Consensus is possible !
Paxos

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https://www.lrde.epita.fr/~renault/teaching/algorep/

A Word on Paxos

- Is Paxos hard ?
  ⇒ Not overly complex
- A troubled history
  ⇒ L. Lamport waited 10 years before paper accepted for publication (1998)
  ⇒ Build on work by Lynch and Liskov
  ⇒ Proved accidentally by Lamport
- **Altruism** : goal is to reach consensus, not "win"

Intuition

- You are with a group of friends and decide to go diner
- **Constraint** :
  - The whole group has to agree “gladines” or “pizza”
  - No leader in the group
  - Everybody is hungry : you have to terminate
  - Use person-to-person communication (yelling is useless)

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Solution

Quorum-based solution ⇒ the value is chosen among a majority of person (acceptors)

Problem : Split votes

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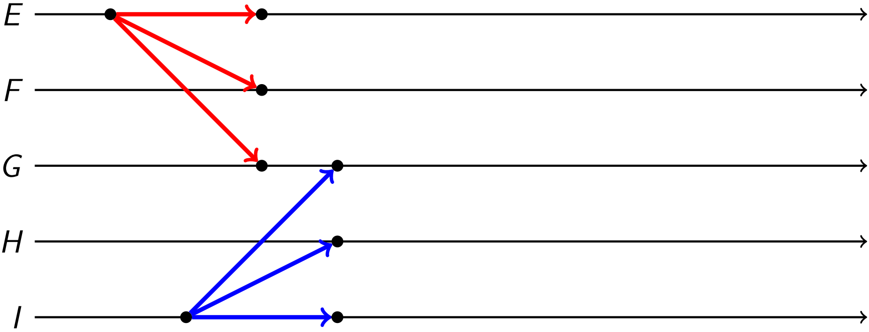
Acceptor might sometime change their mind in order to reach majority.

Toward a solution

Acceptors must sometitme accept multiple (different) values

Problems : Conflicting choices



If an acceptor accept all values it receives, multiple majorities can emerge !

Multiple Phases requirement

Multiple Phases (two) are mandatory

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- Let's go for pizza ! *The majority wins*

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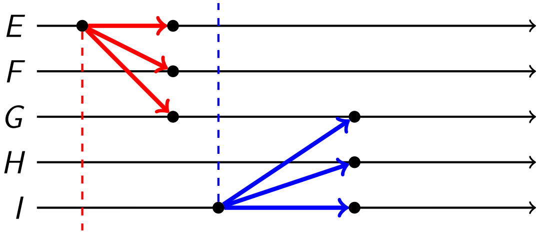
Remark

You cannot have two overlapping majority sets in a group of objects
$\Rightarrow 2m + 1$ processes required to tolerate m faults

2-phases protocol

Solution

A process must check proposed values before submitting a new one !



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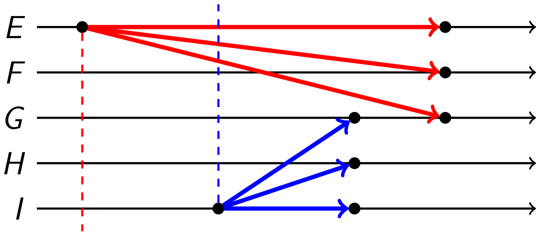
When checking proposed values, some may be in transit !



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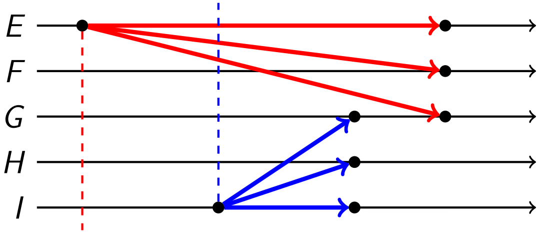

Proposals must be ordered, and old one must be rejected

Need for proposal numbers

Each proposal must be identified uniquely

- Maintain a “round number” (the largest round number seen so far)
- Generate a new proposal number by
  (1) Incrementing the round number
  (2) concatenate with server ID (lower bits so it’s unique)

round number must be stored on disk in case of crash/recovery

Basic Paxos

Two phases approach :

- Phase 1 : Broadcast **Prepare**
  - Find about any chosen values
  - Block older proposal that have not yet been completed
- Phase 2 : Broadcast **Accept**
  - Ask acceptors to accept a specific value

Conceptual Roles in Paxos

A process can have three conceptual roles

- **Proposers** : propose values
  Job : try convince the other nodes to accept proposed values
- **Acceptors** : accept values, where a value is chosen if a majority accept
  Job : remember values proposed by proposers
- **Learners** : learn the outcome (chosen value)

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In practice, a process can play any/all roles

Paxos Protocol Overview 1/2

Phase 1 :

1. **[Proposer]** Choose a proposal number *n*
2. **[Proposer]** Broadcast **prepare(n)** to all servers
3. **[Acceptor]** Response to **prepare(n)**
    - if n $>$ minProposal then minProposal $= n$
    - Return (accepted_proposal, accepted_value)
4. **[Proposer]** When responses received from majority
    - if any accepted_value returned, replace value by accepted_value for highest accepted_proposal

Paxos Protocol Overview 2/2

Phase 2 :

5. **[Proposer]** Broadcast **accept(n, value)** to all servers
6. **[Acceptor]** Response to **accept(n, value)**
   - if n >= minProposal then
     accepted_proposal = min_proposal = *n*
     accepted_value = value
   - Return (min_proposal)
7. **[Proposer]** When responses received from majority
   - Any objection (result > n) ? restart
   - Otherwise, value is chosen

Paxos Protocol Overview 2/2

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Important : Stability Remark

accepted_proposal, min_proposal and accepted_value must be stored on disk.

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Later proposal

Previous value already chosen ⇒ new proposer will find and use it.

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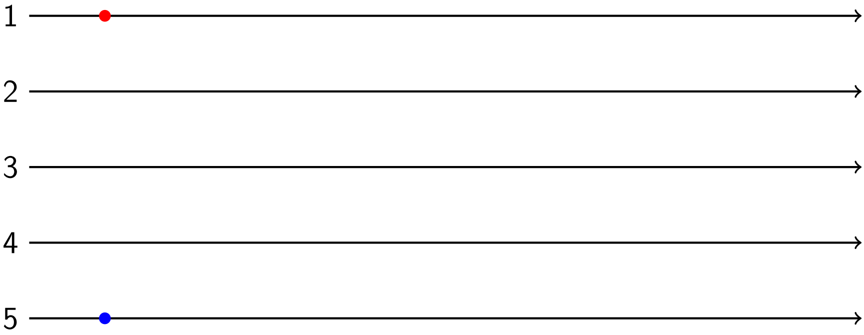

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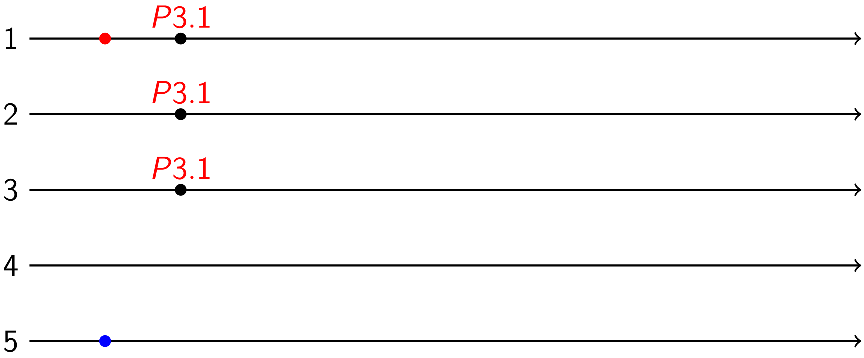

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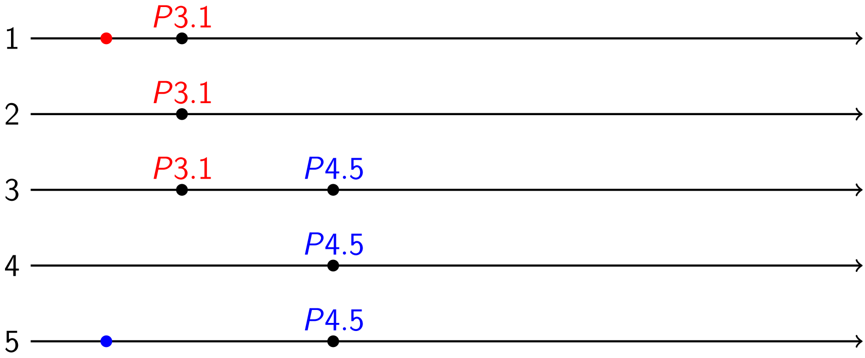

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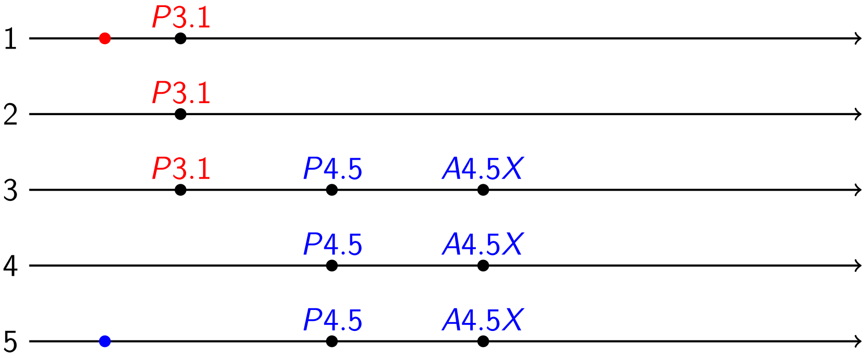

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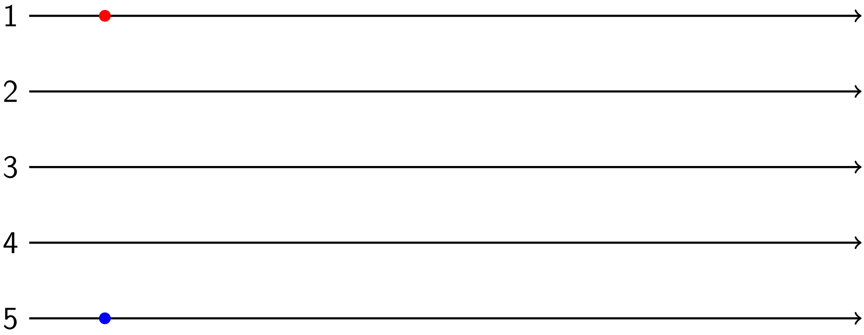

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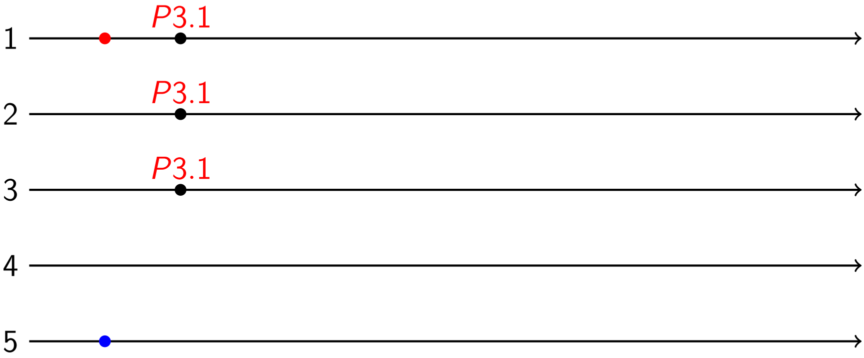

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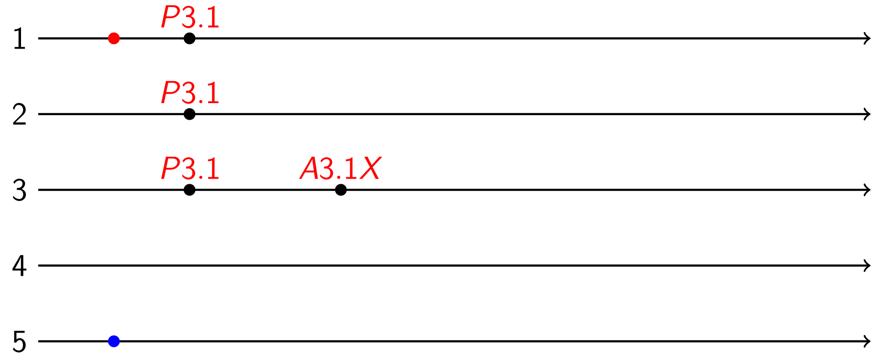

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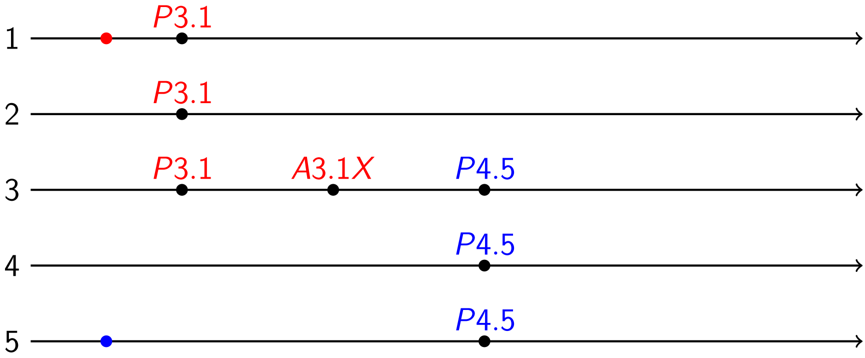

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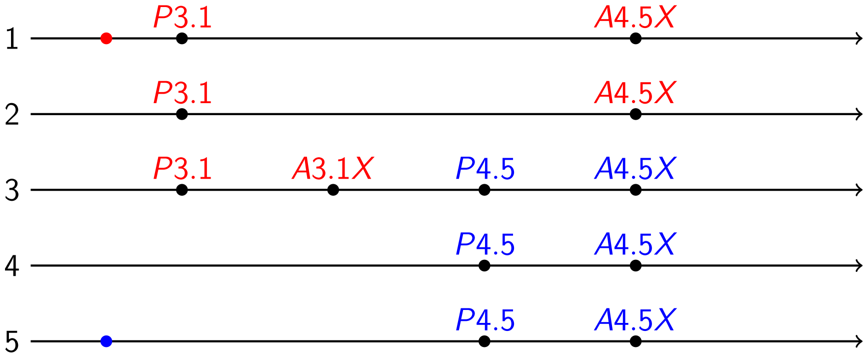

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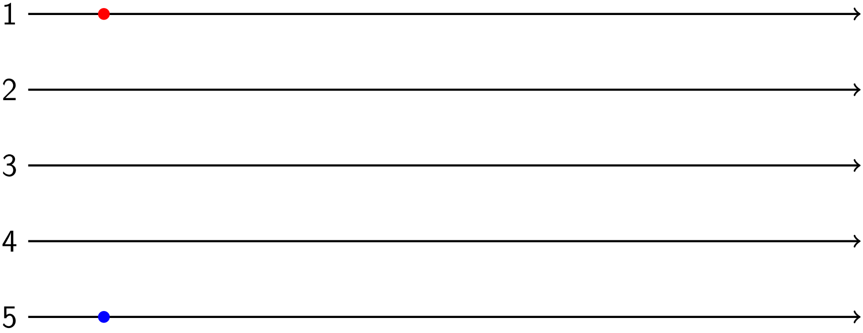

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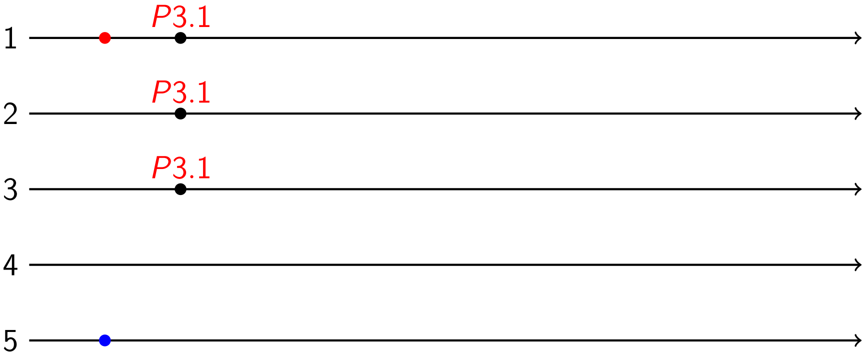

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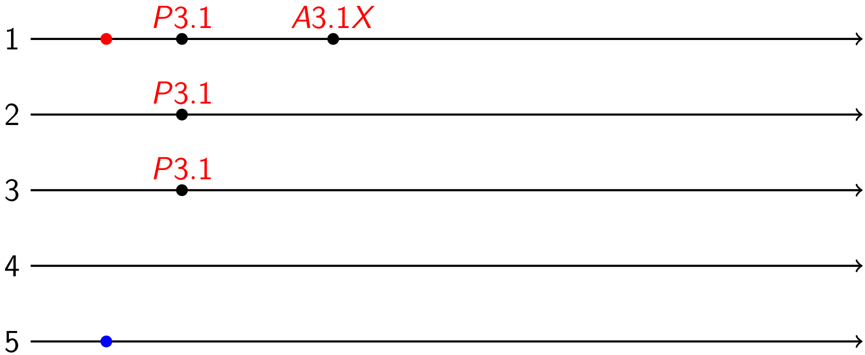

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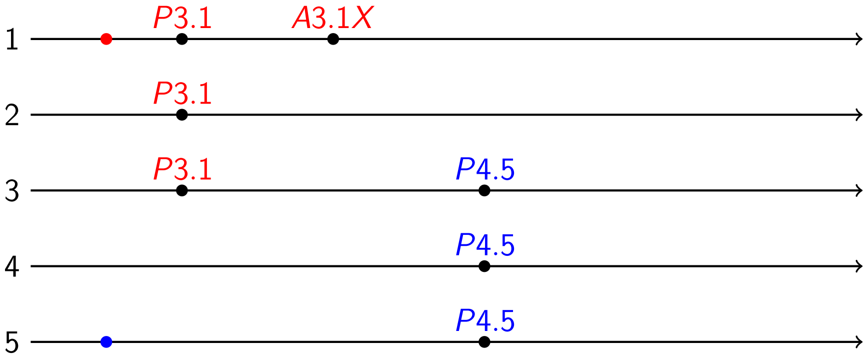

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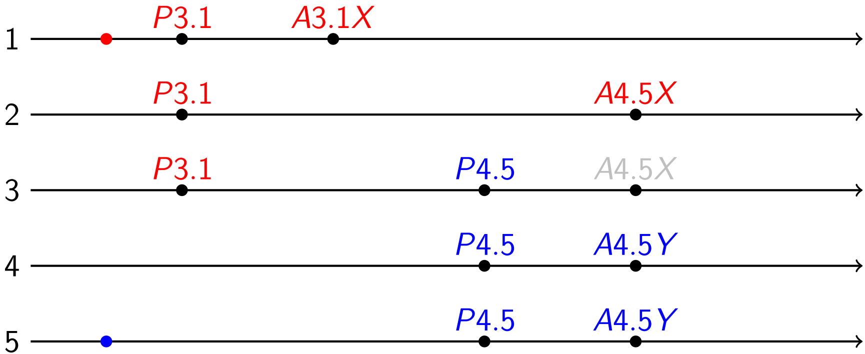

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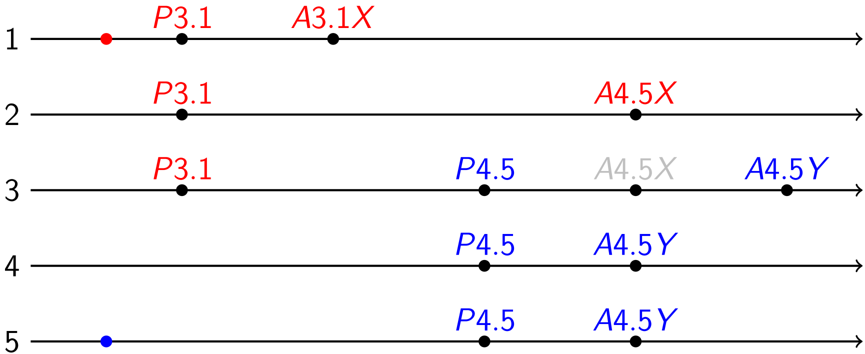

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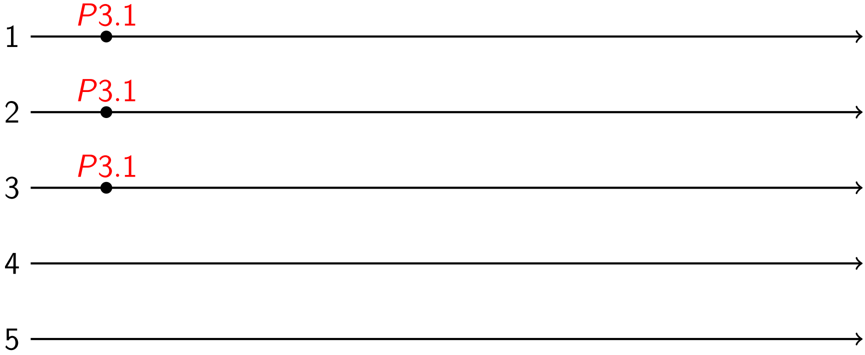

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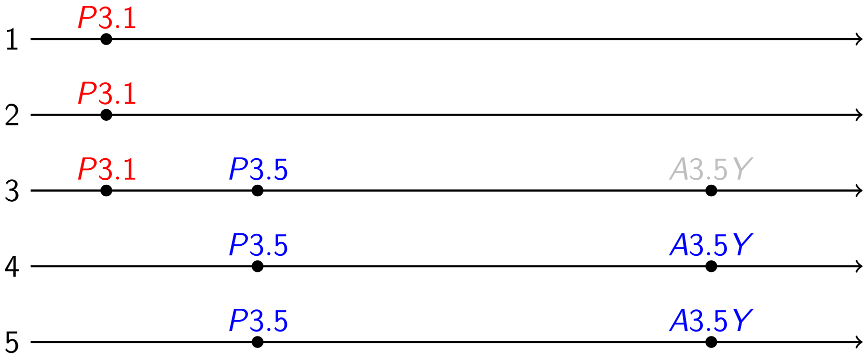

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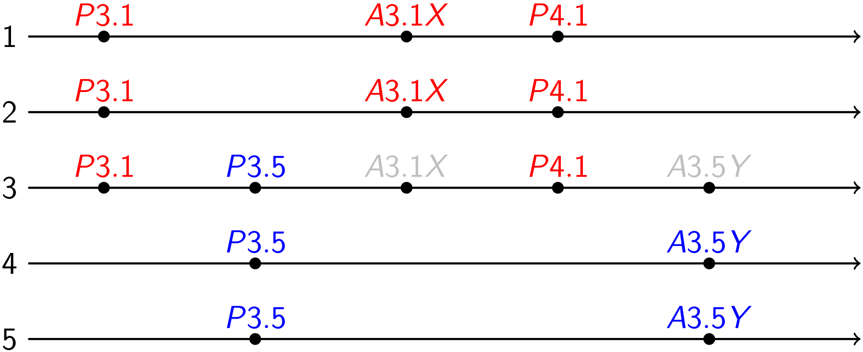

Solutions

Randomized delays before restarting
$\Rightarrow$ Give a chance to a process to finish !

Multi-paxos will use leader election instead

Multi-Paxos

Goal

Create a replicated log.

Main idea :

- Use a collection of Paxos algorithms
- Add index to Prepare and Accept
  This index selects entry in log

Example

1. Client send command to a server
2. Server uses Paxos to choose command as value for log entry
3. Server waits for previous entries to be applied then applied command
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Multi-paxos not specified precisely in litterature !