GCTrees: Garbage Collecting Snapshots

Chris Dragga

Doug Santry

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GCTrees

Support snapshots for enterprise workloads

Minimize write overhead

Prototype implemented in ext4: gcext4

Reduce overhead up to 68x from state of the art

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Outline

1) Overview
2) Theory
3) Implementation
4) Evaluation

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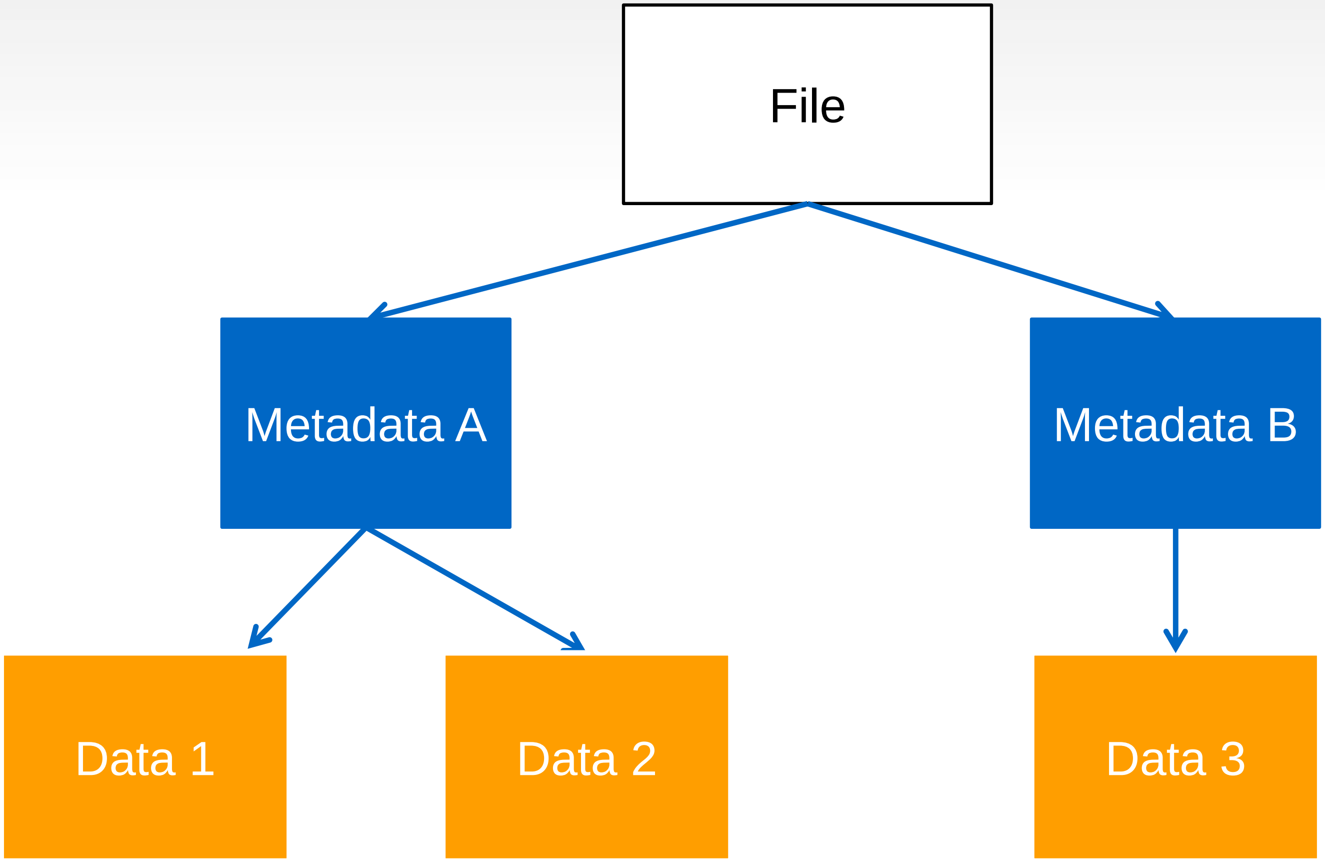
Snapshot Overview



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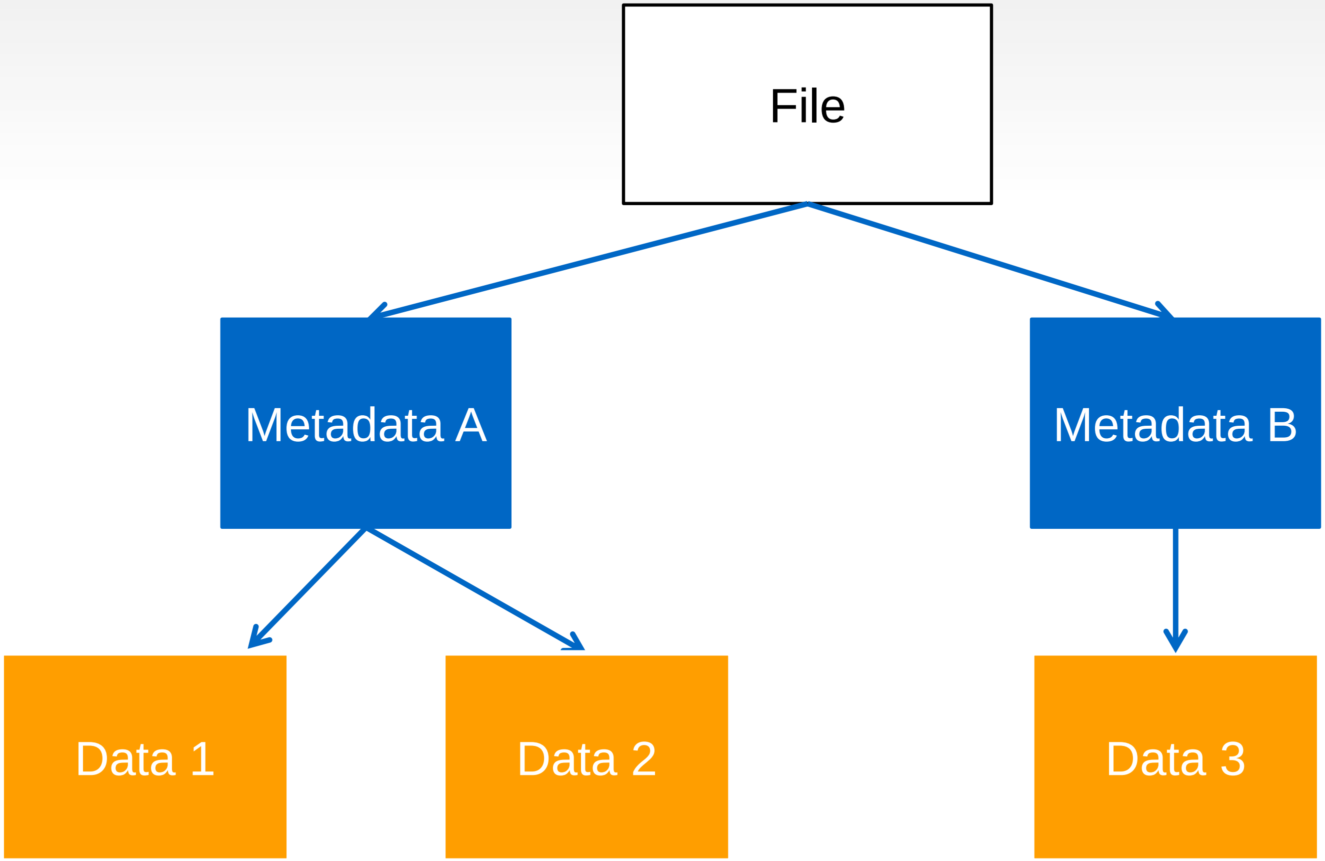
Copy-on-write



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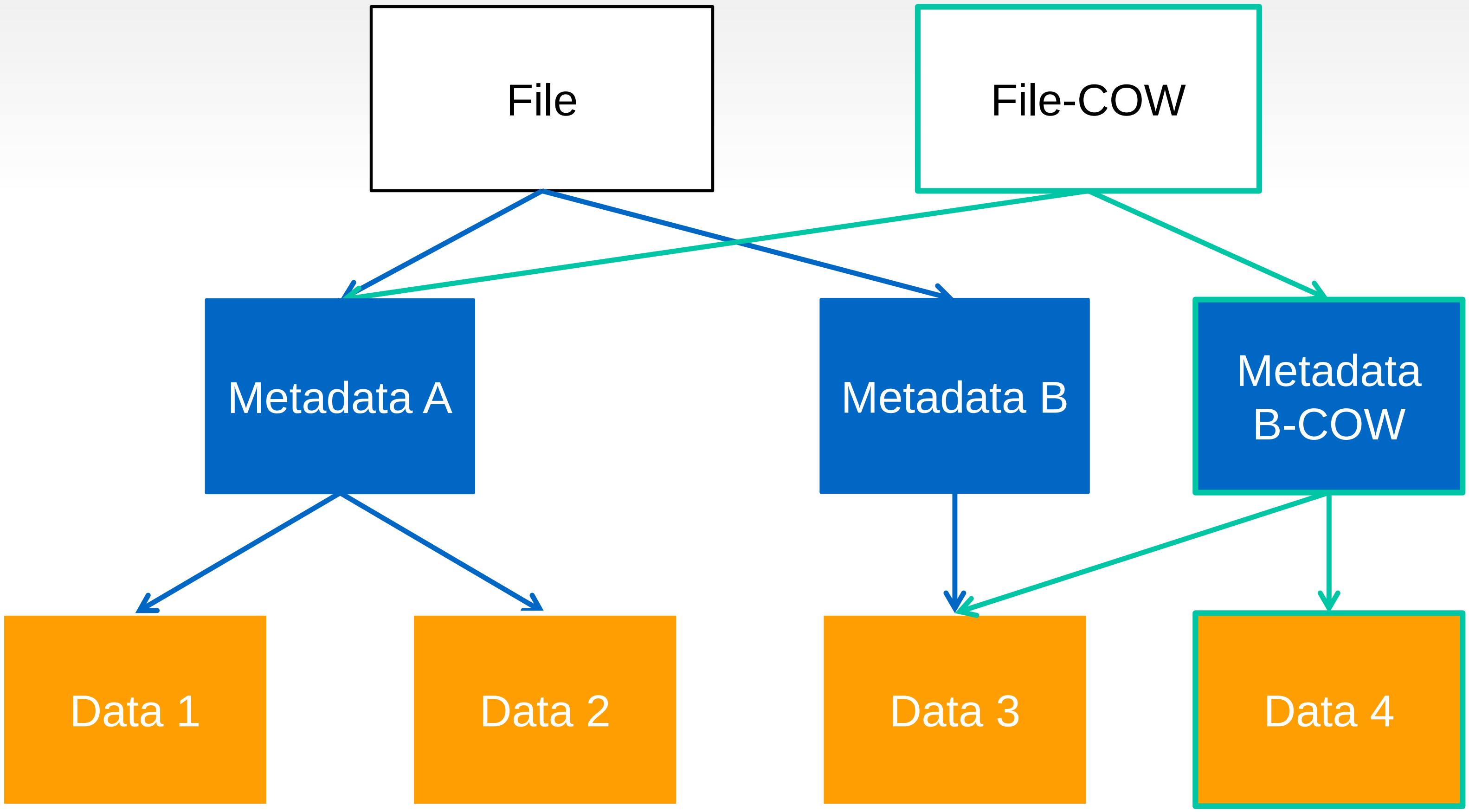
Copy-on-Write: Appending



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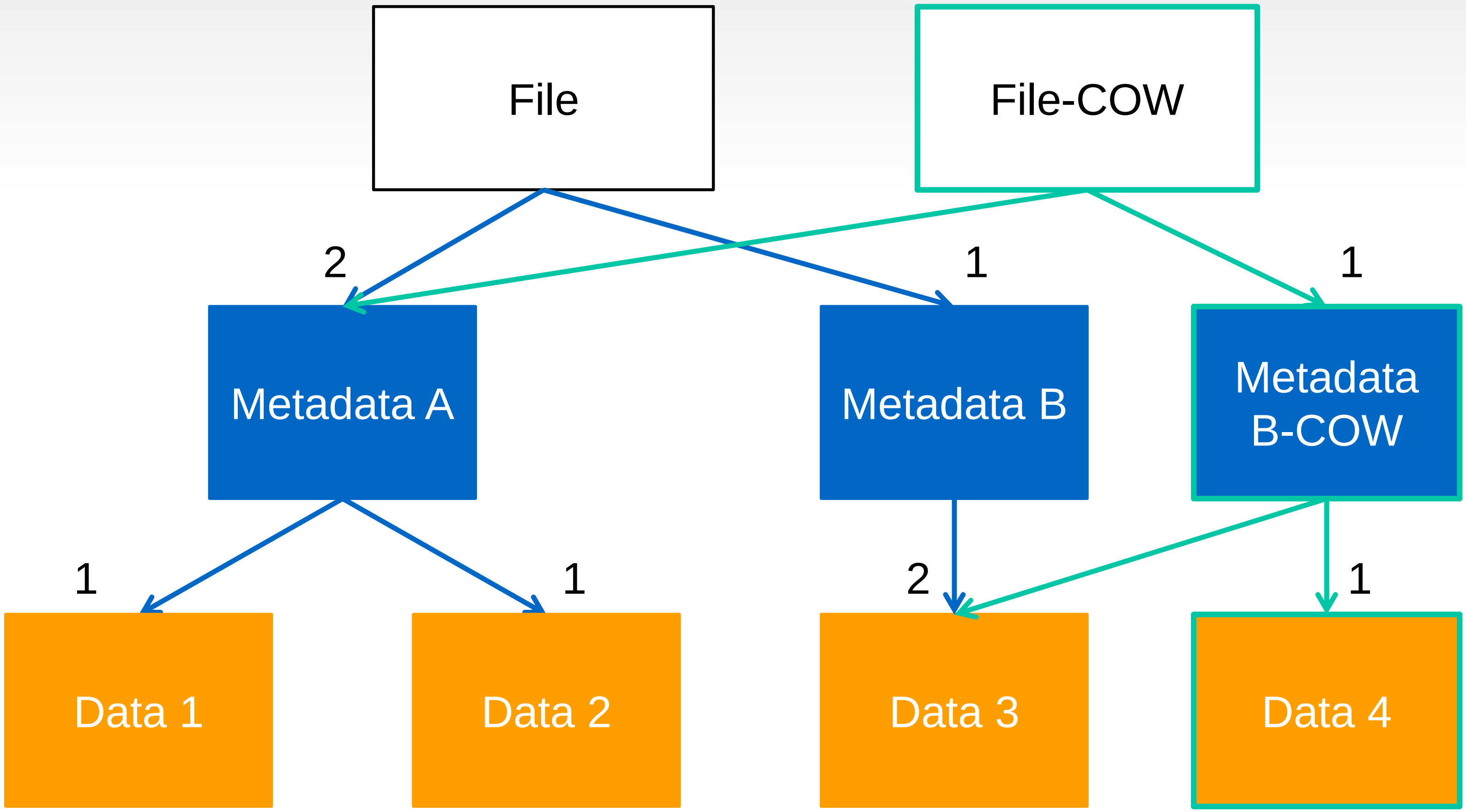
Hierarchical Refcounts



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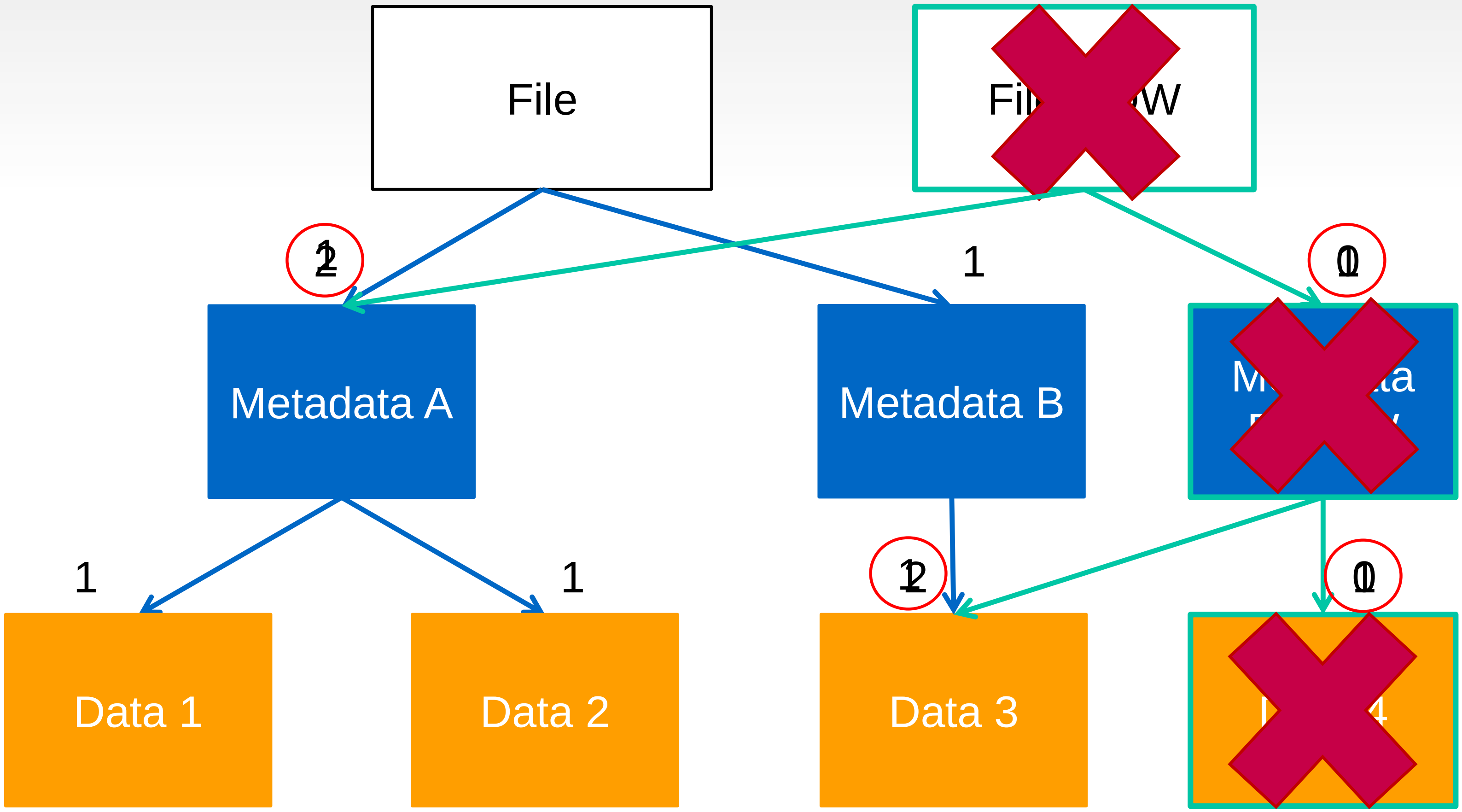
Hierarchical Refcounts: Deletion



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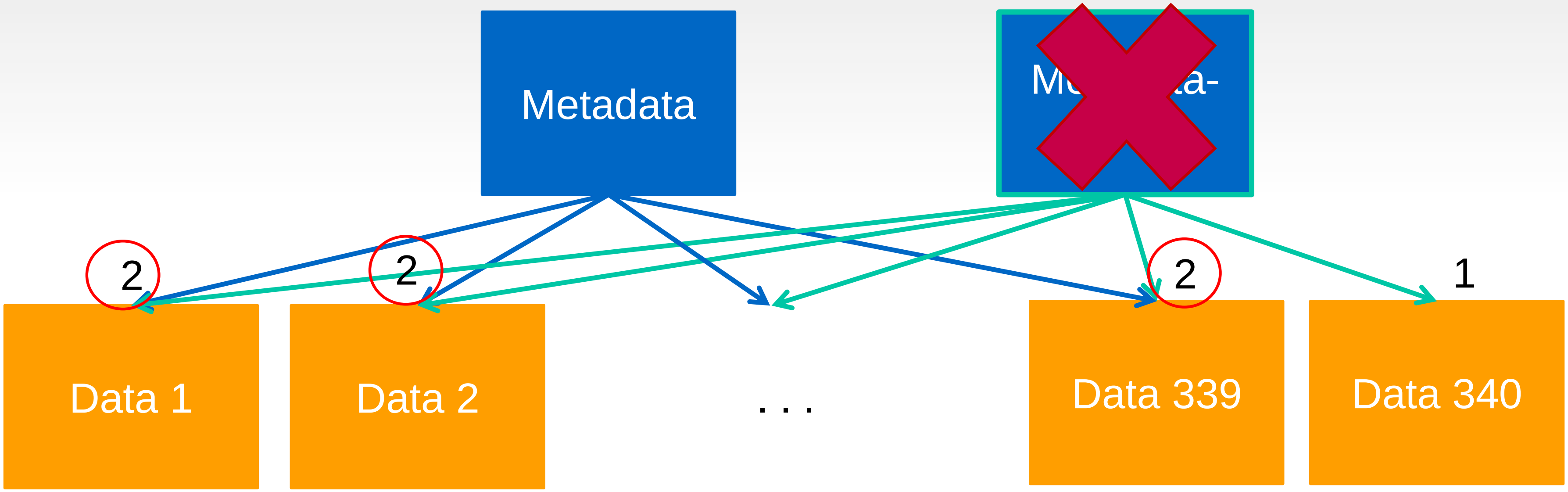
Problem: Fan-out



Even worse for writes

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Potential Solutions

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Delay

Write refcount changes to log, then checkpoint

Hope that they’ll cancel

No guarantee this will actually happen

Update storm

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GCTrees

Don’t count references at all

Track lineage

Use garbage collection (GC) to determine what can be freed

Keep deletion, write overhead minimal

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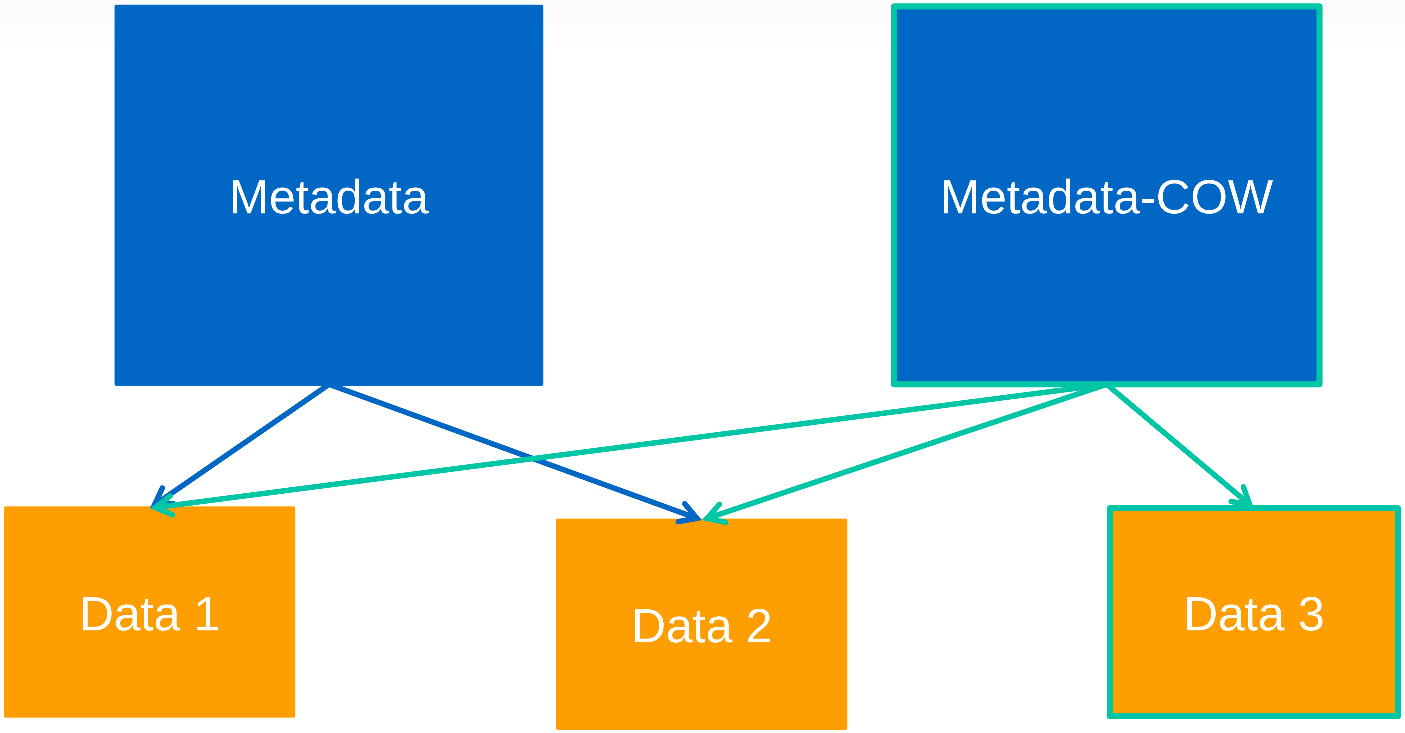
Basic Metadata Structure



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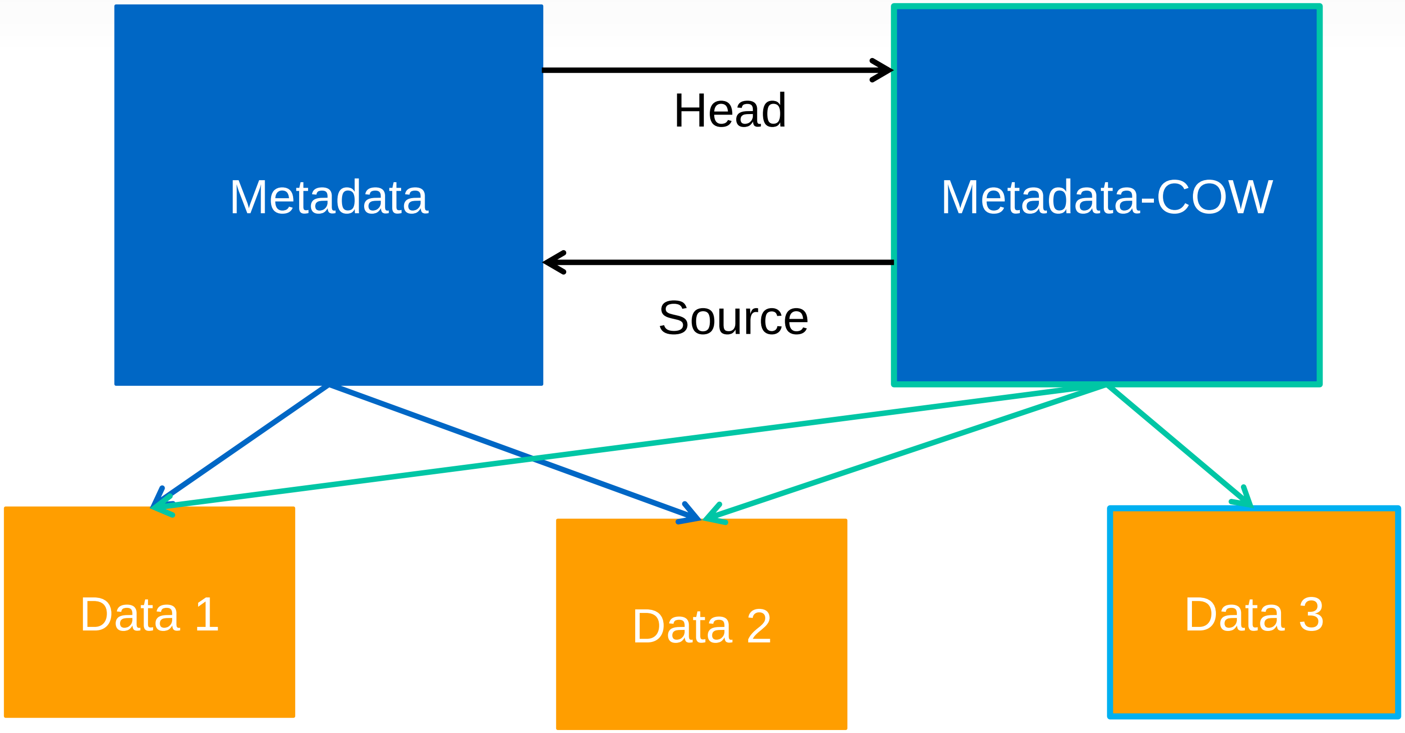
Basic Metadata Structure



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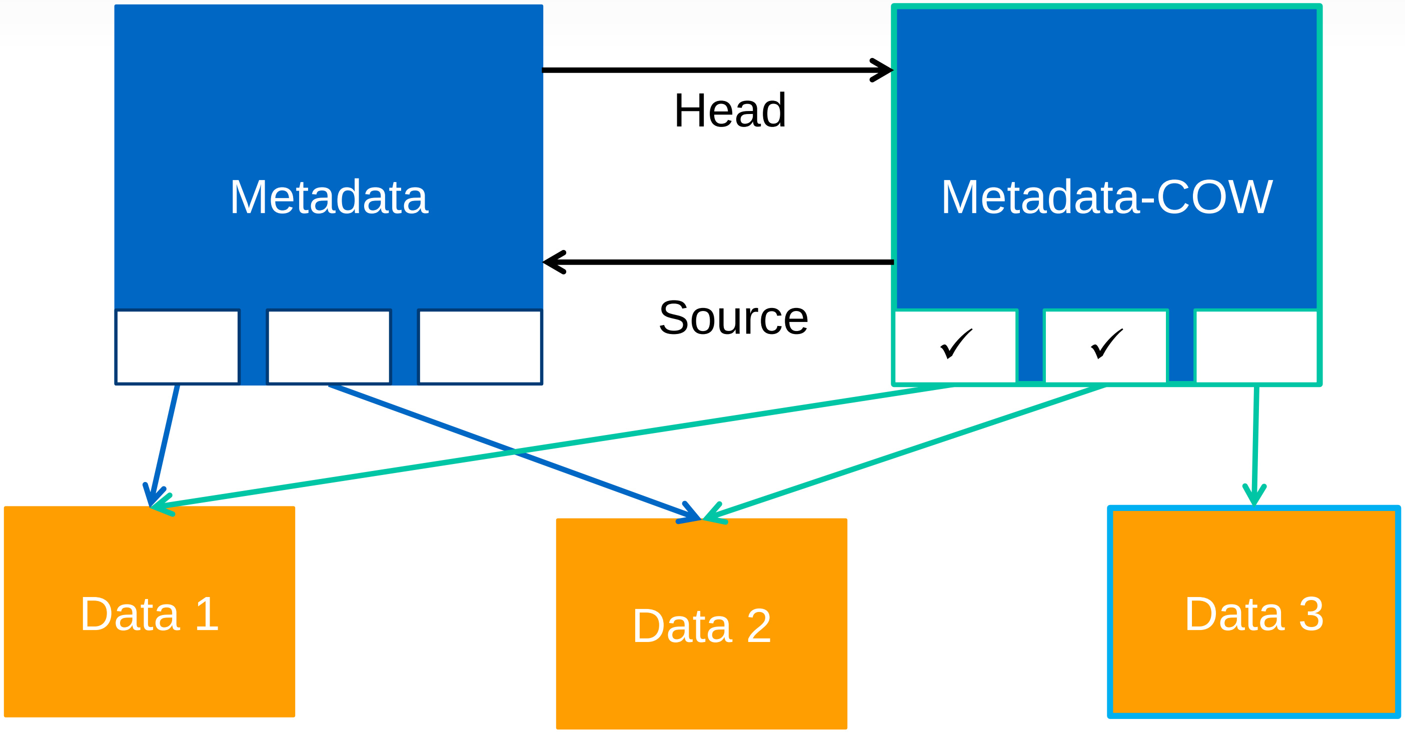
Basic Metadata Structure



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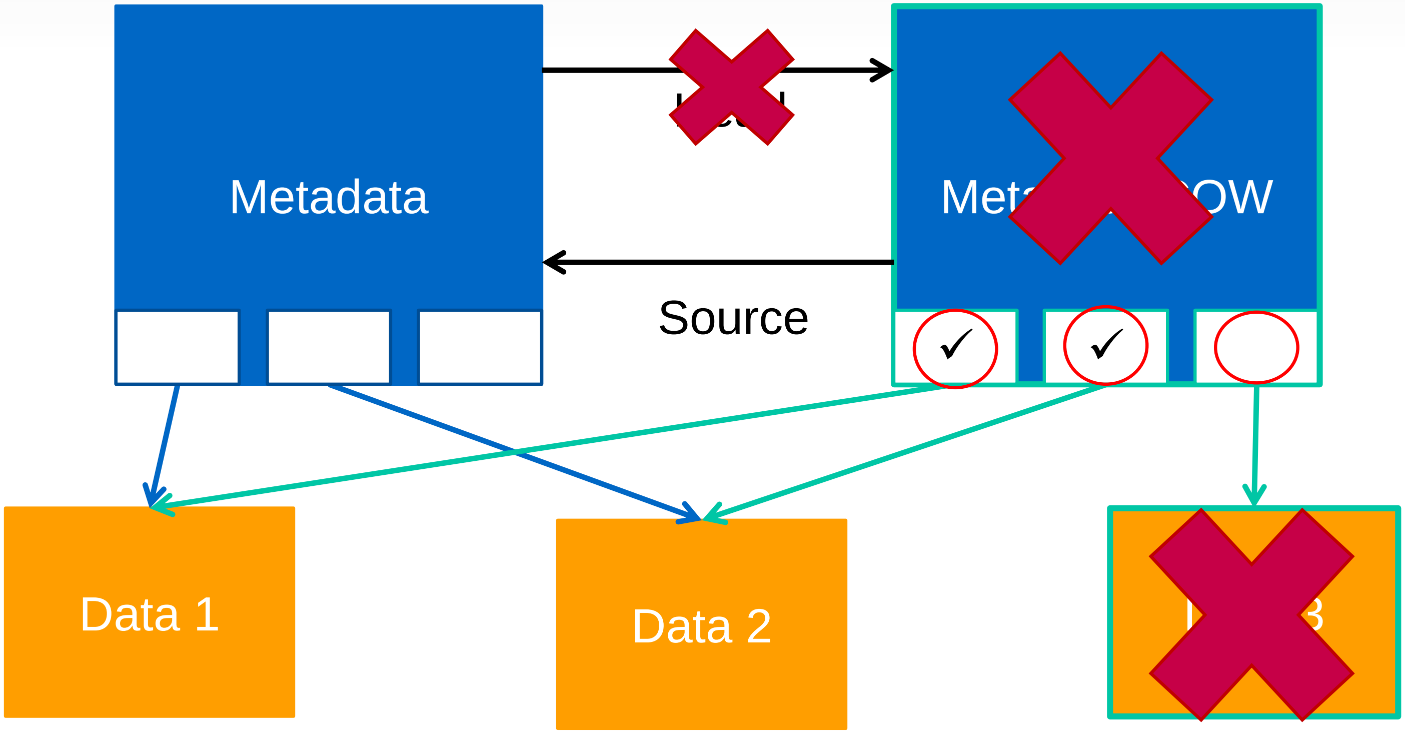
Deletion: Child



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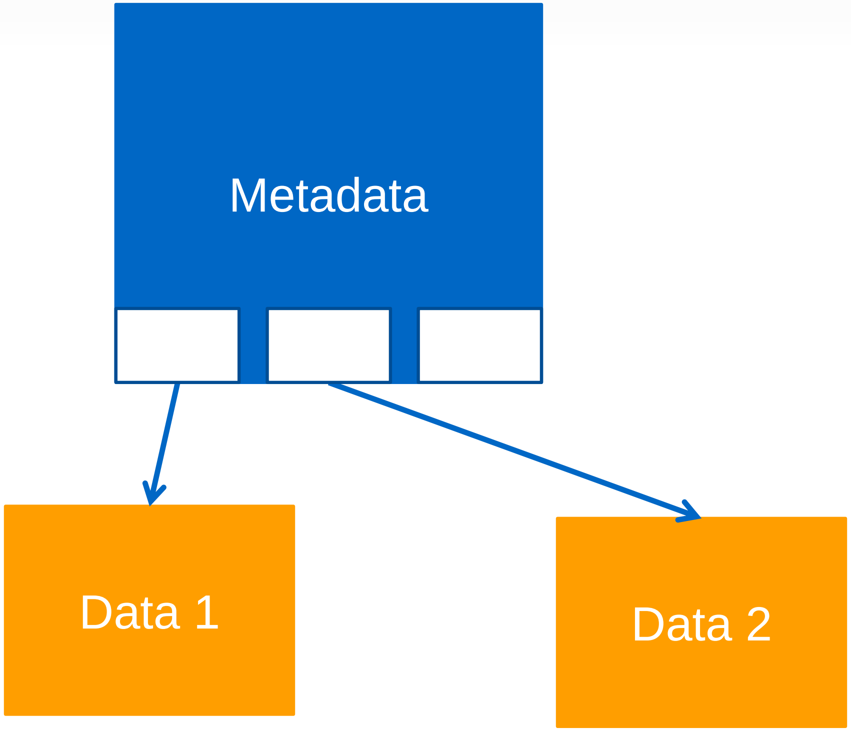
Deletion: Child



1 extra write

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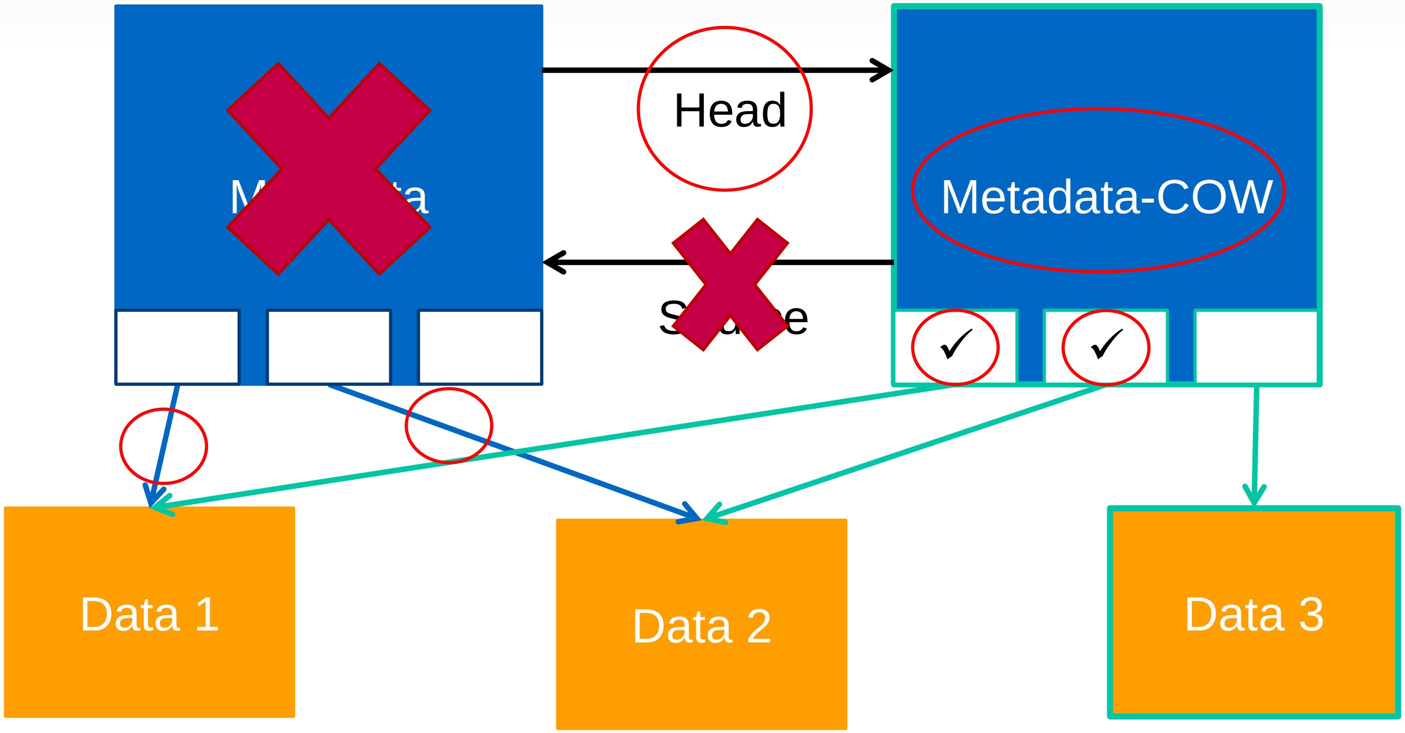
Deletion: Parent



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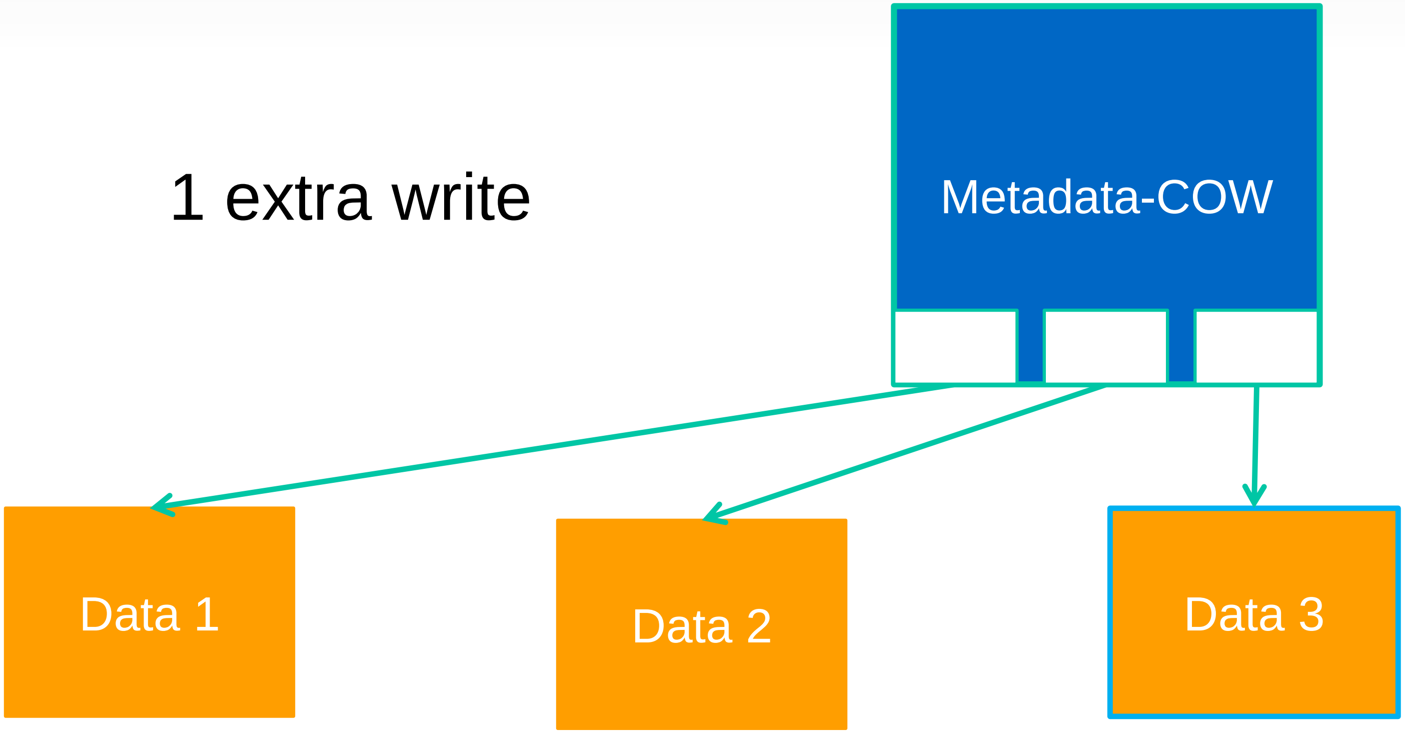
Deletion: Parent

1 extra write



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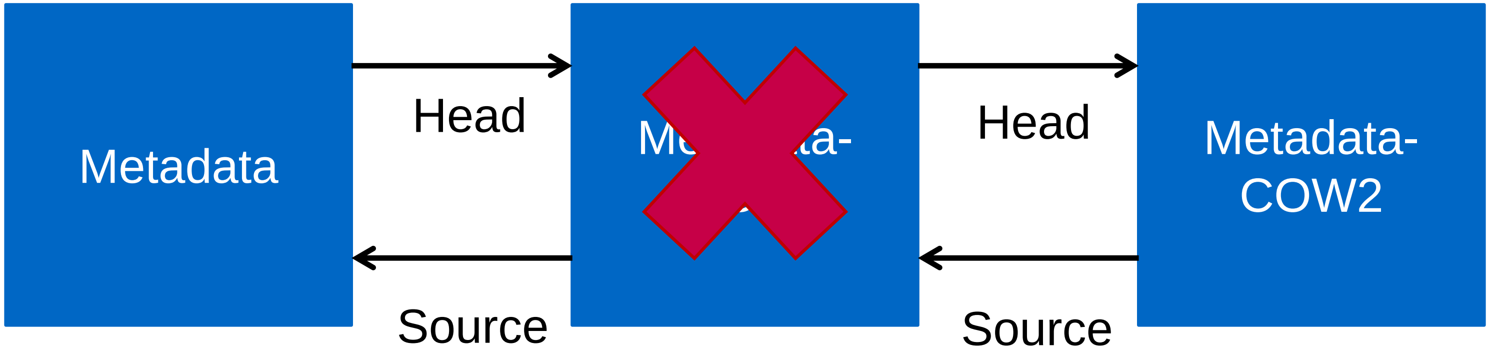
Deletion in a Snapshot Chain



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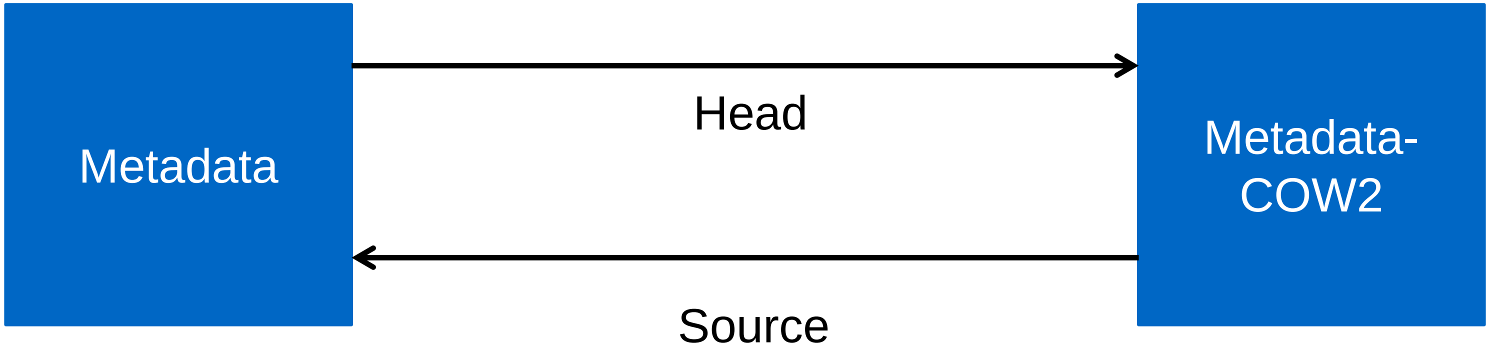
Deletion in a Snapshot Chain



2 extra writes

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What about B+ trees?

Tree ops can move pointers

Need additional pointers: next and previous

Can increase deletion overhead

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GCTree summary

One extra write per metadata block when writing

One to two extra writes for most deletions

Avoid deletion overhead with background scans

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Implementing gcext4

Ext4: Extent-based file system

Two metadata types: inodes, extent blocks

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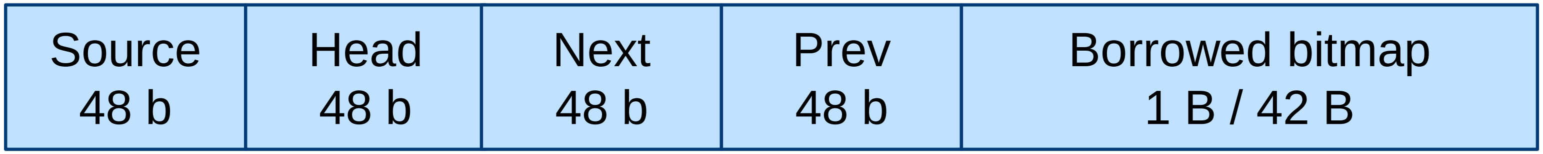
GCTree Metadata Layout



Source	Head	Next	Prev	Borrowed bitmap
48 b	48 b	48 b	48 b	1 B / 42 B

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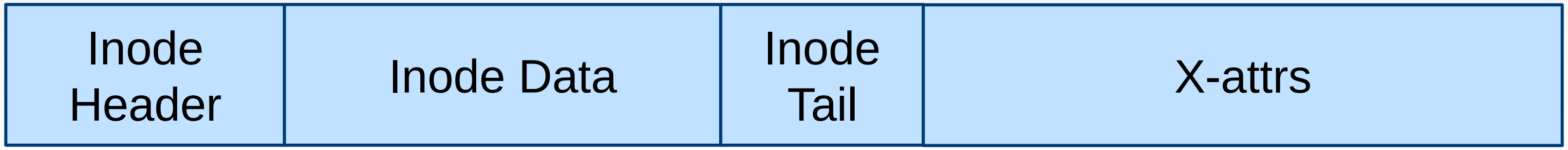
Adding GCTree metadata

ext4 inode (256 B):



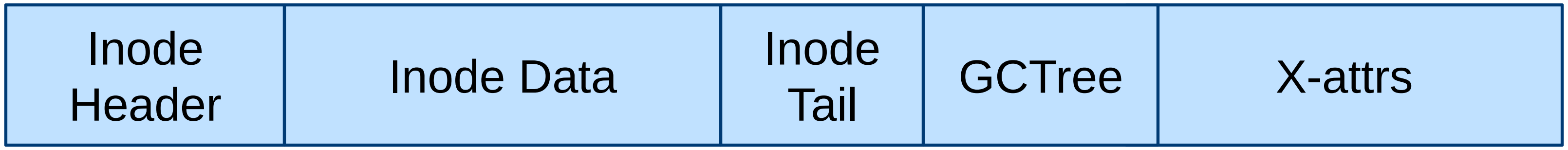
Inode Header

Inode Data

Inode Tail

X-attrs

gcext4 inode (256 B):



Inode Header

Inode Data

Inode Tail

GCTree

X-attrs

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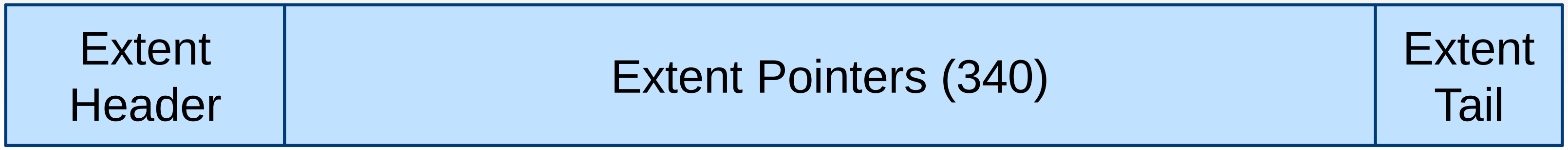
Adding GCTree metadata

ext4 extent (4096 KB):

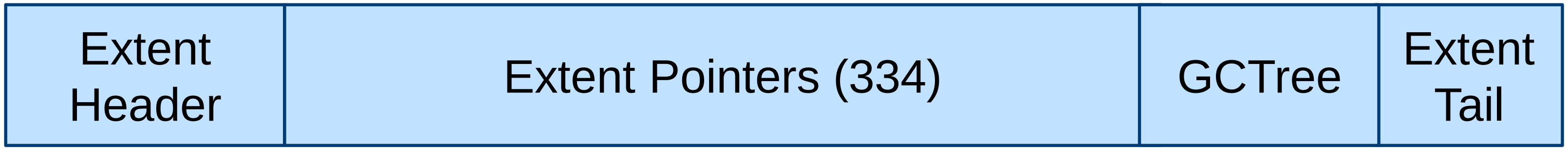


Extent Header

Extent Pointers (340)

Extent Tail

gcext4 extent (4096 KB):



Extent Header

Extent Pointers (334)

GCTree

Extent Tail

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Adapting ext4 to COW:

Straightforward, but fiddly

COW once per snapshot

Inodes proved problematic

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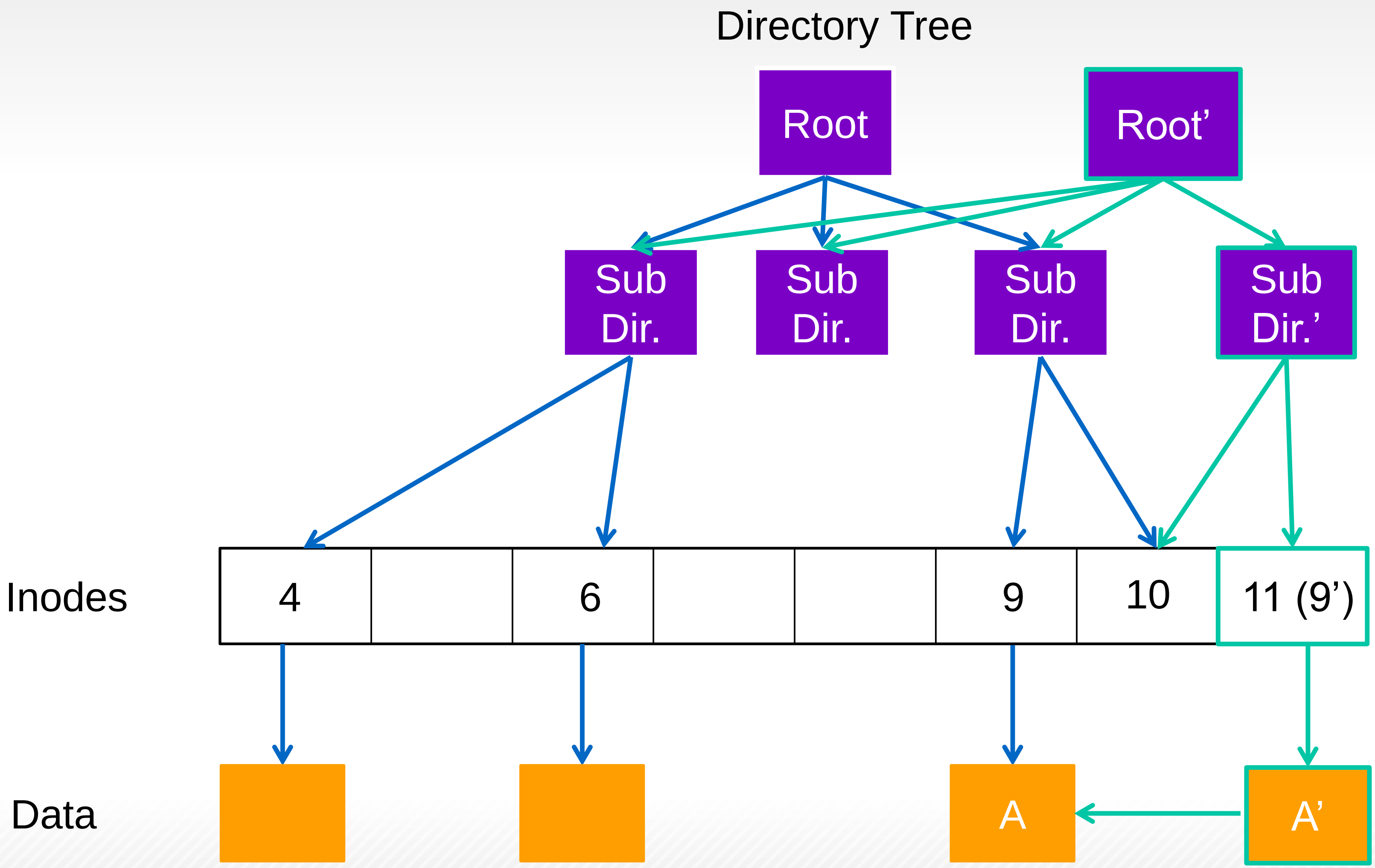
Fixed Location Inodes



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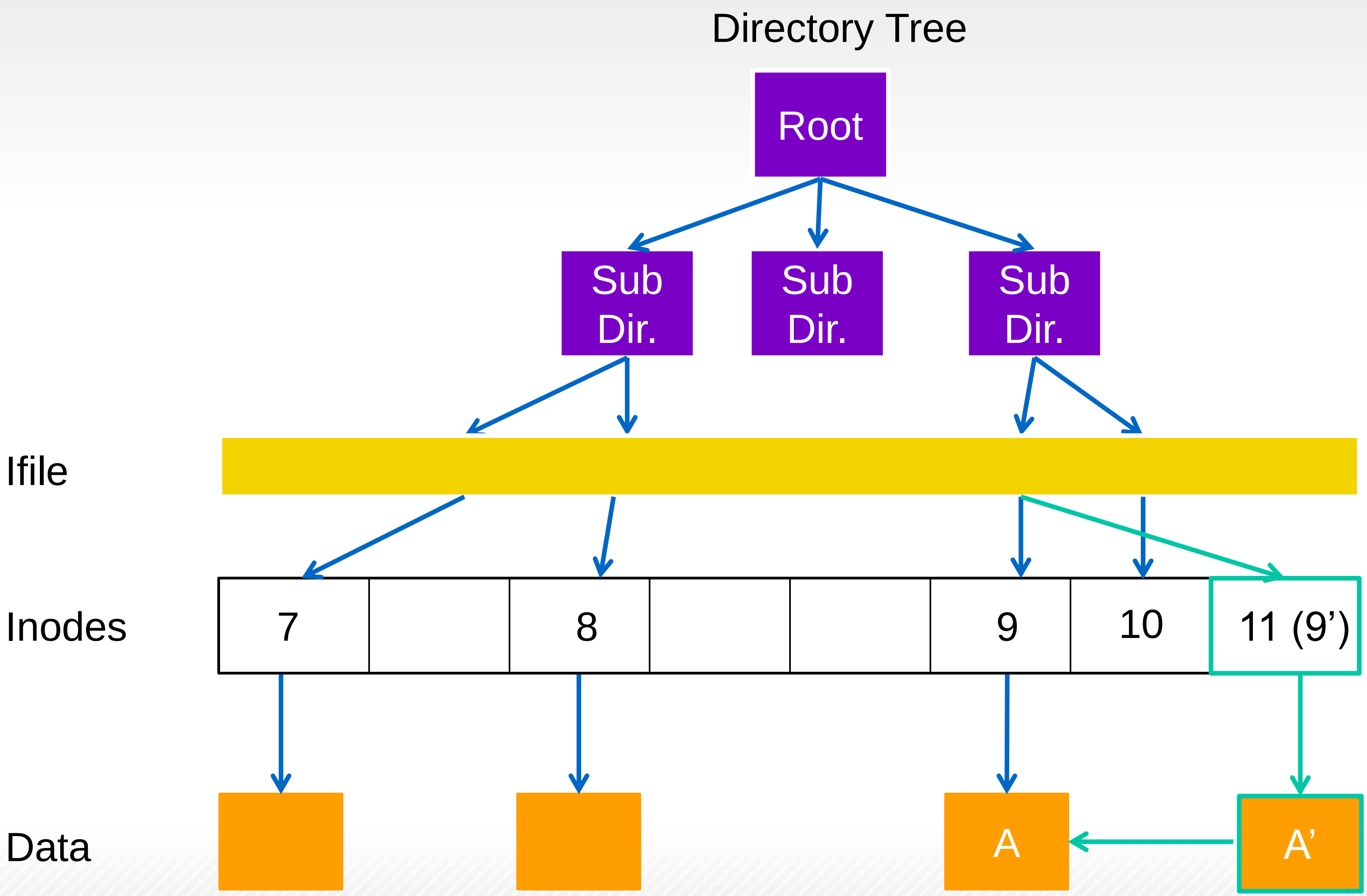
Solution: ifile



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Implementing Deletion

Separate kernel threads act as scanners

Deletion enqueues a message

Scanners process message, do actual deletion

Removing a snapshot deletes an ifile

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Evaluation

Do they work?

How do they compare?

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Experimental Set-up

3GHz Core 2 Duo, 6GB RAM

7200 RPM, 160GB hard drive

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Basic Benchmarks

Fileserver

OLTP

VM: fileserver in VirtualBox

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Benchmark Configuration

Storage footprint: 2x memory

5 repetitions, 3 hours each

Snapshot per hour for Fileserver, VM

Snapshot per five minutes for OLTP

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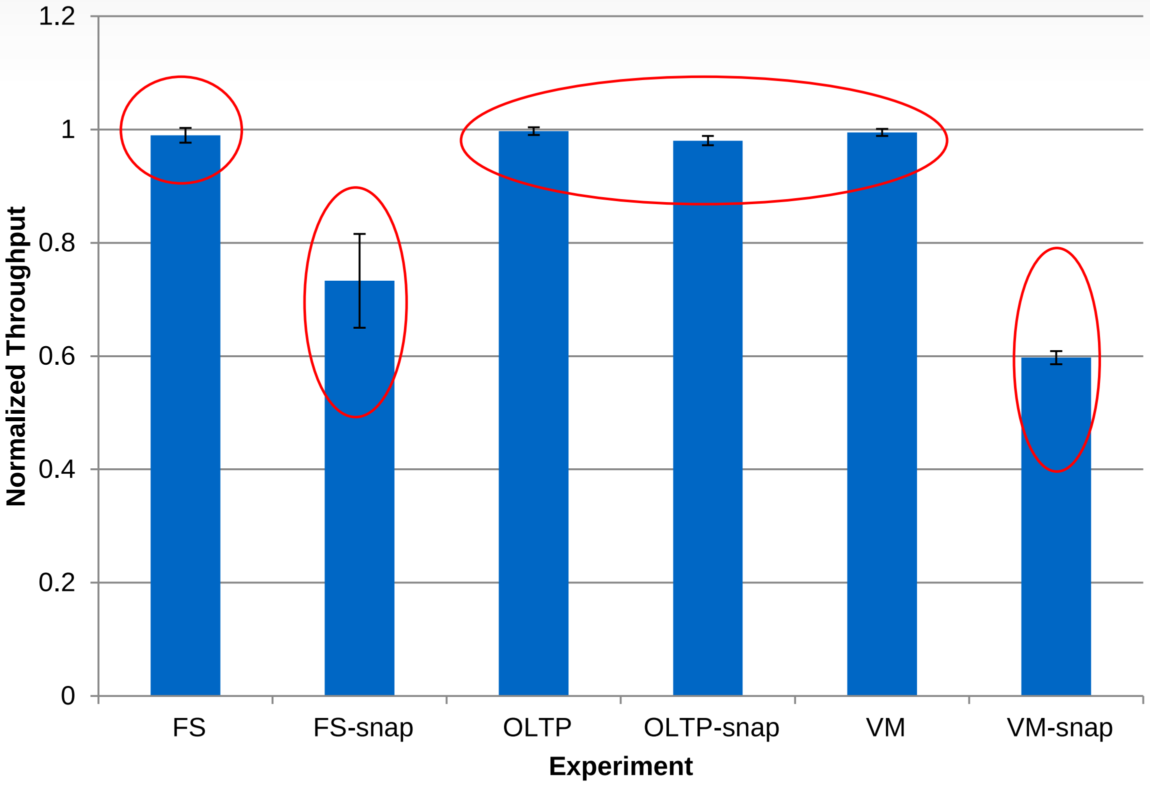
Comparison to ext4



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Hierarchical Refcount Comparison

Direct performance comparison infeasible

Look at block-write overhead

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File Systems for Comparison

Btrfs: refcounting file system

Simulation in gcext4: accounts for differences in btrfs

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Simulation Methodology

Assumes refcounts stored in a contiguous map

Use a 15MB durable log

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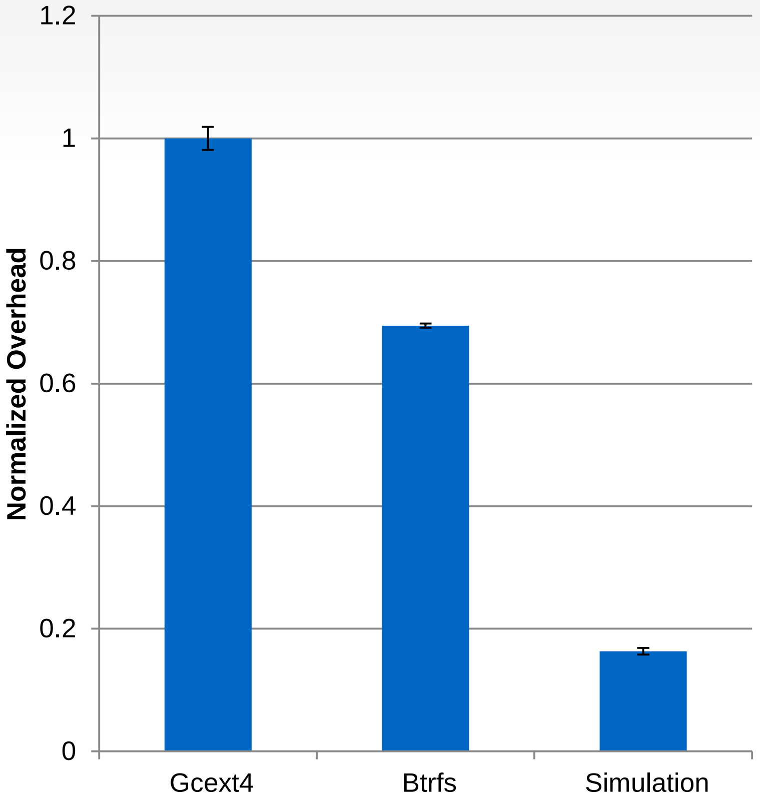
Results: Traditional Workloads



Fileserver

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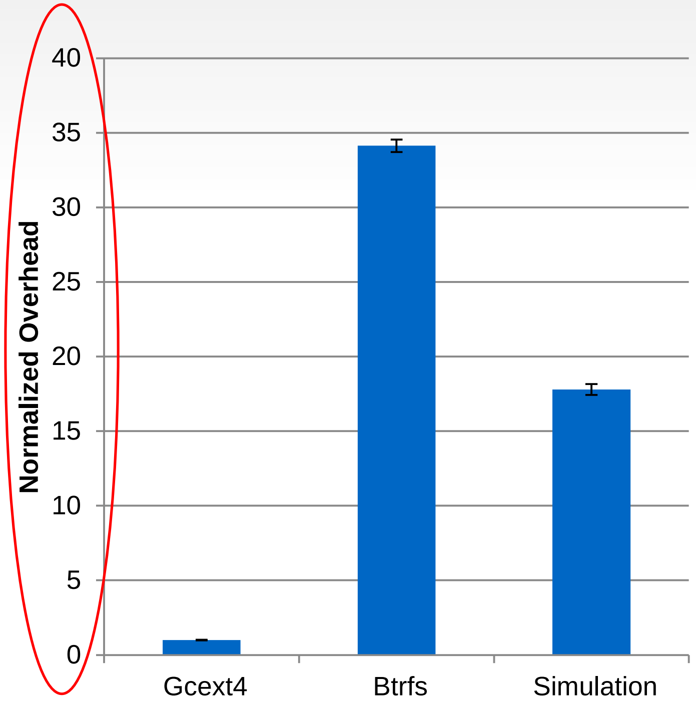
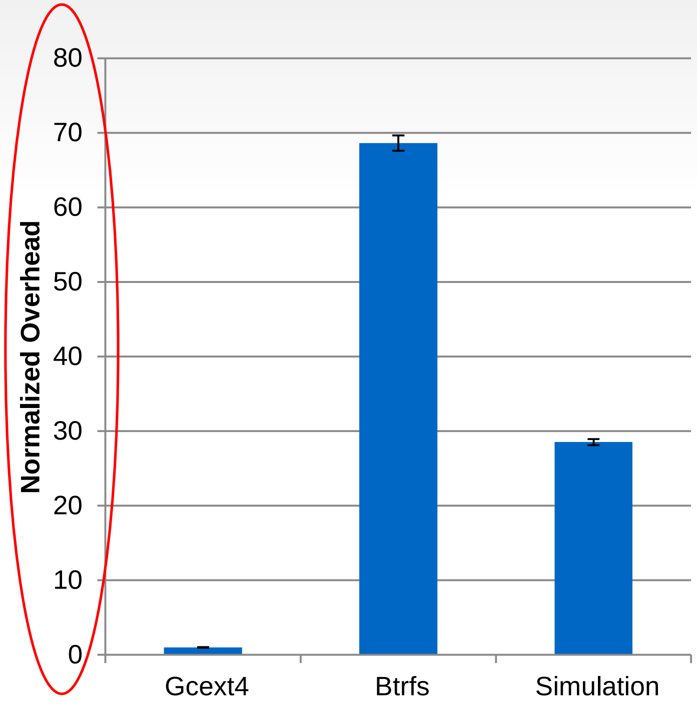
Results: Enterprise Workloads



OLTP



VM

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Conclusion

GCTrees: snapshots for enterprise workloads

Substantial gulf between refcounts and GCTrees

Optimal choice depends on workload

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Thank you!