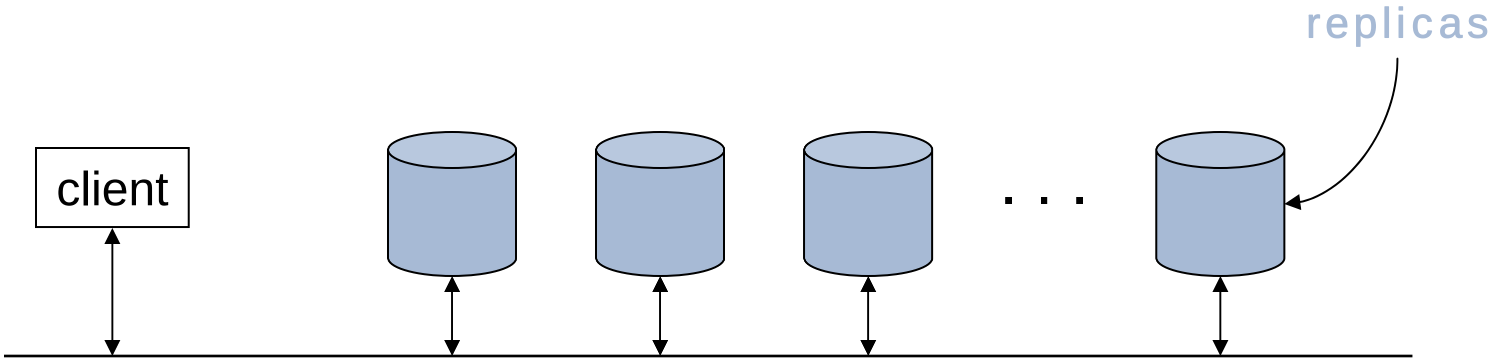
Paxos

A Consensus Algorithm for Fault Tolerant Replication

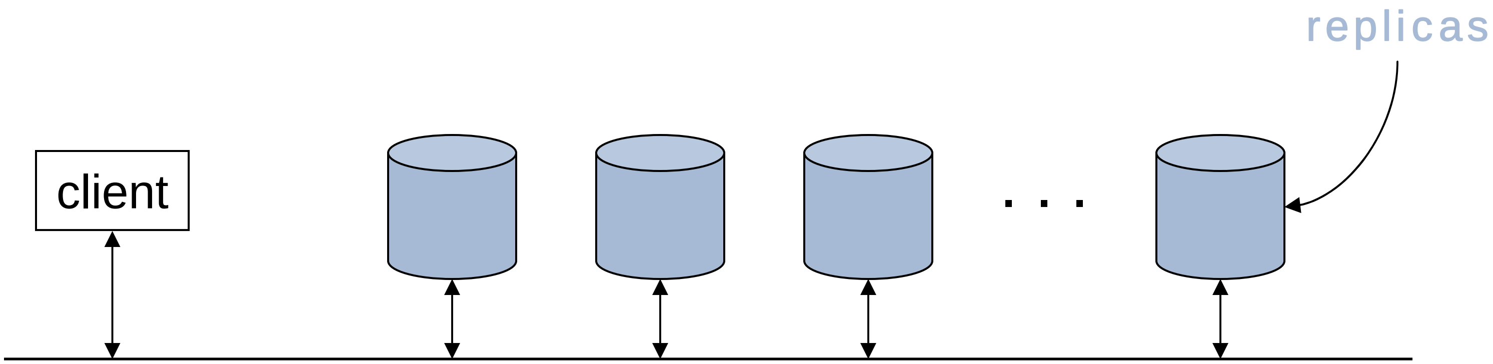
System Model



- Replicas
  - □ identical
  - □ fail/stop/restart failures
  - □ stable storage available
- Messages
  - □ possible indefinite delay
  - □ possible duplication or loss
  - □ delivered messages not corrupted

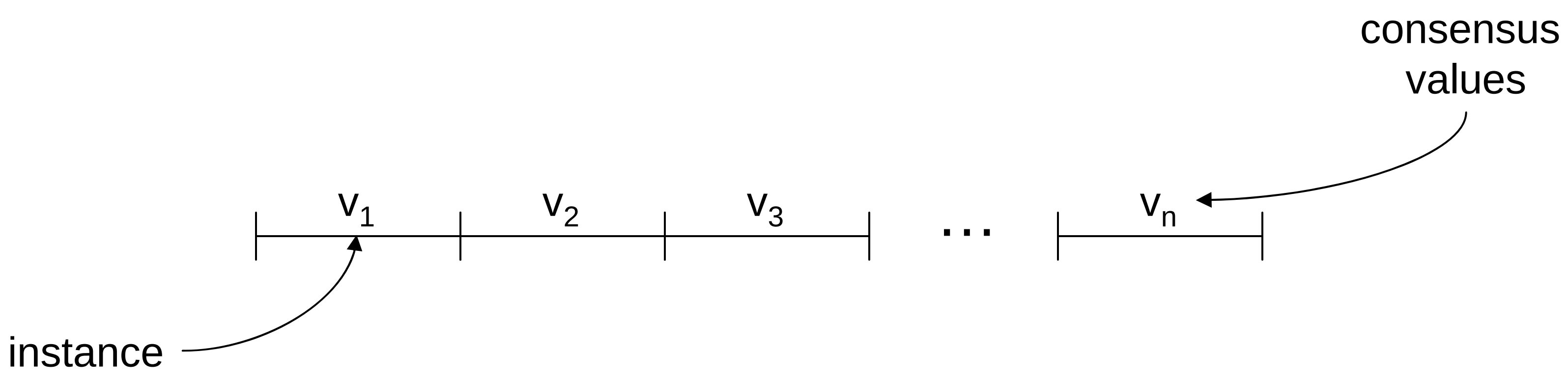
- **Goal:** insure that all replicas remain identical despite replica failure and message loss.

Safety requirements



- Only a value that has been proposed (by a replica) may be chosen.
- Only a single value is chosen.
- A process never learns that a value has been chosen unless it actually has been.

Multi-Paxos



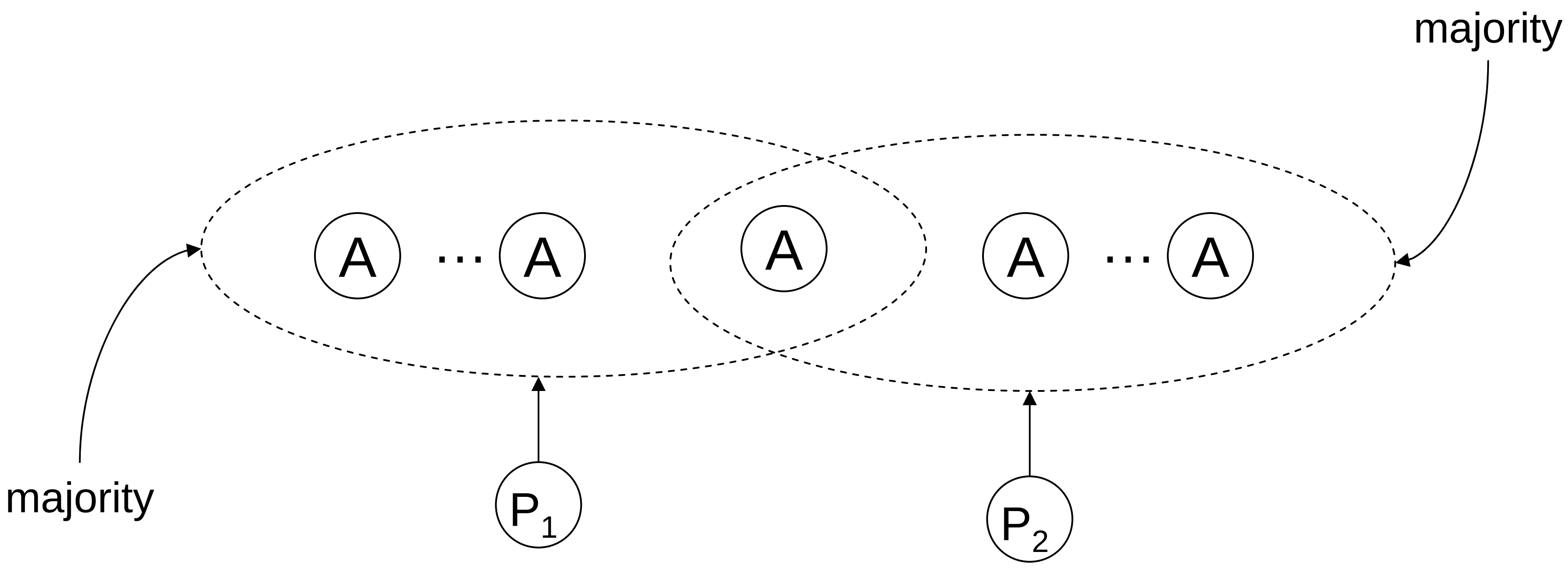
- Within each instance (basic) Praxos is used to arrive at a consensus of the value to be used by all replicas
- The sequence of instances determines a sequence of values accepted by all replicas

Roles

- Proposer(s): offer proposals of the form [value, number].
- Acceptor(s): accept or reject offered proposals so as to reach consensus on the chosen proposal/value.
- Learner(s): become aware of the chosen proposal/value.

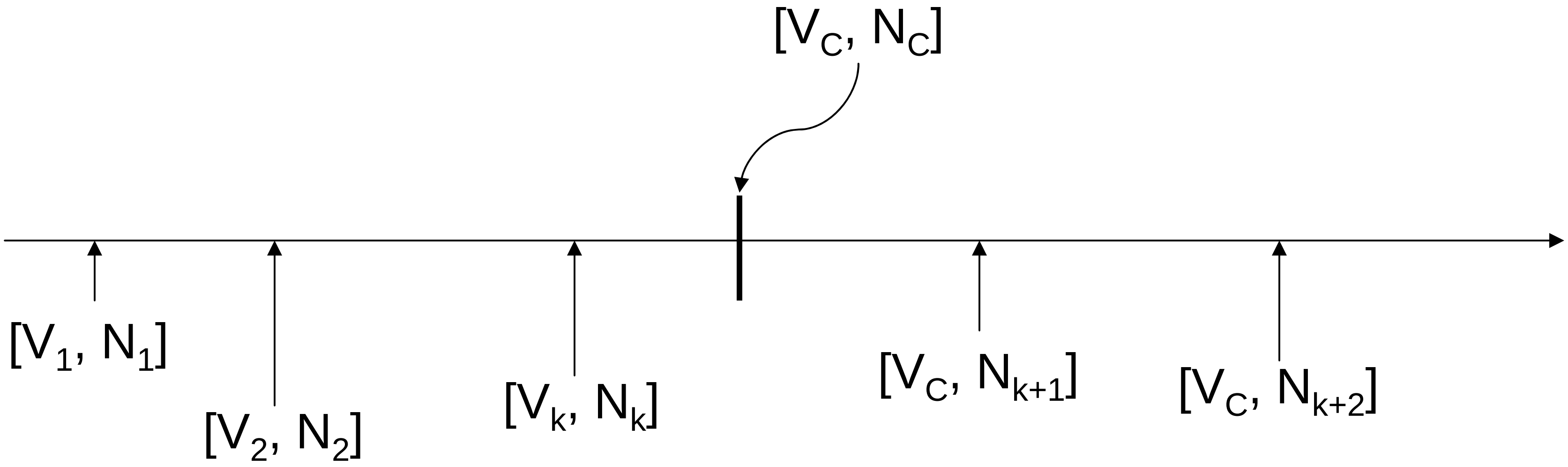
- Notes:
  - □ The proposal number is unique
  - □ A single distinguished proposer can be elected to guarantee progress
  - □ A single distinguished learner can be elected
  - □ In practice, all replicas play all roles
  - □ In practice, an elected “master” plays the roles of the distinguished proposer and the distinguished learner

Majority consensus



- Each proposer makes a proposal to some majority of the acceptors.
- A majority of acceptors must accept a proposal for the proposed value to be chosen as the consensus value.
- If P_1 and P_2 are making different proposals, then there must be at least one acceptor that they share in common (and this common acceptor will decide which proposal prevails).

Choosing a value



- An acceptor will accept the proposal with the largest proposal number.
- A value is chosen once a majority of acceptors have accepted a proposal with that value.
- Once a proposal/value is chosen all proposals with a higher proposal number are “forced” to have the chosen value.

Key idea

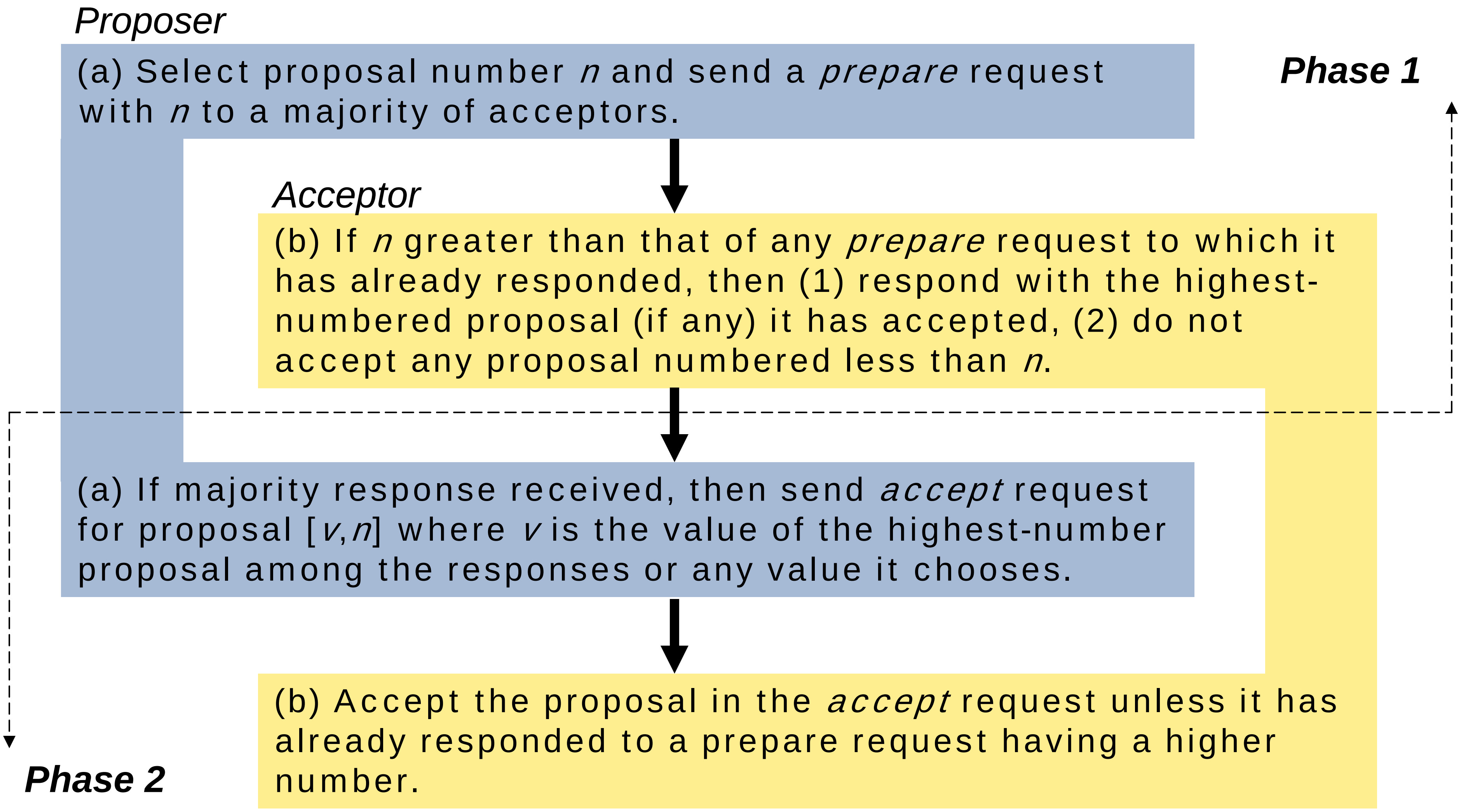
The property:

> P2^b: If a proposal with value *v* is chosen, then every higher-numbered proposal issued by any proposer has value *v*.

is guaranteed by maintaining the invariant:

> P2^c: For any *v* and *n*, if a proposal with value *v* and number *n* is issued, then there is a set *S* consisting of a majority of acceptors such that either (a) no acceptor in *S* has accepted any proposal numbered less than *n*, or (b) *v* is the value of the highest-number proposal among all proposals numbered less than *n* accepted by the acceptors in *S*.

Paxos Protocol



Proposer

(a) Select proposal number *n* and send a *prepare* request with *n* to a majority of acceptors.

Acceptor

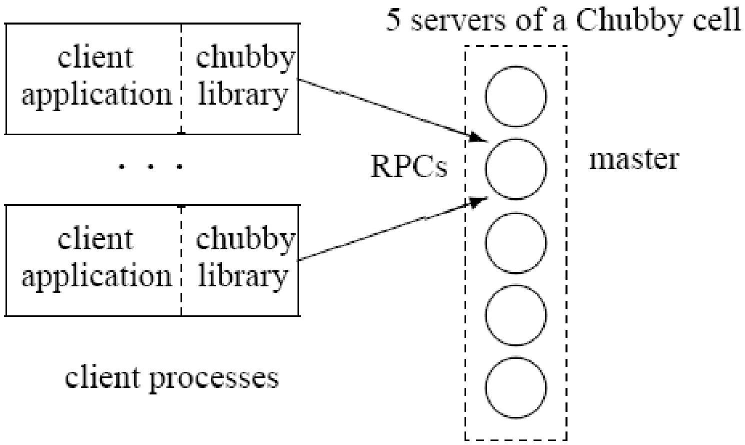
(b) If *n* greater than that of any *prepare* request to which it has already responded, then (1) respond with the highest-numbered proposal (if any) it has accepted, (2) do not accept any proposal numbered less than *n*.

(a) If majority response received, then send *accept* request for proposal [*v*,*n*] where *v* is the value of the highest-number proposal among the responses or any value it chooses.

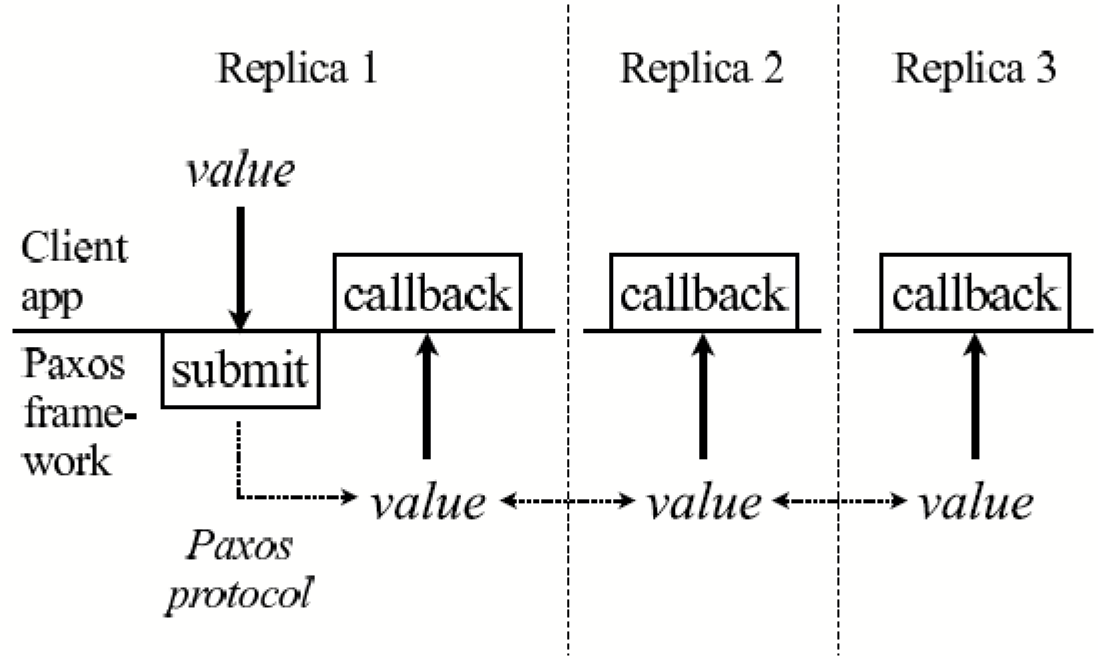
(b) Accept the proposal in the *accept* request unless it has already responded to a prepare request having a higher number.

Chubby – applying Paxos

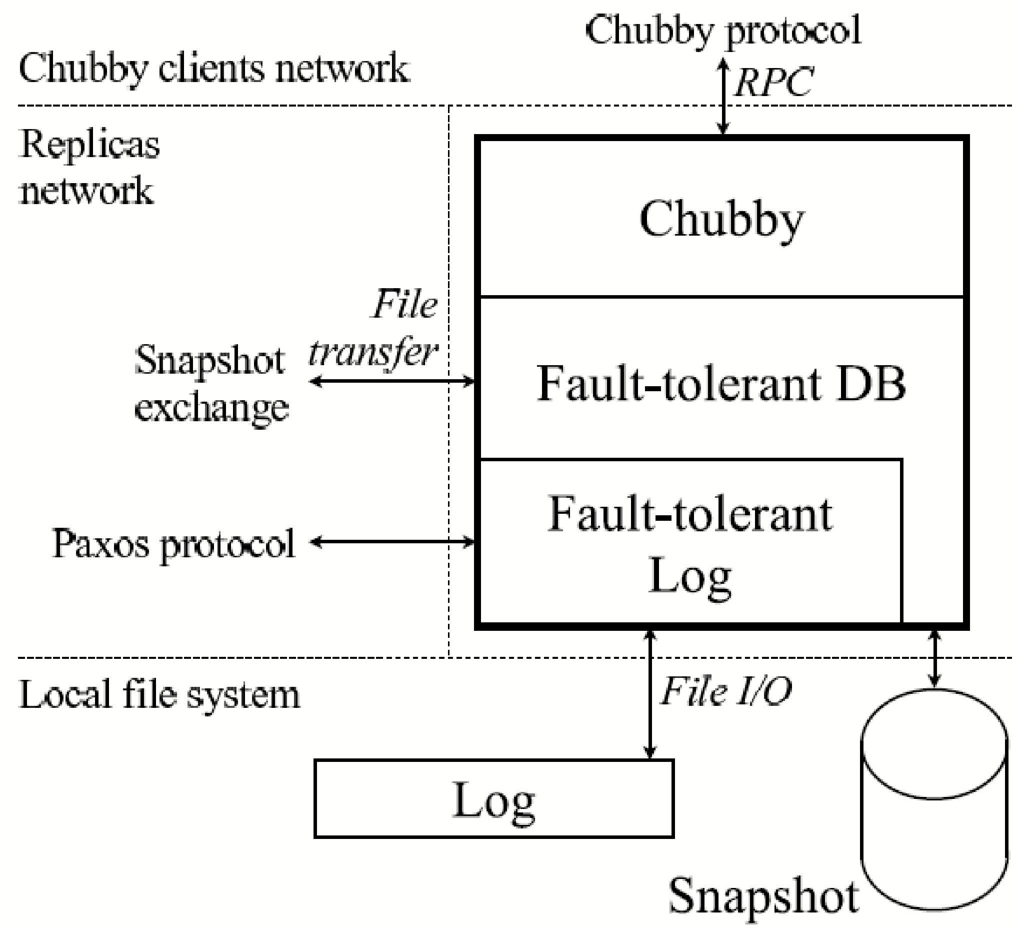
- A high-availability lock service
- Stores small files for applications having elected primary servers to advertise their existence and parameters
- Based on replicated architecture with elected master
- Used by GFS, Bigtable



Chubby – Paxos framework



Chubby – Replica Architecture


Chubby protocol
RPC
Chubby clients network
Replicas
network
Chubby
File
transfer
Snapshot
exchange
Fault-tolerant DB
Fault-tolerant
Log
Paxos protocol
Local file system
File I/O
Log
Snapshot