Paxos Made Simple

John Nguyen
Problem

How to agree on a value in a distributed system that tolerate non-malicious failures?
Problem

Distributed consensus problem

- Group of processes must agree on a single value
- Value must be proposed
- After value is agreed upon, it can be learned
Requirements

► Safety

► Liveness
Properties: Safety

- Only a proposed value is chosen
- Only a single value is chosen.
- Only chosen values are learned by processes
Properties: Liveness

- Some proposed value is eventually chosen if fewer than half of processes fail.

- If a value has been chosen, a process can eventually learn the value.
Paxos’s notation

- Classes of agents:
  - Proposers
  - Acceptors
  - Learners

- A process can act as more than one clients (usually 3).

- Assumption: asynchronous, non-byzantine model
Paxos Phase 1 (prepare)

► Proposer:
- Each proposal should be of form \langle n, v \rangle where n is strictly increasing
- A proposer sends a prepare request with number n to majority of acceptors.

► Acceptors:
- If n > n*
  - N* = n \leftarrow promise not to accept any new proposals n’ < n
- If no prior proposal accepted
  - Reply \langle promise, n, \varnothing \rangle
- Else
  - Reply \langle promise, n, (na, va) \rangle
- Else
  - Reply reject
Phase 1 Example

► Proposal is $<5, 100>$

► Acceptor

  ▪ Already accepted proposals
  ▪ For example, if it has accepted $<1, 20>$, $<2, 30>$ and $<4, 40>$
  ▪ it will respond with $<4, 40>$
  ▪ Did not accepted any proposal
  ▪ $<5, 100>$
Paxos Phase 2 (accept)

- If the proposer receives a response YES to its prepare requests from a majority of acceptors, then it sends an accept request to each of those acceptors for a proposal numbered \( n \) with a value \( v \) which is the value of the highest-numbered proposal among the responses.

- If an acceptor receives an accept request for a proposal numbered \( n \), it accepts the proposal unless it has already responded to a prepare request having a number greater than \( n \).
Paxos algorithm

- Phase 3 (learn):
  - Learners need to know which value has been chosen
  - Elect a set of “distinguished learners”
    - Acceptors respond with to learn requests with their acceptance
    - These distinguished learners informs other learners
Definition of chosen

A value is chosen at proposal number n iff majority of acceptor accept that value in phase 2 of the proposal number.
Progress

- Proposers can continually propose higher and higher proposal numbers without ever being accepted.
- Distinguished Proposer: the only one trying to initiate proposals.
Paxos’s properties

► P1: Any proposal number is unique.
► P2: Any two set of acceptors have at least one acceptor in common.
► P3: the value sent out in phase 2 is the value of the highest-numbered proposal of all the responses in phase 1.
Example

- **Proposer**
  - prepare = 8

- **Acceptors**
  - prepare = 8
Example
Example

- Proposer: accept = (8, foo)
- Acceptors:
  - Highest proposed = 8
  - Highest proposed = 8
  - Highest proposed = 8
Example

proposer

accepted = (8, foo)

acceptors

highest accepted = (8, foo)

highest accepted = (8, foo)

highest accepted = (8, foo)