

Motivation

- ▶ Eventual consistency not (always) enough
- ▶ State Machine Replication protocols like Paxos are not scalable

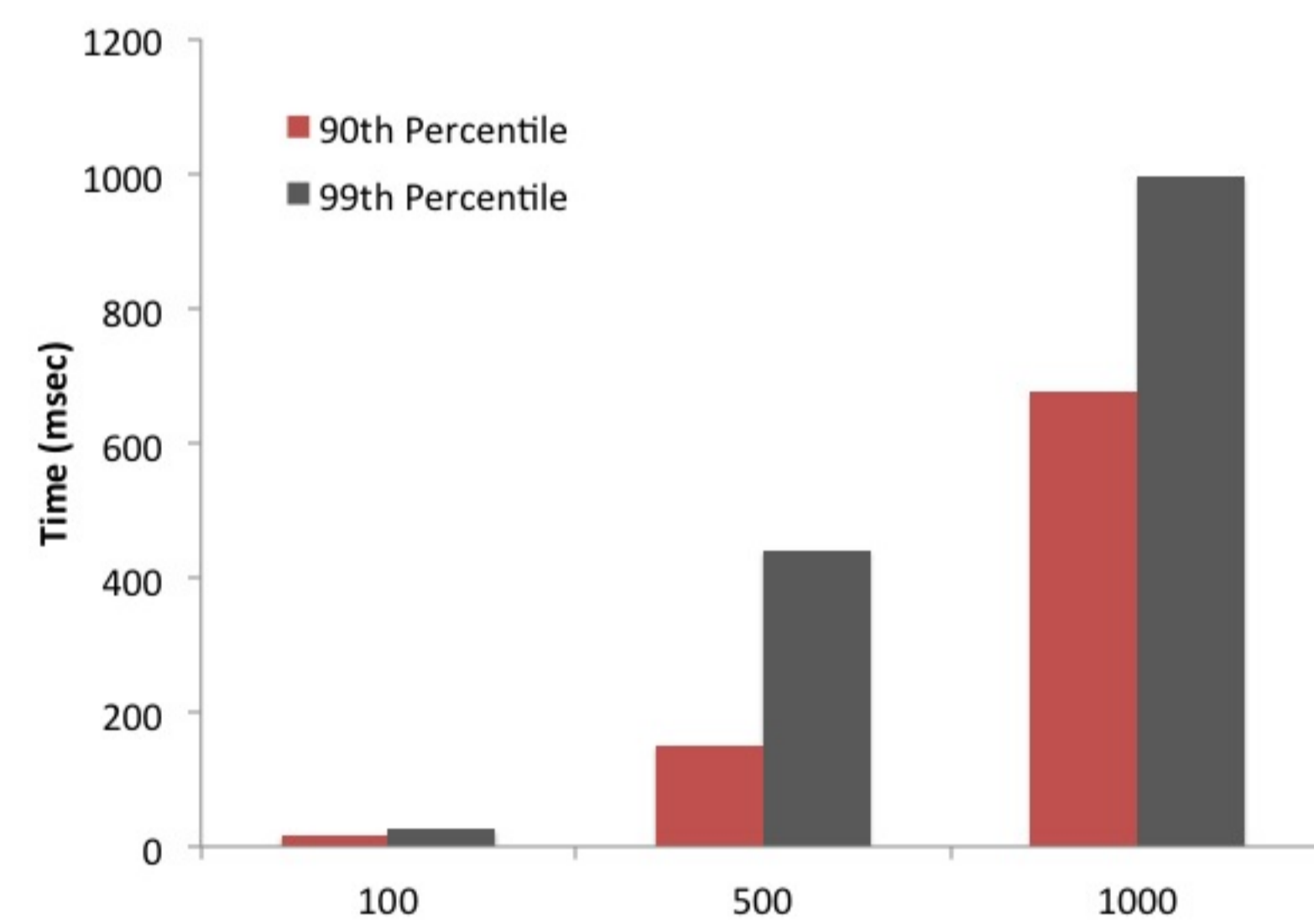
Can we build scalable and strongly consistent services?

Salient properties:

- ▶ Do not assume accurate failure detection (crash-failure)
- ▶ Minimize replica count (no majority voting)
- ▶ Fully decentralized implementation

Possible Solution

- ▶ Fail-stop protocols + centralized configuration manager.
- ▶ Manager notifies clients when configuration changes.



Time difference for clients to learn of configuration change using ZooKeeper

Stale configurations lead to inconsistencies!

- ▶ Not all clients learn about new configuration at the same time.
- ▶ Some might continue to talk to defunct replicas.

Elastic Replication Internals

- Replicate state to a *configuration* of replicas.
- One replica designated *orderer*.
- All replicas must see an update before responding.
- Stop replicas on fault suspicion.

(each configuration has at least one correct/non-suspected-faulty replica)

Tolerating Failures

Suspect a replica is faulty?

- Broadcast a *wedge* command to all replicas.
- A wedged replica does not modify its state.
- At least one replica will be wedged.

Wedging Guarantees Safety!

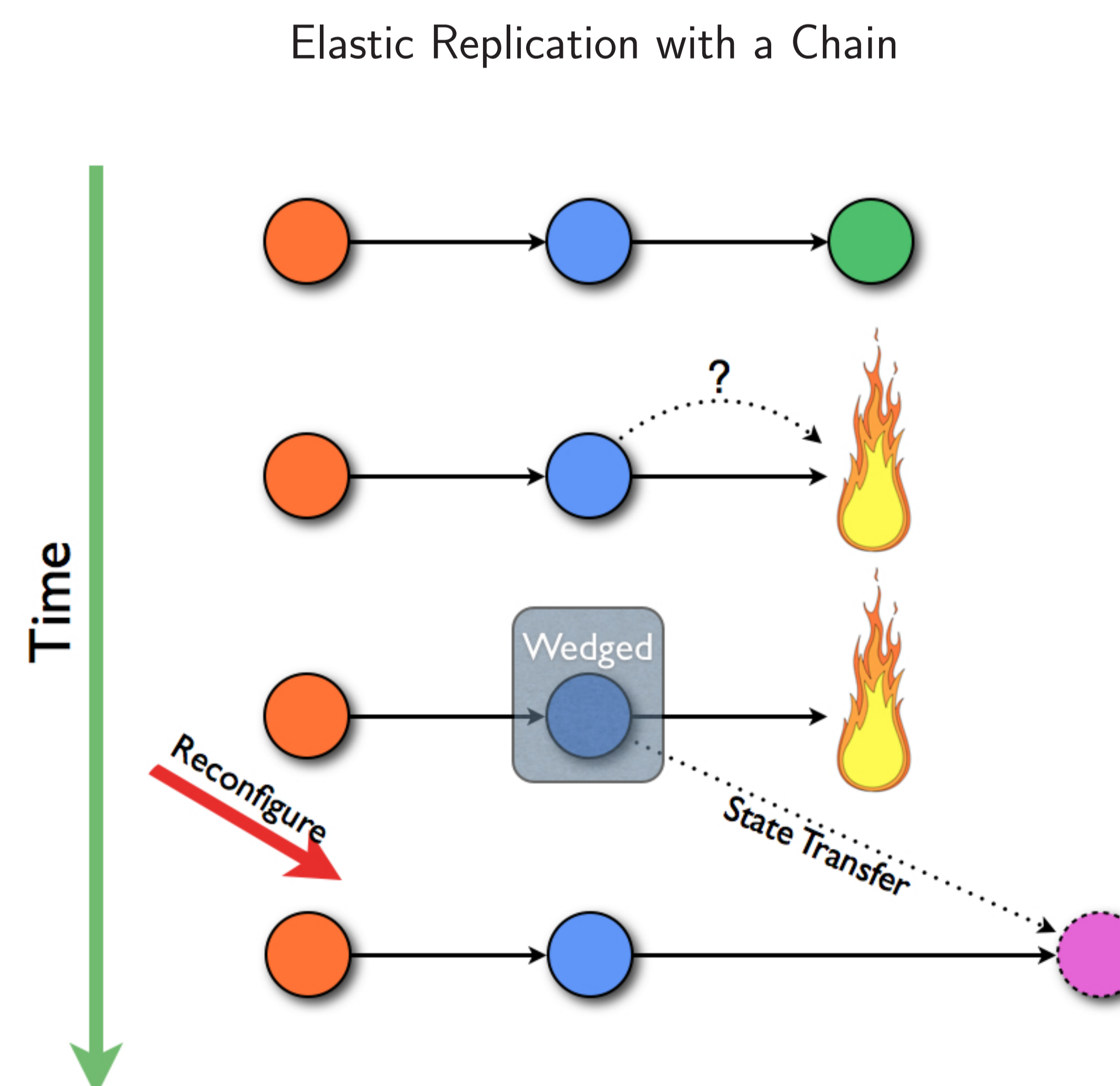
State cannot diverge and clients cannot see inconsistency due to network partitioning or inaccurate failure detection.

Reconfigure for Liveness

New configuration's replicas *inherit* state from any wedged replica of prior configuration.

Novelty:

Wedging eliminates need to vote on new configuration's state!



Scaling Out

Horizontal partitioning to cut costs

- Each partition is an elastically replicated object.
- A partition's state is separate from its configuration.
- Partitions act as *configuration sequencers* of one another.
- When a partition needs to be reconfigured, its sequencer wedges the old configuration and issues a new one.



- ▶ No need for a centralized configuration management service.

- ▶ Each partition only needs $f + 1$ replicas to tolerate f crash failures.

(as long as there always exists at least one partition with no faulty replicas)

