Two-phase commit

Setting

Atomic update to data stored in multiple locations

- Ex: Multikey update to a sharded key-value store
- Ex: Bank transfer
- Ex: Calendar update for multi-person meeting

Data stores can fail (temporarily), or operation can fail

Implications of Two Generals

Cannot get agreement in a distributed system to perform some action at the same time.

Perform group of operations at some logical instant in time, not physical instant

- linearizable: after request start, before request end

Goals

Atomicity: all changes or none

Linearizability: multi-key operation appears to happen at some logical instant in time, consistent with real time

Availability: (next time)

Fast reads: (Spanner)

One Phase Commit?

Central coordinator decides, tells everyone else

What if some participants can't do the request?

- Bank account has zero balance
- Bank account doesn't exist, …

What if we want more throughput?

- Multiple coordinators can't decide unilaterally
- What if concurrent operations conflict?

Locks?

How do we get linearizability with multiple coordinators?

- Need to apply changes at same logical point in time
- Need all other changes to appear before/after

Acquire read/write lock on each location

What if some lock is busy?

- Wait? Could get into deadlock
- Give up and retry? Might fail again

Two Phase Commit

Central coordinator asks

- May be many coordinators, one per transaction

Participants commit to commit

- Acquire any locks
- In the meantime no other ops allowed on that key
- Delay other concurrent 2PC operations

Central coordinator decides, tells everyone else

- Release locks

Looks Like Caching with Leases?

Acquire shared/exclusive access to data

Perform ops to local data

Write result back to storage layer

What if servers can fail?

What if no node is trusted with data

- ex: transfer between two banks

Calendar event creation

Doug has three advisors (Tom, Zach, Mike)

Want to schedule a meeting with all of them

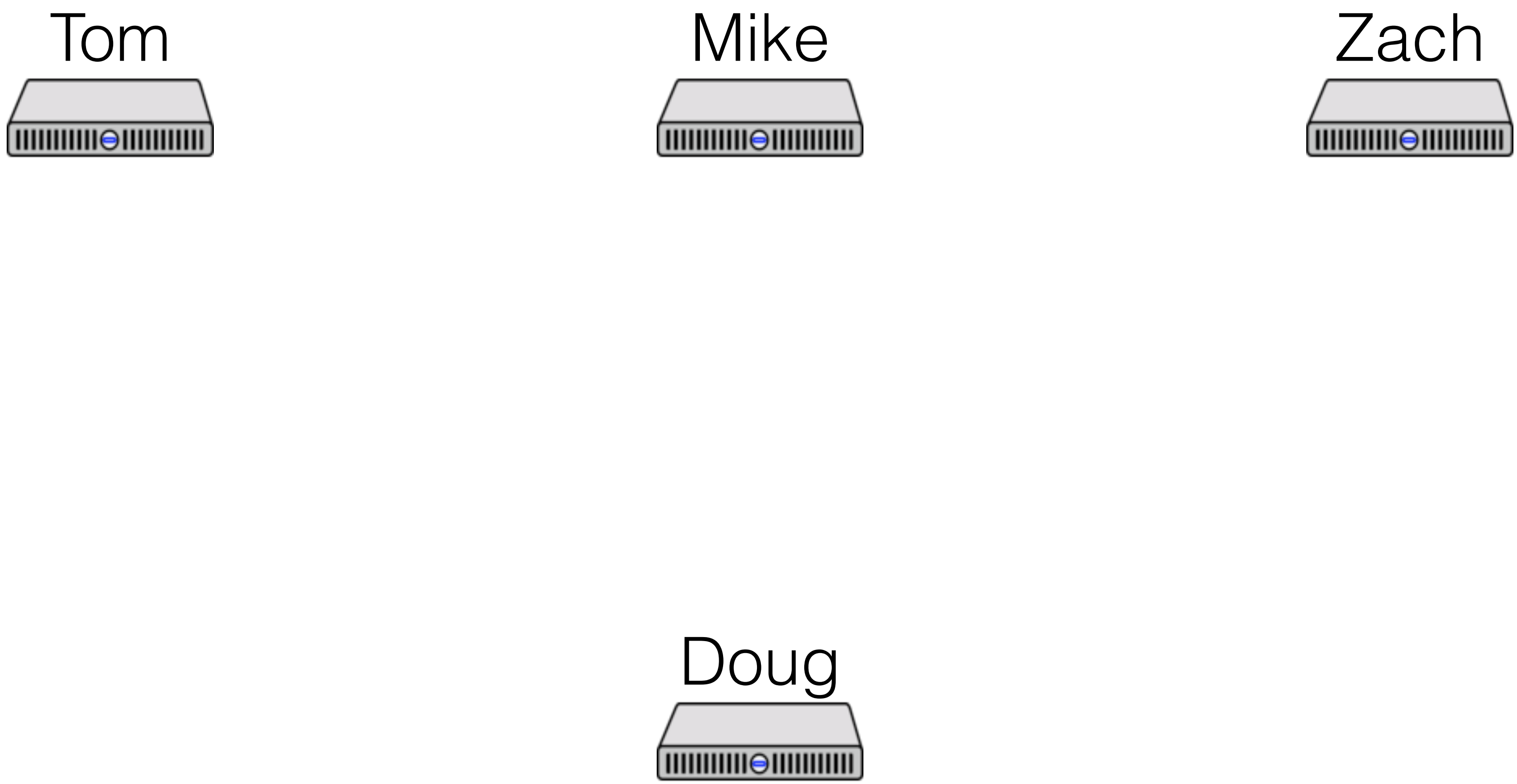
- Let's try Tues at 11, people are usually free then

Calendars all live on different nodes!

Other students also trying to schedule meetings

Nodes can fail, messages can be dropped (of course)

Calendar event creation (wrong)



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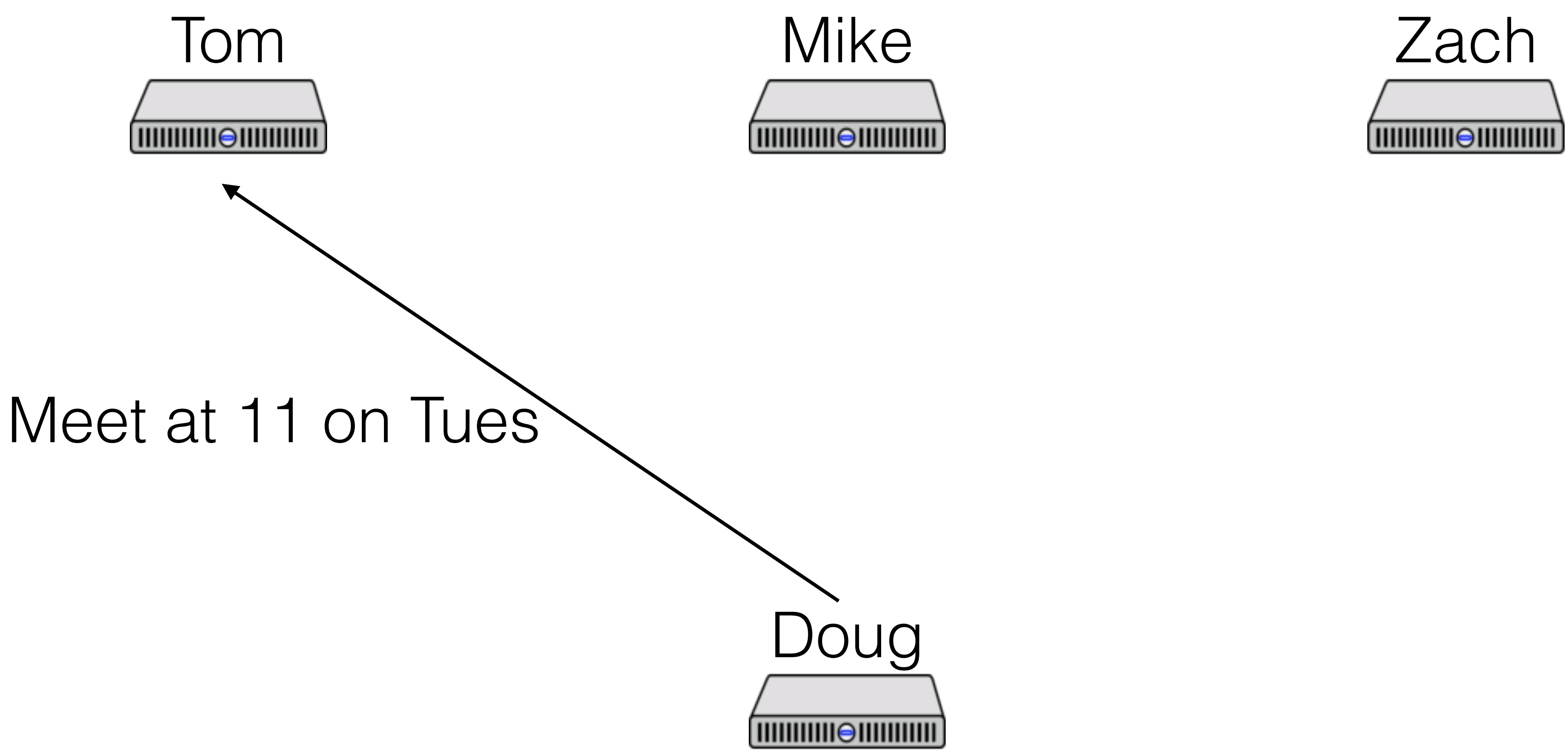

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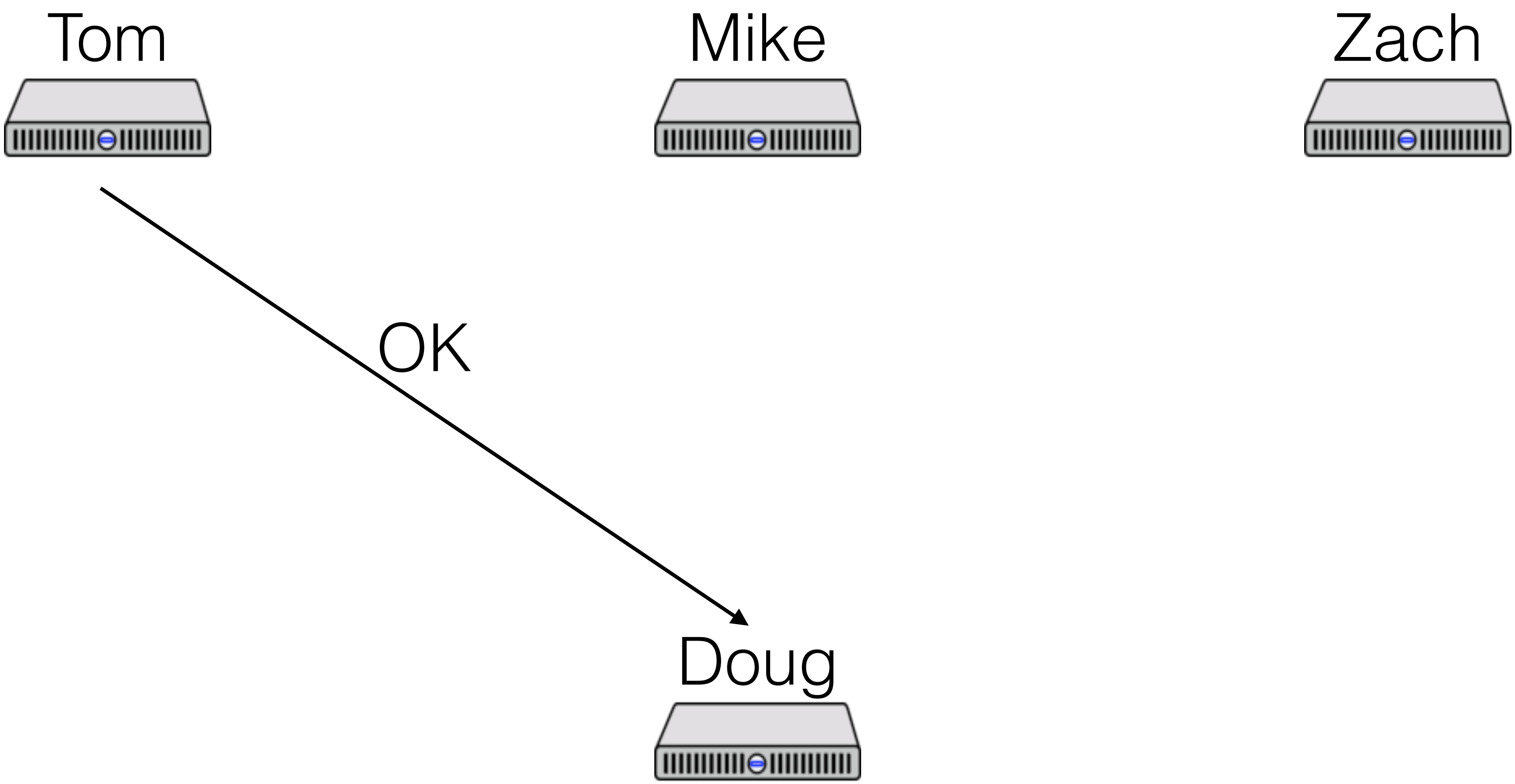

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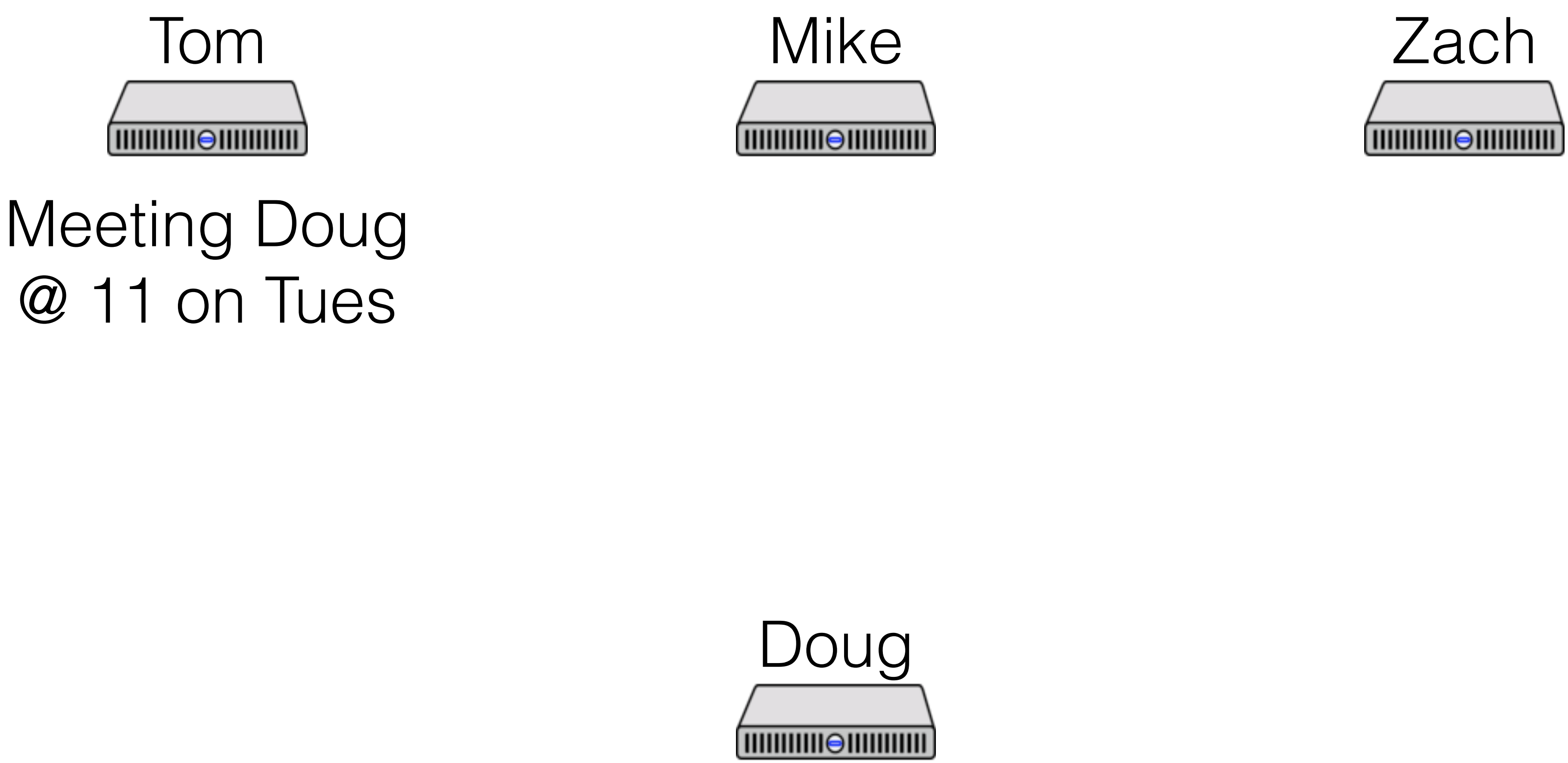

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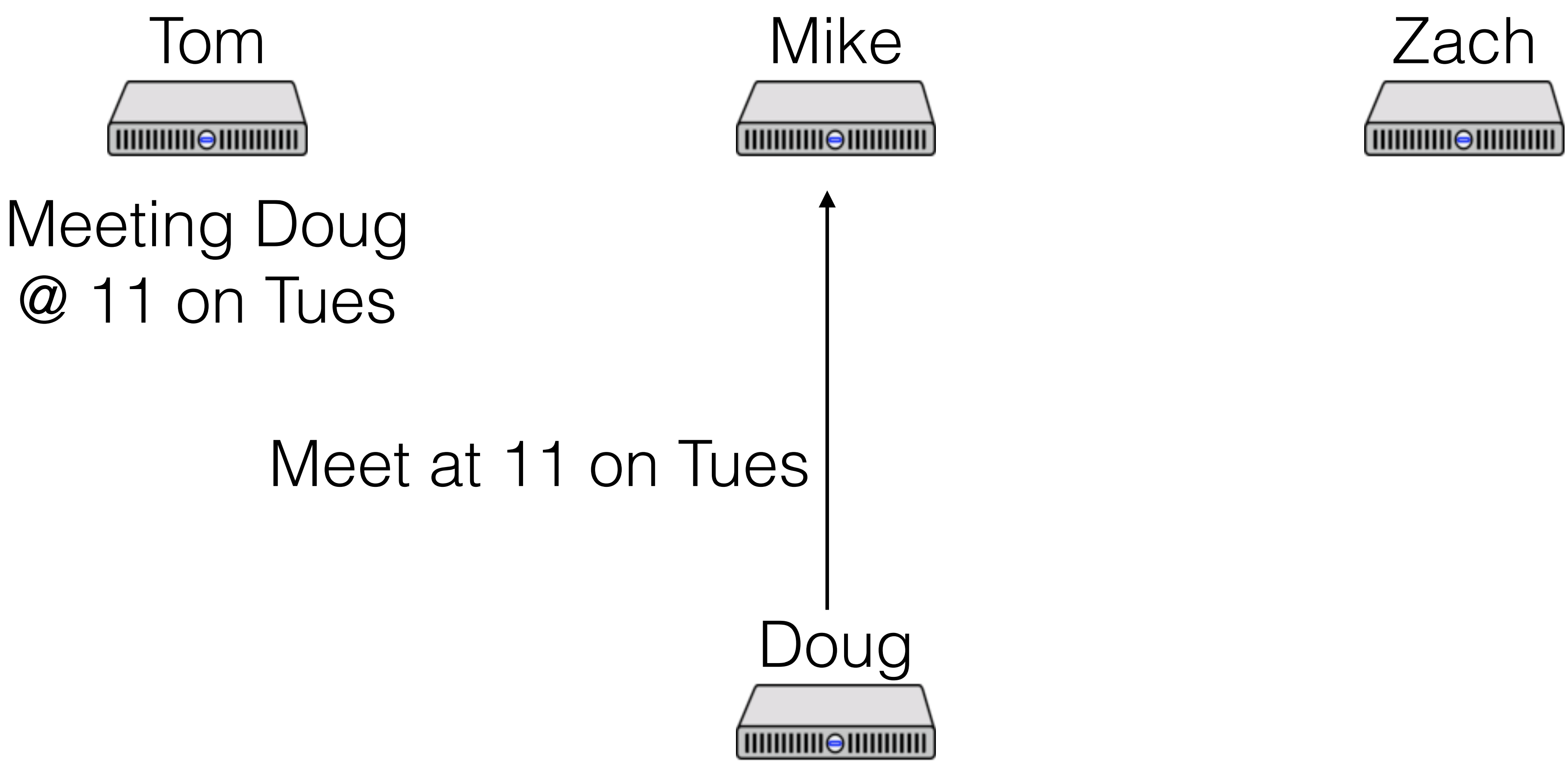

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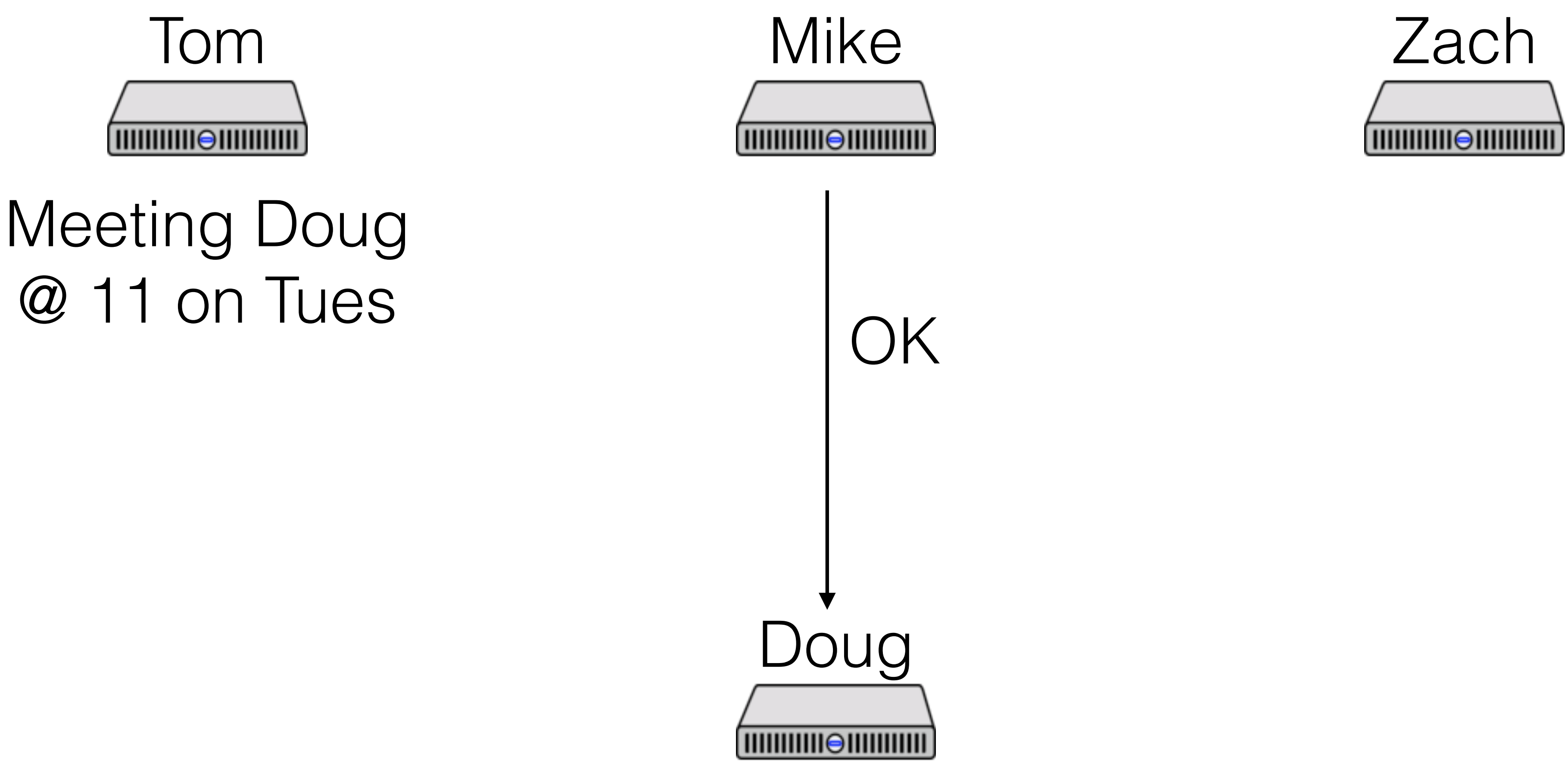

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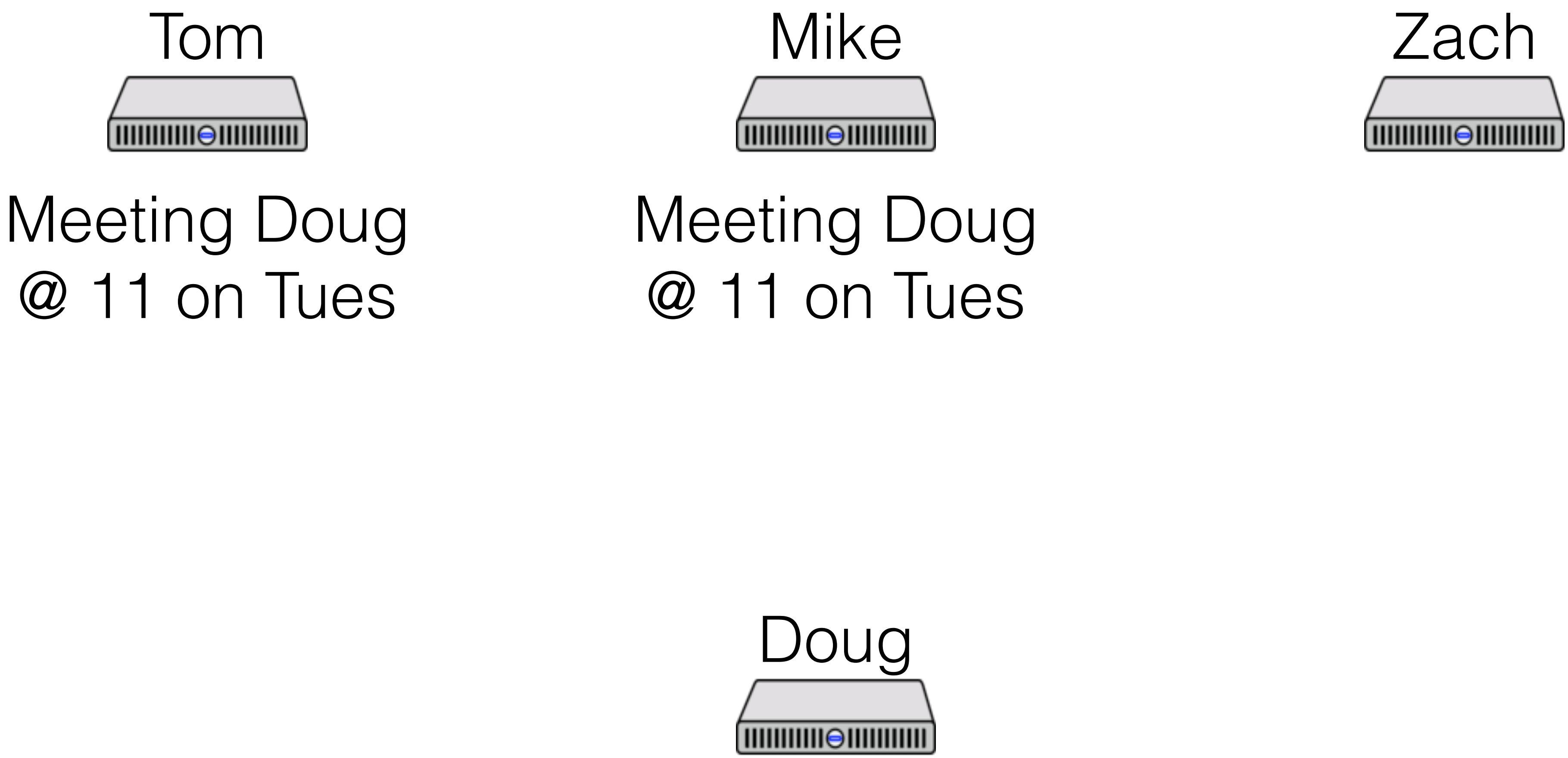

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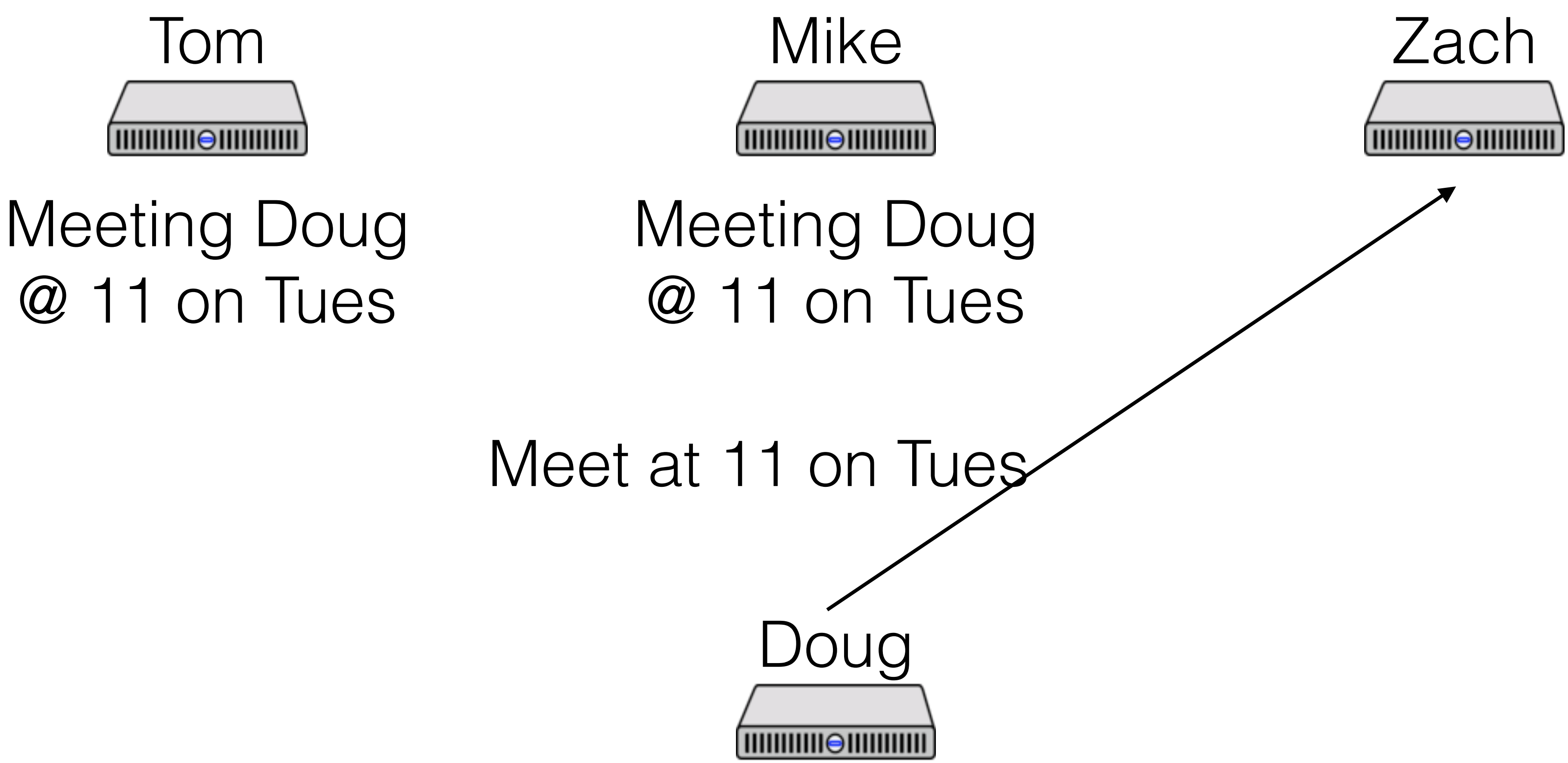

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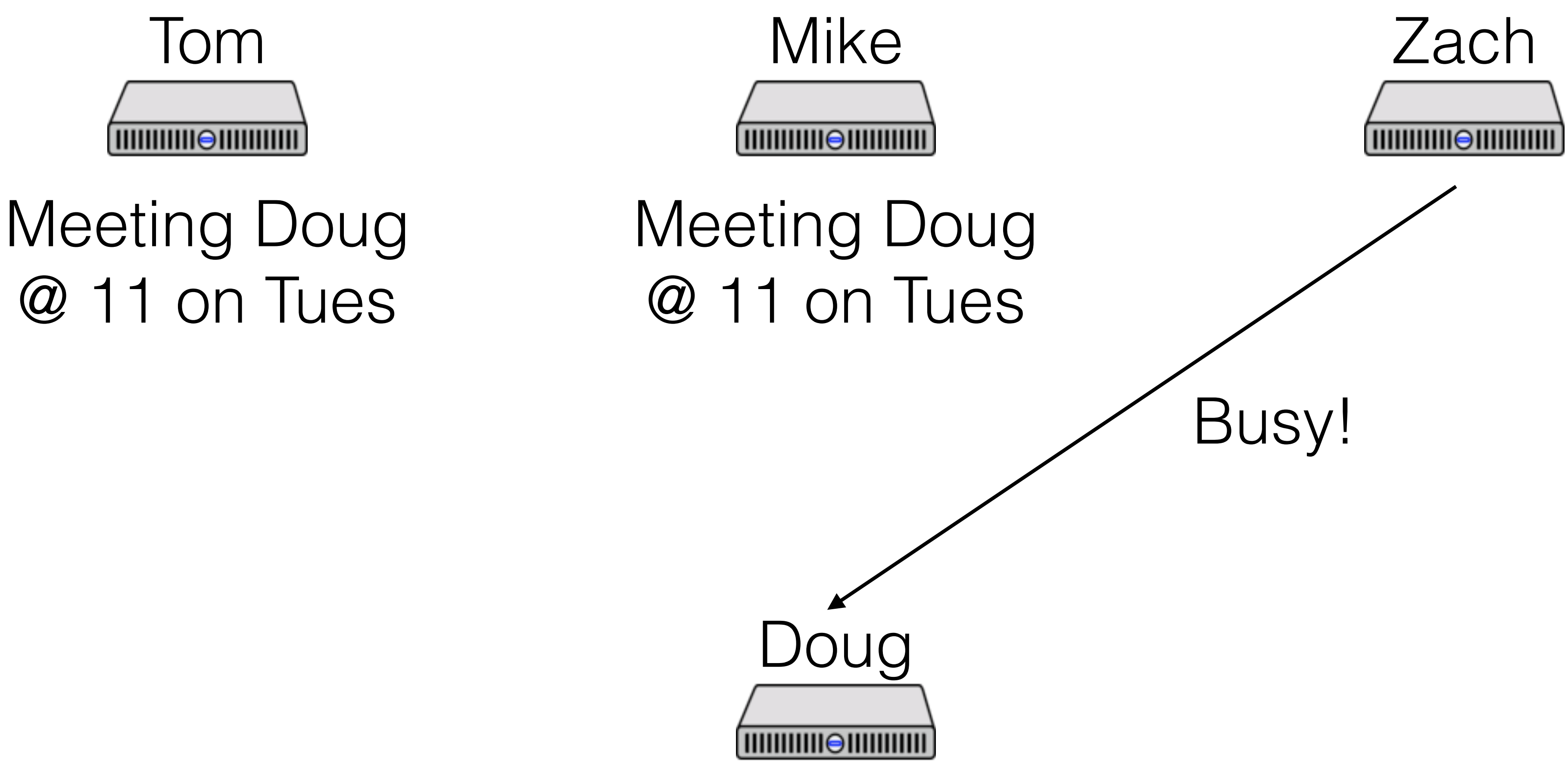


Calendar event creation (wrong)

Calendar event creation (wrong)

Tom

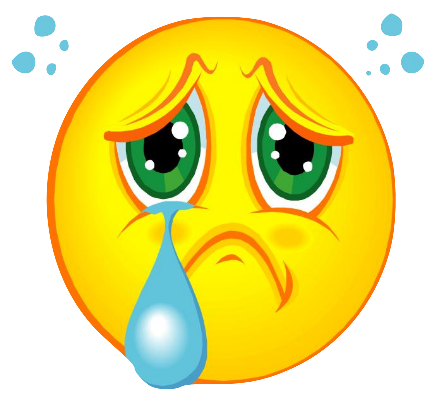
Meeting Doug
@ 11 on Tues

Mike

Meeting Doug
@ 11 on Tues

Zach

Doug



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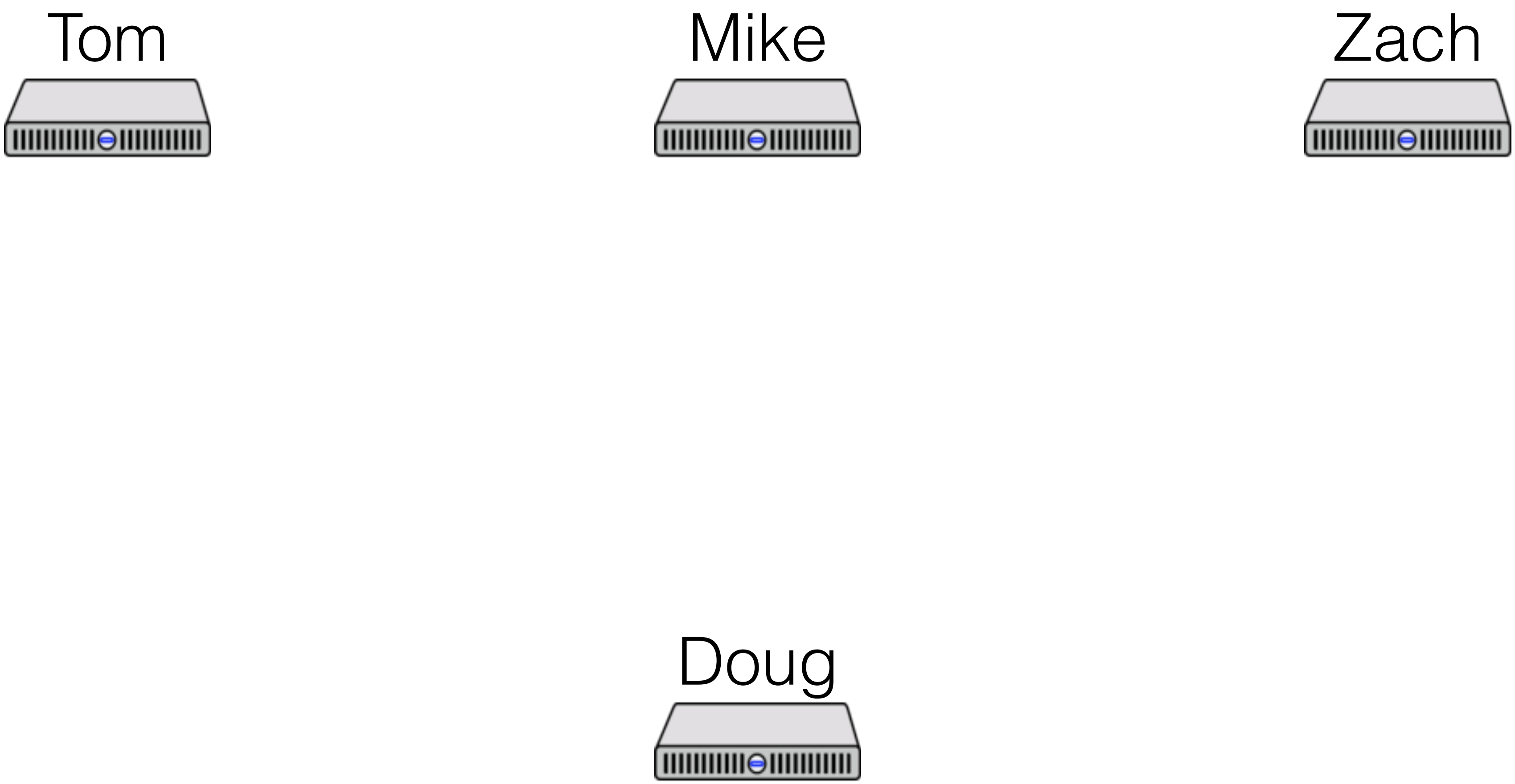

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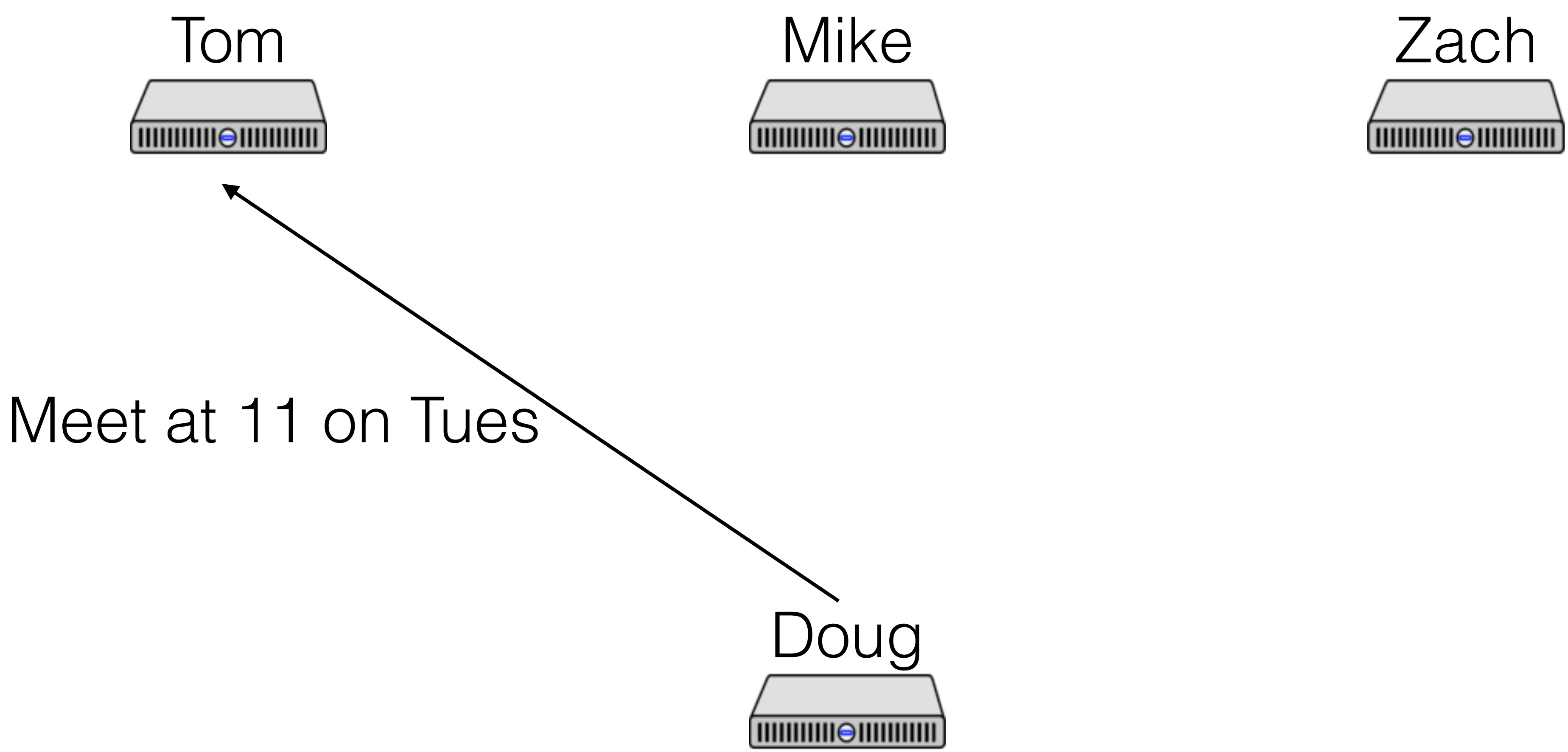

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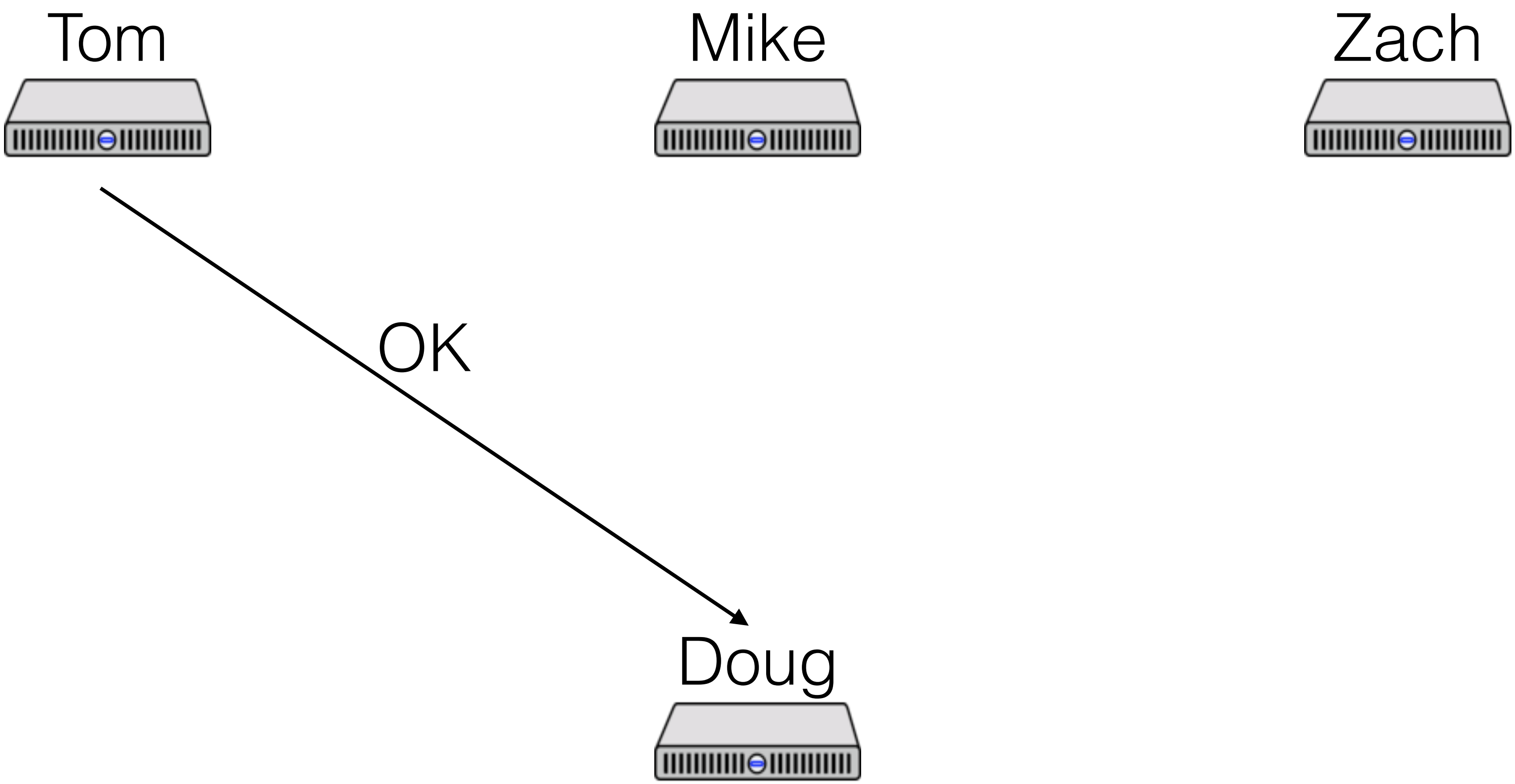

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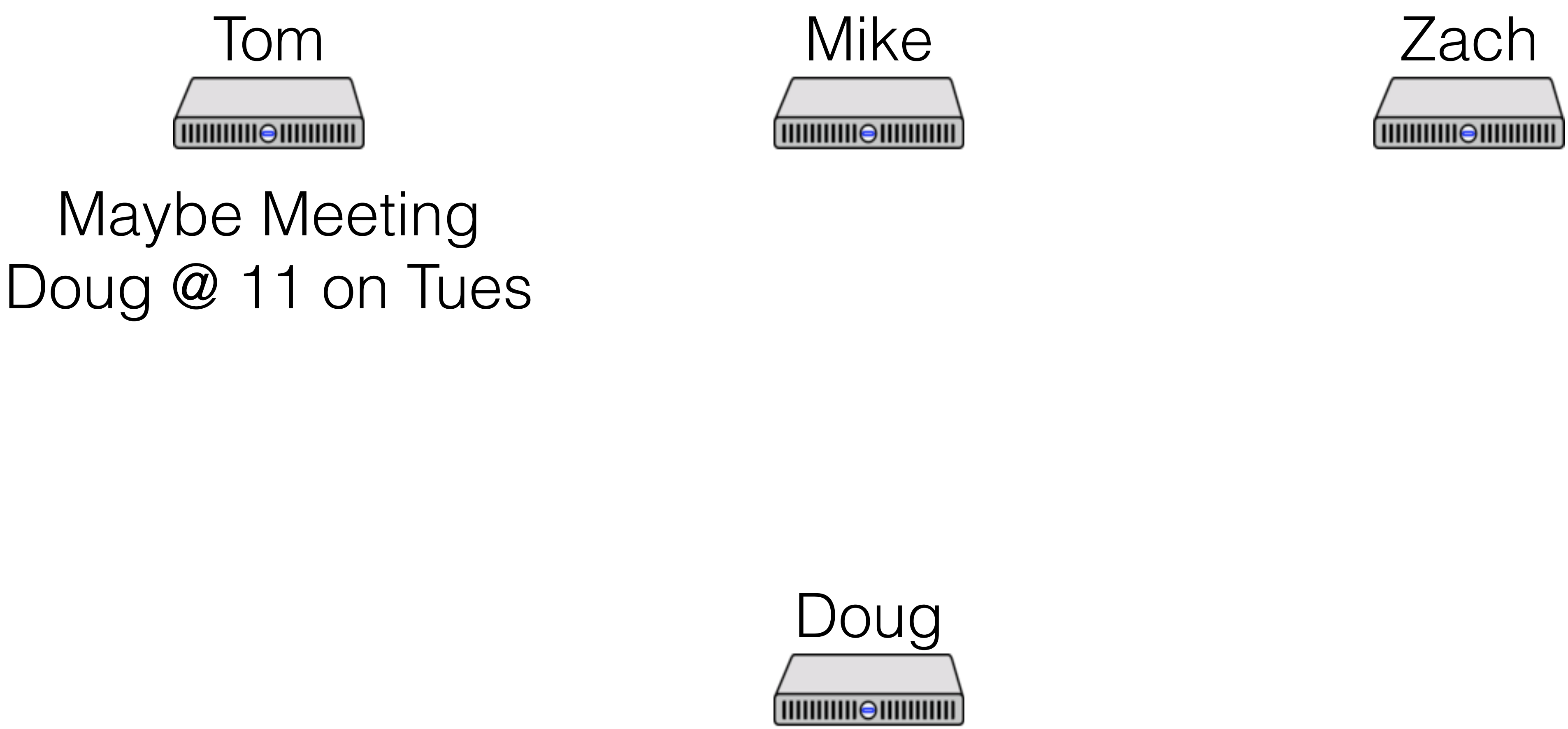

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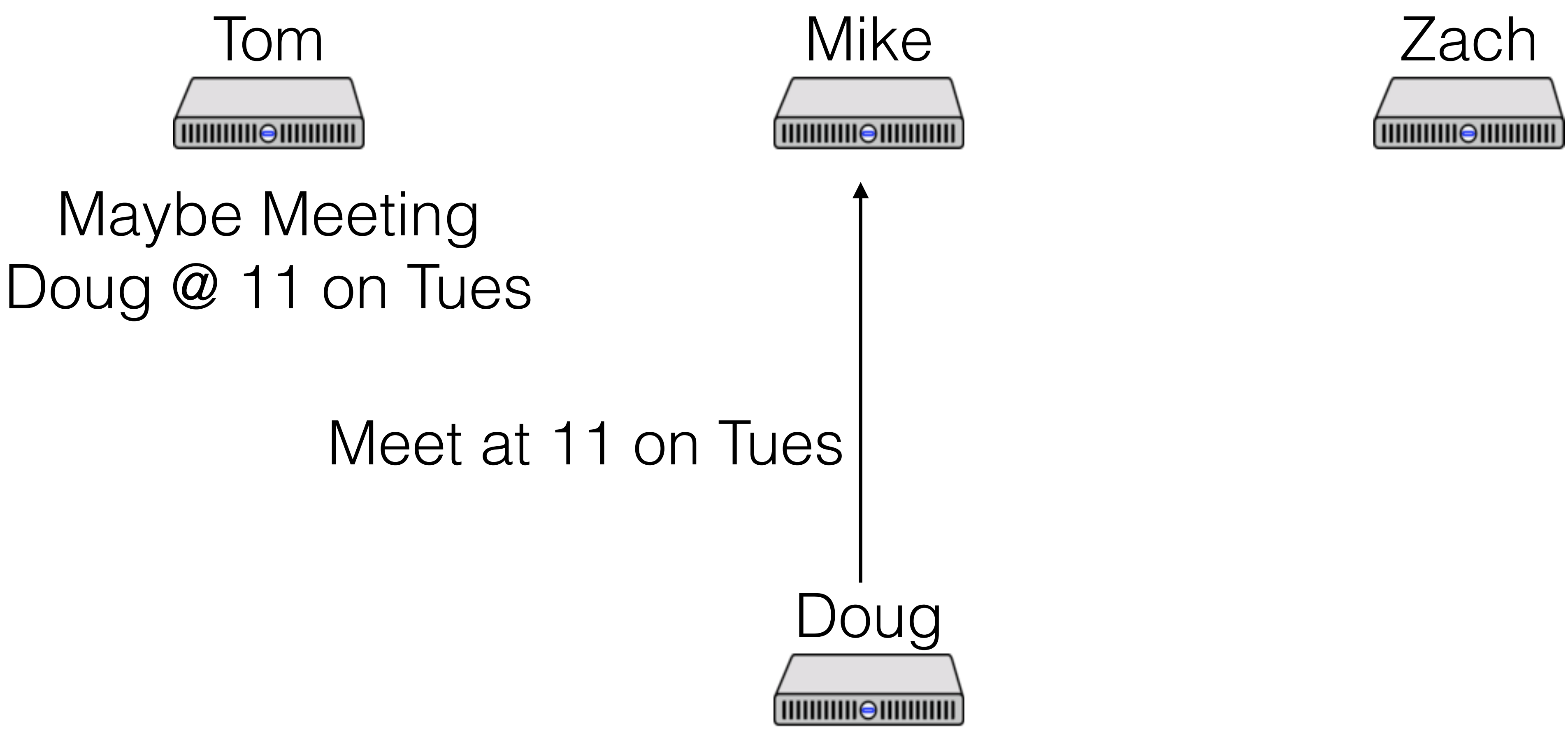

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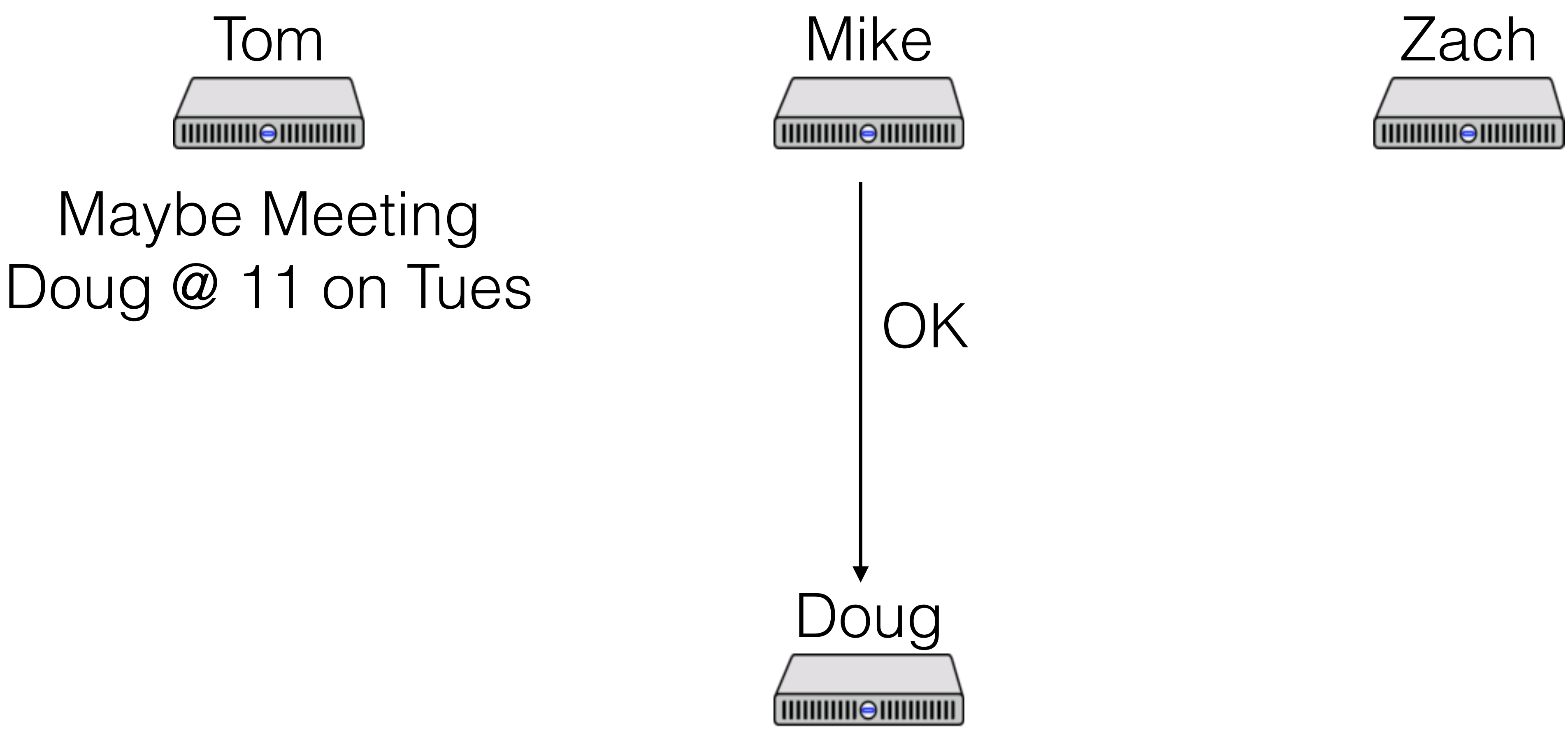

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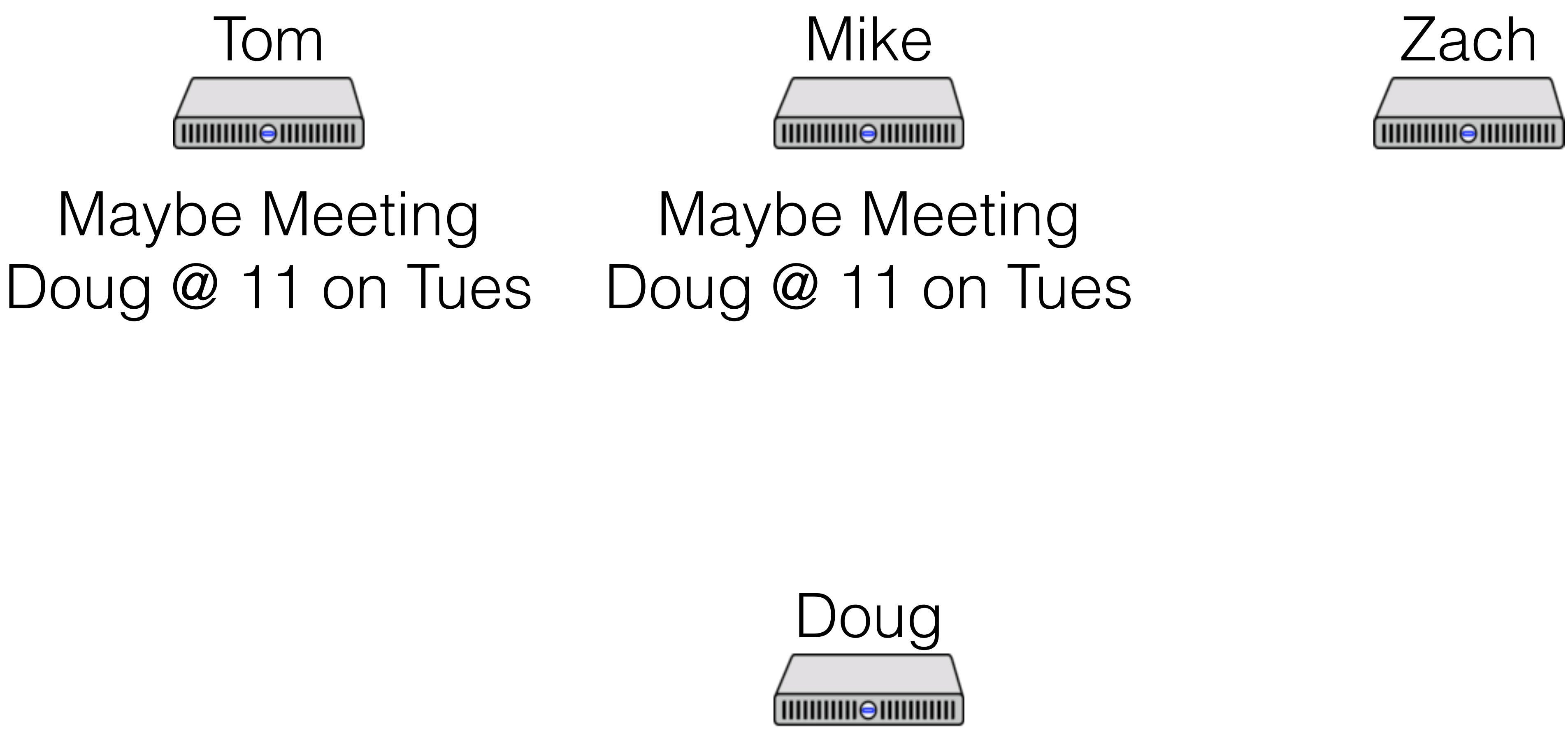

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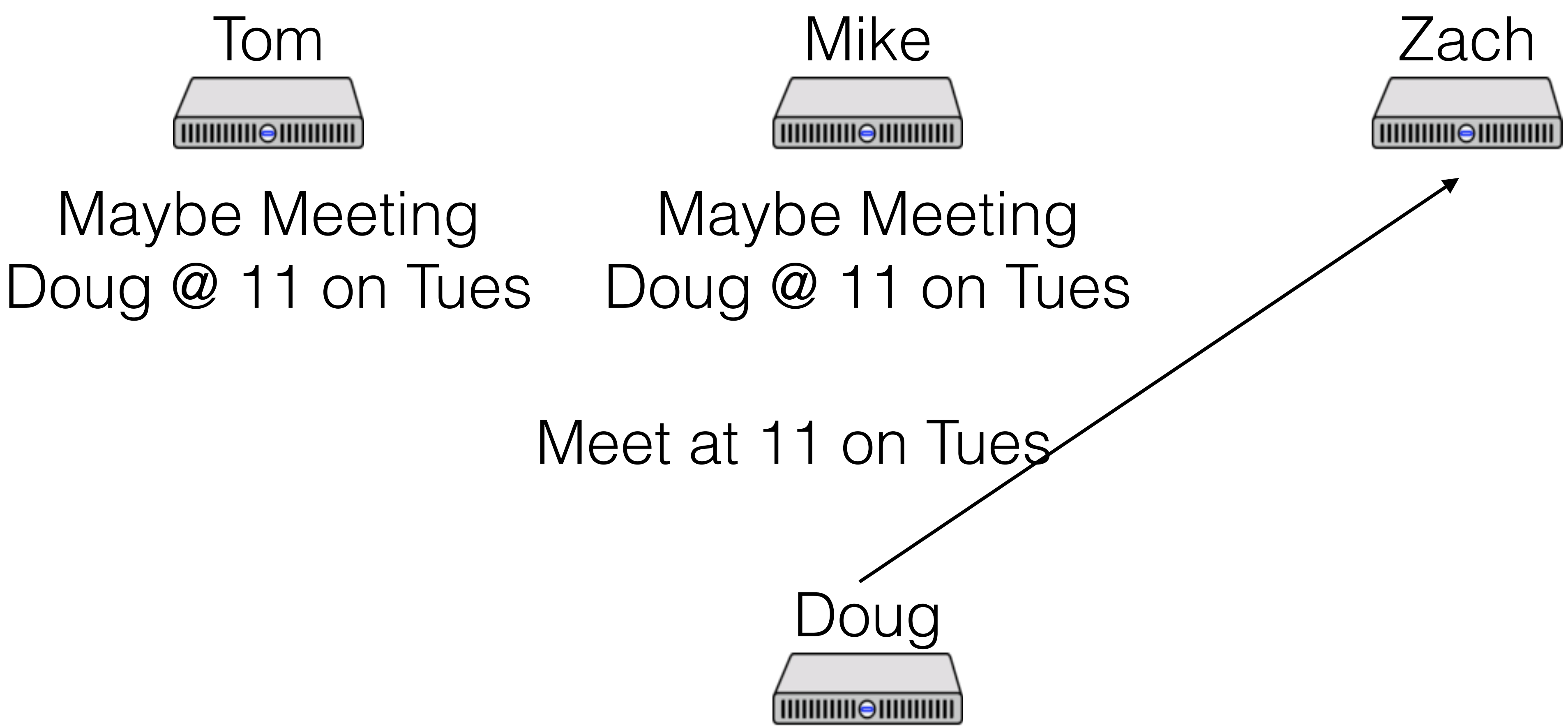

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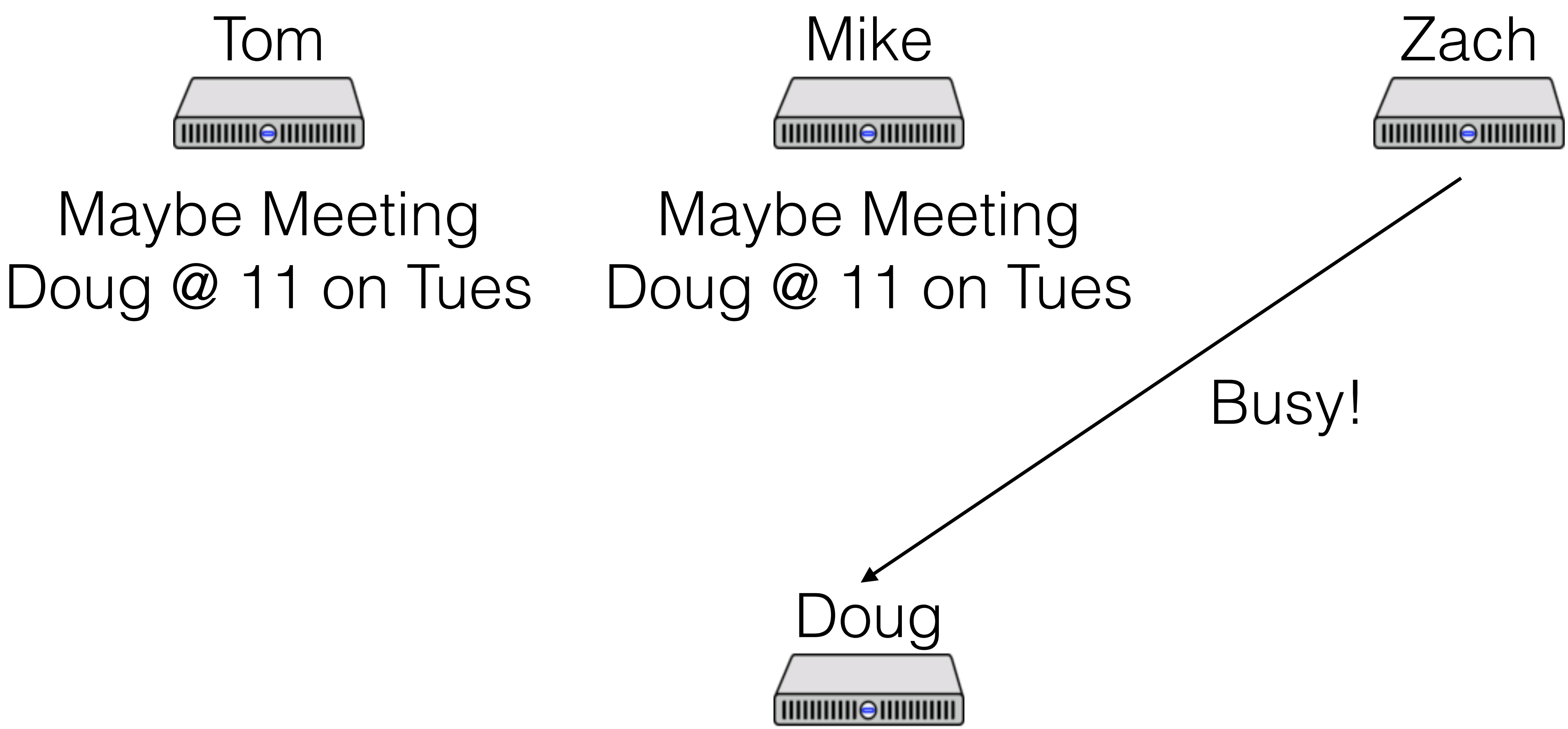

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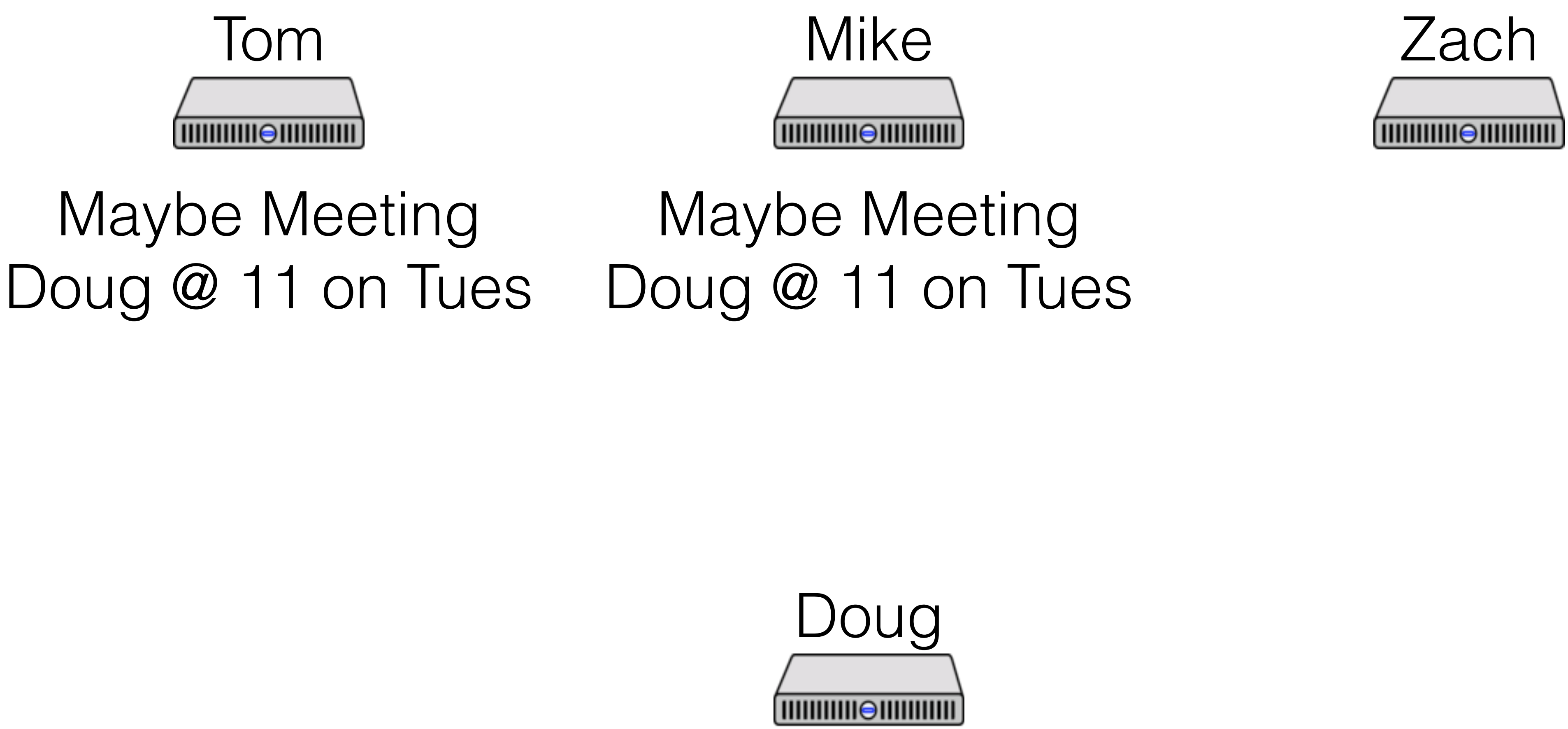

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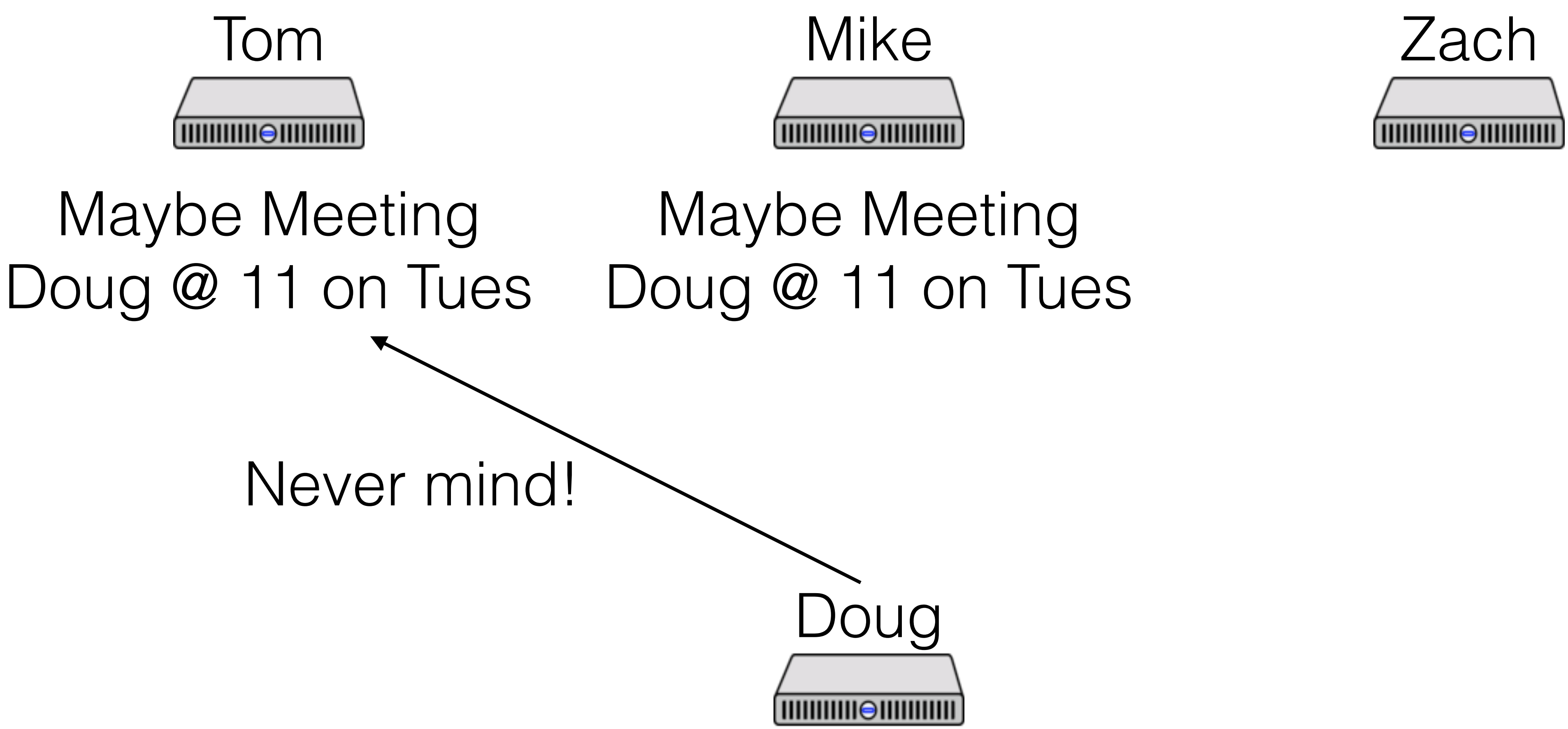

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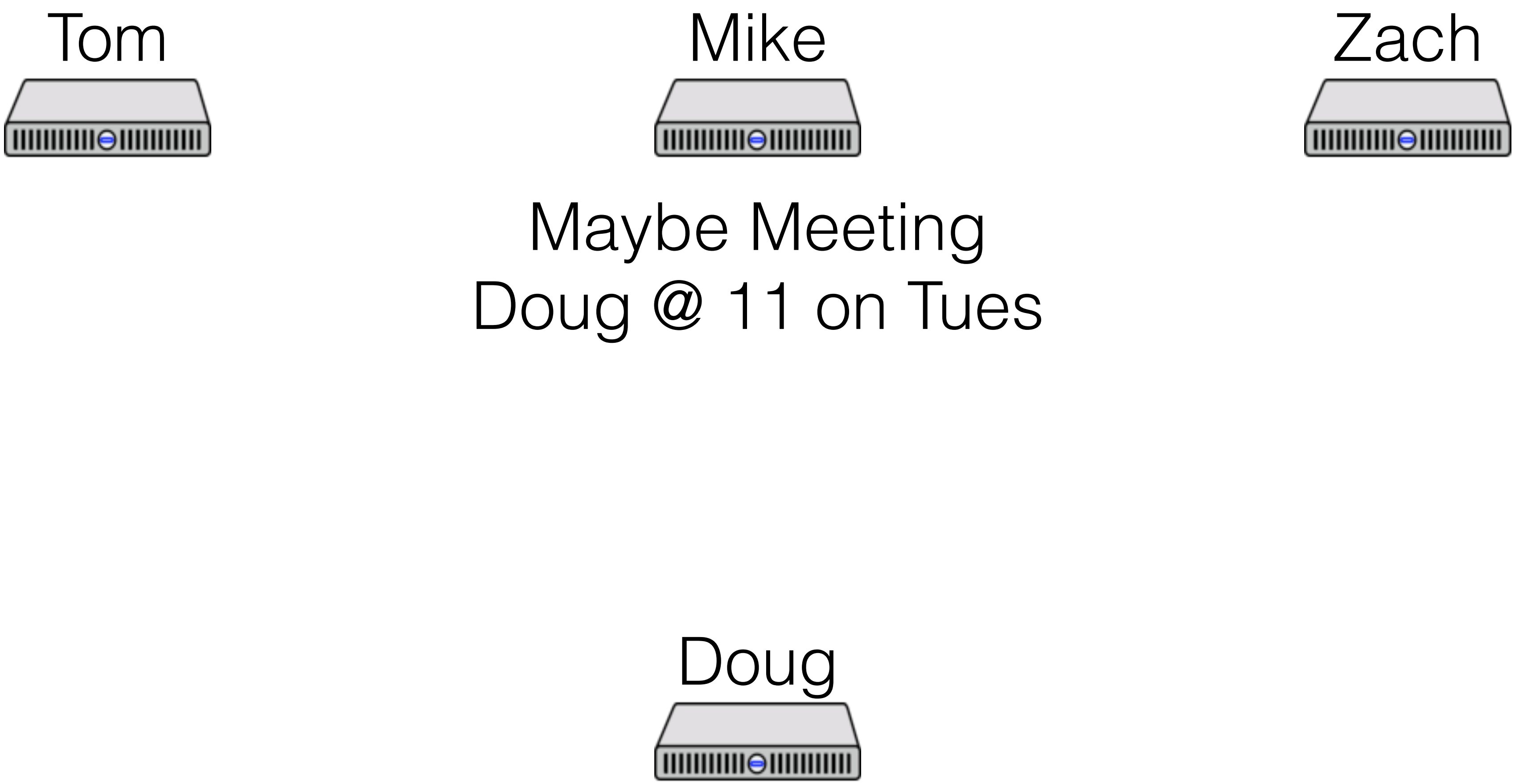

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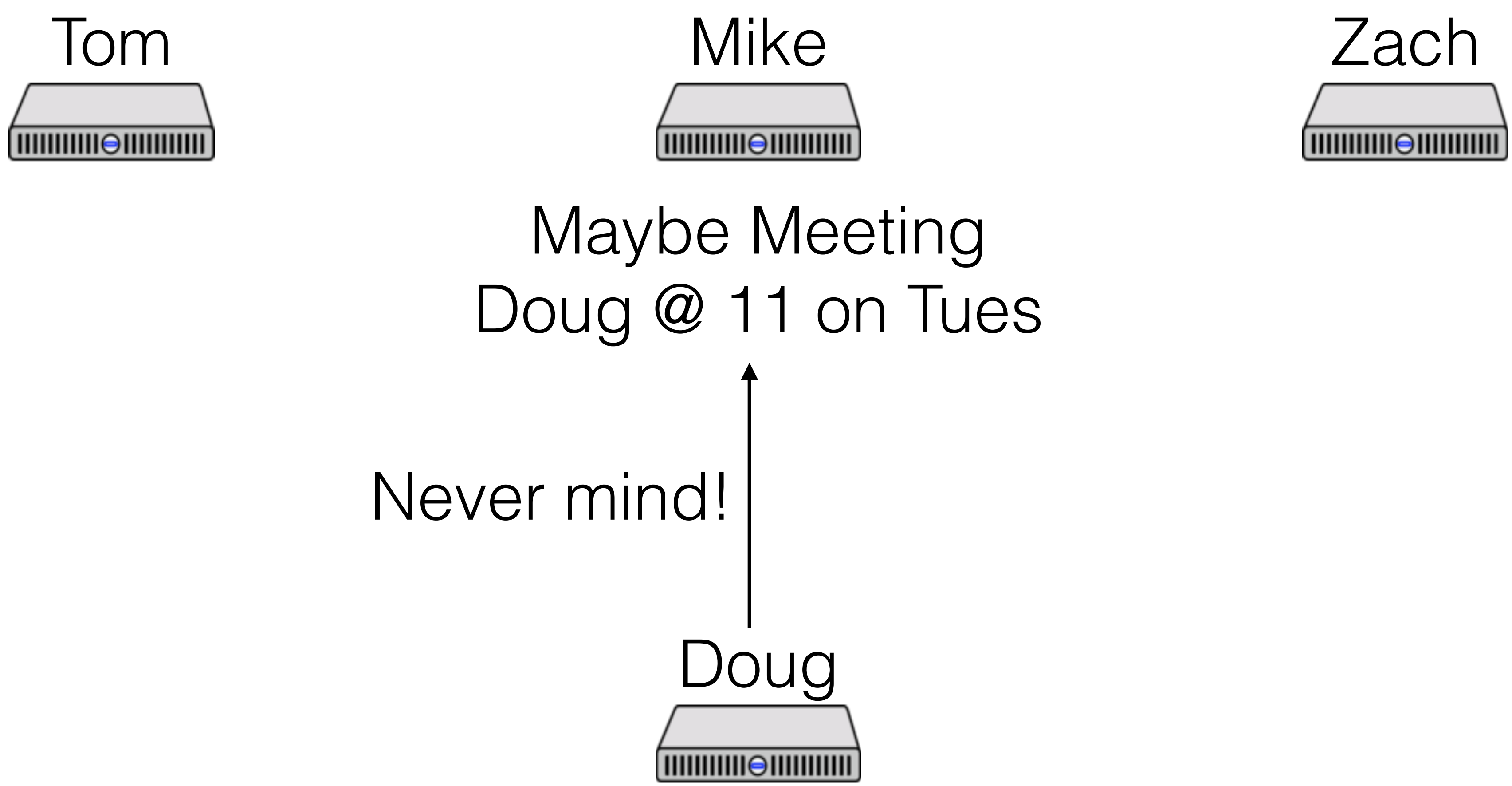

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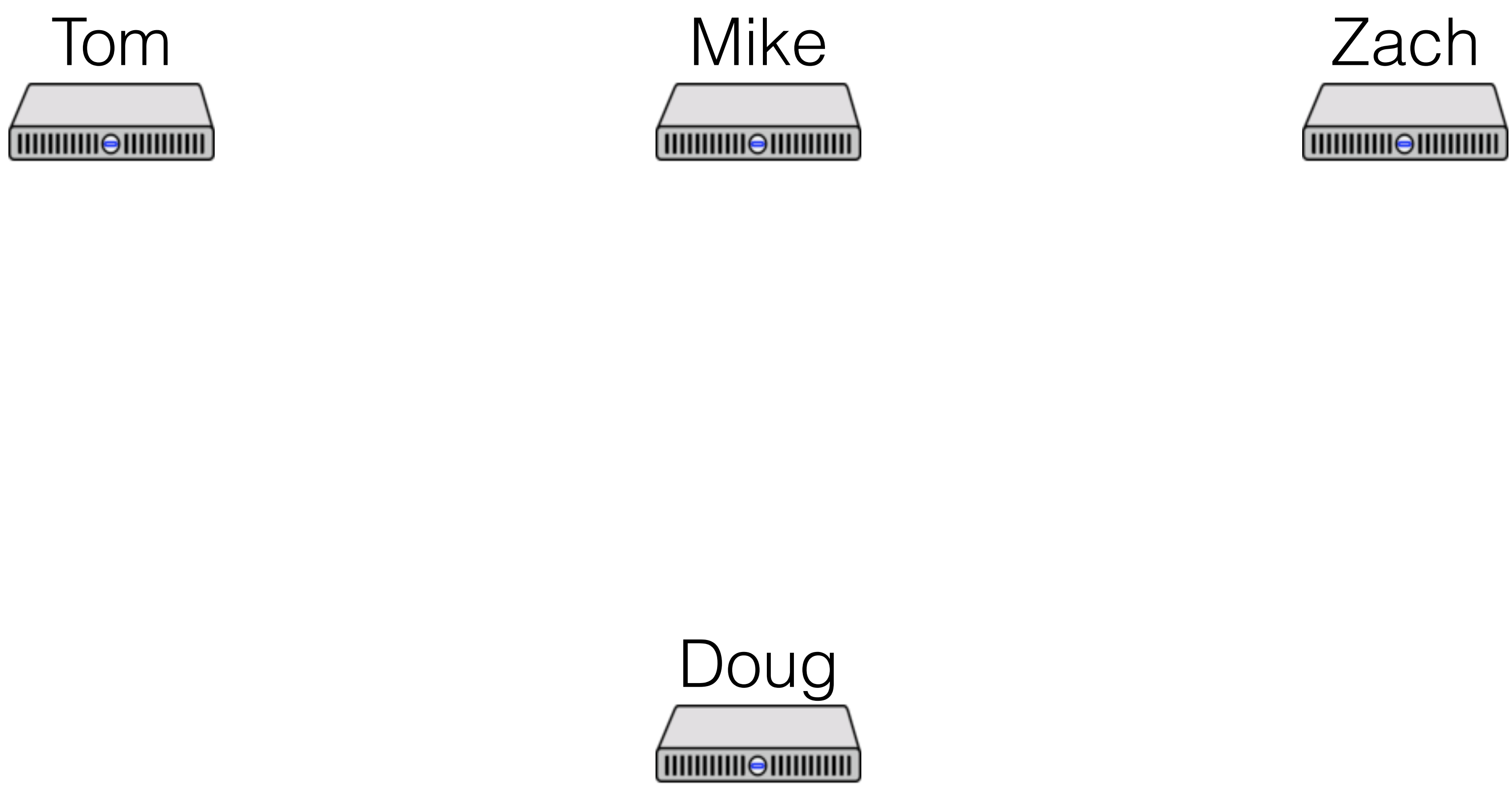


Two-phase commit

Atomic commit protocol (ACP)

- Every node arrives at the same decision
- Once a node decides, it never changes
- Transaction committed only if all nodes vote Yes
- In normal operation, if all processes vote Yes the transaction is committed
- If all failures are eventually repaired, the transaction is eventually either committed or aborted

Two-phase commit

Roles:

- Participants (Mike, Tom, Zach): nodes that must update data relevant to the transaction

- Coordinator (Doug): node responsible for executing the protocol (might also be a participant)

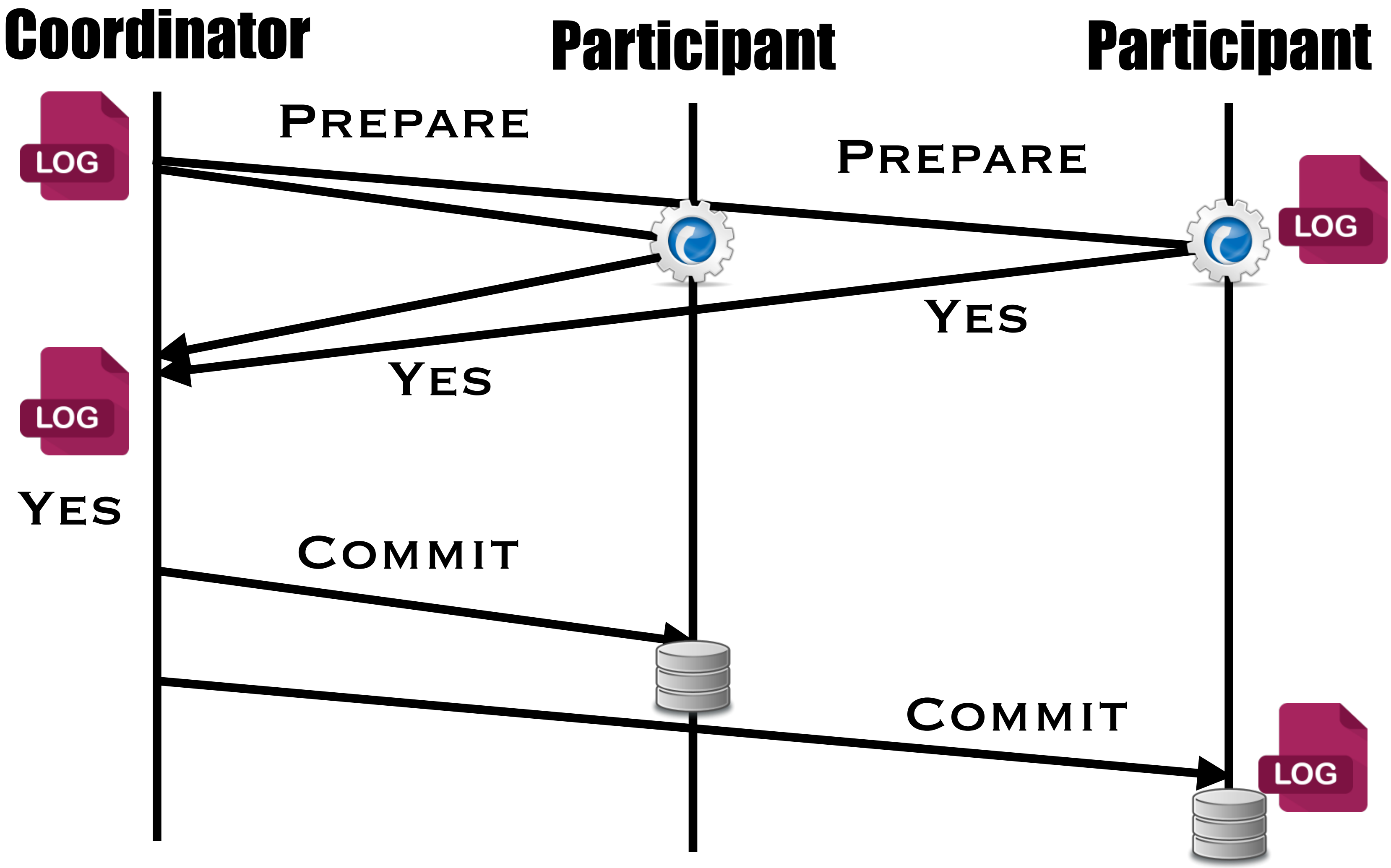
Messages:

- **PREPARE:** Can you commit this transaction?

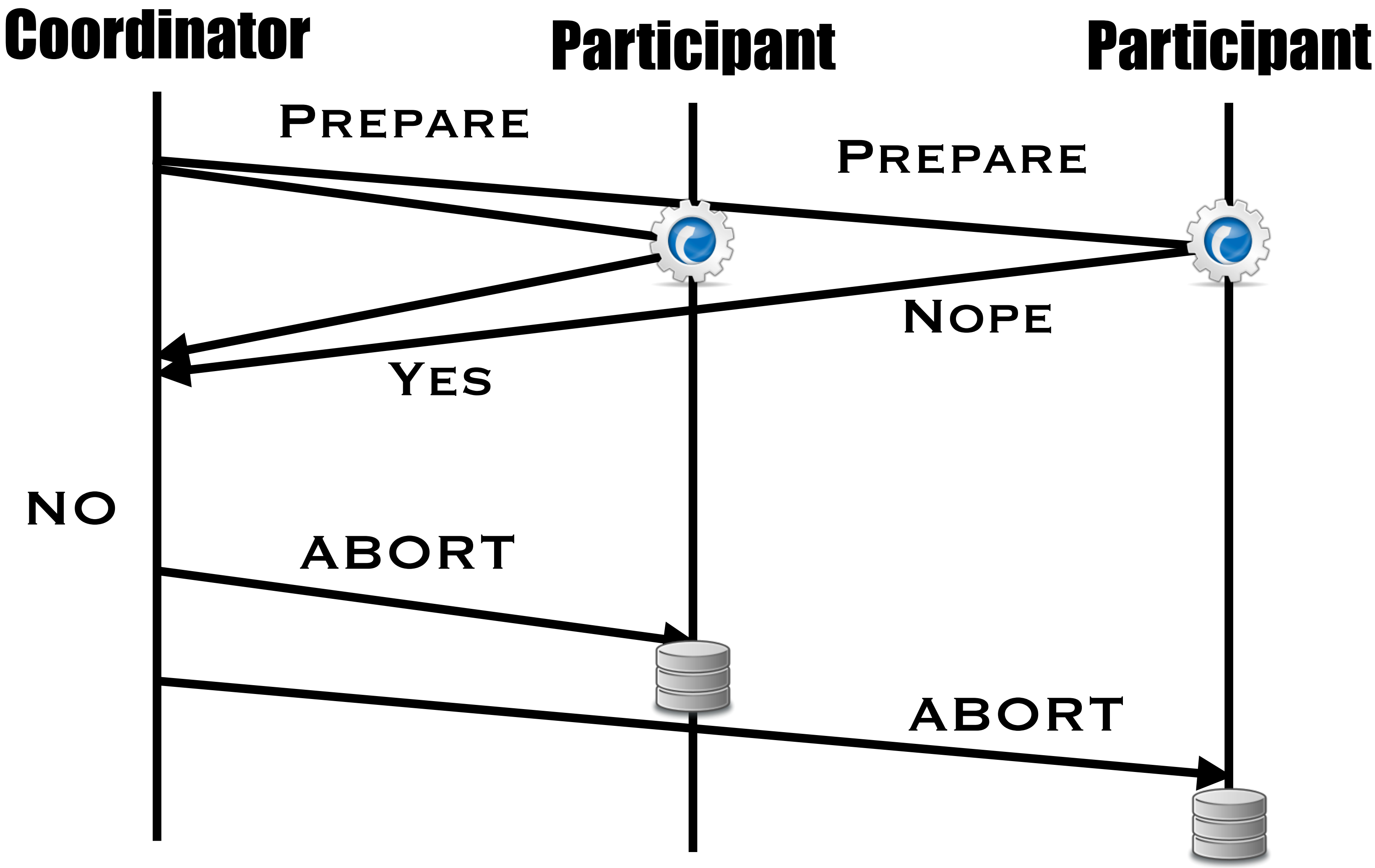
- **COMMIT:** Commit this transaction

- **ABORT:** Abort this transaction

2PC without failures



2PC without failures



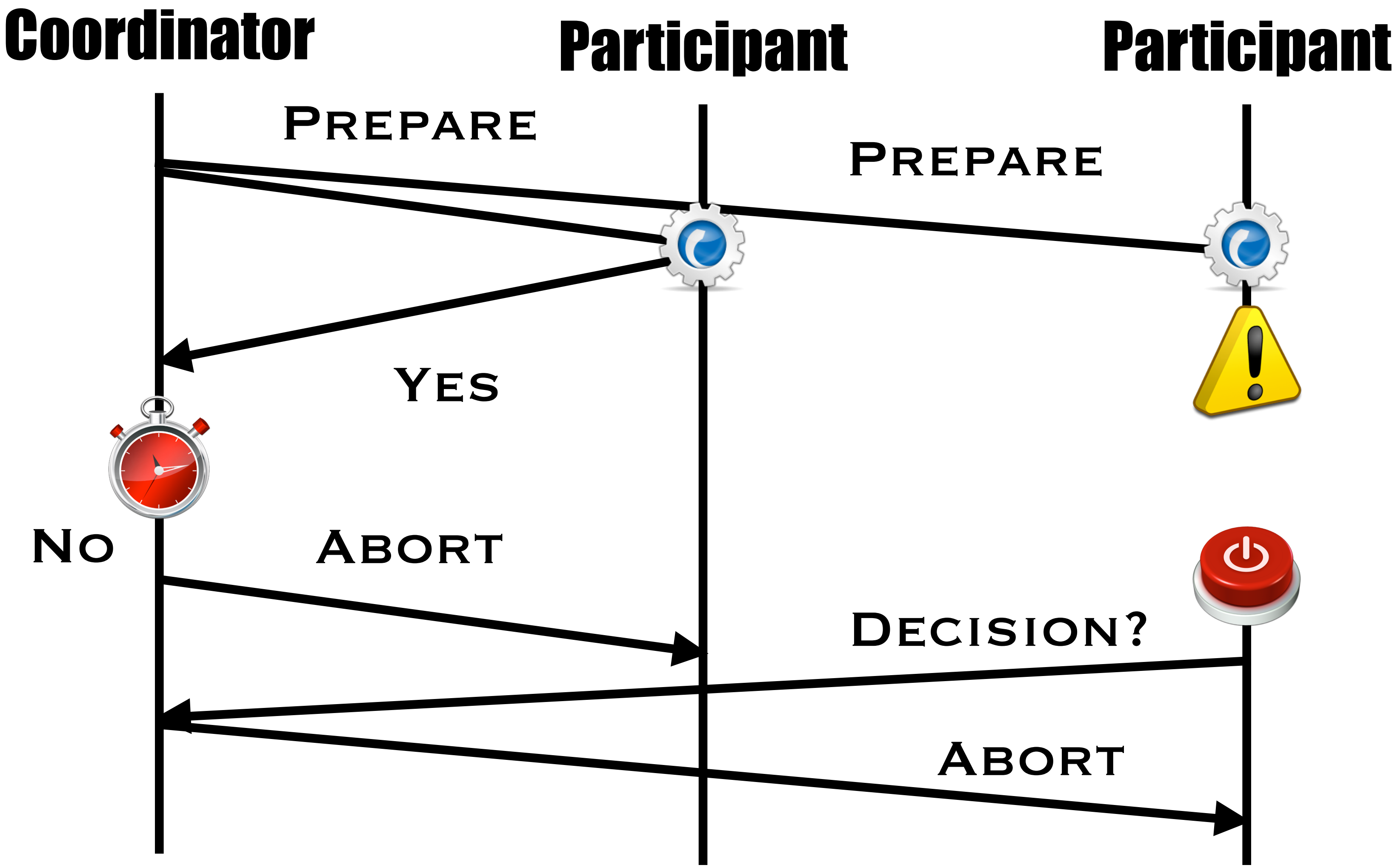
Failures

In the absence of failures, 2PC is pretty simple!

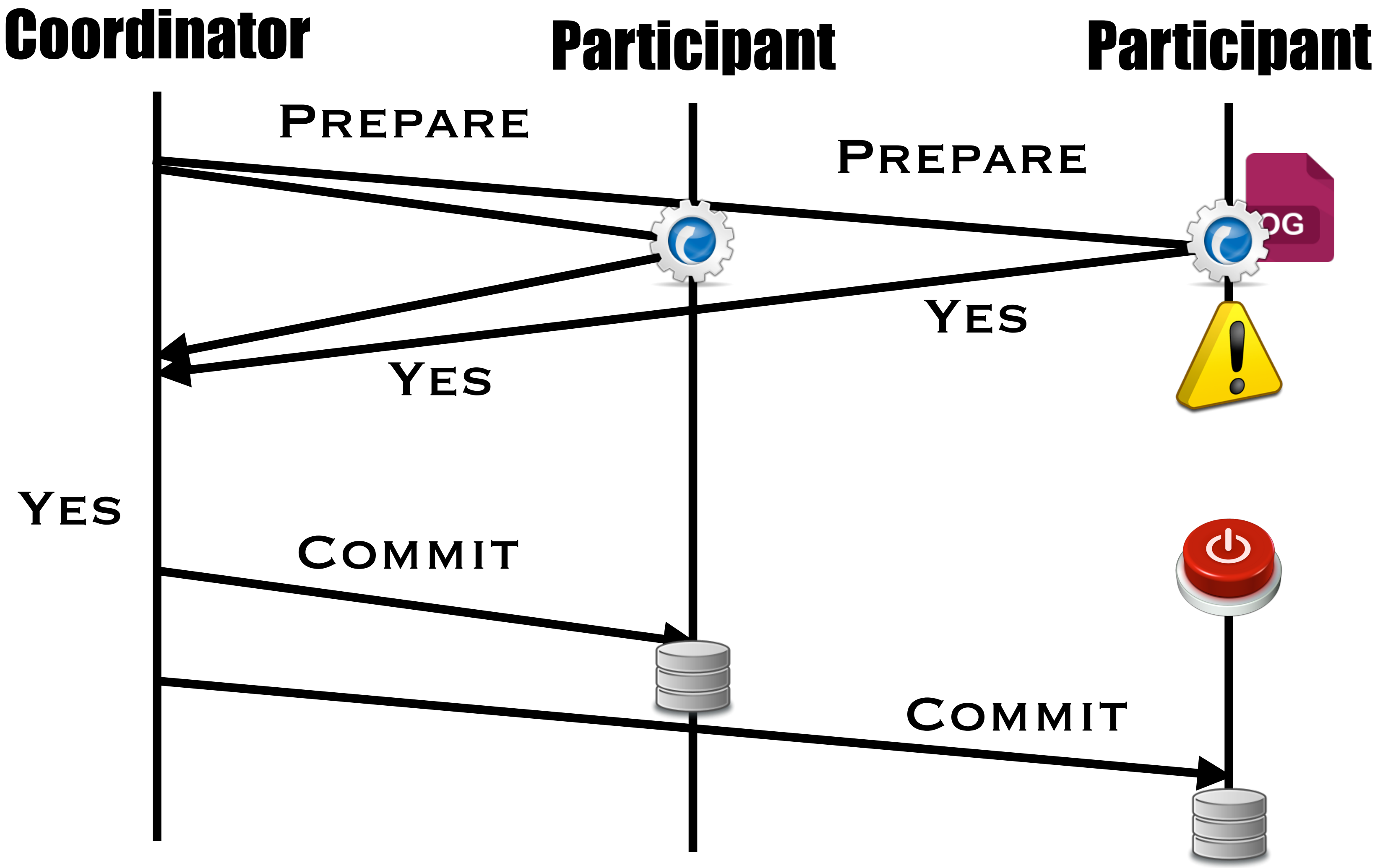
When can interesting failures happen?

- Participant failures?
- Coordinator failures?
- Message drops?

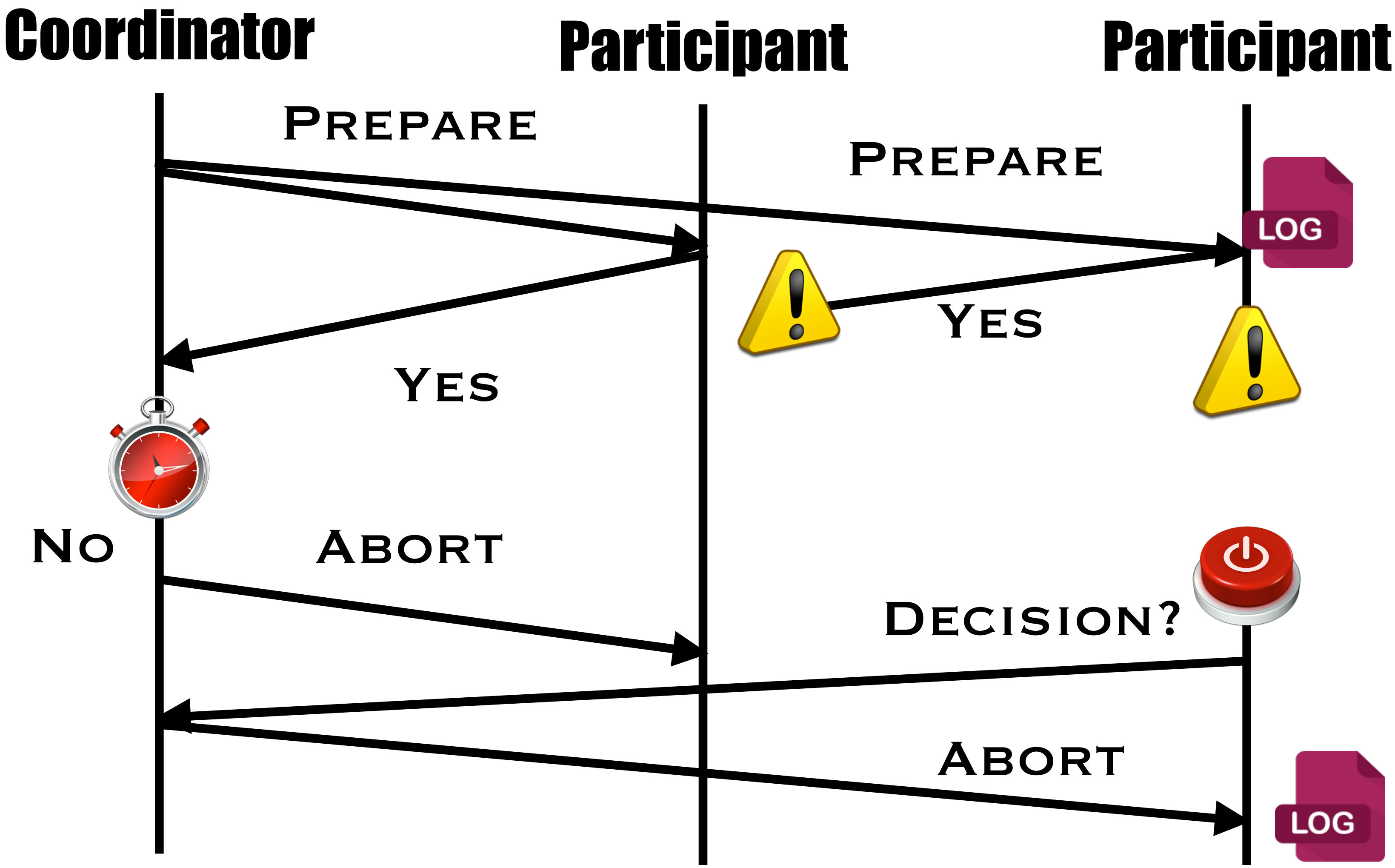
Participant failures:
Before sending response?



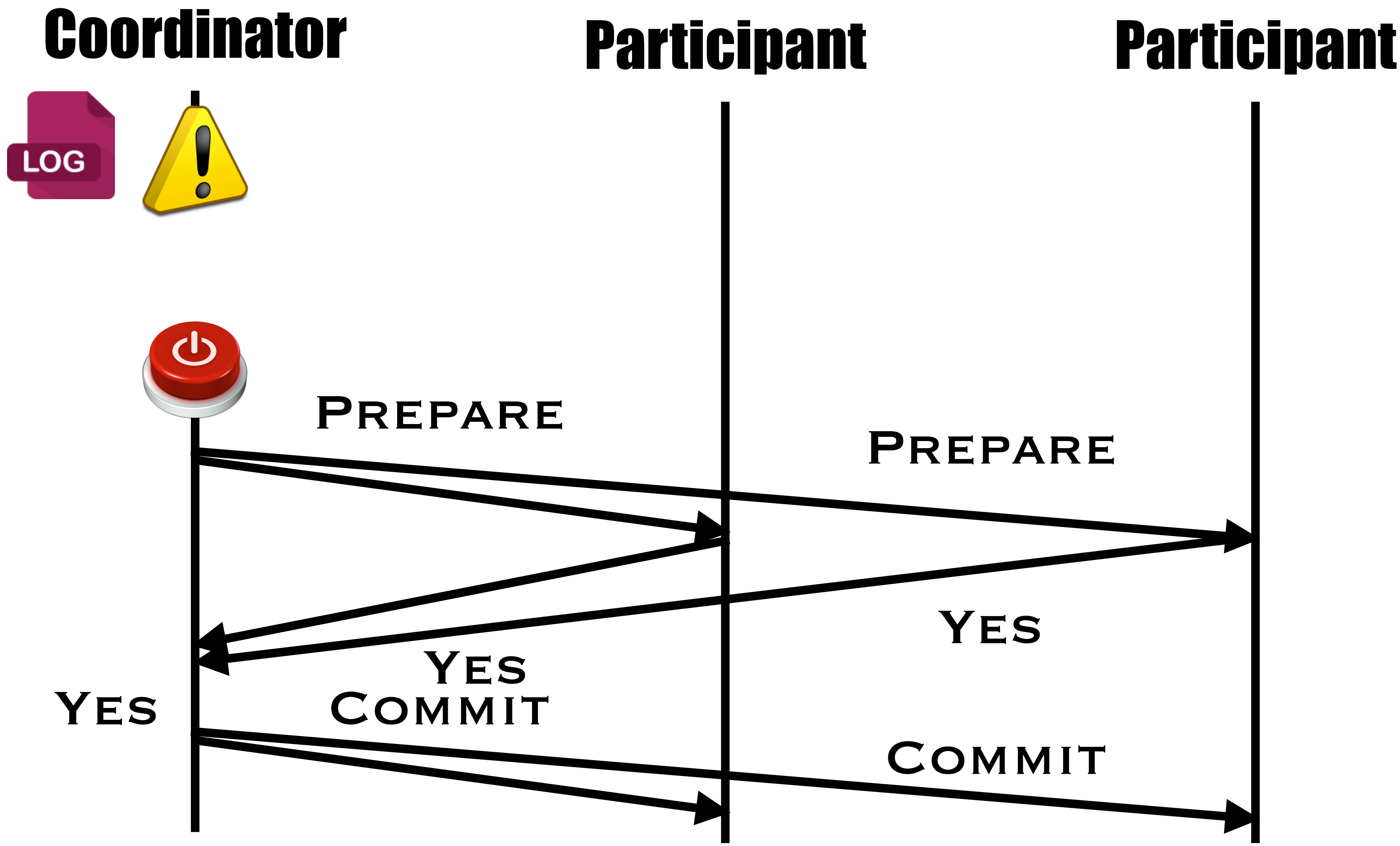
Participant failures: After sending vote?



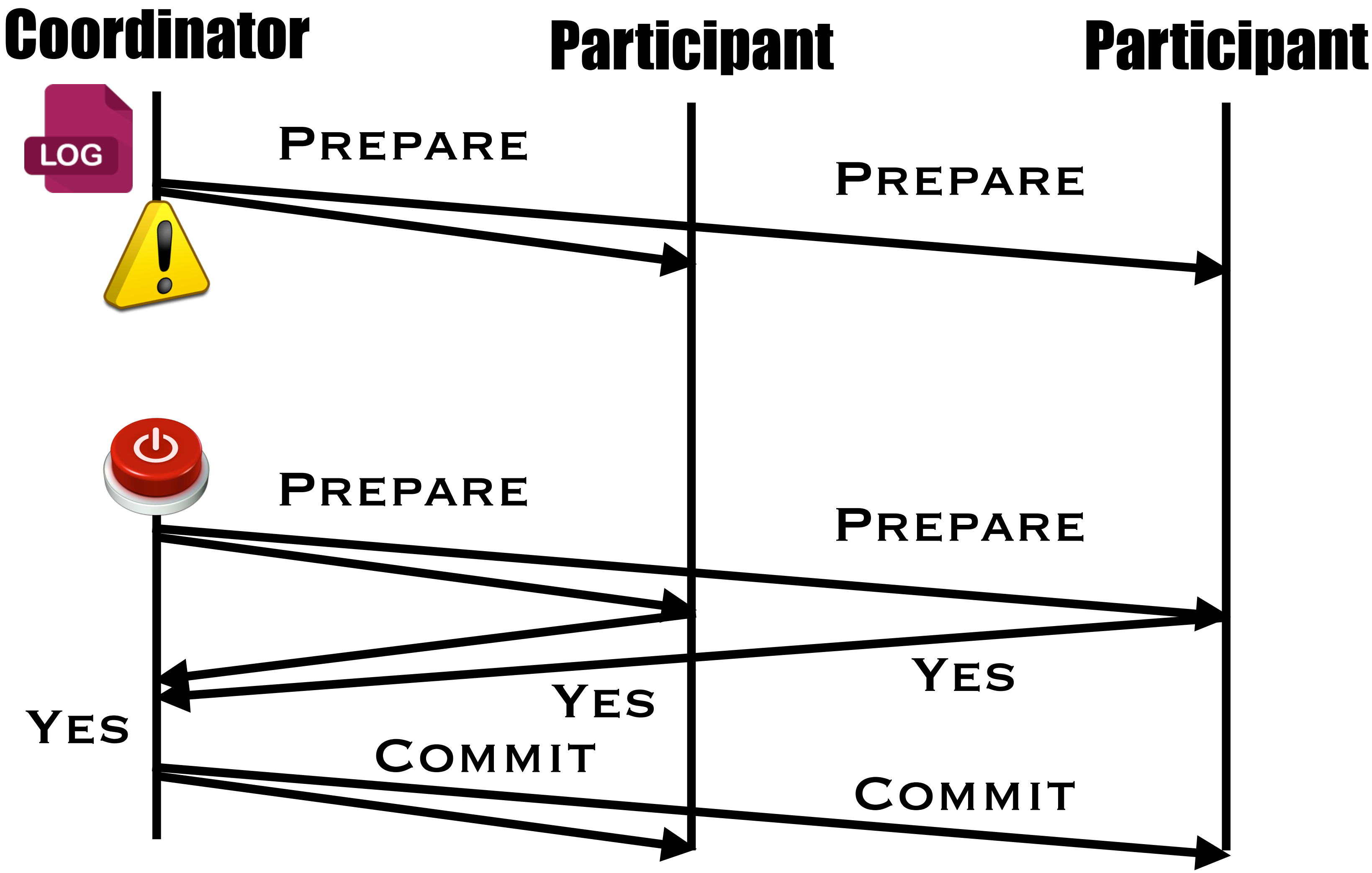
Participant failures: Lost vote?



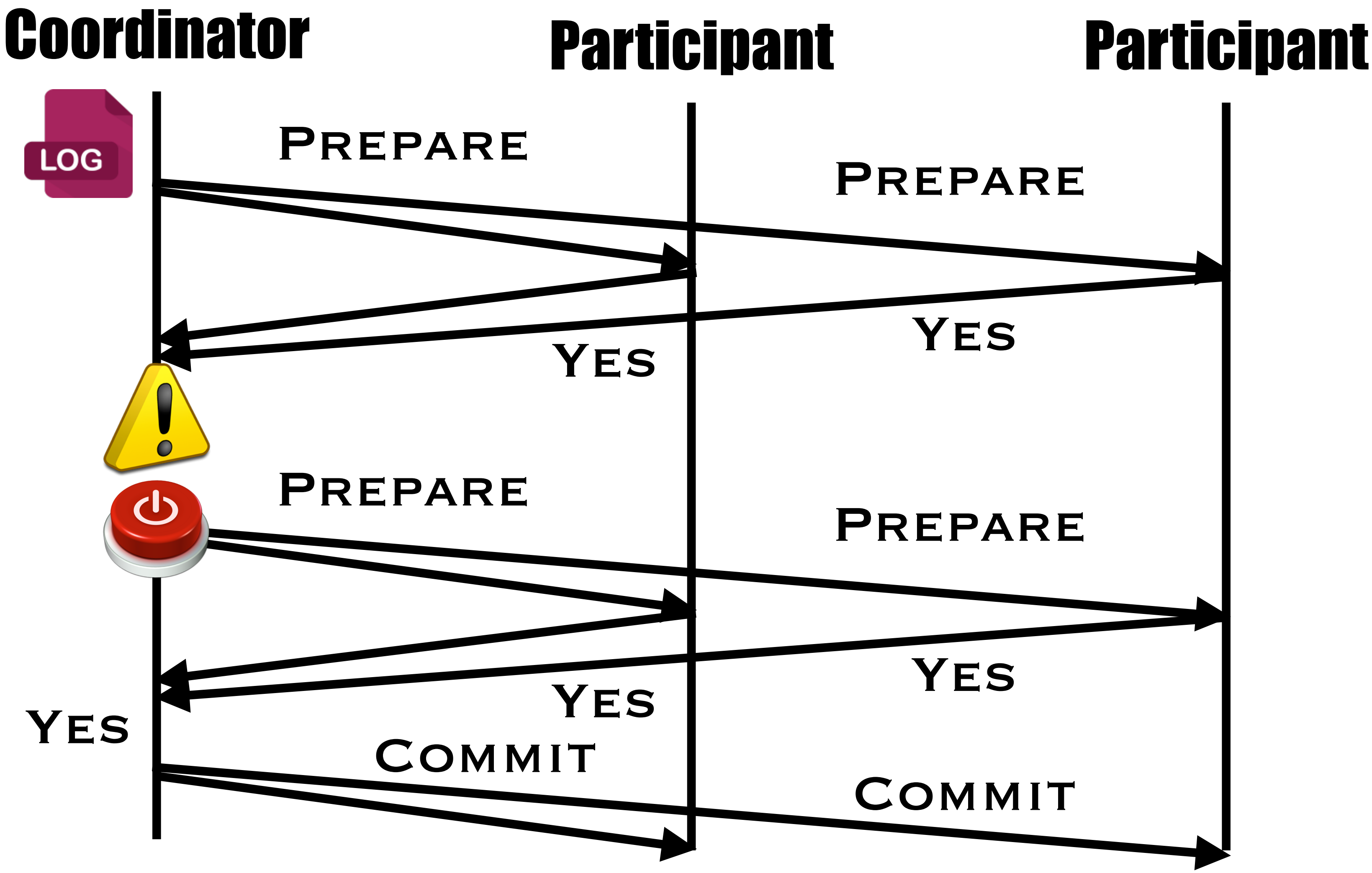
Coodinator failures:
Before sending prepare



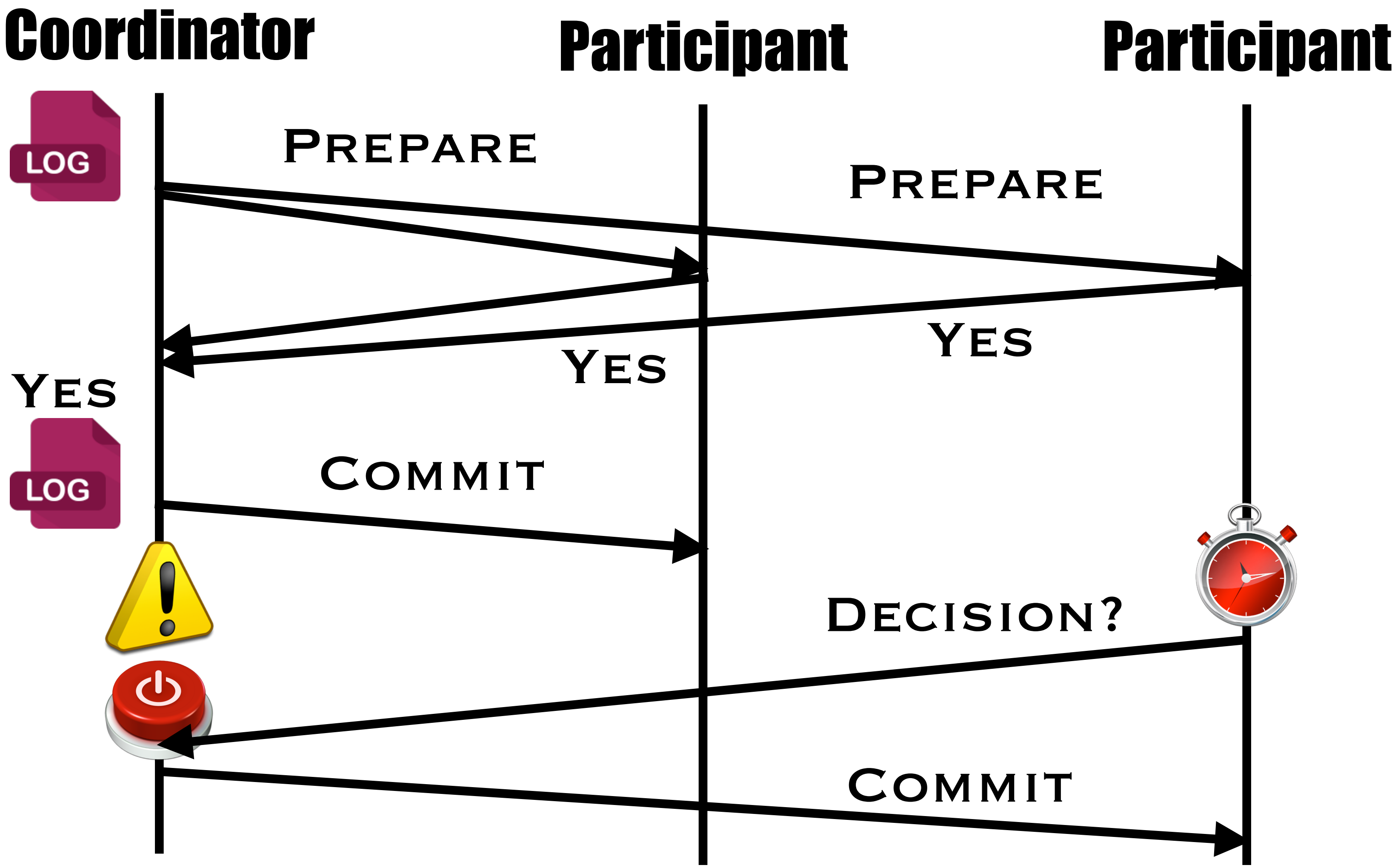
Coordinator failures: After sending prepare



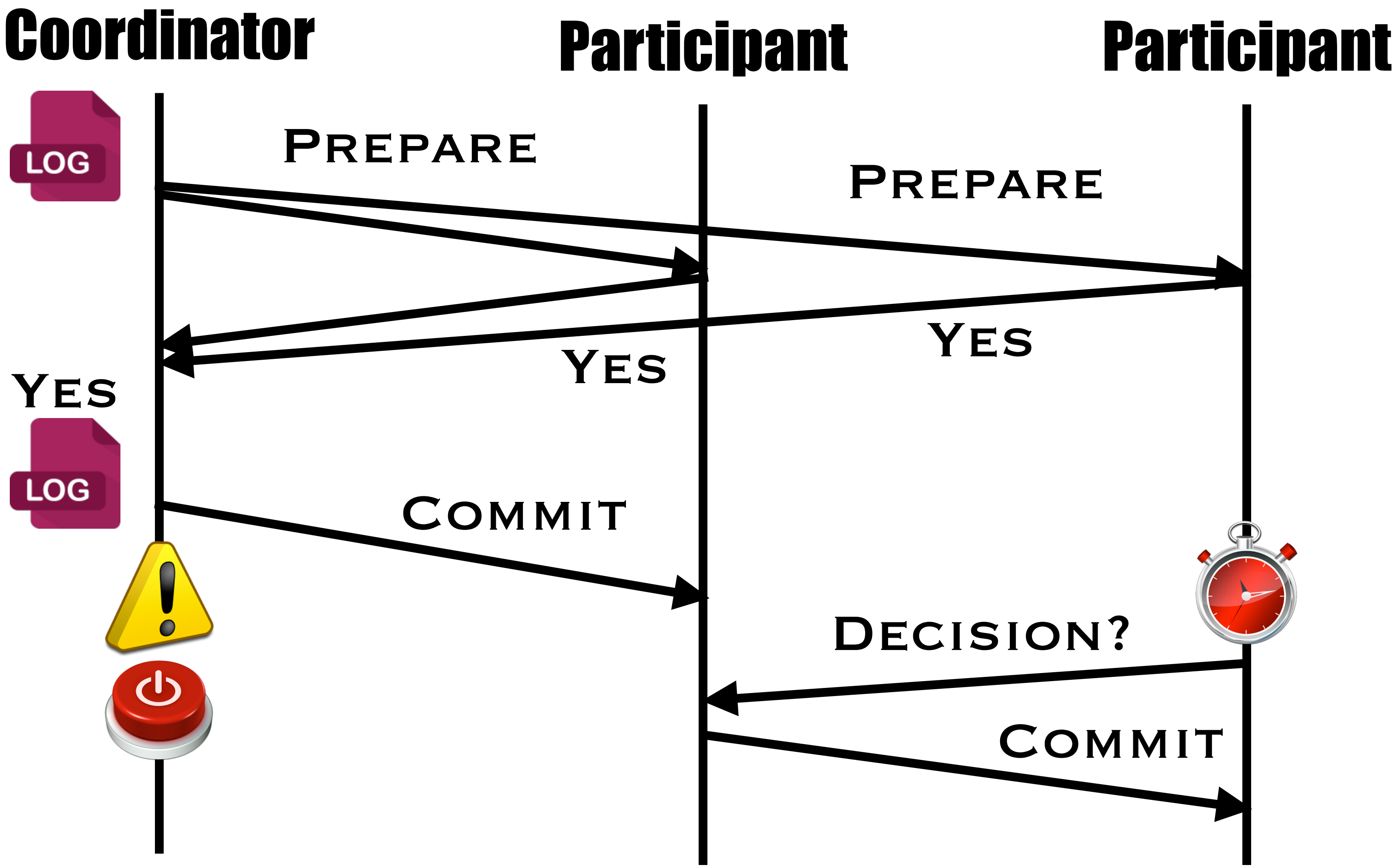
Coordinator failures: After receiving votes



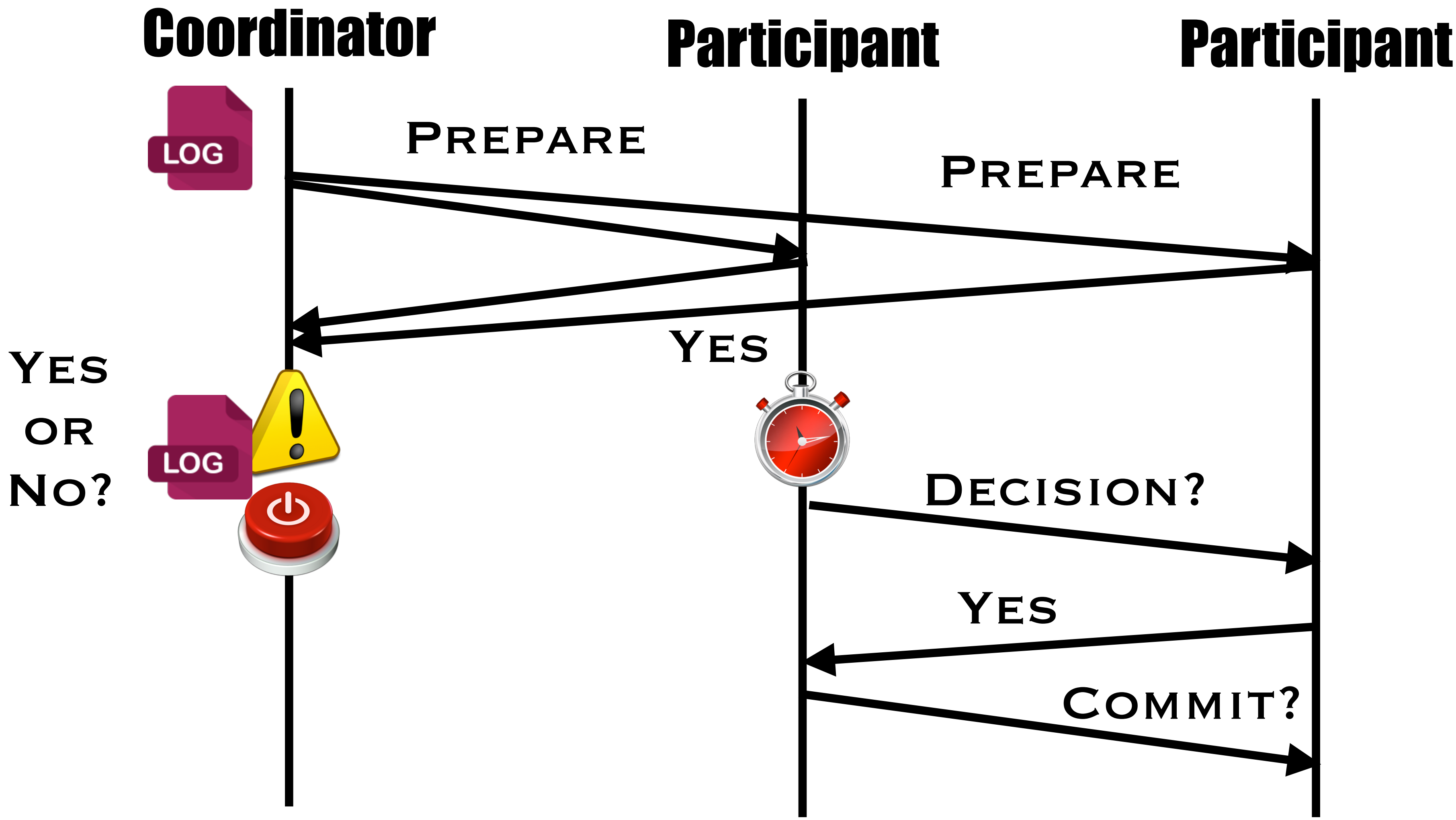
Coordinator failures: After sending decision



Do we need the coordinator?



Can the Participants Decide Amongst Themselves?



Can the Participants Decide Amongst Themselves?

- Yes, if the participants can know for certain that the coordinator has failed
- What if the coordinator is just slow?
  - Participants decide to commit!
  - Coordinator times out, declares abort!

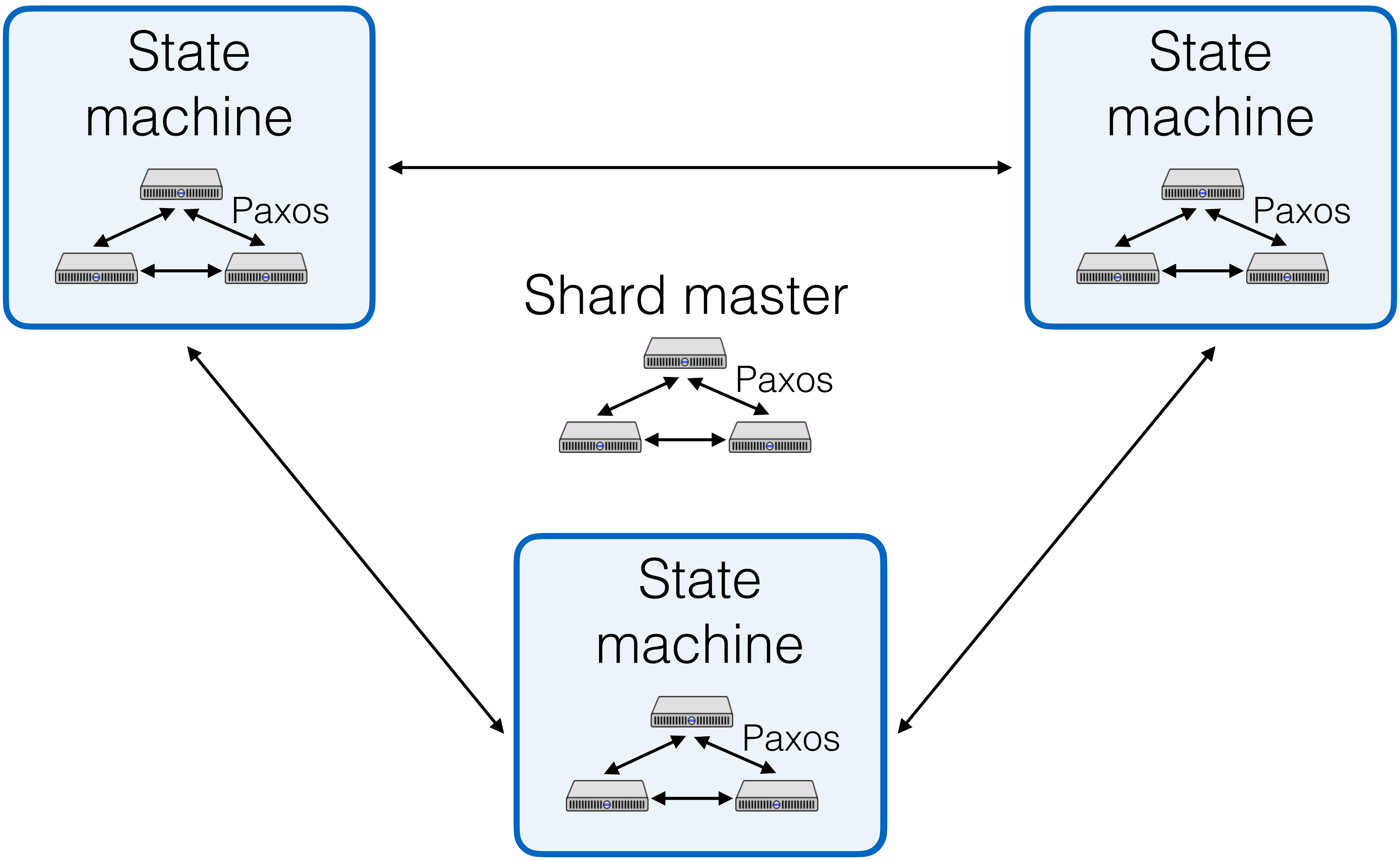
2PC is a *blocking* protocol

- A blocking protocol is one that cannot make progress if some of the participants are unavailable (either down or partitioned).
- It has fault-tolerance but not *availability*.
- This limitation is fundamental.

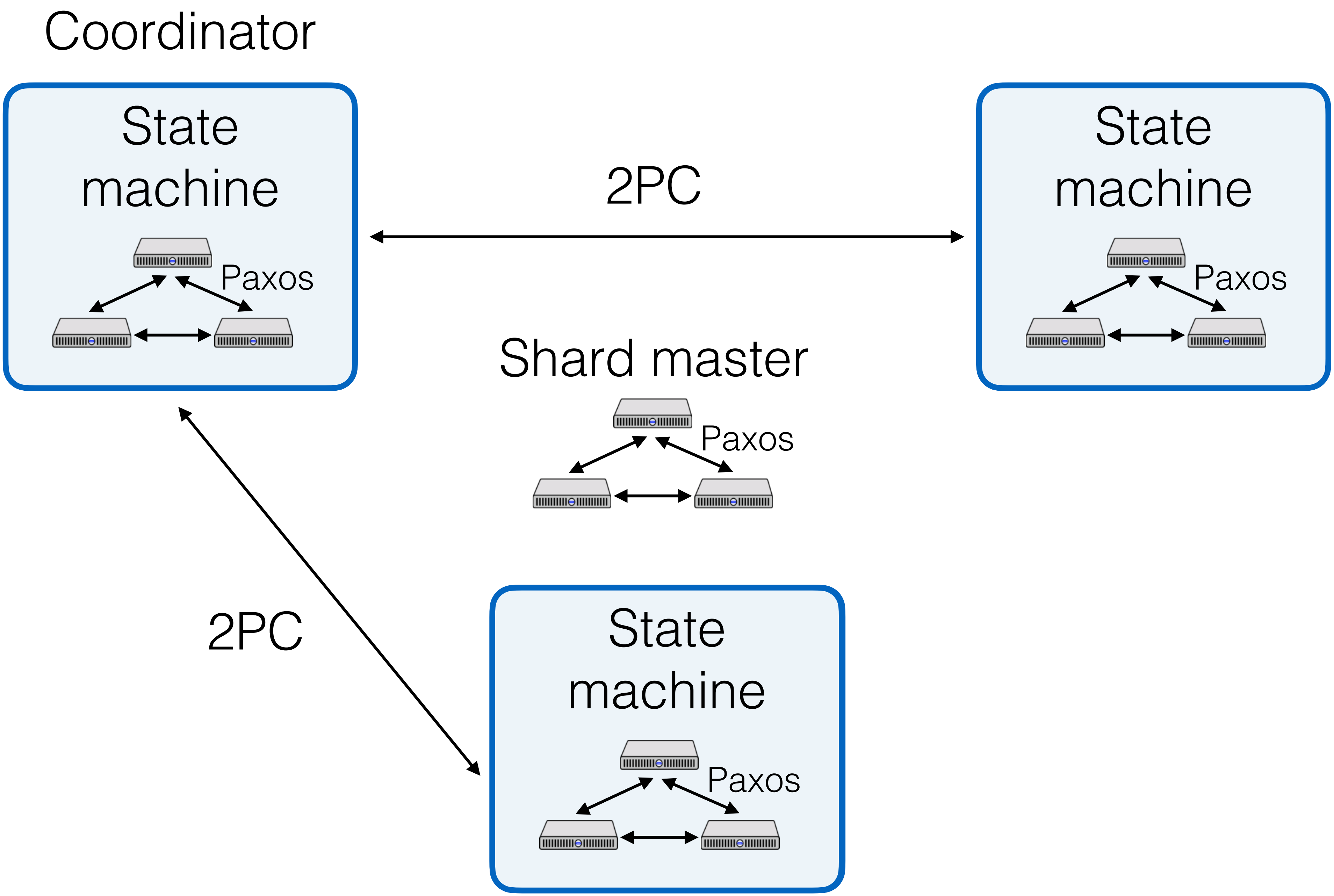
Can We Make 2PC Non-Blocking?

- Paxos is non-blocking
- We can use Paxos to update individual keys
- Can we use Paxos to update multiple keys?
    - If both are on the same shard, easy
    - What if on different shards?

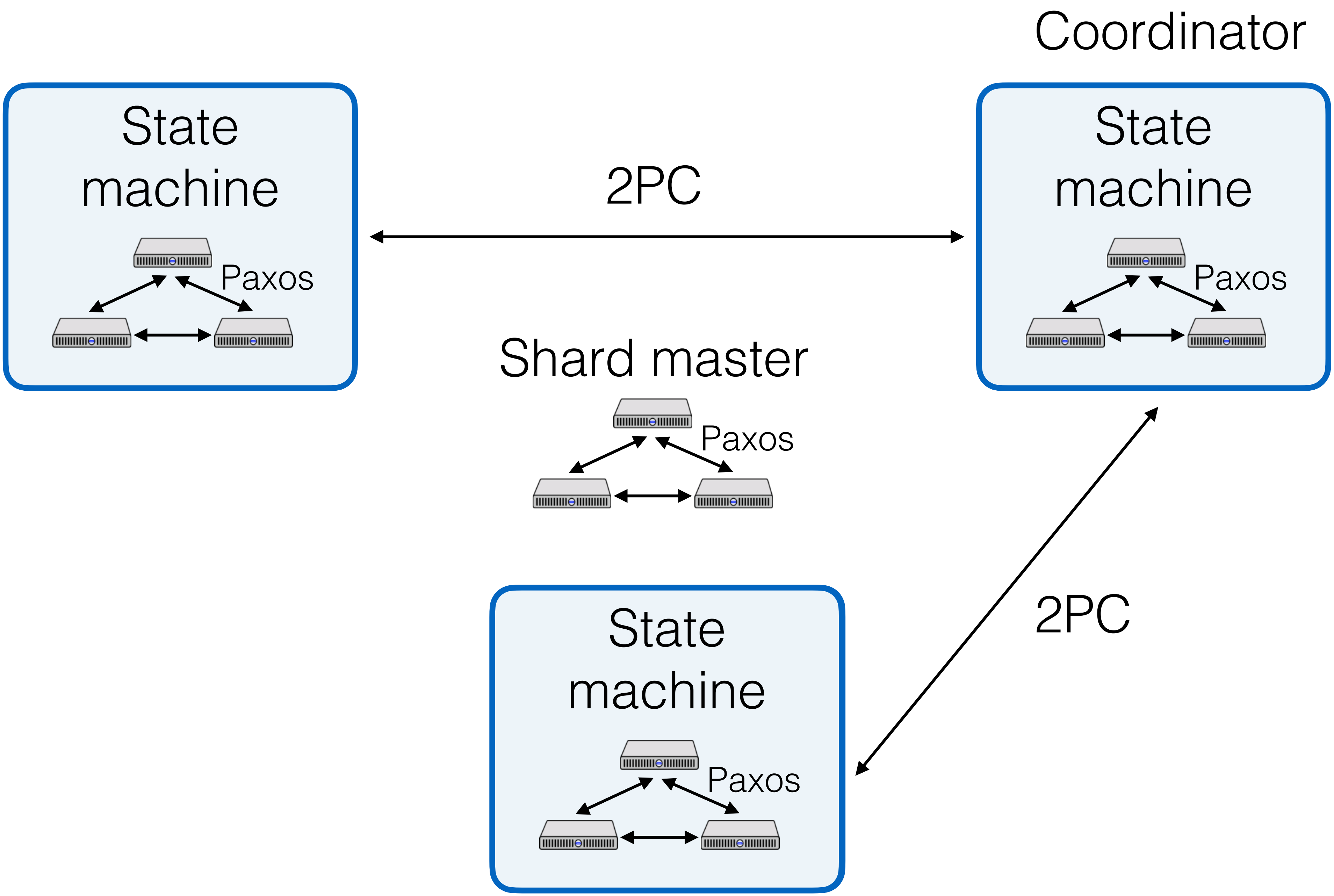
Lab 4


State machine
Paxos
State machine
Paxos
Shard master
Paxos
State machine
Paxos

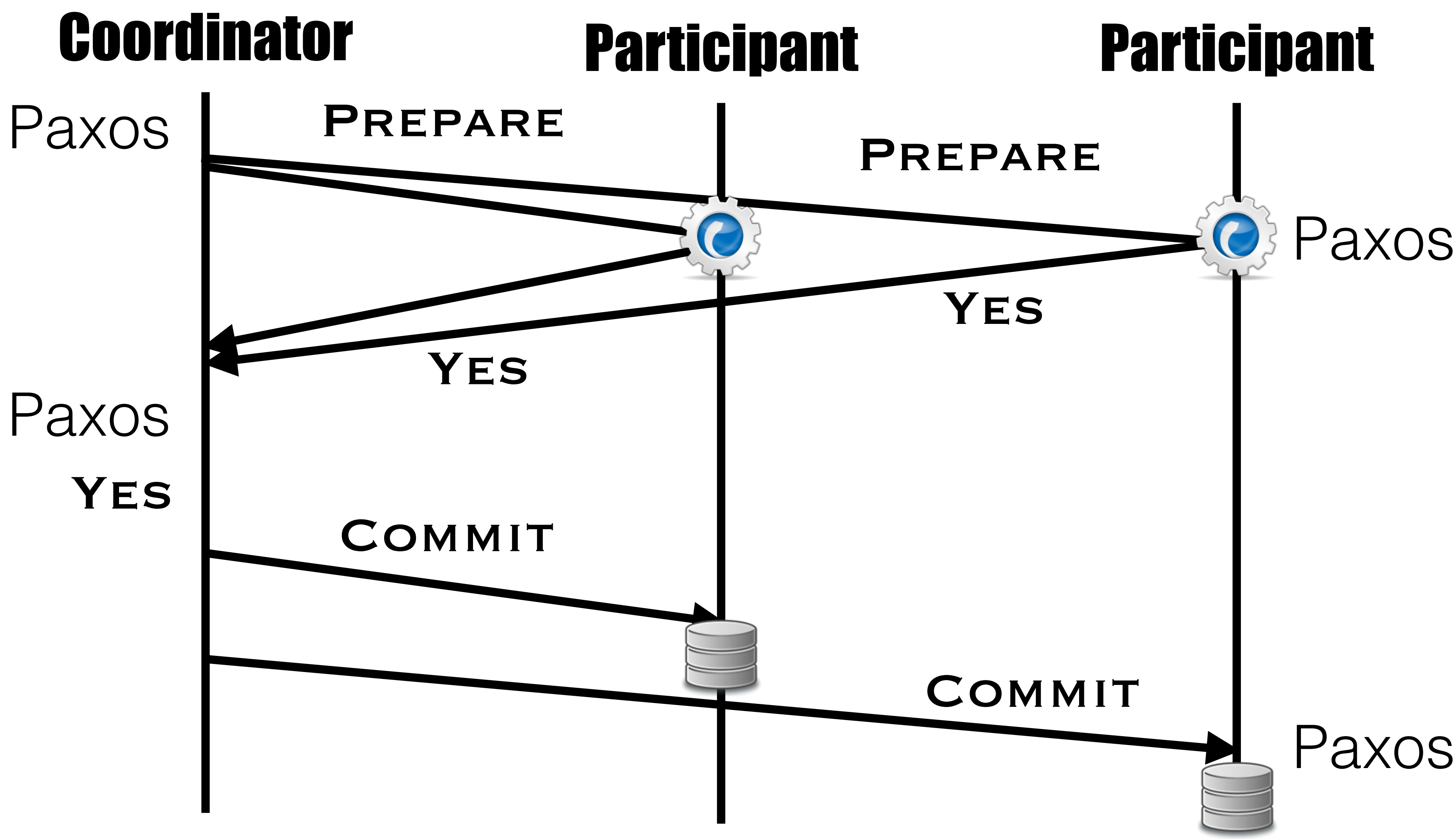
Lab 4


Coordinator
State machine
Paxos
2PC
State machine
Paxos
Shard master
Paxos
2PC
State machine
Paxos

Lab 4


Coordinator
State machine
Paxos
2PC
State machine
Paxos
Shard master
Paxos
State machine
Paxos
2PC

2PC on Paxos



Paxos: state machine replication of operation log

Two Phase Commit on Paxos

Client requests multi-key operation at coordinator

Coordinator logs request

- Paxos: available despite node failures

Coordinator sends prepare

Replicas decide to commit/abort, log result

- Paxos: available despite node failures

Coordinator collects replies, log result

- Paxos: available despite node failures

Coordinator sends commit/abort

Replicas record result

- Paxos: available despite node failures