The Chubby lock service for loosely-coupled distributed systems

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Slide acks to: Shimin Chen
(http://www.cs.cmu.edu/~chensm/Big_Data_reading_group/ slides/shimin-chubby.ppt)

Introduction

- What is Chubby?
  - Lock service in a loosely-coupled distributed system
  - Client interface similar to:
    - Whole-file advisory locks (think .lck files)
    - Notification of various events (e.g., file modifications, think inotify)
  - Primary goals: reliability, availability, easy-to-understand semantics

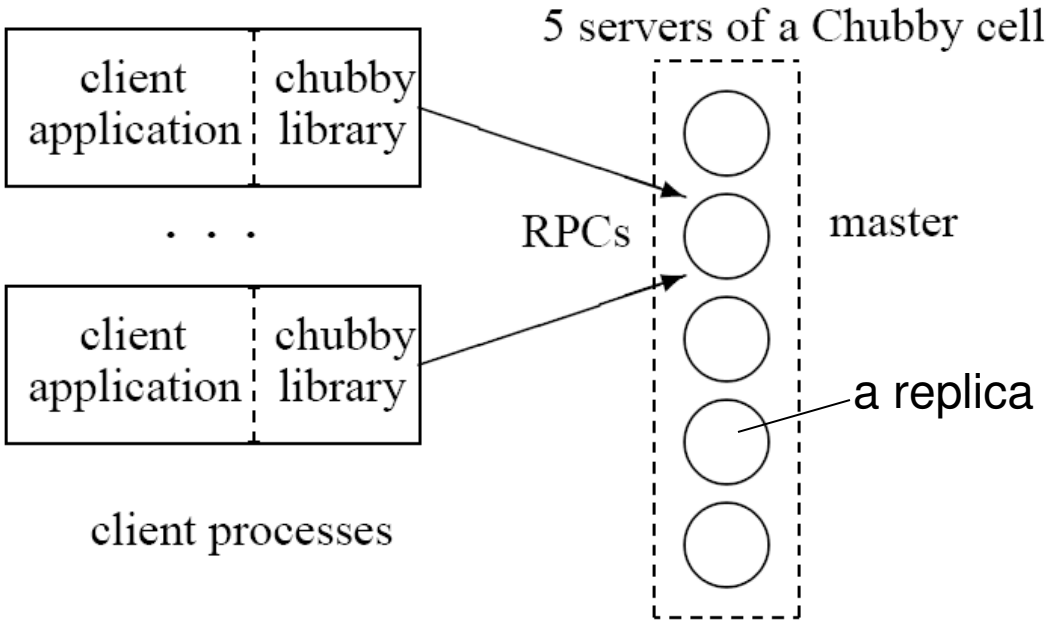
- How is it used?
  - Used in Google: GFS, Bigtable, etc.
  - Purposes: elect masters; store small amount of metadata, such as the root of the distributed data structures
  - Open-source version of Bigtable, Hbase, uses an open-source lock service, called Zookeeper

What Was the Chubby Paper About?

"Building Chubby was an engineering effort … it was not research. We claim no new algorithms or techniques. The purpose of this paper is to describe what we did and why, rather than to advocate it."

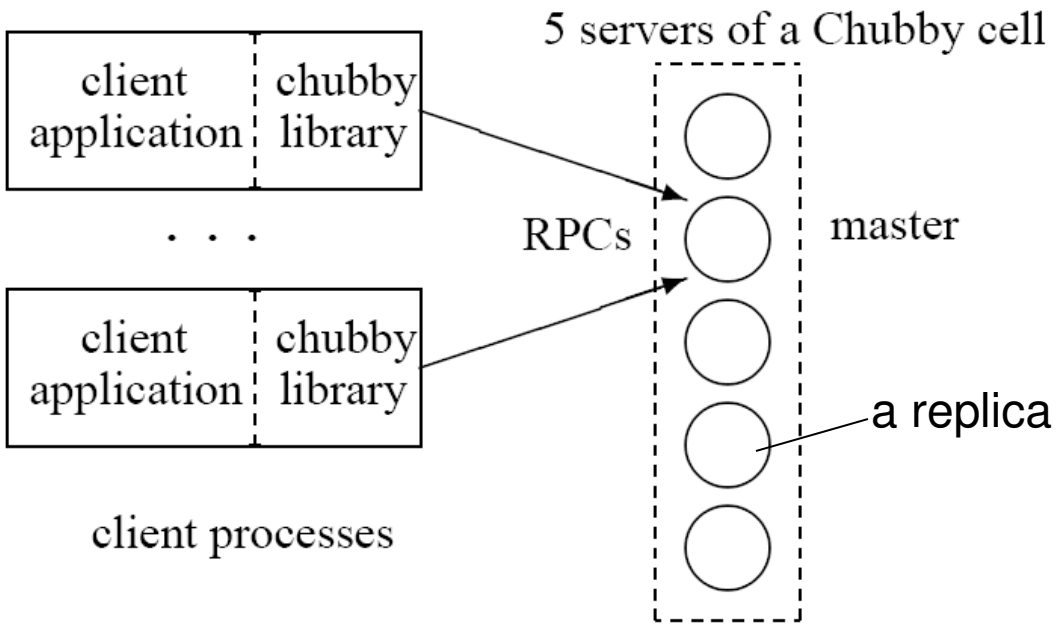
Chubby paper, OSDI 2006

System Architecture



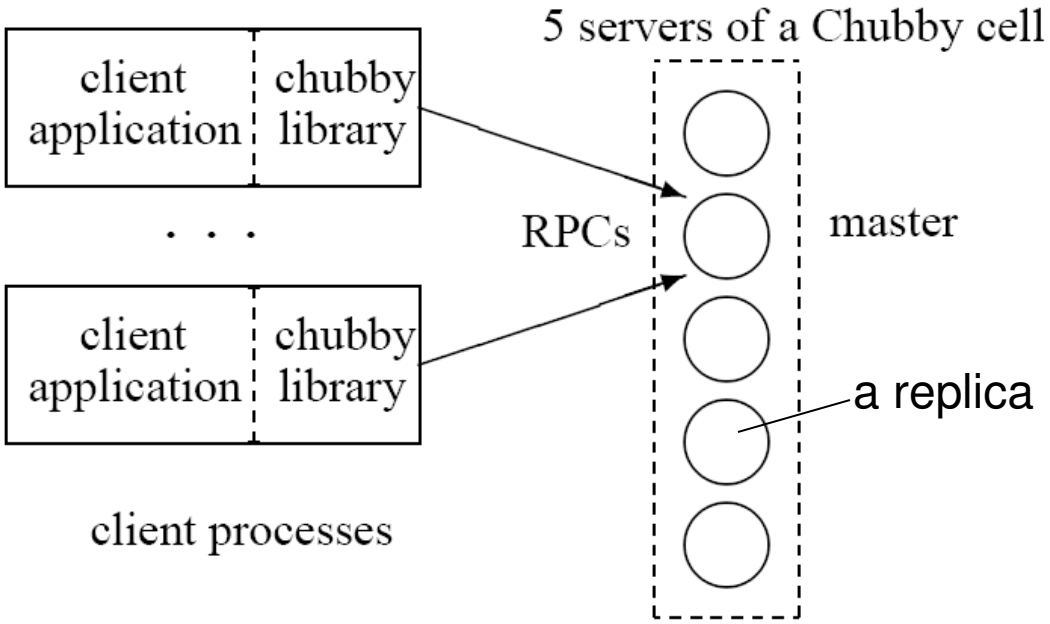
- A chubby cell consists of a small set of servers (replicas)
  - Placed in different racks, so as to minimize chance of correlated failures
- A master is elected from the replicas via Paxos
  - Master lease: several seconds
  - If master fails, a new one will be elected, but only after master leases expire
- Client talks to the master via the chubby library
  - All replicas are listed in DNS; clients discover master by talking to any replica

System Architecture (2)



- Replicas maintain copies of a simple database
- Clients send read/write requests only to the master
- For a write:
  - The master propagates it to replicas via Paxos
  - Replies after the write reaches a majority of replicas
- For a read:
  - The master satisfies the read alone

System Architecture (3)



- If a replica fails and does not recover for a long time (a few hours)
  - A fresh machine is selected to be a new replica, replacing the failed one
  - It updates the DNS
  - Obtains a recent copy of the database
  - The current master polls DNS periodically to discover new replicas
  - Integrating the new replica into the group is another Paxos run

Paxos Use in Master Election

- At any point in time, there must be at most one master
  - No two nodes must think they are masters at same time
- Example:
  - Suppose A is master and it gets disconnected from B
  - B times out trying to talk to A, thinks A is dead, and proposes that it be the master
  - If other nodes agree and A doesn't hear about the new master, then A will continue to act as master for a while, accepting read requests for what could be stale data, for example
  - How would you solve this?

Paxos Use in Master Election

- Chubby combines Paxos with a lease mechanism
  - When a master dies, a node proposes a master change through Paxos
  - When nodes receive the proposal, they will only accept it if the old master's lease has expired
  - A node becomes the master if a majority of nodes have given it the accept to become the master
  - Once a node becomes a master, it knows that it will remain so for at least the lease period
    - It can extend the lease by getting the accept from a majority of the nodes

Chubby Interface: UNIX File System

- Chubby supports a strict tree of files and directories
  - The way to think about these files is that they are locks with a little bit of contents (e.g., identity and location of a primary)
  - No symbolic links, no hard links
  - /ls/foo/wombat/pouch
    - 1st component (ls): lock service (common to all names)
    - 2nd component (foo): the chubby cell (used in DNS lookup to find the cell master)
    - The rest: name inside the cell
- Support most normal operations
  - Create, delete, open, write, …
- Support reader/writer lock on a node

Chubby Events

- Clients can subscribe to events
  - File contents modified: e.g., if the file contains the location of a service, this event can be used to track the service's location
  - Master failed over
  - Child node added, removed, modified
  - Handle becomes invalid: probably communication problem
  - Lock acquired (rarely used)
  - Locks are conflicting (rarely used)

APIs

- Open()
  - Mode: read/write/change ACL; Events; Lock-delay
  - Create new file or directory?
- Close()
- GetContentsAndStat(), GetStat(), ReadDir()
- SetContents(): set all contents; SetACL()
- Delete()
- Locks: Acquire(), TryAcquire(), Release()
- Sequencers: GetSequencer(), SetSequencer(), CheckSequencer()

Example: Primary Election

```
Open("/ls/foo/OurServicePrimary", "write mode");
if (successful) {
    // primary
    SetContents(primary_identity);
} else {
    // replica
    Open("/ls/foo/OurServicePrimary", "read mode",
            "file-modification event");
    when notified of file modification:
            primary = GetContentsAndStat();
}
```

Five Nodes?! Is that Enough?

- It seems so, but Chubby's users need to be very careful!
- Most typical use: as a name service
  - Bigtable, systems that need a more consistent DNS, …
- Abusive uses:
  - Publish/subscribe system on Chubby!
  - Repeated open/close calls for polling a file
  - Solution for the above: cache file handles
  - General solution: Review clients' code before they can use shared Chubby cells!
- How can Chubby scale??
  - E.g., to support more files

Chubby Summary

- Lock Service
- UNIX-like file system interface
- Reliability and availability

- Chubby uses Paxos for everything
  - Propagate writes to a file
  - Choosing a Master
  - Even for adding new Chubby servers to a Chubby cell

- Paxos transforms a multi-node service into something that looks very much like one fault-tolerant, albeit slower, server! → pretty close to distributed systems' core goal