Ozone: scaling HDFS to trillions of objects

Xiaoyu Yao & Anu Engineer

Apache Committers & PMC members

HDFS

- Apache HDFS is designed for large objects – not for many small objects.
- Small files create memory pressure on namenode.
  - Metadata in memory is the strength of the original GFS and HDFS design, but also the weakness in scaling to large number of files and blocks.
- Each file adds metadata to the namenode.
  - Datanodes send all block information to namenode in BlockReports.
- Both of these create scalability issues on Namenode.

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Ozone and HDFS - past

- HDFS-5477 – Separate Block Management.
- HDFS-8286 - Partial Namespace In Memory.
- HDFS-1052 Federation aims to address namespace and Block Space scalability issues.
  - Federation deployment and planning adds complexity
  - Requires changes to other components in the Hadoop stack
- HDFS-10467 Router based federation
- HDFS-7240 - Ozone borrows many ideas learned from these efforts and is a super set of these approaches.

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Ozone and HDFS - now

- HDFS-7240 merged into Apache Hadoop trunk
  - New sub-project named HDDS (Hadoop Distributed Data Store).
  - Loadable module running in/out of process with HDFS datanode.
  - HDDS release is independent release Hadoop.
  - Maven profile (-pHdds) that disable HDDS compile by default.
  - Thanks to all the contributors from the community that made Ozone real!

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Ozone Overview

- Ozone is an S3 like object store, which exposes REST API and Hadoop RPC interfaces.
- OzoneFS is a Hadoop compatible file system.
- Applications like Hive, Spark, YARN and MapReduce run natively on OzoneFS **without any modifications**.

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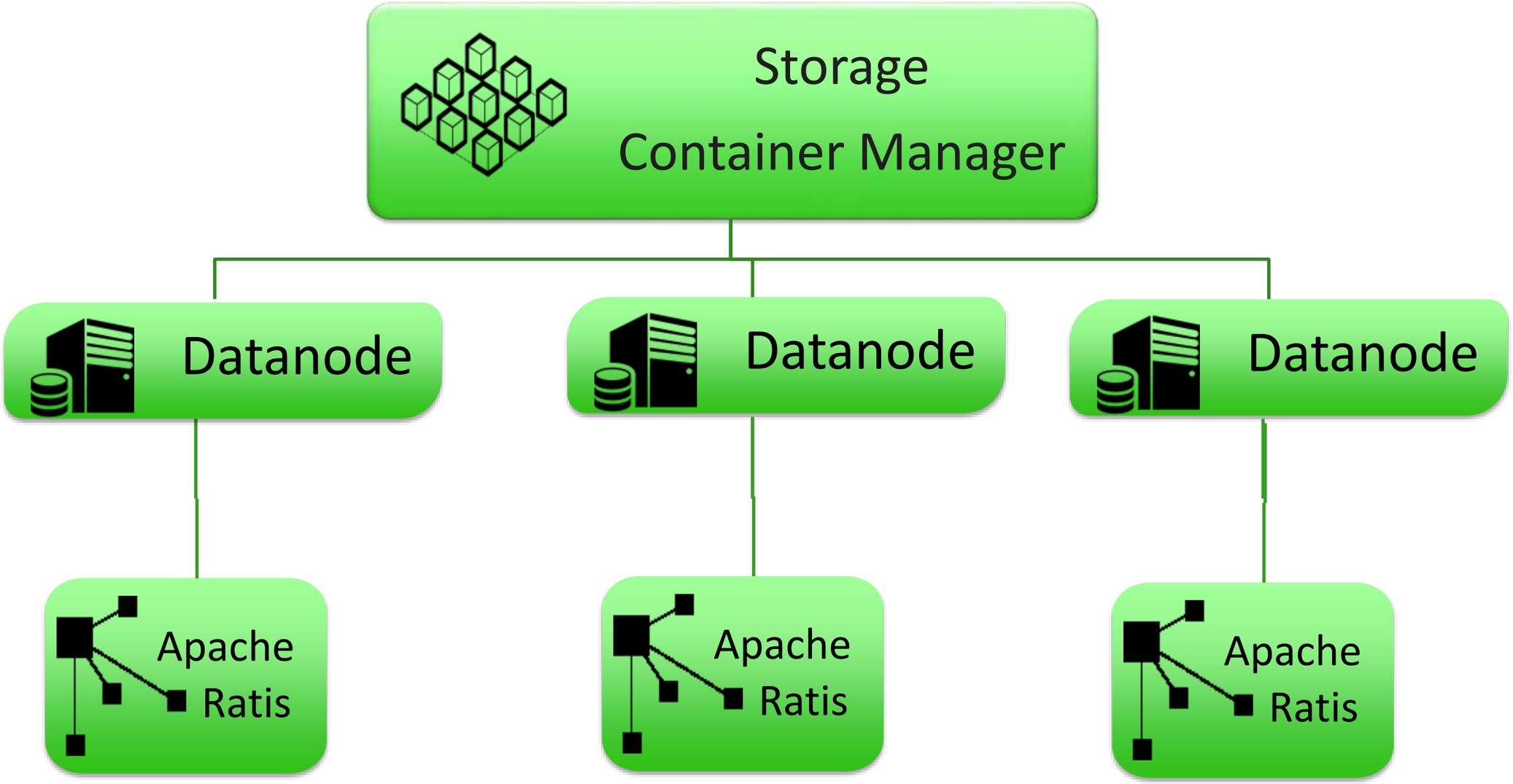
Ozone and Block layer

- The most basic abstraction in Ozone is a block layer called –
  - **Hadoop Distributed Data Store or HDDS.**
- This talk is really about HDDS; how it works and how it will be used by other name space services.
  - For example, Ozone, HDFS and Quadra (CBlock) are simple namespace services that can be built using HDDS.
- HDDS is a Distributed, Highly available block storage framework. It is designed to be used by a system that provides it own namespace management.
- HDDS consists of a block manager called Storage Container Manager (SCM) and a set of nodes that act as the data stores. The following architectural diagram shows the components that makeup HDDS.

HORTONWORKS

Hadoop Distributed Data Store Architecture



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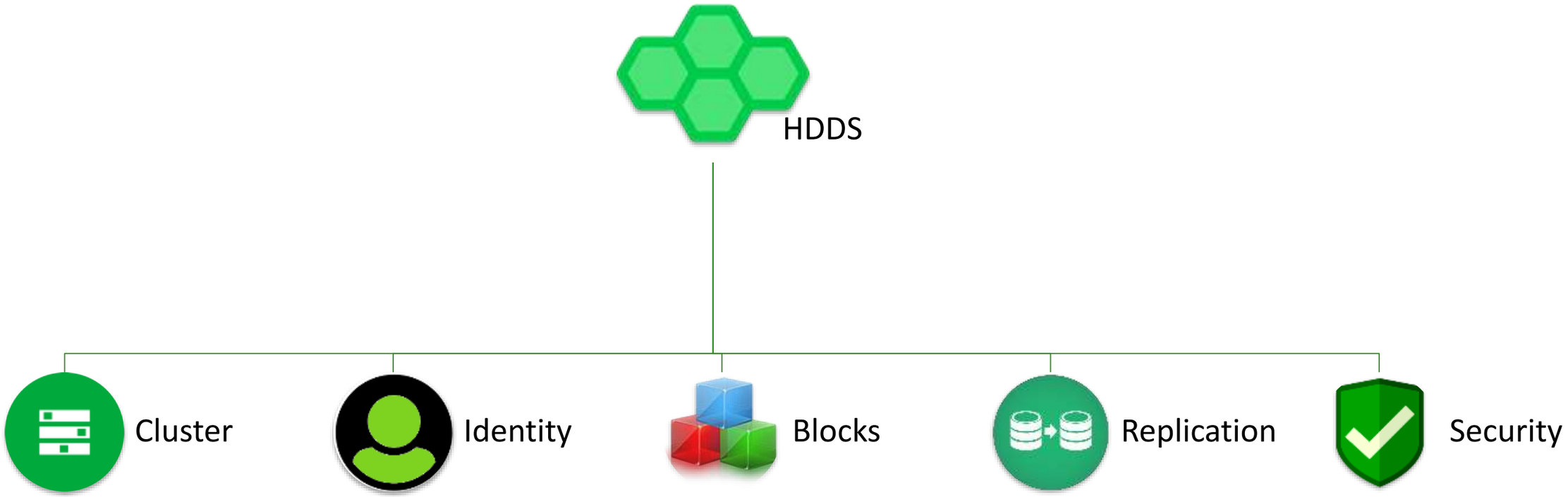
Hadoop Distributed Data Store Services



Booting a Cluster

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Booting up a Cluster

- HDDS acts as the central identity manager for the cluster.
- HDDS has a complete Certificate Infrastructure built-in
- The identity management service of HDDS provides the following identities
  - name service identities.
  - datanode identities.
- When SCM boots up it creates its own Certificate Authority
  - Yes, You can provision it to be an Intermediate authority – That is be a part of an existing CA infra-structure
- When datanodes join the cluster, SCM verifies datanode identity and issues a datanode certificate.
- Other name space services like Ozone Manager, Namenode' or Quadra Server will obtain service identity certificates from SCM.

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Booting up a Cluster – Initializing SCM

1. Generate Cluster ID & SCM ID

2. Generate Self-Signed Certificates

3. Wait for Data nodes to register

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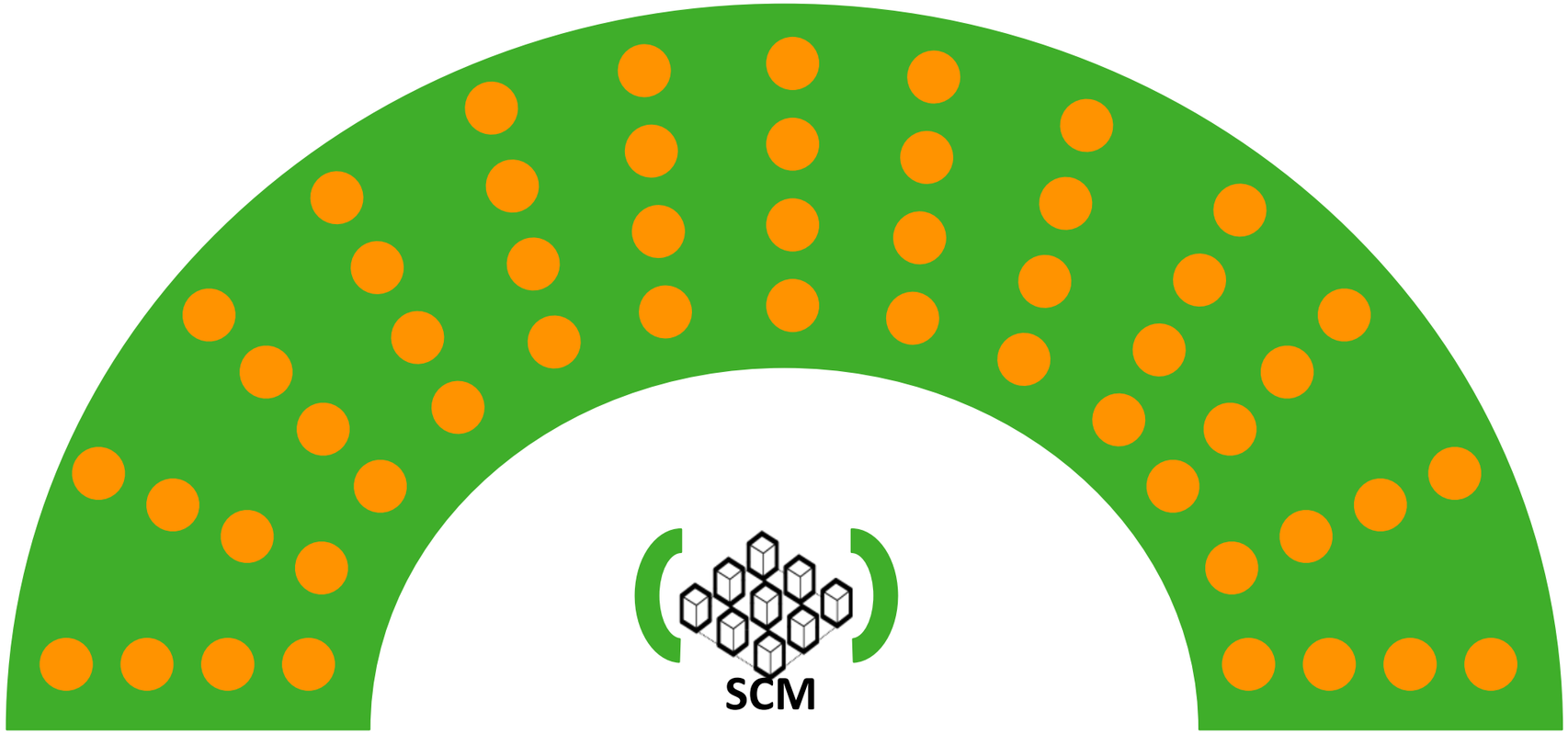
Booting up a Cluster – Issuing certificates to Data nodes

1. Data nodes make a certificate request

2. SCM issues certificate after verifying the identity

3. Data nodes are functional



- Kerberos is not required on datanodes for a secure cluster.

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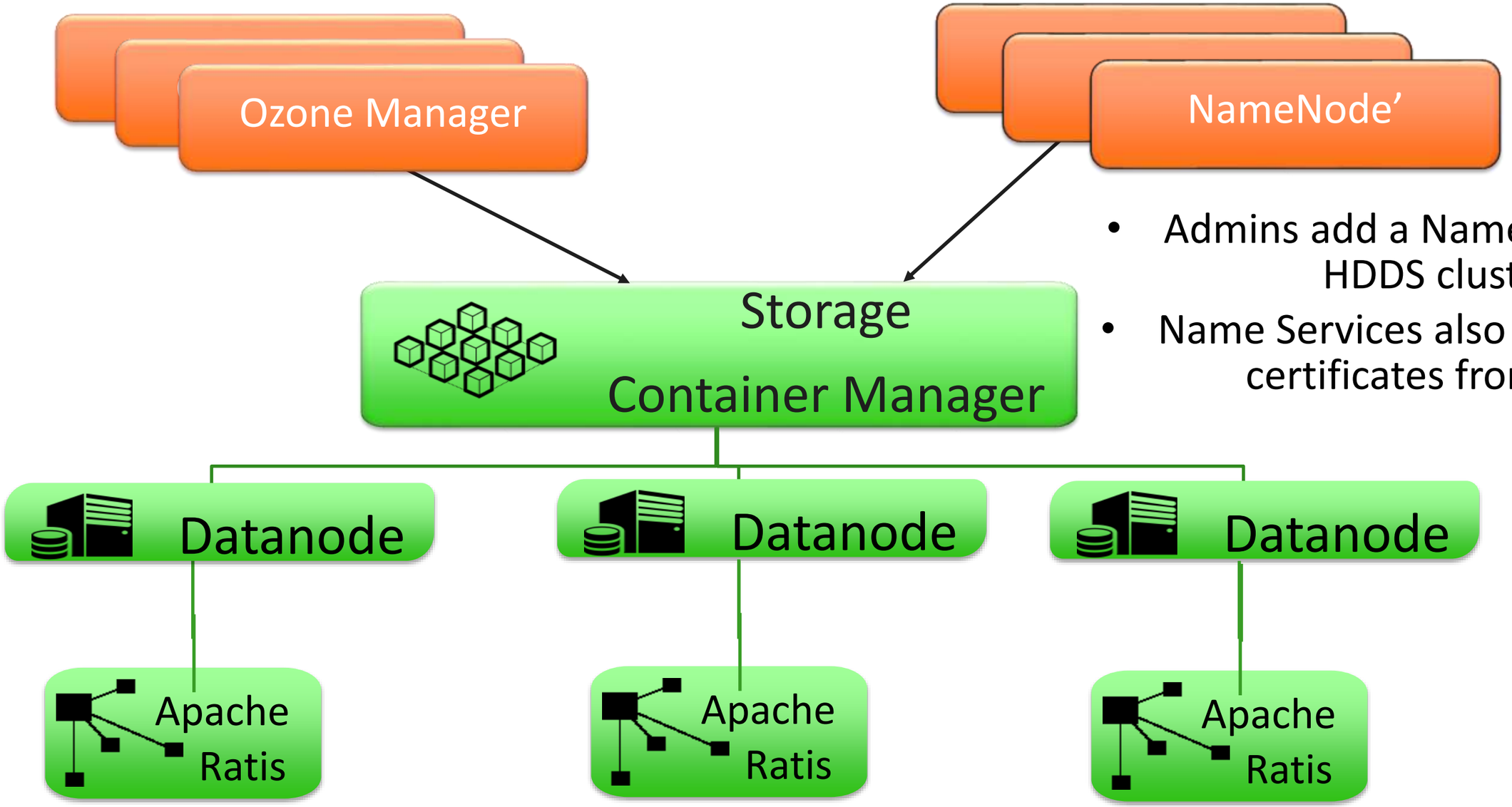
Booting up a Cluster – Registering a name service



- Admins add a Name Service to HDDS cluster
- Name Services also get identity certificates from SCM

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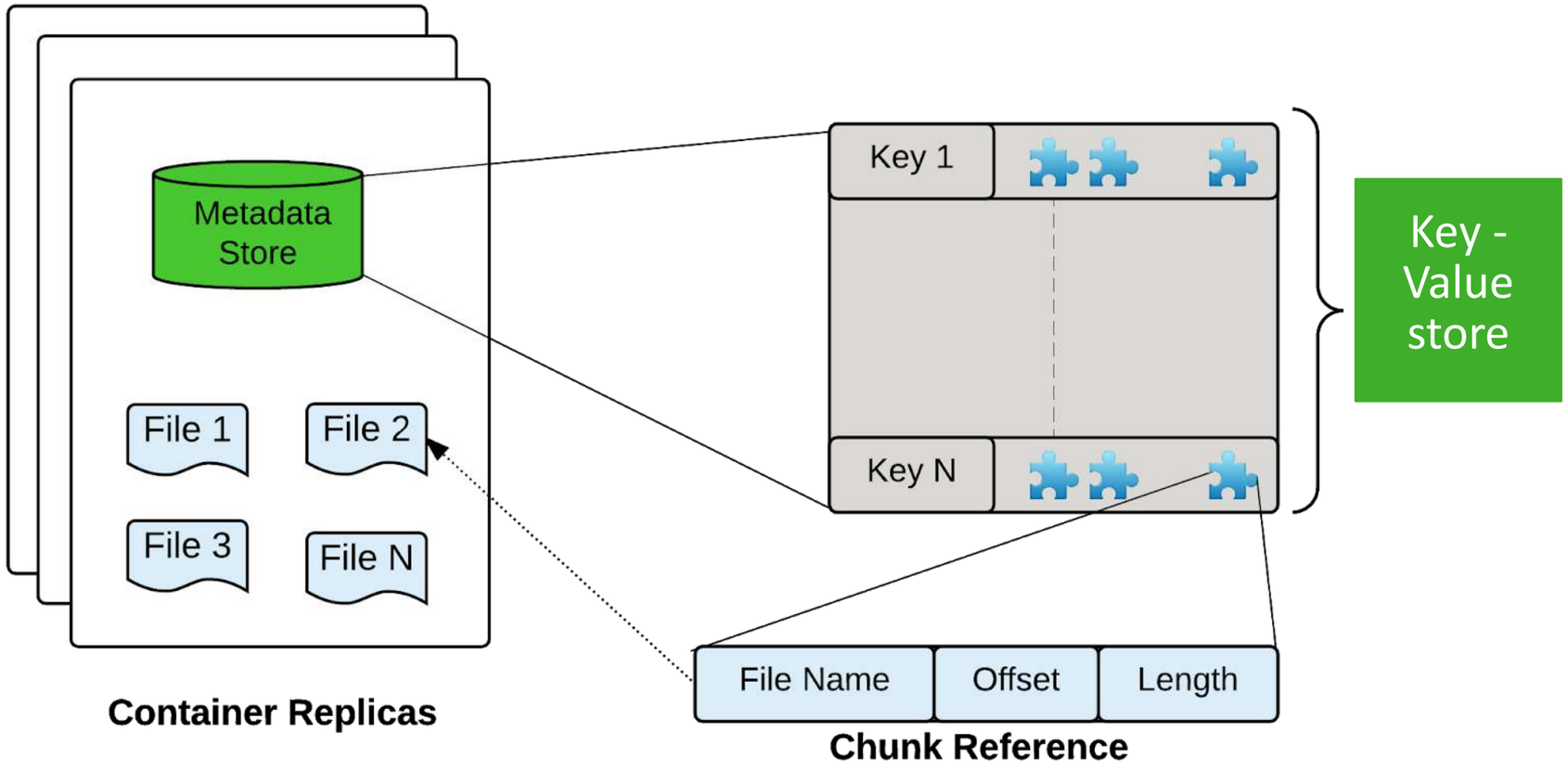
Writing Data

HORTONWORKS

Writing Data – Understanding Storage Containers

- HDDS datanode is a plug-in service running in Datanodes.
- Container is basic unit of replication (2-16GB).
- Fully distributed block metadata in LSM-based K-V store.
- No centralized block map in memory like HDFS.



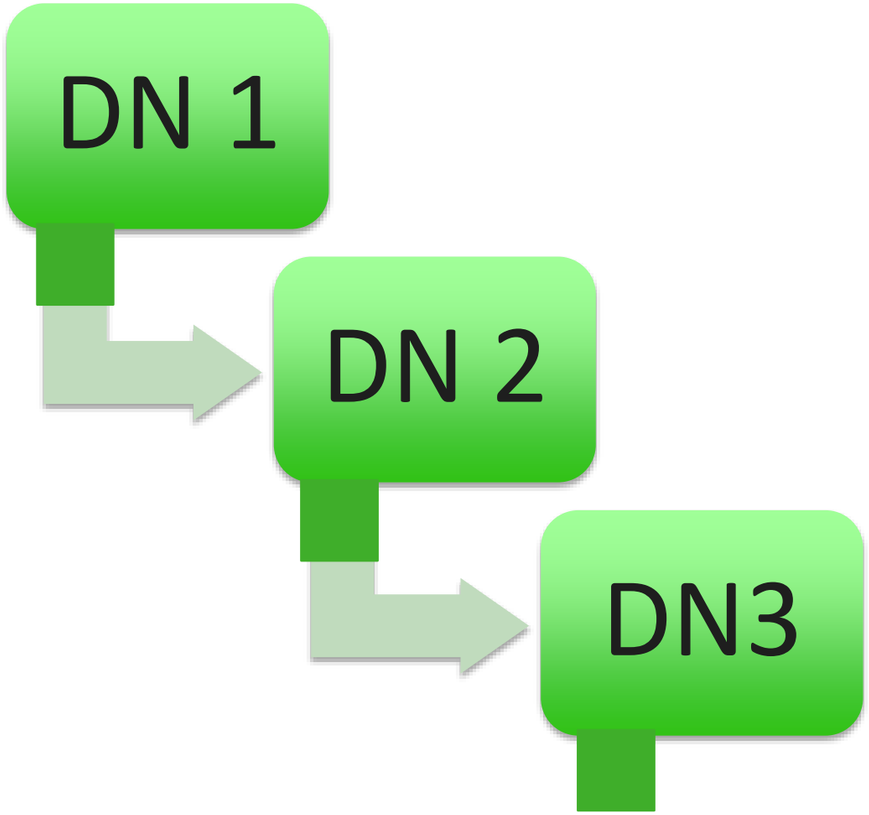
Writing Data – Understanding Open/Close Containers

- Close Container: keys and their blocks are immutable
  - Write is not allowed.
  - Container closed when is it is close to full or failure.

- Open Container: keys and their blocks are mutable
  - Write via Apace Ratis

Writing Data – Understanding Pipelines

- **A pipeline is a replicated stream.**
- HDDS is designed to have different kind of streams – that allows support for different strategies.
- For example, if we are using HDFS replication, a Pipeline would like this.



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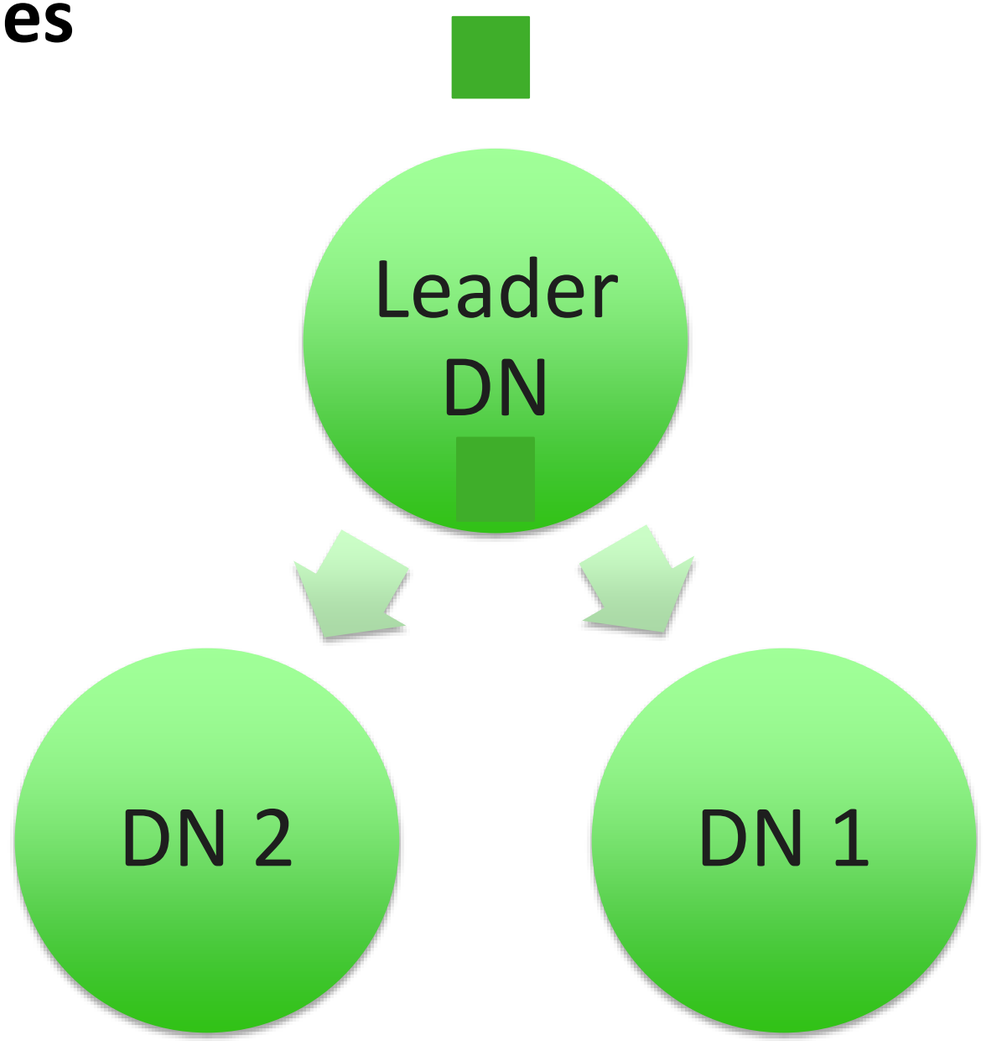
Writing Data – Understanding Pipelines

- **HDDS writes to Containers using Pipelines**.
- HDDS uses Apache Ratis based pipeline, which still appears as a stream.
  - Apache Ratis is a highly customizable Raft consensus protocol library.
  - Support high throughput data replication use cases like Ozone.
- For example, if we are using HDDS and Apache Ratis based replication, a Pipeline would like this.



Writing Data -- Blocks

Client

1. Write Key

1. Client makes a request to Ozone Manager to write a key.

Ozone Manager

2. Get Block

2. Ozone Manager requests SCM to allocate a block.

SCM

3. SCM allocates a block.

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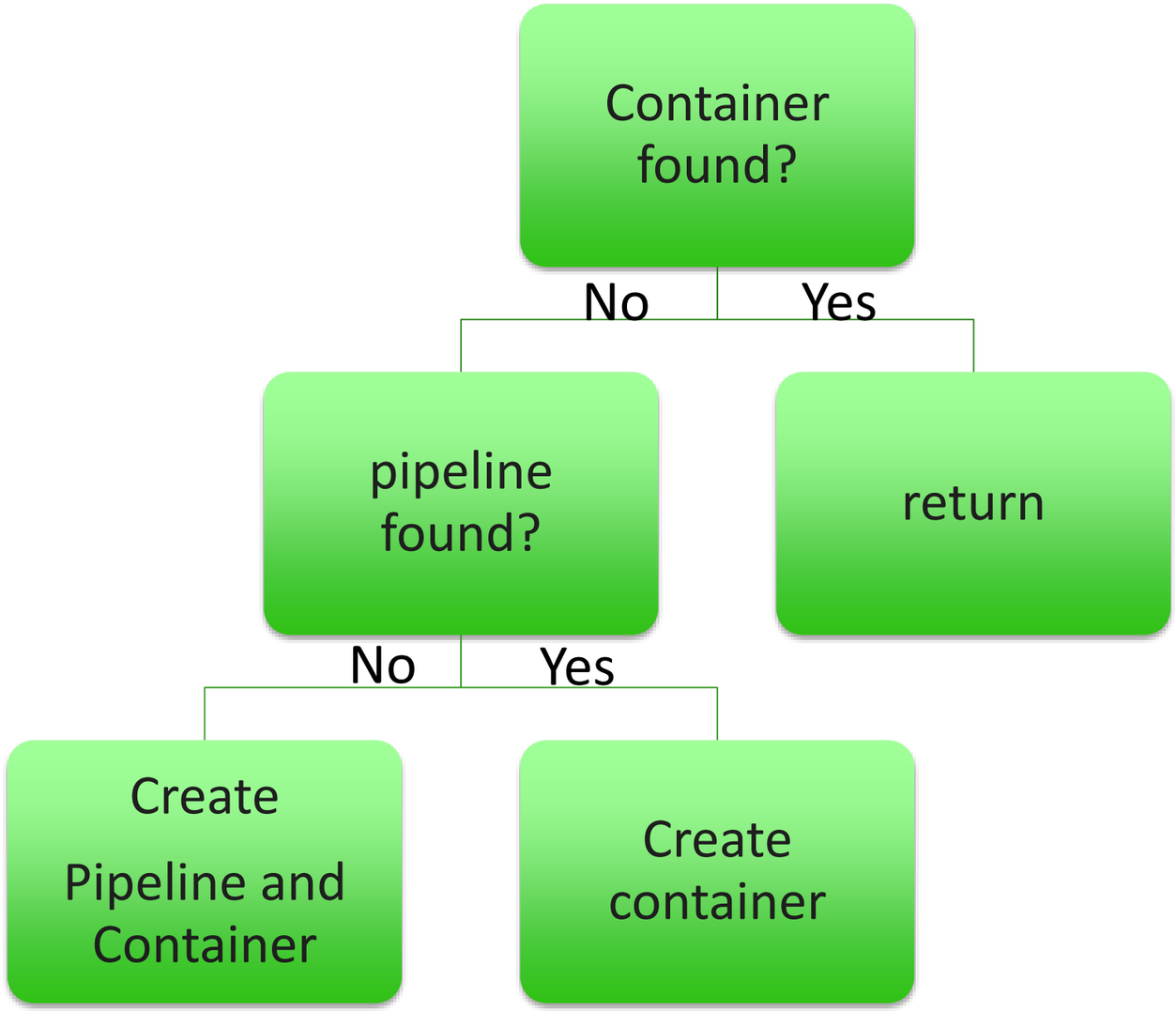
Writing Data – SCM Allocating Container/Pipeline for Blocks



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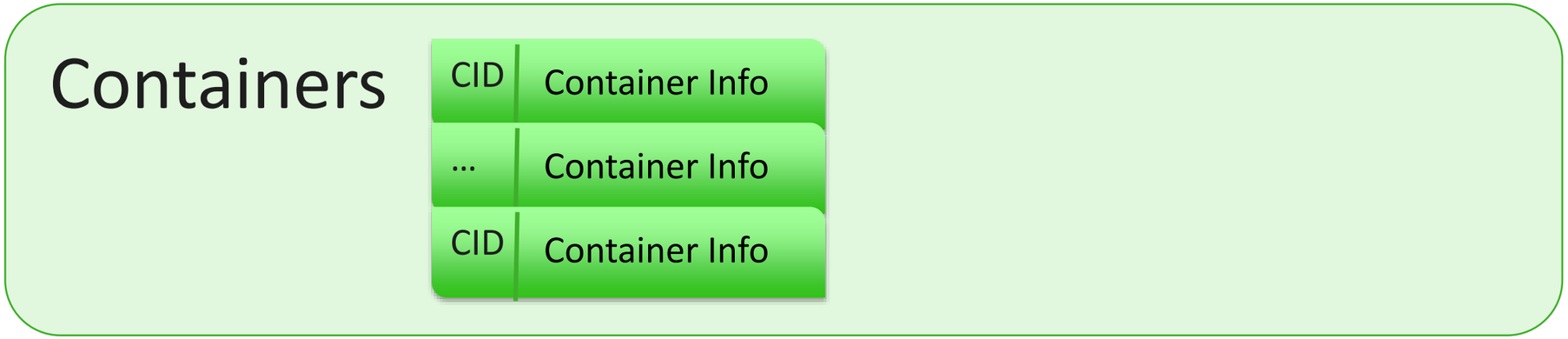
Writing Data - SCM records the Container state

Storage Container Manager persists the container states to LSM-based K-V Store



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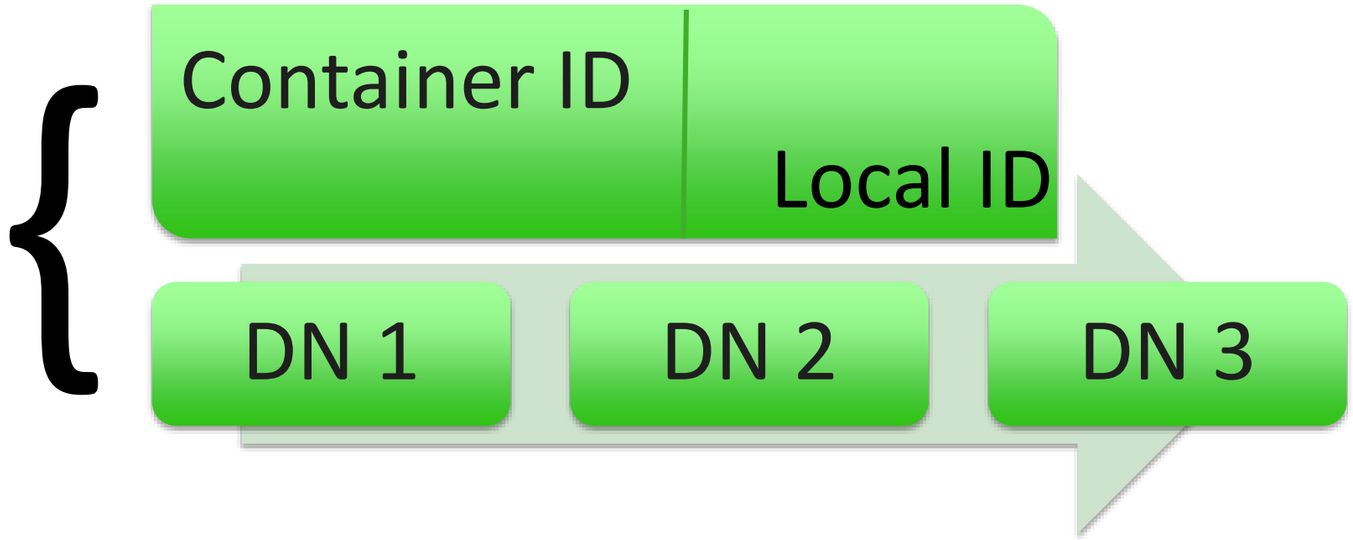
Writing Data

SCM returns a Block ID and a Pipeline to Ozone Manager.

Client needs Block ID and Pipeline to write data



This is similar to HDFS block and data node locations.

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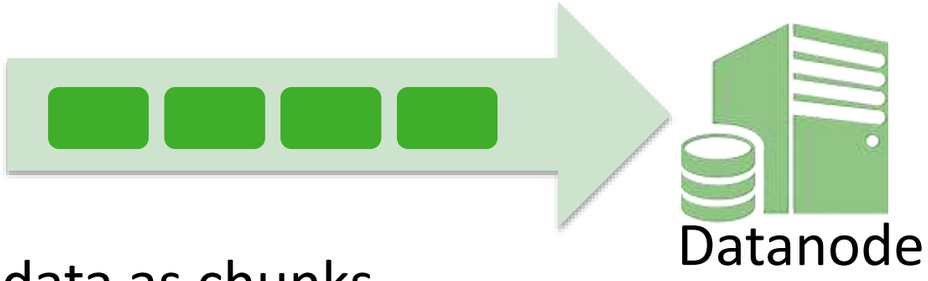
Block Commit Protocol

1. Client → PutKey → Ozone Manager → Allocate Block → SCM

2. Client → Datanode



- Writes data as chunks
- Update metadata of a block

Block	Value
Block 001	{ List of Chunks }
Block 002	{ List of Chunks }

3. Client → Commit Key → Ozone Manager

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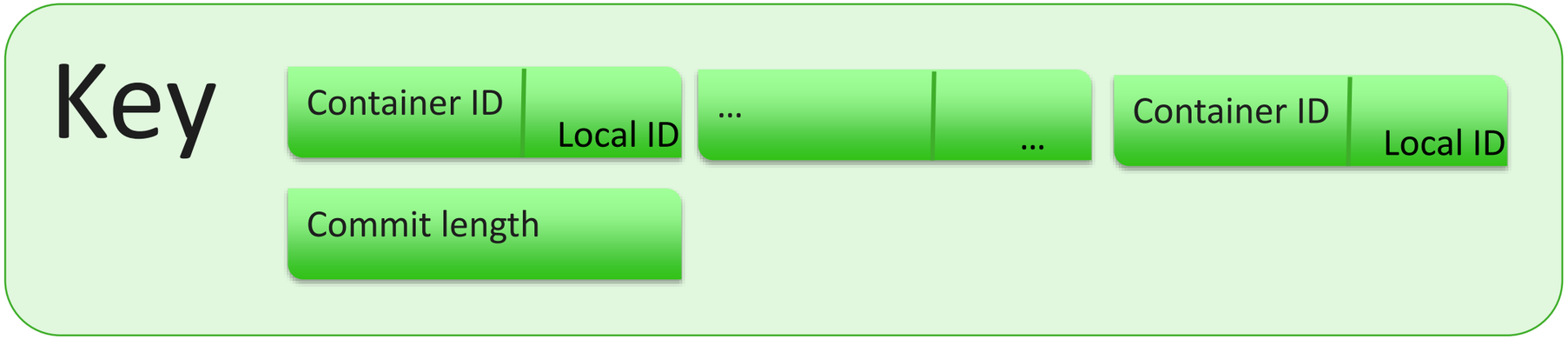
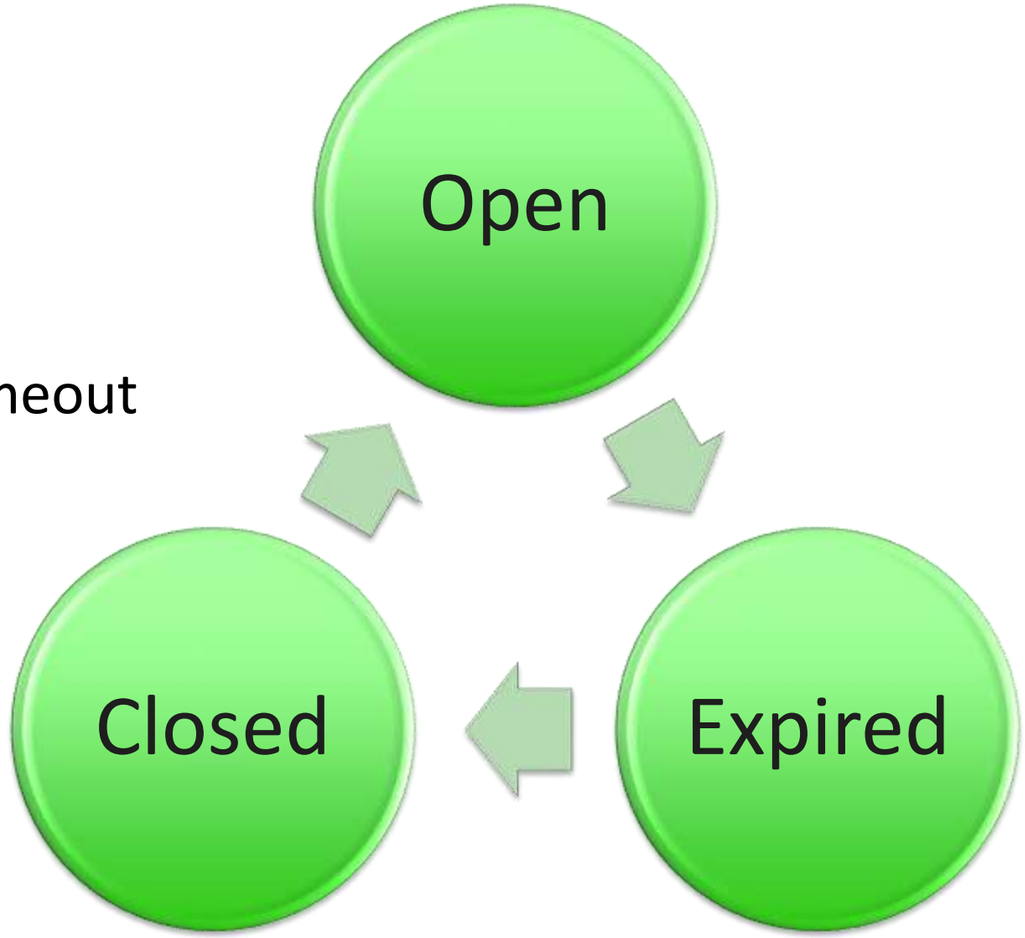
Writing Data – Ozone Manager records the Key info

Ozone Manager saves the Key Info to LSM-based K-V Metadata Store



Writing Data – Ozone Key State

- **Open Key:** Uncommitted key
  - commit length subject to change
- **Closed Key:** Commit length won't change
- **Expired Open Key:**
  - Open key is garbage collected after timeout



Reading Data

Reading Data

Client

1. Read Key

1. Client makes a request to Ozone Manager to write a key.

Ozone Manager

2. GetLatestKeyLocations

2. Ozone Manager returns key location info, i.e. list of blocks.

DN

3. Client connects to DN and reads blocks.

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Deleting Data

Deleting Data – Open/Close Containers

- Close Container: keys and their blocks are immutable
  - Delete key/blocks via SCM Delete log.
    - Each delete log has a unique ID
    - SCM sort delete logs by Datanodes and Containers
    - SCM send deleted logs to Datanode via heartbeat response
    - SCM clear delete log entry only if delete entry processing is marked done on all the datanodes.
- Open Container: keys and their blocks are mutable
  - Delete key/blocks via SCM Delete log.
    - SCM holds off sending delete logs to datanode on open containers until the container is closed.

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Scaling Ozone

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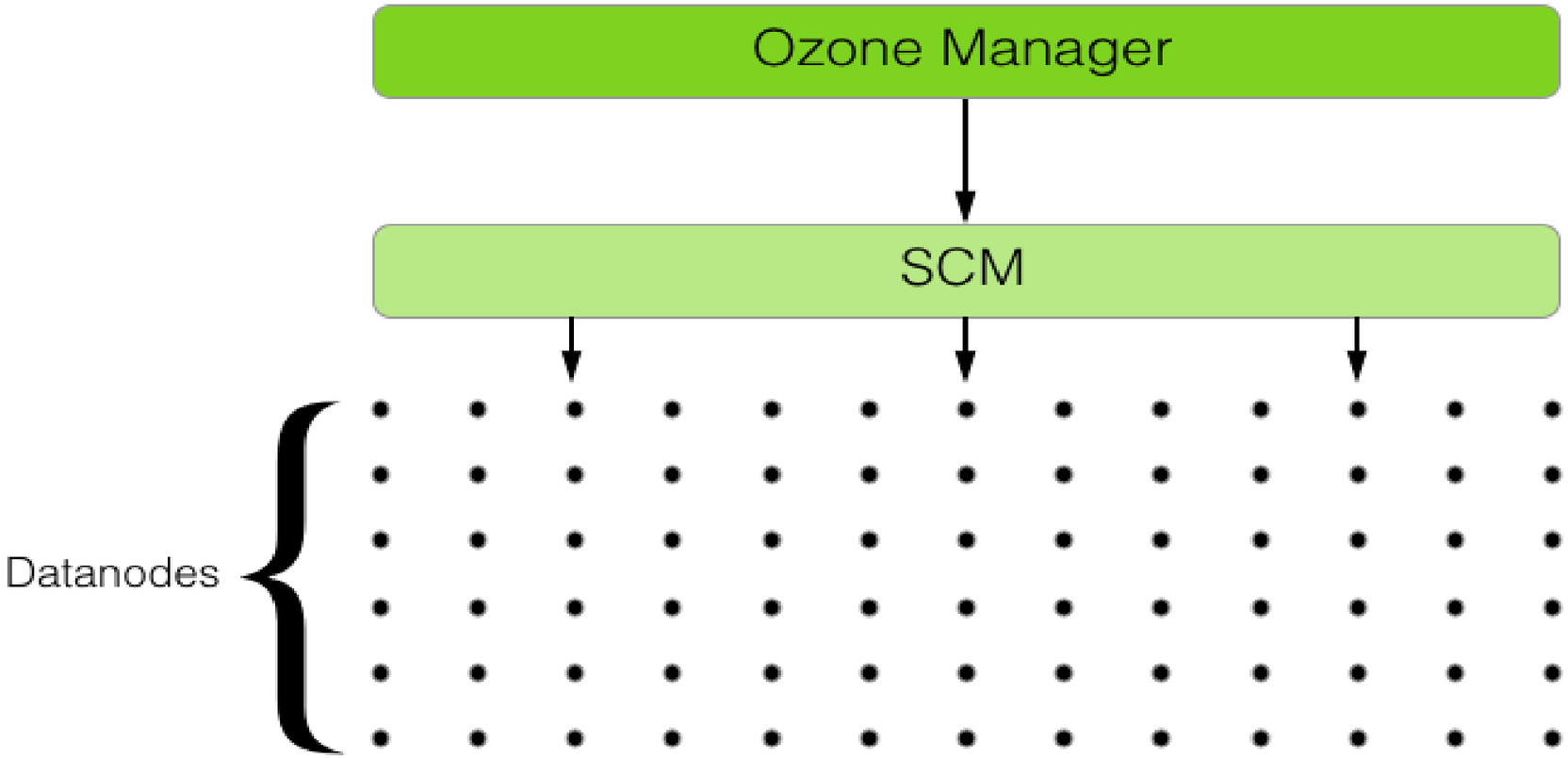
Single Ozone Manager + Single SCM



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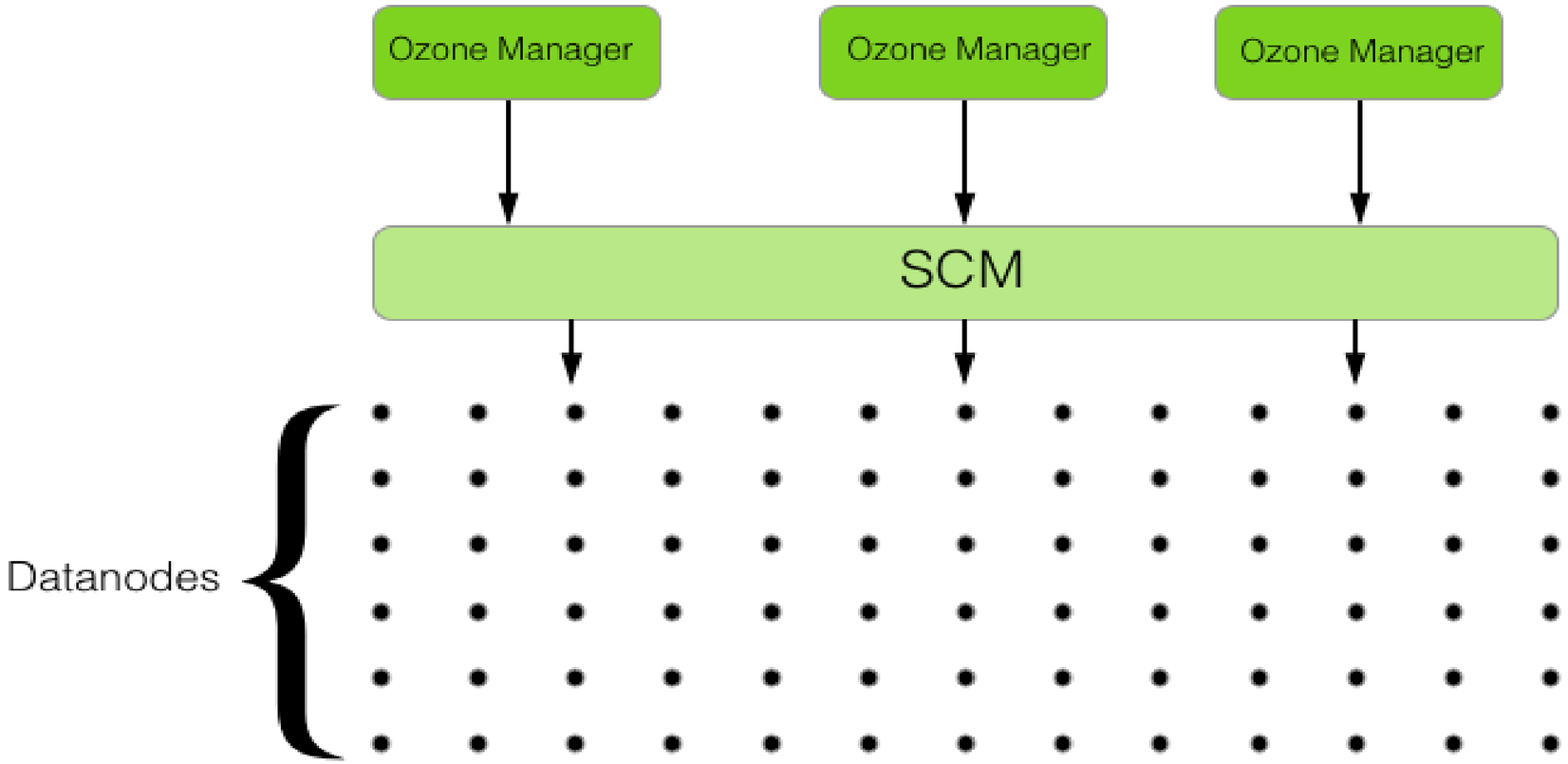
Multiple Ozone Managers + Single SCM



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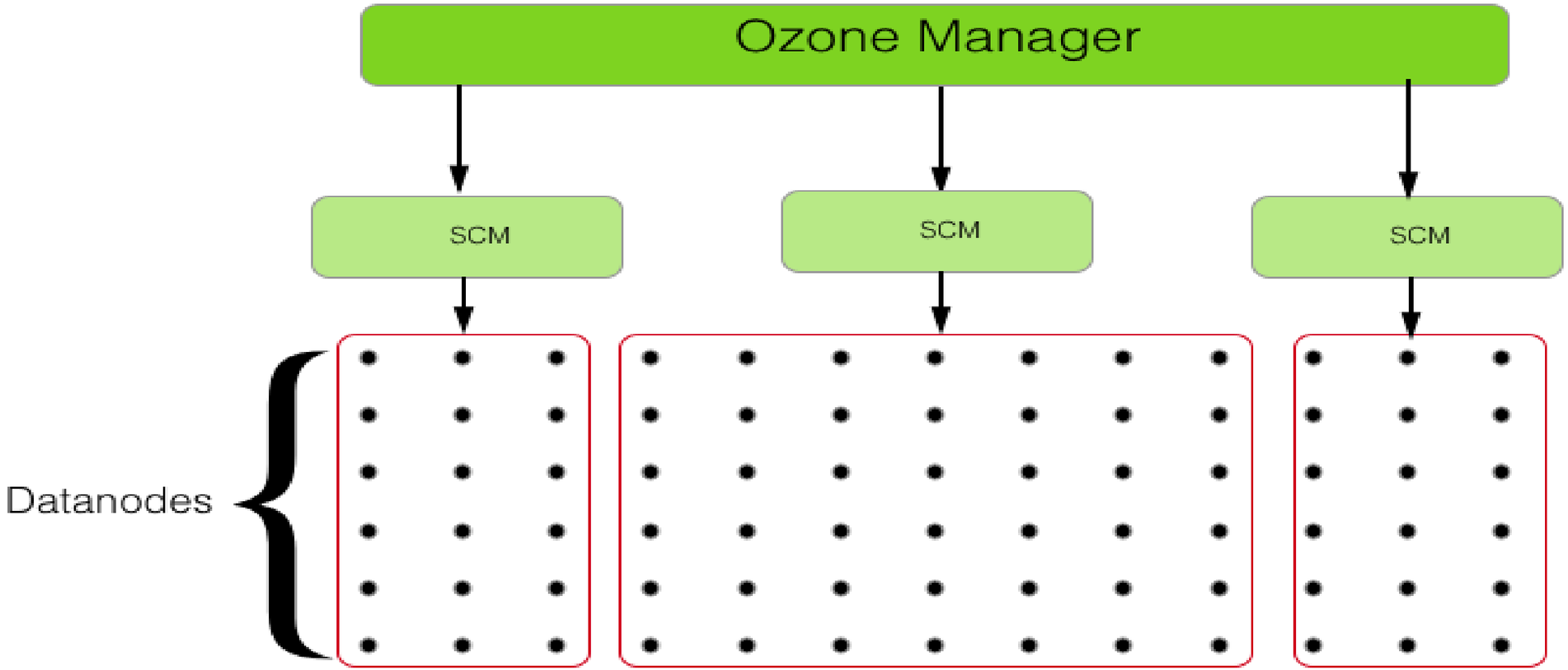
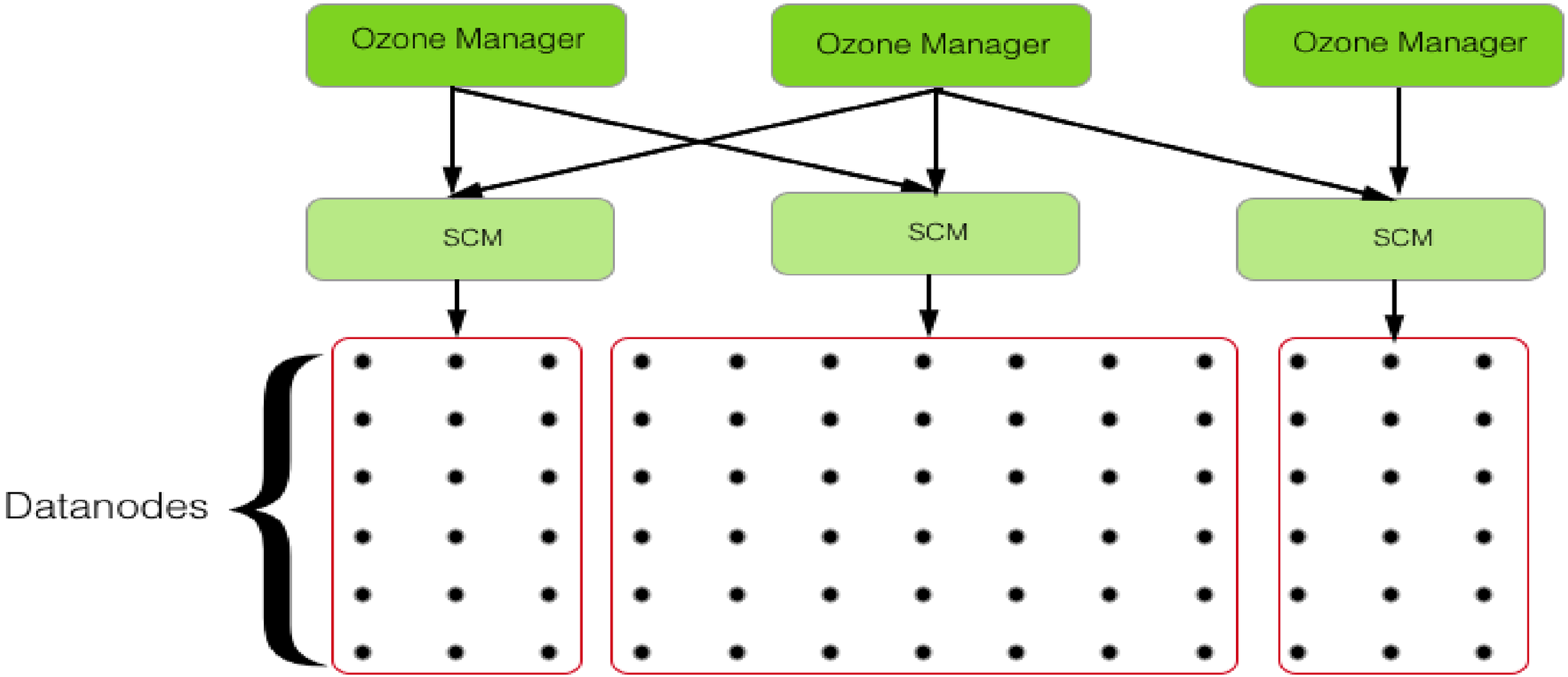
Single Ozone Manager + Multiple SCMs



HORTONWORKS

Multiple Ozone Managers + Multiple SCMs



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Ozone Security

Ozone Security

- Authentication
  - Identity
    - Kerberos (OM/SCM/Client)
    - Certificate (SCM/OM/Datanodes)
  - Token
    - Delegation Token
    - Block Token

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Certificate-based Delegation Token

- OM token <-> HDFS namenode token
  - For MR jobs to access OM

	Ozone	HDFS
Issued by	OM	Namenode
Validated by	OM Certificate(Public Key)	Namenode
Signed by	HMAC-SHA256	HMAC-SHA1
	OM Private Key	Shared Key
Protocol	Hadoop RPC/REST	Hadoop RPC

Certificate-based Block Token

- OM block token <-> HDFS block token
  - To authenticate block access on datanodes from Ozone clients.

	Ozone	HDFS
Issued by	OM	Namenode
Validated by	HDDS Datanode **OM(Public Key)**	Datanode (Shared Key)
Signed by	HMAC-SHA256 OM(Private Key)	HMAC-SHA1 (Shared Key)
Protocol	gRPC	Hadoop RPC
Secure Block Token Transfer	DN Public Key	Hadoop RPC encryption

HORTONWORKS

Ozone HDDS in progress

- High Availability
  - Apache Ratis-based OM/SCM metadata replication
  - HDDS-151 branch
- Pluggable Container Storage I/O
  - HDFS-48 branch
- Security
  - Kerberos/Delegation Token/Audit
  - HDDS-4 branch

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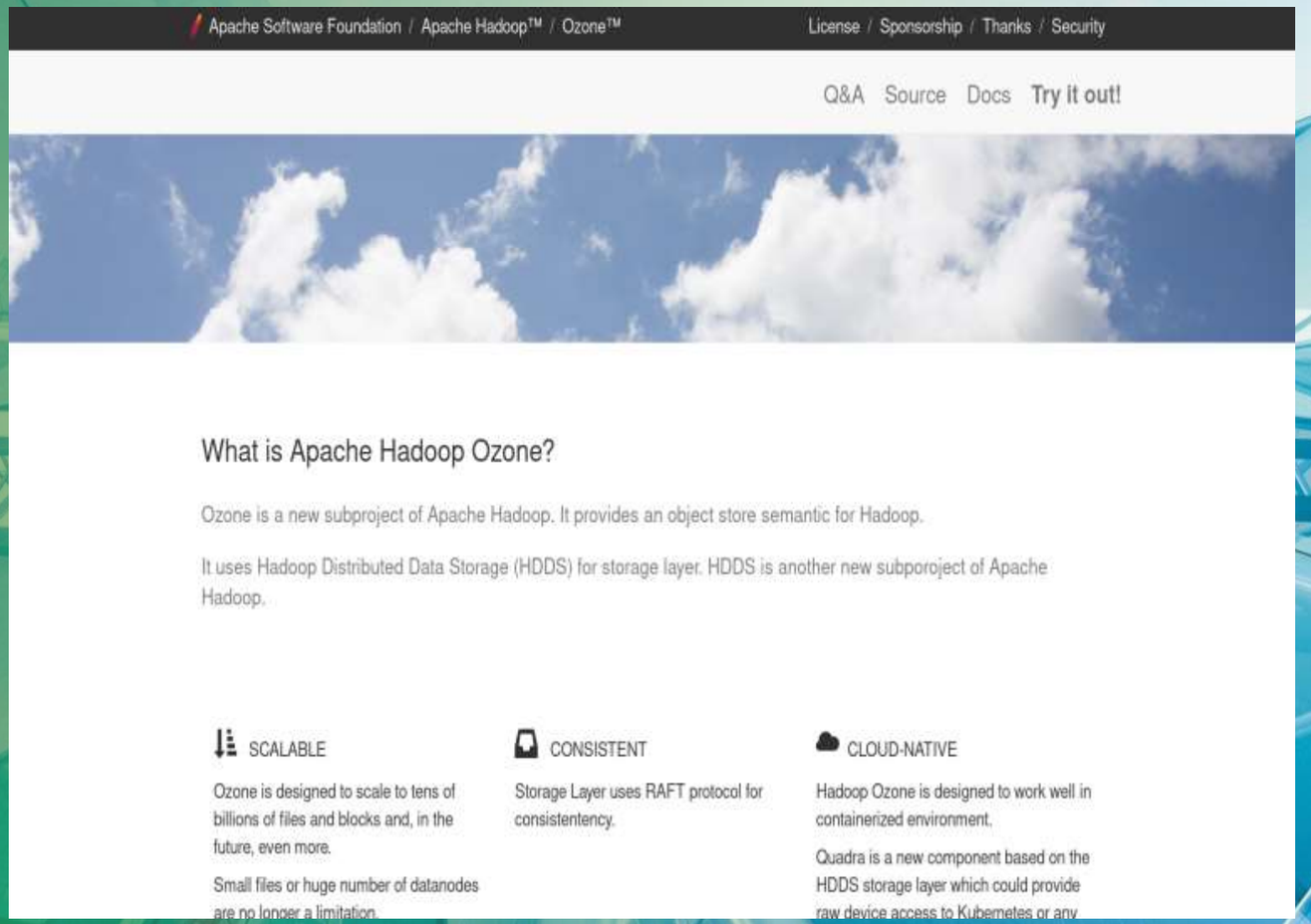
Questions?

- Visit Ozone website:
  - http://ozone.hadoop.apache.org

- Visit Ozone Booth@Ask Me Anything
  - Ozone Demo
  - Q & A



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Thank you