ZooKeeper:
Wait-free coordination for Internet-scale systems

Paper Presentation for EECS 591

Jiongsheng Cai

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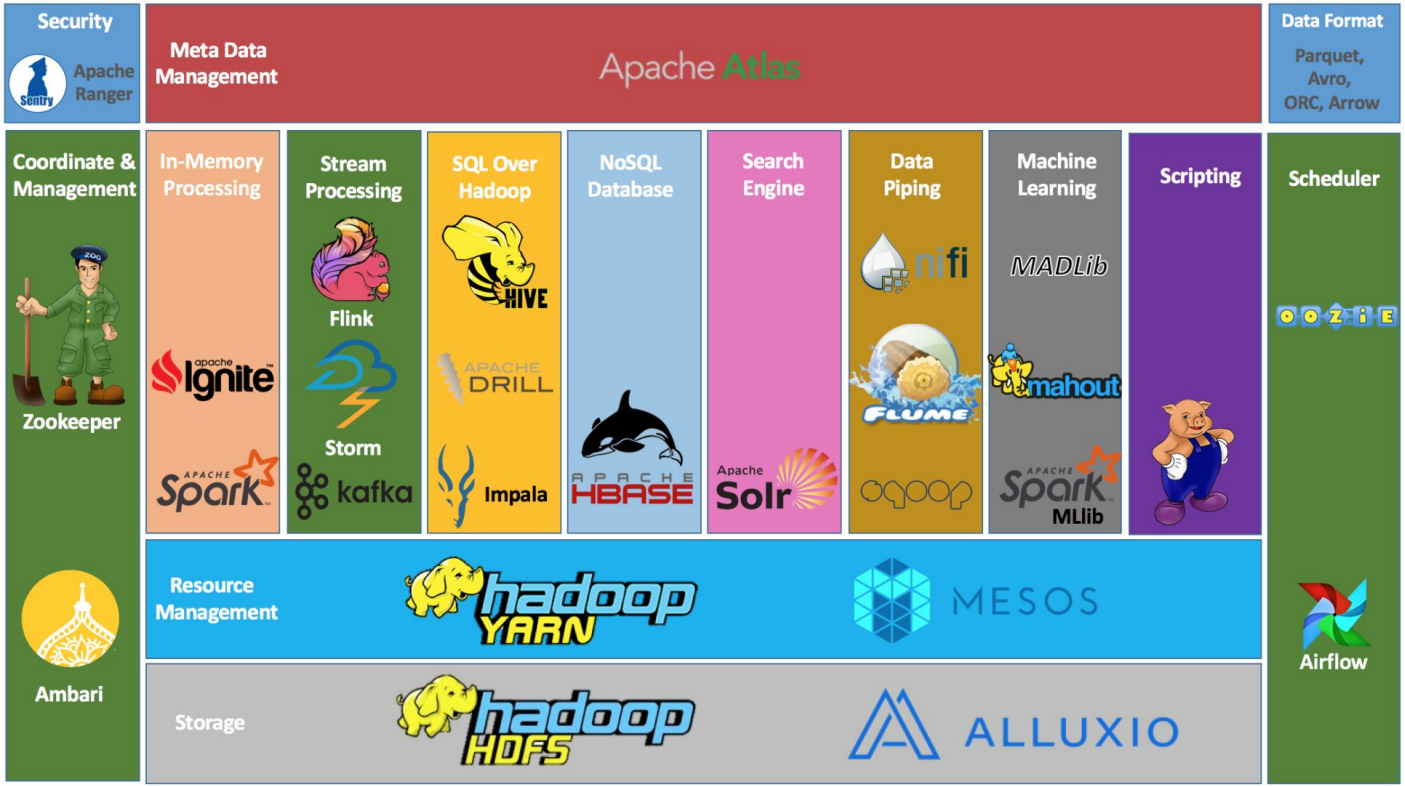
“ZooKeeper”?

ZooKeeper


Security
Apache Ranger
Meta Data Management
Apache Atlas
Data Format
Parquet, Avro, ORC, Arrow
Coordinate & Management
Zookeeper
Ambari
In-Memory Processing
apache Ignite
Spark
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Scripting
Scheduler
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hadoop YARN
MESOS
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ALLUXIO

ZooKeeper

- Developed at Yahoo! Research
- Started as sub-project of Hadoop, now a top-level Apache project
- Development is driven by application needs

Motivation

- In the past: a single program running on a single computer with a single CPU
- Today: **distributed applications** consist of independent programs running on a changing set of computers

Developers have to deal with **coordination logic** and **application logic** at the same time!

Question: How do you elect the leader?

应用程序逻辑

application logic

A program that crawls the Web

网络请求

one machine (the leader) should coordinate the effort

主节点应该协调负荷

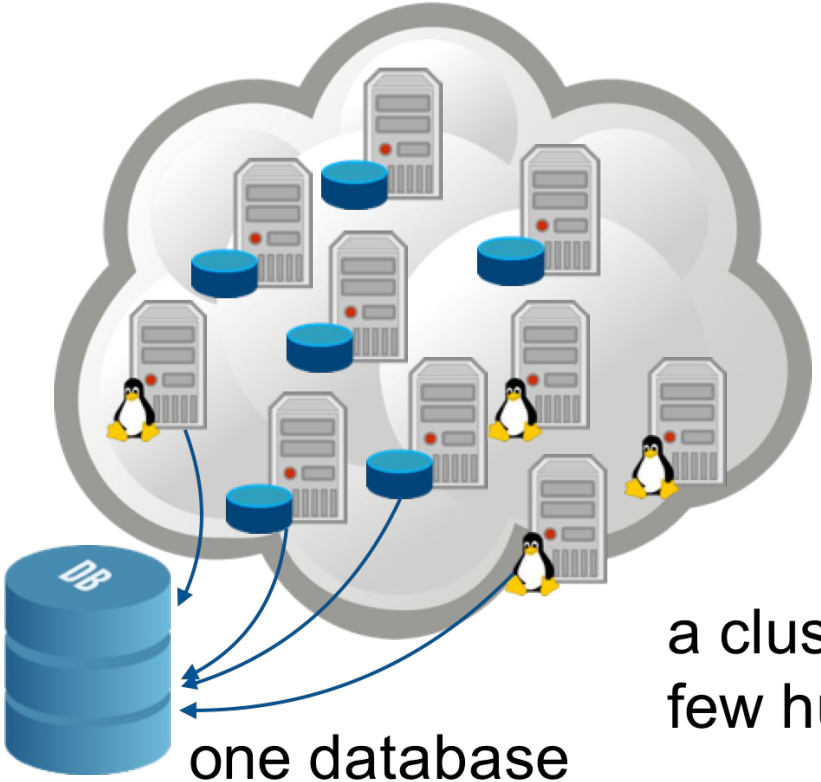
coordination logic

协调逻辑

一个有若干机器的集群

a cluster with a few hundred machines

Question: How do you lock a service?



application logic

A program that crawls the Web

请求处理的数据存储在数据库中：谁访问、何时访问

The progress of the crawl is stored in a DB: who accesses what & when?

coordination logic

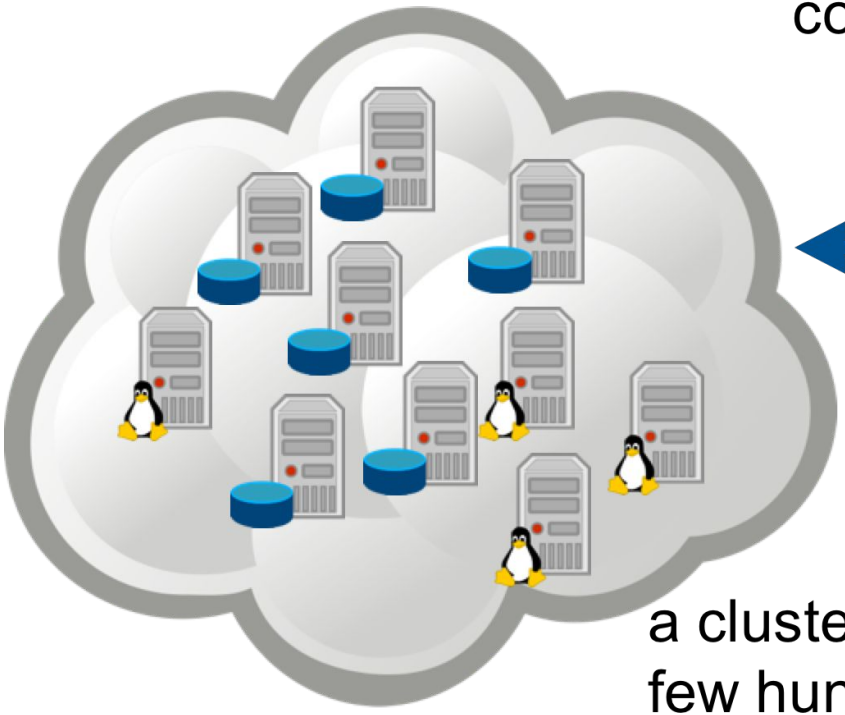
a cluster with a few hundred machines

one database

Question: How can the configuration be distributed?

配置文件

configuration file



application logic

A program that crawls the Web

每个请求都以同一个配置文件开始

Every worker should start with the same configuration

coordination logic

a cluster with a few hundred machines

Solution approaches

- Be specific: develop a particular service for each coordination task
  - Leading election
  - Locking service
  - Configuration
- Be general: provide an API to make many services possible

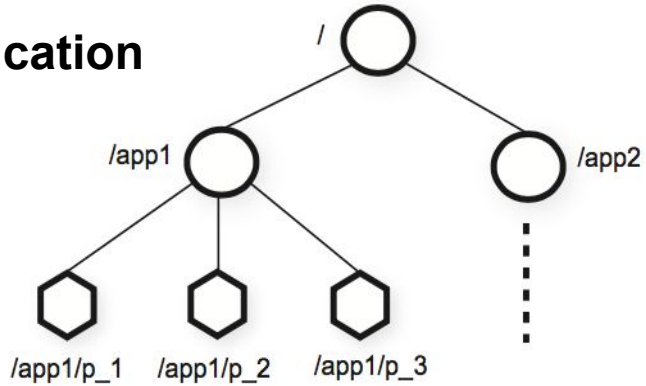
ZooKeeper: exposing an API that enables application developers to **implement their own primitives**

ZooKeeper Terminology

- **Client**: user of the ZooKeeper service
- **Server**: process providing the ZooKeeper service
- **znode**: **in-memory data** node in ZooKeeper, organised in a hierarchical name space (the data tree)
- **Update/write**: any operation which modifies the state of the data tree
- Clients establish a **session** when connecting to ZooKeeper

ZooKeeper's data model

- znodes are organized in a hierarchical name space
- use the standard UNIX notation for file system paths
- znodes are not designed for general data storage. Instead, they map to **abstractions of the client application**



Znode

- **Regular**: Create and delete by client explicitly

- **Ephemeral**: Either delete them explicitly, or let the system remove them automatically when the session that creates them terminates (deliberately or due to a **failure**).

Znode

- **SEQUENTIAL** flag:
  - monotonically increasing counter appended to a znode's path
  - counter value of a new znode under a parent is always larger than value of existing children

- **WATCH** flag:
  - allow clients to receive timely notifications of changes without requiring polling
  - Watches indicate that a change has happened, but do not provide the change

ZooKeeper API

- `String create(path, data, flags)`
  - creates a znode with path name path, stores data in it and sets flags (ephemeral, sequential)
- `void delete(path, version)`
  - deletes the anode if it is at the expected version
- `Stat exists(path, watch)`
  - watch flag enables the client to set a watch on the znode
- `(data, Stat) getData(path, watch)`
  - returns the data and meta-data of the znode
- `Stat setData(path, data, version)`
  - writes data if the version number is the current version of the znode
- `String[] getChildren(path, watch)`

ZooKeeper API

- ZooKeeper does not use handles to access znodes
  (no `open()` or `close()` methods)

- All methods have both a synchronous and an asynchronous version

ZooKeeper Guarantees

- **Linearizable writes**: all requests that **update** the state of ZooKeeper are serializable and respect precedence
- **FIFO client order**: all requests from a given client are executed in the order that they were sent by the client

A-linearizability (asynchronous linearizability)

Think!

When electing a new leader:

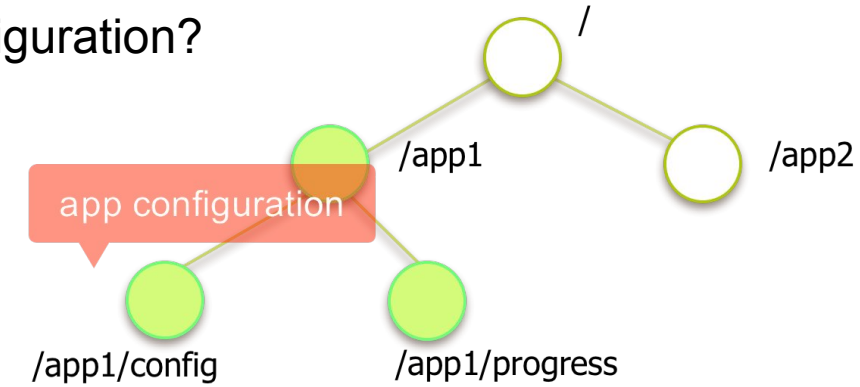
- As the new leader starts making changes, we do not want other processes to start using the configuration that is being changed
- If the new leader dies before the configuration has been fully updated, we do not want the processes to use this partial configuration

deleting ***ready*** znode -> updating the various configuration znodes -> creating ***ready*** znode

Example of primitives: Configuration

Questions:

1. How does a **new** worker query for a configuration?
2. How does an administrator **change** the configuration **on the fly**?
3. How do the workers read the **new** configuration?



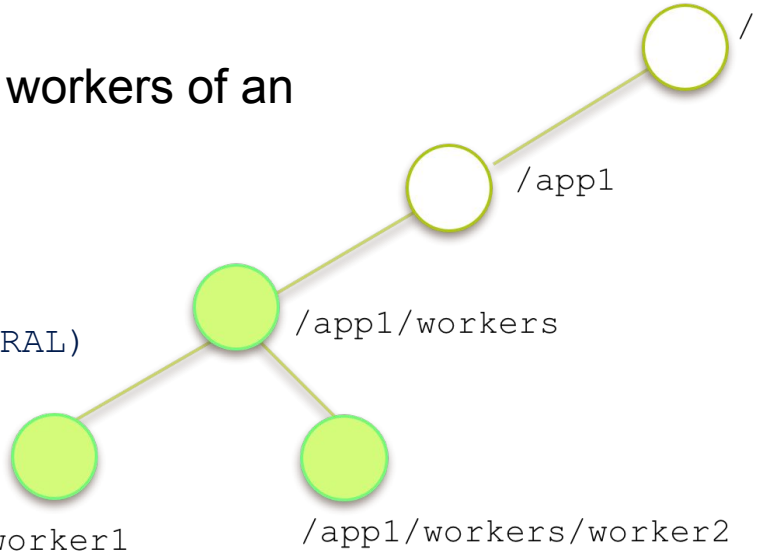

```
[configuration stored in/app1/config]
1.  getData(/app1/config,true)
2.  setData(/app1/config/config_data,-1)
    [notify watching clients]
3.  getData(/app1/config,true)
```

Example of primitives: Group Membership

Questions: 一个应用程序中的所有 workers 如何注册他们自己？

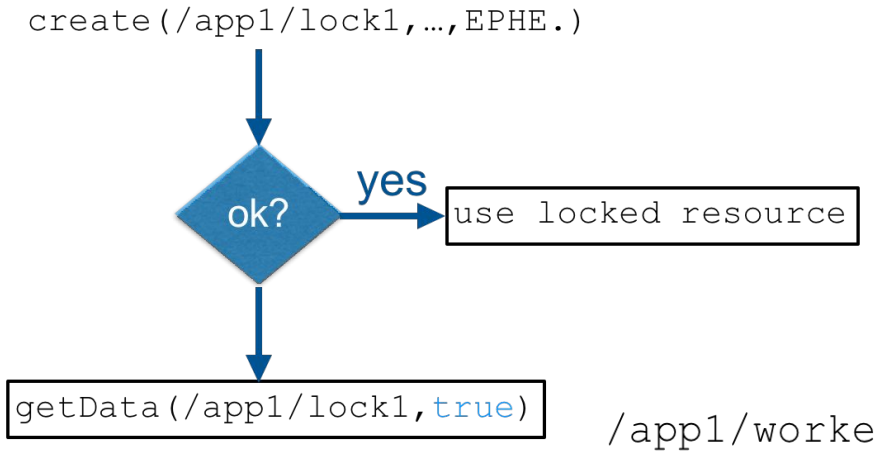
1. How can all workers (slaves) of an application register themselves?
2. How can a process find out about all active workers of an application? 进程如何找到一个应用程序中的所有活跃的workers？

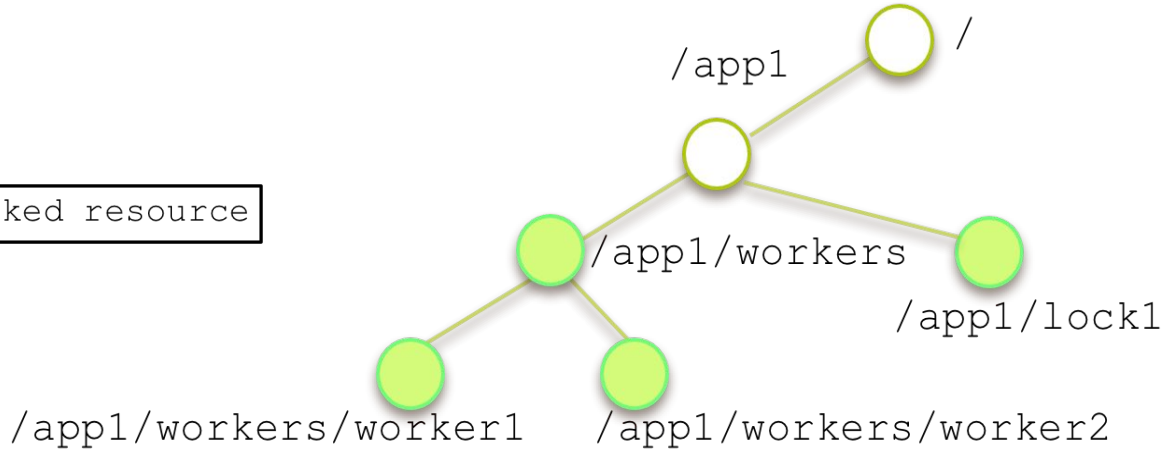
```
[a znode is designated to store workers]
1.  create(/app1/workers/worker, data, EPHEMERAL)
2.  getChildren(/app1/workers, true)
```



Example of primitives: Simple Locks

Questions: How can all workers of an application use a single resource through a lock?





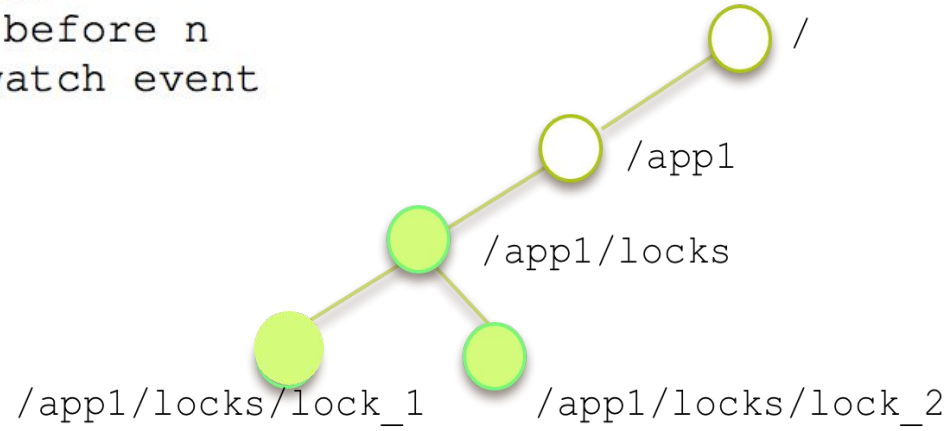
Example of primitives: Simple Locks without Herd Effect

Lock

```
1 n = create(l + "/lock-", EPHEMERAL|SEQUENTIAL)
2 C = getChildren(l, false)
3 if n is lowest znode in C, exit
4 p = znode in C ordered just before n
5 if exists(p, true) wait for watch event
6 goto 2
```

Unlock

```
1 delete(n)
```



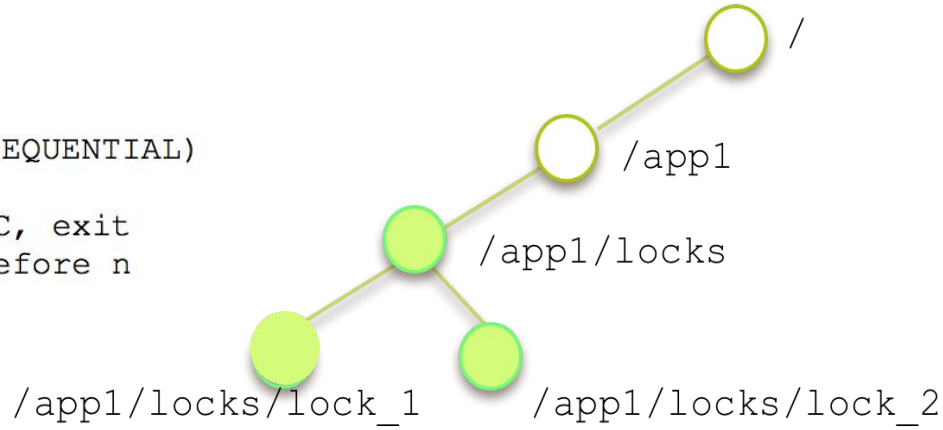
Example of primitives: Read/Write Locks

Write Lock

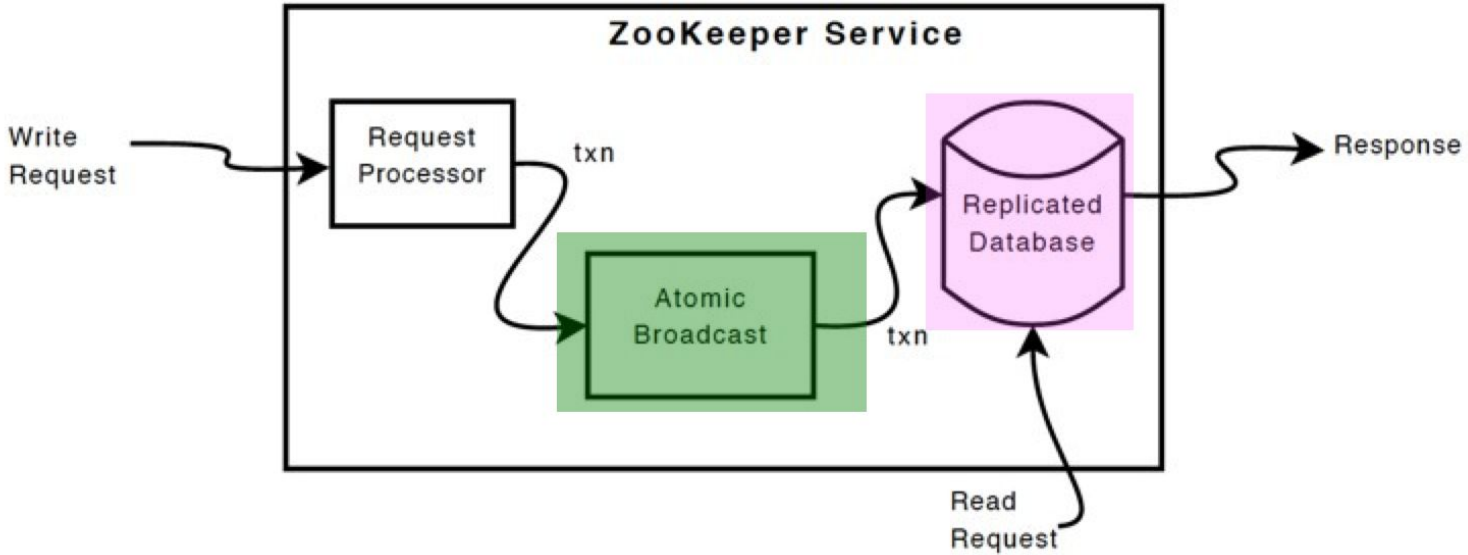
```
1  n = create(l + "/write-", EPHEMERAL|SEQUENTIAL)
2  C = getChildren(l, false)
3  if n is lowest znode in C, exit
4  p = znode in C ordered just before n
5  if exists(p, true) wait for event
6  goto 2
```

Read Lock

```
1  n = create(l + "/read-", EPHEMERAL|SEQUENTIAL)
2  C = getChildren(l, false)
3  if no write znodes lower than n in C, exit
4  p = write znode in C ordered just before n
5  if exists(p, true) wait for event
6  goto 3
```

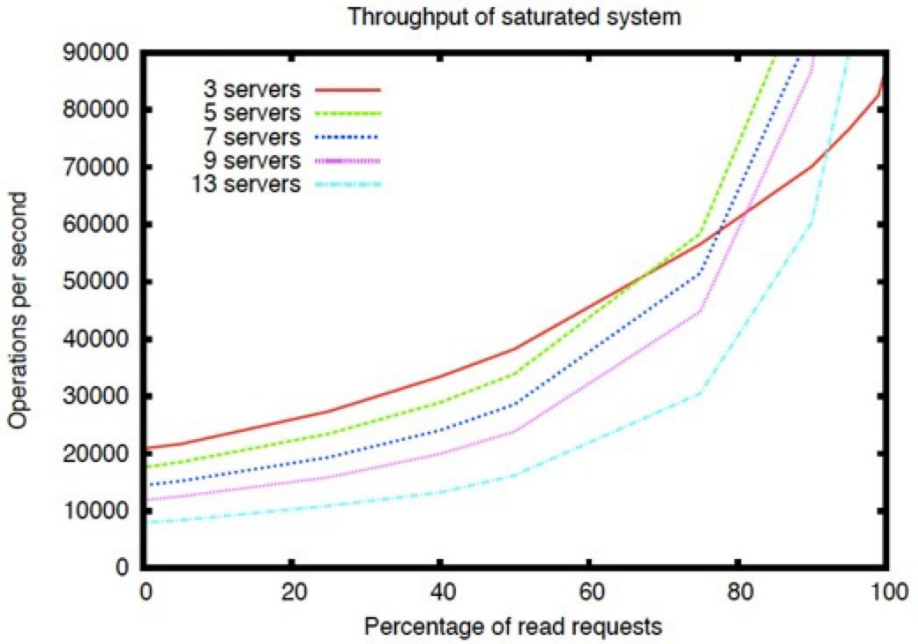


A little about implementation



Throughput

Setup: 250 clients, each client has at least 100 outstanding requests (read/write of 1K data)



Summary

- Wait-free
- Event ordering
- Watch mechanism

Thoughts

- a minimalist and flexible coordination system
- scales well with increase in read operations, but does not with increase in write operations
- punts the ball to the clients

Questions?

Reference

ZooKeeper: Wait-free coordination for Internet scale system, Hunt al., 2010

https://people.eecs.berkeley.edu/~istoica/classes/cs294/15/notes/18-zookeeper.pdf

http://deptinfo.unice.fr/twiki/pub/Minfo/DistributedAlgo/TUDelft-coordination_zookeeper.pdf