Introduction to Apache ZooKeeper™

http://zookeeper.apache.org/

Who am I?

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- Engineer at Symantec
- Work in Hadoop & Distributed System
- FOSS enthusiast

What is a Distributed System?

> “A distributed system consists of multiple computers that communicate through a computer network and interact with each other to achieve a common goal.”

- Wikipedia

Fallacies of Distributed Computing

- The network is reliable.
- Latency is zero.
- Bandwidth is infinite.
- The network is secure.
- Topology doesn't change.
- There is one administrator.
- Transport cost is zero.
- The network is homogeneous.

Reference: *http://en.wikipedia.org/wiki/Fallacies_of_Distributed_Computing*

Coordination in a distributed system

- *Coordination*: An act that multiple nodes must perform together.
- Examples:
  - Group membership
  - Locking
  - Publisher/Subscriber
  - Leader Election
  - Synchronization
- Getting node coordination correct is very hard!

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Introducing ZooKeeper

> “ZooKeeper allows distributed processes to coordinate with each other through a shared hierarchical name space of data registers.”
>
> ***- ZooKeeper Wiki***

ZooKeeper is much more than a distributed lock server!

What is ZooKeeper?

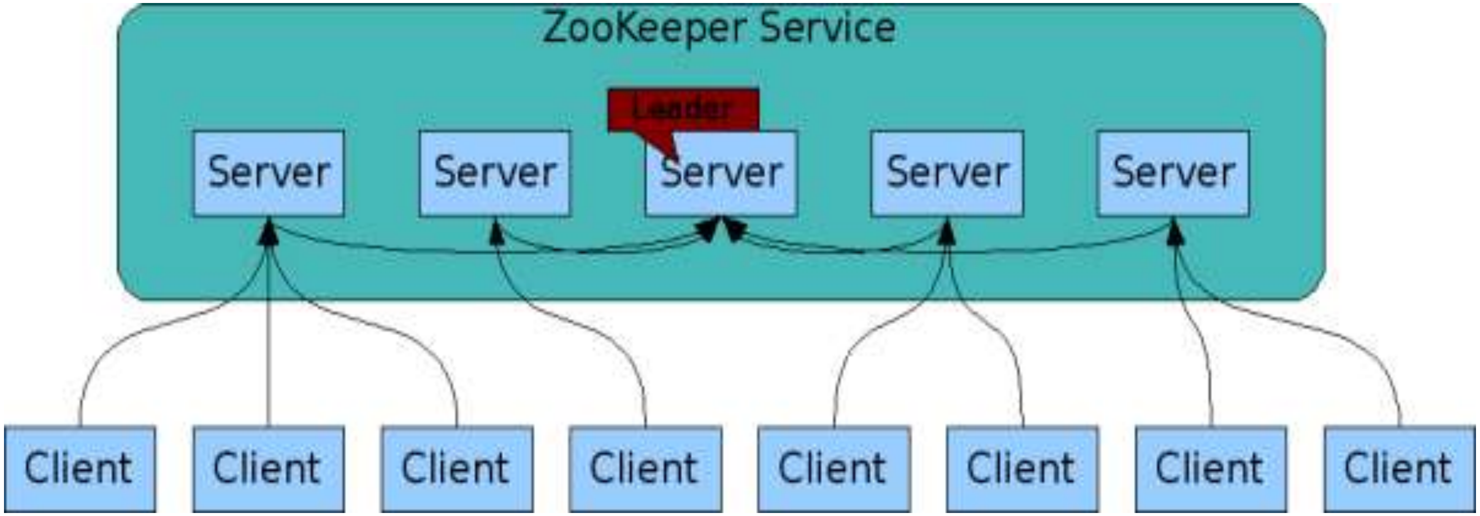
- An open source, high-performance coordination service for distributed applications.
- Exposes common services in simple interface:
  - naming
  - configuration management
  - locks & synchronization
  - group services

  … developers don't have to write them from scratch
- Build your own on it for specific needs.

ZooKeeper Use Cases

- Configuration Management
  - Cluster member nodes bootstrapping configuration from a centralized source in unattended way
  - Easier, simpler deployment/provisioning
- Distributed Cluster Management
  - Node join / leave
  - Node statuses in real time
- Naming service – e.g. DNS
- Distributed synchronization - locks, barriers, queues
- Leader election in a distributed system.
- Centralized and highly reliable (simple) data registry

The ZooKeeper Service



- ZooKeeper Service is replicated over a set of machines
- All machines store a copy of the data (in memory)
- A leader is elected on service startup
- Clients only connect to a single ZooKeeper server & maintains a TCP connection.
- Client can read from any Zookeeper server, writes go through the leader & needs majority consensus.

Image: https://cwiki.apache.org/confluence/display/ZOOKEEPER/ProjectDescription

The ZooKeeper Data Model

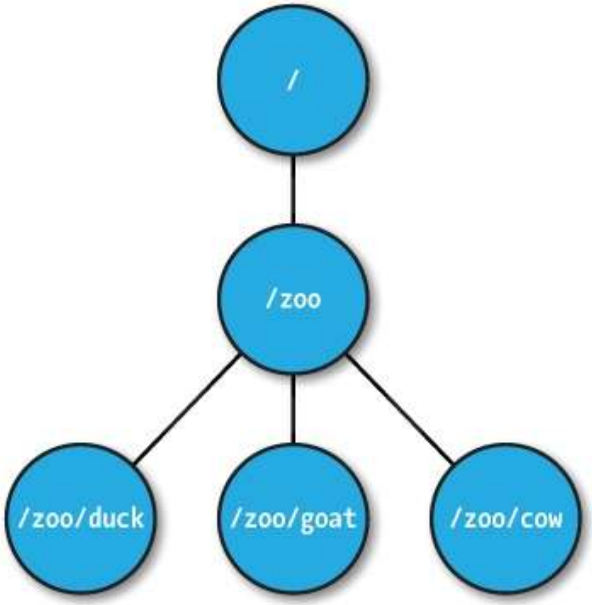
- ZooKeeper has a hierarchal name space.
- Each node in the namespace is called as a *ZNode.*
- Every ZNode has data (given as byte[]) and can optionally have children.

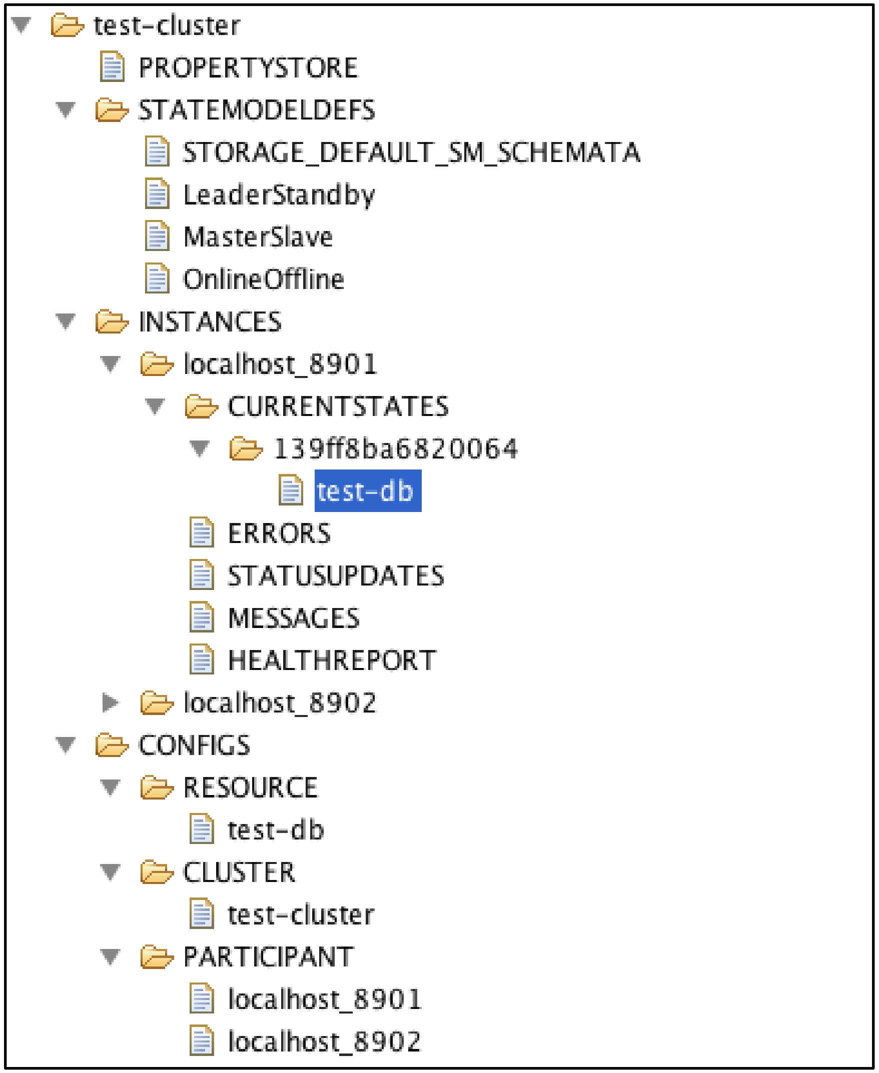
```
parent : "foo"
    |-- child1 : "bar"
    |-- child2 : "spam"
    `-- child3 : "eggs"
              `-- grandchild1 : "42"
```

- ZNode paths:
  - canonical, absolute, slash-separated
  - no relative references.
  - names can have Unicode characters

ZNodes

- Maintain a stat structure with version numbers for data changes, ACL changes and timestamps.
- Version numbers increases with changes
- Data is read and written in its er





- test-cluster
  - PROPERTYSTORE
  - STATEMODELDEFS
    - STORAGE_DEFAULT_SM_SCHEMATA
    - LeaderStandby
    - MasterSlave
    - OnlineOffline
  - INSTANCES
    - localhost_8901
      - CURRENTSTATES
        - 139ff8ba6820064
          - test-db
      - ERRORS
      - STATUSUPDATES
      - MESSAGES
      - HEALTHREPORT
    - localhost_8902
  - CONFIGS
    - RESOURCE
      - test-db
    - CLUSTER
      - test-cluster
    - PARTICIPANT
      - localhost_8901
      - localhost_8902

Image: http://helix.incubator.apache.org/Architecture.html

ZNode Types

- Persistent Nodes
  - exists till explicitly deleted
- Ephemeral Nodes
  - exists as long as the session is active
  - can’t have children
- Sequence Nodes (Unique Naming)
  - append a monotonically increasing counter to the end of path
  - applies to both persistent & ephemeral nodes

ZNode Operations

Operation	Type
create	Write
delete	Write
exists	Read
getChildren	Read
getData	Read
setData	Write
getACL	Read
setACL	Write
sync	Read

ZNodes are the main entity that a programmer access.

ZooKeeper Shell

```
[zk: localhost:2181(CONNECTED) 0] help
ZooKeeper -server host:port cmd args
        connect host:port
        get path [watch]
        ls path [watch]
        set path data [version]
        rmr path
        delquota [-n|-b] path
        quit
        printwatches on|off
        create [-s] [-e] path data acl
        stat path [watch]
        close
        ls2 path [watch]
        history
        listquota path
        setAcl path acl
        getAcl path
        sync path
        redo cmdno
        addauth scheme auth
        delete path [version]
        setquota -n|-b val path
```

```
[zk: localhost:2181(CONNECTED) 1] ls /
[hbase, zookeeper]

[zk: localhost:2181(CONNECTED) 2] ls2 /zookeeper
[quota]
cZxid = 0x0
ctime = Tue Jan 01 05:30:00 IST 2013
mZxid = 0x0
mtime = Tue Jan 01 05:30:00 IST 2013
pZxid = 0x0
cversion = -1
dataVersion = 0
aclVersion = 0
ephemeralOwner = 0x0
dataLength = 0
numChildren = 1

[zk: localhost:2181(CONNECTED) 3] create /test-znode HelloWorld
Created /test-znode
[zk: localhost:2181(CONNECTED) 4] ls /
[test-znode, hbase, zookeeper]
[zk: localhost:2181(CONNECTED) 5] get /test-znode
HelloWorld
```

ZNode Watches

- Clients can set watches on znodes:
  - NodeChildrenChanged
  - NodeCreated
  - NodeDataChanged
  - NodeDeleted
- Changes to a znode trigger the watch and ZooKeeper sends the client a notification.
- Watches are one time triggers.
- Watches are always ordered.
- Client sees watched event before new znode data.
- Client should handle cases of latency between getting the event and sending a new request to get a watch.

API Synchronicity

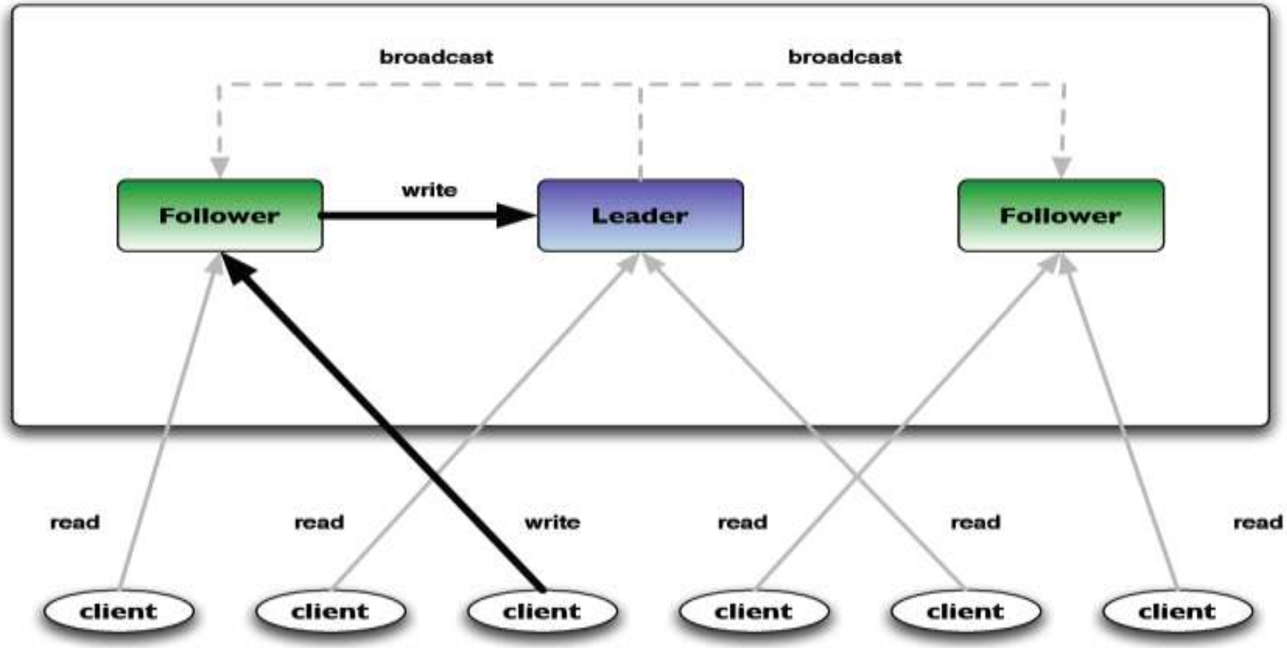
- API methods are sync as well as async
- Sync:

```
exists(“/test-cluster/CONFIGS", null);
```

- Async:

```
exists("/test-cluster/CONFIGS", null, new StatCallback() {
    @Override
    public processResult(int rc, String path, Object ctx, Stat stat)
    {
            //process result when called back later
    }
    }, null);
```

ZNode Reads & Writes



- Read requests are processed locally at the ZooKeeper server to which the client is currently connected
- Write requests are forwarded to the leader and go through majority consensus before a response is generated.

Image: http://www.slideshare.net/scottleber/apache-zookeeper

Consistency Guarantees

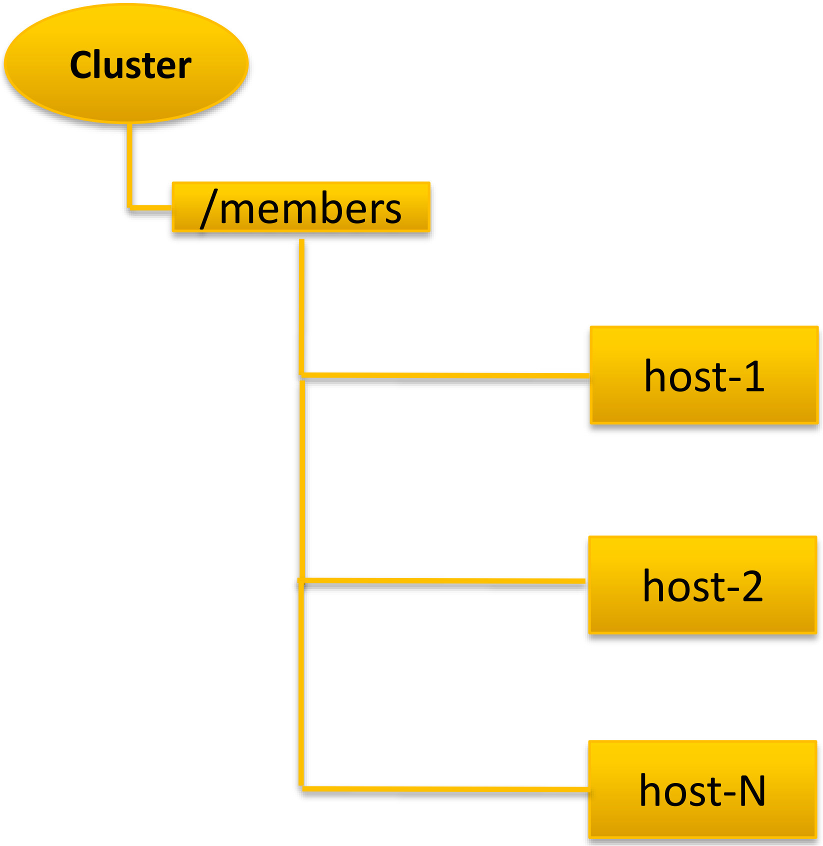
- **Sequential Consistency**: Updates are applied in order
- **Atomicity**: Updates either succeed or fail
- **Single System Image**: A client sees the same view of the service regardless of the ZK server it connects to.
- **Reliability**: Updates persists once applied, till overwritten by some clients.
- **Timeliness**: The clients’ view of the system is guaranteed to be up-to-date within a certain time bound. (Eventual Consistency)

Recipe #1: Cluster Management

Each Client Host i, i:=1 .. N

1. Watch on /members
2. Create /members/host-${i} as ephemeral nodes
3. Node Join/Leave generates alert
4. Keep updating /members/host-${i} periodically for node status changes

   (load, memory, CPU etc.)



Recipe #2: Leader Election

1. A znode, say "/svc/election-path"
2. All participants of the election process create an ephemeral-sequential node on the same election path.
3. ***The node with the smallest sequence number is the leader.***
4. Each "follower" node listens to the node with the next lower seq. number
5. Upon leader removal go to election-path and find a new leader, or become the leader if it has the lowest sequence number.
6. Upon session expiration check the election state and go to election if needed

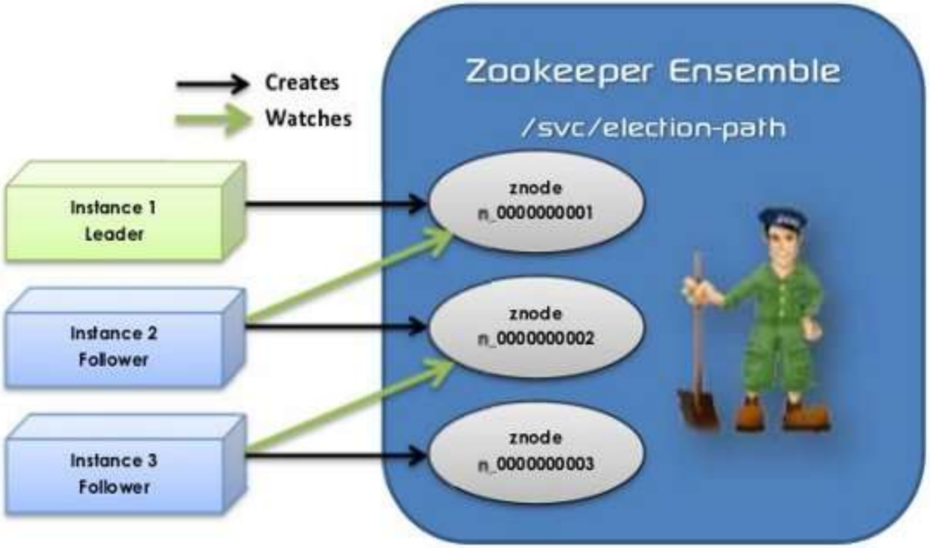


Image: http://techblog.outbrain.com/2011/07/leader-election-with-zookeeper/

Recipe #3: Distributed Exclusive Lock

Assuming there are N clients trying to acquire a lock

- Clients creates an ephemeral, sequential znode under the path /Cluster/_locknode_
- Clients requests a list of children for the lock znode (i.e. _locknode_)
- ***The client with the least ID according to natural ordering will hold the lock.***
- Other clients sets watches on the znode with id immediately preceding its own id
- Periodically checks for the lock in case of notification.
- The client wishing to release a lock deletes the node, which triggering the next client in line to acquire the lock.

```
ZK
|---Cluster
   +---config
   +---memberships
   +---_locknode_
      +---host1-3278451
      +---host2-3278452
      +---host3-3278453
      +--- …
      \---hostN-3278XXX
```

Language Bindings

- ZooKeeper ships client libraries in:
  - Java
  - C
  - Perl
  - Python
- Community contributed client bindings available for Scala, C#, Node.js, Ruby, Erlang, Go, Haskell

  https://cwiki.apache.org/ZOOKEEPER/zkclientbindings.html

A few points to remember

- Watches are one time triggers
  - Continuous watching on znodes requires reset of watches after every events / triggers
- Too many watches on a single znode creates the "*herd effect*" - causing bursts of traffic and limiting scalability
- If a znode changes multiple times between getting the event and setting the watch again, carefully handle it!
- Keep session time-outs long enough to handle long garbage-collection pauses in applications.
- Set Java max heap size correctly to *avoid swapping.*
- Dedicated disk for ZooKeeper transaction log

Who uses ZooKeeper?

Companies:

- Yahoo!
- Zynga
- Rackspace
- LinkedIn
- Netflix
- *and many more…*

Projects in FOSS:

- Apache Map/Reduce (Yarn)
- Apache HBase
- Apache Solr
- Neo4j
- Katta
- *and many more…*

Reference: https://cwiki.apache.org/confluence/display/ZOOKEEPER/PoweredBy

ZooKeeper In Action @Twitter

- Used within Twitter for service discovery
- How?
  - Services register themselves in ZooKeeper
  - Clients query the production cluster for service “A” in data center “XYZ”
  - An up-to-date host list for each service is maintained
  - Whenever new capacity is added the client will automatically be aware
  - Also, enables load balancing across all servers.

Reference: http://engineering.twitter.com/

References

- The Chubby lock service for loosely-coupled distributed systems

  Google Research (7th USENIX Symposium on Operating Systems Design and Implementation (OSDI), {USENIX} (2006))
- ZooKeeper: Wait-free coordination for Internet-scale systems

  Yahoo Research (USENIX Annual Technology Conference 2010)
- Apache ZooKeeper Home: http://zookeeper.apache.org/
- Presentations:
  - http://www.slideshare.net/mumrah/introduction-to-zookeeper-trihug-may-22-2012
  - http://www.slideshare.net/scottleber/apache-zookeeper
  - https://cwiki.apache.org/confluence/display/ZOOKEEPER/ZooKeeperPresentations

Interesting Reads

- The Google File System
- The Hadoop Distributed File System
- MapReduce: Simplified Data Processing on Large Clusters
- Bigtable: A Distributed Storage System for Structured Data
- PNUTS: Yahoo!’s Hosted Data Serving Platform
- Dynamo: Amazon's Highly Available Key-value Store
- Spanner: Google's Globally Distributed Database
- Centrifuge: Integrated Lease Management and Partitioning Cloud Services (Microsoft)
- ZAB: A simple totally ordered broadcast protocol (Yahoo!)
- Paxos Made Simple by Leslie Lamport.
- Eventually Consistent by Werner Vogel (CTO, Amazon)
- http://www.highscalability.com/

Questions?

Thank You!

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