Ozone User Group Summit

Nov 10, 2022

CLOUDERA

THE HYBRID DATA COMPANY

We believe that data can make what is impossible today, possible tomorrow

We empower people to transform complex data anywhere into actionable insights faster and easier

We deliver a hybrid data platform with secure data management and portable cloud-native data analytics

“The future data ecosystem should leverage distributed data management components — which may run on multiple clouds and/or on-premises — but are treated as a cohesive whole with a high degree of automation. Integration, metadata and governance capabilities glue the individual components together.”

Gartner®

Strategic Roadmap for Migrating Data Management to the Cloud
Published 21 March 2022 - ID G00746011,
Analyst(s): Robert Thanaraj, Adam Ronthal, Donald Feinberg

“The reality: Hybrid cloud is the de facto model.”

Deloitte.

CLOUDERA DATA PLATFORM

The only hybrid data platform for modern data architectures with data anywhere

Data Lakehouse | Data Fabric | Data Mesh

Open data fabrics, lakehouses and data meshes with data anywhere at scale

aws | Azure | Google Cloud | + Ozone

Multi-cloud & on-premises data management and analytics

DATA FLOW | DATA ENG | DATA WH | OP DB | AI/ML

"Write once, run anywhere" data analytics portability

SDX

Unified security & governance with open cloud-native storage formats

BIG DATA STORAGE REQUIRES ...

Performance

Can it handle **large** workloads

Scale

Can it **Scale** To 100's PB, 1000's of nodes and billions of objects

API Compatibility

Does it support **S3 API** and Modern Architecture ?

… AND NATIVE INTEGRATION WITH BIG DATA WORKLOADS

Application

Support **HDFS and S3 API** based applications

Security

Support **access control policy, lineage and governance**

Encryption

Is the data **protected** at rest and in-transit?

Apache Ozone

Scalable, redundant distributed object store

Designed for data applications to store structured, unstructured binary data at scale with the capability to read, write and run enterprise applications and workloads at scale as often as possible.

MEETUP AGENDA

- History and Overview (Sid Wagle)
- Ozone bucket types (Ethan Rose)
    - Legacy, Object Store (OBS), and Filesystem Optimized (FSO)
    - Diverse workloads and when/how to use?
    - Demo
- Ozone Snapshots (Prashant Pogde, Siyao Meng)
    - Key differentiator
    - Use cases in a hybrid world
    - Demo
- Ozone Performance (Ritesh Shukla)
    - Benchmarks and certifications
    - Optimized for the new DC outlook

A BRIEF HISTORY OF OZONE

Siddharth (Sid) Wagle
PMC, committer (Ozone, Ratis, Hadoop)

HISTORICAL MILESTONES

2015	Jun	HDFS-7240	Hadoop feature branch	First hadoop-ozone commit lands
2018	Apr	HDDS-1	Hadoop sub-project	Hadoop Distributed Data Store
2020	Oct	Ozone-1.0.0	Apache Ozone now a TLP	Apache board establishes Apache Ozone as a top-level project

Initial Goal

Scale HDFS - 2x

New Goal

Storage Containers
Native S3 , HCFS
Scale HDFS - 10x

Cloudera GA

THRIVING COMMUNITY

Open source Partner Logos

APACHE OZONE COMMUNITY

Snapshot - 2022

- Ozone PMC Chair: Sammi Chen
- 28 PMC members, 61 Committers
    - Committers / PMC members located in US, Hungary, India, China, Germany, …
    - from Cloudera, Tencent, G-Research, Infinstor, Oracle, Microsoft, Intel, Target
- 199 contributors (at least one PR merged), 127 active contributors in the past two years.
- 5000+ commits in total on the main branch, 2100+ merged in the past two years.

APACHE OZONE RELEASES

- Generally Available since 1.0.0 in Sep 2020
- 1.2.1, released in Dec 2021
- Version 1.3.0 is in-progress
  - **Tons** of new features and improvements
    - Erasure Coding
    - Container Balancer
    - S3 Multi-Tenancy
    - S3 gRPC improvements
  - 1000+ new commits since 1.2.1 release and counting
    - 2,265 changed files with 150,474 additions and 36,212 deletions

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OVERVIEW

APACHE OZONE - What is it?

Ozone is a distributed **Key Value Object Store** with native S3 and FS interfaces.

Ozone is designed and **optimized** for Big Data workloads.

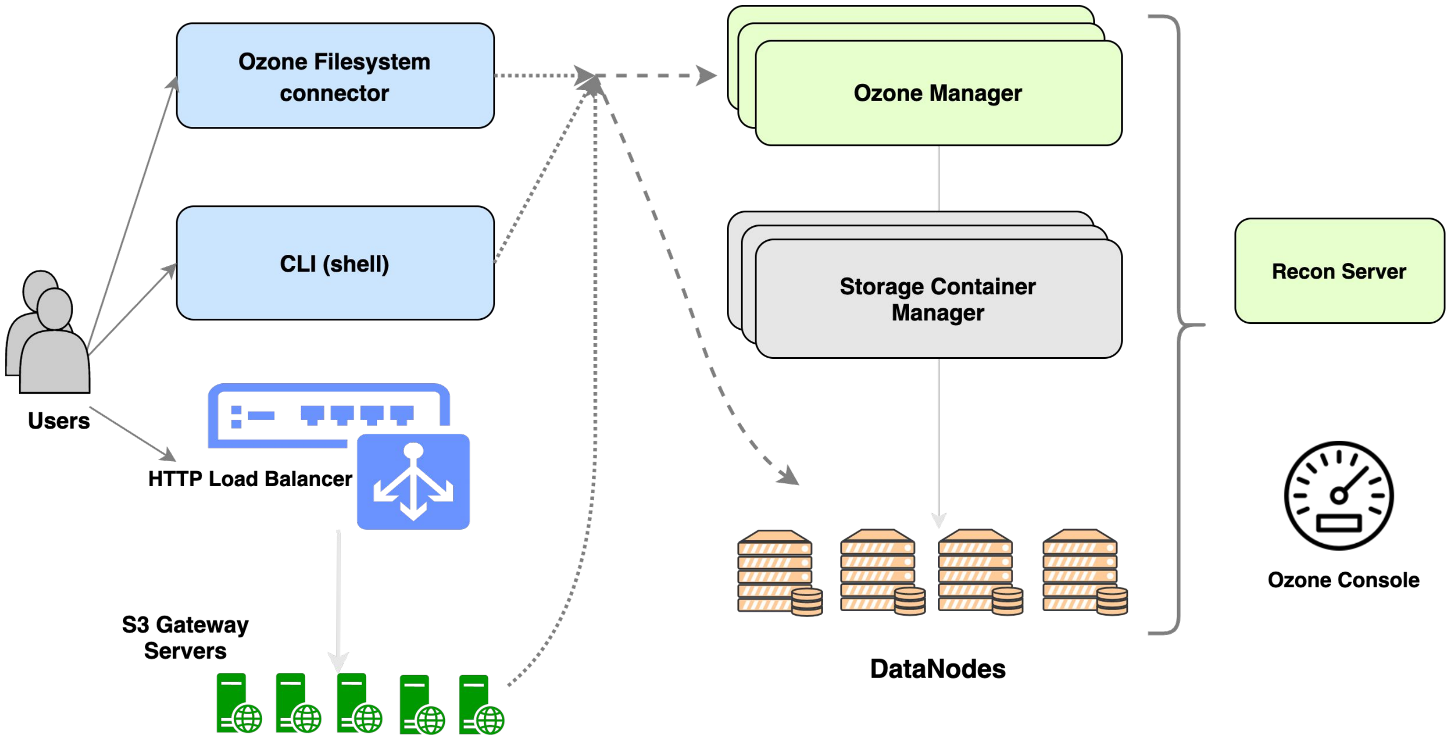
Ozone can **scale** up to **billions of objects** and work effectively in containerized environments like Yarn or Kubernetes. (30x of HDFS)

Ozone is **strongly consistent** and provides the benefits of traditional HDFS and S3 Object Store

Scale to **1000's of nodes** with dense storage configurations

Reduce cost per TB using commodity hardware

HIGH LEVEL ARCHITECTURE



KEY CONCEPTS

- Ozone consists of **volumes, buckets, and keys.**
- ***Volumes*** are similar to user accounts or tenants. Only administrators can create or delete volumes.
- ***Buckets*** are similar to Amazon S3 buckets. A bucket can contain any number of keys, but buckets cannot contain other buckets.
- **Keys** are similar to files.
- The hierarchical file system builds on top of the flat key-value store.

BUILDING BLOCKS

Use proven technologies - don't reinvent the wheel

- **RAFT** replication – http://raft.github.io
  - Open source Java implementation of RAFT - Apache Ratis Library.
- **Storage Containers** – Unit of replication (collection of blocks)
  - RocksDB - container metadata
    - Supported by and battle-tested at Facebook.
- **OM** – a namespace manager (also uses RocksDB to store the namespace)
- **HDDS** – a distributed container management layer
- Hadoop security model and Hadoop RPC

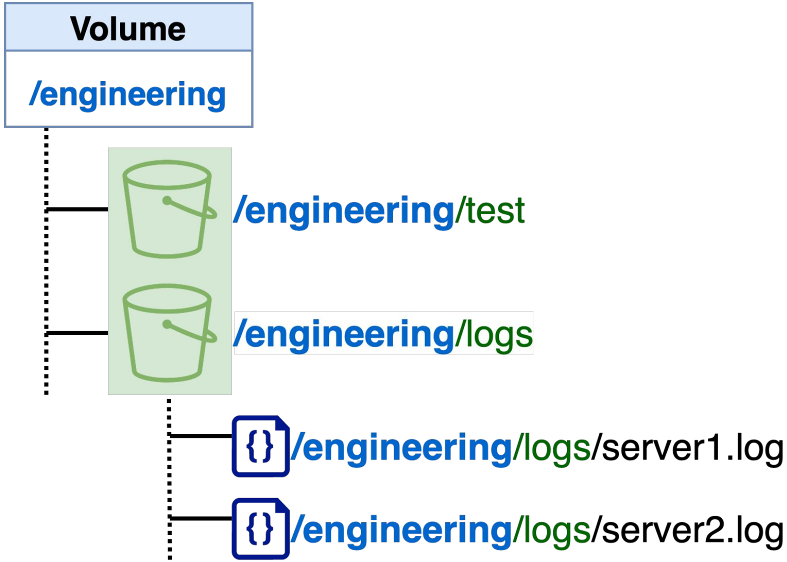
OZONE BUCKET TYPES

Ethan Rose
Ozone PMC, committer

OZONE NAMESPACE LAYOUT

/volume/bucket/key

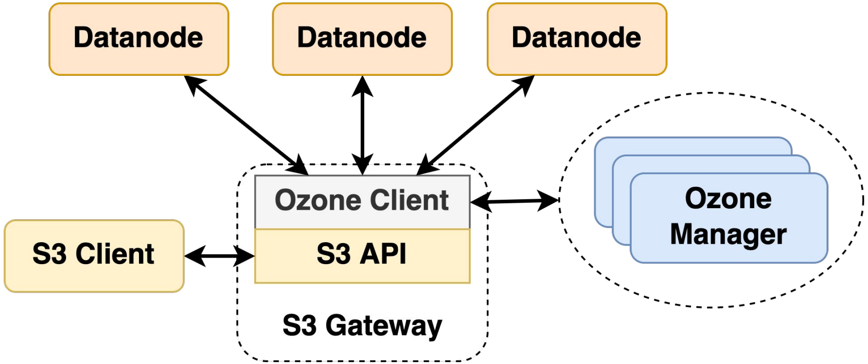
- **Volume**
  - Top level namespace grouping
  - Must have unique names
  - Can only contain buckets
- **Bucket**
  - Must have unique names within the same volume
  - Can only contain keys
- **Key**
  - A file stored in the system



S3 GATEWAY

Allows S3 clients to talk to Ozone

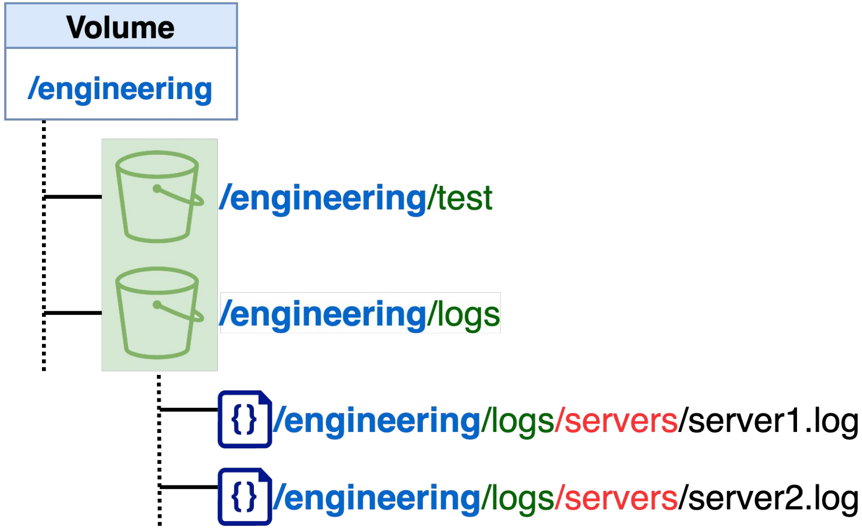
- Stateless server
- Translates S3 REST API calls to Ozone client RPC calls



BEFORE BUCKET LAYOUT TYPES

History

- Ozone was originally built as a object store
- Directories were simulated with prefixes



BEFORE BUCKET LAYOUT TYPES

Problems

- Directory **rename** and **delete** were slow and non-atomic
  - Could cause problems for services expecting Ozone to be a drop-in replacement for HDFS
- Strict S3 compatibility was opt in/out for the whole cluster
  - Is /volume/bucket/dir1/..///dir2/key1
    - The literal name of a key?
    - A path to resolve to /volume/bucket/dir2/key1?

EXISTING: LEGACY BUCKETS

- Path normalization handled by config key: ozone.om.enable.filesystem.paths
- No directories, only prefixes
- Existing buckets automatically inherit this layout

Interface	Legacy buckets accessible?
ozone sh	✓
ofs (Hadoop compatible)	✓
S3	✓

NEW: OBJECT STORE BUCKETS (OBS)

- Strict S3 compatibility
  - /volume/bucket/dir1/..///dir2/key1 is the name of a key
- No directories, only prefixes

Interface	OBS buckets accessible?
ozone sh	✓
ofs (Hadoop compatible)	✘
S3	✓

NEW: FILE SYSTEM OPTIMIZED BUCKETS (FSO)

- Path normalization
  - /volume/bucket/dir1/..///dir2/key **->** /volume/bucket/dir2/key1
- Quick, atomic directory operations
  - Rename
  - Delete

Interface	FSO buckets accessible?
ozone sh	✓
ofs (Hadoop compatible)	✓
S3	✓ (Paths normalized)

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FSO BUCKET IMPLEMENTATION

- Implement a hierarchical layout with a key value store (RocksDB)
  - Key: **<**Parent object ID**>**/**<**Object name**>**
  - Value: Object metadata, including ID
- Resolve /engineering/sre/servers/datacenter1/server1.log

BucketTable

Bucket	Object ID
/engineering/sre	**512**

DirectoryTable

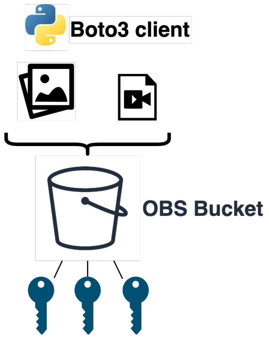
Directory	Object ID
512/servers	**1024**
1024/datacenter1	**1025**

FileTable

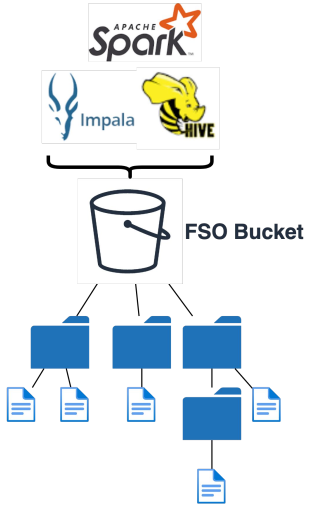
File	Object ID
1025/server1.log	1026
1025/server2.log	1027

WHICH BUCKET TYPE SHOULD YOU USE?

- **OBS:**
  - Services built for S3
  - Object store workloads



- **FSO:**
  - Services built for HDFS
  - Analytic workloads



IMPALA + OZONE

Featuring FSO Buckets

IMPALA + OZONE

- **Impala:** SQL engine built to run in Hadoop clusters
  - Metadata stored in Hive Metastore
  - Data stored in Hadoop compatible storage
- We will store Impala's data in Ozone instead of HDFS

IMPALA-9400: IMPALA OZONE SUPPORT

Jira	Description
IMPALA-10212	ofs support in Impala
IMPALA-9448	Test coverage for Ozone transparent data encryption
IMPALA-10213	Support data locality of Impala daemons on Ozone
IMPALA-10214	Support file handle cache for Ozone

CHOOSING BUCKET TYPE

- Impala has native support for HDFS
- Some Impala operations will have poor performance without fast directory renames and deletes:
  - DROP TABLE/PARTITION
  - INSERT OVERWRITE
  - LOAD IN PATH
- Therefore, we will put Impala's data in an **FSO bucket**

DEMO

Bucket types in a live Ozone cluster

Q&A

Contribute! https://github.com/apache/ozone

OZONE SNAPSHOTS

Prashant Pogde, Siyao Meng
Ozone PMC, committer

SNAPSHOT USE CASES

- Data protection and backup
  - Bucket Granularity
- Replication and DR
  - Stable source image for replication
  - Efficient way to find changes since last replication
  - Near continuous replication
- Compliance
- Easy Rollbacks for Application state
- Malware protection
- Time Travel for data sets
- Incremental analytics

OBJECT VERSIONING VS SNAPSHOTS

- A single object - multiple versions
- A group of objects as a unit
  - Consistent with each other
  - Point in time, together as a group
- Examples :
  - Application updating multiple rows of a table to get to a consistent state
  - Application updating a group of tables to move from one state to another
- Easy rollback for a DB/table to last App consistent view

APP CONSISTENT VIEW EXAMPLE

App Consistent State 1

Table Object 1 - v1

- Row- Object-1 - v5
- Row- Object-2 - v10
- Row- Object-3 - v15

App Inconsistent State

Table Object 1 - v2

- Row- Object-1 - v5
- Row- Object-2 - v8
- Row- Object-3 - v17

App Consistent State 2

Table Object 1 - v3

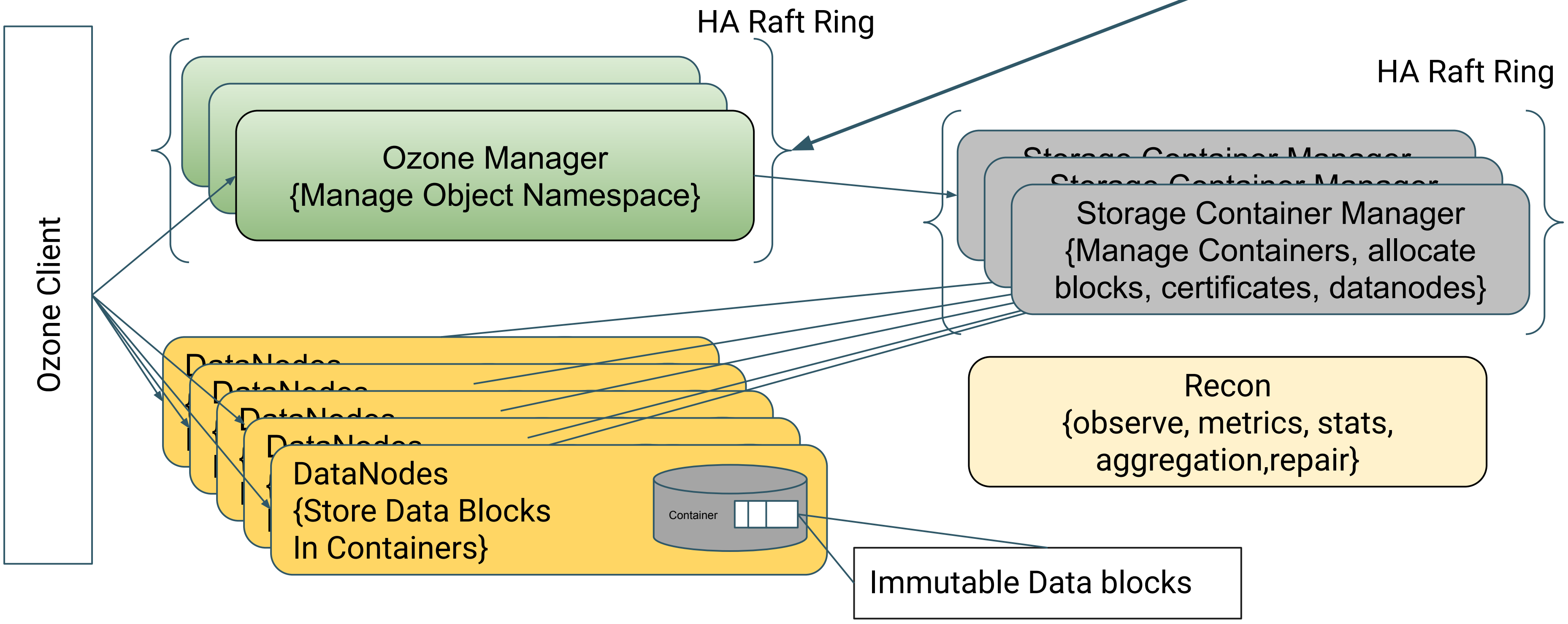
- Row- Object-1 - v10
- Row- Object-2 - v15
- Row- Object-3 - v20

VALUE DIFFERENTIATORS

- Instantaneous Snapshot creation,
- Immediately available for list/read/restore
- Bucket Snapshots,
  - Extensible to volumes.
  - No nested snapshots
- Basic operations : create/list/delete/restore
- Support out of order deletion
- Snapshot diff between two arbitrary snapshots of the same bucket
- Efficient Snapshot diff mechanism
- Insights : support stats e.g.
  - space locked by snapshots
  - Space freed if a snapshot is deleted

SNAPSHOT DESIGN

Snapshotting the object NameSpace is enough to get point in time image of the object store



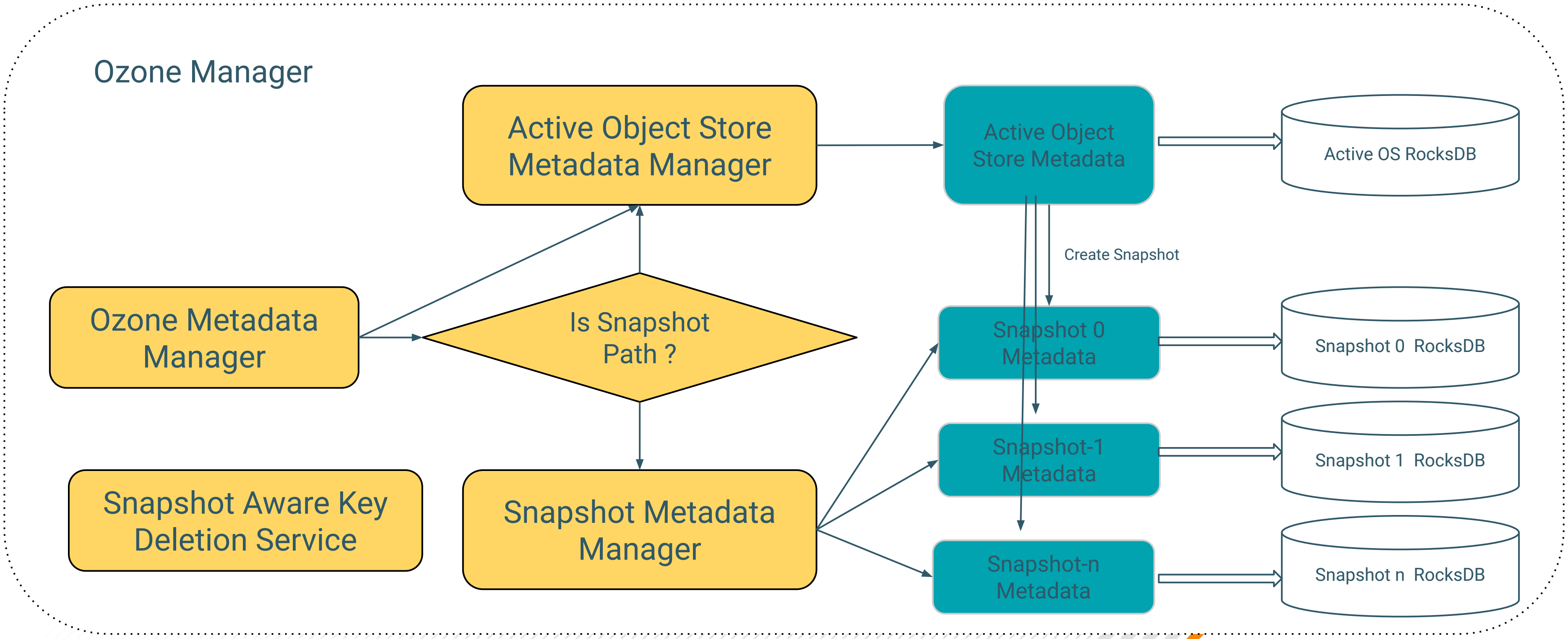
SNAPSHOT DESIGN : KEY IDEAS

- Leverage RocksDB Checkpoining mechanism
  - Flush the WAL
  - Create Checkpoint
- Instant Snapshots
  - Hard links for the SST files
  - All Snapshots are self contained with hard links
  - In future, it can also be used to support writable Snapshots
- RATIS driven for consistency across all OM HA nodes
  - OM nodes issue the checkpoint creation at exactly the same point

ACCESSING SNAPSHOTS

- Snapshots can be accessed through ".snapshot" hidden directory in the namespace
- Only bucket level snapshots are supported currently
- ".snapshot" hidden directory will be available under the bucket path
- For example, key *"/volume1/bucket1/k1"* from snapshot *"snap1"* can be read through path *"/volume1/bucket1/.snapshot/snap1/k1"*
- Snapshots & OM HA

SNAPSHOT DESIGN (Continued ...)



SNAPSHOT DIFF

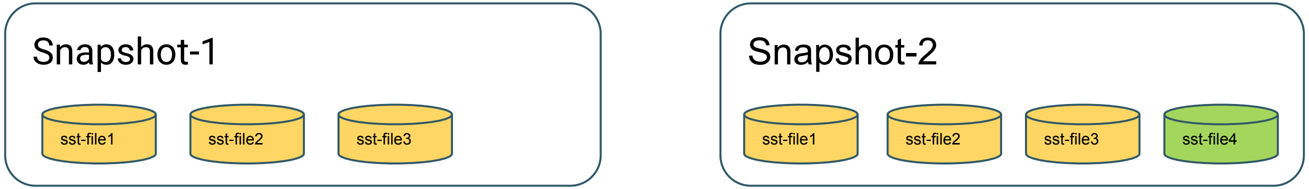
- Given two snapshots of a bucket: Identify changes
- Some of the Use cases
  - It can be used for incremental backup
  - Incremental Replication for DR
  - Efficient virus scans
  - Incremental analytics

SNAPSHOT DIFF : MECHANISM

- Namespace walk to identify changes
- Simple but it doesn't scale
  - Ozone is designed to hold billions of objects
- SnapDiff needs to be an efficient mechanism
- Proportionate to amount of churn in the Object Store
- Other alternatives
  - Maintain Change Log : grows too quickly, latency impact
  - Leverage LSM architecture

SNAPSHOT DIFF : LEVERAGING LSM ARCHITECTURE

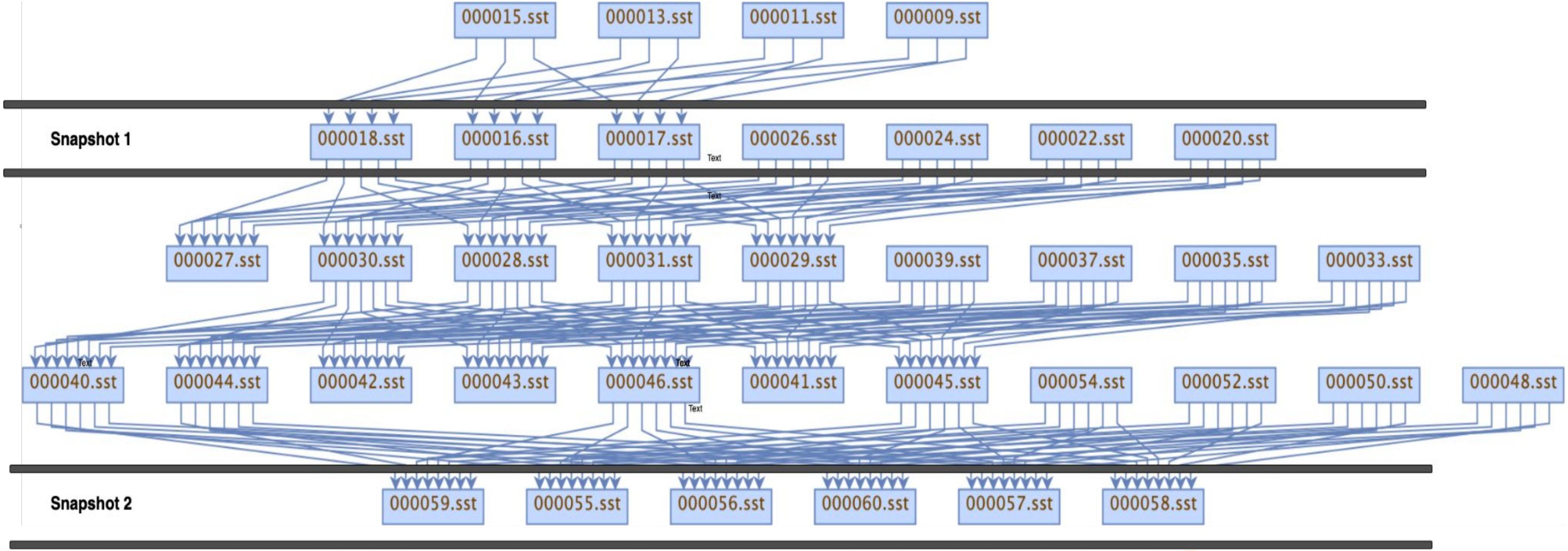
- LSM doesn’t do in-place updates
- RocksDB SST files are immutable
- New updates always go to new set of SST files
- In a simple world :
  - Just compare the SST files between two snapshots



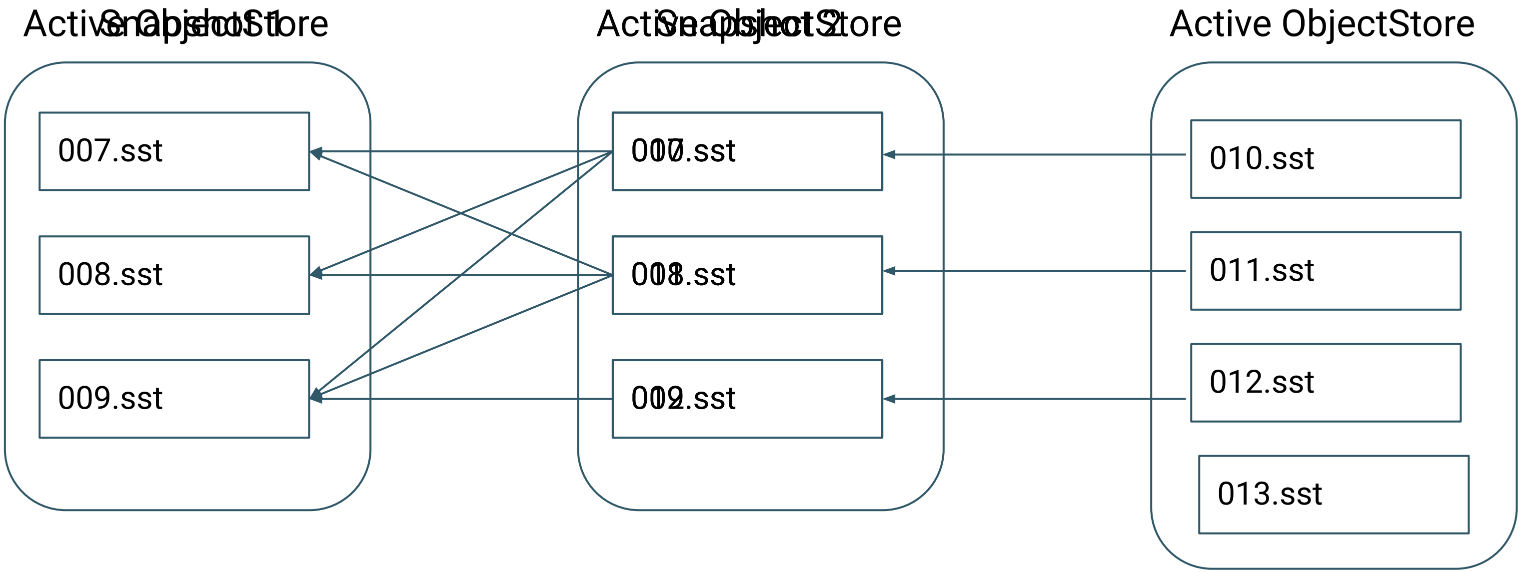
Only if it were that simple

SNAPSHOT DIFF : ROCKSDB COMPACTIONS

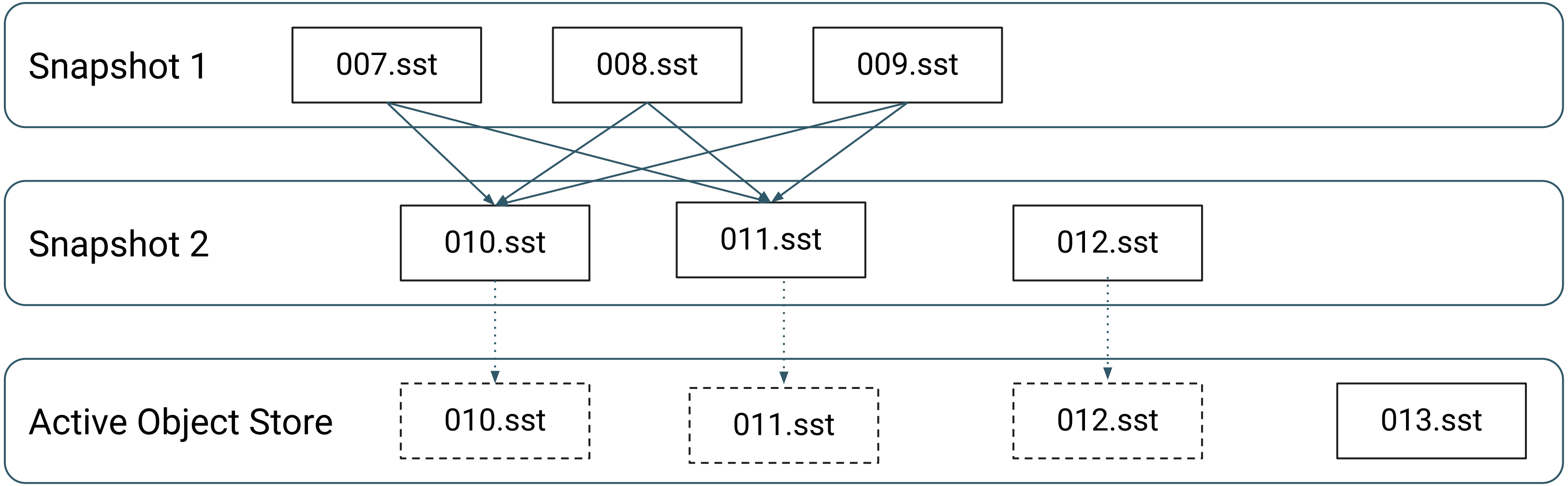
- RocksDB compaction keeps compacting existing SST files into new files



SNAPSHOT DIFF : OVERALL PICTURE



SNAPSHOT DIFF : COMPACTION DAG



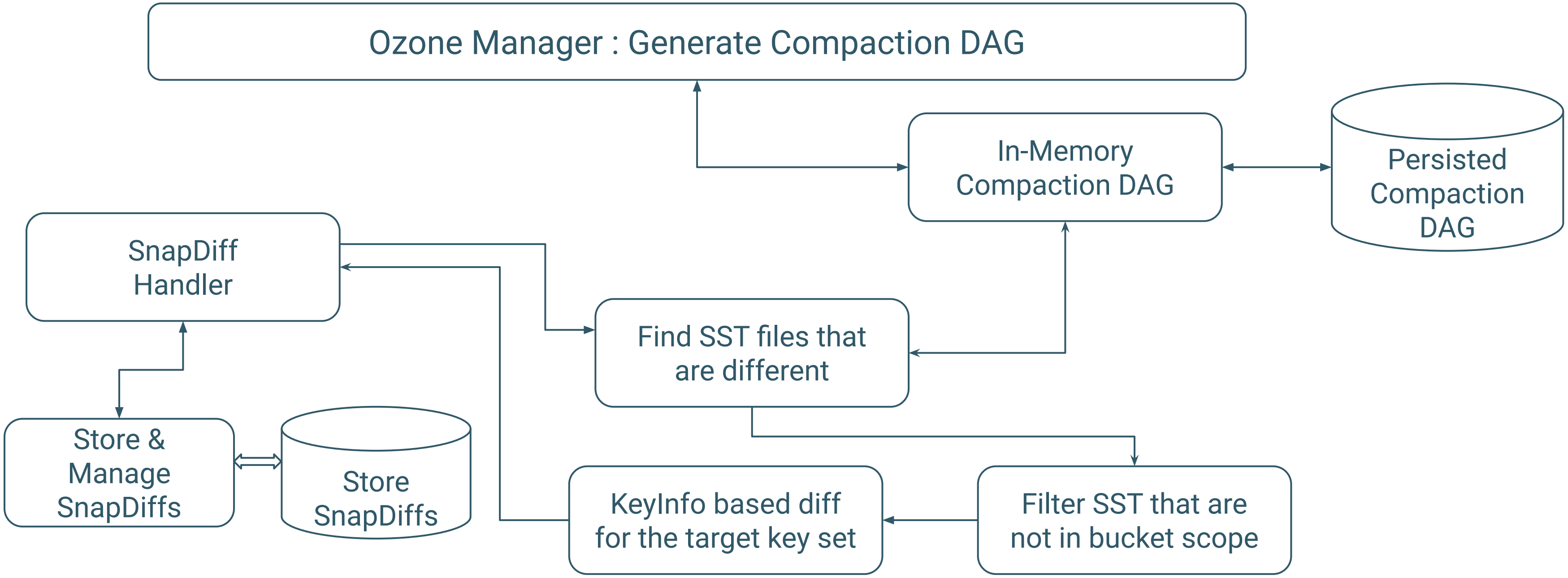
SnapDiff (Snapshot1, Snapshot2) = {12.sst}
Note that {007.sst, 008.sst, 009.sst} is same as {010.sst, 011.sst}

SNAPSHOT DIFF (Continued...)

- Rename Handling ?
  - Use unique Object IDs to track renames
- Store the Computed Snapdiffs
- Compute Snapdiffs using existing Snapdiffs
  - Diff(snap1,snap3) = Merge{Diff(snap1, snap2), Diff(snap2, snap3)}
- SnapDiffs can be served from any OM node including the follower nodes
- Snapshot reads can also be directed to OM follower nodes

“Only use published RocksDB APIs”

SNAPSHOT DIFF : Overall Picture



SNAPSHOTS : GARBAGE COLLECTION

- Updated Key Deletion Service
- Key Deletion from Active Object store
    - Just check previous snapshot before reclamation
- Snapshot Deletion
    - Check both previous and next snapshot for key claimation
    - No need to check the entire snapshot chain

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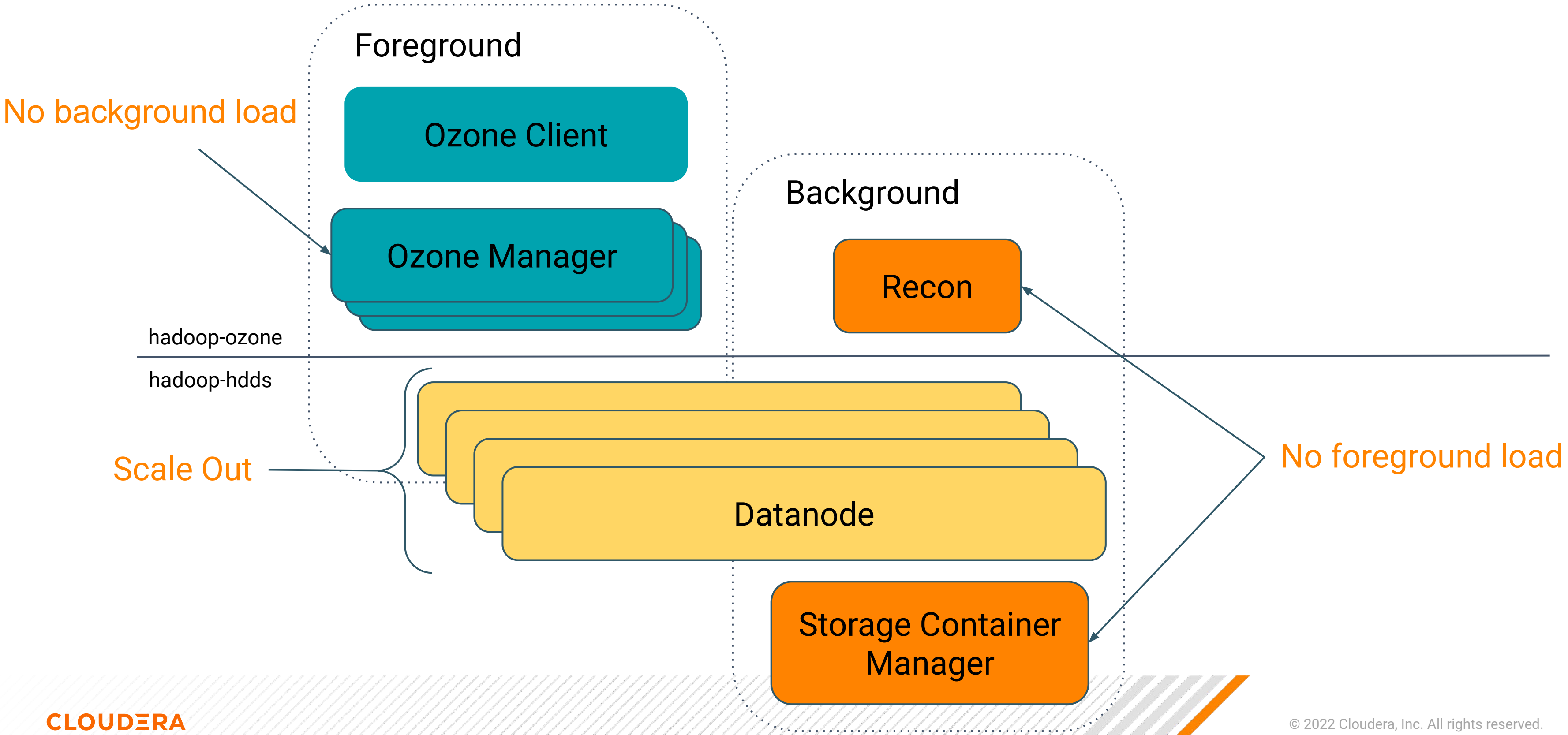
SNAPSHOTS : DEMO

- Creating Snapshots
- Listing Snapshots
- Read from Snapshots
- Read from Snapshots after updates to active ObjectStore
- Snapdiff

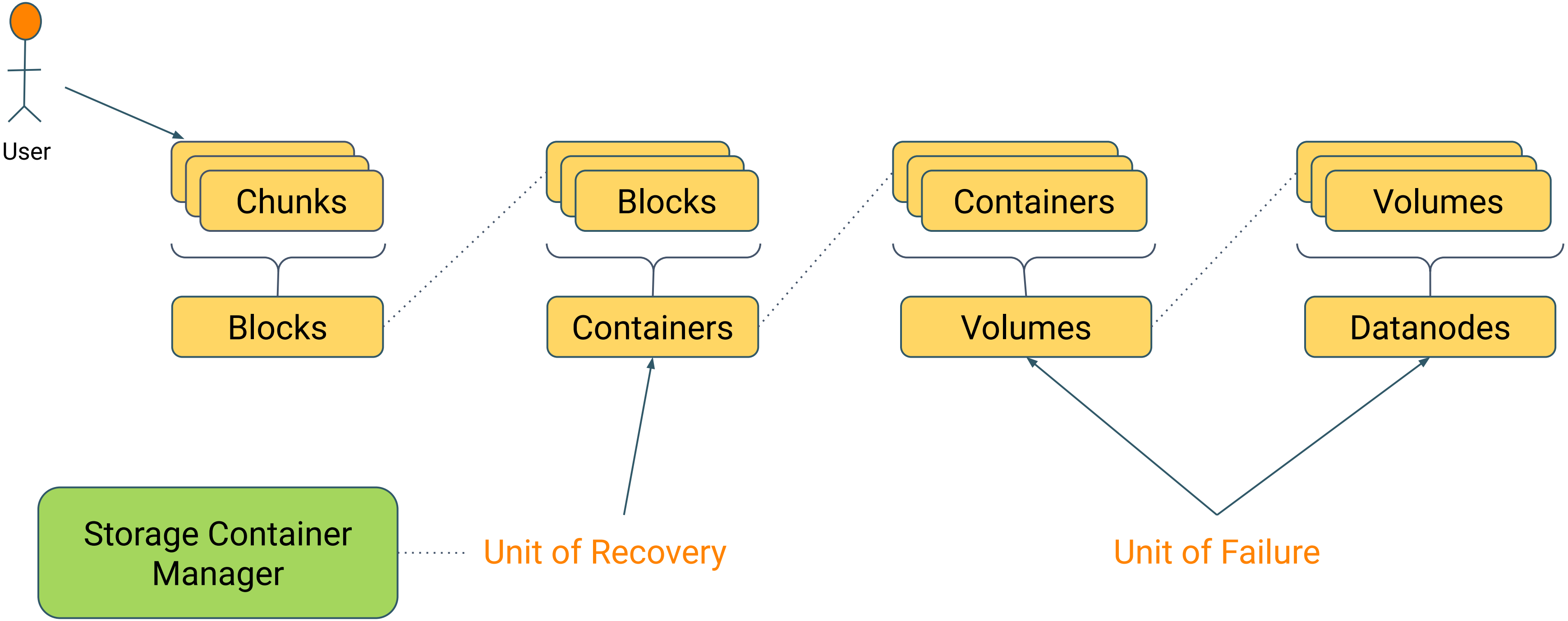
OZONE PERFORMANCE

Ritesh Shukla
Ozone committer

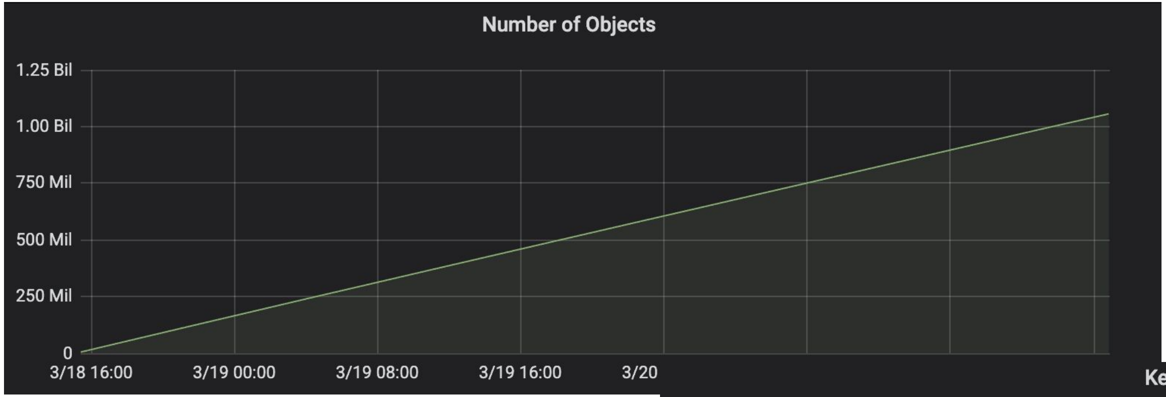
SEPARATION OF CONCERNS

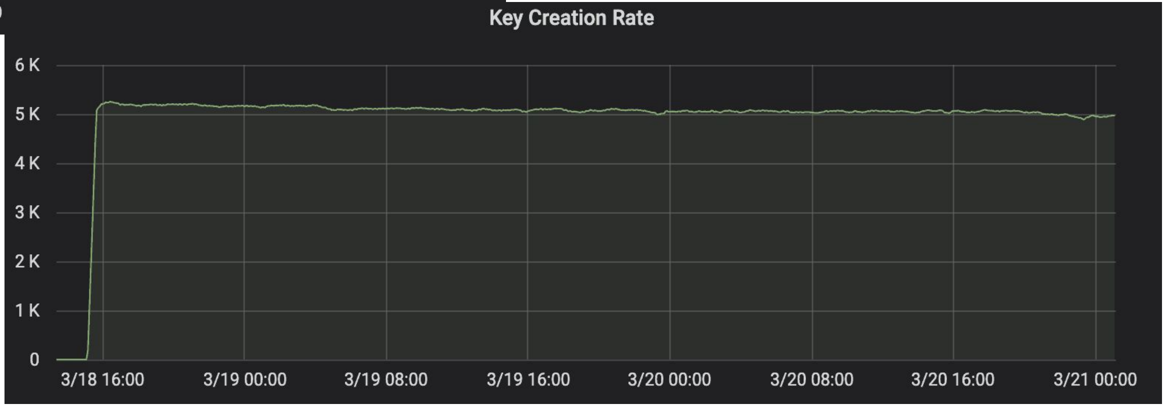


AGGREGATION VIA CONTAINERS



OZONE SCALES!





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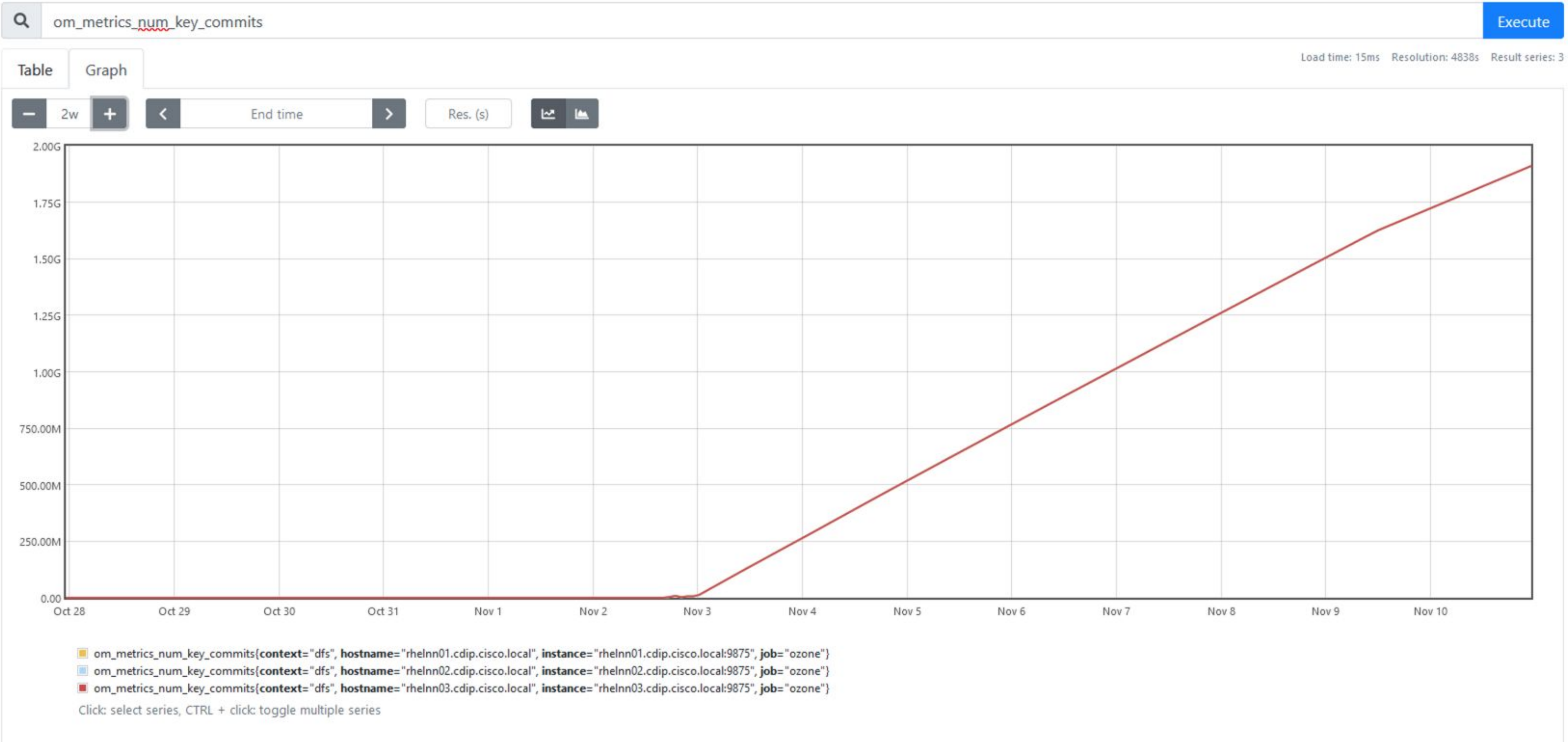
OZONE SCALES!



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WHY DOES FOREGROUND SCALE

Ozone Manager is designed to optimize application load and object count

- **No heap limitations**: Working set can be cached in memory and unused data can be destaged to disk via RocksDB
- **No block report load:** Background processing is separated from foreground.
- **NVME:** OM uses NVME to store RocksDBs
- **Simplicity:** Written with simplicity in mind
  - Example: Snapshots leverage RocksDB to preserve simplicity of IO path.

BACKGROUND SCALES UP AND SCALES OUT

Ozone is designed to optimize node density and node count

- **Container abstraction:** Container count scales only with capacity and not object count.
  - Node count scales better than HDFS.
- **Storage Container Manager:** Dedicated service to track, recover and rebalance containers.
- **Higher density:**
  - Datanodes certified against ~0.5 Petabyte capacity nodes
    - Cisco UCS M6: 256 TB per datanode
    - Cisco UCS S3260: 384 TB per datanode
  - Datanodes simulated against 1 Petabyte capacity nodes (200k containers)

OZONE VS. HDFS

Capability	Ozone	HDFS
Storage Density	1000’s of nodes at 600TB per node	1000’s of nodes at 100TB per node
Scalability	10B Objects	400M Objects
Recovery	Fast recovery	Slow startup based on size
High Availability	Active - Active	Active - Standby
Protocol Support	Hadoop / S3 API	Hadoop API

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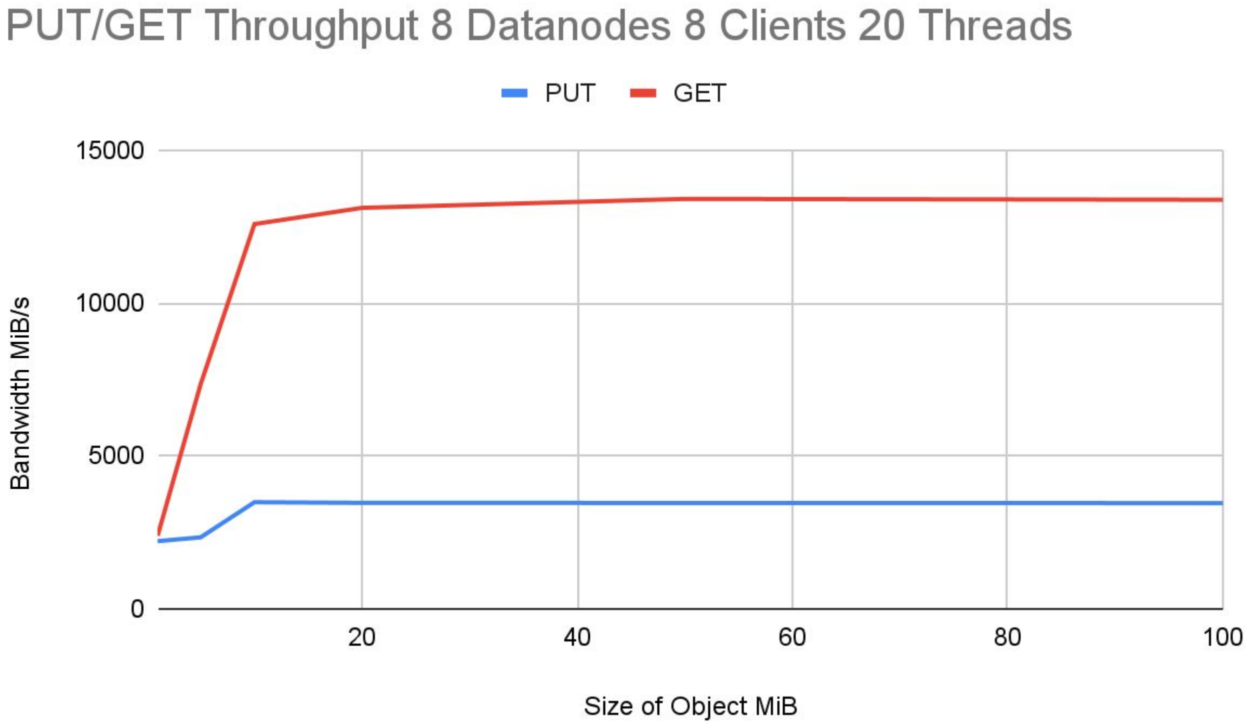
SMALL OBJECTS… WELCOME!

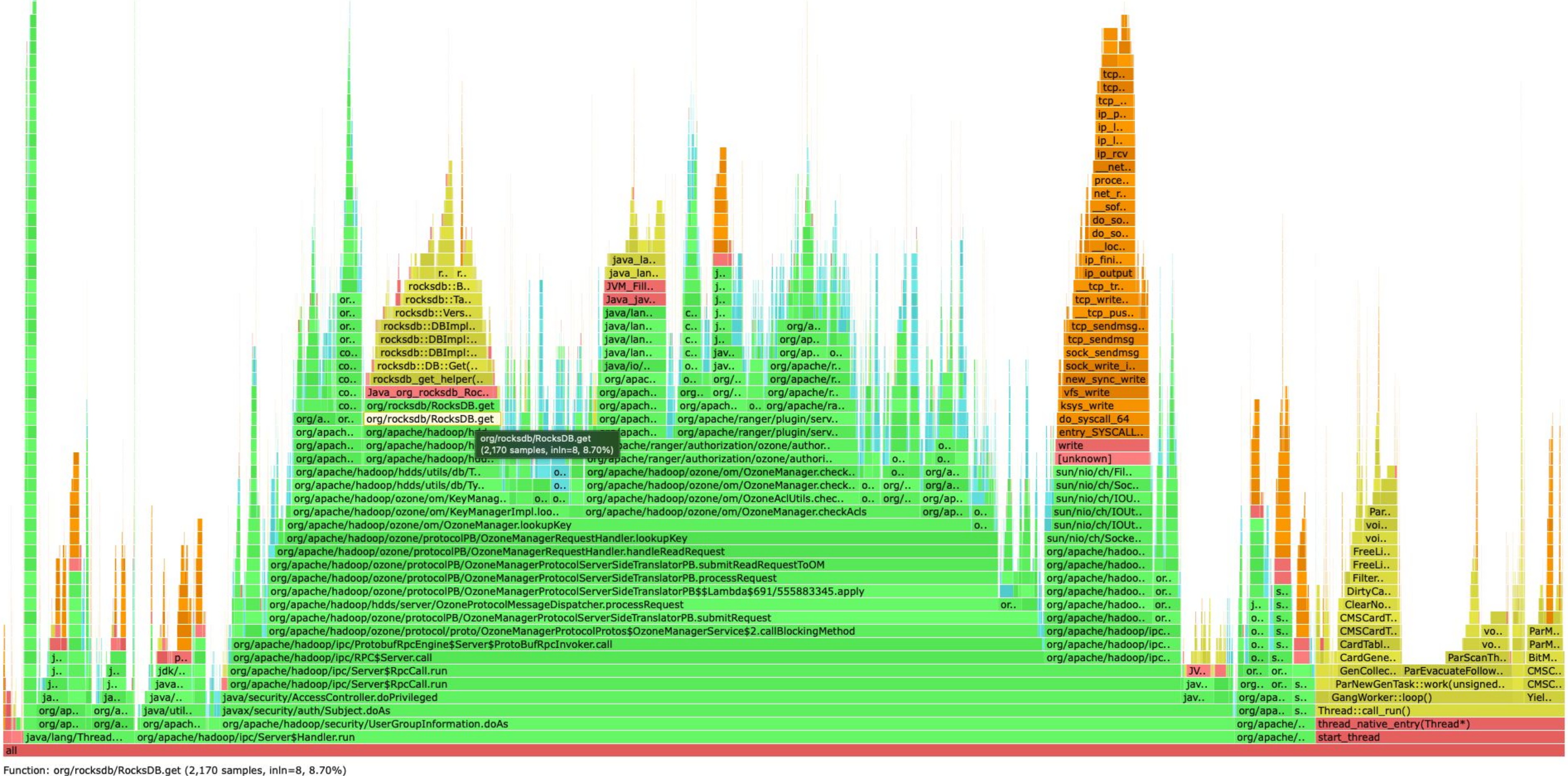


HARDWARE TRENDS

All NVME clusters are increasingly common

- Ozone's metadata is stored on SATA SSD or NVME
- Increasing number of customers using all NVME clusters (metadata and data)
  - High density nodes with Ozone
  - High performance workloads
  - Effectively lower TCO for all NVME clusters.

COST OF DESTAGING DATA



IMPALA + OZONE

- Data warehouse is popular use case for Ozone customers
- Cloudera is investing in optimizing Impala + Ozone stack

Ozone is close to HDFS in performance

SCR: Short circuit read

Remote: replica preference = remote

Ozone is close to HDFS in performance

SCR: Short circuit read

Remote: replica preference = remote

INVESTING INTO PERFORMANCE

Upcoming releases are performance focused

- Datanode - saturating the network
  - RATIS streaming
    - Efficient data path with rack awareness
    - Zero copy buffers
  - Simplified IO path for erasure coding
- OM - operations per second
  - Concurrency improvements
  - Caching background updates
  - Reducing latency per operation
- Impala improvements against Ozone

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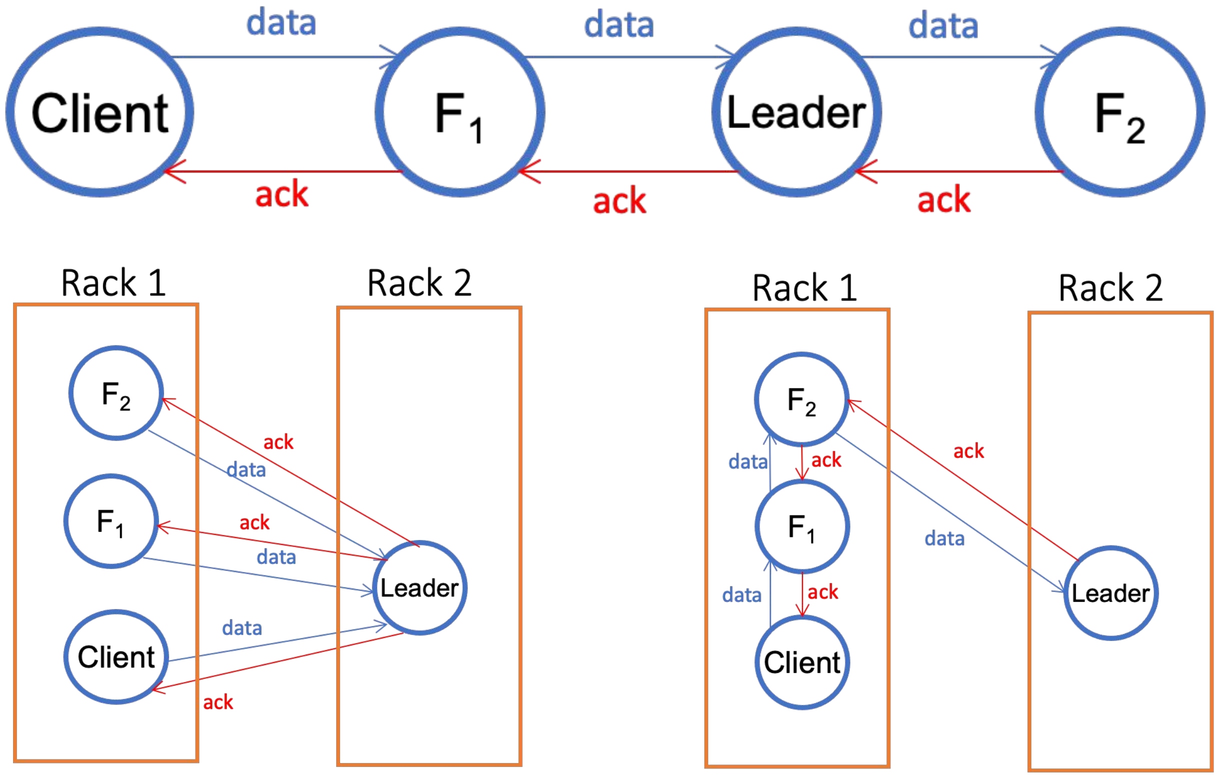
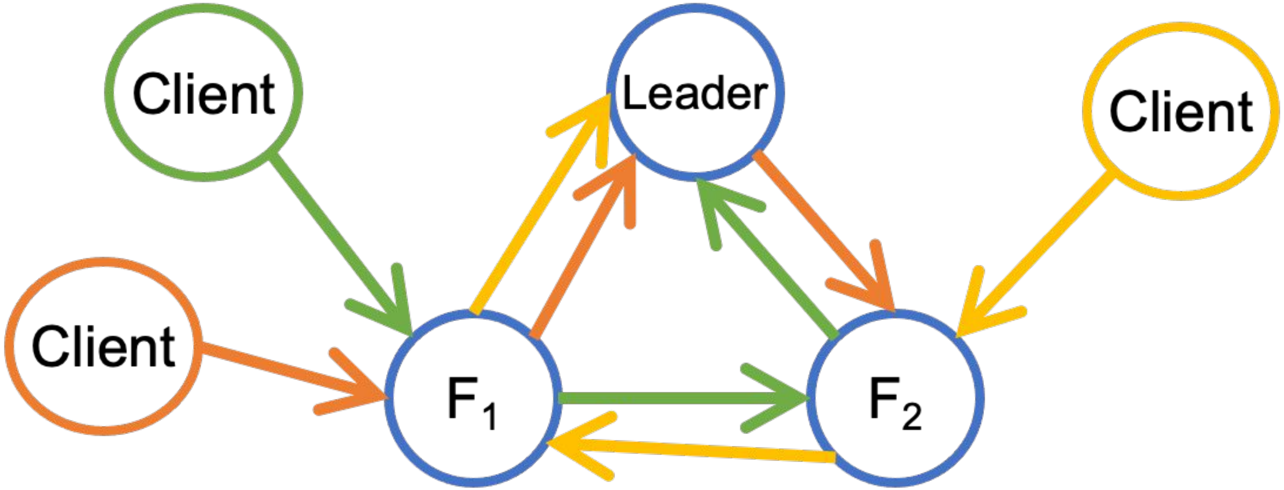
RATIS STREAMING



RATIS STREAMING - MULTIPLE CLIENTS

Multiple clients can achieve 3x performance over current implementation



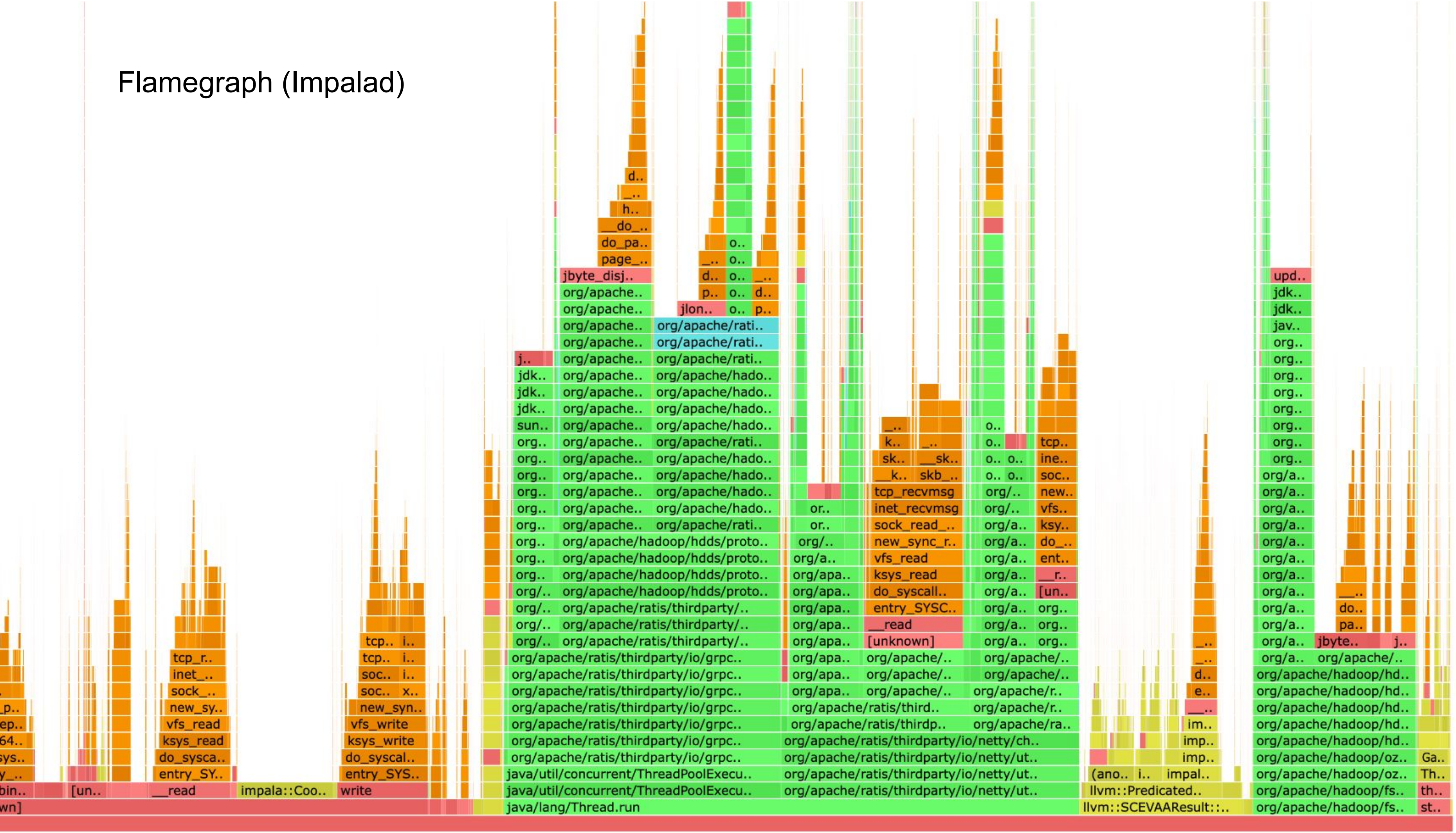
SUMMARY

- Ozone architecture solves big data scale issues
- Ozone is cost effective and meets performance
- Cloudera is continuing to push performance across the stack for Ozone
- Hardware trends well suited to leverage Ozone's capabilities.
- Performance tests validate architecture and direction for Ozone.

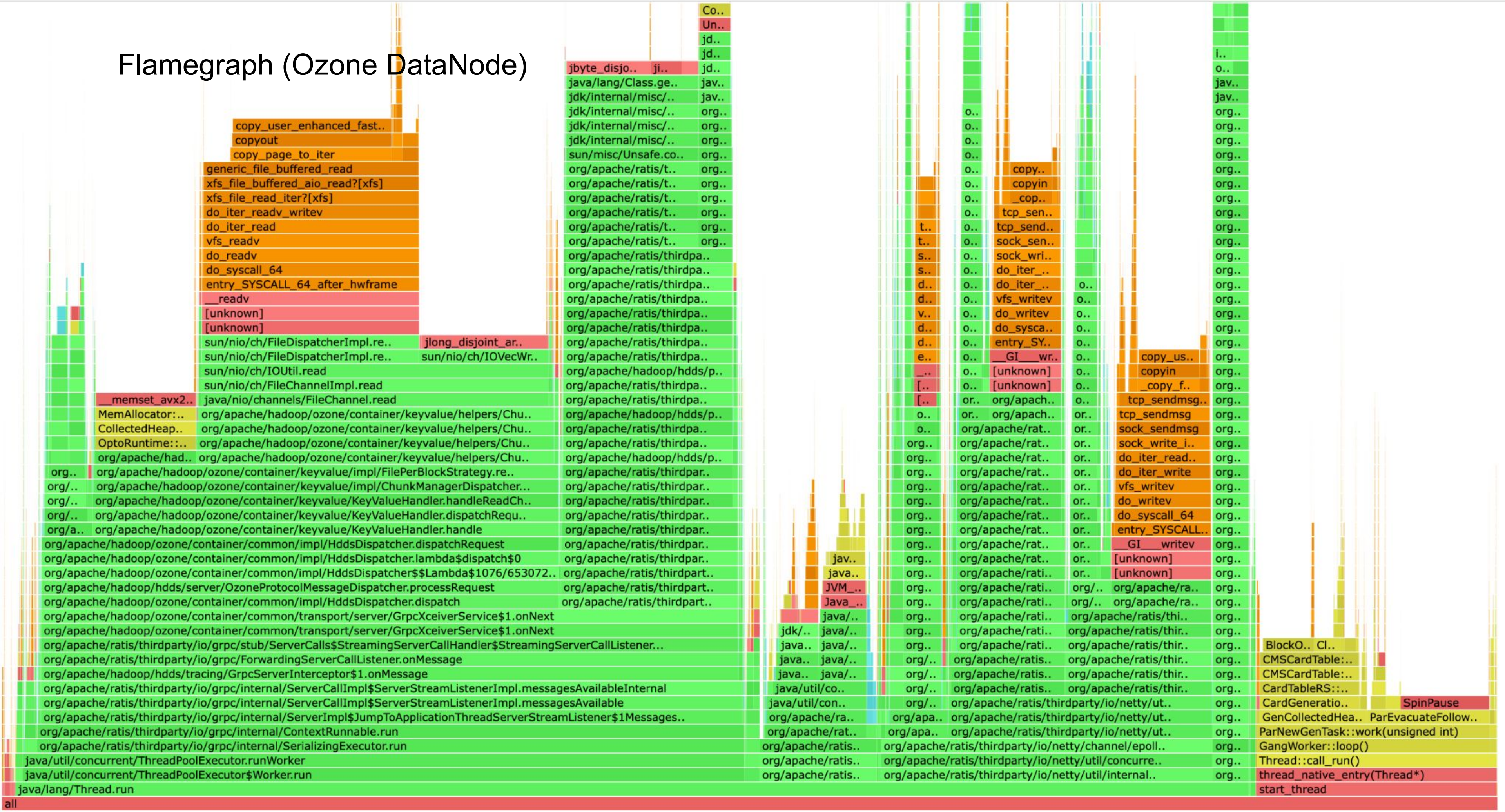
CONTRIBUTIONS WELCOME!

Questions?

Flamegraph (Impalad)



Flamegraph (Ozone DataNode)



Tests conducted

- Freon read load post hard restart (minimal caching)
- Warp test to measure network saturation when using S3
- Impala TPCDS benchmark
- Ratis streaming performance tests

Software under test

CDP Private Cloud Base 7.1.8 +

- IMPALA-11457 Fix regression with unknown disk id
- HDDS-4970 Significant overhead when DataNode is over-subscribed
- HDDS-7135 ofs file input stream should support StreamCapabilities interface
- HDDS-7136 Memory leak due to ChunkInputStream.close() not releasing buffer
- HDDS-7161 Make Checksum.int2ByteString() zero-copy

All fixes are upstreamed in Apache Ozone 1.3.0 + Apache Impala 4.1.1

Software under test

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Testbed

3 x master nodes, 16 x DataNodes

Master nodes

CPU	2 x Intel(R) Xeon(R) Gold 6230 CPU @ 2.10GHz/20 cores
memory	384GB (12 x 32GB DDR4 @ 2933MHz)
OS Boot	Cisco Boot optimized M.2 Raid controller with 2 x 240GB SATA SSD
SSD	3.8TB SATA SSD Enterprise Value
Storage Controller	Cisco 12G Modular Raid Controller with 2GB cache
Network Adapter	Cisco UCS VIC 1387 2 x 40Gbps ports x8 PCIe Gen3

Data Nodes

CPU	2 x Intel(R) Xeon(R) Gold 6262V CPU @ 1.90GHz/24 cores
memory	384GB (12 x 32GB DDR4 @ 2933MHz)
OS Boot	Cisco Boot optimized M.2 Raid controller with 2 x 240GB SATA SSD
NVMe	10 x 8TB Intel P4510 U.2 High Performance Value
Storage Controller	NA
Network Adapter	Cisco UCS VIC 1387 2 x 40Gbps ports x8 PCIe Gen3