Moving from Zookeeper to Raft

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ALLUXIO

Analytics & AI in the Hybrid & Multi-Cloud Era

Available:

Open Source Started From UC Berkeley AMPLab in 2014

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Top 10 Most Critical Java Based Open Source Project

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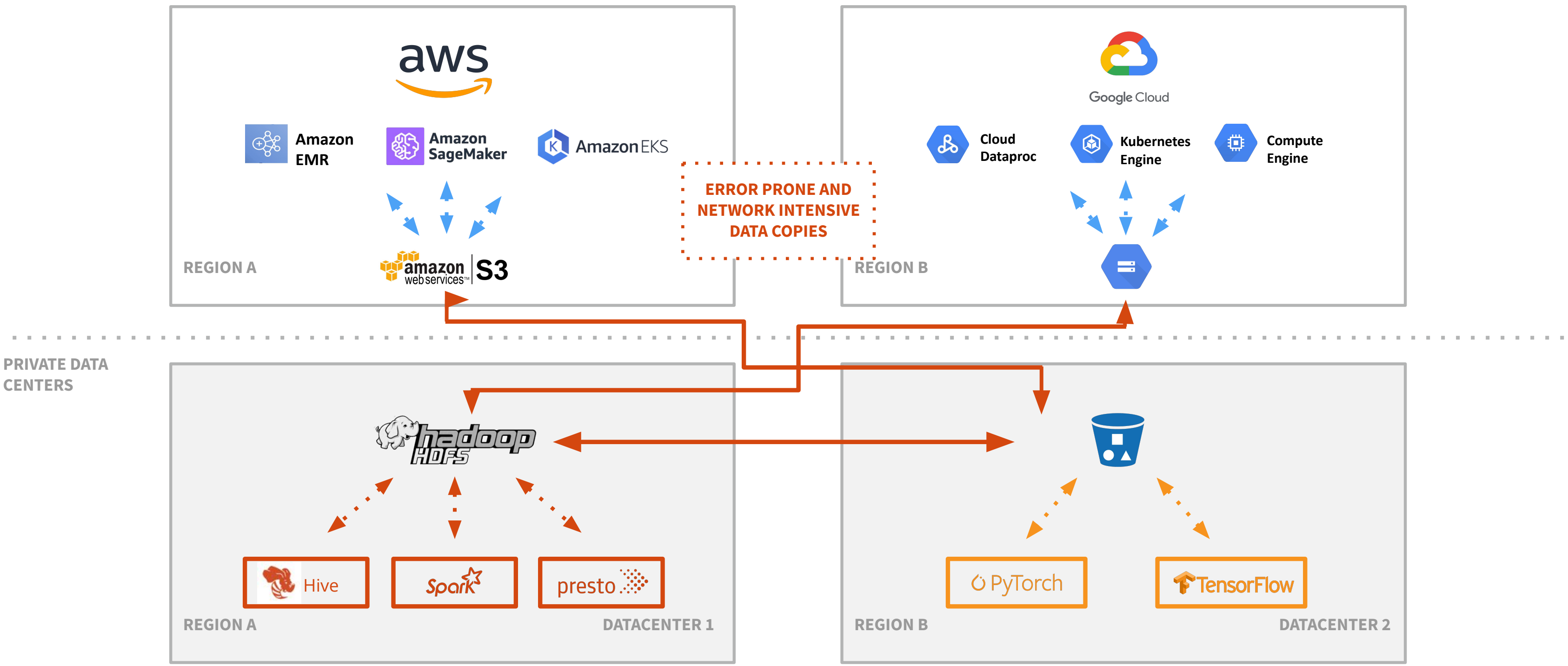
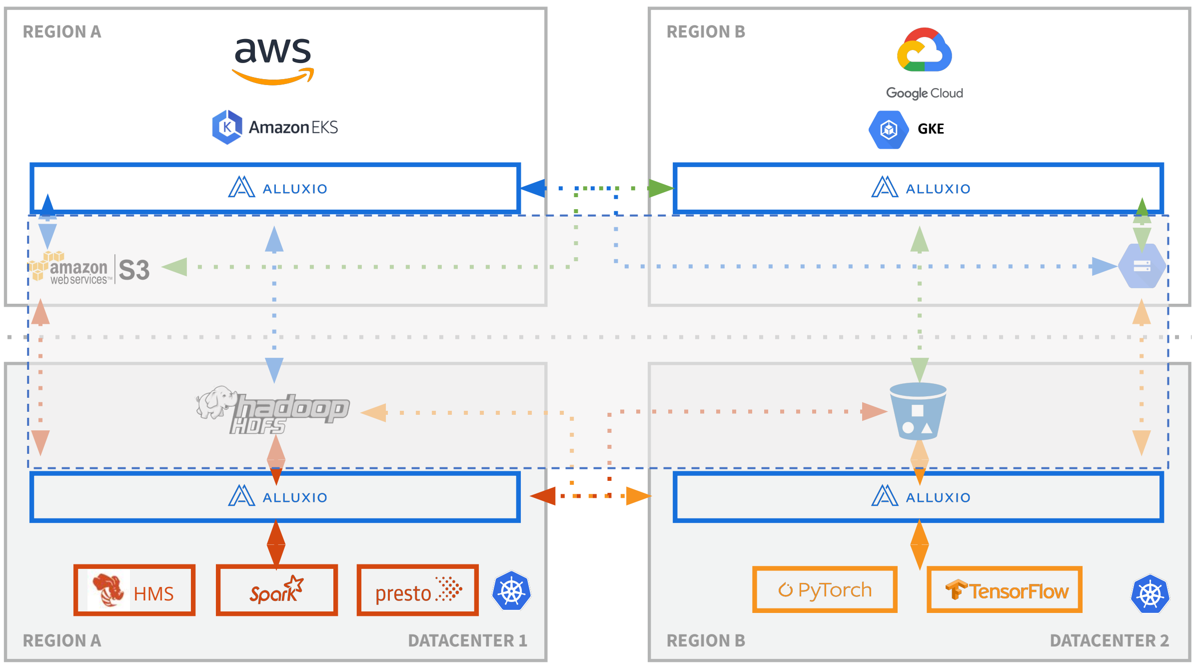


Solution

Multi-Cloud Ready Analytics & AI Platform



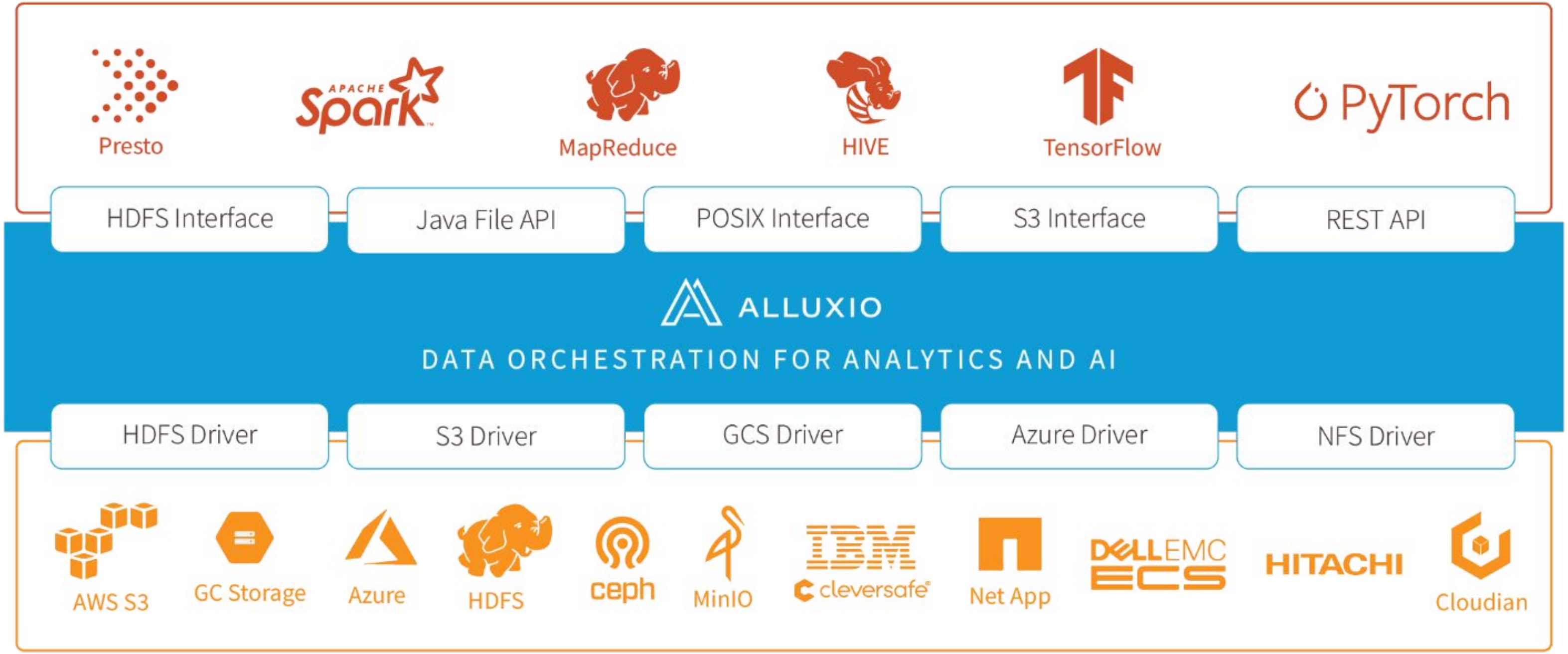
No-copy data access across silos

agnostic to compute engine

Foundation of a **heterogeneous data platform** across geos

Stateful Distributed Coordination Services

Alluxio


Presto
Spark
MapReduce
HIVE
TensorFlow
PyTorch
HDFS Interface
Java File API
POSIX Interface
S3 Interface
REST API
ALLUXIO
DATA ORCHESTRATION FOR ANALYTICS AND AI
HDFS Driver
S3 Driver
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Azure Driver
NFS Driver
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GC Storage
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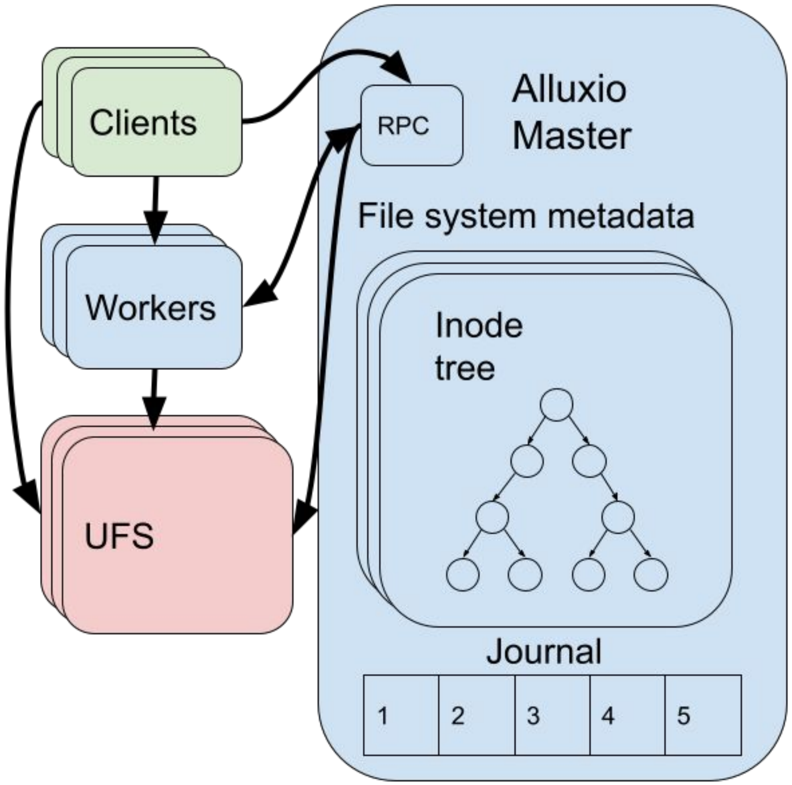
Key features

- Alluxio Caching provides cost saving, faster access
- Long-living cache scales independently of ephemeral compute resources
- Multiple interface support allow chaining of data pipeline across different compute engines / frameworks
- Unified namespace, physical data migration without needing to change application code

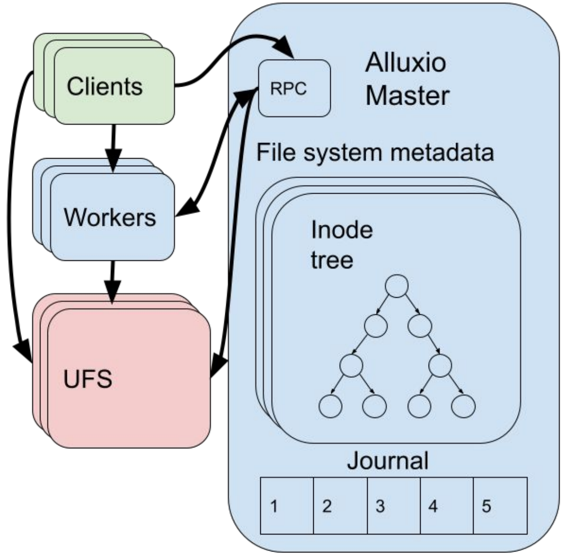
Alluxio Architecture

- UFS (Under File System)
  - E.g. Amazon S3, HDFS, etc
  - Object stores



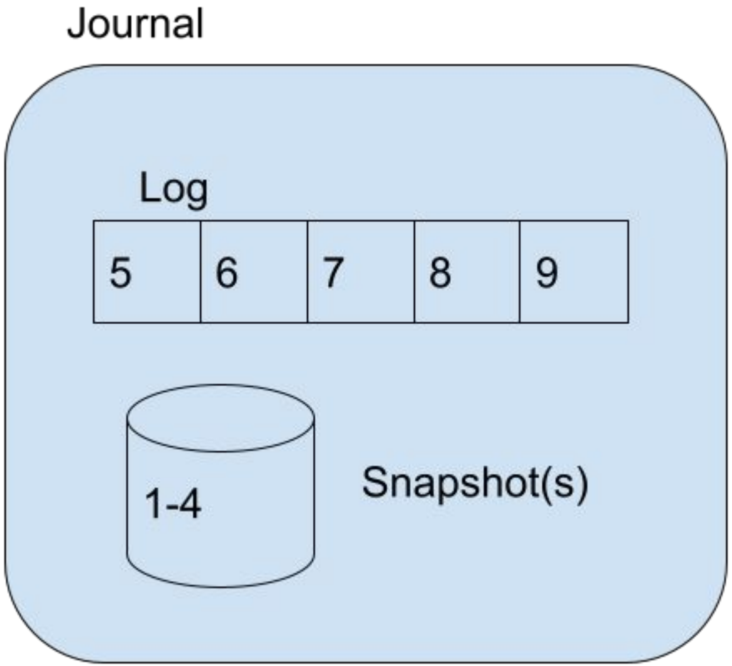
Fault tolerance

- Workers can be replicated, act as a cache for the various UFS
- Many UFS have high availability, fault tolerance guarantees
- Master becomes single point of failure



Journal details

- Total order log of state changes
- Can recover state by replaying the operations
- Snapshots to efficiently store state
    - Faster recovery
    - Smaller size



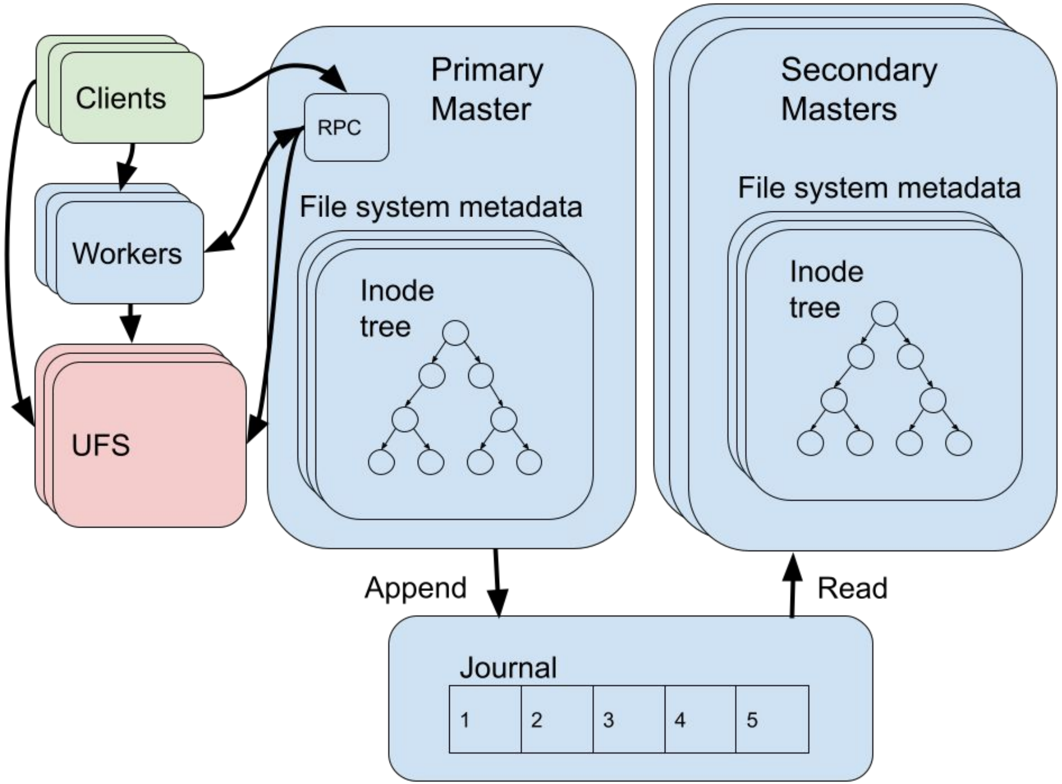
Basic fault tolerance

- Create a fault tolerant journal
- If the master crashes
  - Start a new master
  - Replay the journal
  - Start serving clients
- Detecting a failure, starting a new node, and replaying the journal takes time
  - The system will be unavailable during this time

Basic high availability

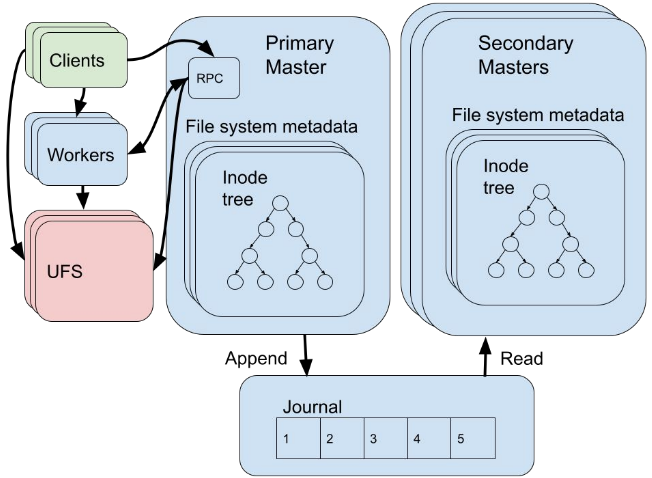
- Run multiple masters
- A primary master will serve requests
- Secondary master(s) will replicate the state of the primary master, and take over in case of failure

Basic highly available/ fault tolerant architecture



Problems to solve

- Ensure a single primary master running at all times
- Journal needs to be
  - Fault tolerant
  - Masters must agree on a single valid order of journal entries
    - **Consensus**



Implementation 1: Zookeeper + UFS Journal

Ensure a single primary master running at a time

- Leader election using Zookeeper
- Apache Zookeeper an open-source server which enables highly reliable distributed coordination
    - Provides a file-system (hierarchical namespace) like abstraction built on top of an Atomic Broadcast (consensus) protocol
    - Run on a cluster of nodes to provide fault tolerance/high availability

Apache Zookeeper Curator leader election **recipe**

- Each master subscribes to the leader election **recipe**
- The **recipe** will elect one of the nodes leader
- If the leader fails or is unable to be reached due to network issues, the recipe will elect a new leader

UFS Journal

- Write journal entries to the UFS
- Use the availability / fault tolerance guarantees of the UFS

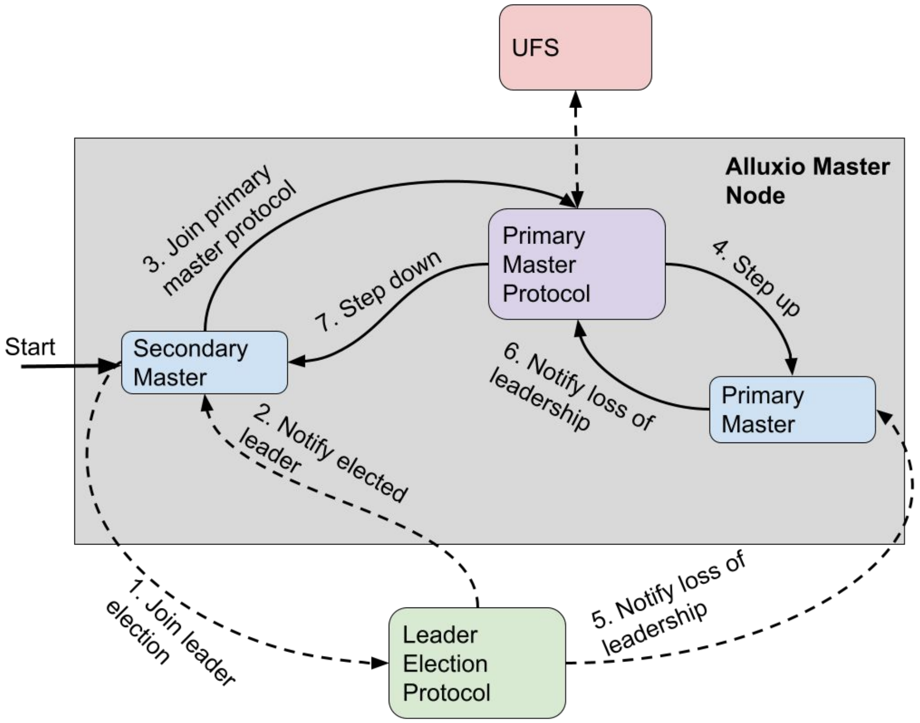
Does leader election solve all our problems?

- Not quite
- The Zookeeper recipe will do its best to ensure only a single node is chosen leader at a time, but due to asynchrony in the system two nodes may believe they are leader at the same time
- Multiple nodes may be trying to write to the journal concurrently
    - Note leader election is sufficient to provide consensus, but is not a consensus protocol itself

Defer to the UFS

- Can use the consistency guarantees of the UFS to ensure only a single writer to the journal

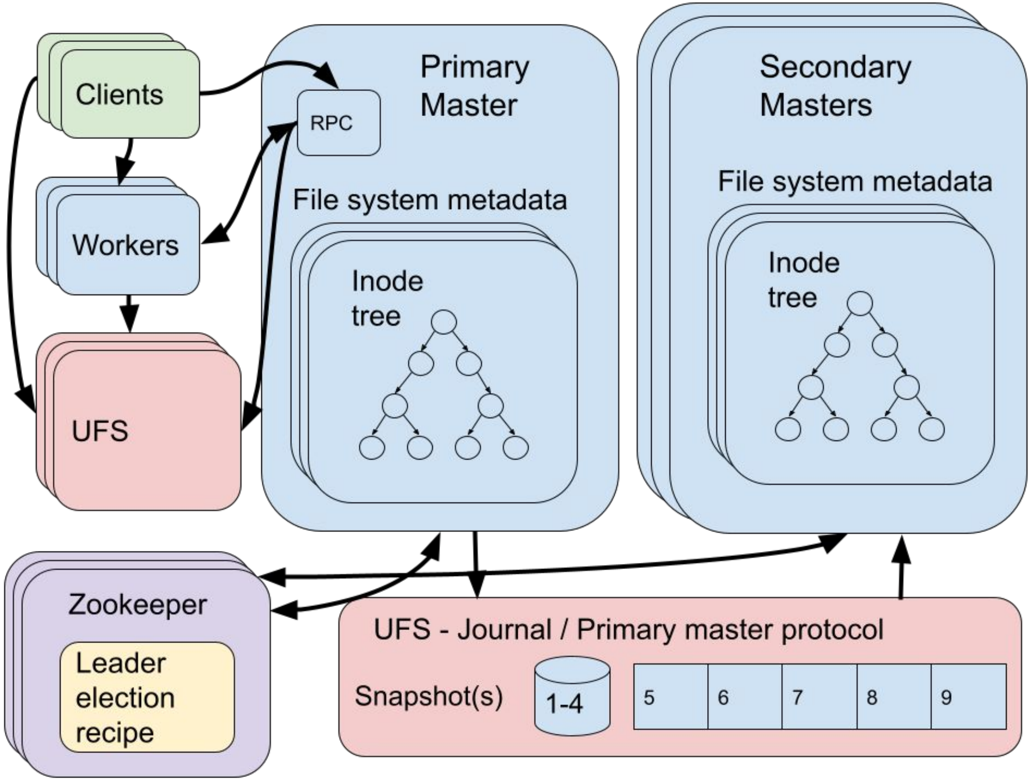
- Alluxio Primary/ secondary master state transition



Ensure a single journal writer to the UFS

- Use a mutual exclusion protocol based on log file names
- Rename is atomic on HDFS
    - (1, 12) (13, 20) (21, 300) (301, MAX_INT)
- New primary master must ensure current log file is “complete” before writing to a new log
    - (1, 12) (13, 20) (21, 300) (301, 327)
- Create a new log
    - (1, 12) (13, 20) (21, 300) (301, 327) (328, MAX_INT)

Zookeeper + UFS architecture



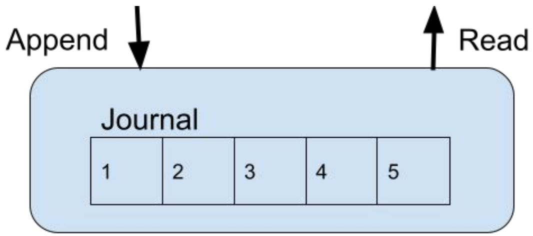
Issues

- Relies on multiple systems
  - Each having their own fault tolerance/availability models
  - More complicated
- Different UFS have different consistency models and performance
  - May not be efficient for appending log entries

Implementation 2: Raft Journal

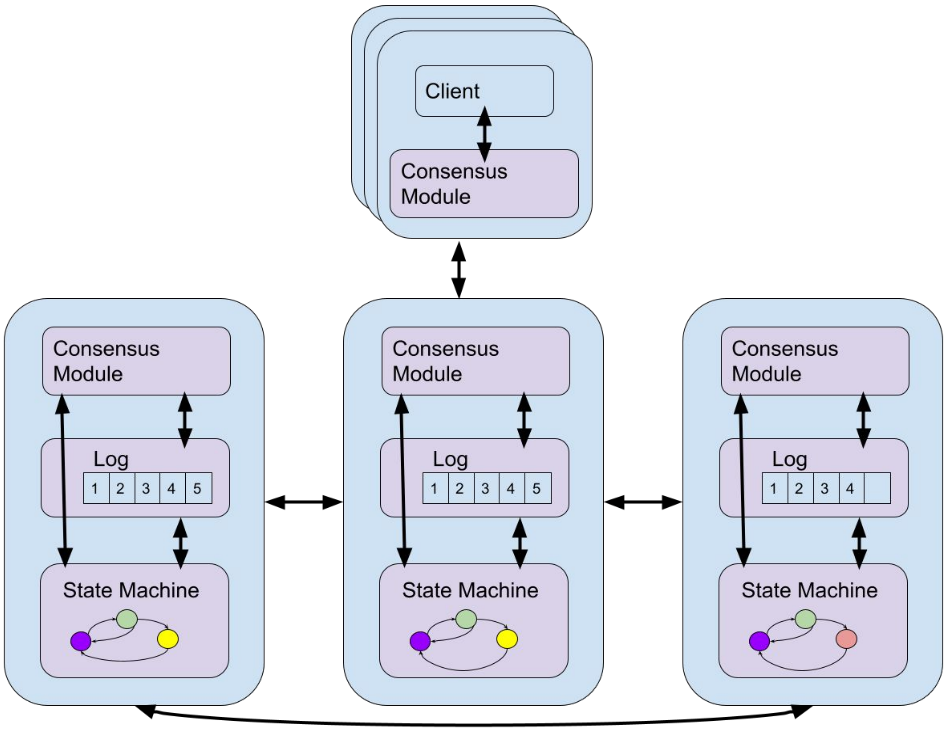
The journal as a (deterministic) state machine

- Input: command
  - Append
- State transition (deterministic):
  - Add the journal entry to the log



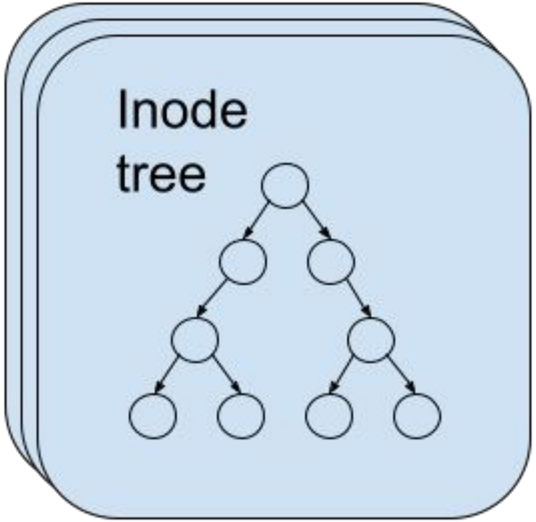
Raft - replicated state machine

- Clients interact with the state machine as if it was a single instance (linearizability)
    - Clients send commands to the state machine and receive responses
- But the state machine is fault tolerant and has high availability
- Apache Ratis (java implementation of Raft)



Forget the Journal as a Log

File system metadata



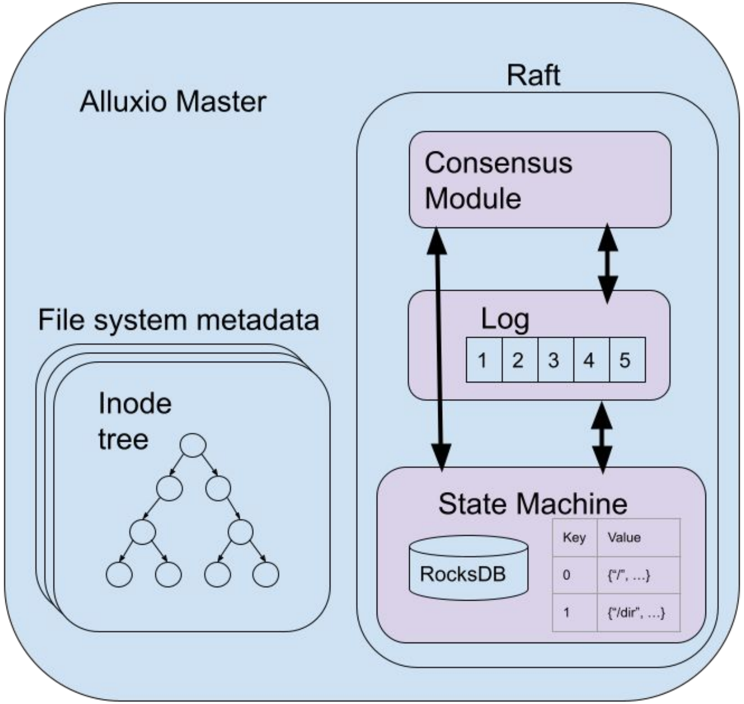
Key-value store state machine commands:

- Write(key, value)
- Remove(key)
- Read(key) -> value

Inode ID	Inode metadata	Worker location
0	…	…
1	…	…

The Alluxio metadata as a replicated state machine

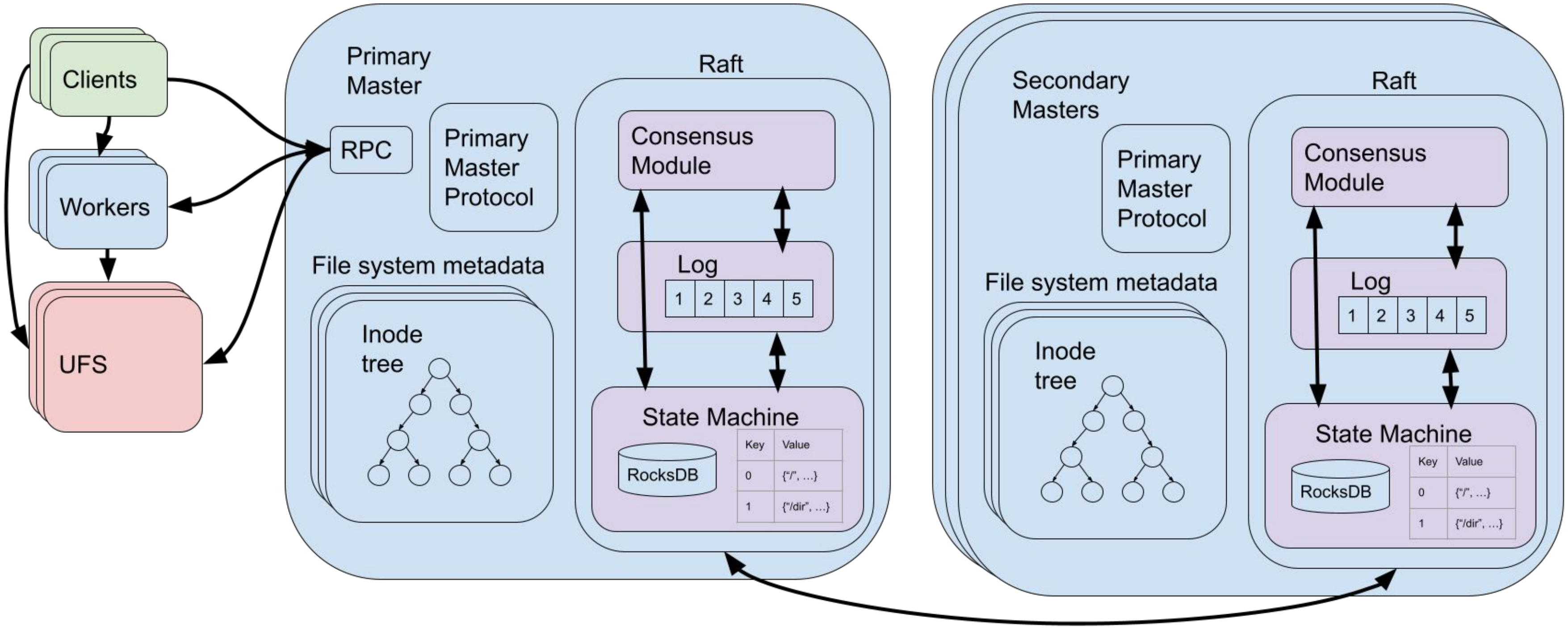
- Raft simplifies the task of implementing the journal.
- It handles snapshotting and recovery
- The journal just becomes a key-value store keeping track of the file-system meta-data
- Raft is colocated with the Alluxio masters



RocksDB as the key-value store

- Log-structured merge tree
    - Efficient inserts
- Key-value store
    - Inode tree as a key-value map
- Alluxio provides an additional in-memory cache for fast reads
- Efficient snapshots

Alluxio + Raft architecture



Advantages

- Simplicity
    - No external systems (raft colocated with masters)
    - Journal as a key-value store (higher level abstraction)
    - No longer relying on UFS rename semantics
- Performance
    - Journal operations stored locally on masters
    - RocksDB as an efficient key-value store

Other systems

- Kubernetes - etcd - key/value store run on Raft
- Kafka - coordinator running Zookeeper -> Now on Raft
- FoundationDb - coordinators running Paxos

- Generally a paxos based replicated state machine of a simple data store with some custom application logic running over this

Questions?

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www.alluxio.io

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