An Introduction to Consensus with Raft

Diego Ongaro John Ousterhout

Stanford University

http://raftconsensus.github.io

RAFT ONLY
RAFT
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EPAL
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SOFTWARE CRAFTSMANSHIP MATTERS
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Distributed Systems

availability or consistency

Inside a Consistent System

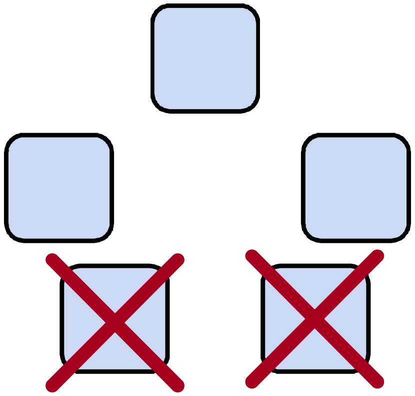
- **TODO: eliminate single point of failure**
- **An ad hoc algorithm**
  - "This case is rare and typically occurs as a result of a network partition with replication lag."
  - Watch out for @aphyr

– OR –

- **A consensus algorithm (built-in or library)**
  - Paxos, Raft, …
- **A consensus service**
  - ZooKeeper, etcd, consul, …

What is Consensus?

- **Agreement on shared state (single system image)**
- **Recovers from server failures autonomously**
  - Minority of servers fail: no problem
  - Majority fail: lose availability, retain consistency

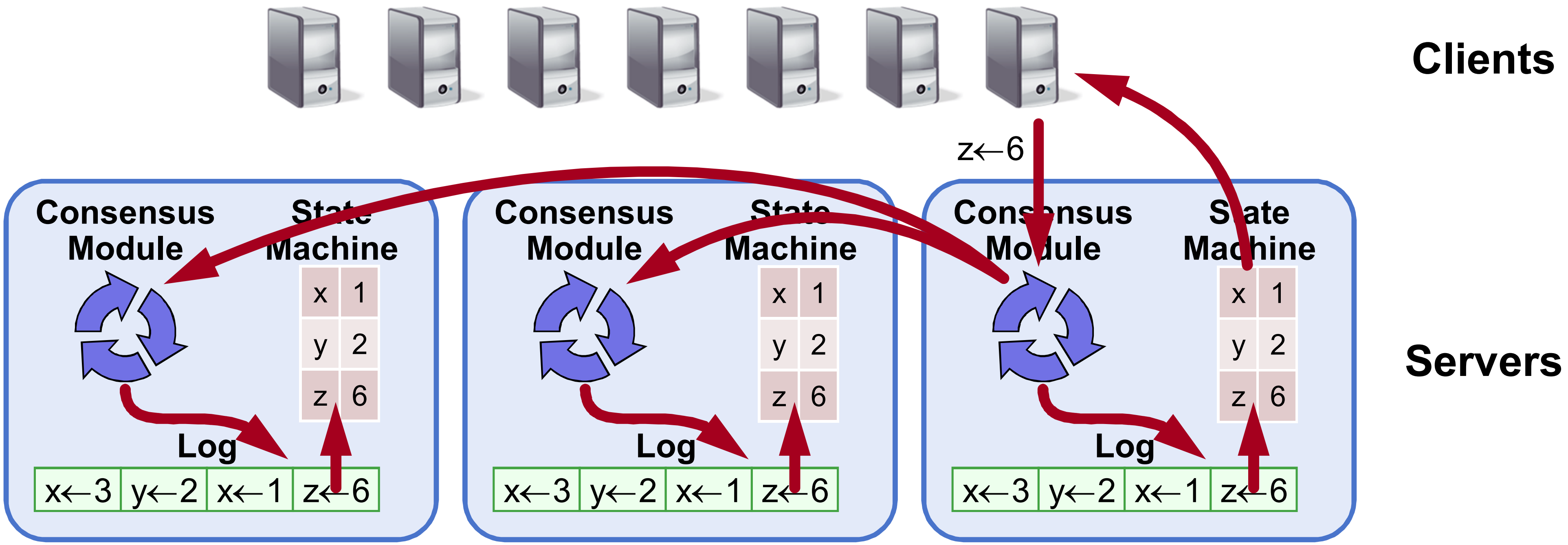


Servers

Why Is Consensus Needed?

- **Key to building consistent storage systems**
- **Top-level system configuration**
  - Which server is my SQL master?
  - What shards exist in my storage system?
  - Which servers store shard X?
- **Sometimes used to replicate entire database state (e.g., Megastore, Spanner)**

Goal: Replicated Log



- **Replicated log ⇒ replicated state machine**
  - All servers execute same commands in same order
- **Consensus module ensures proper log replication**
- **System makes progress as long as any majority of servers are up**
- **Failure model: fail-stop (not Byzantine), delayed/lost messages**

Paxos Protocol

- **Leslie Lamport, 1989**
- **Nearly synonymous with consensus**
- **Hard to understand**

  "The dirty little secret of the NSDI community is that at most five people really, truly understand every part of Paxos ;-)." – Anonymous NSDI reviewer

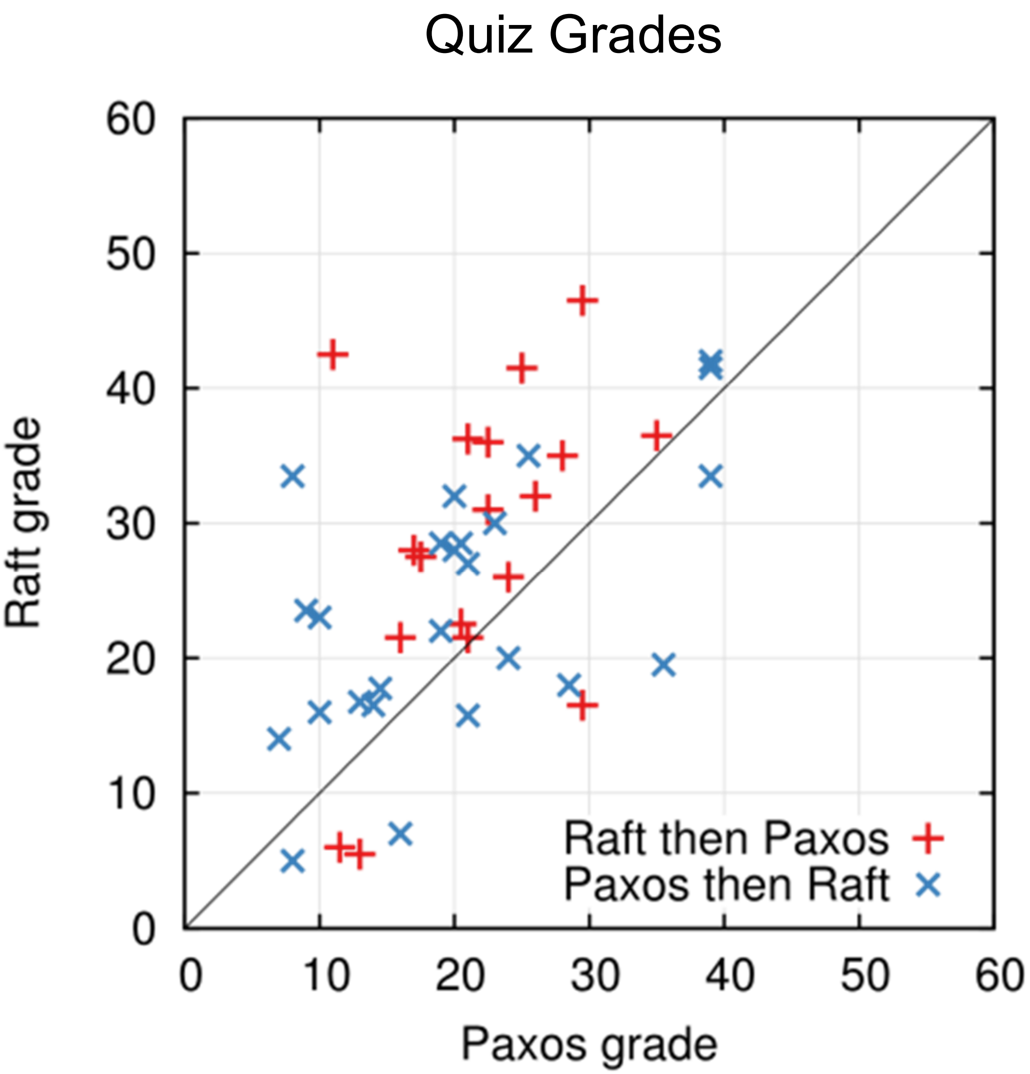
- **Bad foundation for building systems**

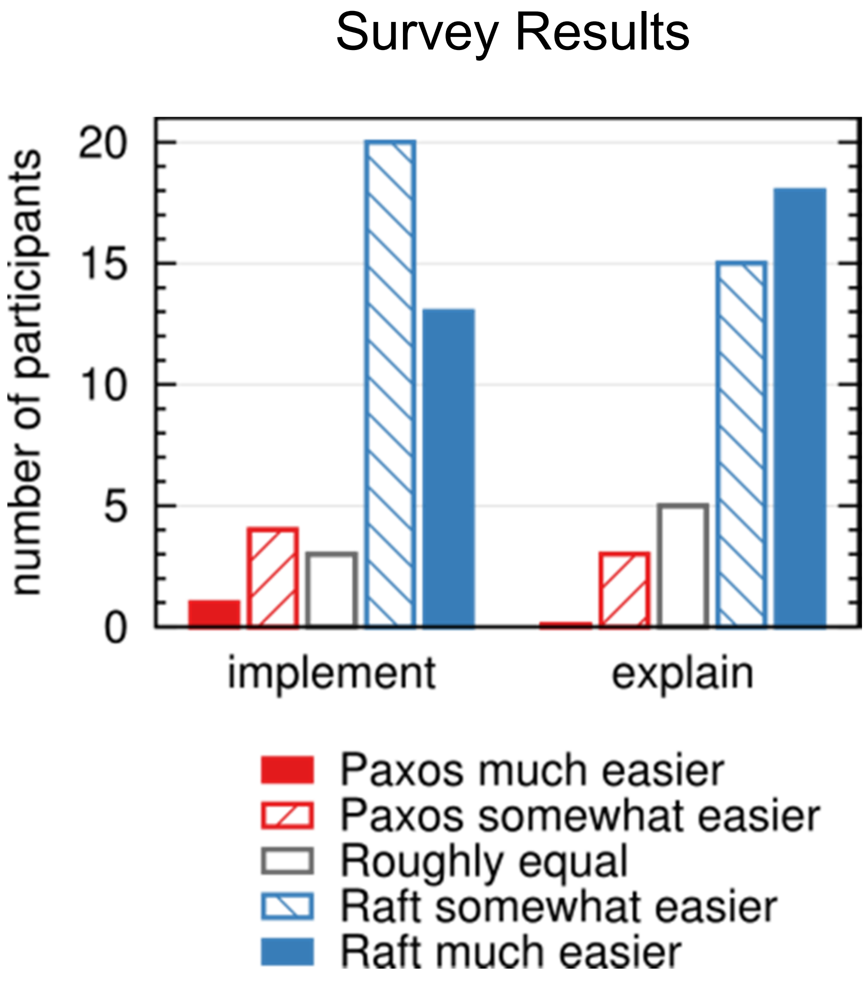
  "There are significant gaps between the description of the Paxos algorithm and the needs of a real-world system…the final system will be based on an unproven protocol." – Chubby authors

Raft’s Design for Understandability

- **We wanted the best algorithm for building real systems**
  - Must be correct, complete, and perform well
  - Must also be understandable
- **“What would be easier to understand or explain?”**
  - Fundamentally different decomposition than Paxos
  - Less complexity in state space
  - Less mechanism

User study


Quiz Grades
Raft grade
Paxos grade
0
10
20
30
40
50
60
Raft then Paxos +
Paxos then Raft ×

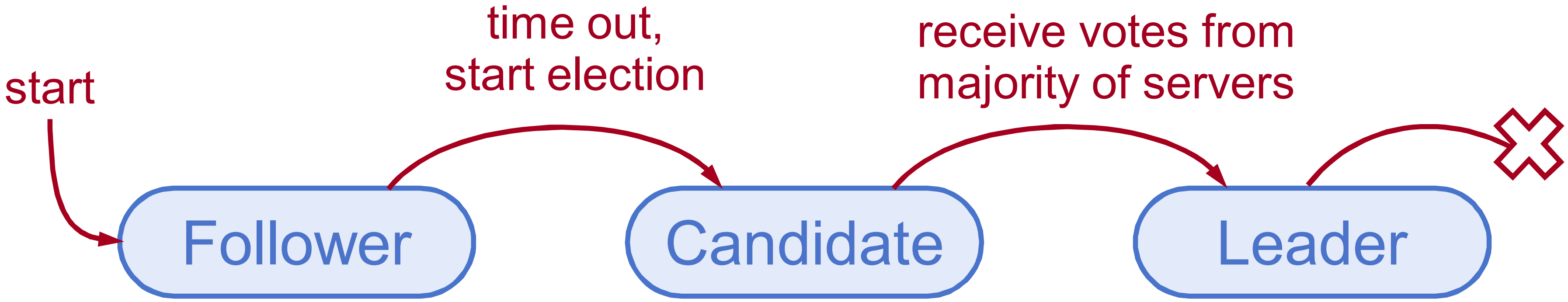

Survey Results
number of participants
0
5
10
15
20
implement
explain
Paxos much easier
Paxos somewhat easier
Roughly equal
Raft somewhat easier
Raft much easier

Raft Overview

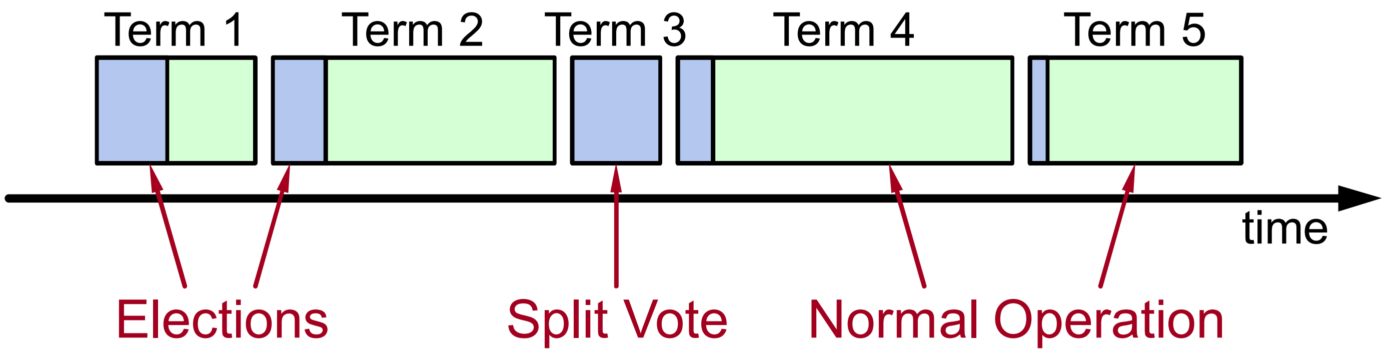
1. **Leader election**
   - Select one of the servers to act as leader
   - Detect crashes, choose new leader
2. **Log replication (normal operation)**
   - Leader takes commands from clients, appends them to its log
   - Leader replicates its log to other servers (overwriting inconsistencies)
3. **Safety**
   - Only elect leaders with all committed entries in their logs

Server States

- **At any given time, each server is either:**
  - Follower: completely passive replica (issues no RPCs, responds to incoming RPCs)
  - Candidate: used to elect a new leader
  - Leader: handles all client interactions, log replication
    - At most one viable leader at a time



Terms



- **Time divided into terms:**
  - Election
  - Normal operation under a single leader
- **At most one leader per term**
- **Each server maintains current term value**
- **Key role of terms: identify obsolete information**

Leader Election

Leaders send heartbeats to maintain authority.

Upon election timeout, start new election:

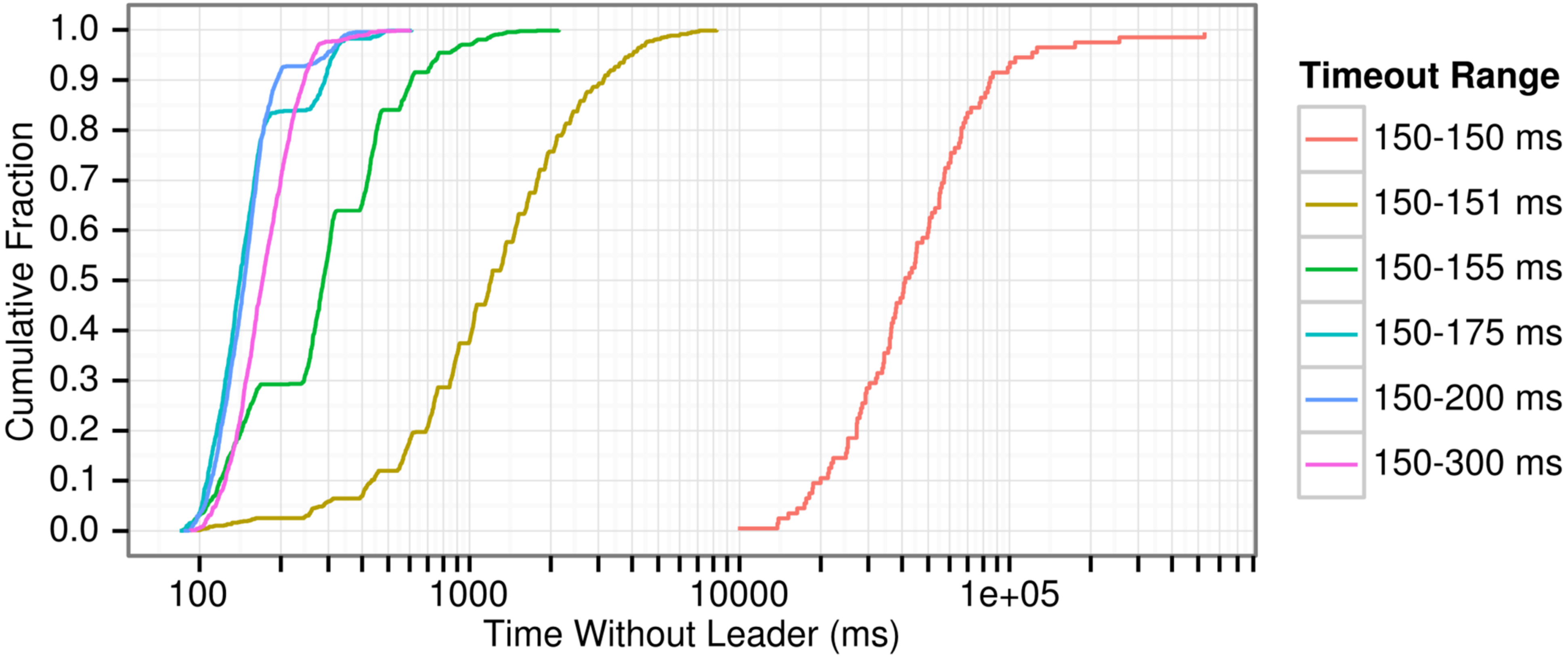
- **Increment current term**
- **Change to Candidate state**
- **Vote for self**
- **Send Request Vote RPCs to all other servers, wait until either:**
  1. Receive votes from majority of servers:
     - Become leader, send heartbeats to all other servers
  2. Receive RPC from valid leader:
     - Return to follower state
  3. No-one wins election (election timeout elapses):
     - Increment term, start new election

Leader Election Visualization

- The Secret Lives of Data
  http://thesecretlivesofdata.com
- Visualizes distributed algorithms, starting with Raft
- Project by Ben Johnson (author of go-raft)

Randomized Timeouts

- If we choose election timeouts randomly,



- One server usually times out and wins election before others wake up

Raft Paper

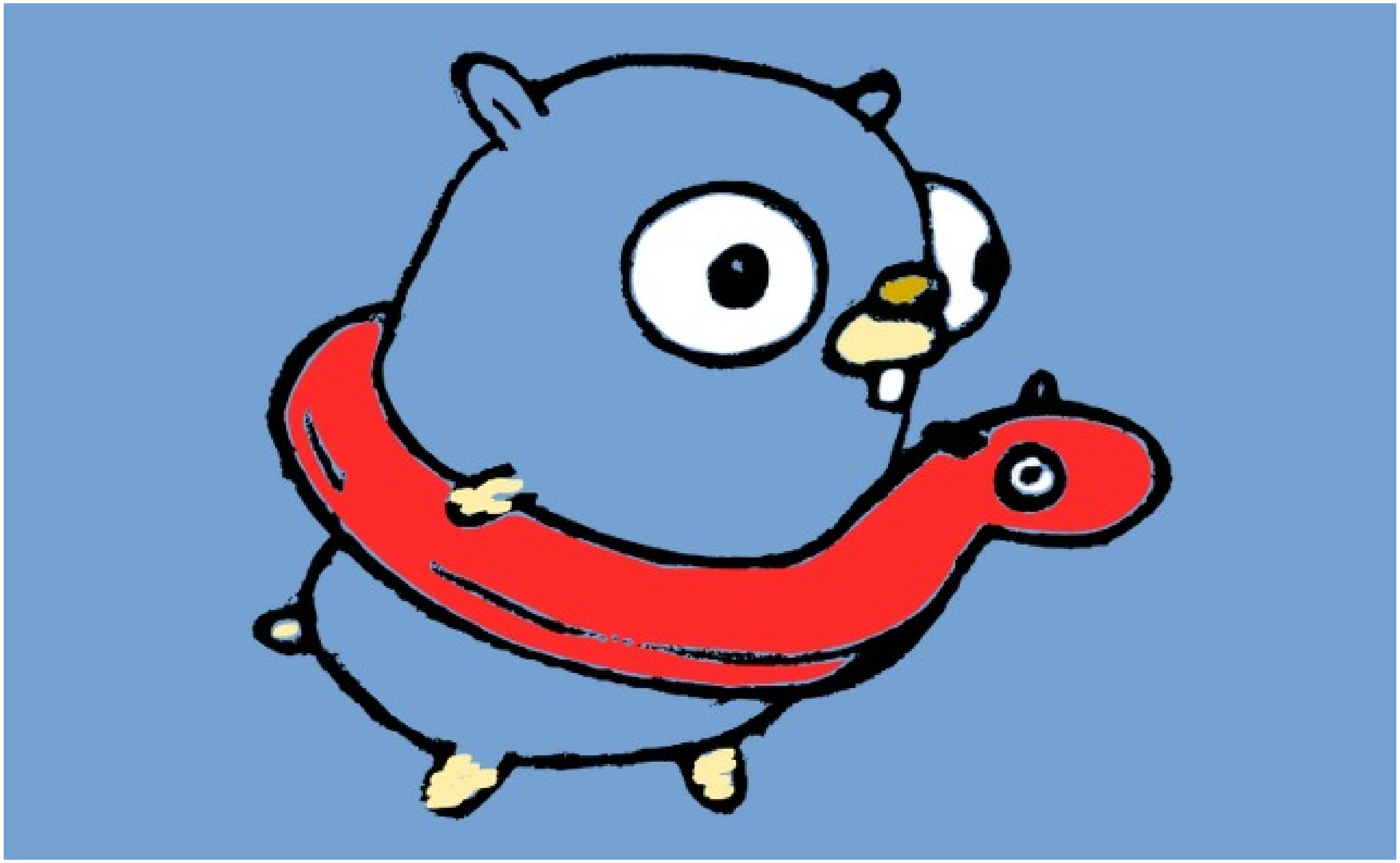
- **Log replication**
- **Client interaction**
- **Cluster membership changes**
- **Log compaction**

- **To appear: 2014 USENIX Annual Technical Conf.**
  - June 19-20 in Philadelphia
  - Draft on Raft website

Raft Implementations

kanaka/raft.js	JS	Joel Martin
go-raft	Go	Ben Johnson (Sky) and Xiang Li (CoreOS)
hashicorp/raft	Go	Armon Dadgar (HashiCorp)
LogCabin	C++	Diego Ongaro (Stanford)
ckite	Scala	Pablo Medina
peterbourgon/raft	Go	Peter Bourgon
rafter	Erlang	Andrew Stone (Basho)
barge	Java	Dave Rusek
py-raft	Python	Toby Burress
ocaml-raft	OCaml	Heidi Howard (Cambridge)
…		

Best Logo: go-raft



by Brandon Philips (CoreOS)

Summary

- **Consensus is key to building consistent systems**
- **Design for understandability**
- **Raft separates leader election from log replication**
  - Leader election uses voting and randomized timeouts

More at http://raftconsensus.github.io:

- **Paper draft, other talks**
- **10 to 50+ implementations**
- **raft-dev mailing list**

Diego Ongaro @ongardie