Snapshots in a Flash with ioSnap™

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Snapshots Overview

- Point-in-time representation of the state of a storage device
- Snapshots are primarily used for backup, disaster recovery
  - Creates/deletes are common operations
  - Accesses/activates are rare operations
- Use Copy-on-Write (CoW) or Redirect-on-Write (RoW)

Why Rethink Snapshots for Flash?

- Flash is revolutionizing storage systems
  - Accelerating data centers, enterprise apps, desktops

- Natural fit for supporting snapshots
  - **Redirect-on-Write:** never overwrite existing data
  - **Log-structuring**: data ordered on their creation time (almost)

- Rate of data-change is higher for Flash devices
  - e.g., multi-threaded 8KB IOs, TB capacity device
    - **Flash**: 30K IOPS and device fills in *~1 hour*
    - **HDD** : 500 IOPS and device fills in *~3 days*

Snapshots in Flash Challenges

- Users are sensitive to performance variability
  - Need predictable performance all the time
- NAND flash has low endurance & inefficient in-place writes
  - In-place updates of reference counts not possible
- Cannot waste storage space for storing snapshot metadata
  - $/GB is high and need to keep costs low

ioSnap™ Overview

- First flash-aware snapshotting system
  - Leverages RoW in FTL to support snapshot operations
  - Supports large number of writable snapshots (2^{16})
  - Proposes usage of *epochs* in FTL to maintain log-time ordering
  - Embraces rate-limiting to minimize performance implications

- Performance Results (prototype built into Fusion-io VSL driver)
  - Instantaneous snapshot creation/deletion (~50usec, 4k metadata)
  - Matches vanilla read/write performance numbers
  - Provides predictable performance for foreground IOs

Outline

- Introduction
- ioSnap™ Design
- Evaluation
- Conclusions

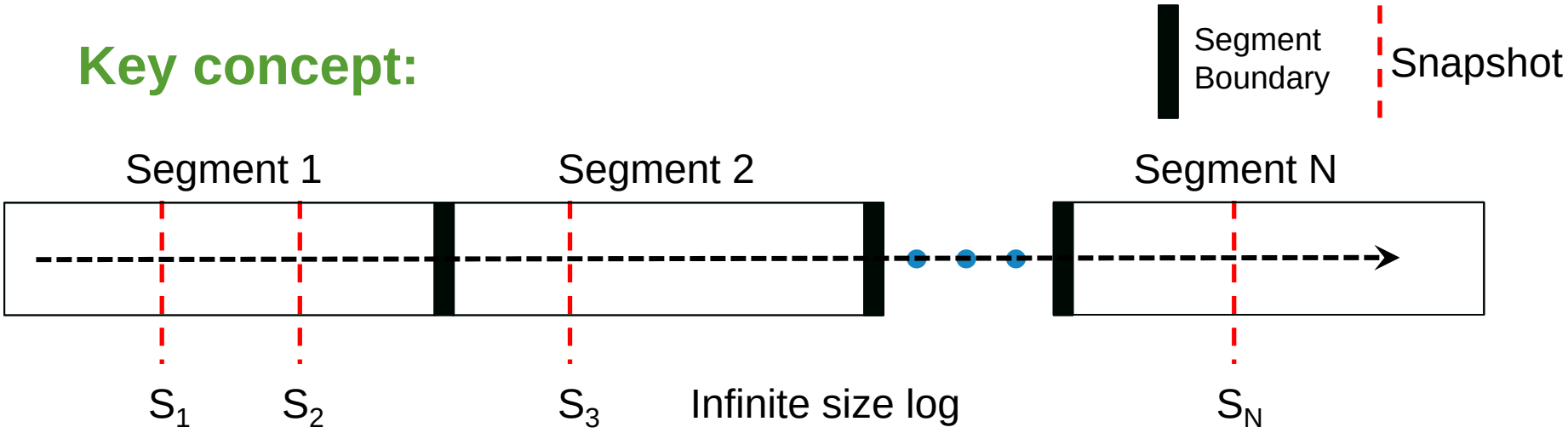
Design Goals

Goals

- Negligible impact on foreground performance
- Predictable foreground performance
- Minimal space overheads for snapshot metadata
- Integrate with existing FTLs

Creating / Deleting Snapshots in Flash

Key concept:



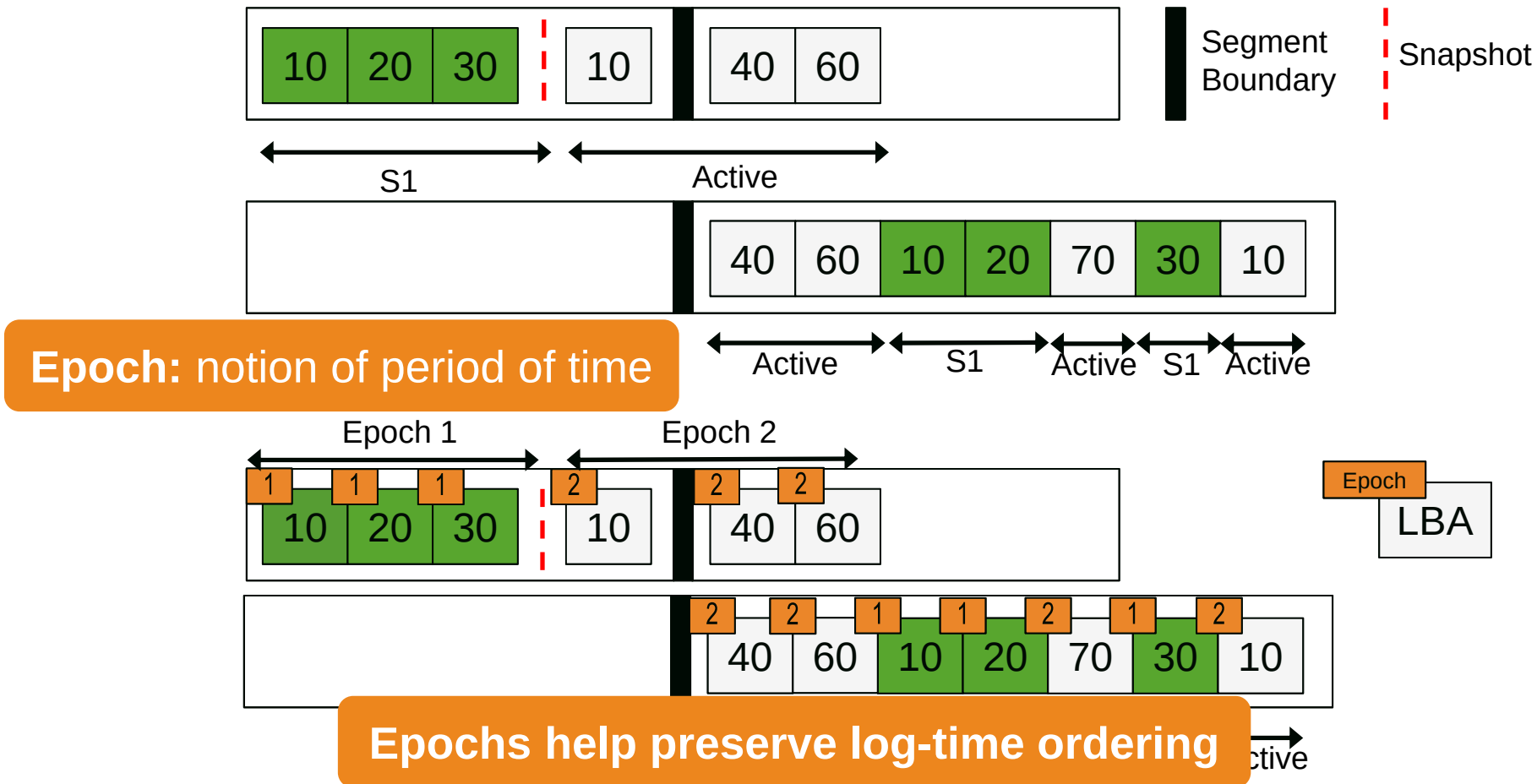
Creation: write a snapshot create note in the log

Deletion: write a snapshot deletion note

Snapshot creation/deletion is fast & negligible (fixed) metadata

Leverage time ordering of data in a log to create snapshots

Well What About Segment Cleaner?



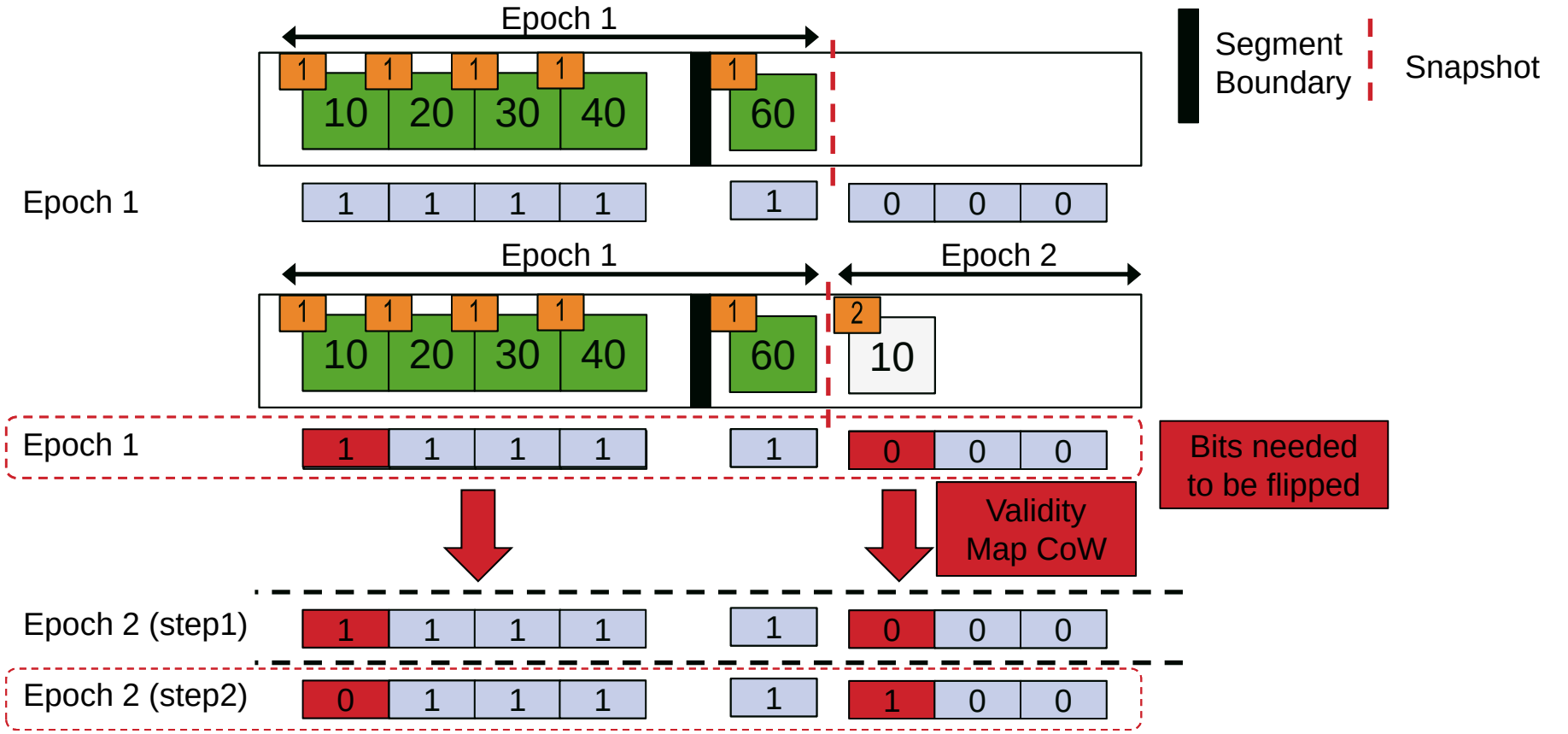
Managing Liveness of blocks

- **Issue:** snapshots indirectly increase the reference count
  - Validity bitmap with a single bit doesn't work

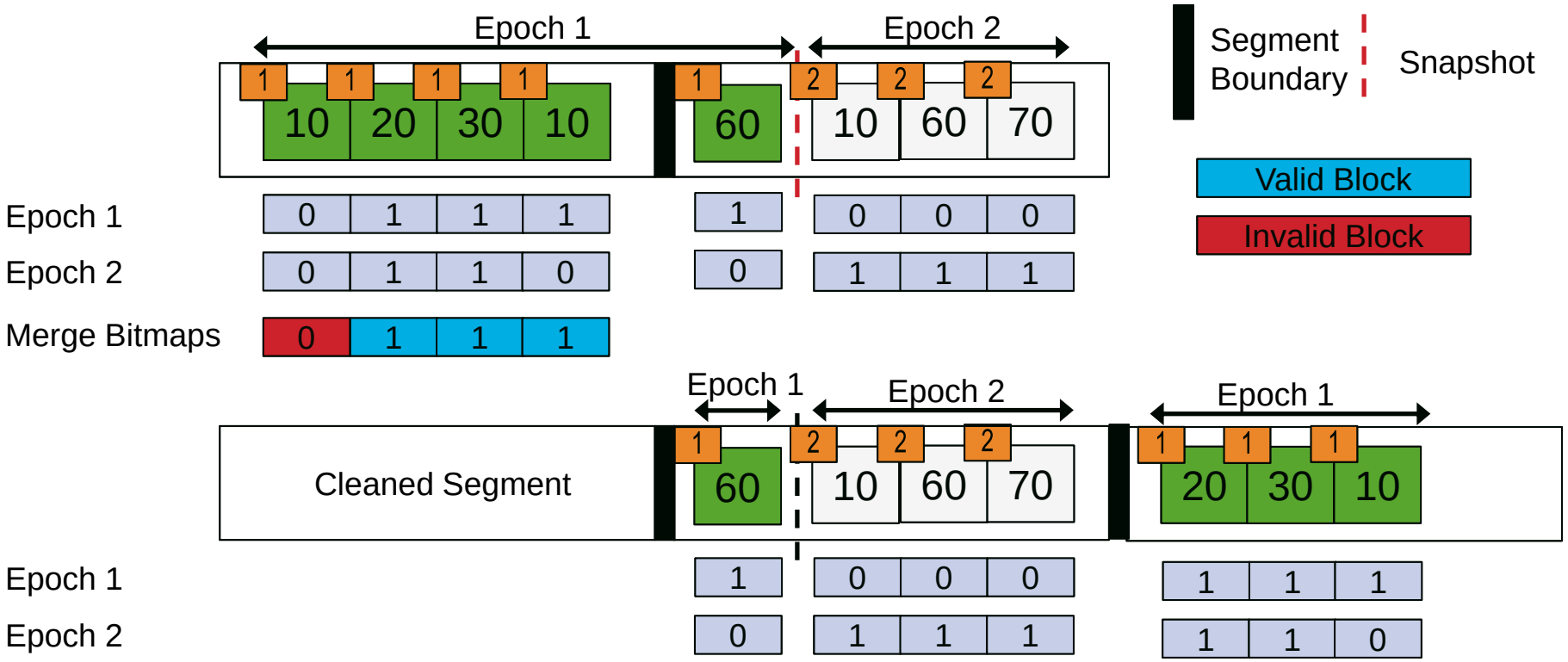
- Possible solutions:
  - Maintain more bits/block (2^{16} snapshot implies 16x increase in bitmaps)
  - Selectively maintain per sub-segment bitmap for snapshots
    - Only create a bitmap if a snapshot has (or modified) data in it

Insight: determine if a given block has at least **one** reference to it

Preserving Liveness Via CoW Validity Bitmaps



Snapshot-Aware Segment Cleaner



Segment cleaner preserves log-time ordering

Design Summary

- Leverage RoW and implicit time ordering in the Log
- Epochs preserve log-time ordering even with a cleaner
- Sub-segment-level bitmaps to track validity of blocks
- Snapshot-aware cleaner preserves log-time and block validity

- Snapshot management
- Background snapshot activation
- Rate-limiting to provide predictable foreground performance

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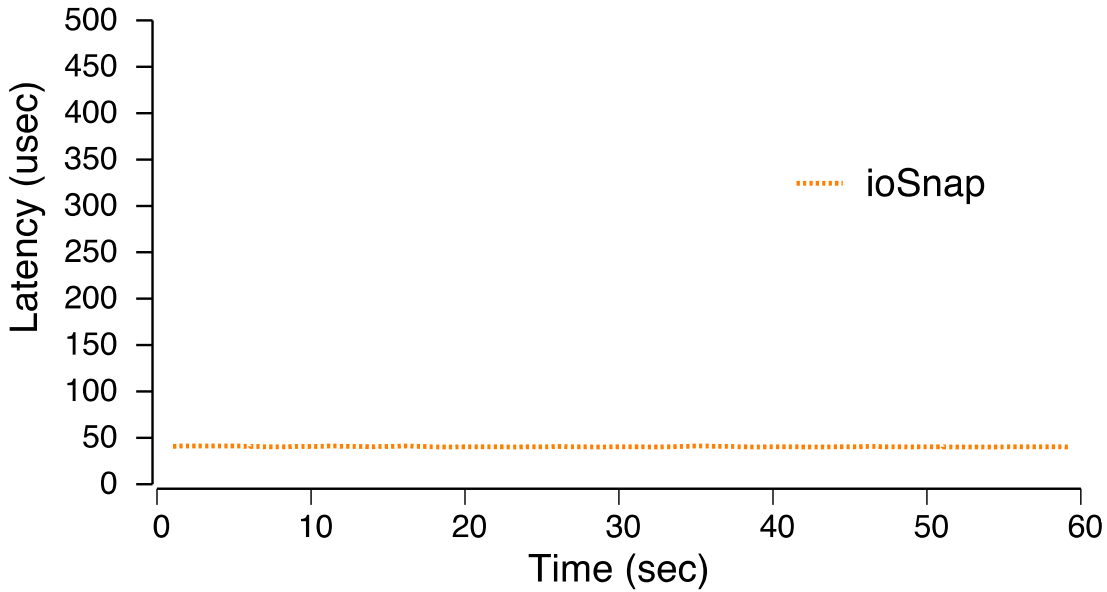
Evaluation

- How does it compare with existing snapshotting systems?
- What's the impact on user IOs in the absence of snapshots?
- Snapshot creation/deletion time? Implications on user IO?
- Implications of a snapshot-aware segment cleaner?
- How long does it talk to activate a snapshot?
- Implications on the crash recovery mechanism?

Setup: quad core Intel i7 processor, 1.2TB NAND flash, 12GB RAM, Linux 2.6.35, older generation of Fusion-io VSL driver, 4K Block sizes

Comparison with BTRFS (1)

Impact on foreground latency upon snapshot creation



Around 8 GB of sequential writes followed by a random workload interspersed by a snapshot every 5 sec

Snapshots in ioSnap does not impact foreground latency

Conclusions

"Make everything as simple as possible, but not simpler."

– Albert Einstein

- Flash is revolutionizing the storage industry
  - Rethink data services to leverage flash's capability & performance
- **ioSnap:** first flash-aware snapshotting system
  - Leverages RoW capability in FTLs to implement snapshots
  - Proposes usage of epochs to preserve log-time ordering
  - Low-overhead instantaneous snapshots (*performance & storage*)
  - Embraces rate-limiting to minimize impact to foreground traffic
  - Activations are slow & can be 10s of sec for a TB size snapshot

Thank you