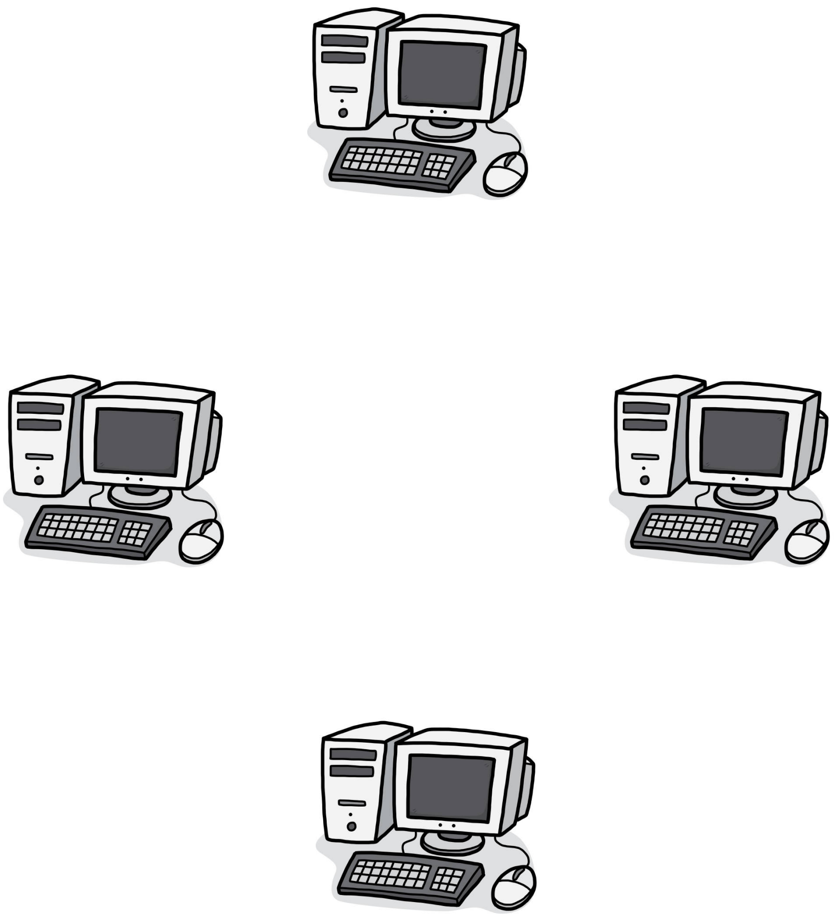
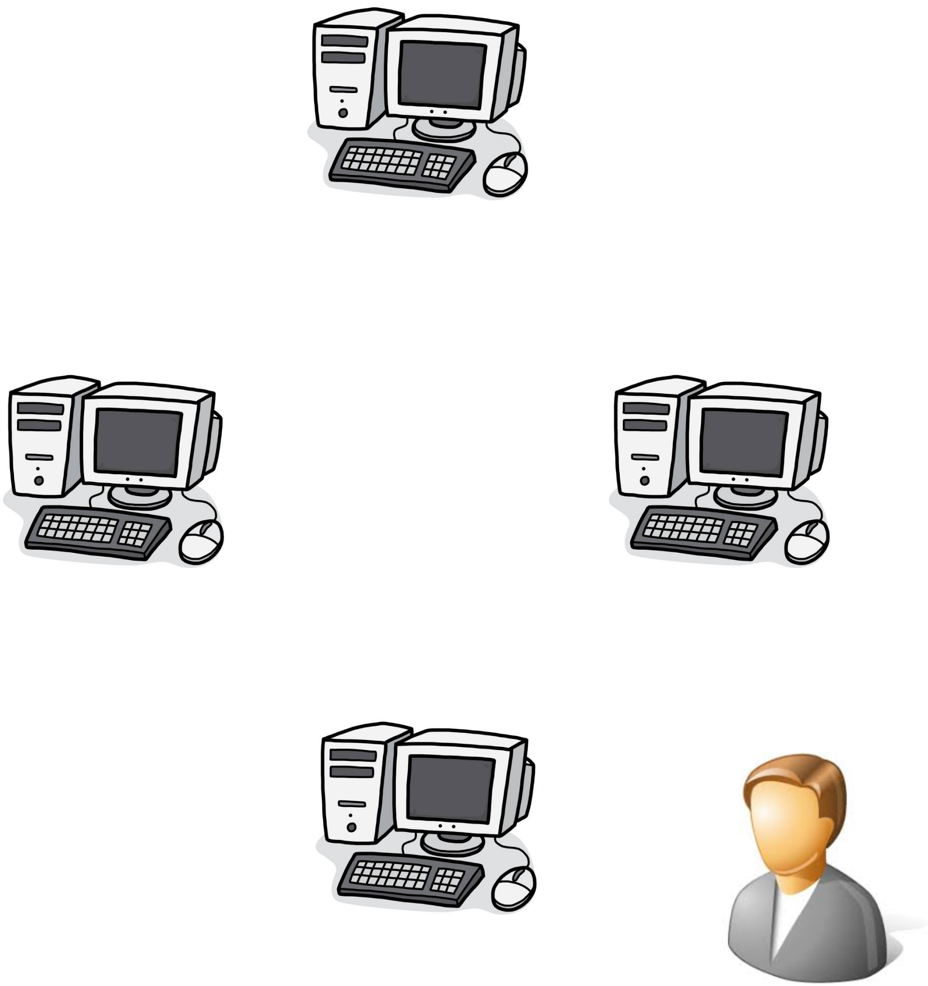
PBFT

Murat Osmanoglu

Practical Byzantine Fault Tolerance



Practical Byzantine Fault Tolerance



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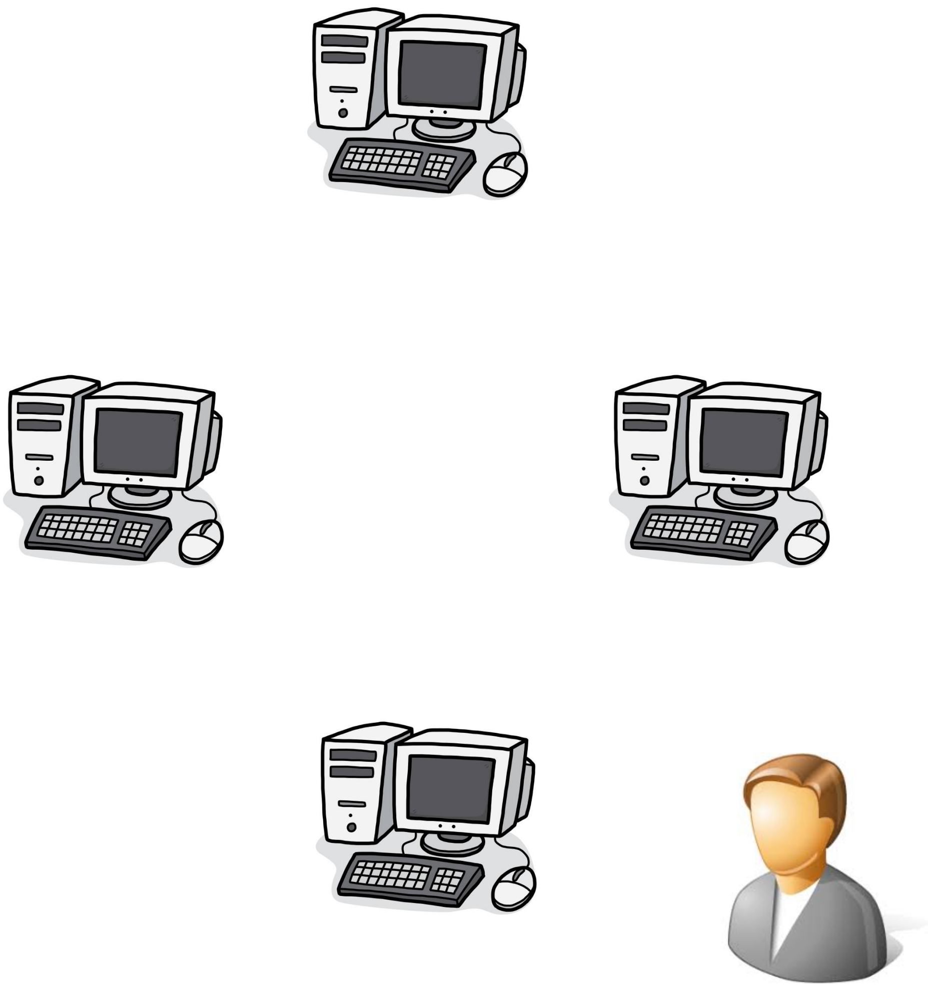

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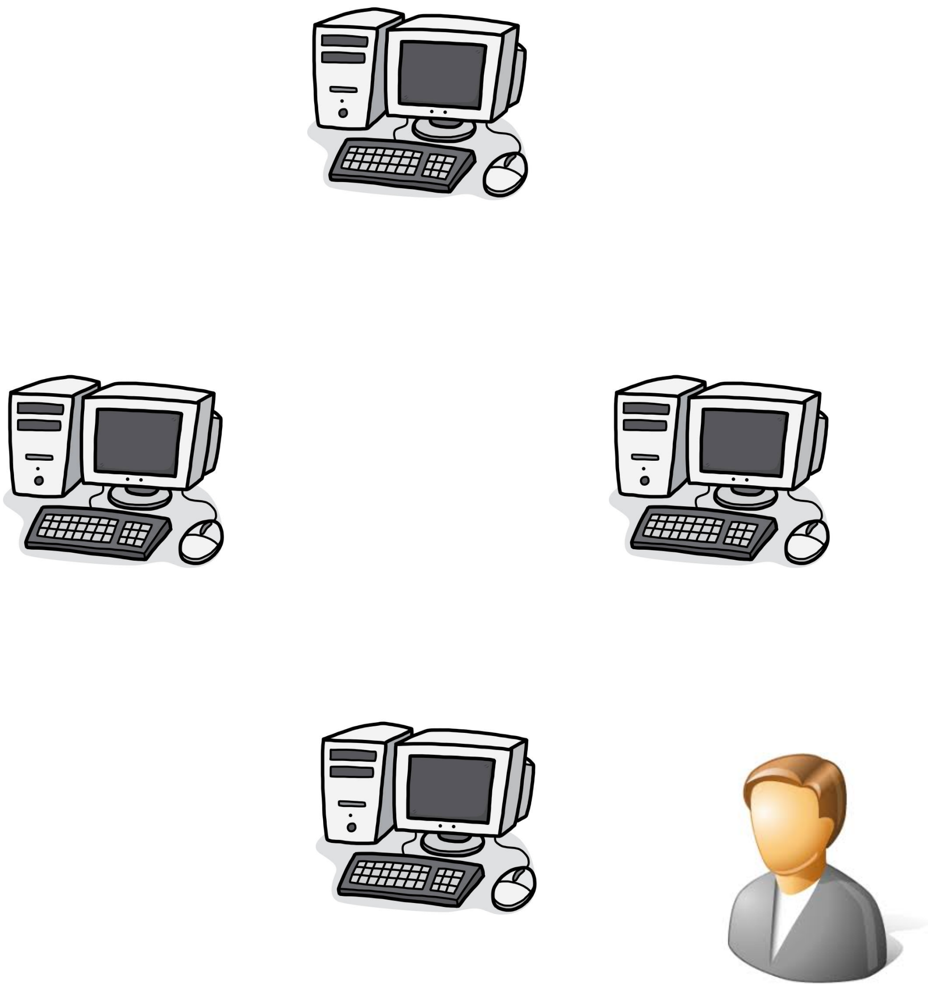

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- service is modeled as a state machine that is replicated across different nodes in a distributed system

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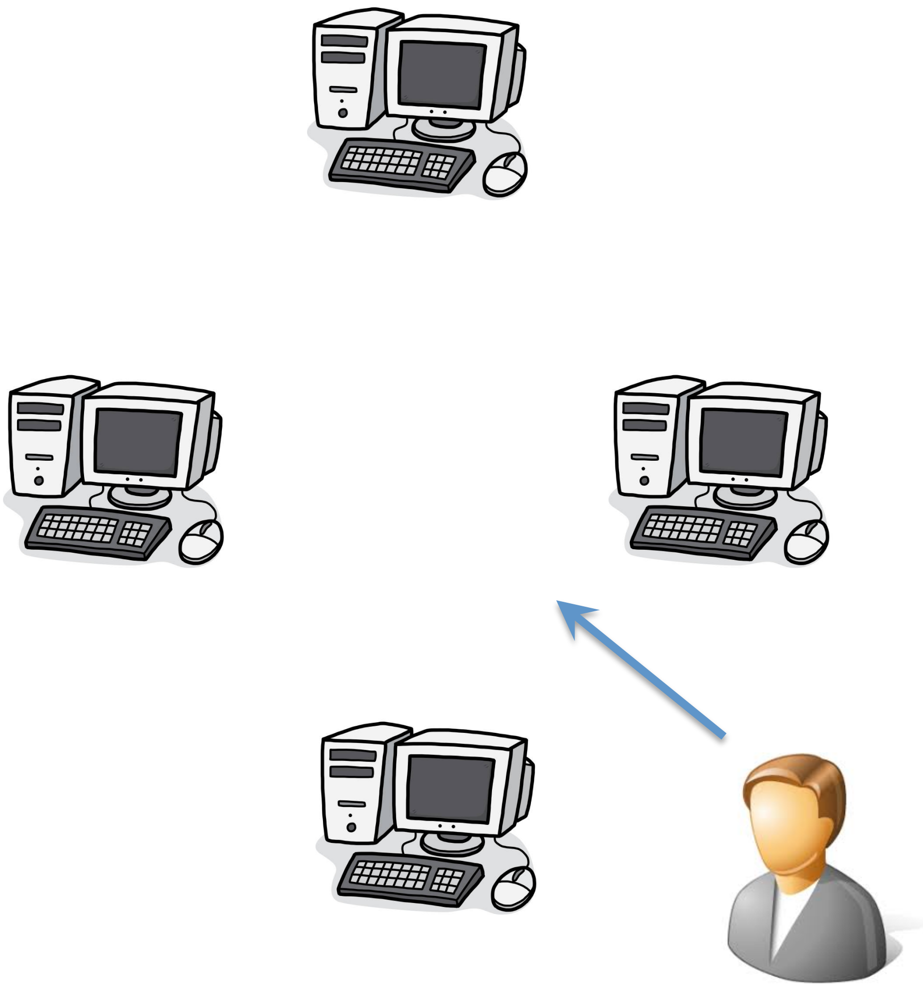

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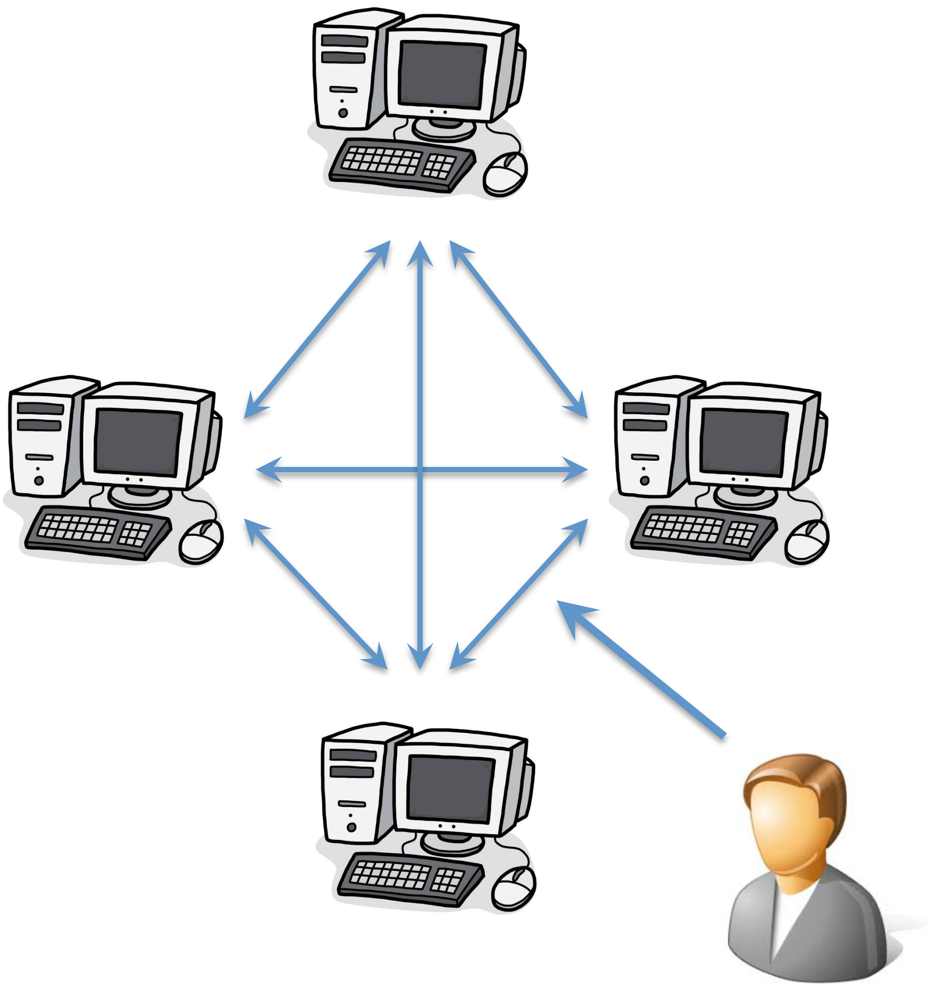

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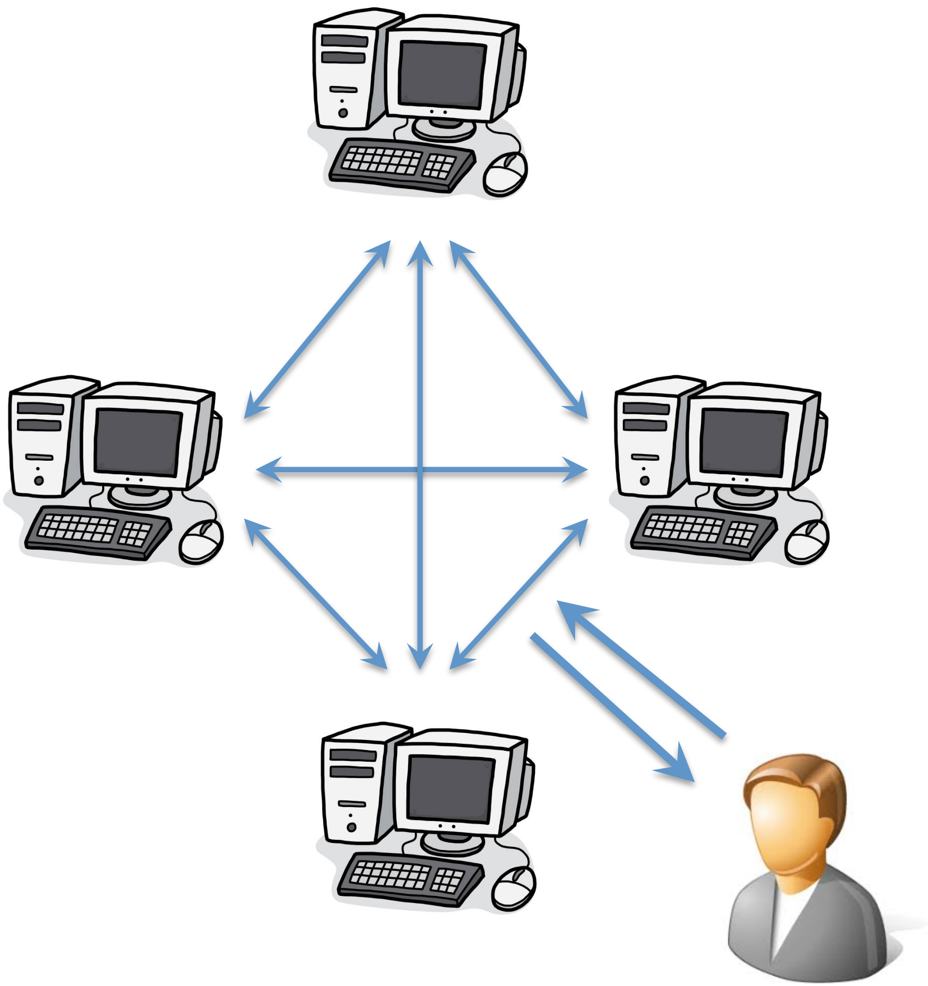

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Practical Byzantine Fault Tolerance

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    delay(t) is the time between the moment t when a message is sent for the first time and the moment when it is received by its destination

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- the replicas move through a succession of configuration called views
- In a view, one replica will be the primary and the others are backups
- the primary of a view will be the replica p such that

$$p = v \bmod |R|$$

where v is the view number

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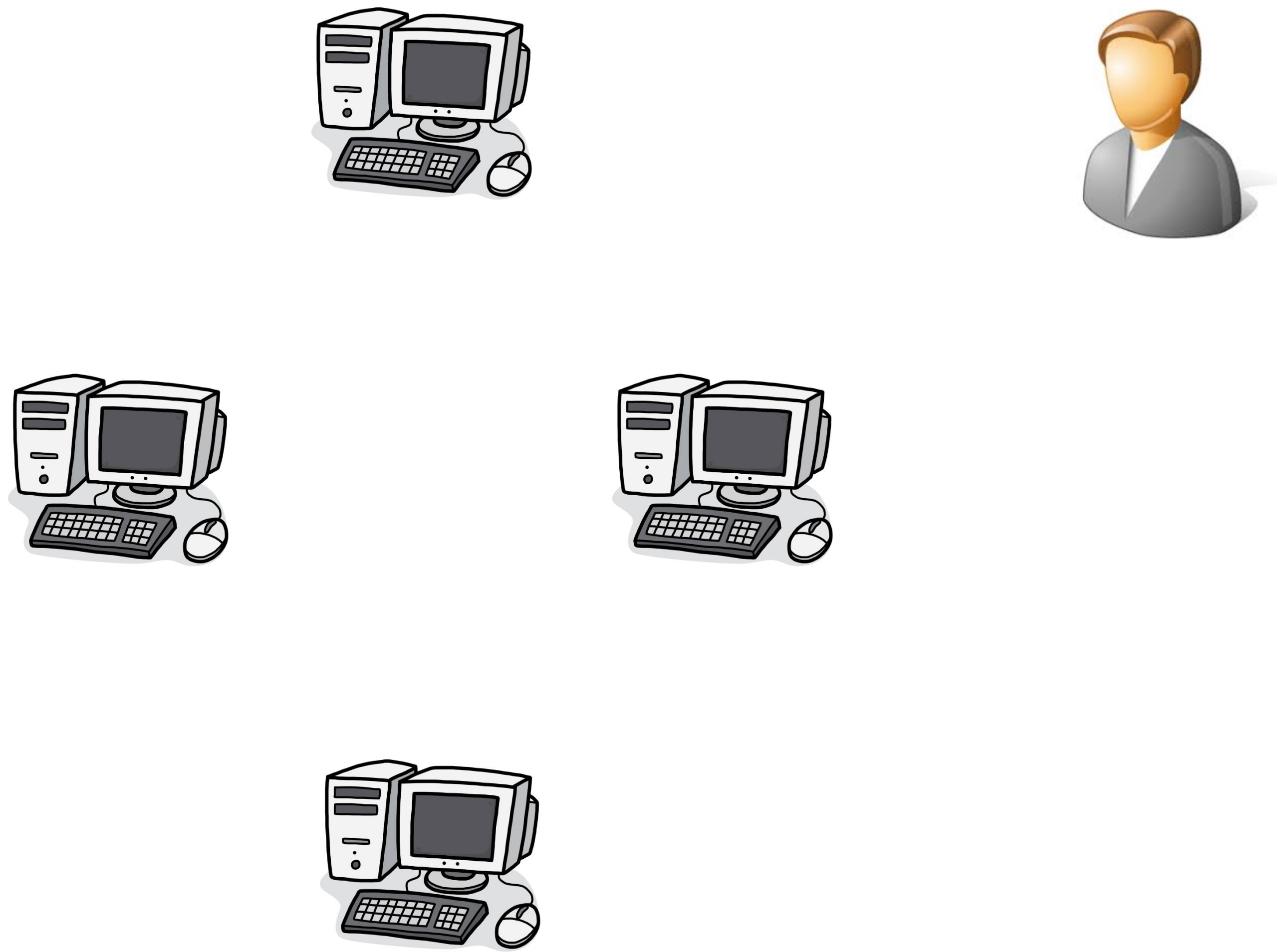

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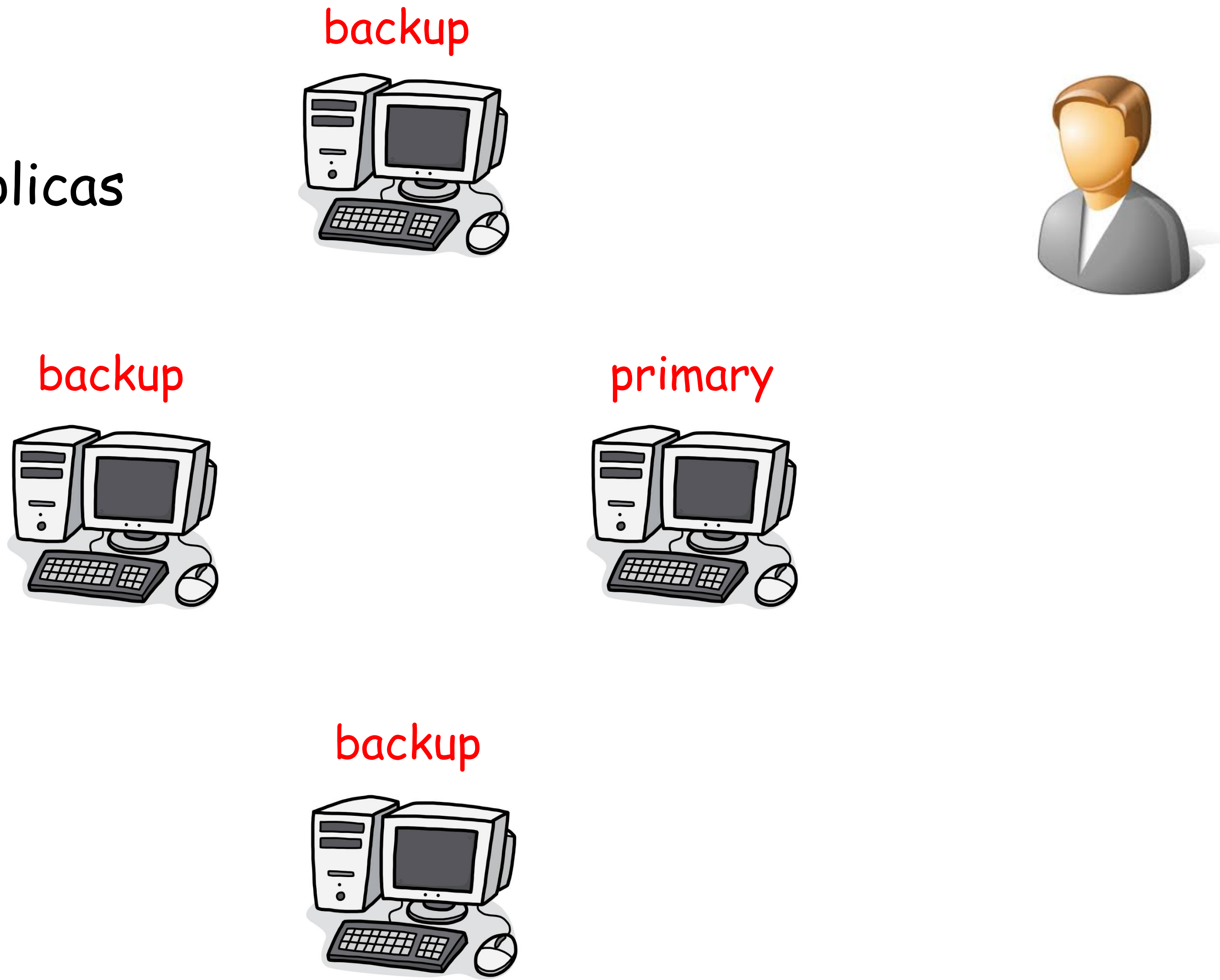

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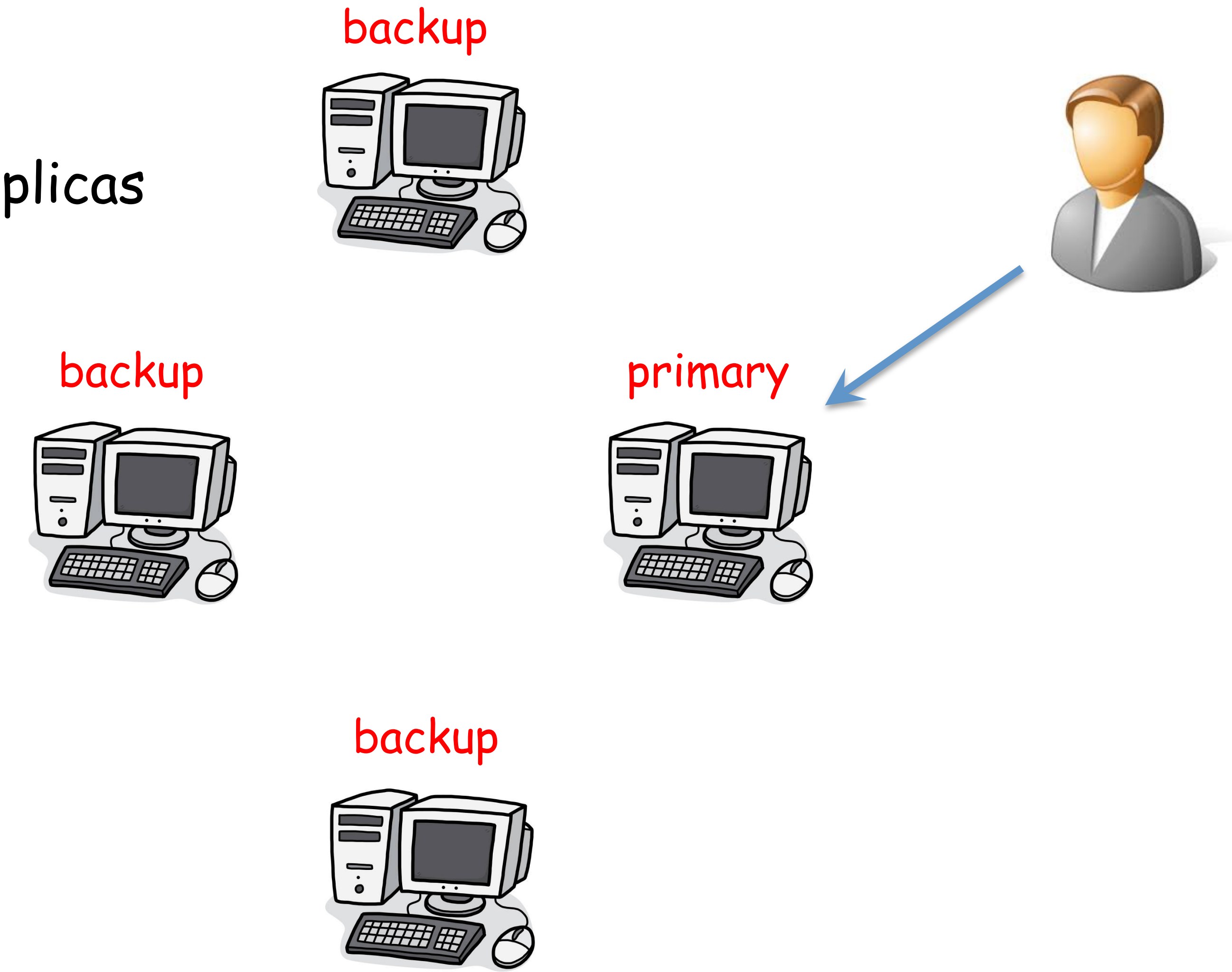

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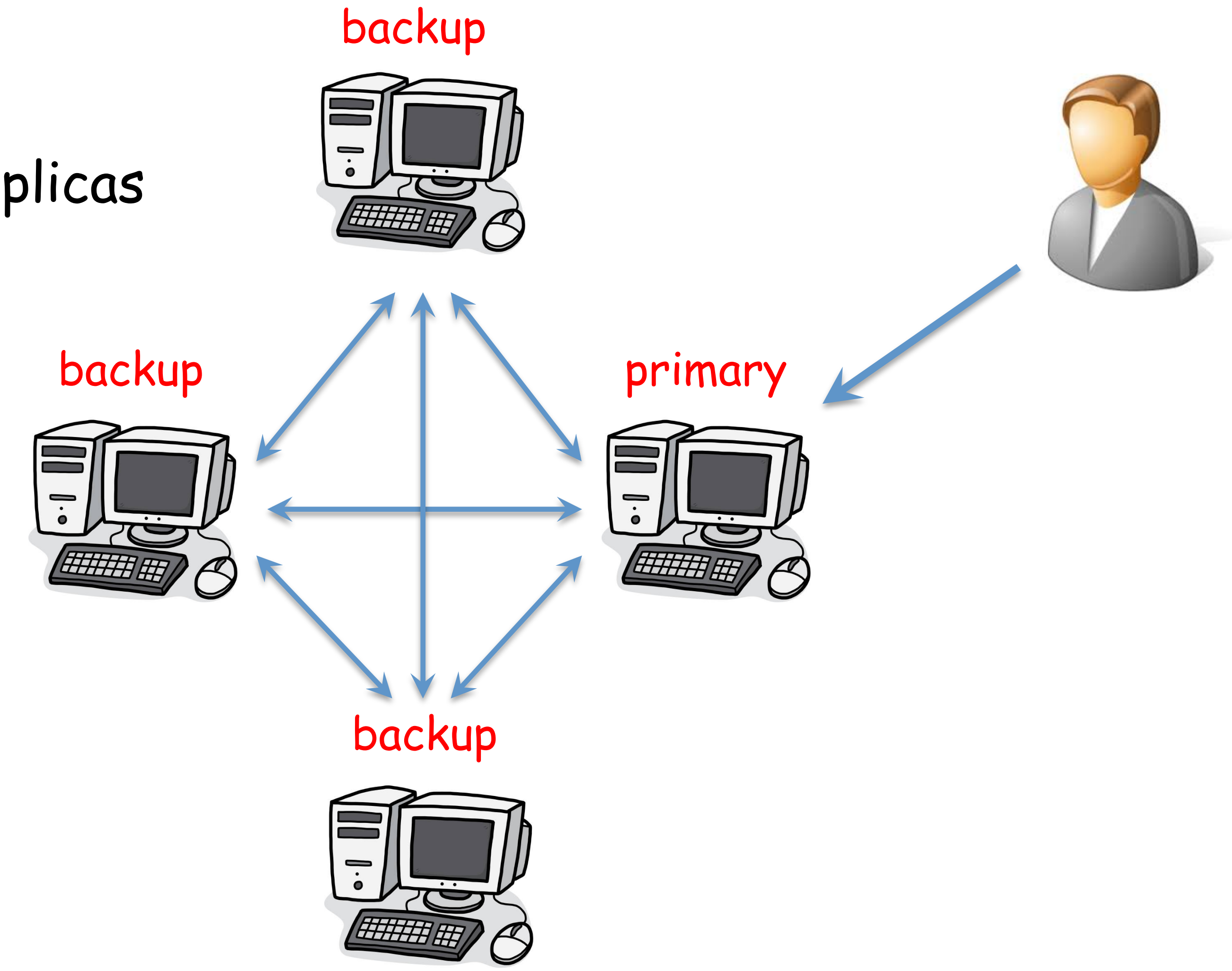

Practical Byzantine Fault Tolerance

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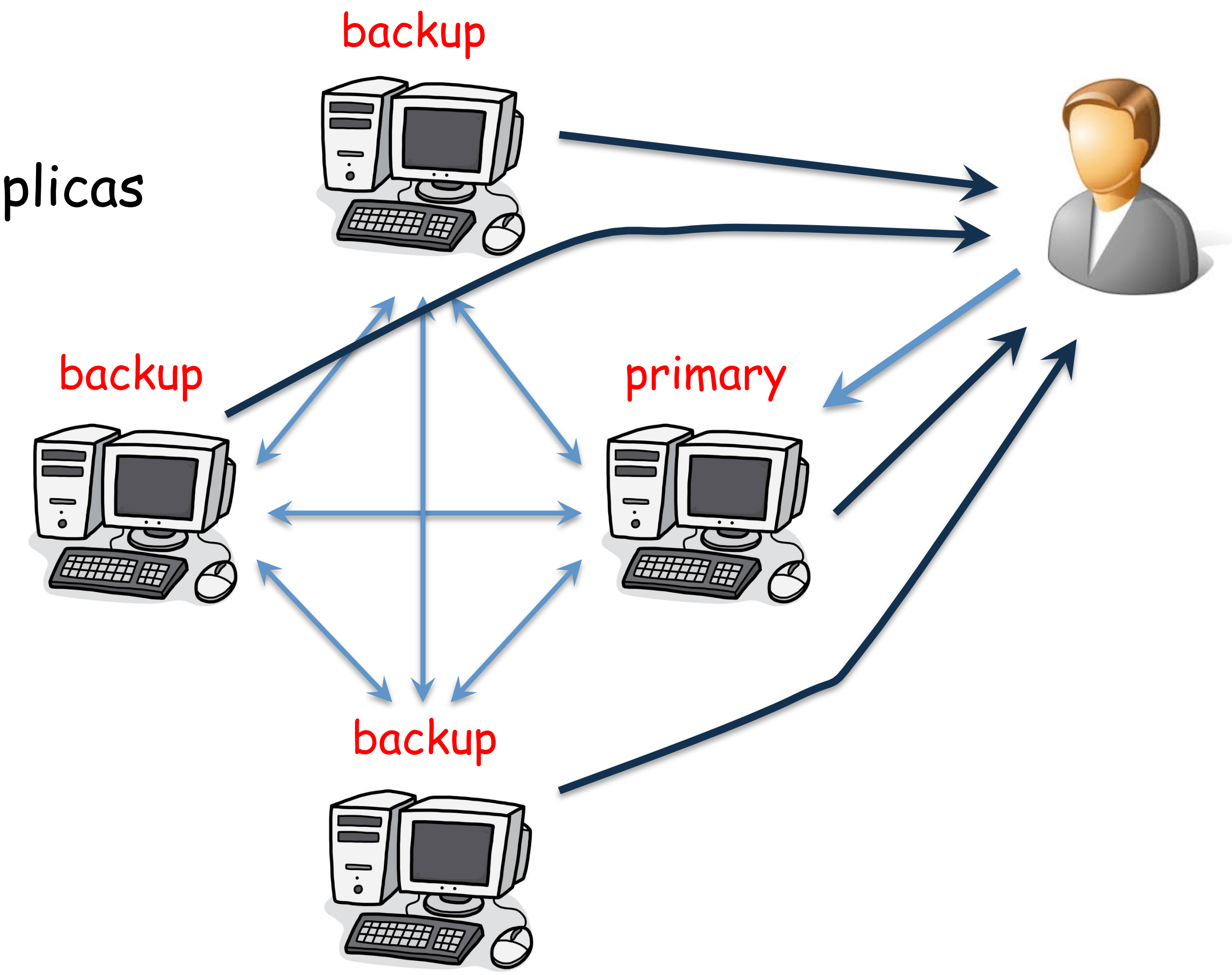

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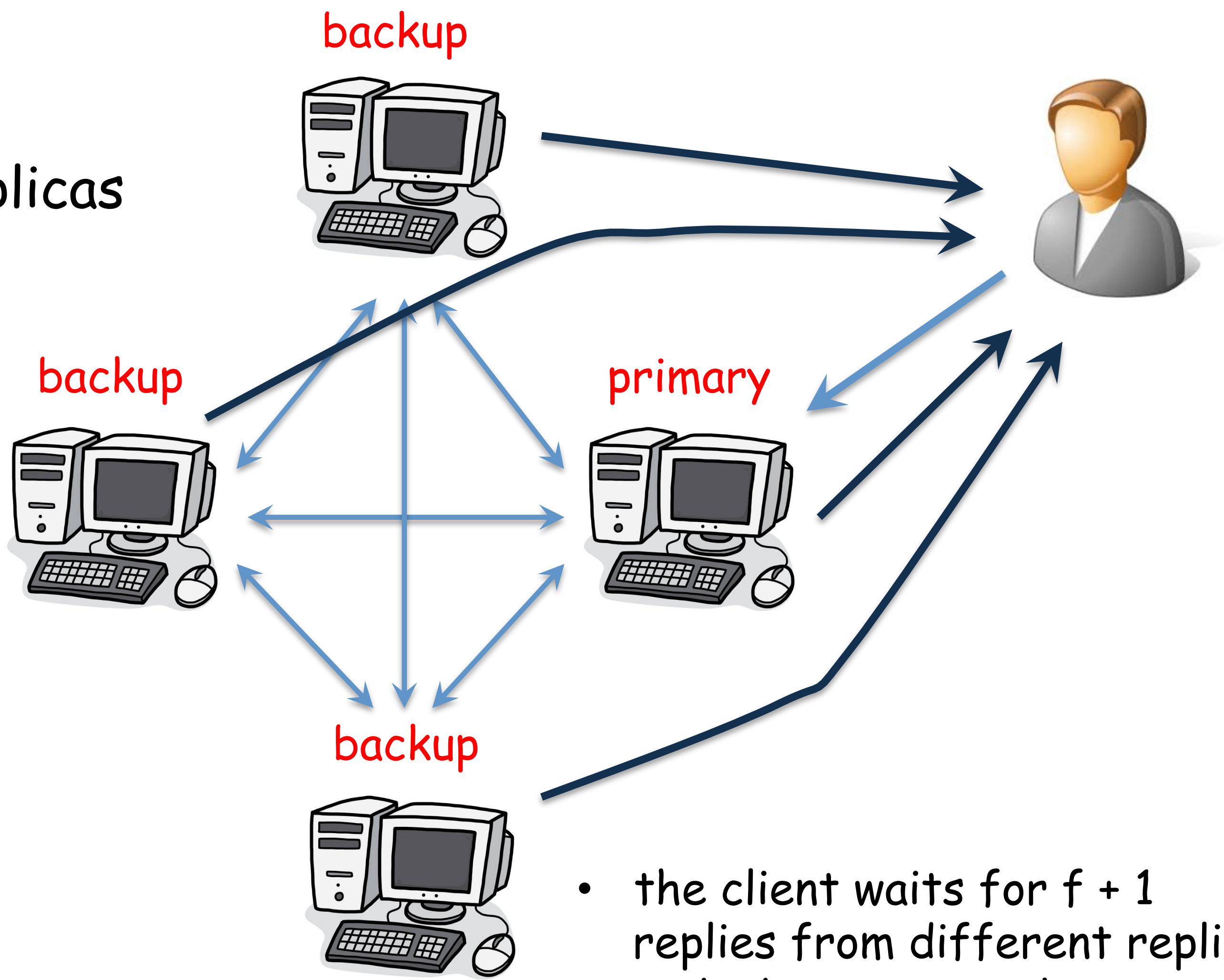

- the client waits for f + 1 replies from different replicas with the same result

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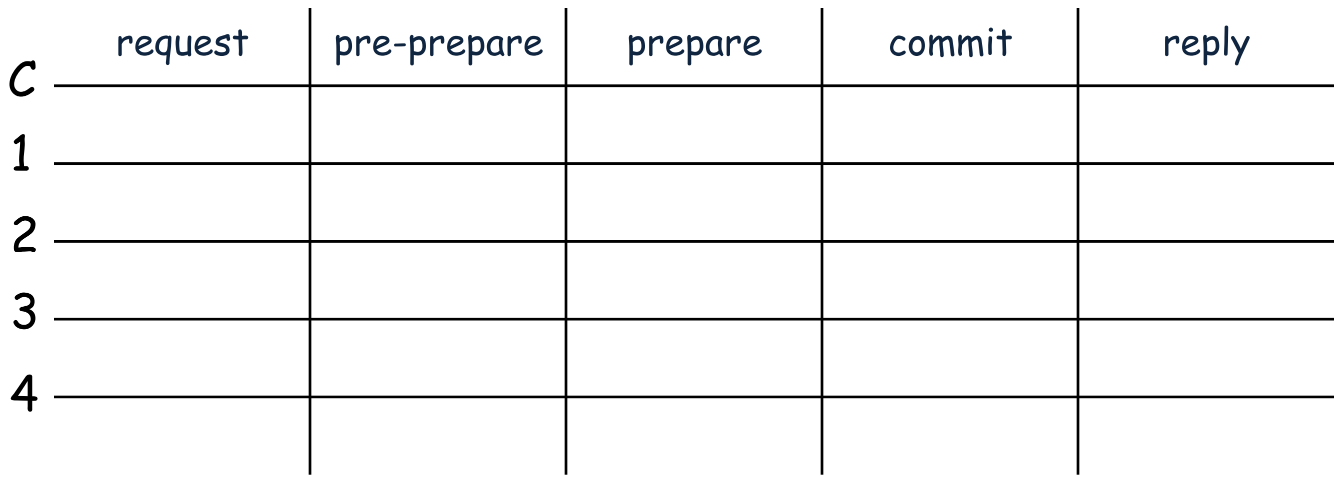

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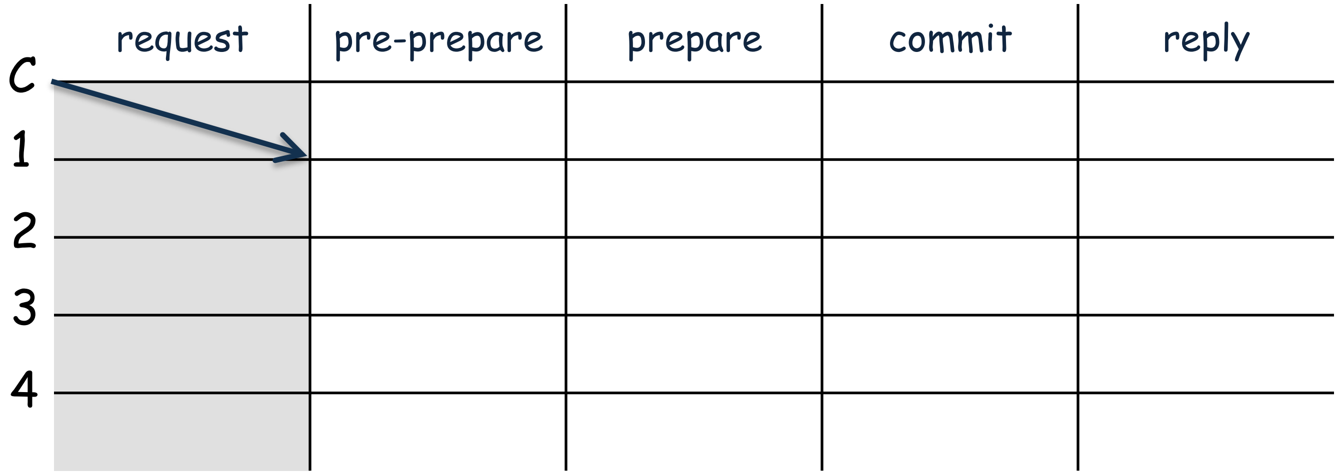

- client C requests the execution of state machine operation o by sending a [REQUEST, o, t, c]$_{SIG}$ message to the primary

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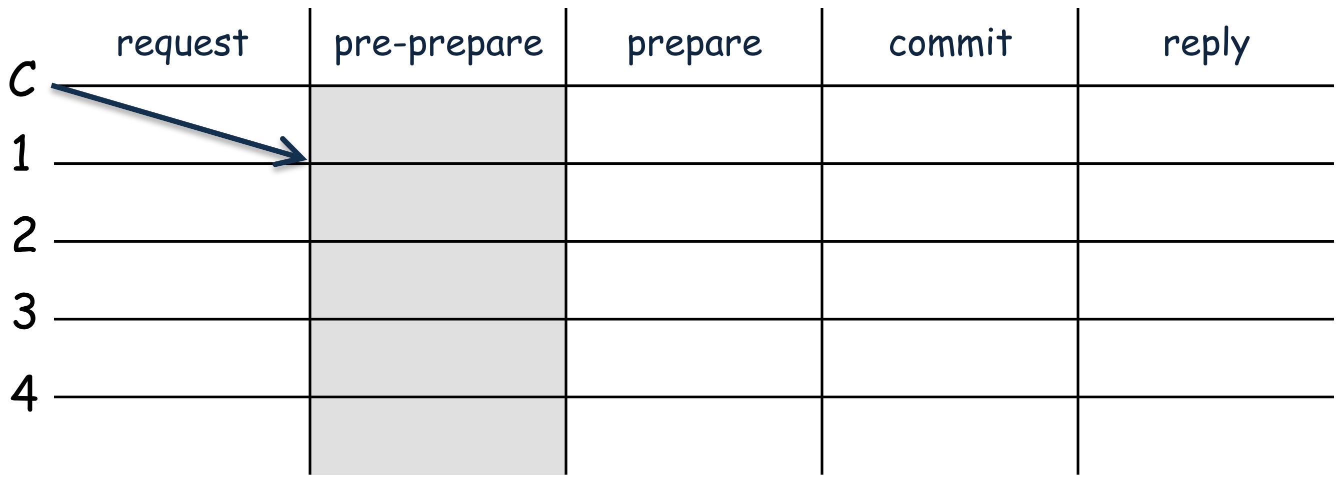

- After receiving a request message [REQUEST, o, t, c]$_{SIG}$ from a client, the primary assigns a sequence number n to the request,

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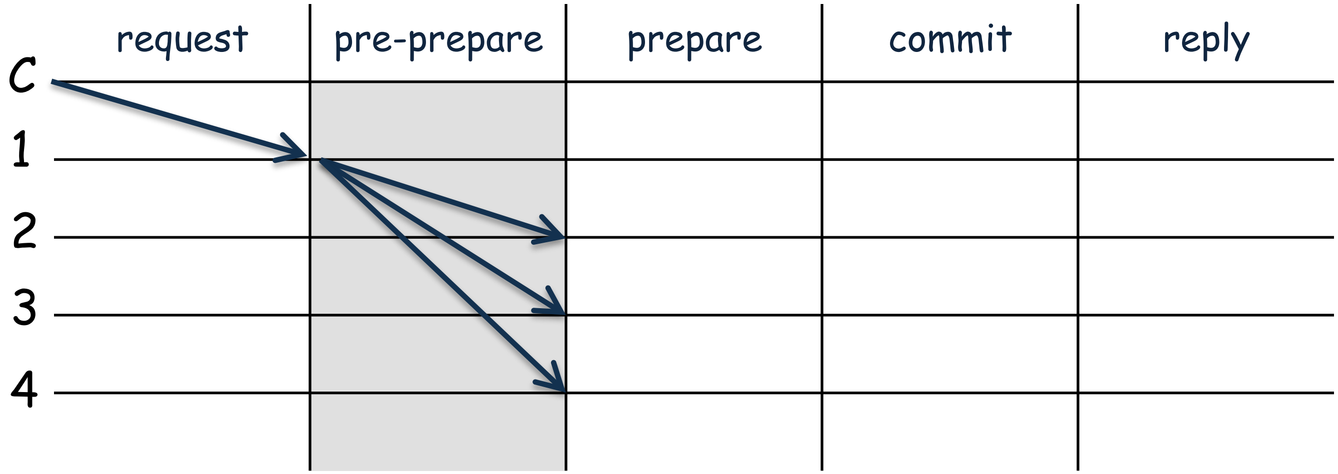
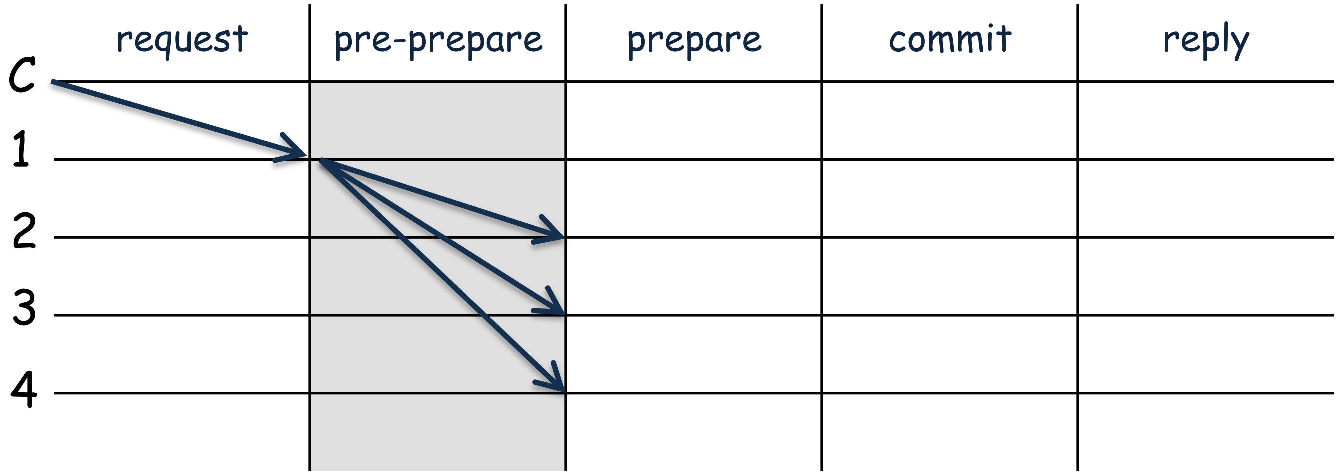


- After receiving a request message $[\text{REQUEST}, o, t, c]_{SIG}$ from a client, the primary assigns a sequence number n to the request, and broadcasts a pre-prepare message

  $$[[\text{PRE-PREPARE}, v, n, d]_{SIG}, m]$$

  to all backups and

Practical Byzantine Fault Tolerance



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  [[PRE-PREPARE, v, n, d]$_{SIG}$, m]

  to all backups and appends the message to its LOG where m is the client's request and d is the digest of m

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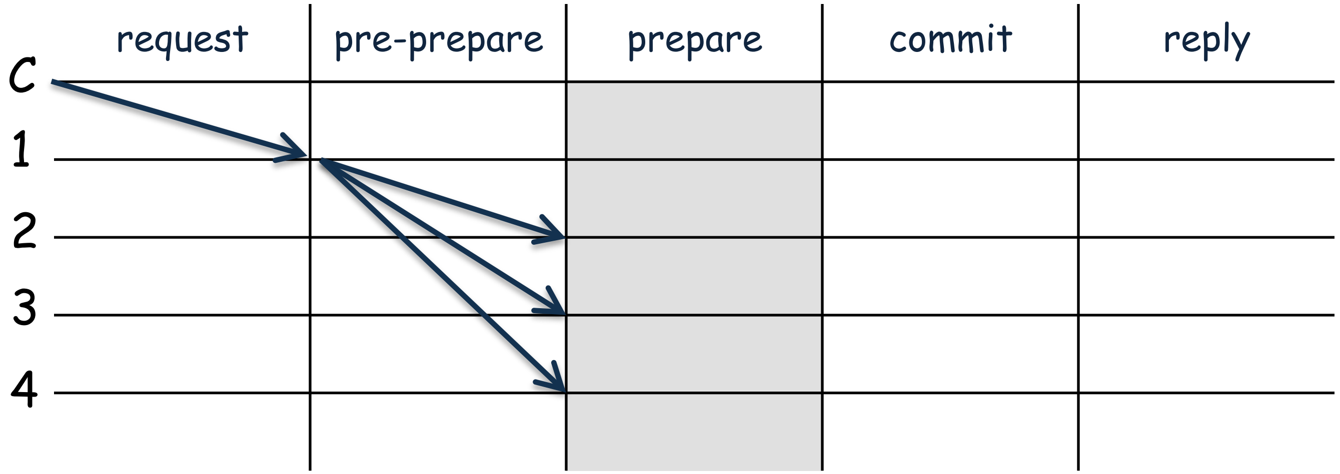

- A backup accepts [[PRE-PREPARE, v, n, d]$_{SIG}$, m] if

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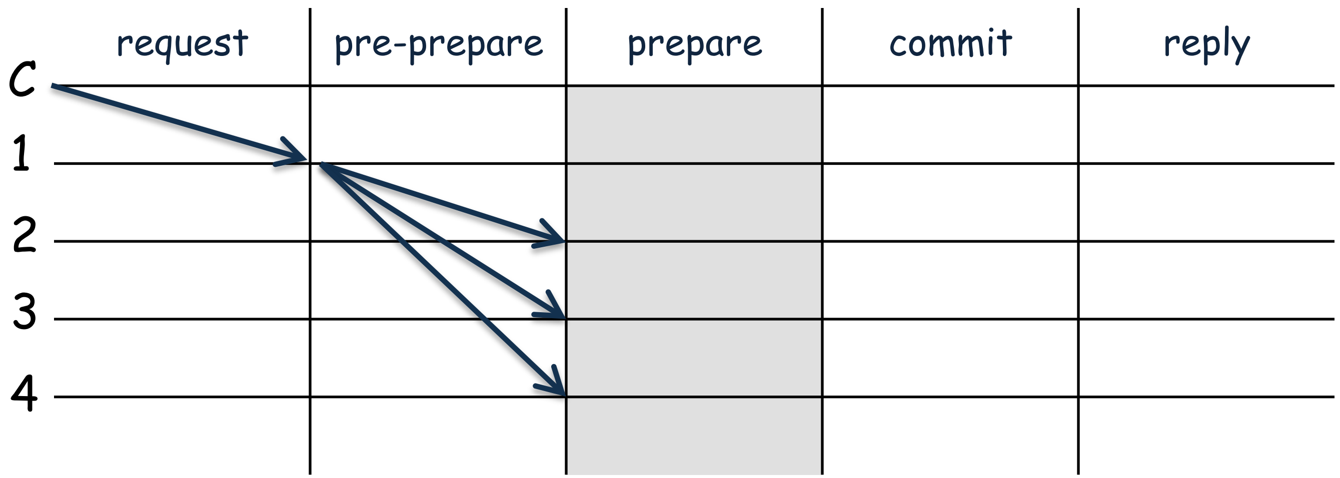

- A backup accepts [[PRE-PREPARE, v, n, d]$_{SIG}$, m] if
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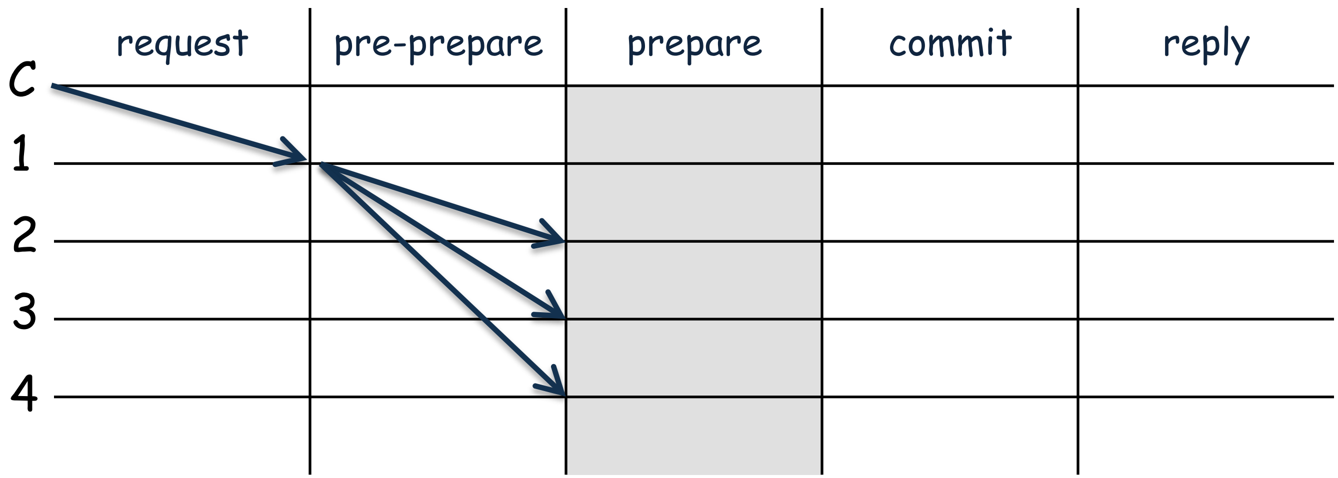

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  - it is in view v

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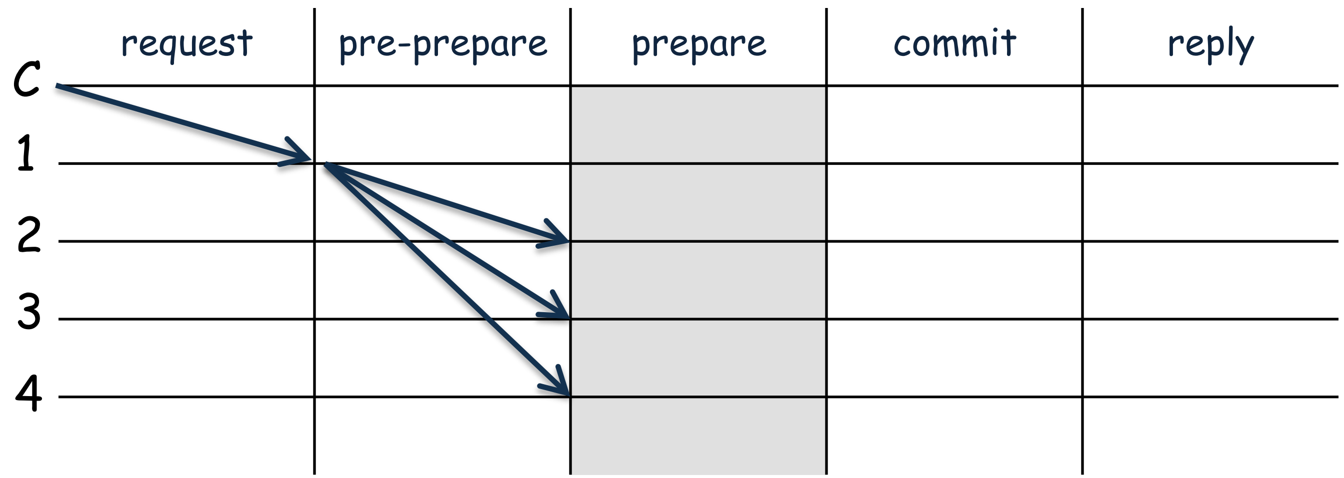

- A backup accepts [[PRE-PREPARE, v, n, d]$_{SIG}$, m] if
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  - it has not accepted a pre-prepare message for view v and sequence number n containing a different digest

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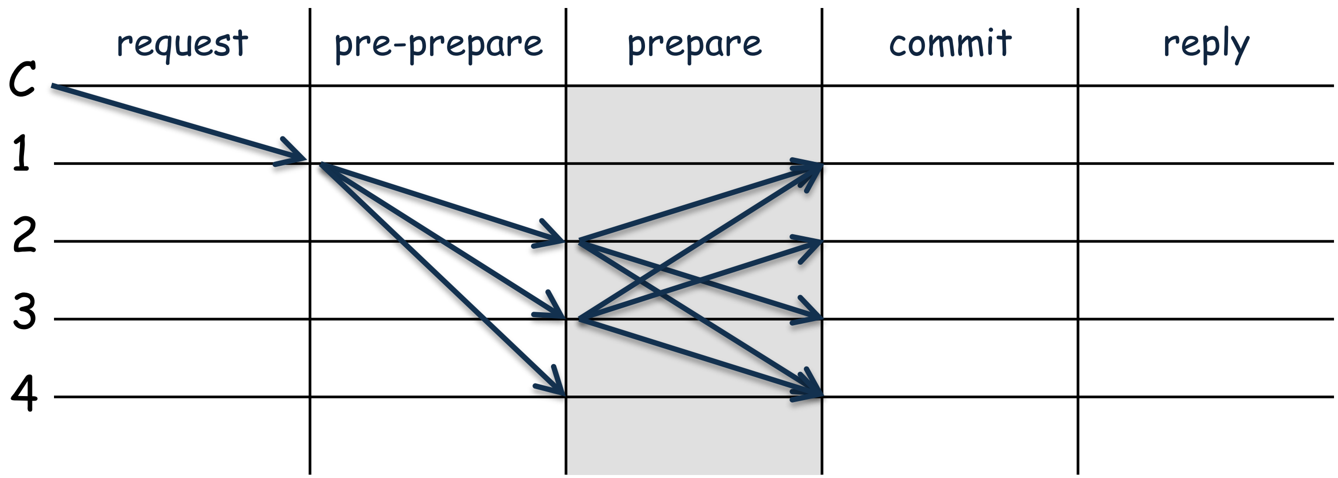

- If backup i accepts [[PRE-PREPARE, v, n, d]$_{SIG}$, m], it broadcasts a prepare message

  [PREPARE, v, n, d, i]$_{SIG\text{-}i}$

  to all other replicas and

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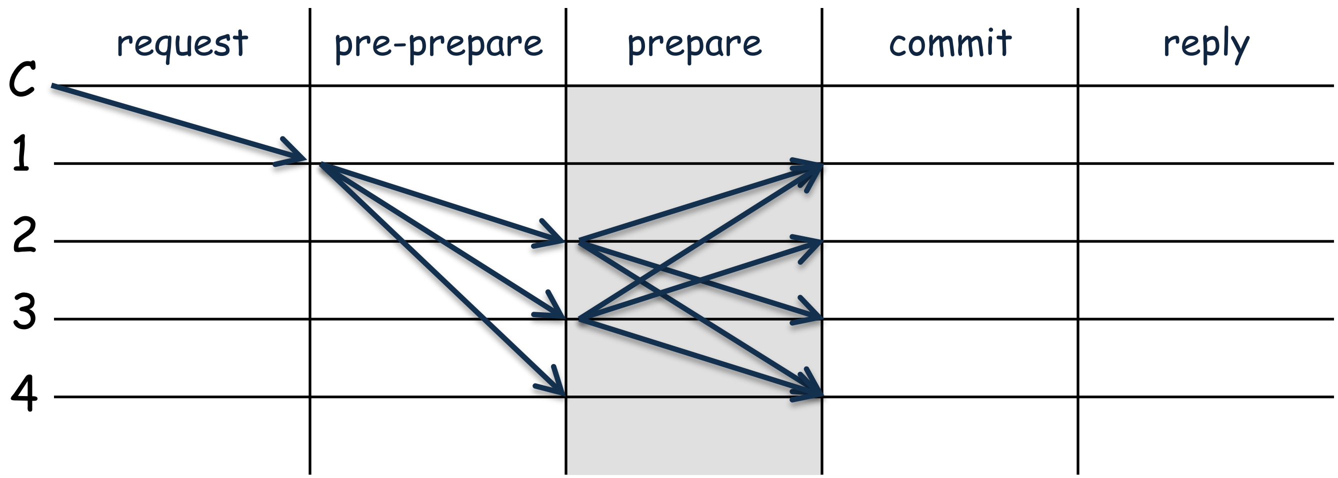

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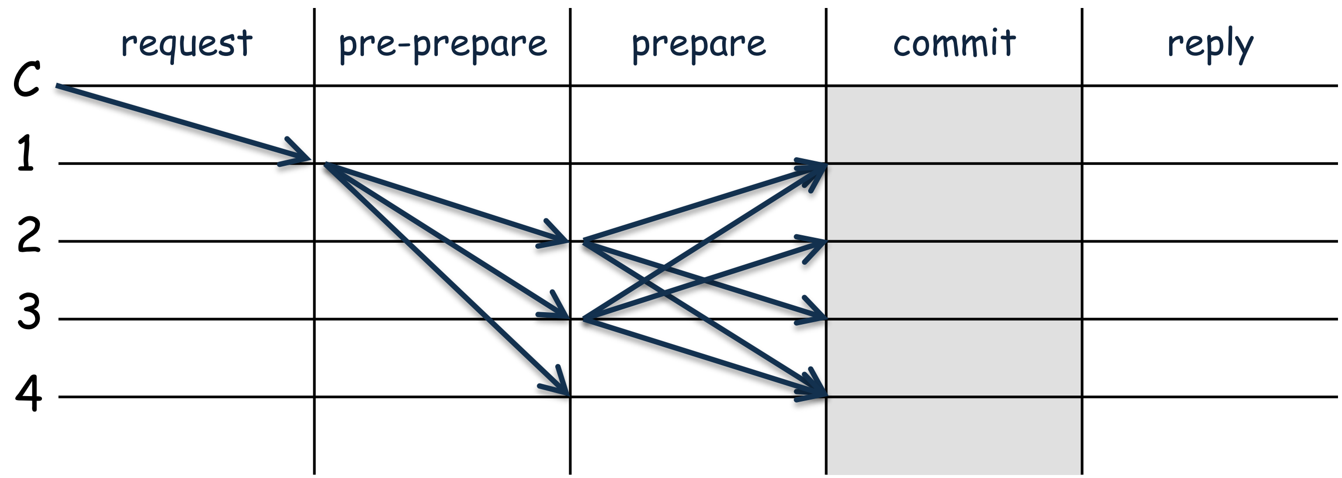

- A backup accepts [PREPARE, v, n, d, i]$_{SIG\text{-}i}$ if
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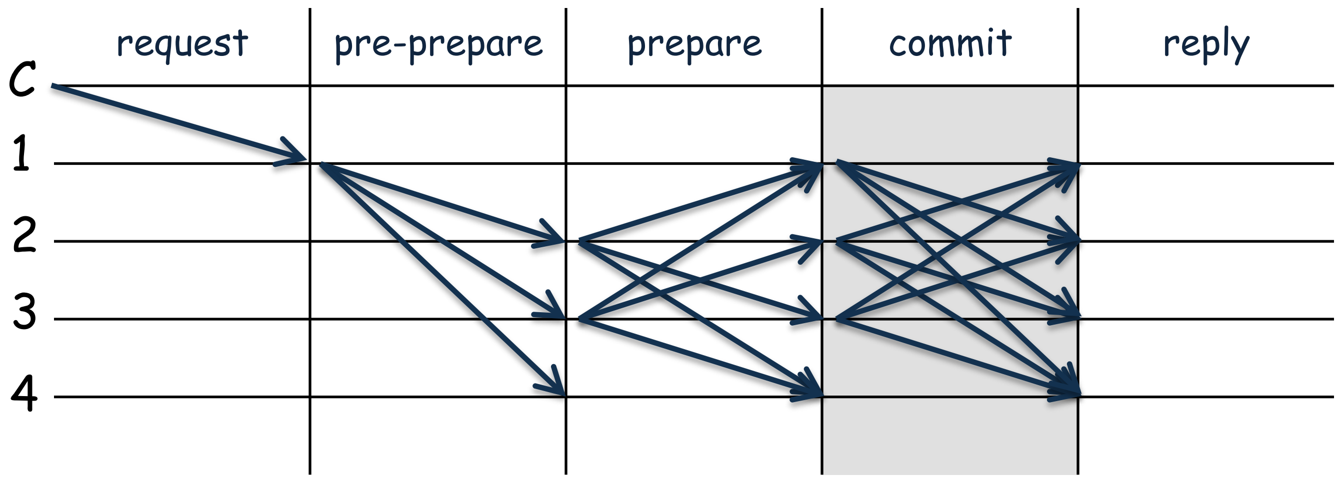

- If 2f prepares message from different backups that match the pre-prepare of the backup i holds, the backup i broadcasts a commit message

$$[\text{COMMIT}, v, n, d, i]_{SIG\text{-}i}$$

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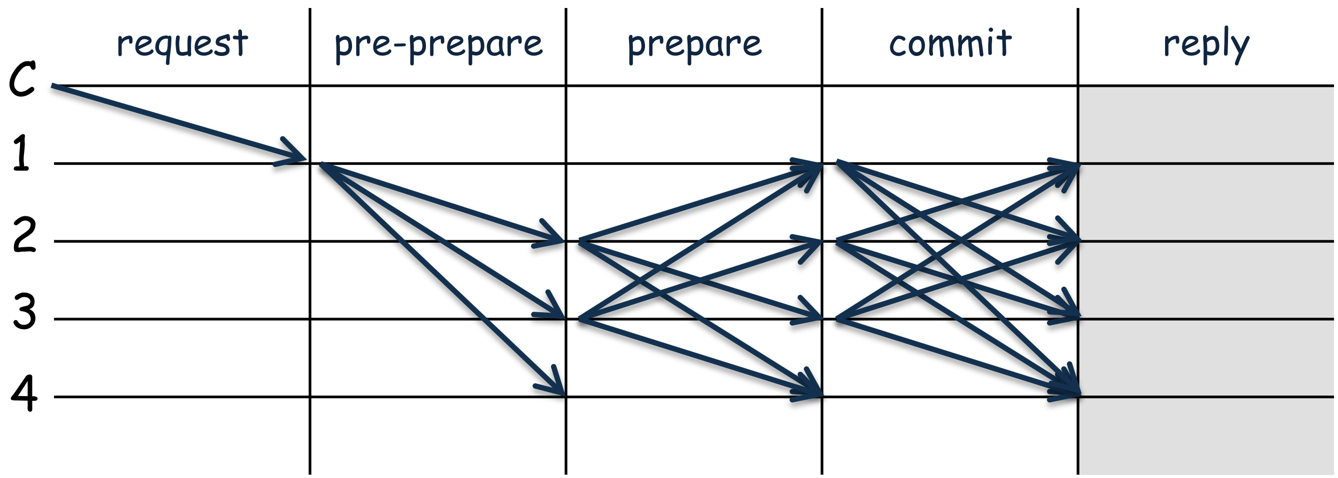

- A backup accepts [COMMIT, v, n, d, i]$_{SIG-i}$ if
  - the signature in Commit is valid
  - the view number v is equal the current view number
  - it has not accepted a commit message for view v and sequence number n containing a different digest
- Backups append commit messages to its LOG after accepting it

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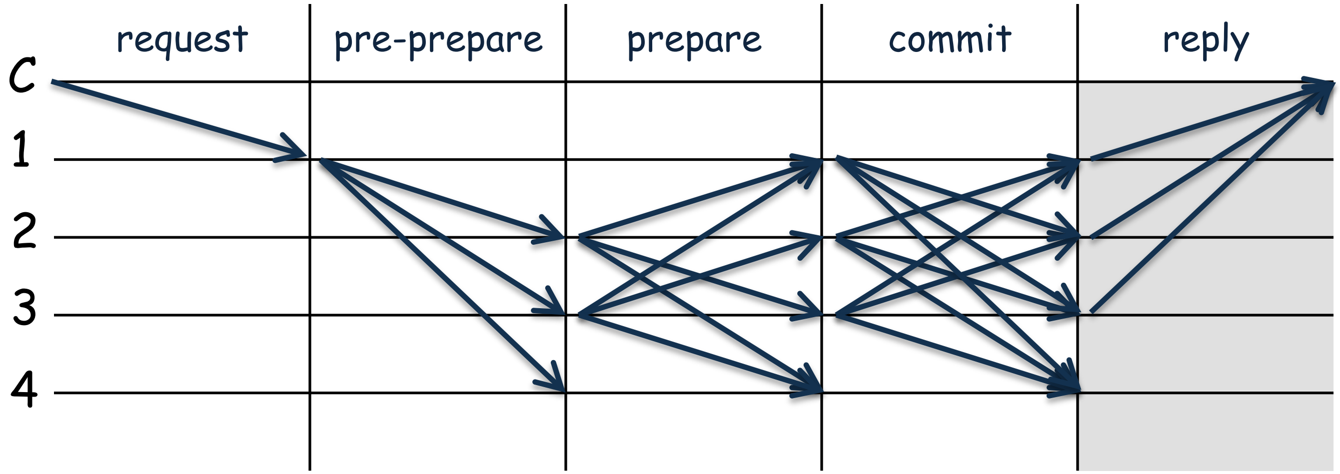

- If 2f commit messages from different backups that match the pre-prepare of the backup i holds, the backup i sends a reply message

$$[\text{REPLY}, v, t, c, r, i]_{SIG\text{-}i}$$

where v is the current view, t is the timestamp of the corresponding request, i is the replica number, r is the result

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- when a replica i produces a checkpoint, it broadcasts a message [CHECKPOINT, n, d, i]$_{SIG-i}$ to other replicas where d is the digest of the state

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- each replica collects checkpoint messages in its LOG until it has 2f + 1 of them (proof for checkpoint)

- a checkpoint with a proof becomes stable and replica discards all pre-prepare, prepare, and commit messages with sequence number less than or equal to n from its LOG, and also discards all earlier checkpoints and checkpoint messages

Practical Byzantine Fault Tolerance

View Changes(Liveness)

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  - each P_m contains a valid pre-prepare message and 2f matching prepare message

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$$[\text{NEW-VIEW}, v + 1, V, O]_{SIG\text{-}p}$$

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- O is a set of pre-prepare messages

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$[PREPARE, v, n, d_1, i]_{SIG\text{-}i}$

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f faulty nodes

$3f < 3f + 1$

Practical Byzantine Fault Tolerance

Why 2f + 1 (Safety)?

f + 1 messages as

[PREPARE, v, n, d_1, i]$_{SIG\text{-}i}$

f + 1 messages as

[PREPARE, v, n, d_2, i]$_{SIG\text{-}i}$

f faulty nodes

$3f + 2 > 3f + 1$