Introducing Fast Dedup

October 2023

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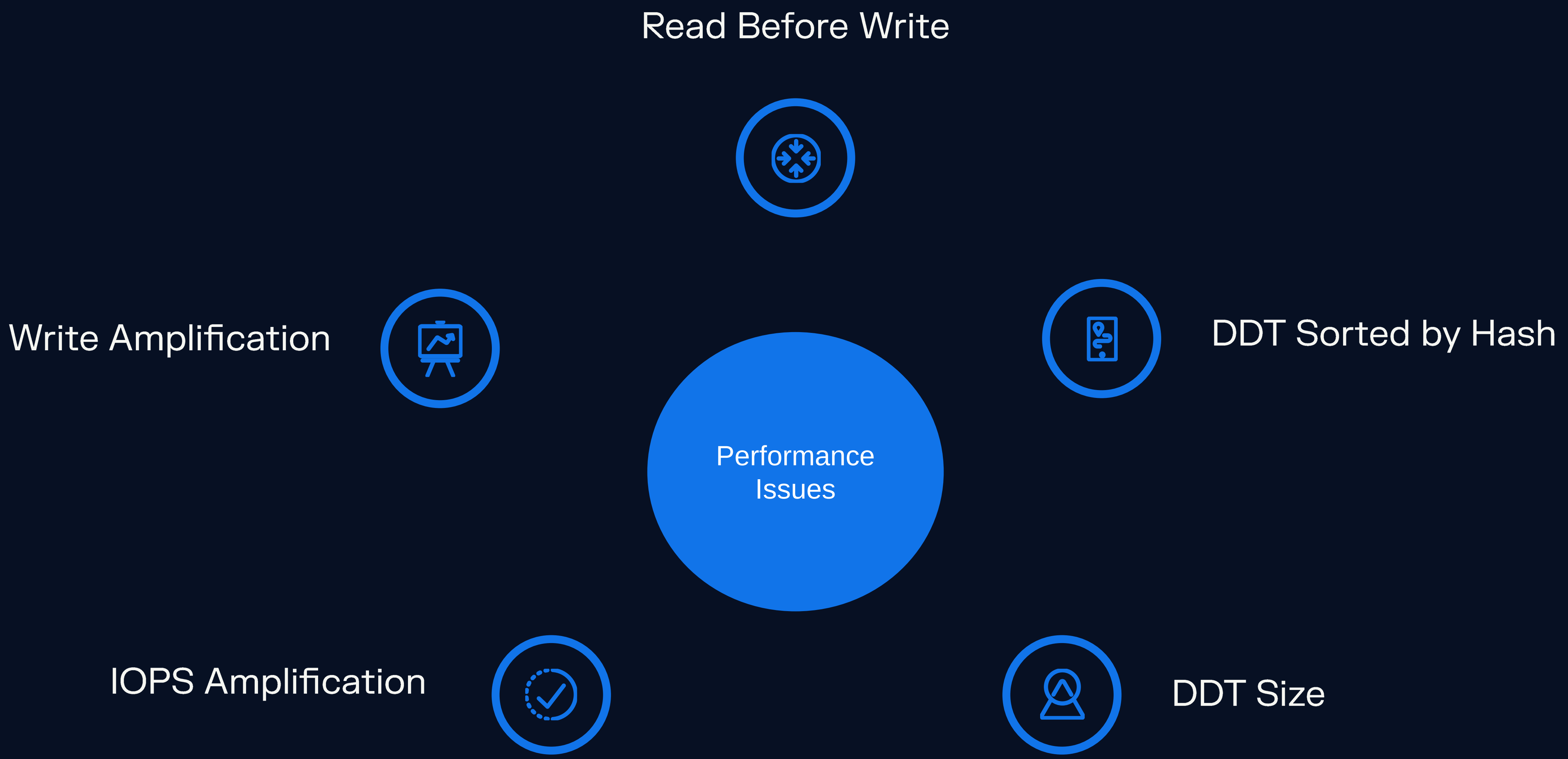
Agenda

1. What Makes Dedup Slow
2. DDT Data Structure
3. Log Dedup
4. Dedup Quota and ZAP Shrinking
5. Pruning and Preload
6. Benchmarks
7. Future Work
8. Q and A

What Makes Dedup Slow



Read Before Write

Write Amplification

DDT Sorted by Hash

Performance Issues

IOPS Amplification

DDT Size

DDT Data Structure

struct ddt_key

- [32] Checksum
- [8] Properties (Compression, PSIZE, LSIZE)

struct ddt_entry

- [256] 4x ddt_phys_t (DITTO, SINGLE, DOUBLE, TRIPLE)
  - [48] 3x DVAs (up to 3 copies)
  - [8] Reference Count
  - [8] Physical Birth TXG

DDT Data Structure

struct ddt_key

- [32] Checksum
- [8] Properties

struct ddt_entry

- [256] 4x ddt_phys_t
  - [48] 3x DVAs
  - [8] Reference Count
  - [8] Physical Birth TXG

struct ddt_key

- [32] Checksum
- [8] Properties

struct ddt_entry

- [72] 1x ddt_phys_t
  - [48] 3x DVAs
  - [8] Reference Count
  - [8] Class change timestamp
  - [8] Physical Birth TXG

Log Dedup

- Write new FDT changes to an append-only log
- Maintain these changes with in-memory AVL tree
- Once log reaches a max size or age, flush to ZAP
- Amortize cost by writing to ZAP in hash order

FDT AVL Trees

- Each TXG, move new entries to the FDT AVL

- Append changes to on-disk FDT-log object

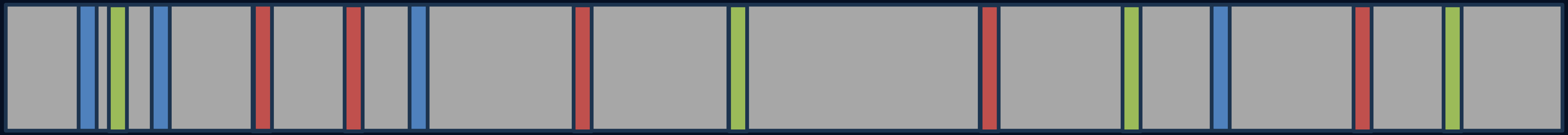
- At pool import, read on-disk FDT-log object
- Larger logs → increased import time

- Entry lookup: Order: Dedup AVL, FDT AVL, ZAP

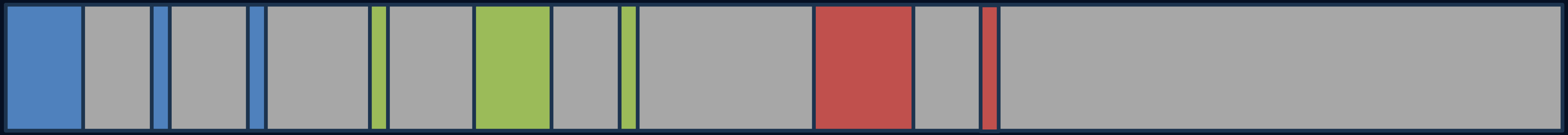
FDT Flushing

- Write changes back to the ZAPs
- Walk the AVL tree in hash order, do some writes
- If more to do, save a checkpoint, resume next TXG
- Checkpoint get written to the bonus buffer
- If finished, truncate the on-disk log, empty the AVL

Comparing ZAP Updates: Dedup



Comparing ZAP Updates: FDT



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Other Improvements

What else can we fix about Dedup

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Dedup Preload

DDT Preload

- DDT performs best when cached in the ARC
- New zpool load –t fdt command
- Load the entire FDT into the ARC
- Also can be trigger automatically at import

Dedup Quota and ZAP Shrinking

Implement a Quota on FDT Size

- Constrain growth to RAM or dedup vdev capacity
- Avoid performance cliff when DDT spills to HDDs

ZAP Shrinking

- DDT is implemented as ZAPs, shrinking required for Quota to be effective, otherwise growth never resumes
- Will also apply to directories, as a bonus

FDT Pruning

- FDT is split into 2 ZAPs: UNIQUE and DUPLICATE

- Prune from the UNIQUE list to keep the FDT small
- Requires special handling during frees

- Purge the oldest entries that have never dedup’d
- Use a new timestamp instead of birth time

Using Fast Dedup

- zpool set feature@fast_dedup=enabled poolname
- zpool set dedup_quota=48G poolname
- zpool set dedup_prune_policy=60d poolname
- zfs_dedup_log_mem_max

Benchmarks

How big of a difference does it make?

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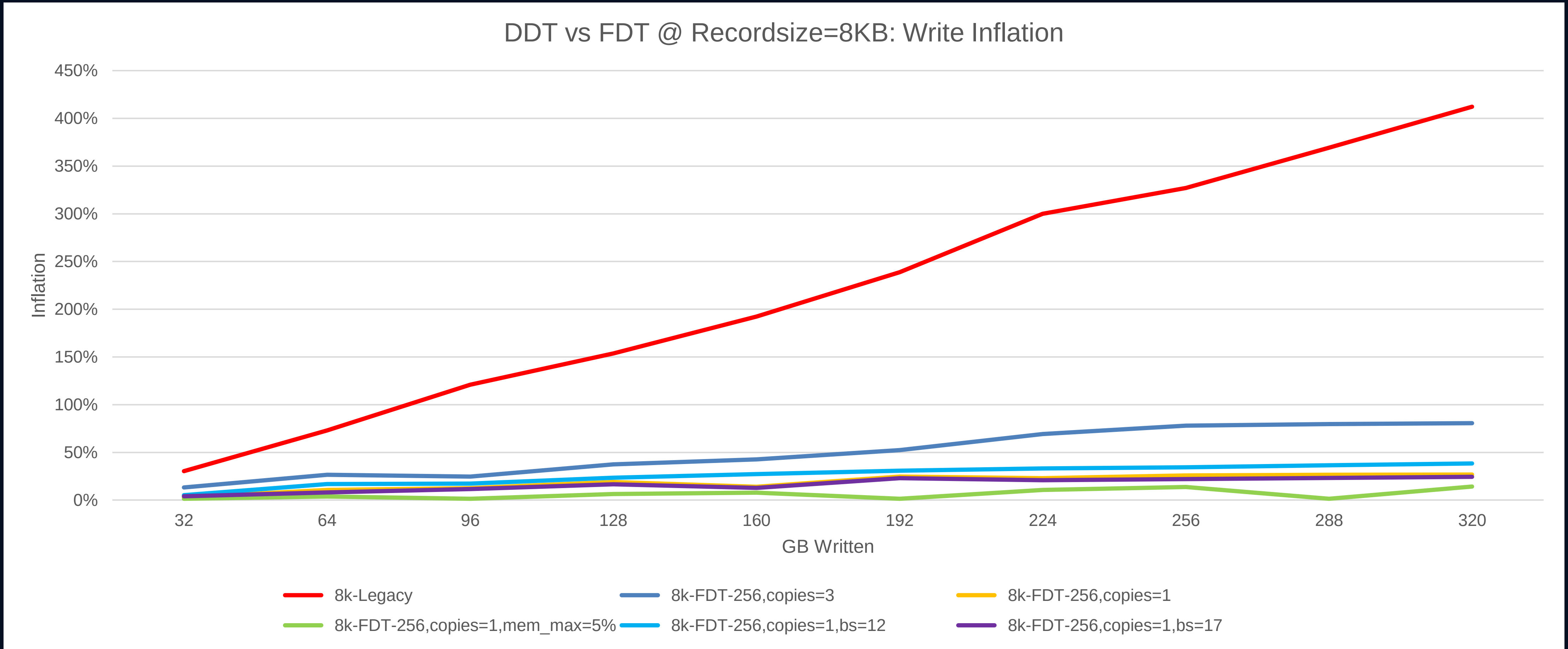
Testing Methodology

- 2x 512 GB SSDs, 32 GB RAM, 10 cores

- Write 8 KiB records with FIO
- Create dataset, write 8x4 GiB files (32 GiB total)
- Repeat in new datasets to increase DDT size, 10x

- After each iteration, export/import pool
- Record total writes to dedicated Dedup VDEV

Fast Dedup: Reduced Inflation



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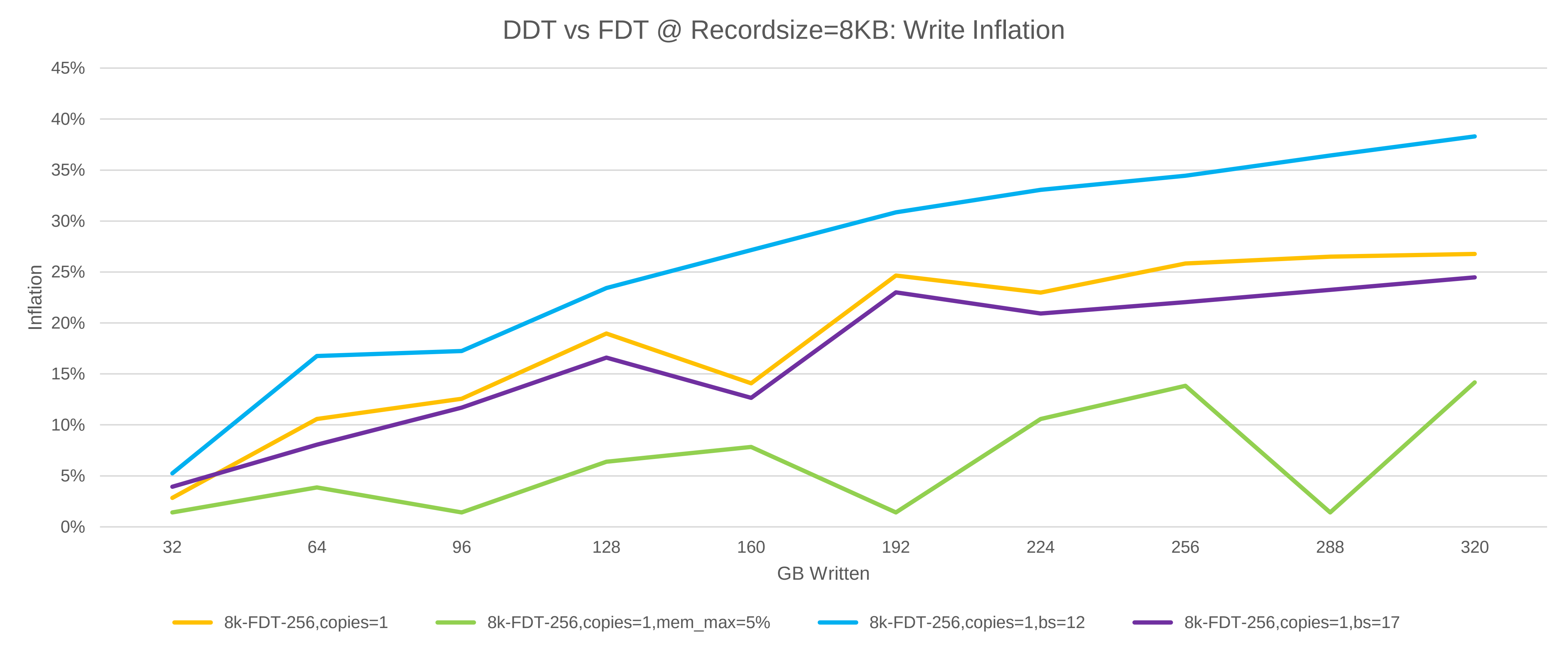
Fast Dedup: Reduced Inflation



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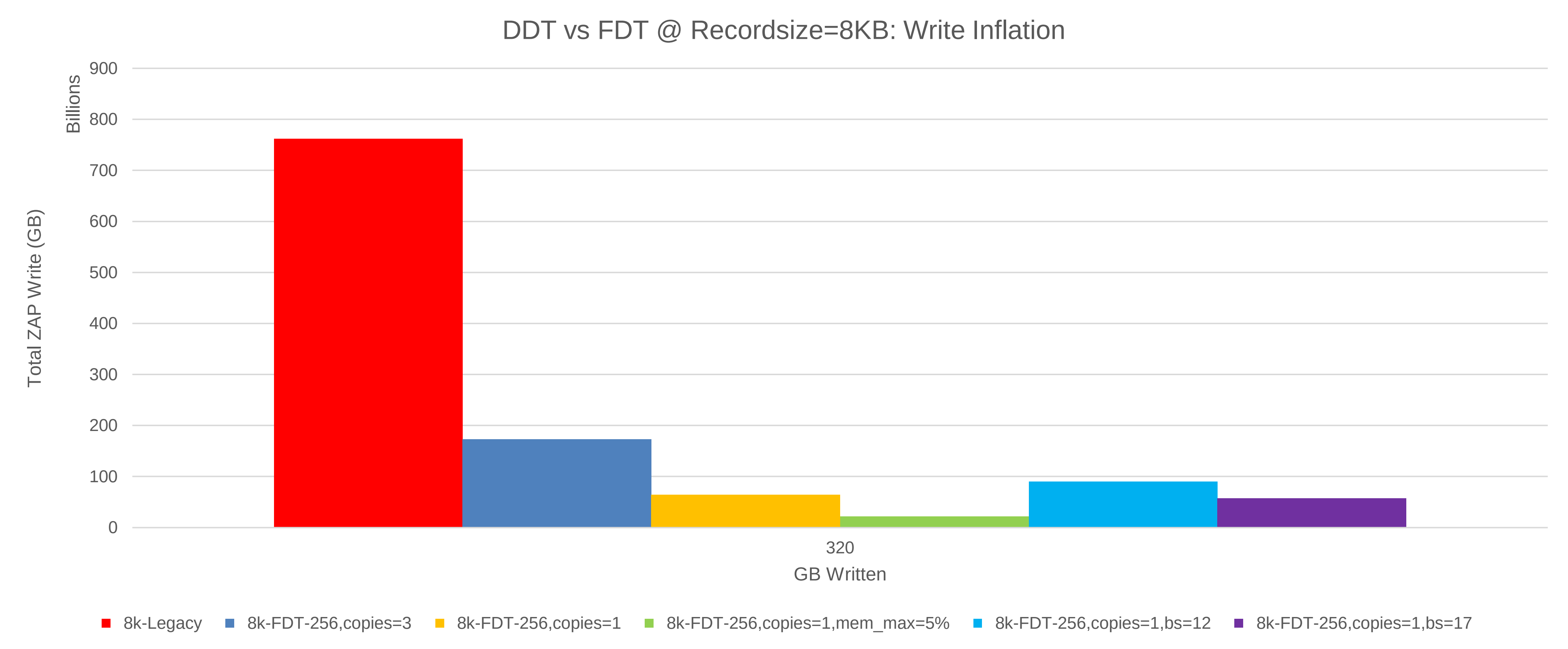
Fast Dedup: Reduced Wear



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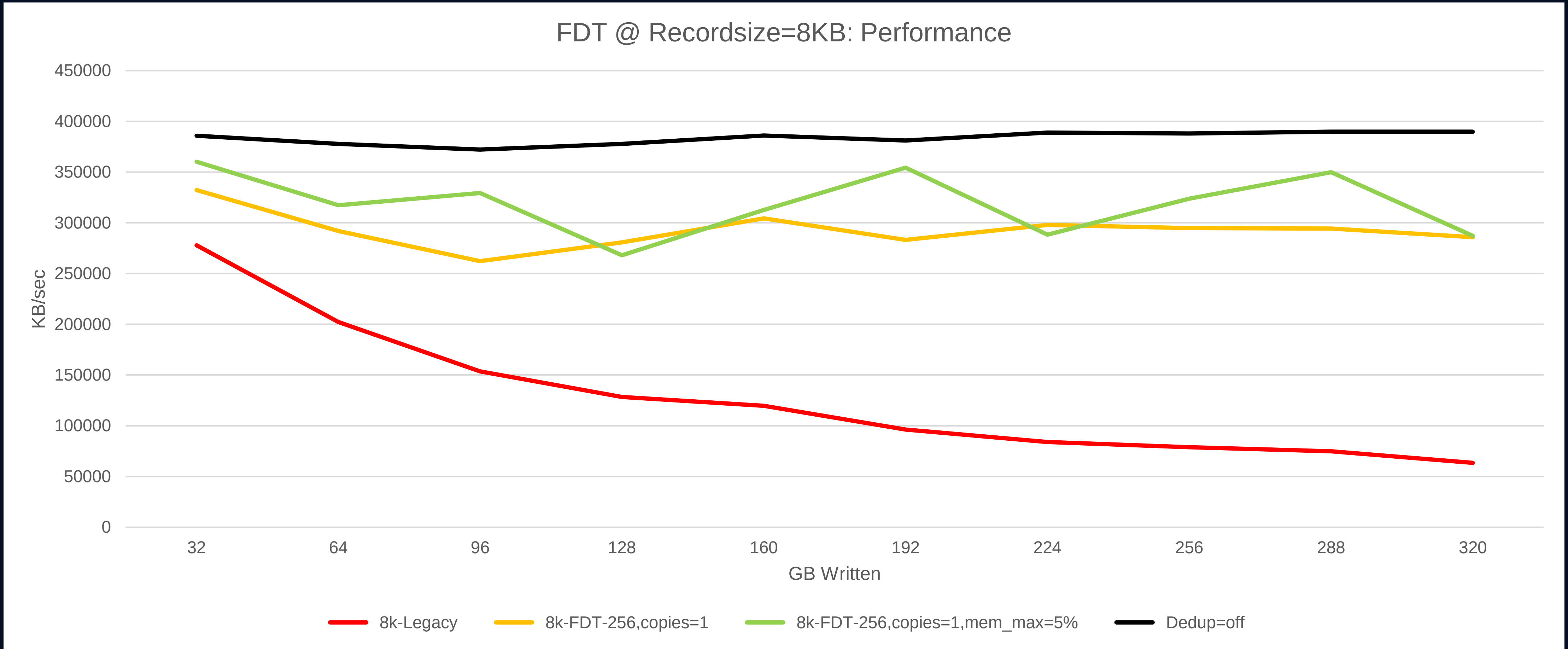
Fast Dedup: Increased Performance



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Future Work

What else can be improved?

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Last Call for Fast Dedup Sponsorship

Expected total cost of Development and Testing will be over $200K

- Planning for 5 people for 4+ months for development (75% complete)
- Initial design work completed by Jude and Motin - 3 months
- iXsystems and Klara have initiated project as Gold Sponsors

Seeking additional sponsorships for Development and Testing

- Gold = $30K = Design reviews, contributions and joint marketing
- Silver = $10K = Prototype access and Recognition (PR and source code)
- Bronze = $5K = Recognition and access to Slack developer channel

Sponsorship Process

- Fill in Sponsorship form or contact morgan@ixsystems.com
- Pay after a full set of PRs made to OpenZFS

OpenZFS Community will contribute to final testing prior to release

Further Optimization

- By default, all DDT ZAPs are copies=3
- This was thought important for DUPLICATES ZAP
  - Loss would be catastrophic

- However, we can now prune from UNIQUE ZAP
- If we detect an unreadable part of the ZAP:
  - Leak the space to avoid data loss
  - L2+ has copies++ so damage is limited to 256 L0s

Thanks

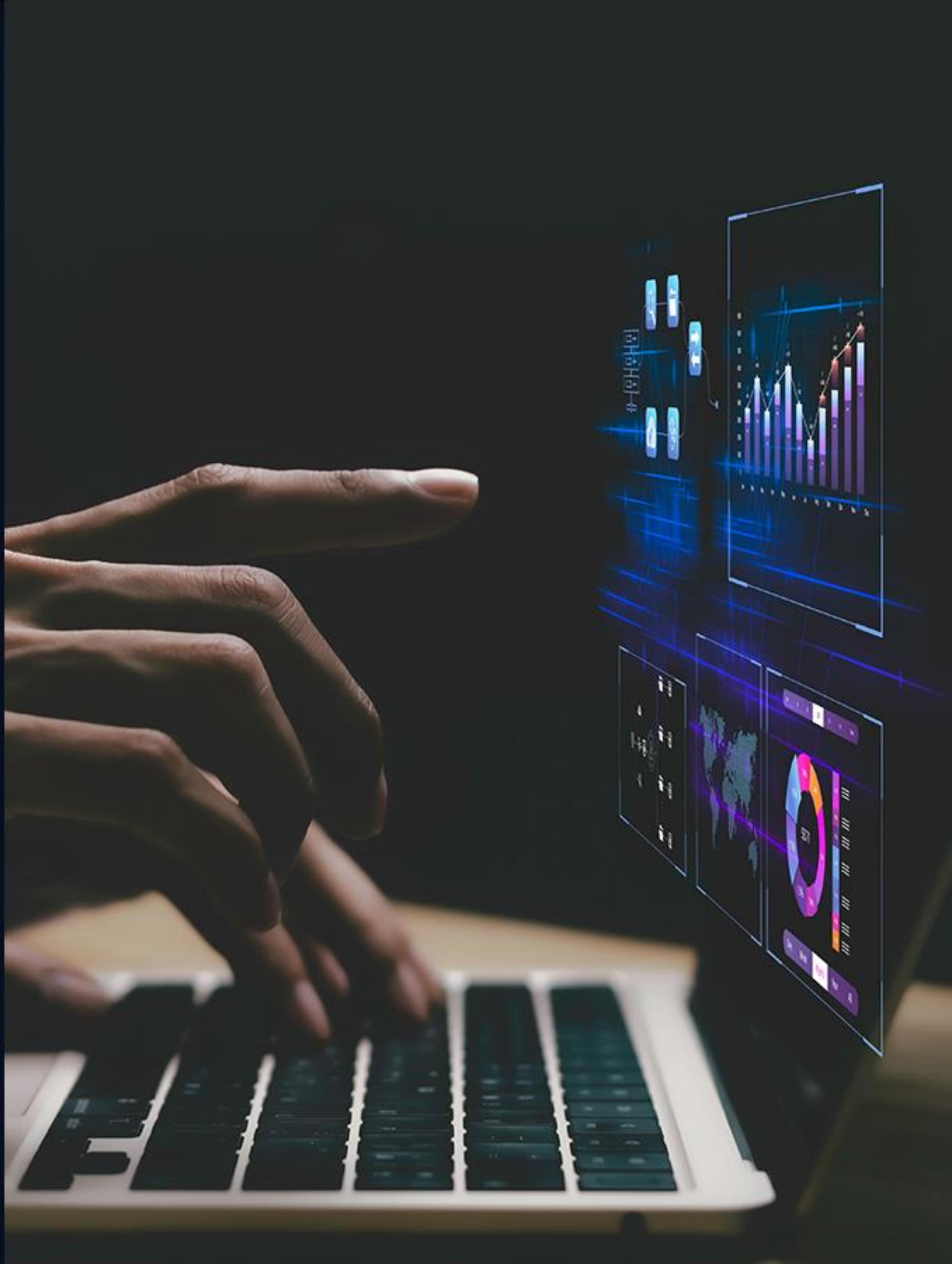
- The entire team at Klara
- Rob Norris, Don Brady, Alex Stetsenko
- Mateusz Piotrowski, Rob Wing, Fred Weigel

- The entire OpenZFS community
- Matt Ahrens, Pawel Dawidek
- Alexander Motin, Rich Ercolani

Klara Does ZFS Development & Support

1.) OpenZFS Development Services
klarasystems.com/zfs/zfs-custom-feature-development

2.) Klara OpenZFS Support Subscription
klarasystems.com/support/zfs-support/



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Q and A

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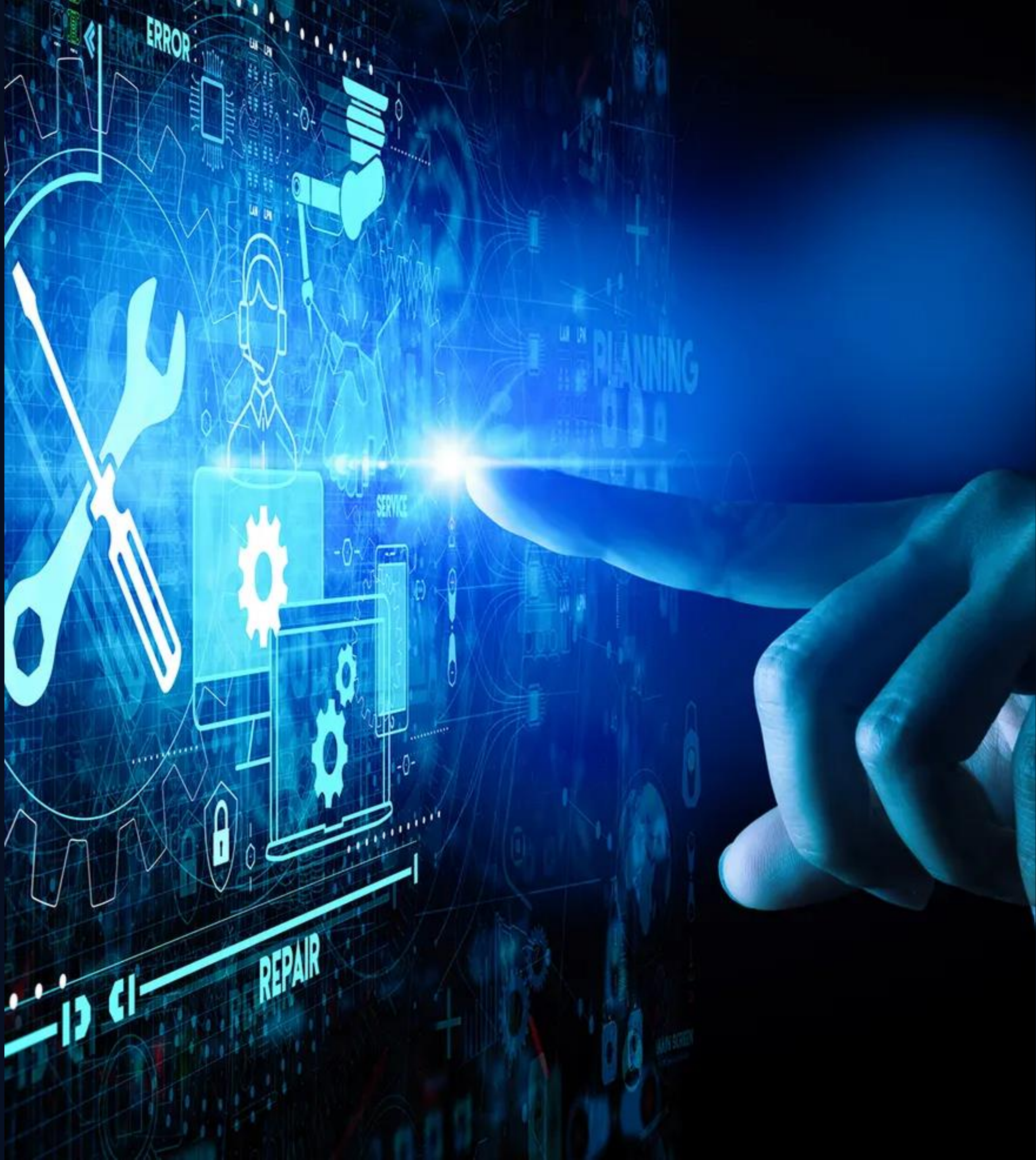

Thank You

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