A New LSM-style Garbage Collection Scheme for ZNS SSDs

12th USENIX Workshop on Hot Topic in Storage and File System (HotStorage 20), 2020

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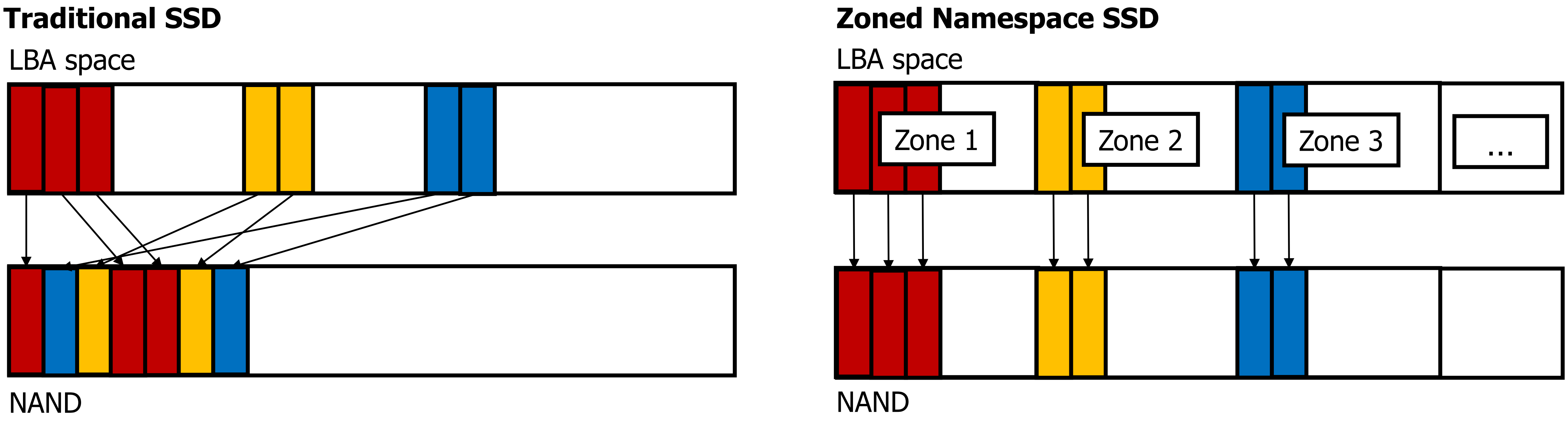
Content

- **What is ZNS SSD?**

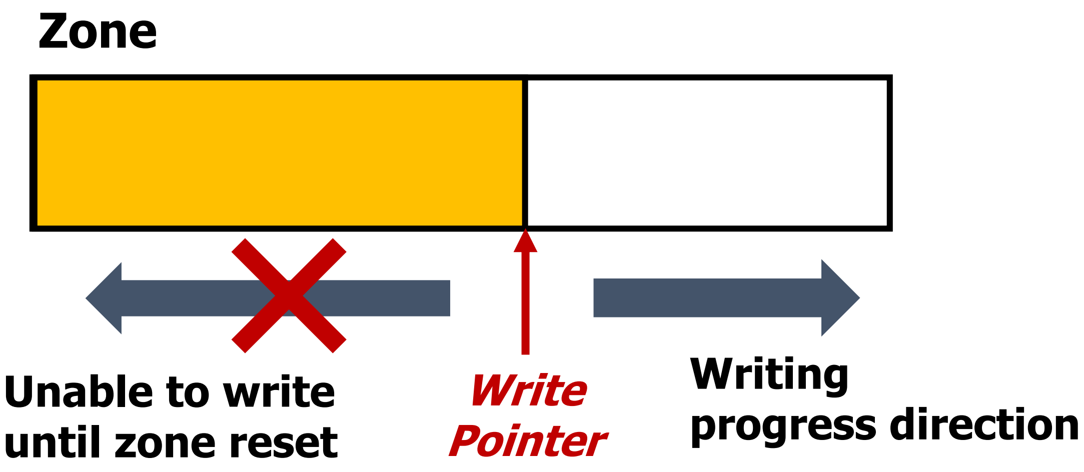


✓ Benefits

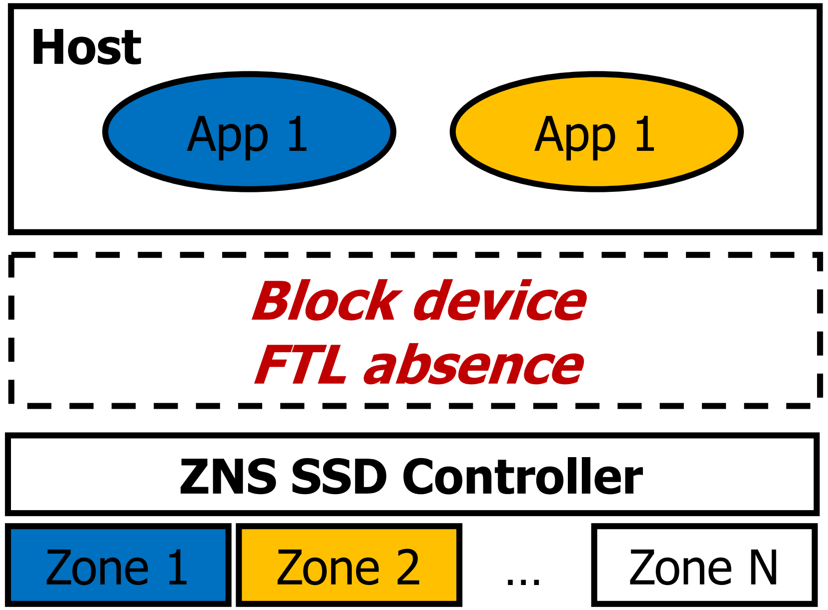
- Better performance and WAF by distributing different workloads into different zones
- Better isolation (IO Determinism)
- Reduce DRAM usage and Over-provisioning area in SSDs

- **What are the issues of ZNS SSD?**

  - ✓ Sequential write constraint: writes need to be conducted in a sequential manner, like the SMR drives.
  - ✓ Host needs to control zones directly such as zone open, close, reset and zone garbage collection.

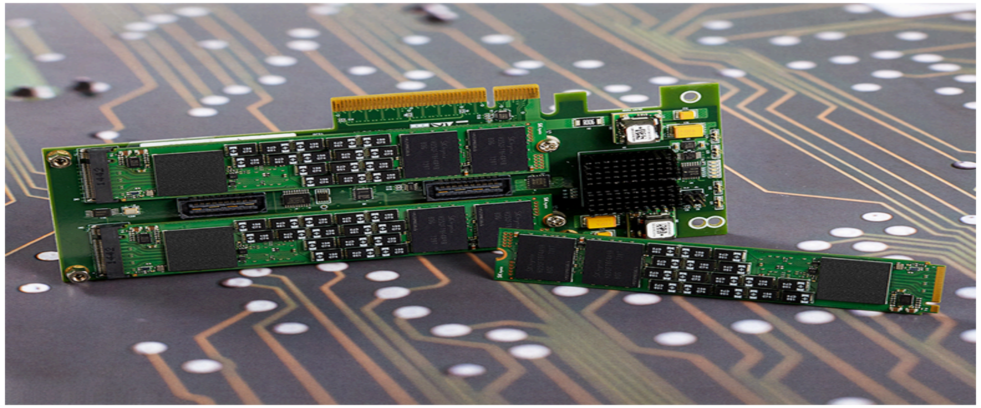


Sequential write constraint



Host Needs to handle zone controls

- **How much is the Zone Garbage Collection (hereafter ZGC) overhead?**
  - ✓ Using real ZNS SSD prototype
  - ✓ Zone size: 1GB (note that the typical segment size in LFS is 2MB)

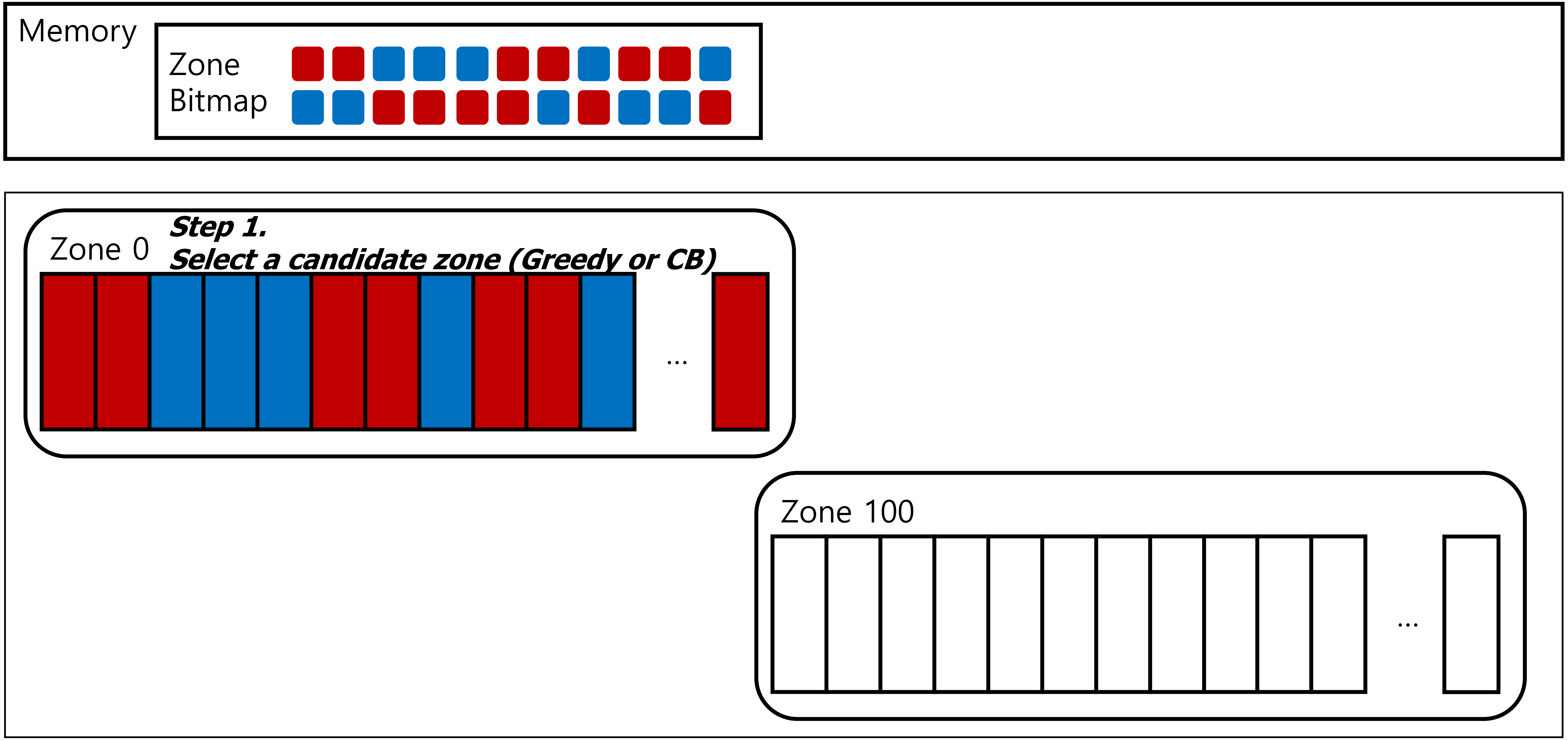


SK Hynix Prototype ZNS SSD

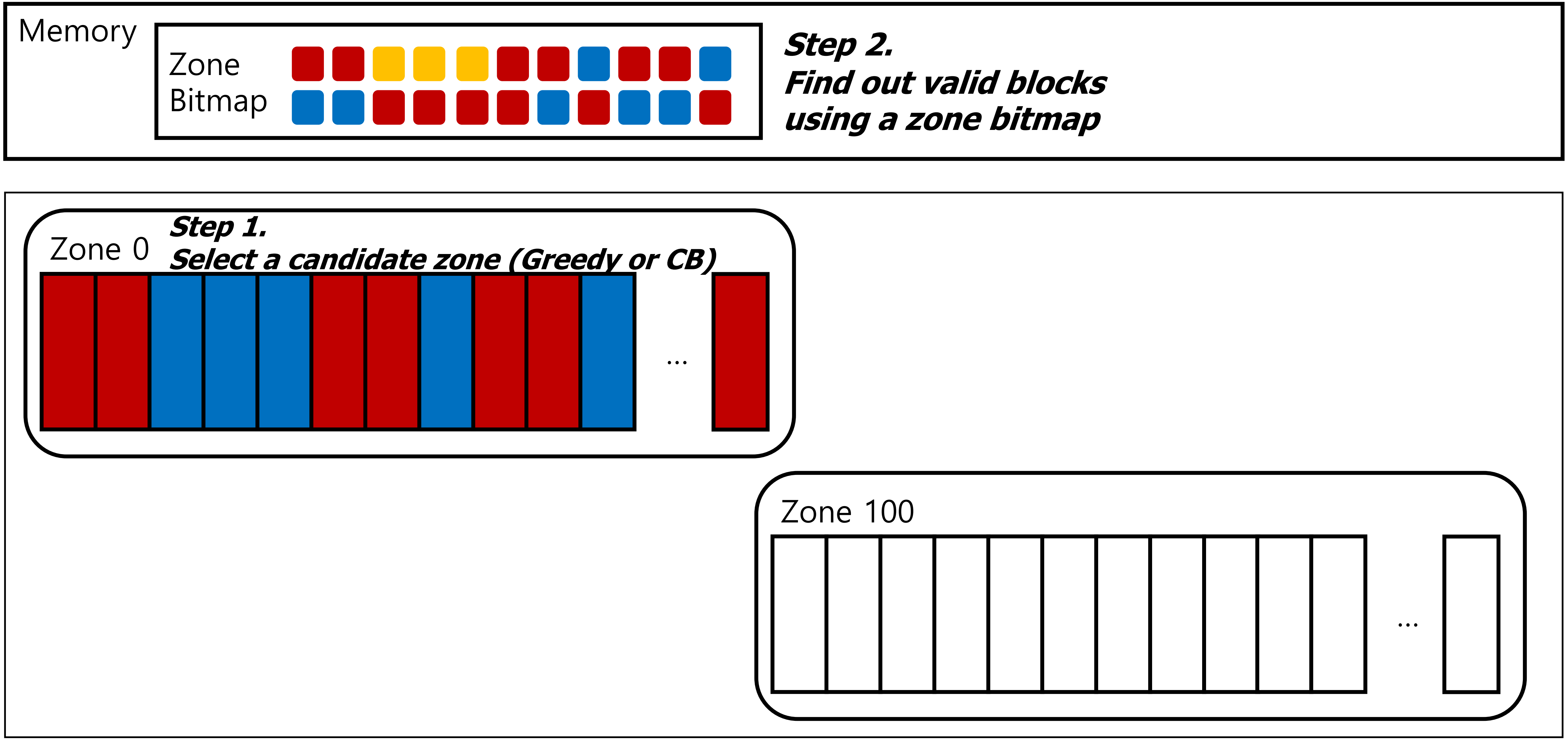
Table 1: ZNS SSD prototype information

Item	Specification
SSD Capacity	1TB
Size of a Zone	1GB
Number of Zones	1024
Interface	PCIe Gen3
Protocol	NVMe 1.2.1

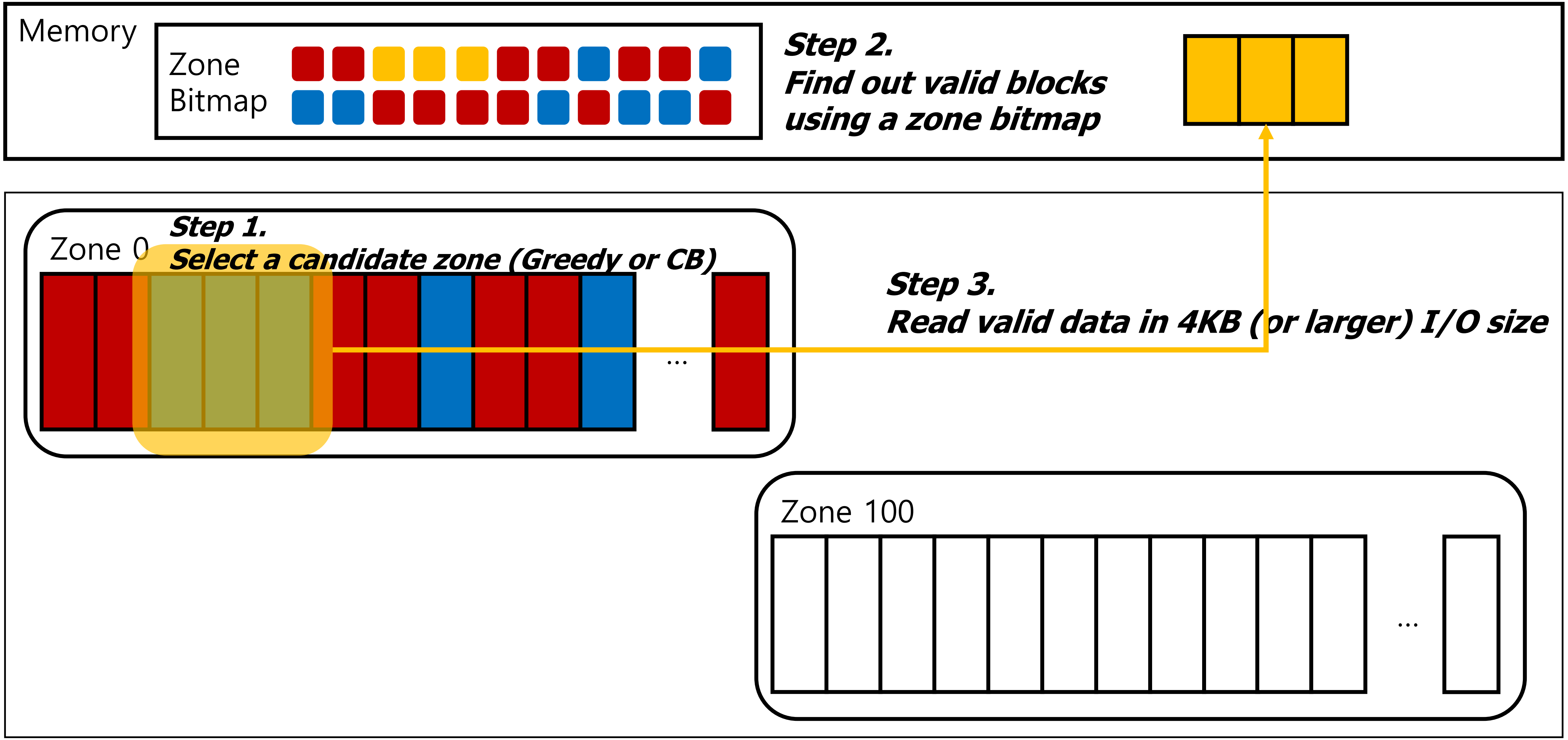
Basic Zone Garbage Collection (Basic_ZGC)



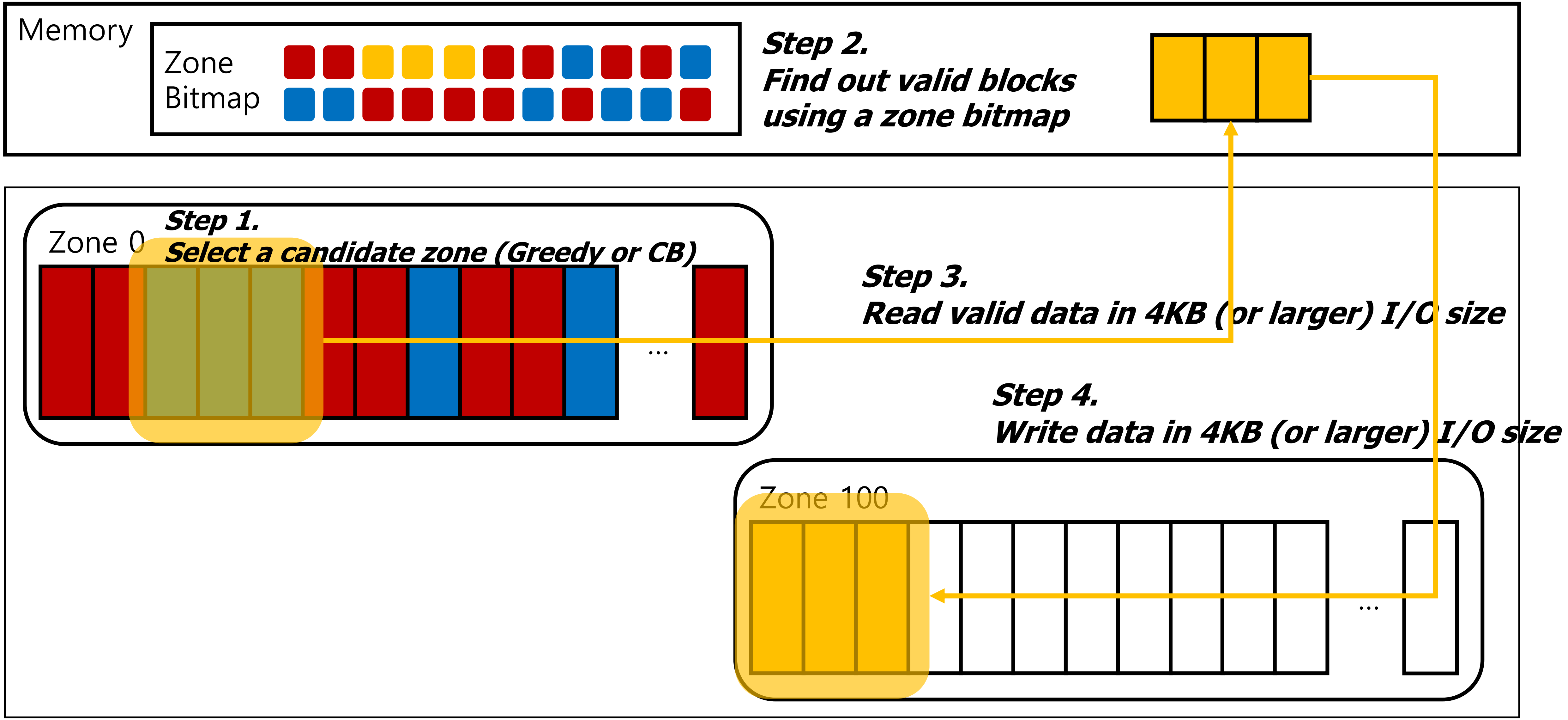
Basic Zone Garbage Collection



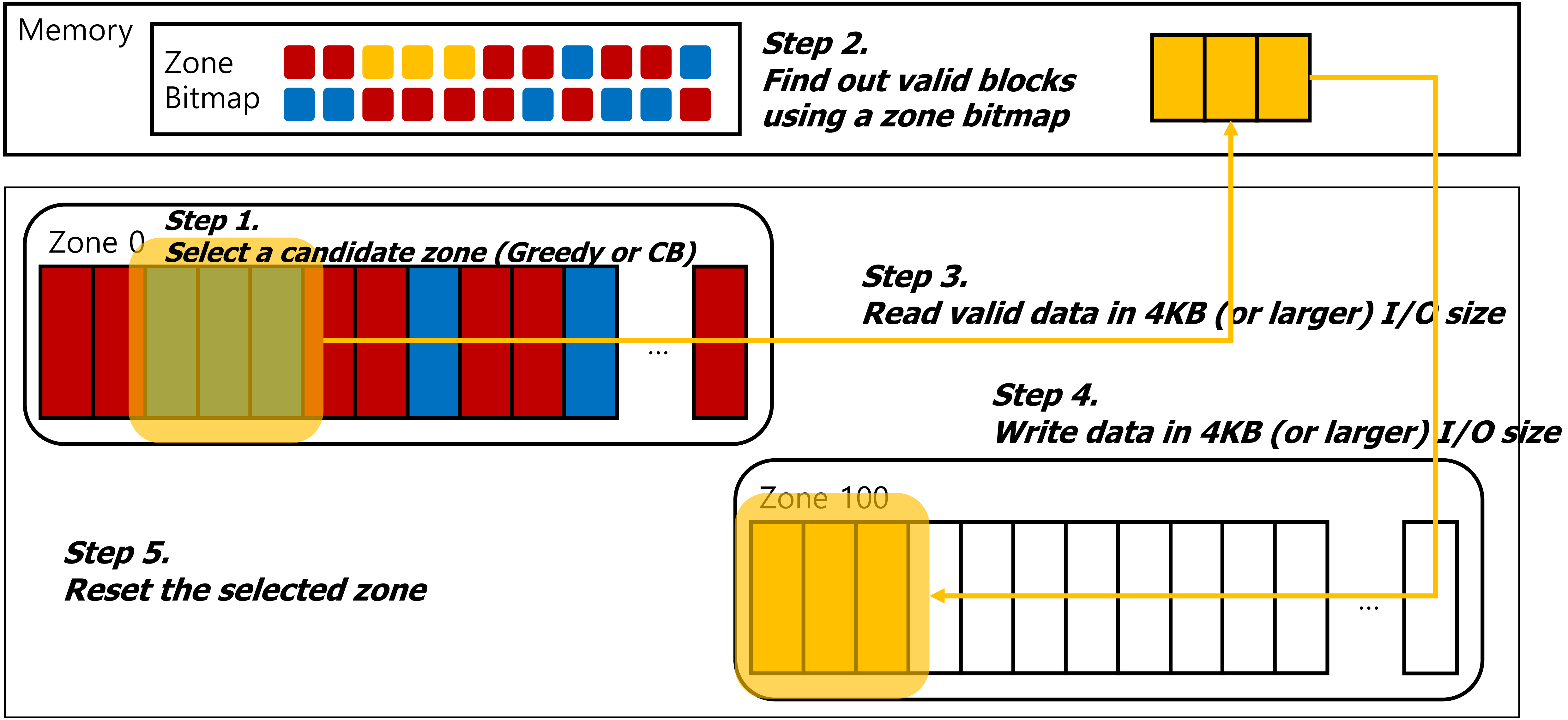
Basic Zone Garbage Collection



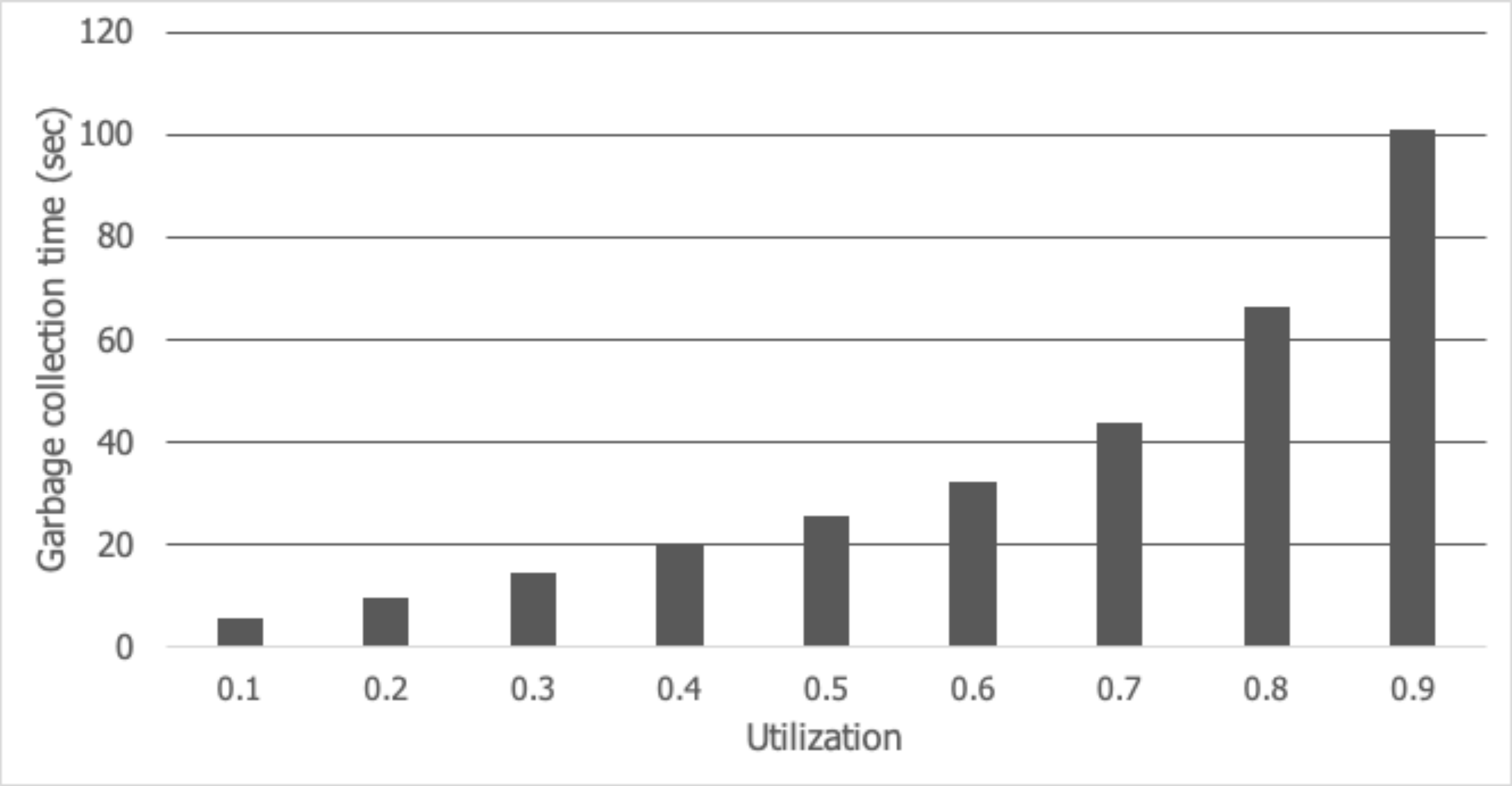
Basic Zone Garbage Collection



Basic Zone Garbage Collection

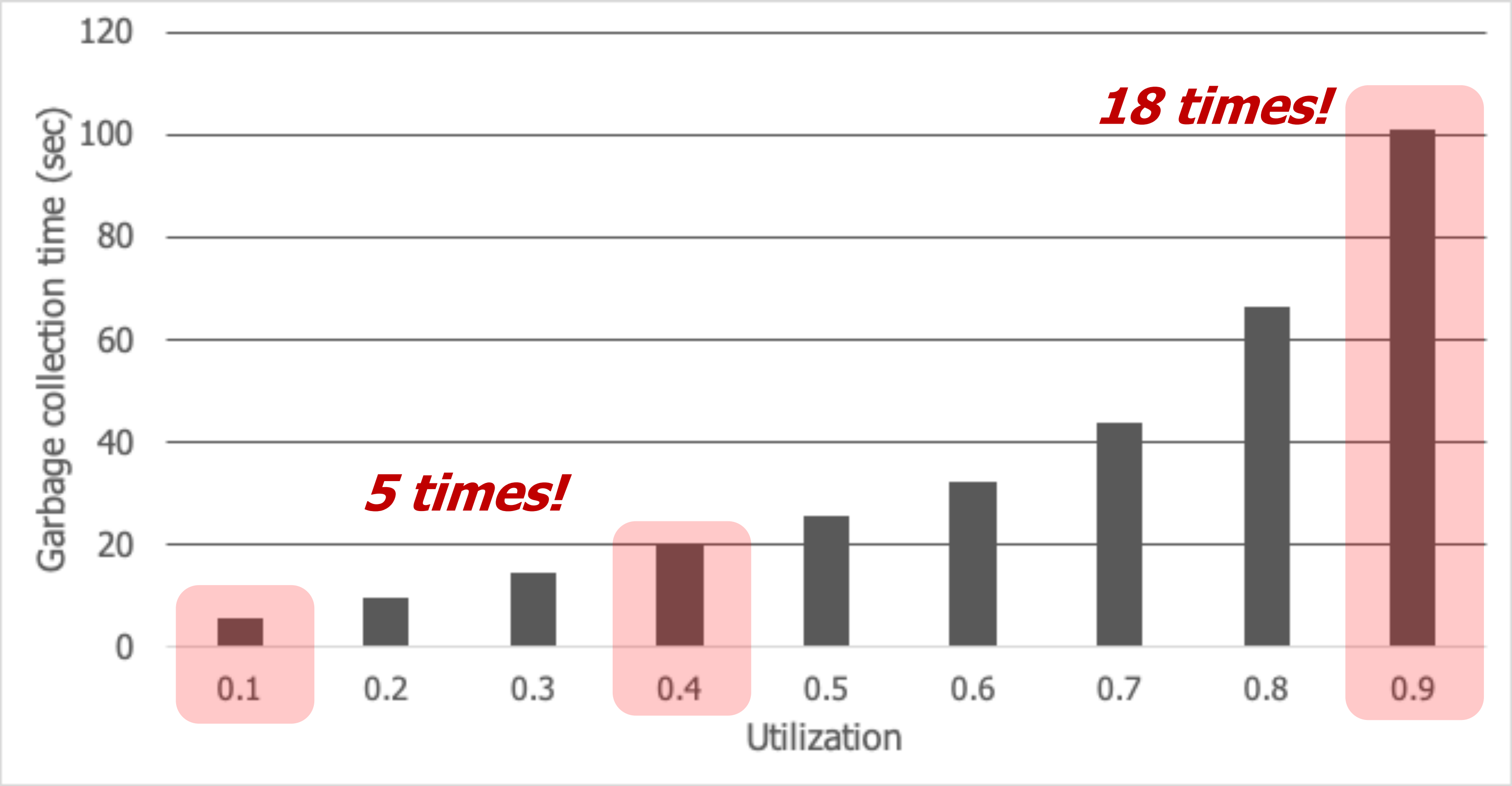


Observation 1: Zone garbage collection overhead



- Zone : 1GB
- Block : 4KB

Observation 1: Zone garbage collection overhead



- Zone : 1GB
- Block : 4KB

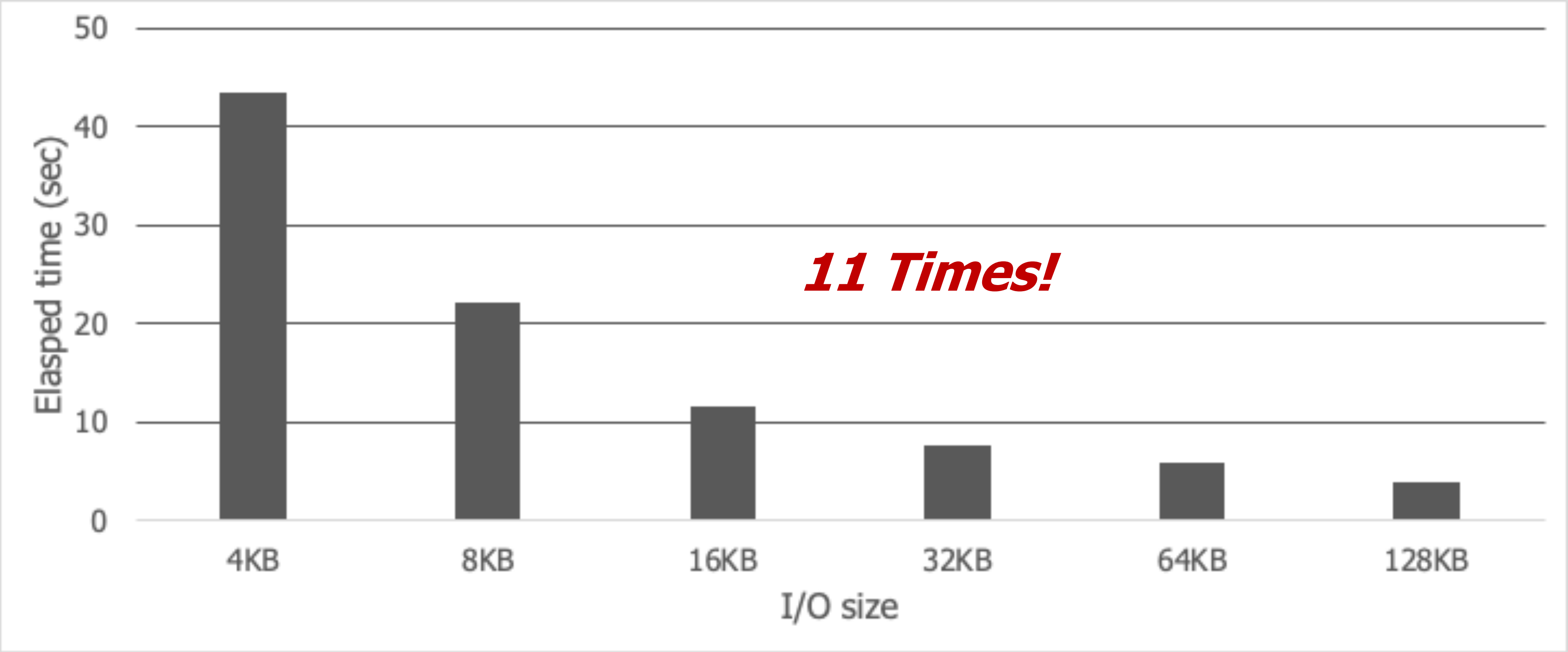
☞ ***Motivation 1: reducing utilization of a candidate zone is indispensable***

Observation 2: I/O size for Read/Write

- **Another feature of ZNS SSD**
  - ✓ **A zone is, in general, mapped into multiple channels/ways.**

- **Then, how about read/write data in a larger I/O size (e.g. 128KB)?**

Observation 2: I/O size for Read/Write



☞ ***Motivation 2: accessing in a larger I/O size is beneficial in ZNS SSDs***

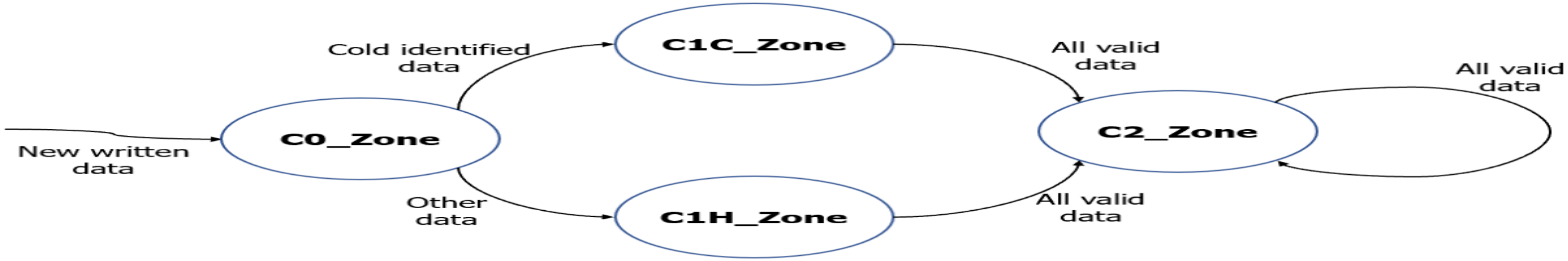
So, Our ideas are

1) Make the utilization of a candidate zone low
2) Access data in a larger I/O size

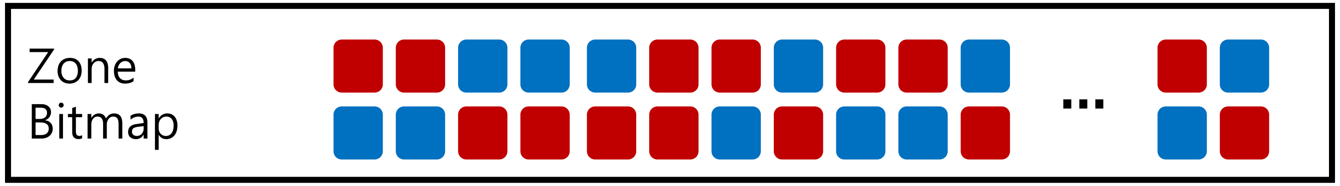
- **How to access data in a larger I/O size?**
  - ✓ **The coexistence of valid and invalid data makes it difficult**
  - ✓ **Read not only valid but also invalid data in a larger I/O size**

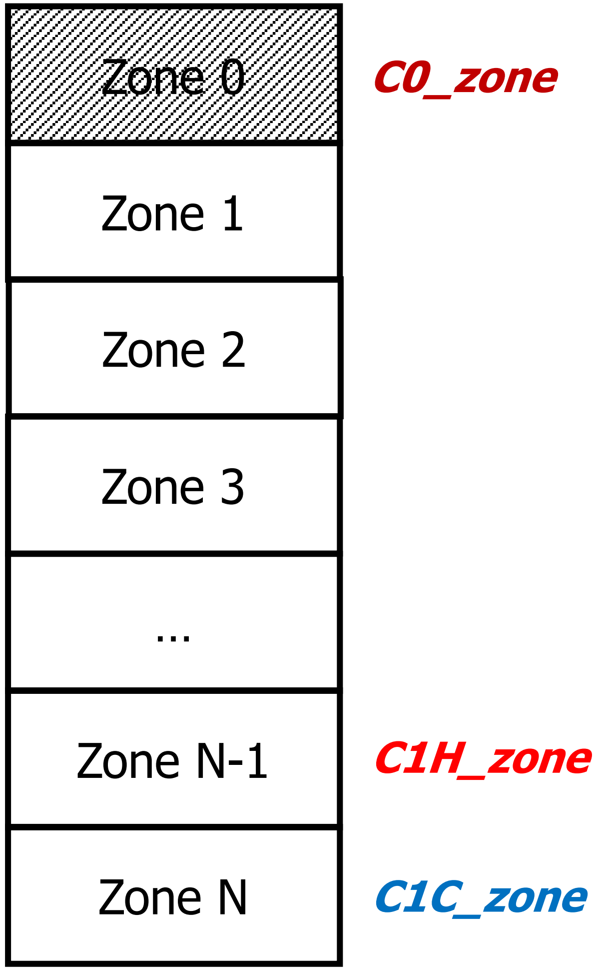
- **How to make the utilization of a candidate zone low?**
  - ✓ **Traditional hot/cold separation is not applicable in ZNS SSDs since zone is quite big**
  - ✓ **Employ the segment concept for finer-grained hot/cold separation**

- **Two management units**
  - ✓ **Zone: for garbage collection vs. Segment: for hot/cold separation**
  - ✓ **A zone is divided into multiple segments (1GB vs. 2MB in this study)**
- **Segment state and transition rule (refer to our paper for details)**
  - ✓ **New data ➔ C0**
  - ✓ **During ZGC, survived data from C0**
    - **Data in a high utilized segment (> threshold_{cold}): cold ➔ C1C**
    - **Others: hot (or unknown) ➔ C1H**
    - **Reasoning: spatial locality, also observed in previous studies such as F2FS (FAST'15), Multi-stream (FAST'19), Key-range locality (FAST'20)**
  - ✓ **During ZGC, survived data from C1C or C1H (second survived data)➔ C2**



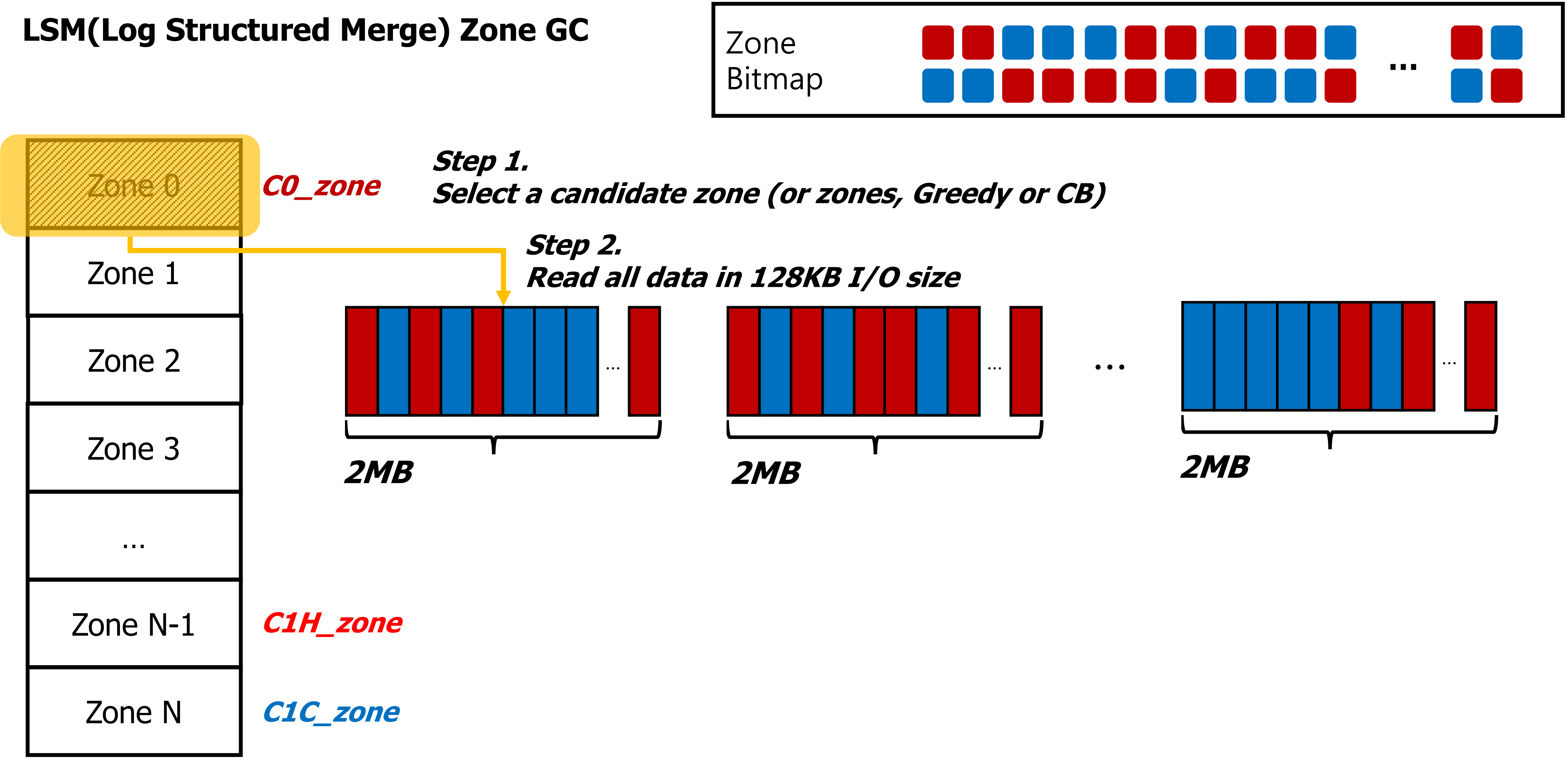
LSM(Log Structured Merge) Zone GC





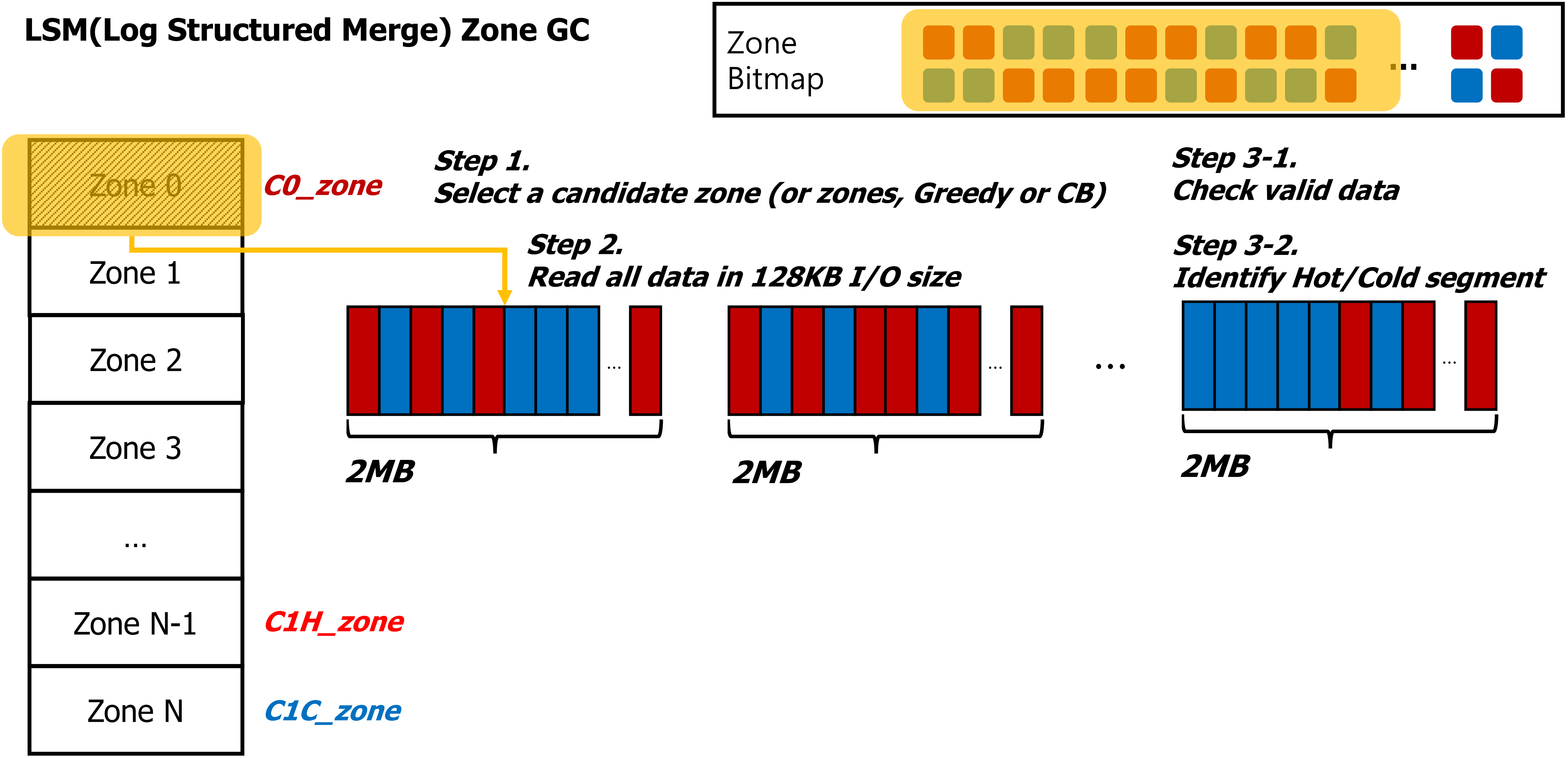
Step 1.
Select a candidate zone (or zones, Greedy or CB)

LSM(Log Structured Merge) Zone GC



3. LSM-ZGC Design

LSM(Log Structured Merge) Zone GC



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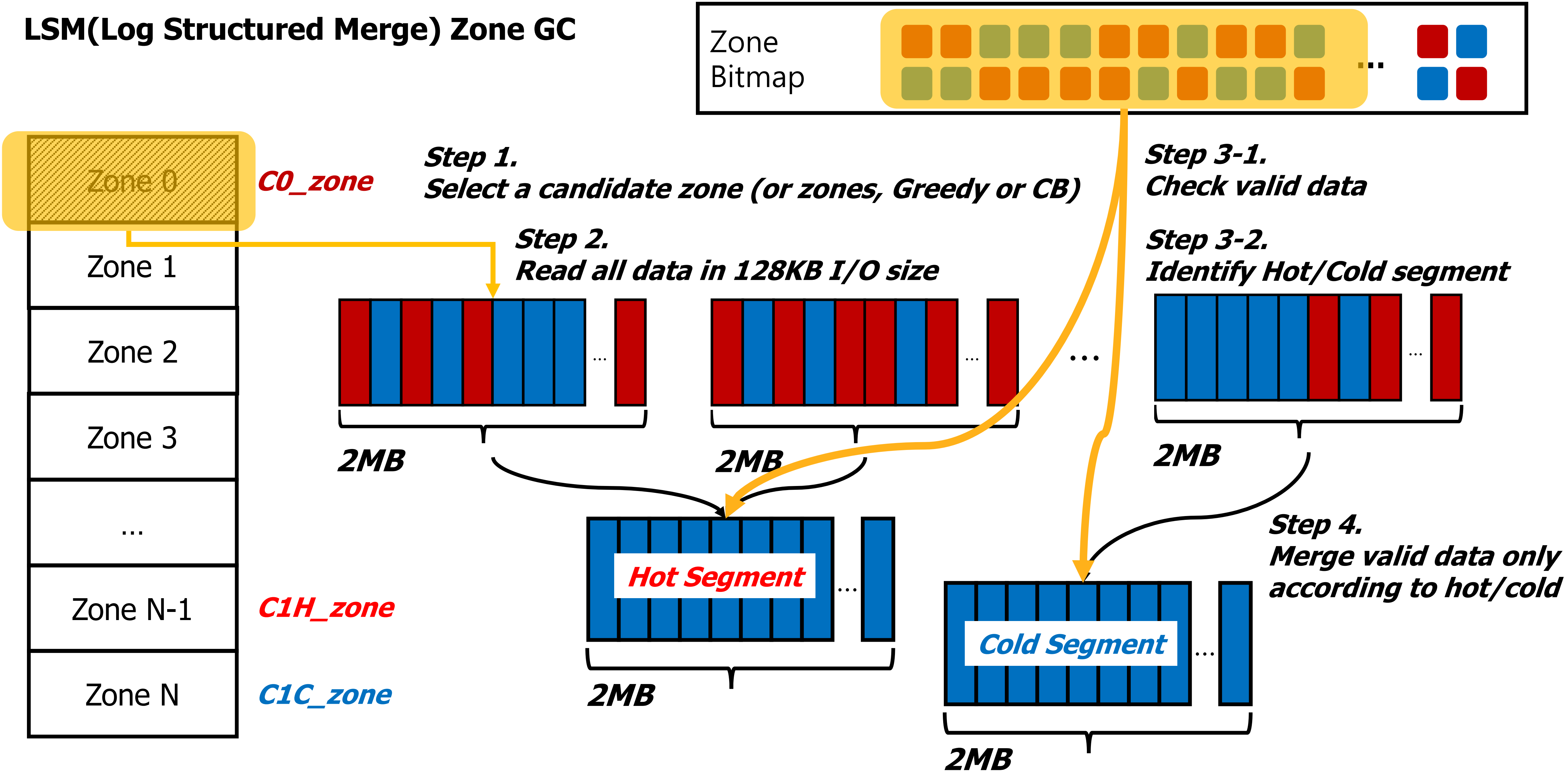
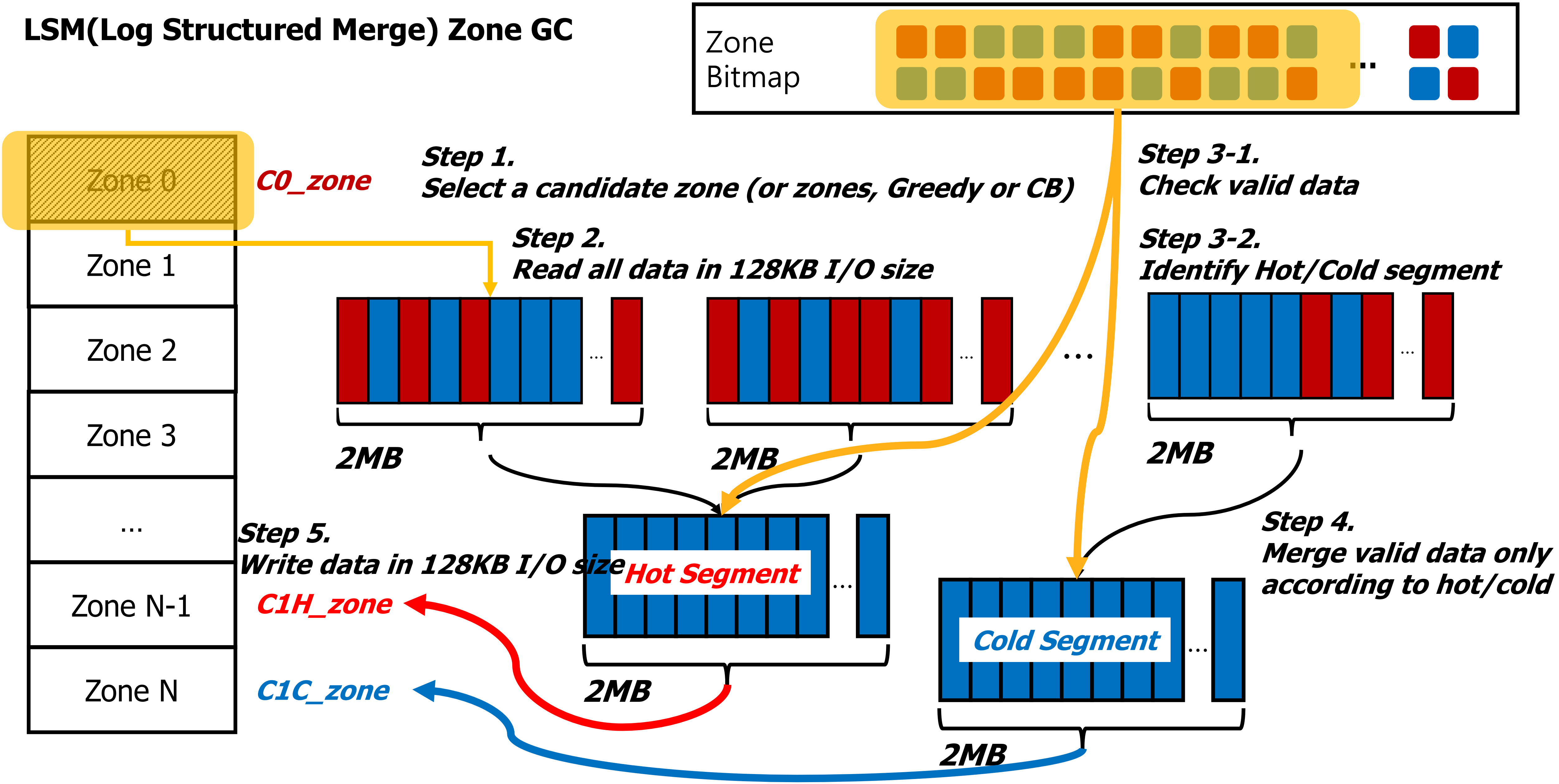
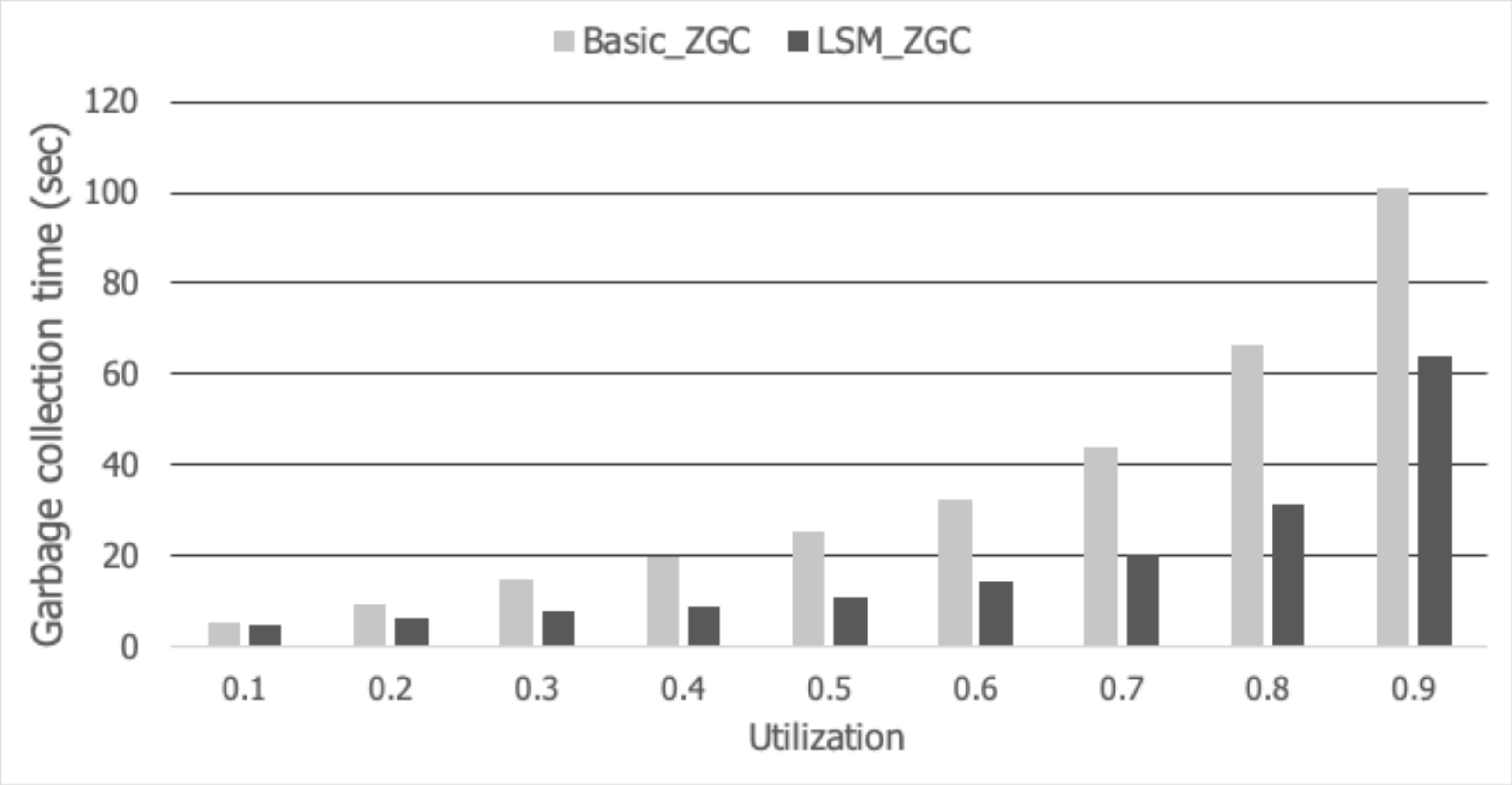


LSM(Log Structured Merge) Zone GC



Garbage collection overhead: uniform update pattern



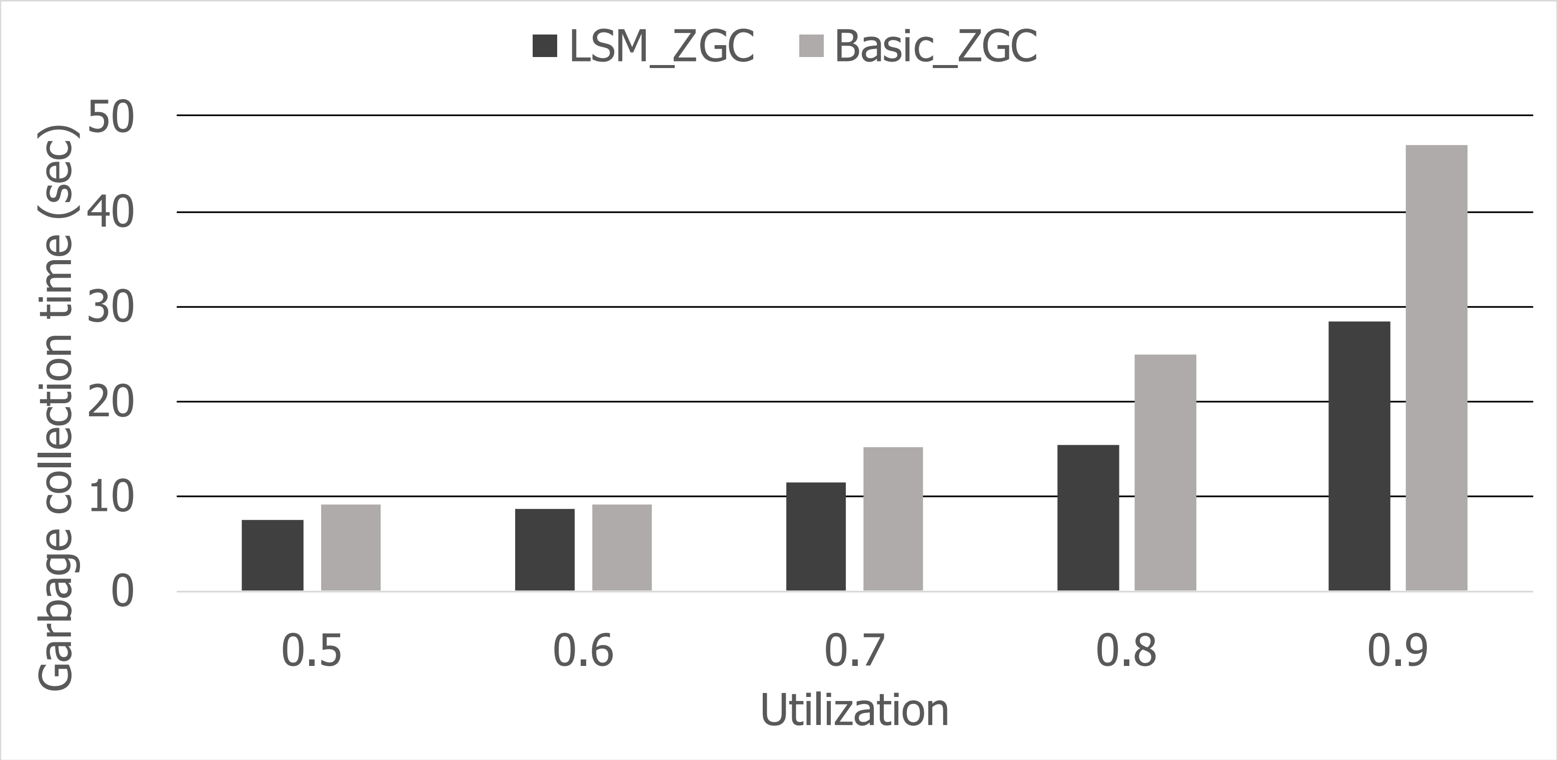
Average of 1.9 times

Max of 2.3 times

Experimental environment

- Intel Core i7 (8 core)
- 16GB DRAM
- 1TB ZNS SSD
- Size of Zone : 1GB

Garbage collection overhead: skewed update pattern



Average of 1.4 times

Max of 1.6 times

Parameters

- Workload: 70/30 hot/cold ratio
- Threahold$_{cold}$: 0.8
- average utilization: x-axis

Experimental environment

- Intel Core i7 (8 core)
- 16GB DRAM
- 1TB ZNS SSD
- Size of Zone : 1GB

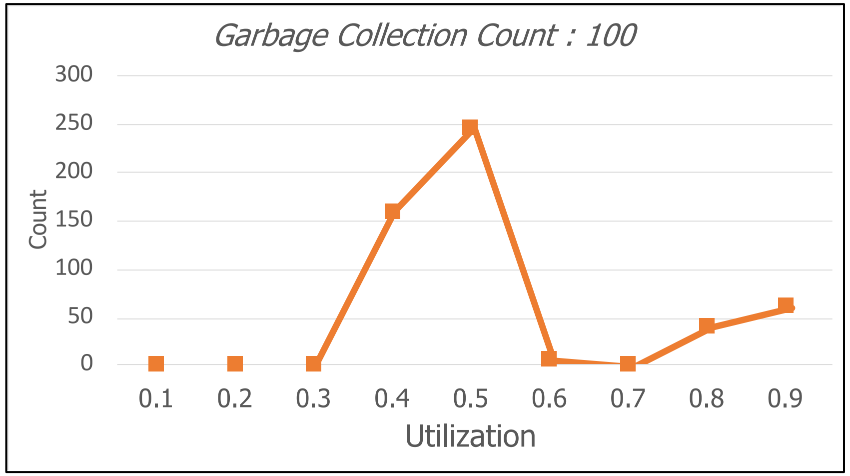
4. Evaluation

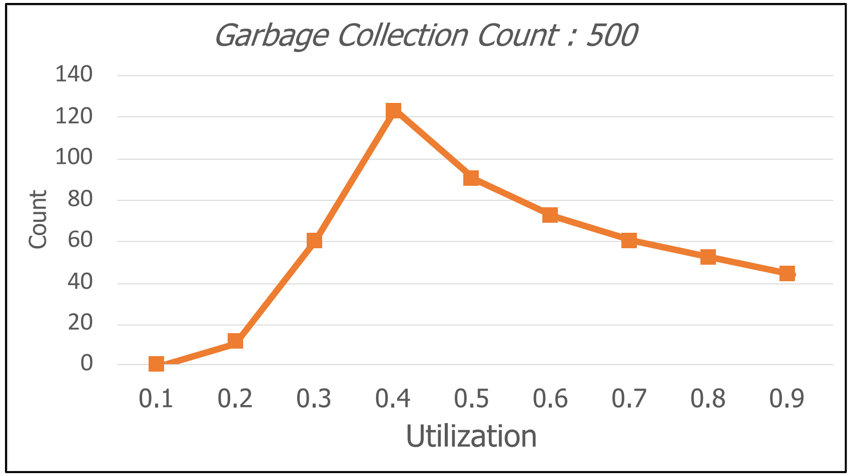
Parameters

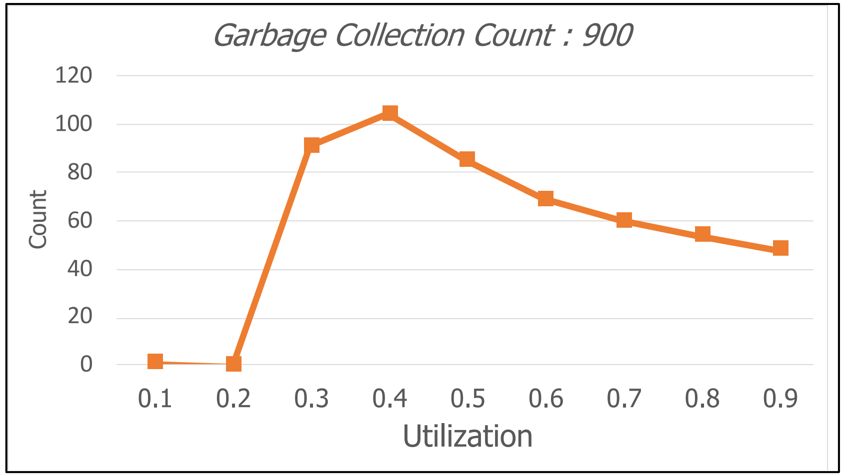
- Workload: 70/30 hot/cold ratio
- Threahold$_{cold}$: 0.8
- Average utilization: 0.6

Hot/Cold Separation

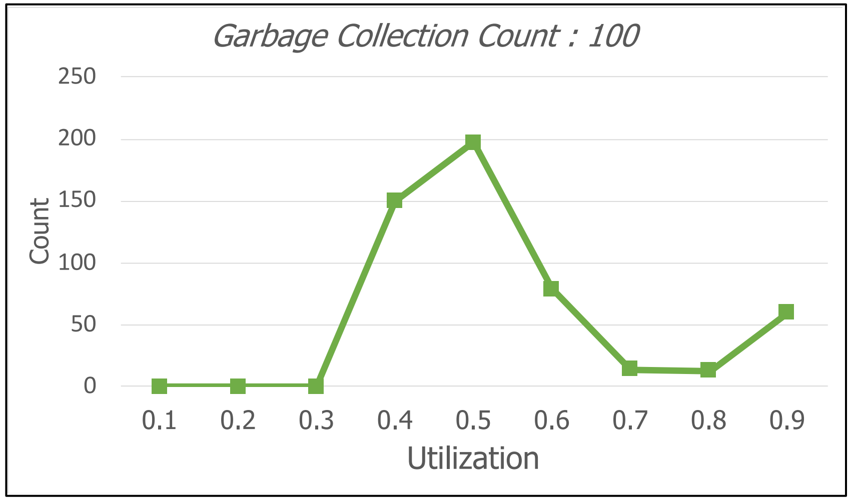
✓ Without hot/cold separation

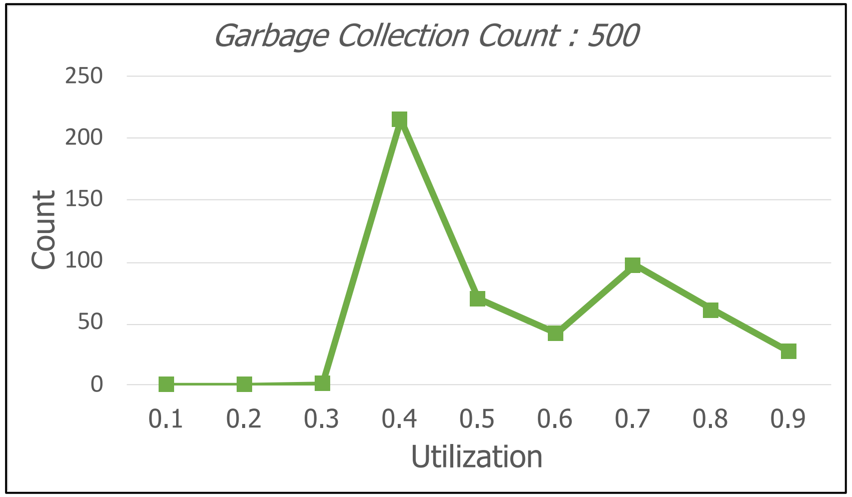


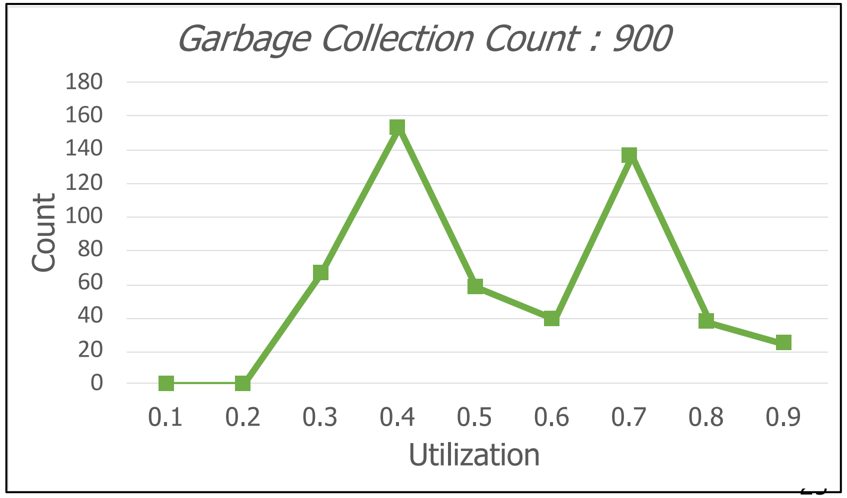




✓ With hot/cold separation







- **Our contributions**
  - *Observation: a zone garbage collection really matters*
  - *Proposal: a new LSM-style zone garbage collection scheme*
  - *Evaluation: real implementation based results*

- **Future work**
  - *We are currently extending F2FS on our ZNS SSD prototype*
  - *Also, evaluating LSM ZGC under diverse workloads with different hot /cold ratio, data size, initial placement and classification policies*

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Thank You!

Questions?

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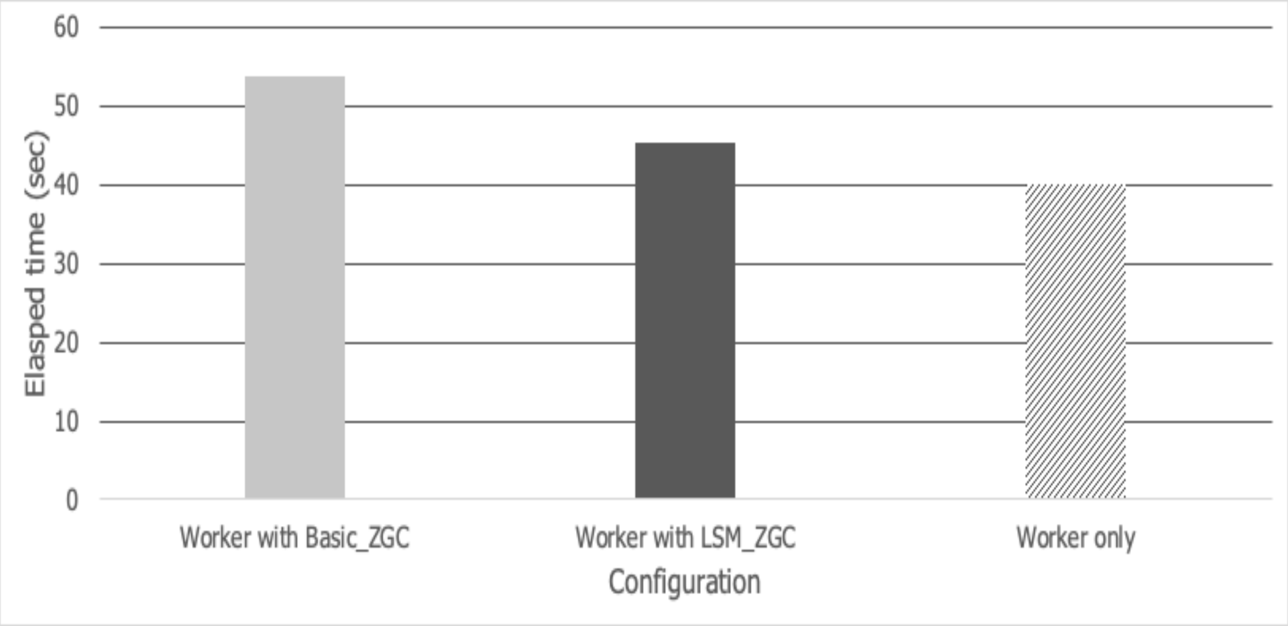
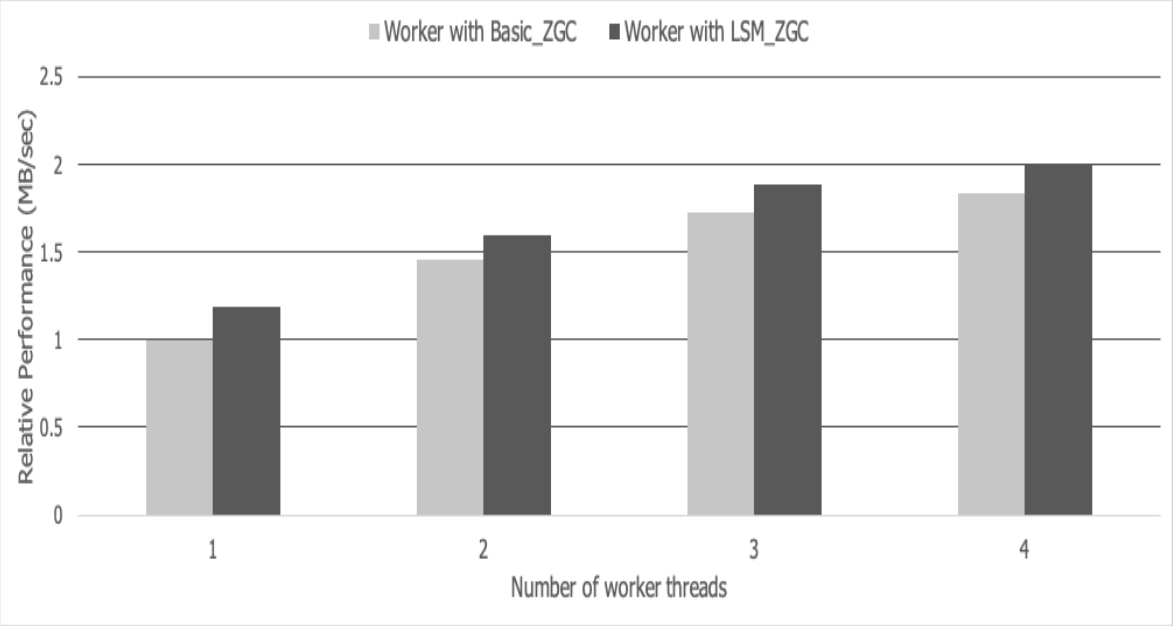
Performance comparison using multi-thread & Scalability





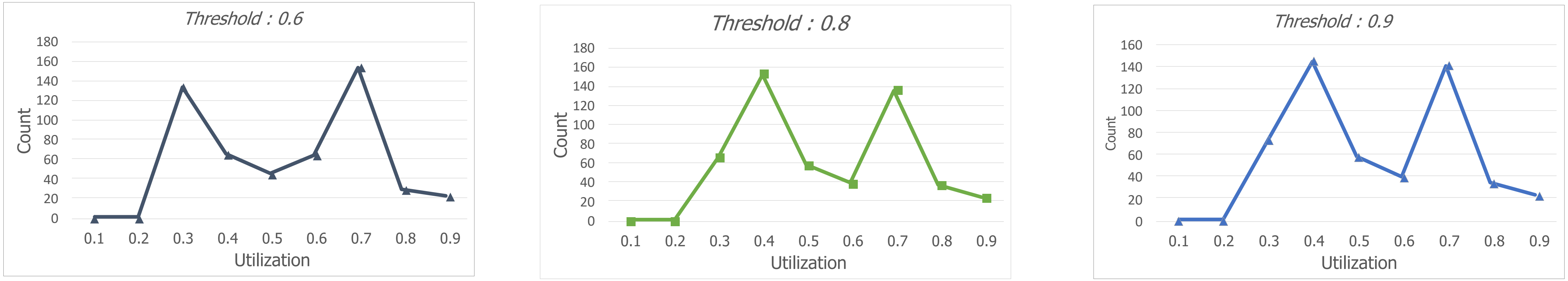
Worker only: 40
With LSM_ZGC : 45
With Basic_ZGC : 53

Non-linear Scalability

6. Appendix

Sensitive Analysis: various parameters

✓ Effect of threshold$_{cold}$ (initial utilization: 0.6)



✓ Effect of initial utilization of a zone (threshold$_{cold}$: 0.8)