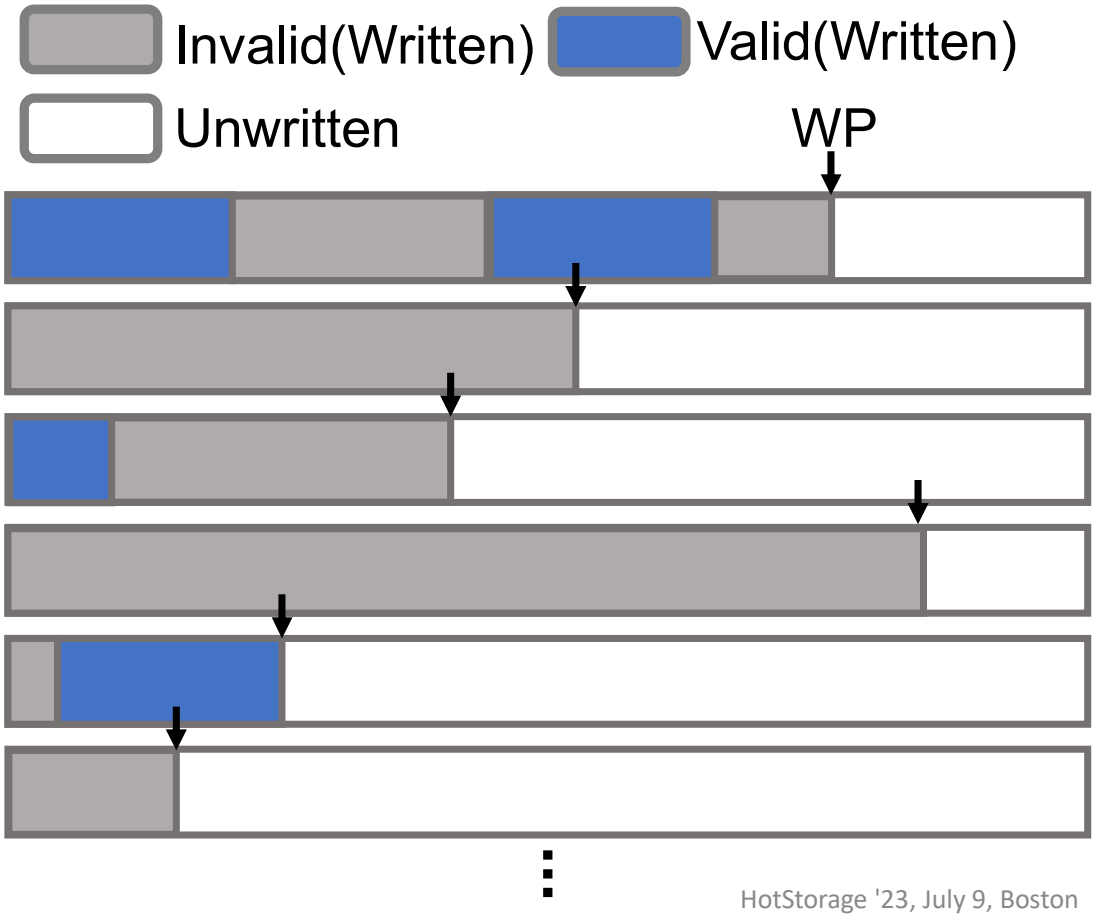
3) Erase zones by zone-reset

(2) Runtime Zone-Reset



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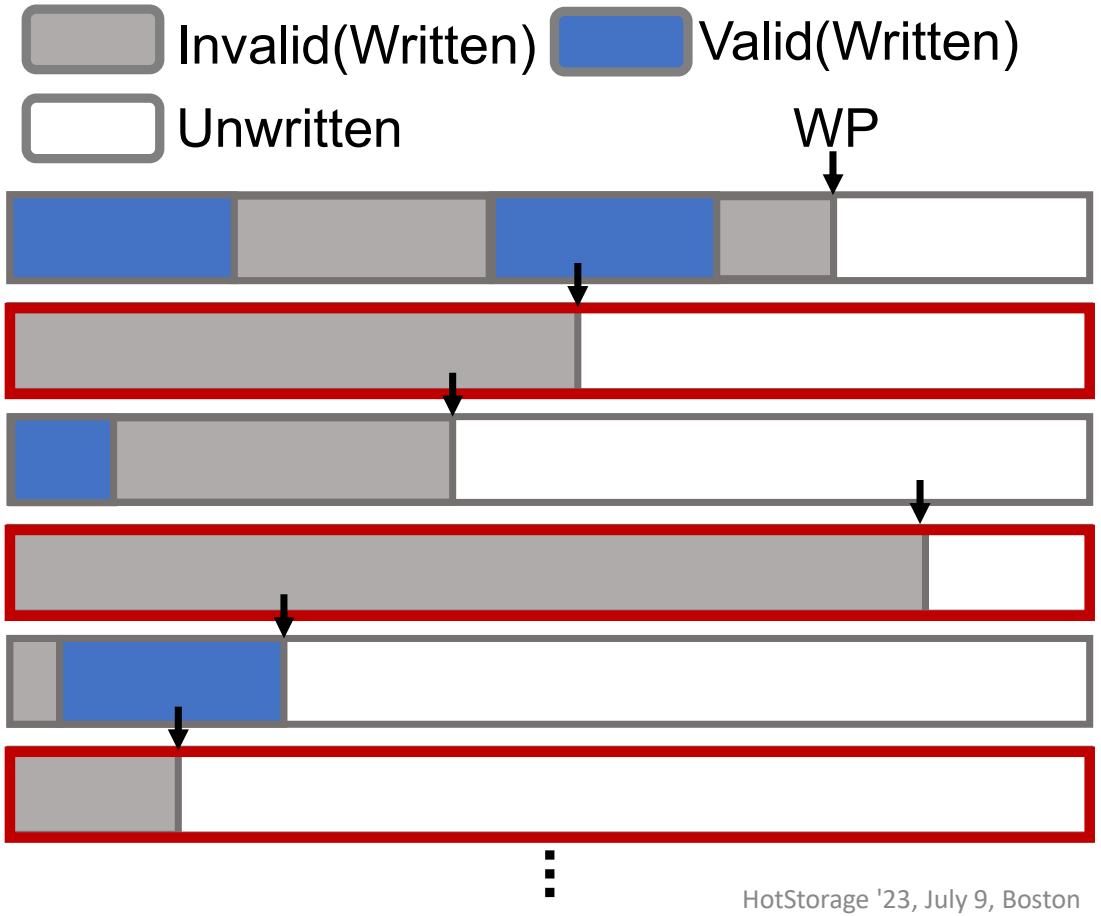
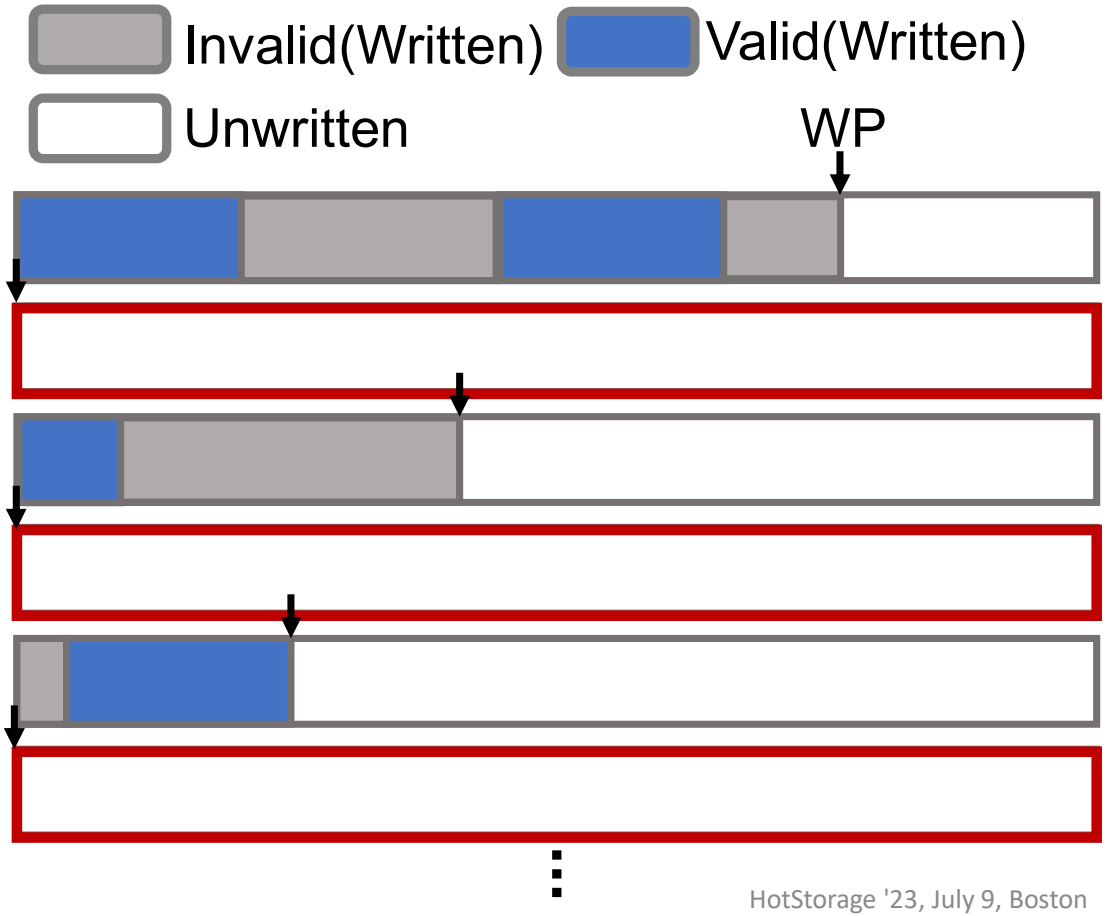


1) Search for zones with all invalid data

(2) Runtime Zone-Reset



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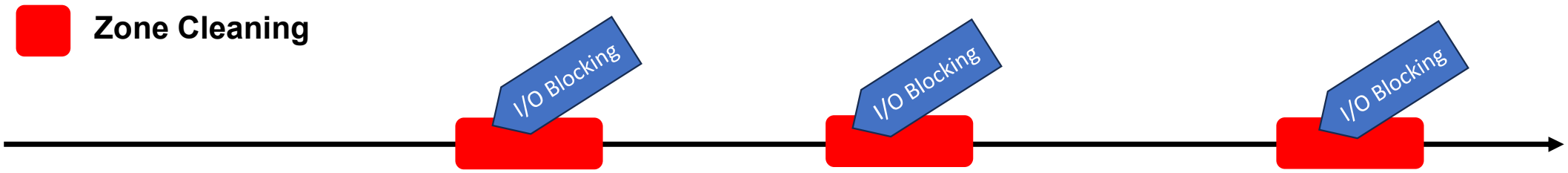
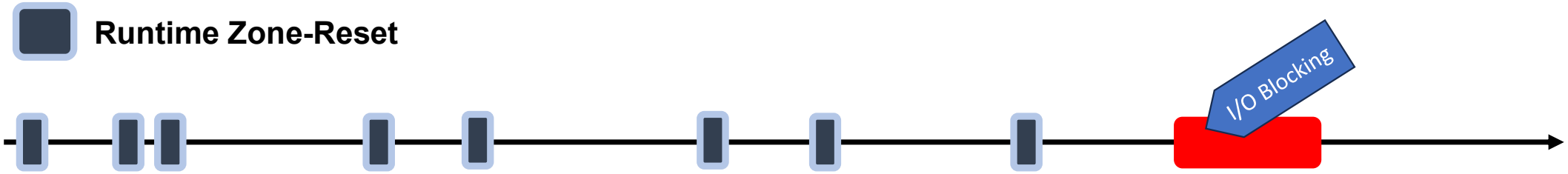
Zone Cleaning vs. Runtime Zone-Reset



- Zone Cleaning calls increase I/O blocking time, resulting poor performance.

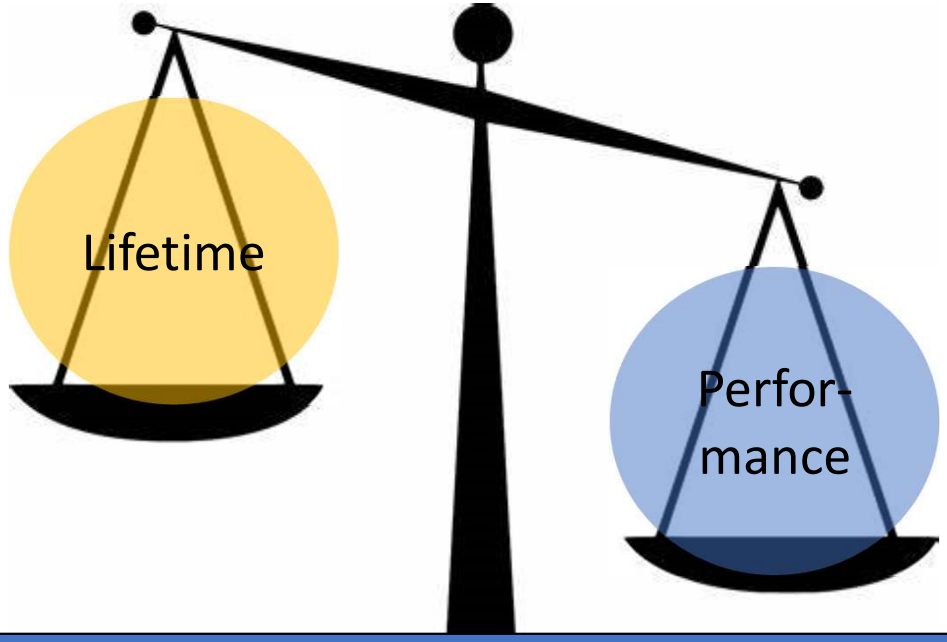


- Runtime Zone-Reset minimizes performance degradation by reducing Zone Cleaning calls.

Problem Definition

- The Runtime-Zone Reset algorithm unnecessarily performs zone-reset, even though there is enough free space in the ZNS SSD.
- This **shortens the lifespan** of ZNS SSD by executing NAND block erase frequently.
- However, excessively reducing Runtime-Zone Reset calls causes frequent ZC calls, resulting in **performance degradation**.

Tradeoffs



Is it possible to balance the lifespan and performance of the ZNS by carefully controlling the Runtime Zone-Reset call?

Contents

Key Ideas

- FAR **<u>determines whether to execute zone-reset</u>** according to a threshold (T_{wp}).

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- More importantly, threshold (T_{wp}) changes depending on the **<u>free space</u>** remaining in the ZNS SSD.

Threshold (T_{wp}) $\propto$

T_{wp} increases with free space increase!

Ready to execute "zone-reset" in runtime!

Key Ideas

- FAR determines whether to execute zone-reset according to a threshold (T_{wp}).
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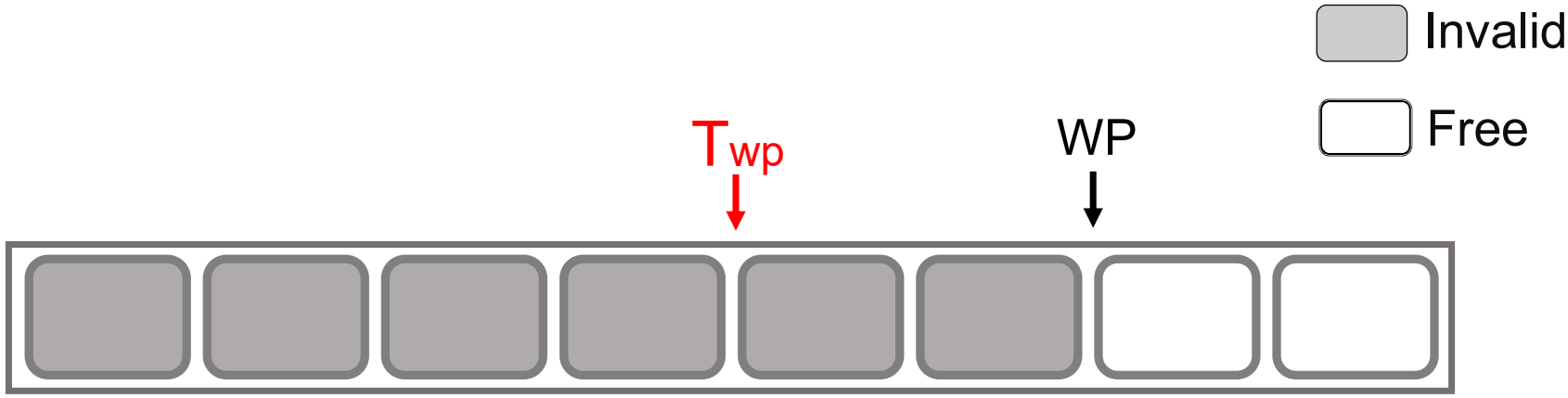
Execute Zone-Reset according to T_{wp}



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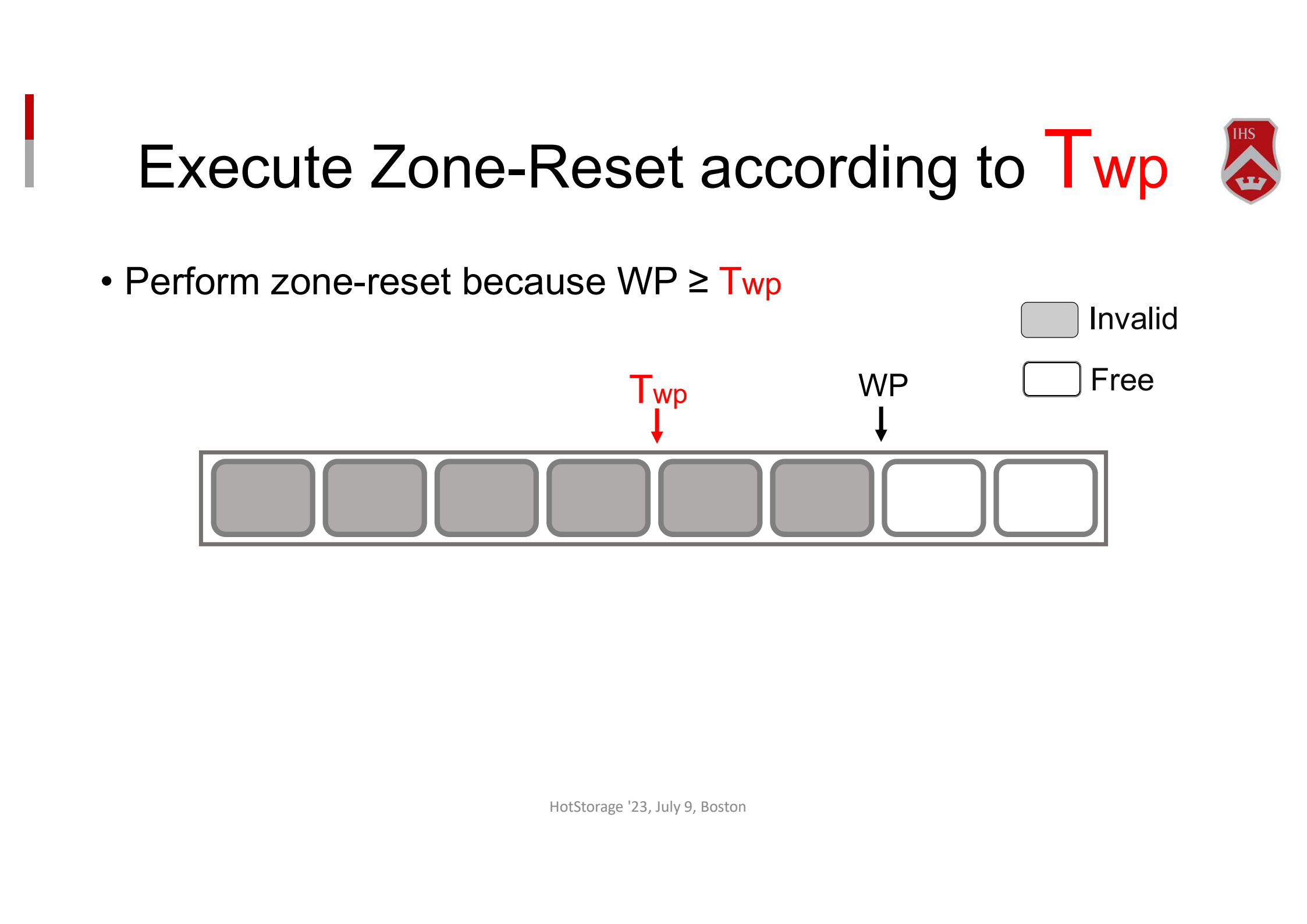
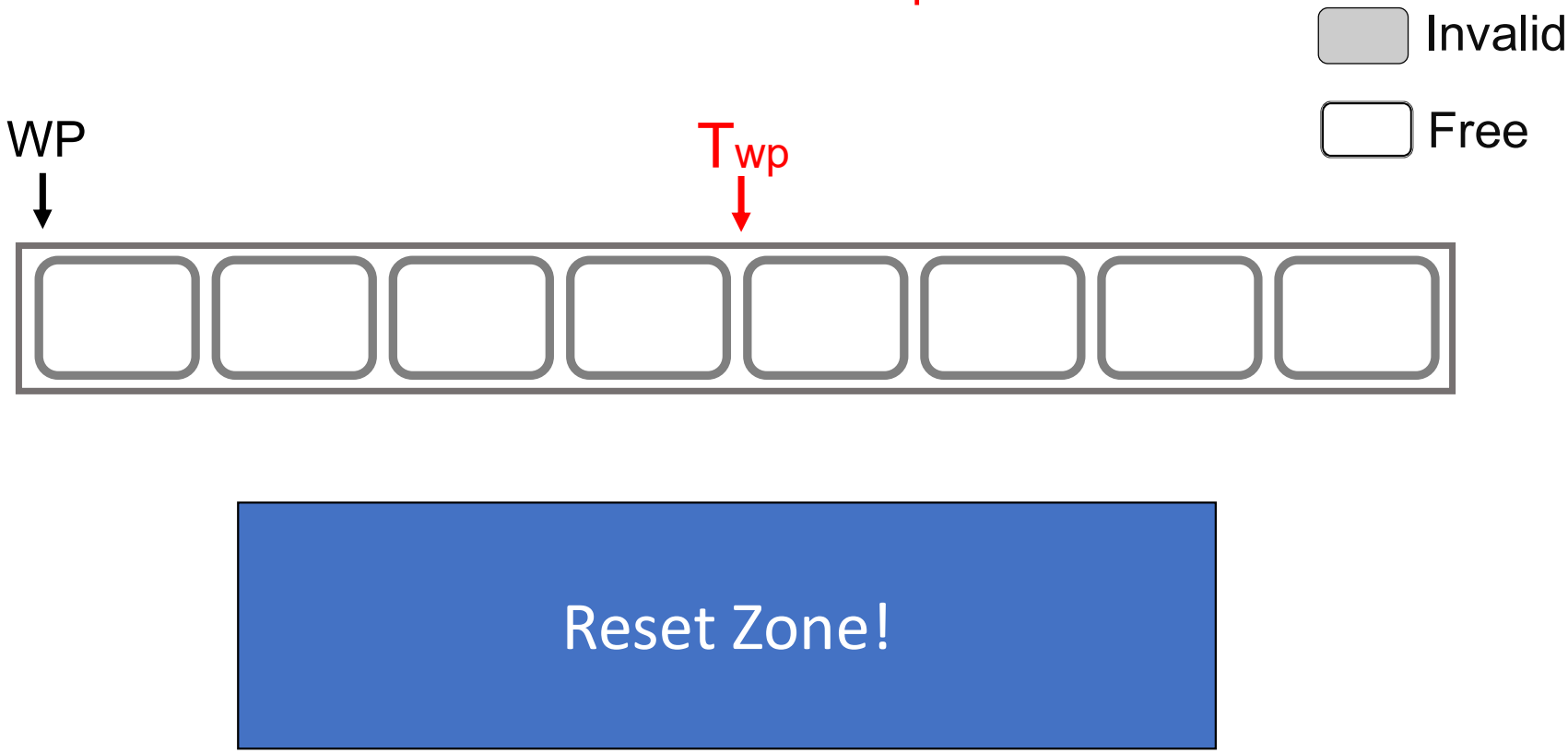


- Perform zone-reset because WP ≥ T_{wp}

Execute Zone-Reset according to T_{wp}

- Perform zone-reset because WP ≥ T_{wp}



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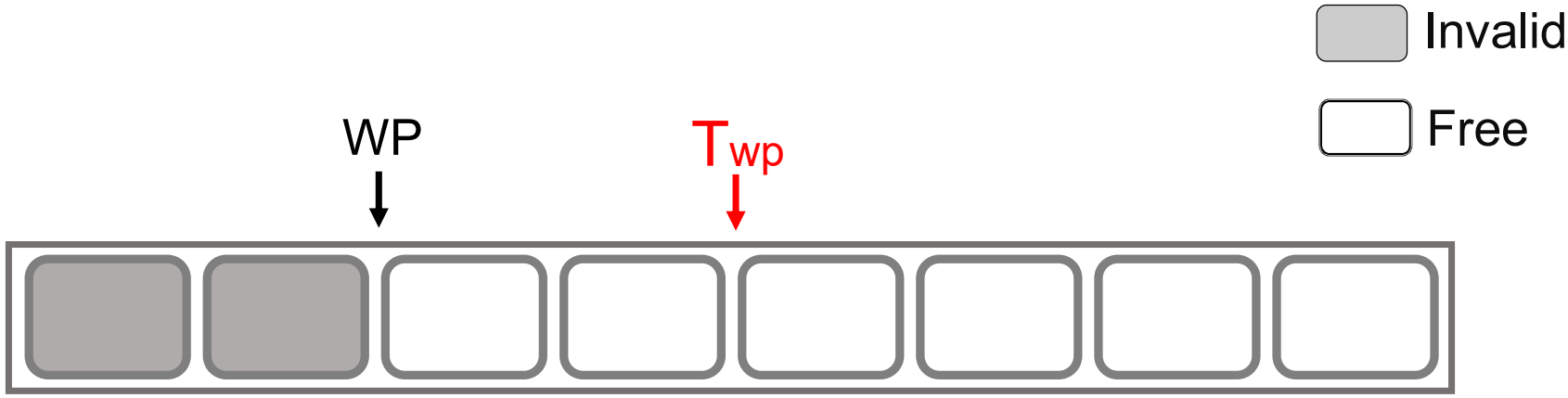
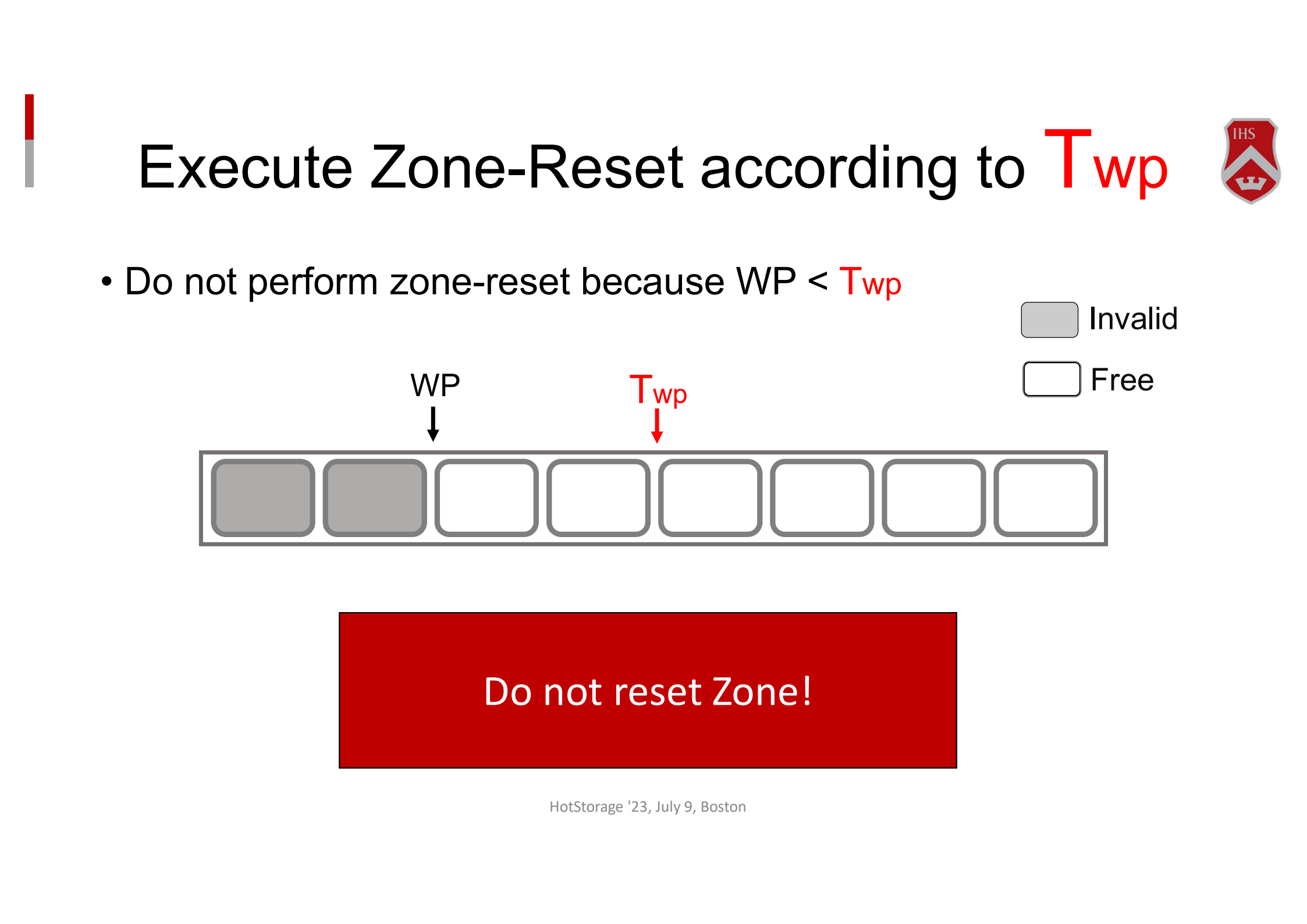


Execute Zone-Reset according to T_{wp}



- Do not perform zone-reset because WP < T_{wp}

Do not reset Zone!

Key Ideas

- FAR determines whether to execute zone-reset according to a threshold (T_{wp}).

- More importantly, threshold (T_{wp}) changes depending on the free space remaining in the ZNS SSD.

Change of T_{wp} according to Free Space

- Threshold (T_{wp}) changes depending on the free space remaining in the ZNS SSD.

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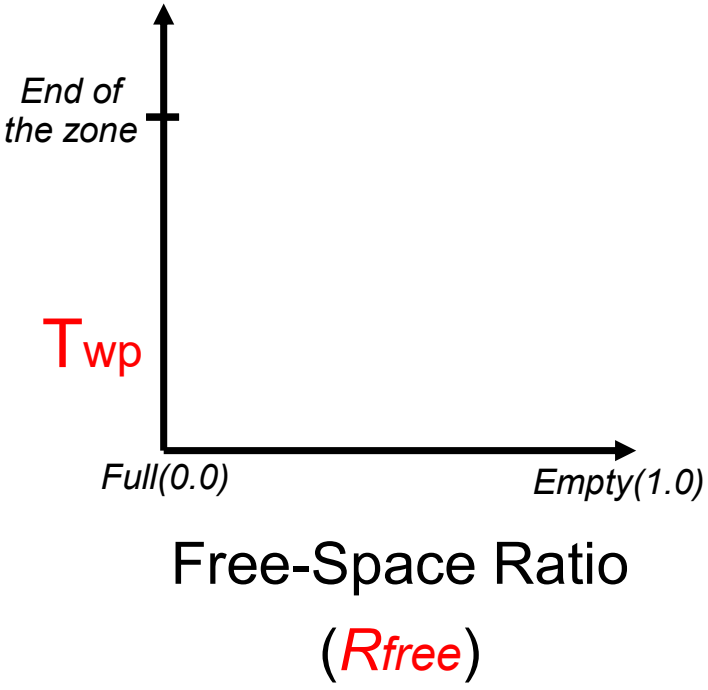

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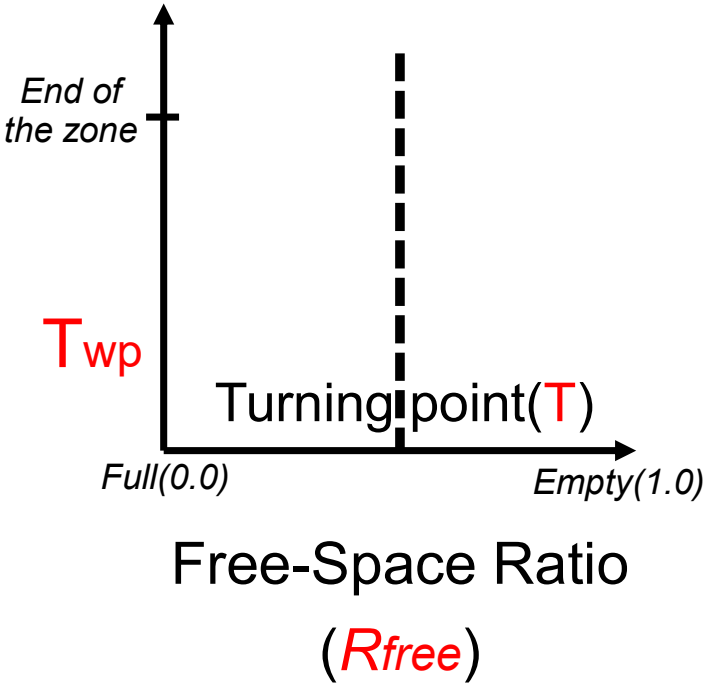

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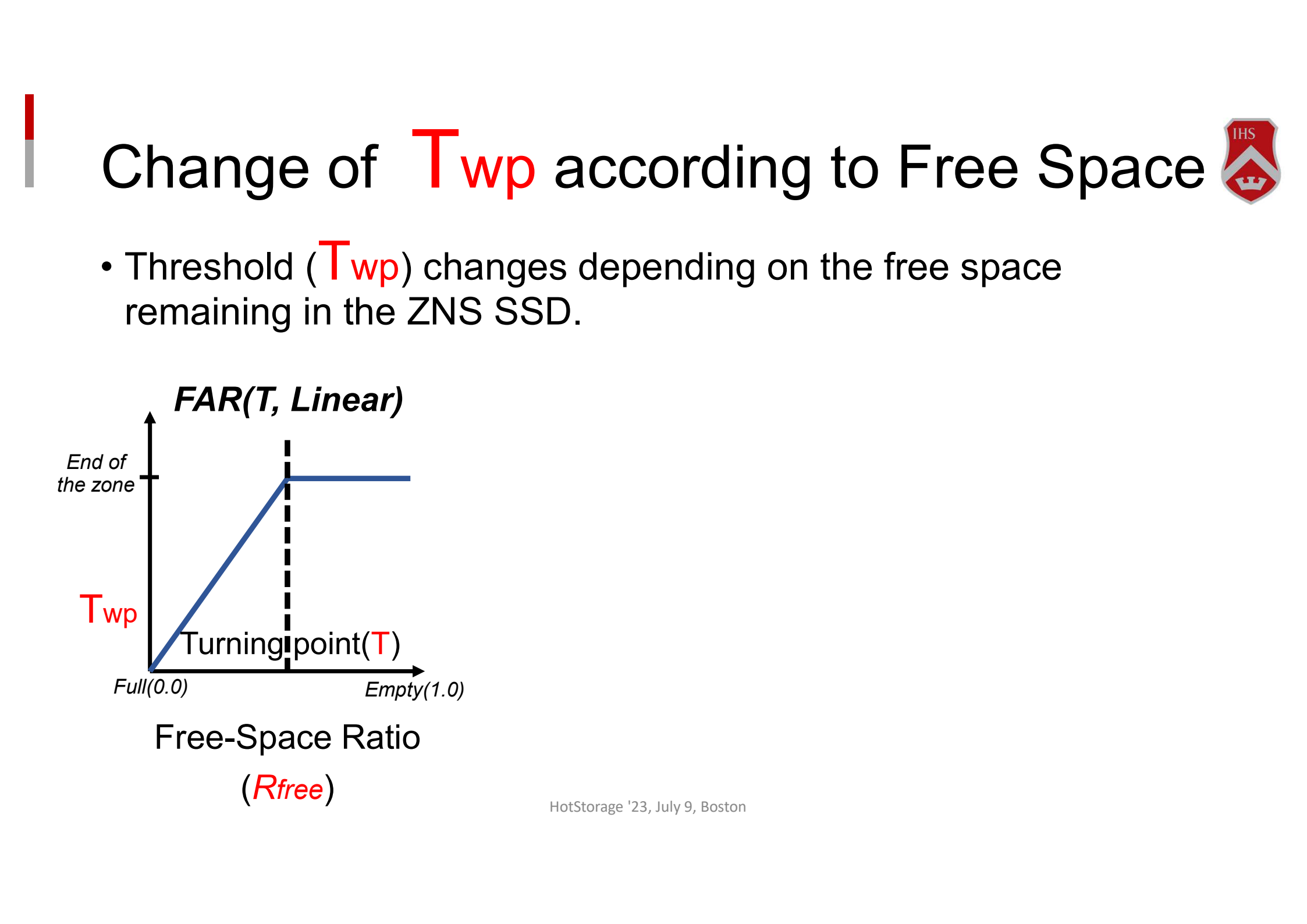

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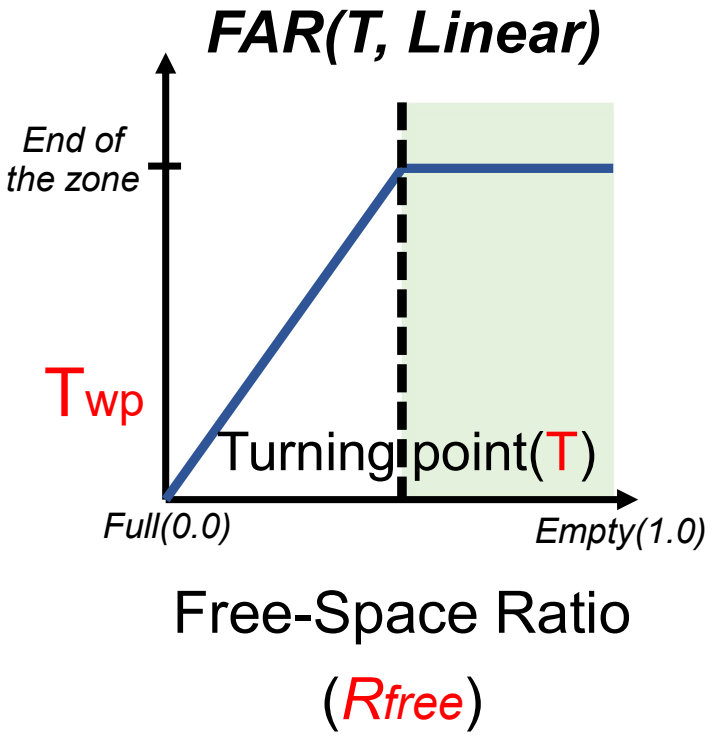

- If free space (R_{free}) > T, threshold (T_{wp}) is set to be the end of a zone.

Change of T_{wp} according to Free Space

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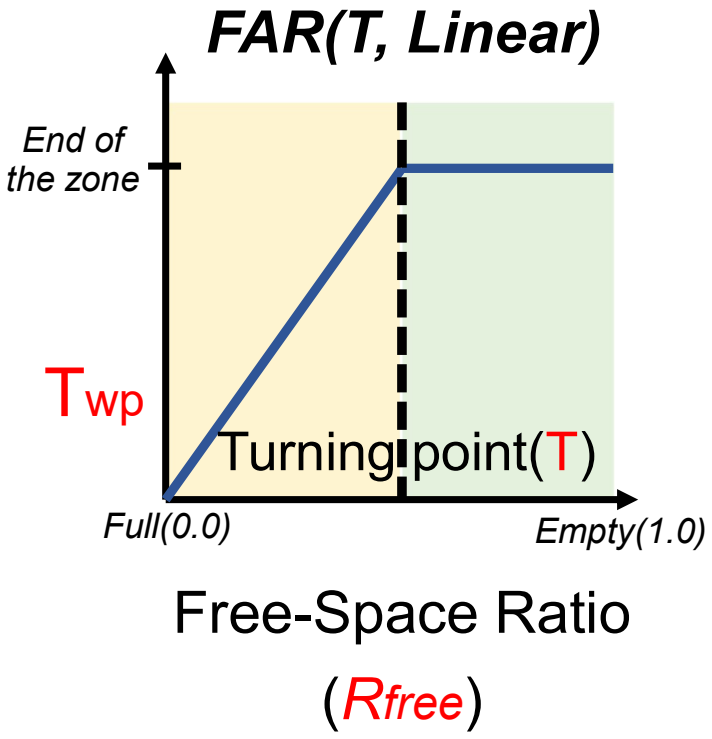
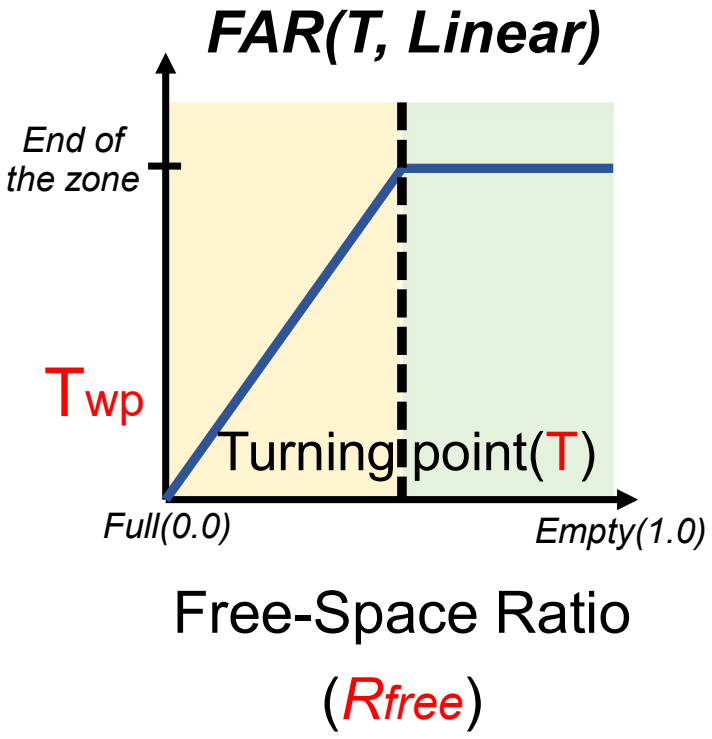


- If free space (R_{free}) > T, threshold (T_{wp}) is set to be the end of a zone.
- Else, threshold (T_{wp}) is a linear function of (R_{free}).

Change of T_{wp} according to Free Space

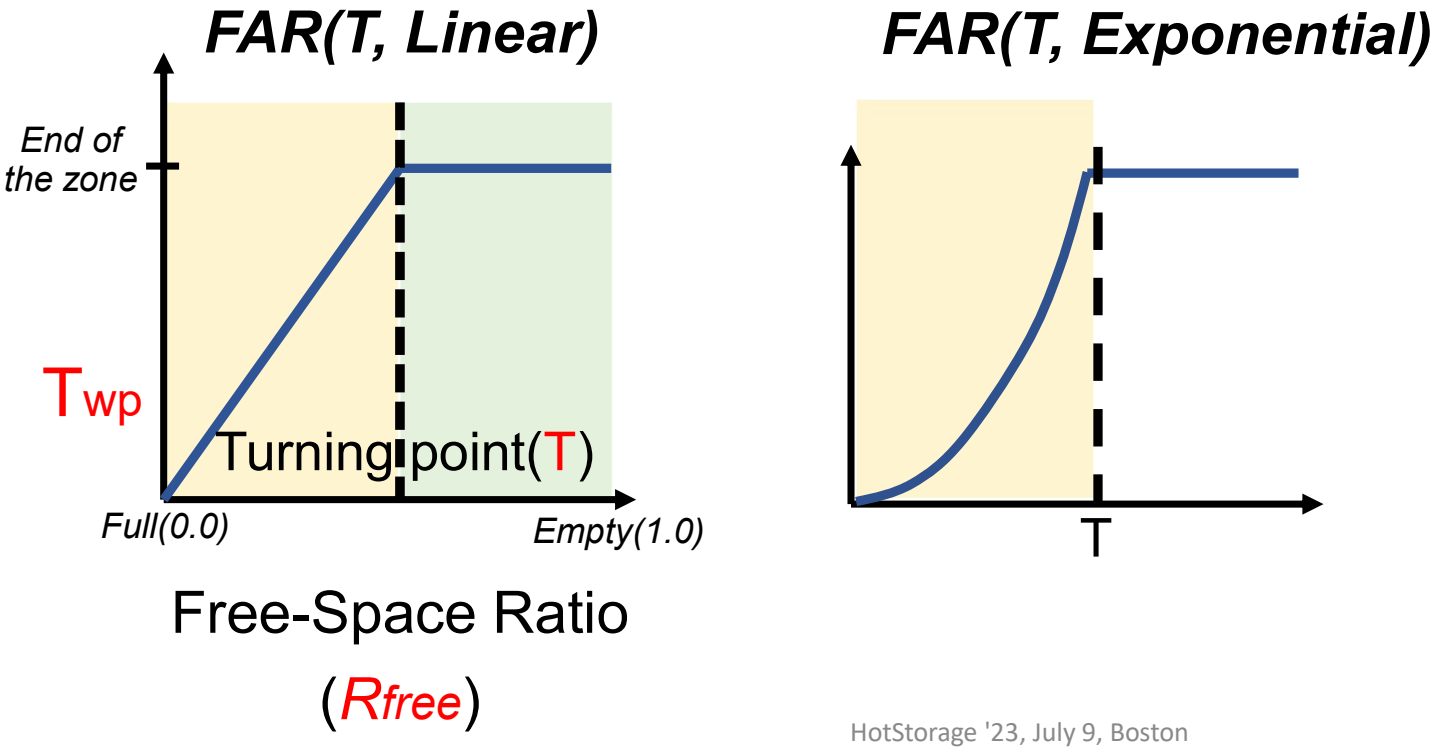
- Threshold (T_{wp}) changes depending on the free space remaining in the ZNS SSD.



- If free space (R_{free}) > T, threshold (T_{wp}) is set to be the end of a zone.
- Else, threshold (T_{wp}) is a linear function of (R_{free}).
- In our experiment, we used 0.7 for T.

Change of T_{wp} according to Free Space

- Threshold (T_{wp}) changes depending on the free space remaining in the ZNS SSD.



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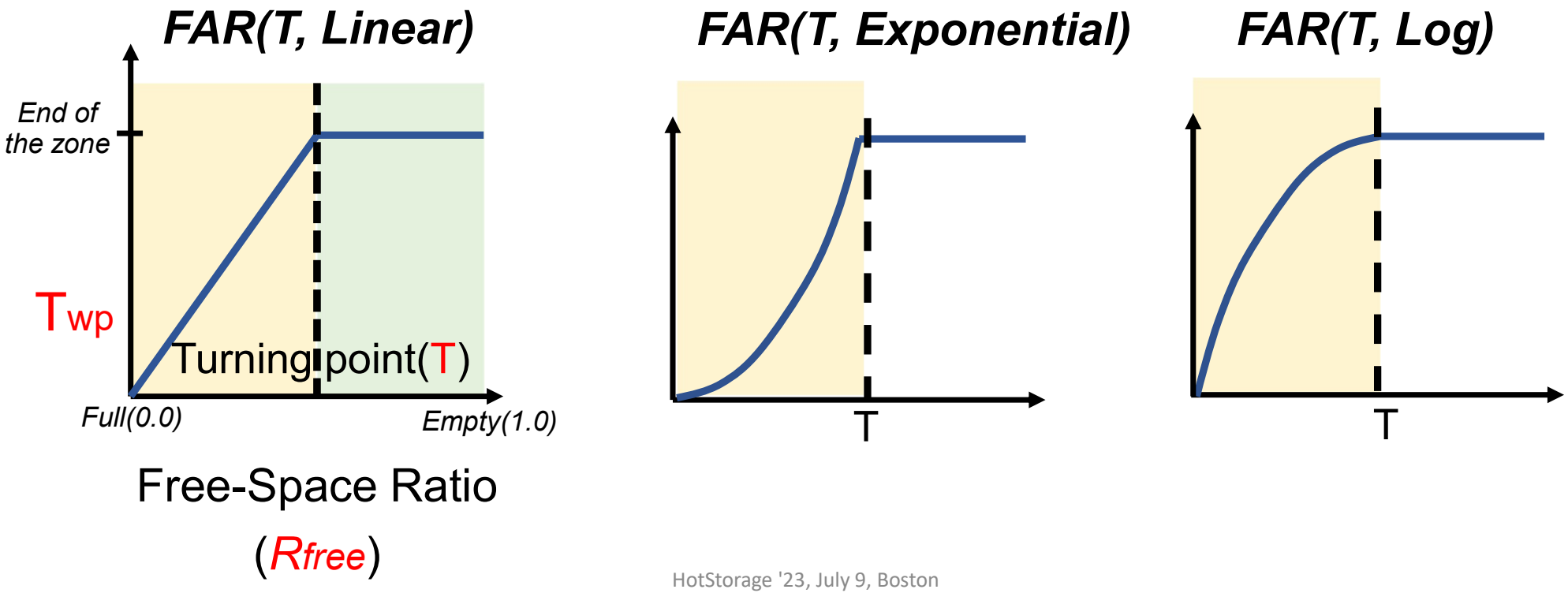

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Experimental Setup

HOST

- i7-4790 3.60Ghz (8 cores)
- Linux Kernel 5.18.0
- UBUNTU 20.04
- RocksDB v.7.4.4
- ZenFS v2.0

ZNS

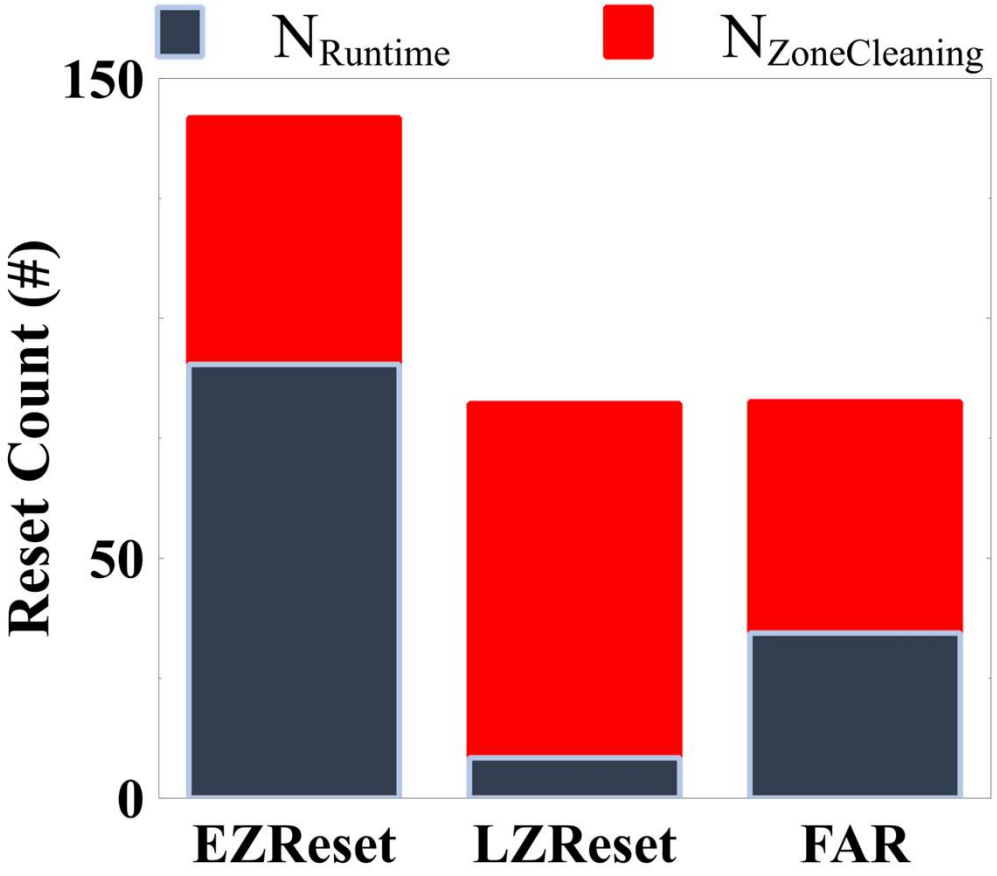
- ZNS Prototype
- Cosmos+ OpenSSD
- 512MB Fixed-size zone
- 40 I/O zones
- 20GB Total Capacity

Experimental Setup

- Workloads
  - Used Rocksdb's db_bench "fillrandom" workloads
  - Used different data size: Small(9GB), Medium(12GB), Large(15GB)

- Comparisons
  - EZReset: Default runtime zone-reset in ZenFS
  - LZReset: Lazy runtime zone-reset with T_{wp} = *end of a zone*
  - FAR (T, $func$): free-space adaptive zone-reset algorithm, where T=0.7 and func=Linear

Lifetime Results



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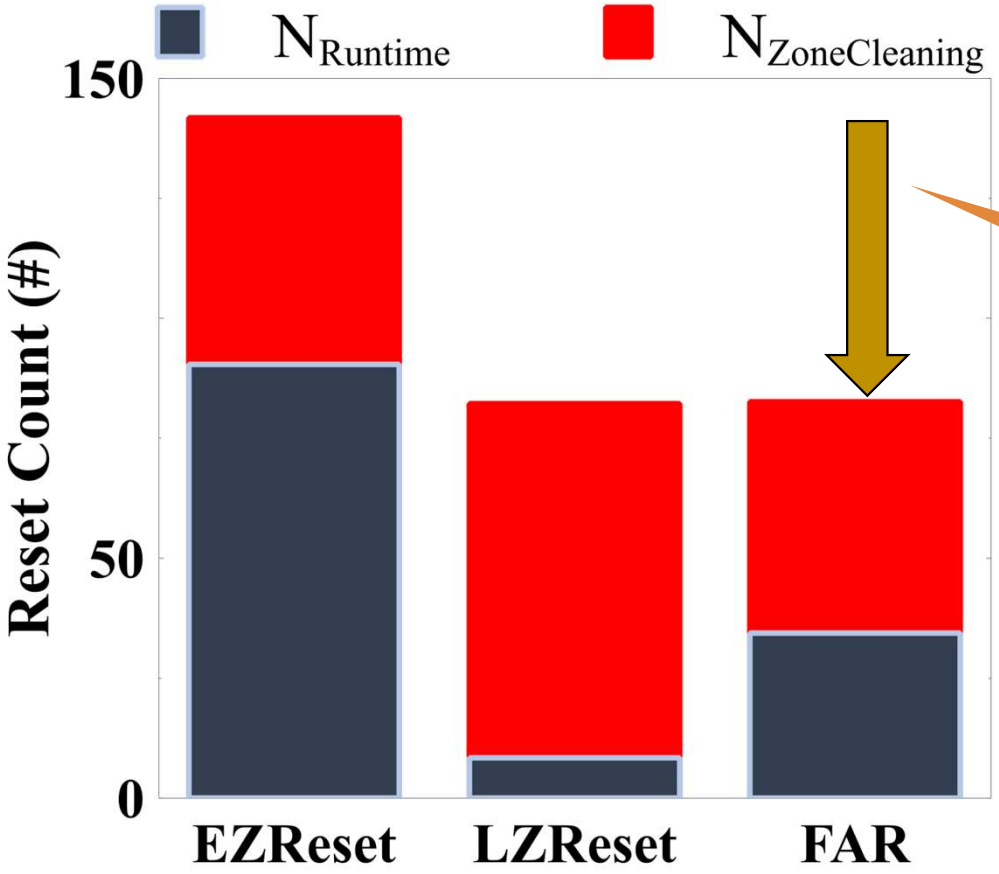
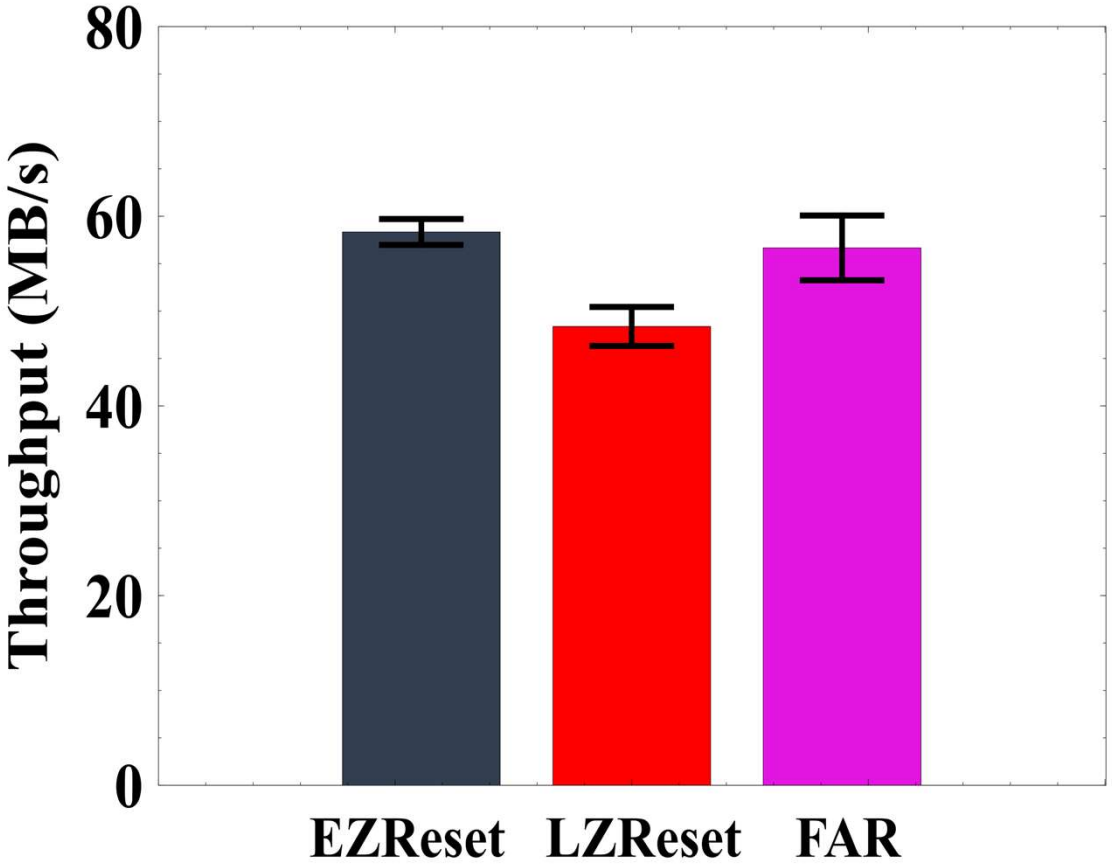


2x Lifetime Improvement

Performance Results



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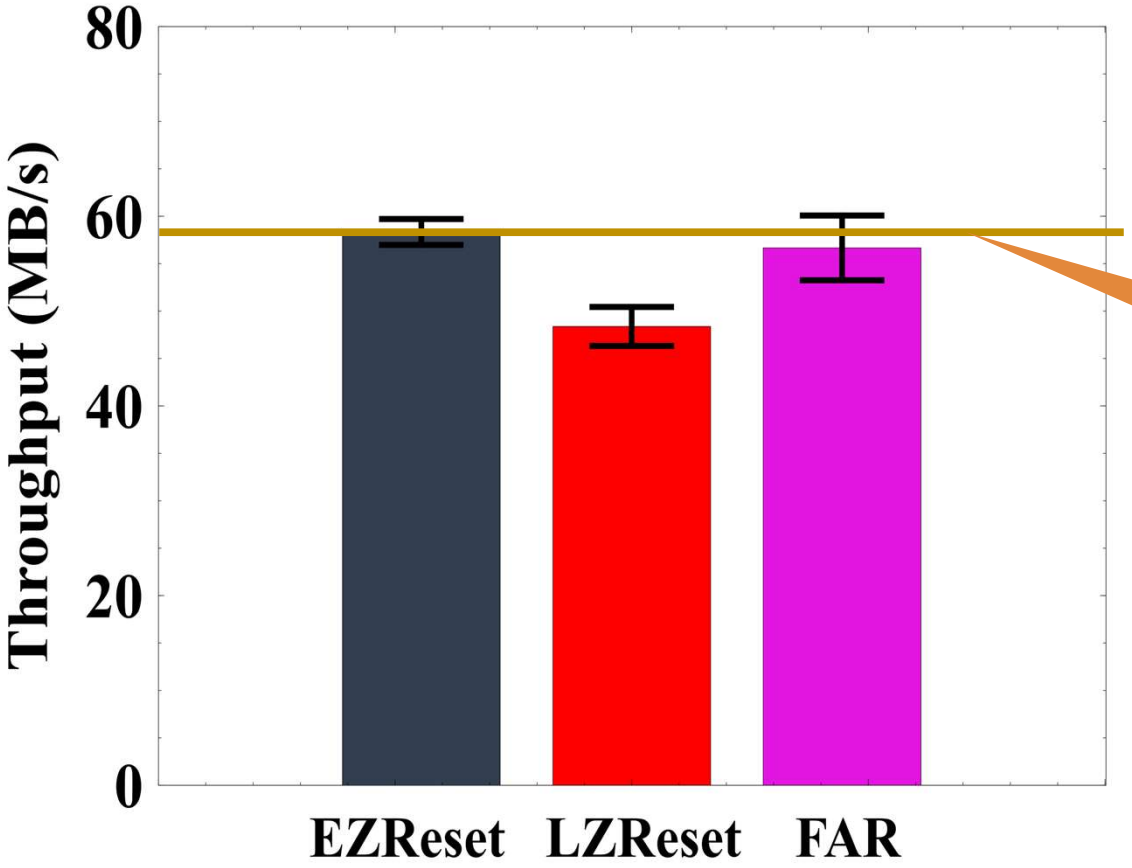

Minimal Performance Degradation

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Conclusion

- We identified that the current implementation of ZenFS's runtime zone-reset algorithm can have a negative impact on device's lifetime.
- We proposed a free-space adaptive runtime zone-reset (FAR) algorithm that balances application's performance and device's lifetime.
- FAR maintains a high performance while improving device's lifetime as factor of 2.

Thank you for listening!
Q&A

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