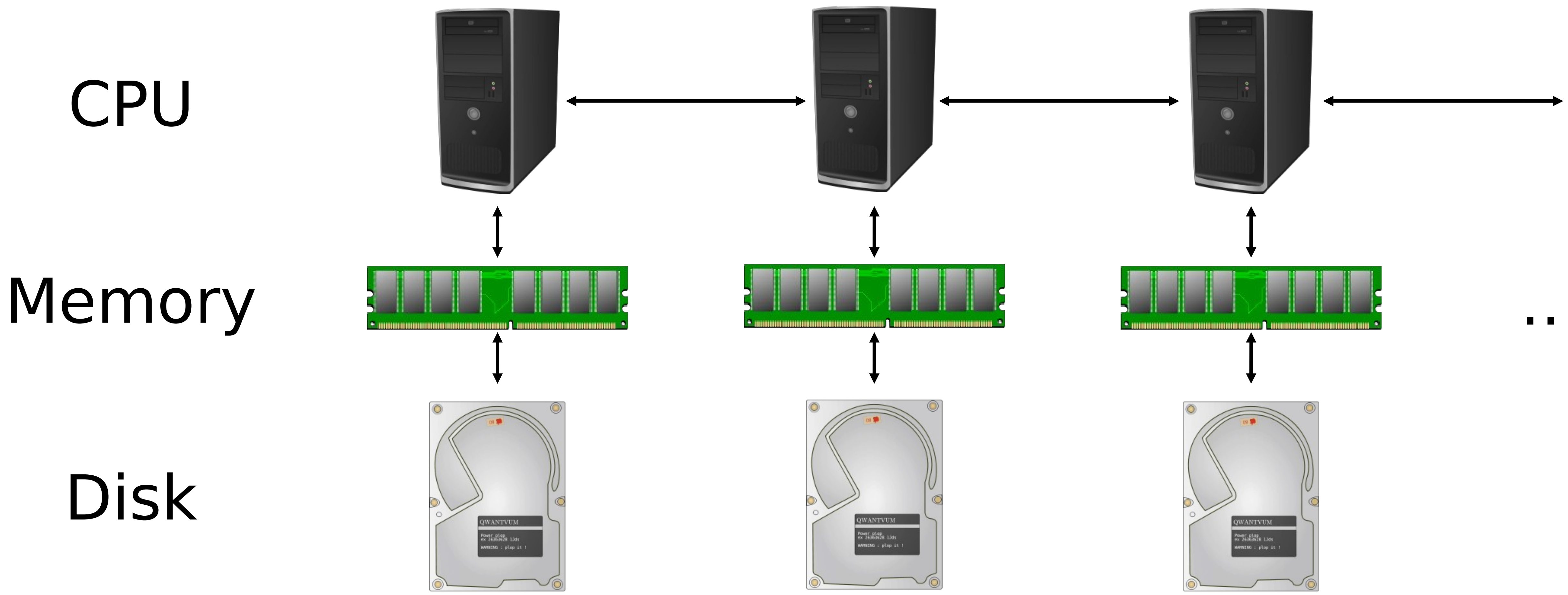
Update Parallelism

Parallelism Models

Option 4: “Shared Nothing” in which all communication is explicit.



We’ll be talking about “shared nothing” today.
Other models are easier to work with.

Data Parallelism

Replication

(needed for safety)

Partitioning

Updates

What can go wrong?

- Non-Serializable Schedules

Node 1

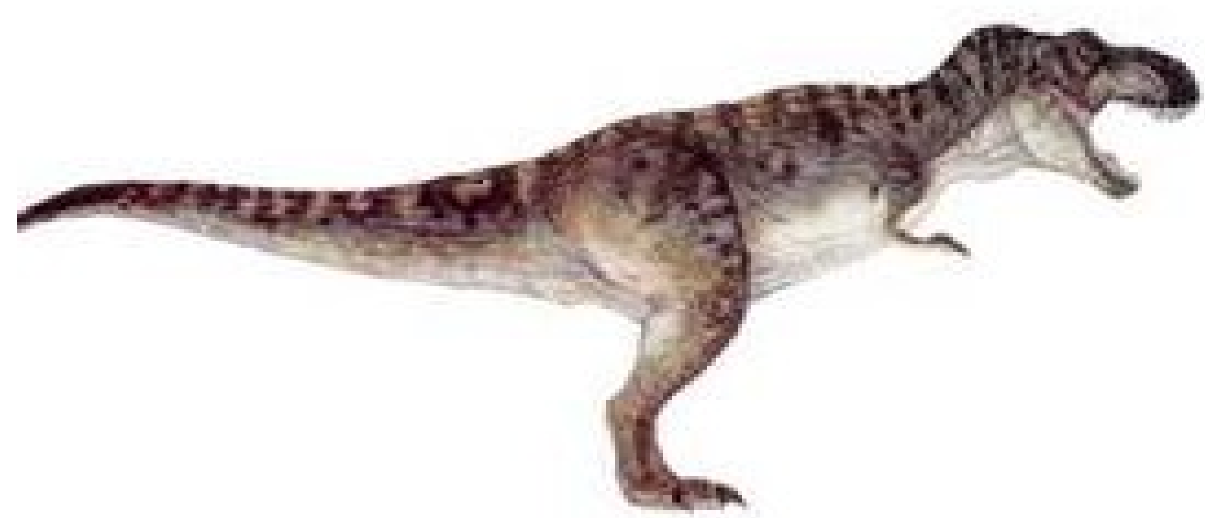
```
T1: W(X)
T2: W(X)
T2: W(Y)
T1: W(Y)
```

Updates (in Parallel)

What can go wrong?

- Non-Serializable Schedules

Node 1

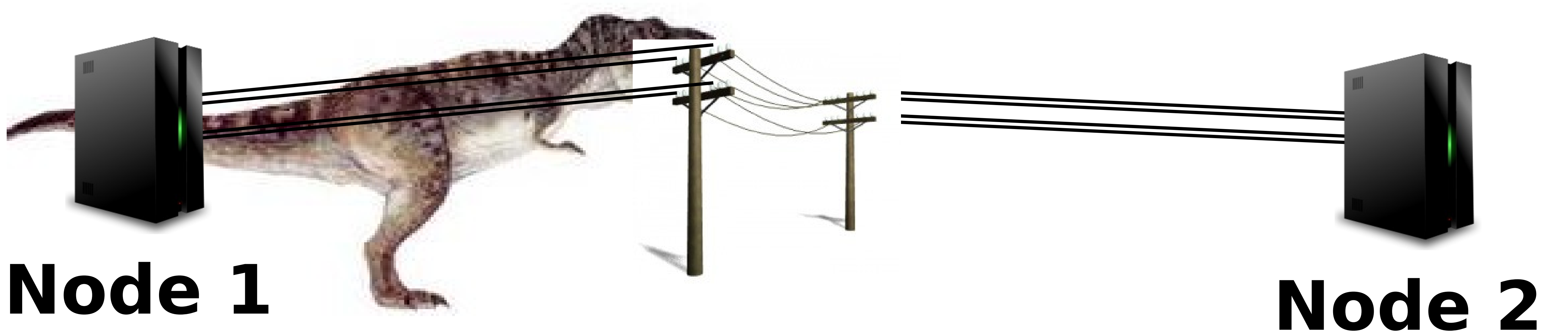


e 2

Updates (in Parallel)

What can go wrong?

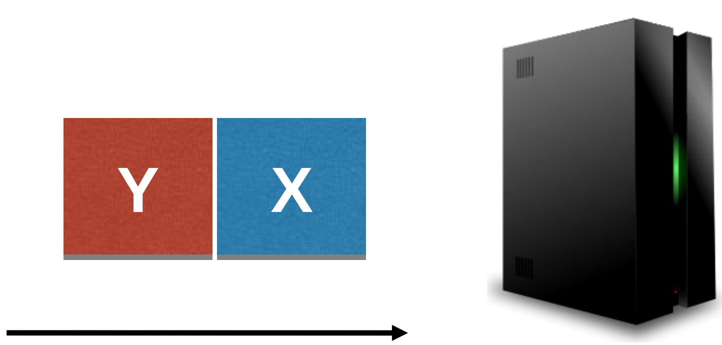
- Non-Serializable Schedules
- One Compute Node Fails



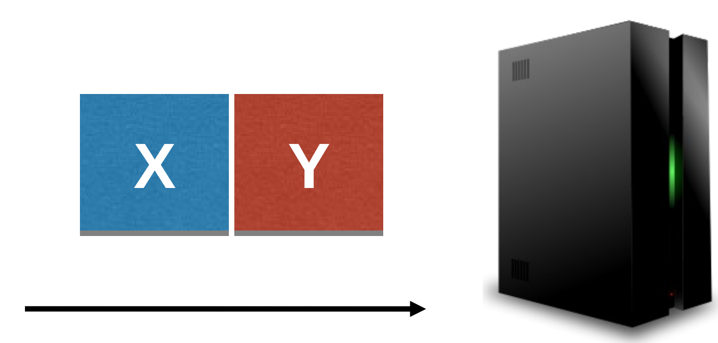
Updates (in Parallel)

What can go wrong?

- Non-Serializable Schedules
- One Compute Node Fails
- A Communication Channel Fails
- Messages delivered out-of-order



Node 1



Node 2

Updates (in Parallel)

What can go wrong?

- Non-Serializable Schedules
- One Compute Node Fails
- A Communication Channel Fails
- Messages delivered out-of-order

Classical Xacts

“Partitions”

Consensus

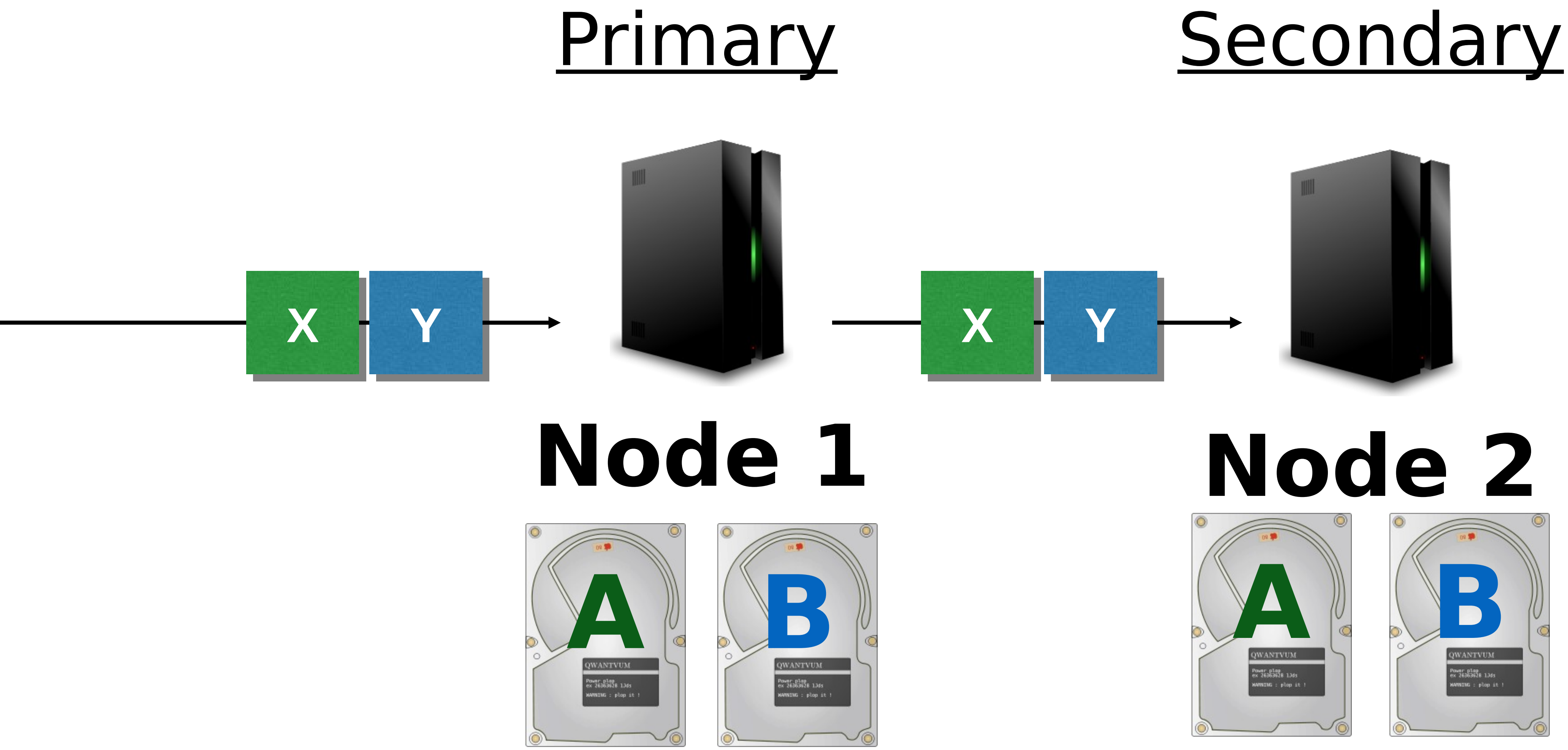
Data Parallelism

Replication

Partitioning

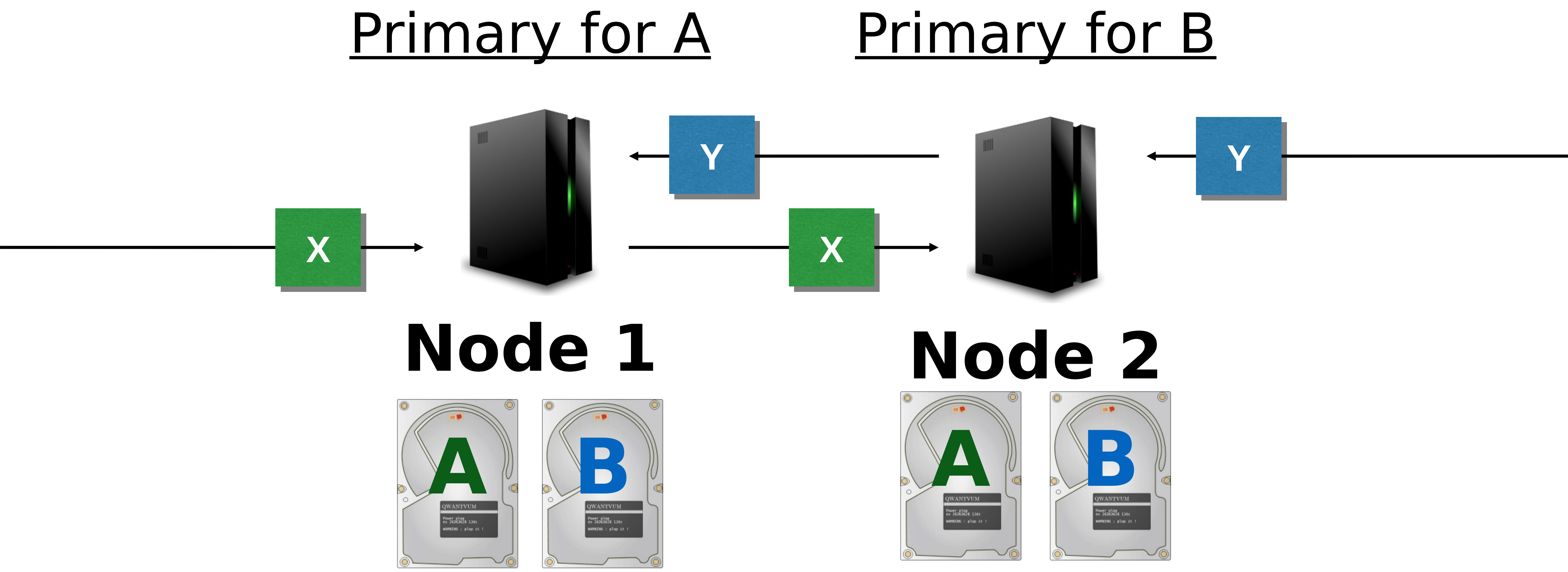
(needed for safety)

Simple Consensus



“Safe” … but Node 1 is a bottleneck.

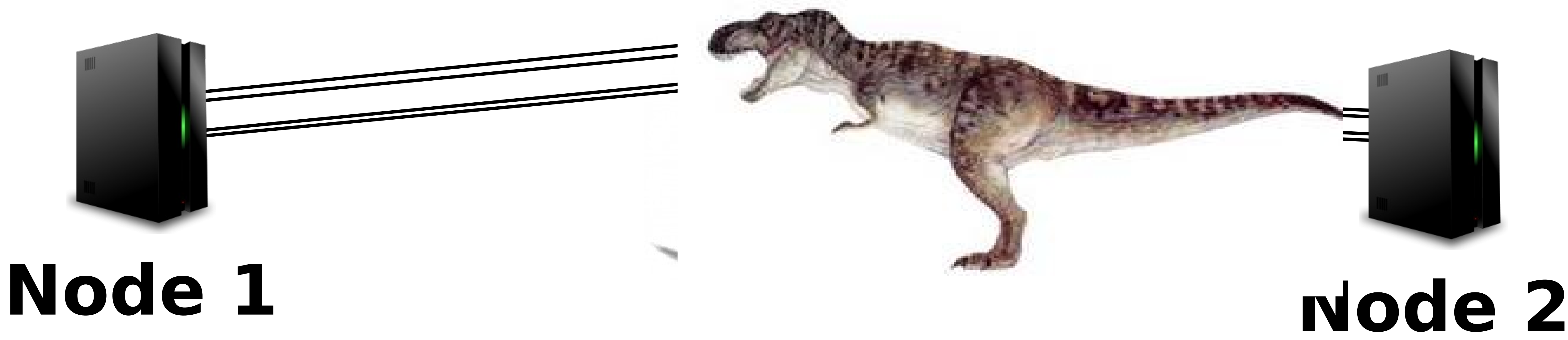
Simpl-ish Consensus



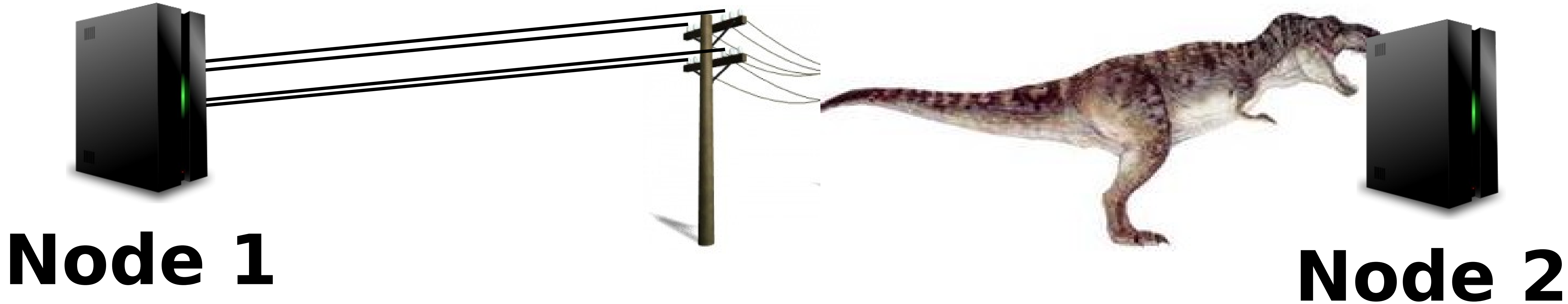
Node 2 agrees to Node 1's order for A.
Node 1 agrees to Node 2's order for B.

Partitions

Channel Failure



Node Failure

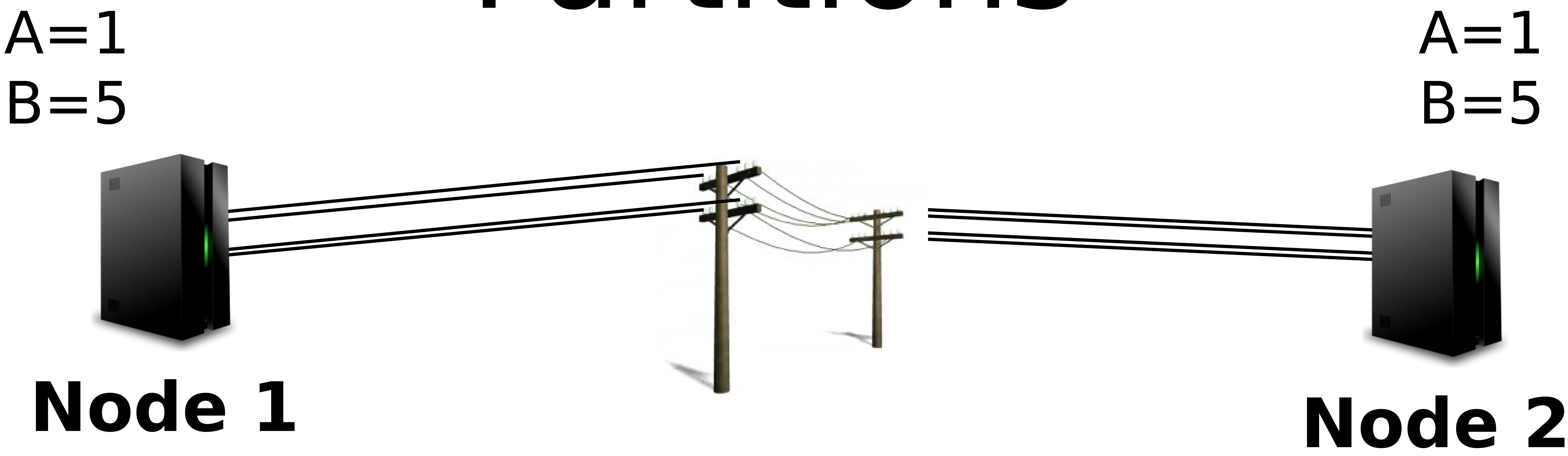


From Node 1's perspective, these are the same!

Failure Recovery

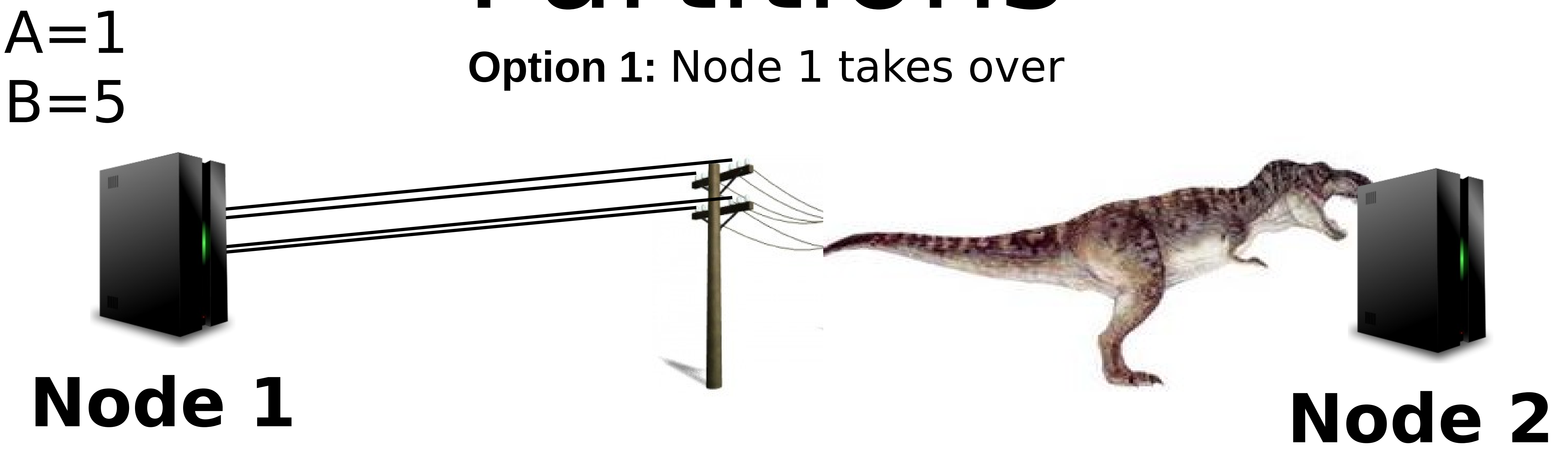
- Node Failure
  - The node restarts and resumes serving requests.
- Channel Failure
  - Node 1 and Node 2 regain connectivity.

Partitions



Partitions

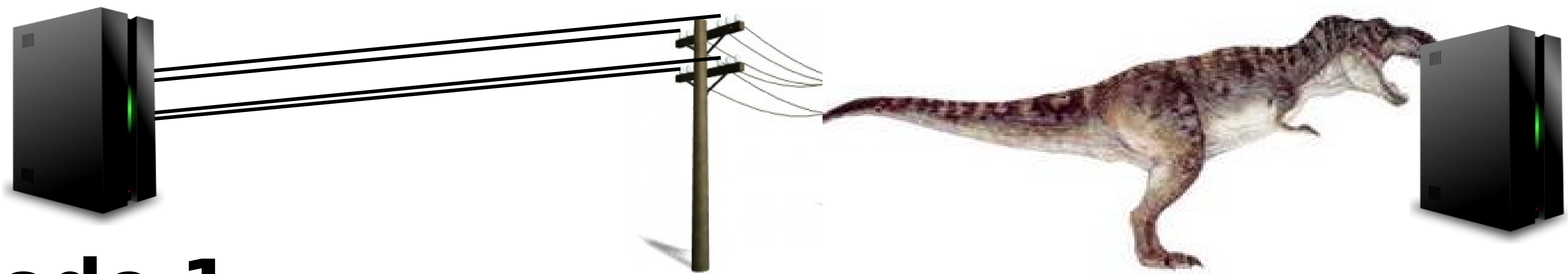
Option 1: Node 1 takes over



Partitions

Option 1: Node 1 takes over

A=1
B=5



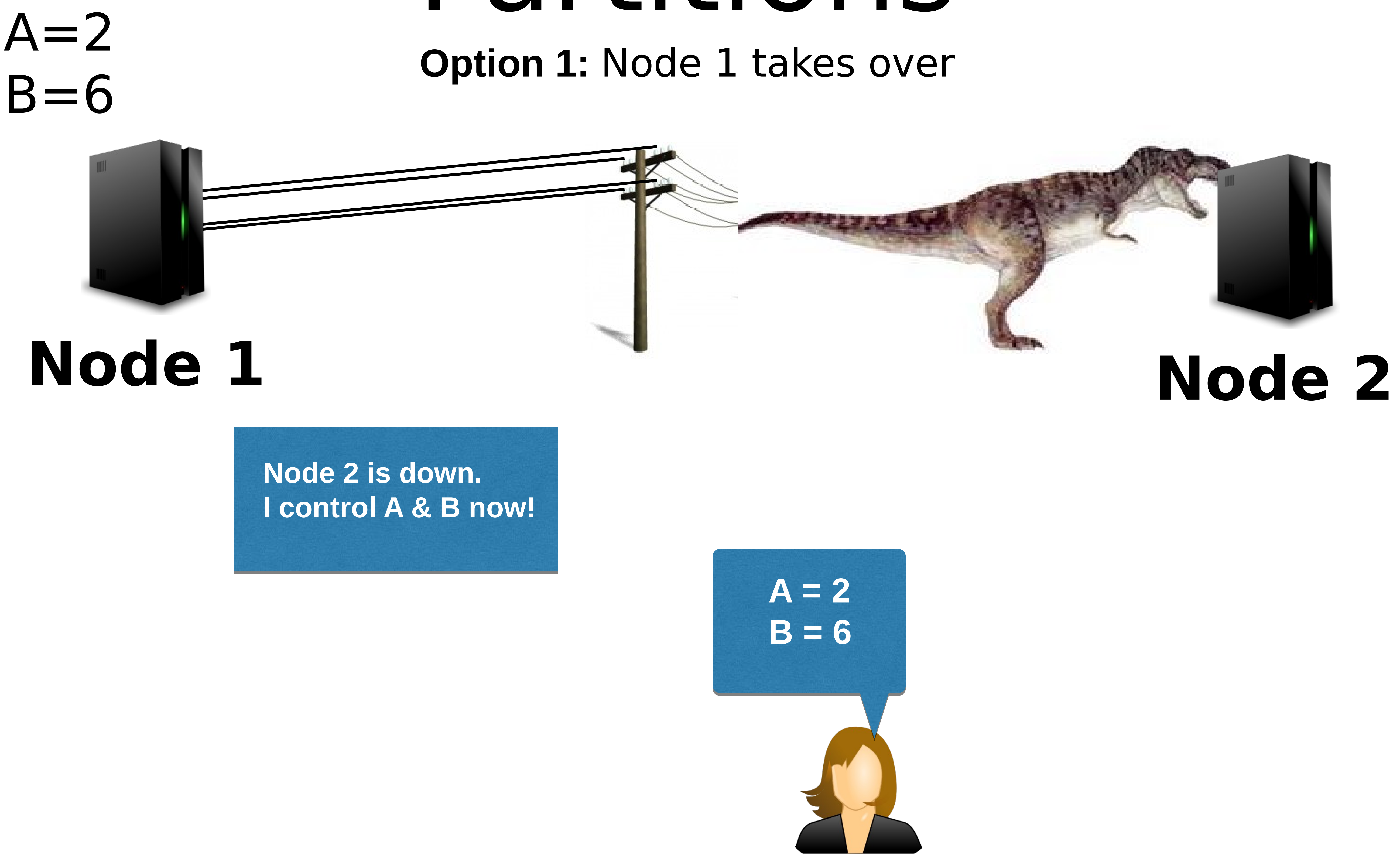
Node 1

Node 2

Node 2 is down.
I control A & B now!

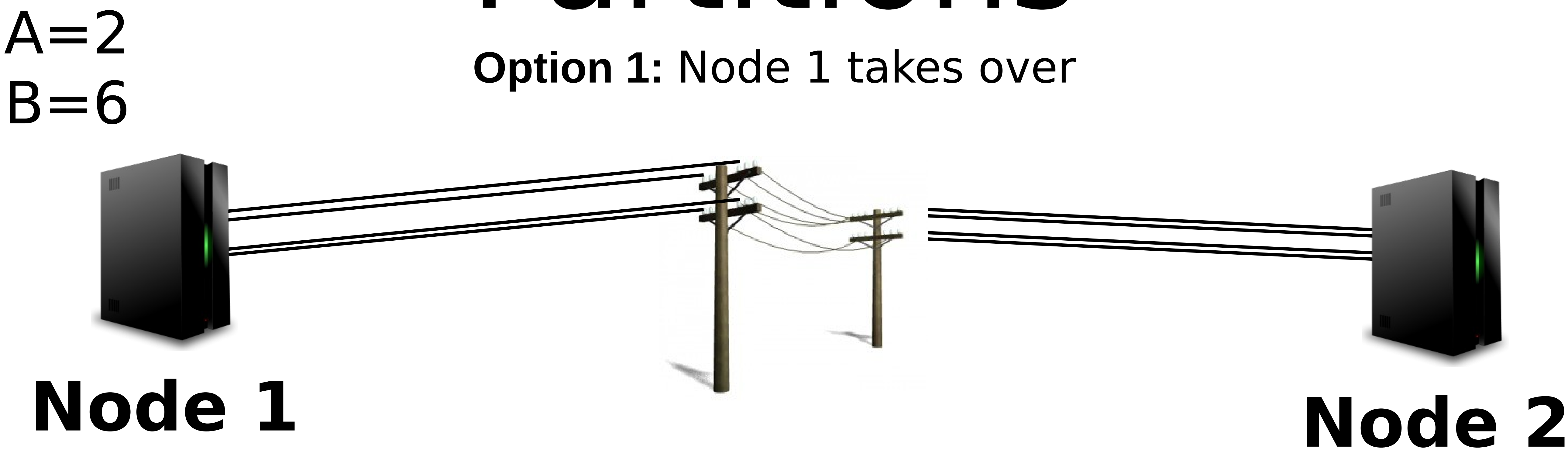
Partitions

Option 1: Node 1 takes over



Partitions

Option 1: Node 1 takes over

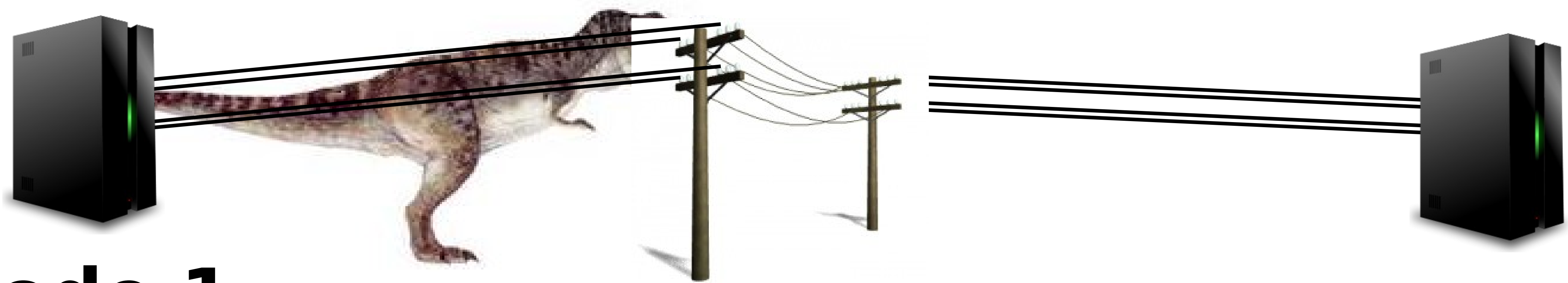


Partitions

Option 1: Node 1 takes over

A=1
B=5

A=1
B=5



Node 1

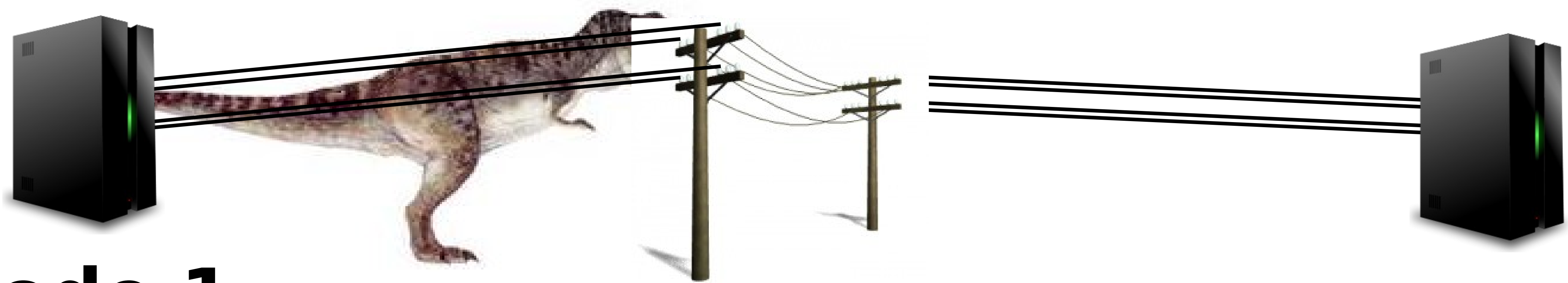
Node 2

Partitions

Option 1: Node 1 takes over

A=1
B=5

A=1
B=5



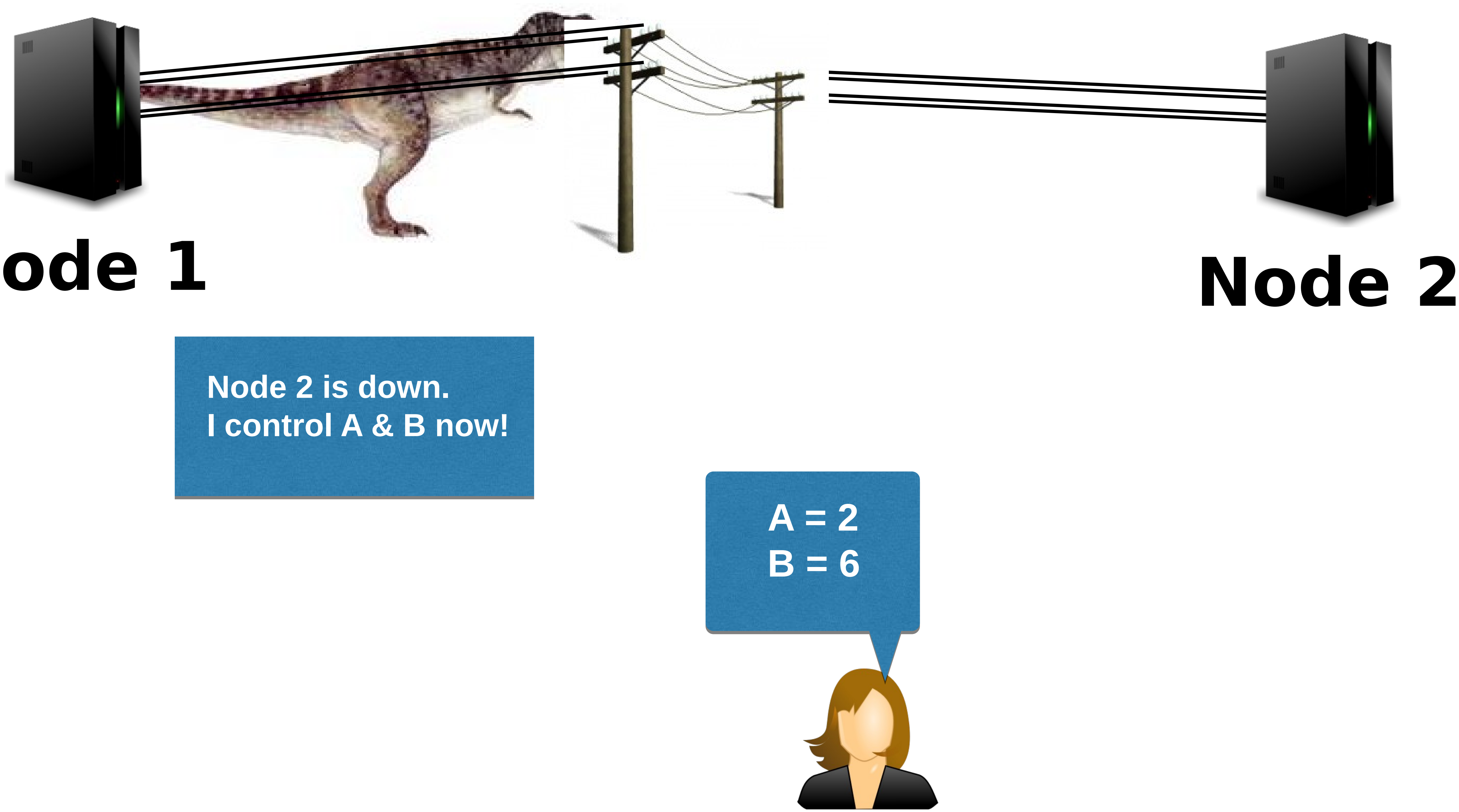
Node 1

Node 2

Node 2 is down.
I control A & B now!

Partitions

Option 1: Node 1 takes over

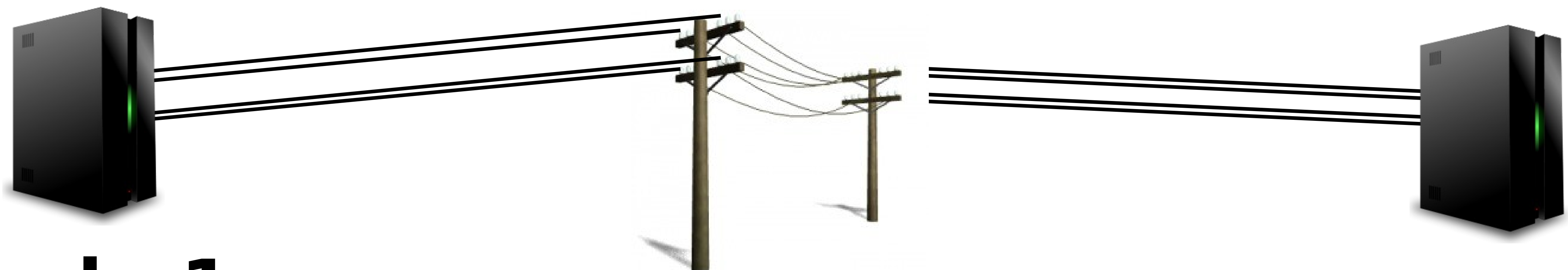


Partitions

Option 1: Node 1 takes over

A=2
B=6

A=1
B=5



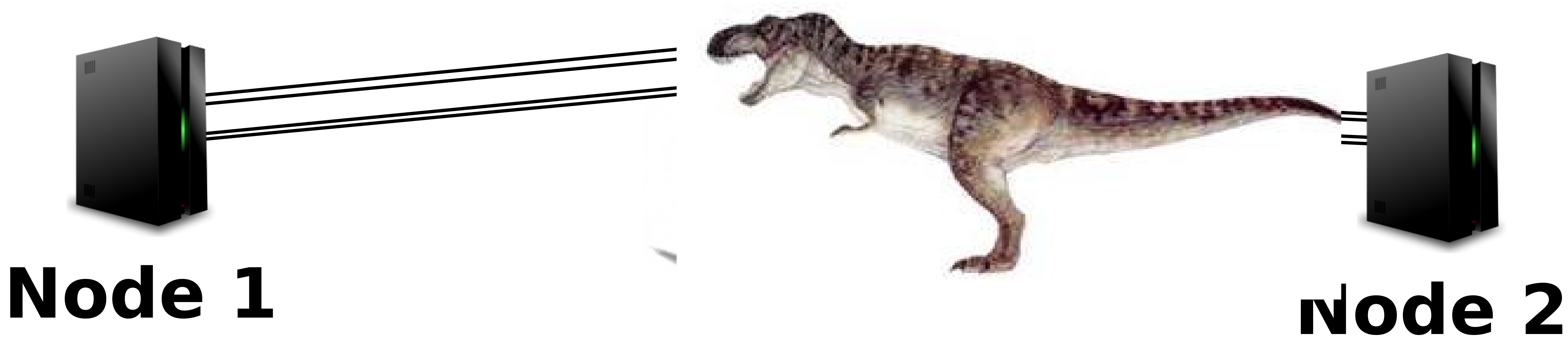
Node 1

Node 2

INCONSISTENCY!

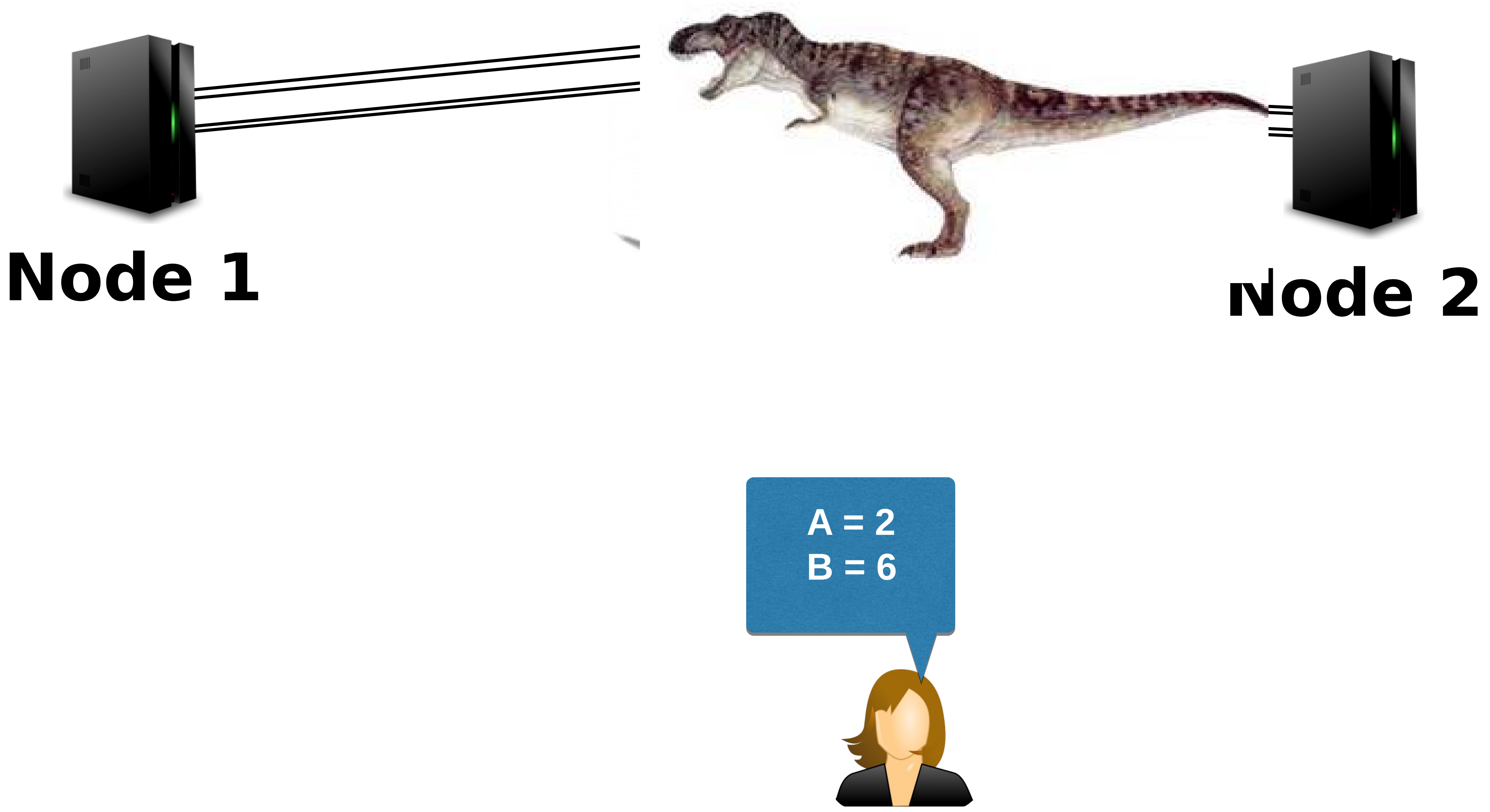
Partitions

Option 2: Wait



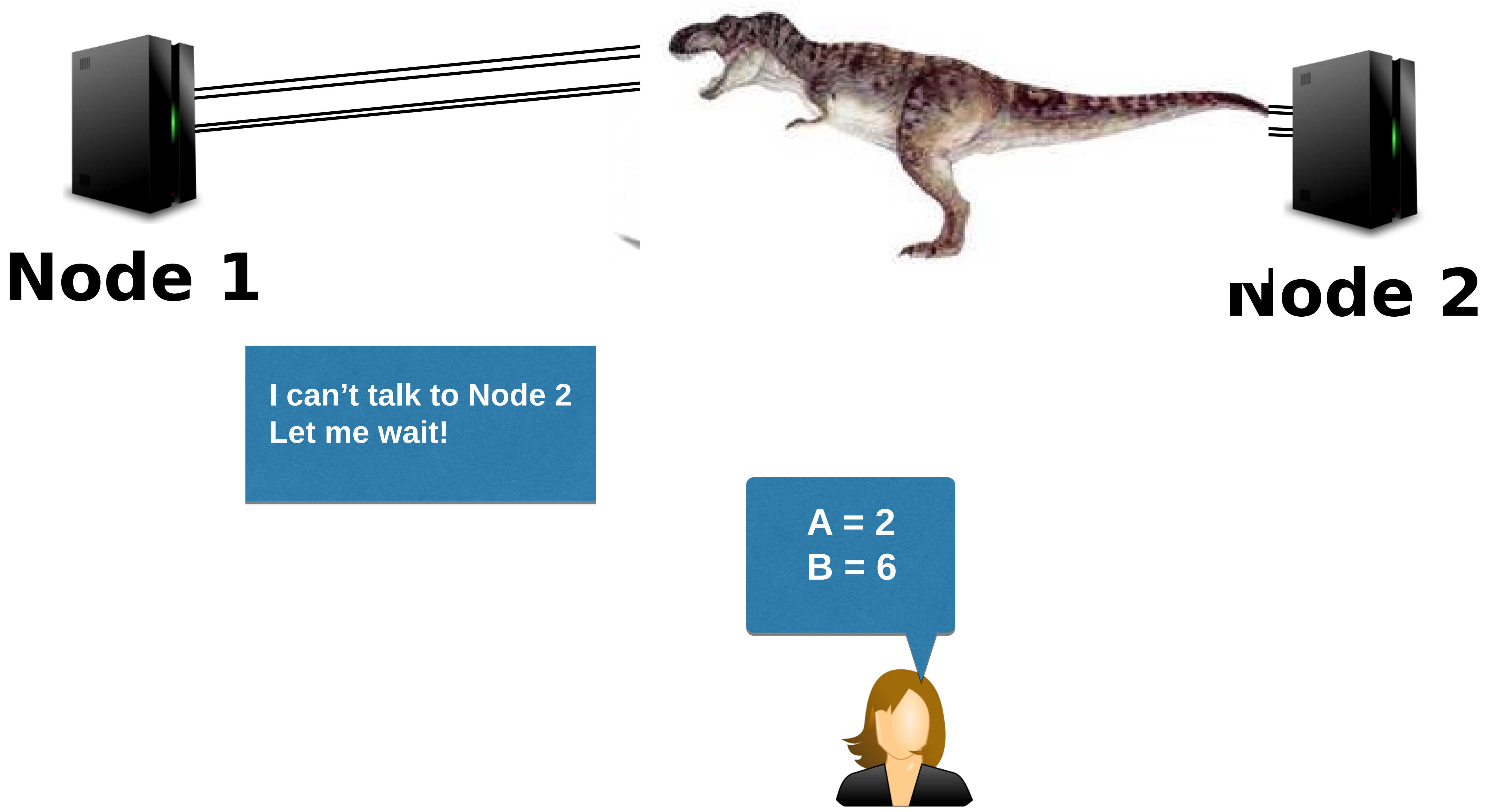
Partitions

Option 2: Wait



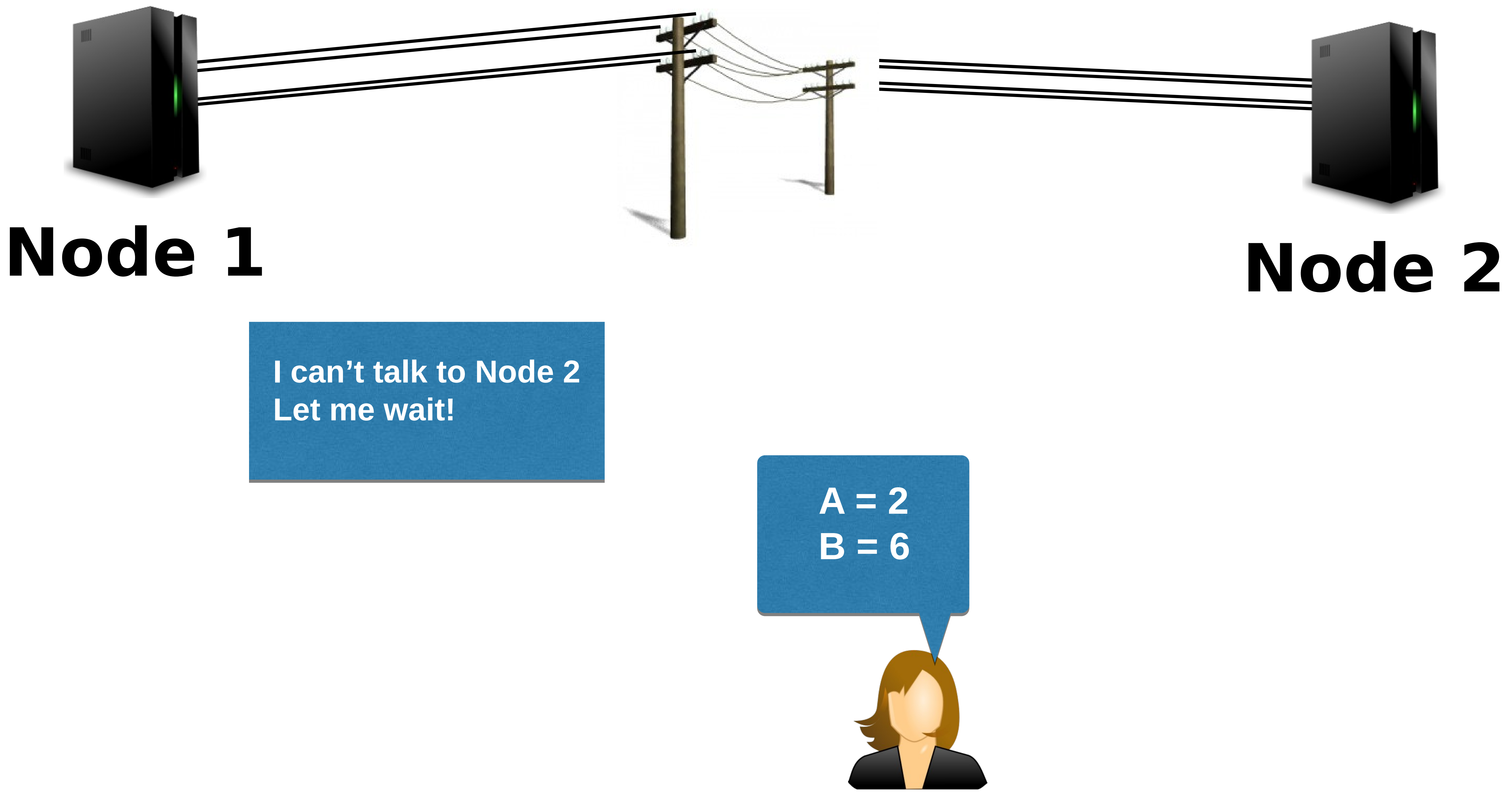
Partitions

Option 2: Wait



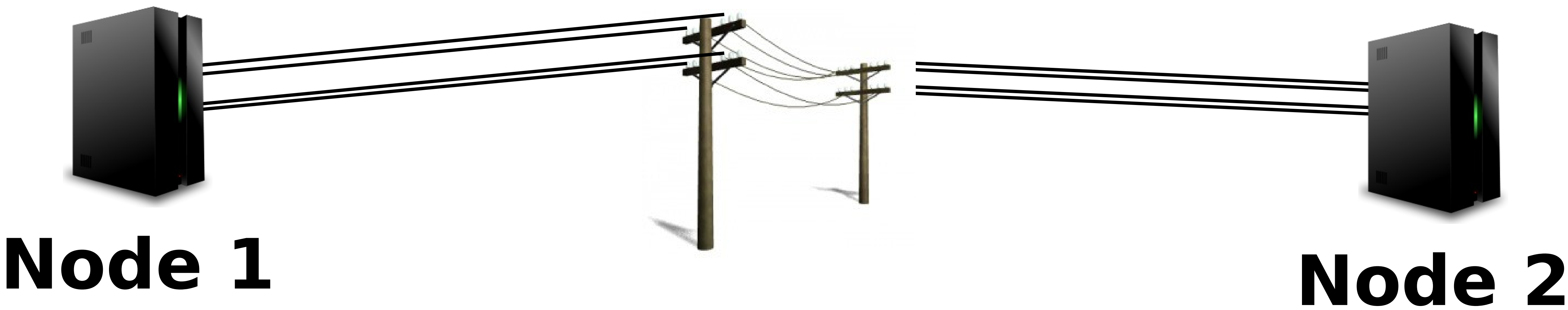
Partitions

Option 2: Wait



Partitions

Option 2: Wait



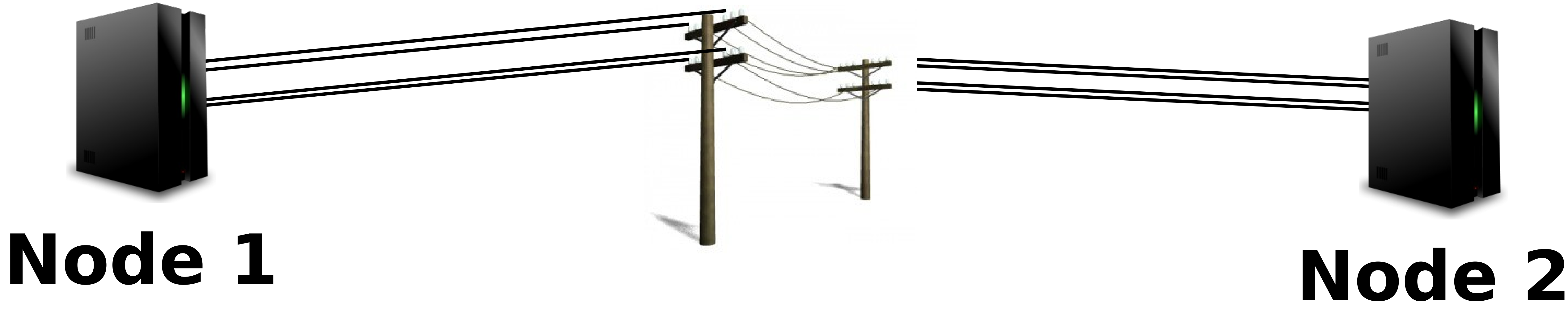
I can't talk to Node 2
Let me wait!

All
set

A = 2
B = 6

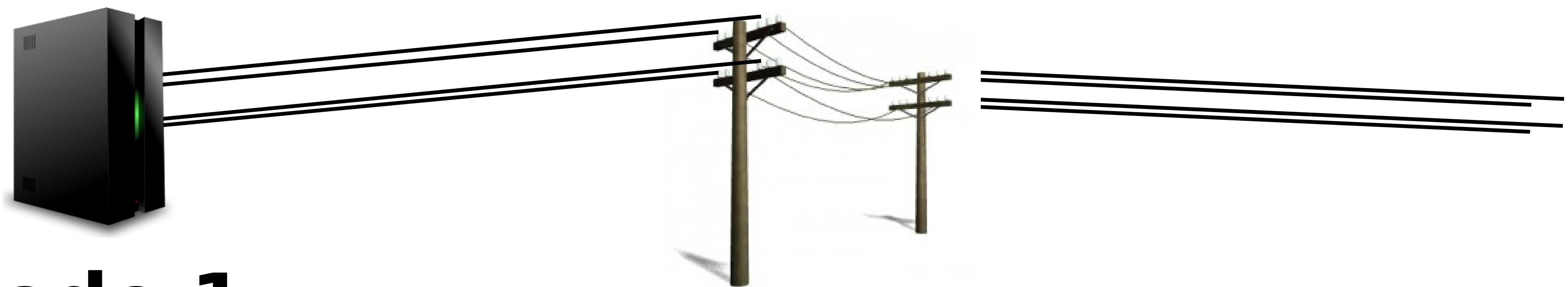
Partitions

Option 2: Wait



Partitions

Option 2: Wait



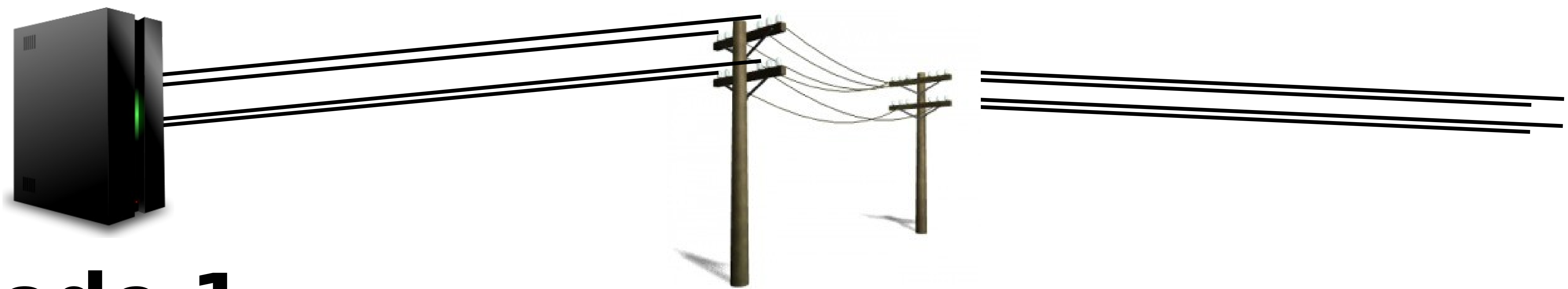
Node 1

I can’t talk to Node 2
Let me wait!

A = 2
B = 6

Partitions

Option 2: Wait



Node 1

I can't talk to Node 2
Let me wait!

Still
waiting…

A = 2
B = 6

Partitions

Option 1: Assume Node Failure

All data is available… but at risk of inconsistency.

Option 2: Assume Connection Failure

All data is consistent… but unavailable

C A P

Consistency or Availability or Partition Tolerance

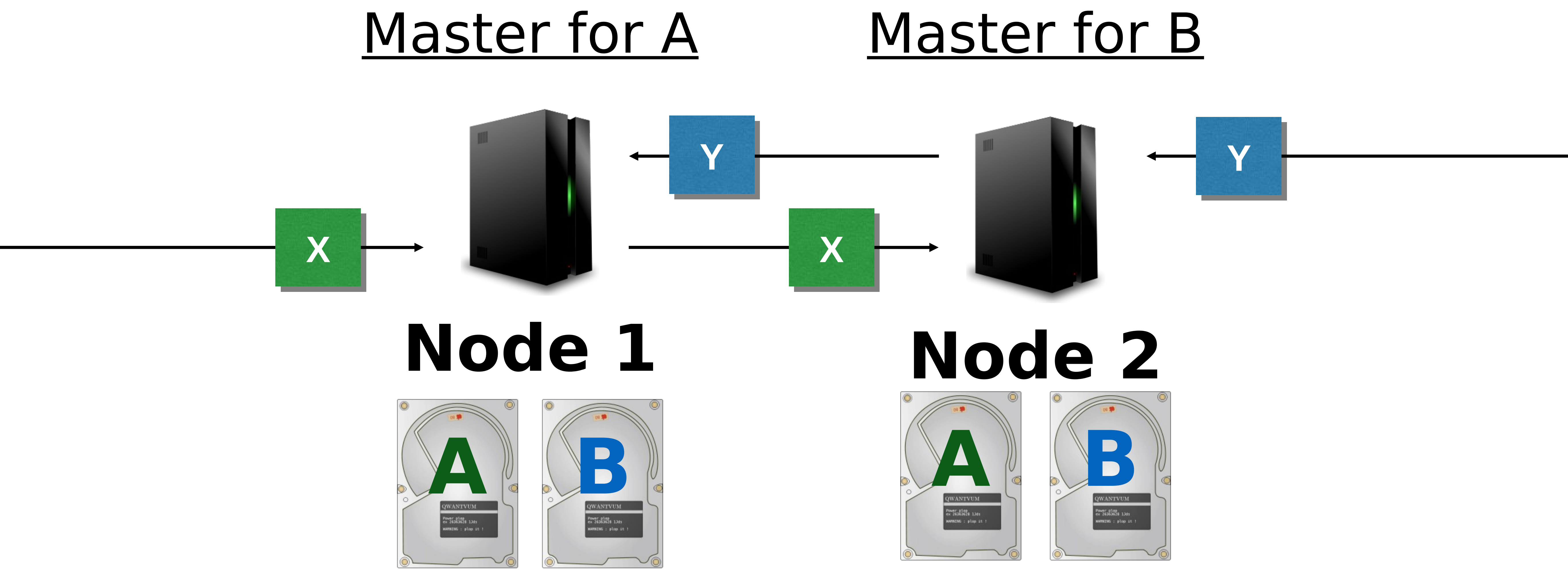
Traditionally: Pick any 2

C A P

Consistency **or** Availability **during** Partitions

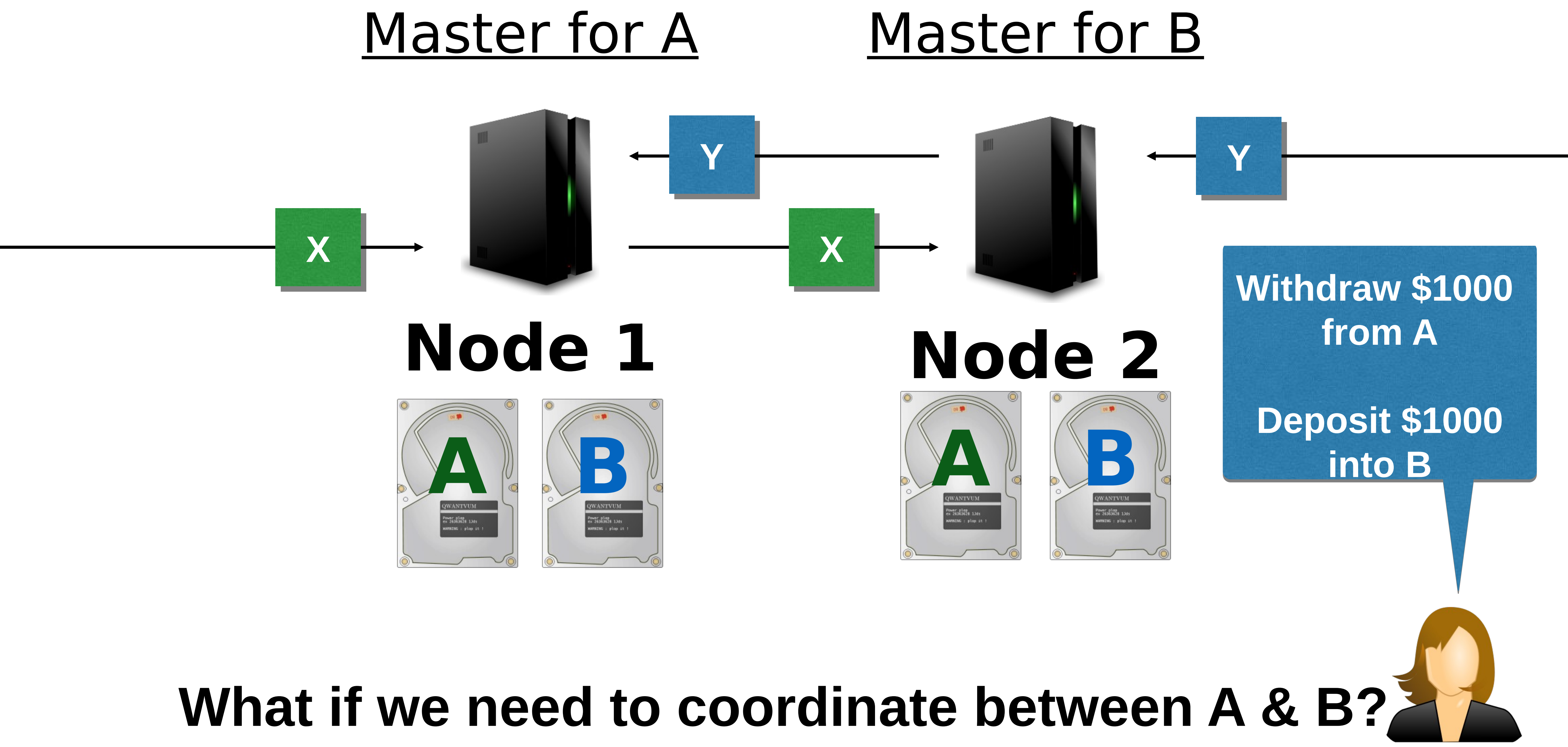
I prefer this phrasing

Simpl-ish Consensus



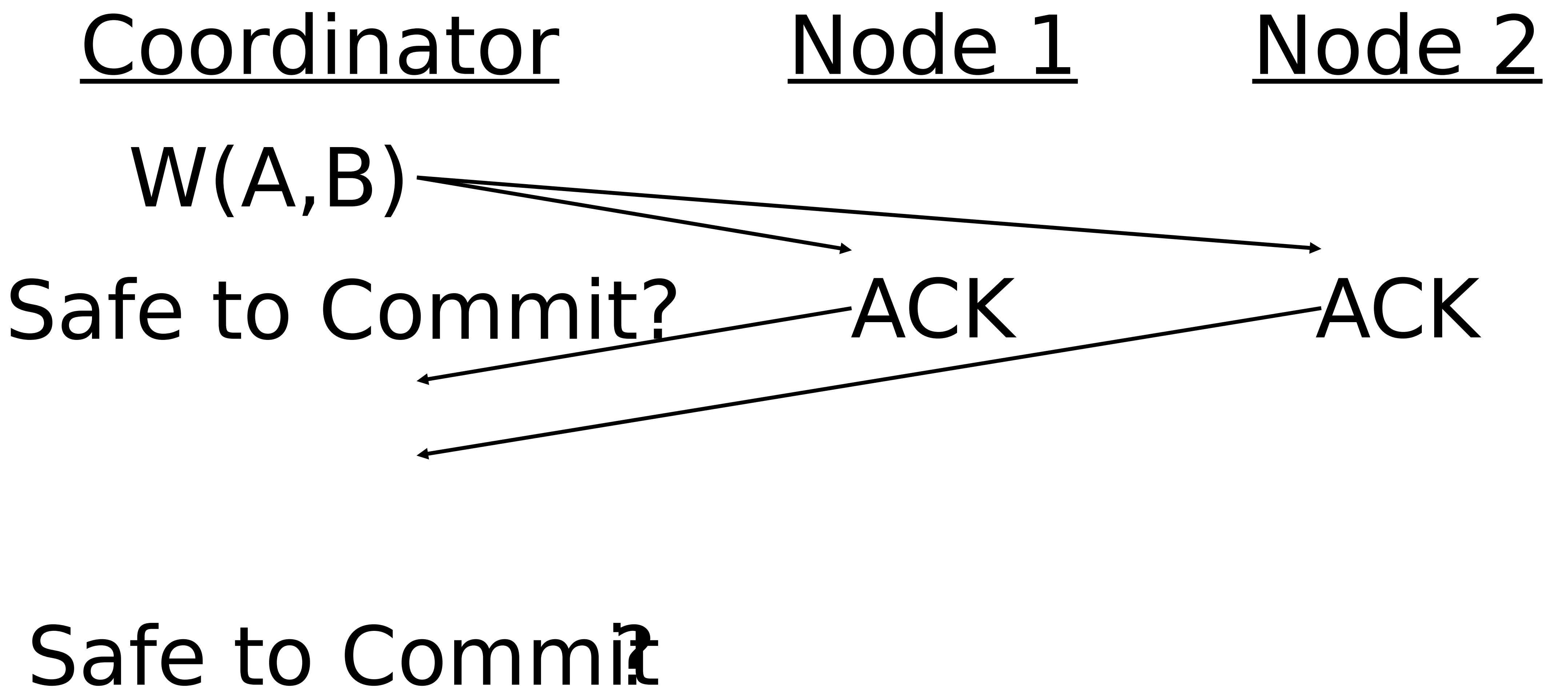
Node 2 agrees to Node 1’s order for A.
Node 1 agrees to Node 2’s order for B.

Simpl-ish Consensus



What if we need to coordinate between A & B?

Naive Commit



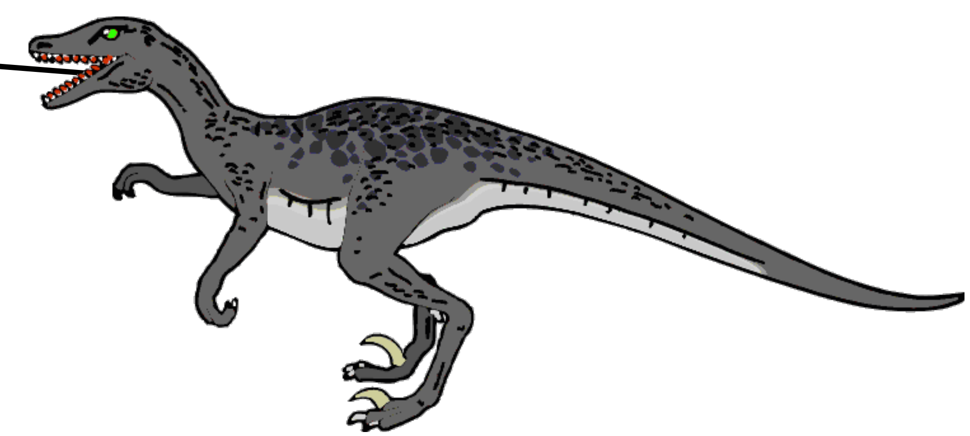
That packet sure does look tasty…

Naive Commit

Coordinator   Node 1   Node 2

W(A,B)

ACK



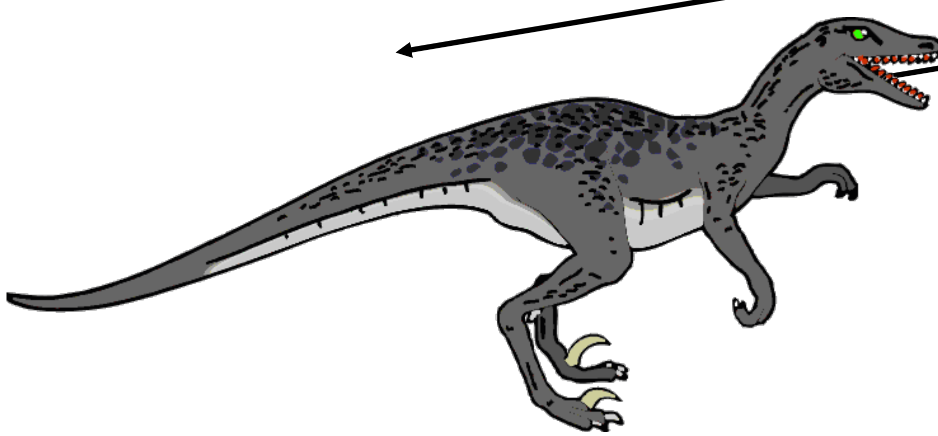
Is it safe to abort?

Naive Commit

Coordinator | Node 1 | Node 2

W(A,B)

ACK ACK

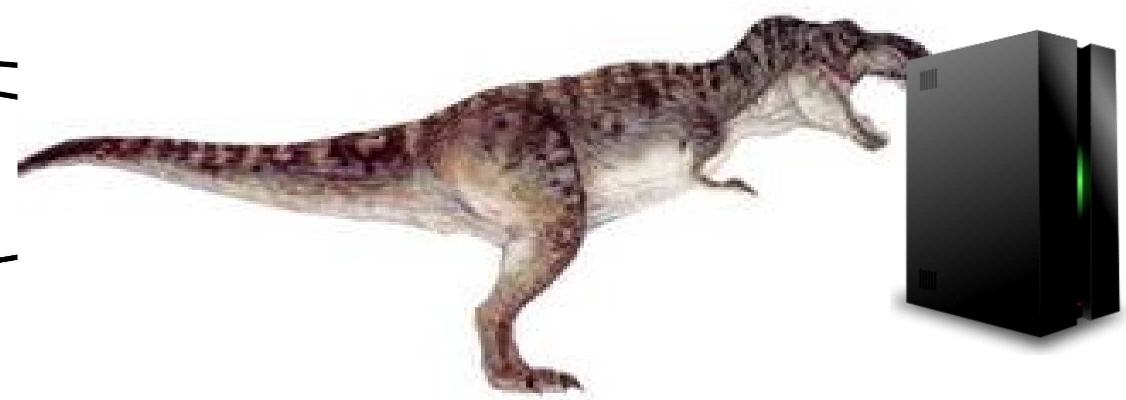


What now?

Naive Commit

Coordinator Node 1 Node 2

W(A)



How do we know Node 2 even still exists?

2-Phase Commit

- One site selected as a coordinator.
  - Initiates the 2-phase commit process.
- Remaining sites are subordinates.
- Only one coordinator per xact.
  - Different xacts may have different coordinators.

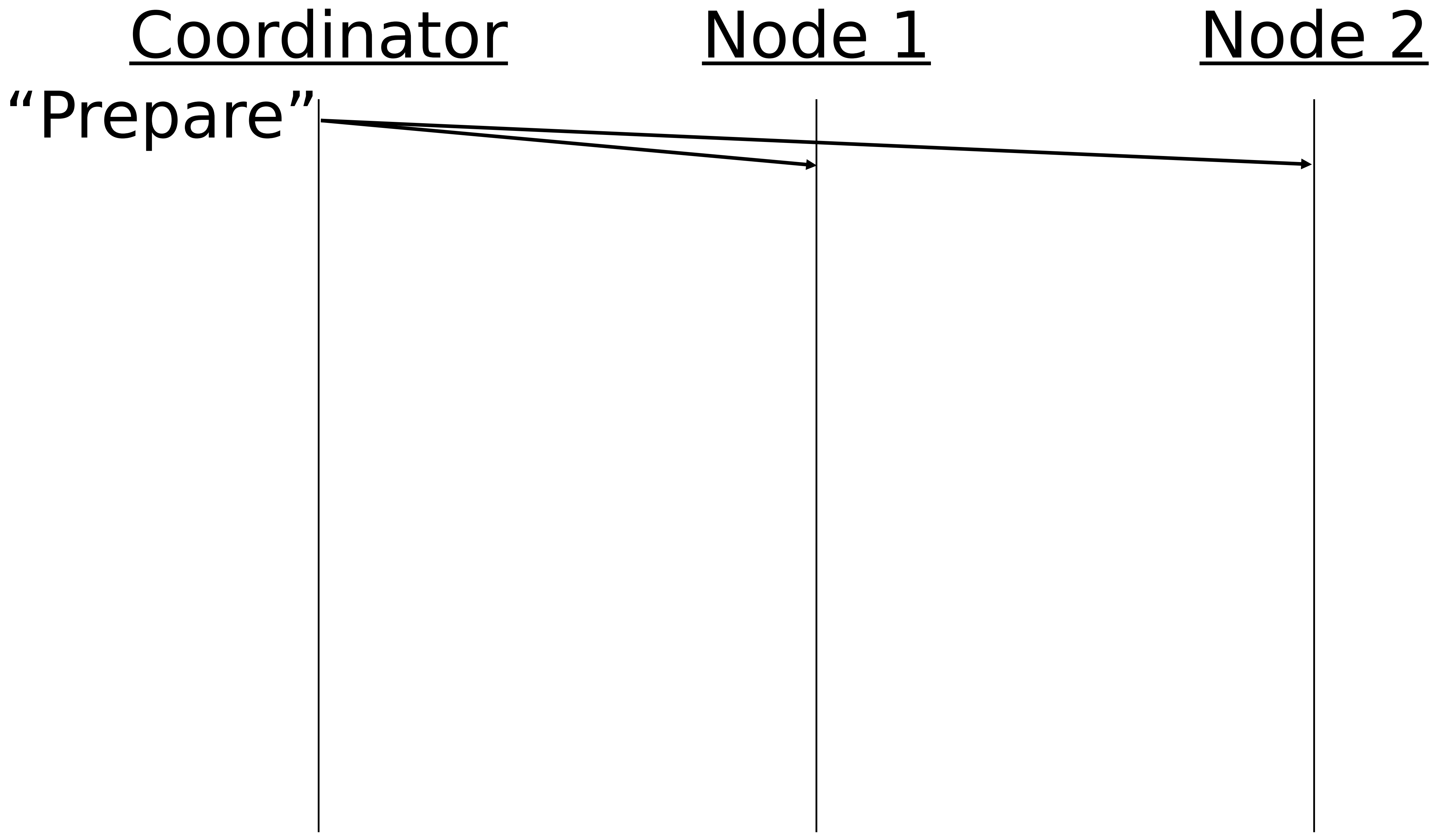
Assumptions

- Undo/Redo Logging at Participants
  - Participants can Abort an Xact at any time
  - Participants can recover from a crash
- Redo Logging at Coordinator
  - Coordinator can recover from a crash
- All logs replicated (to recover from hard failures)

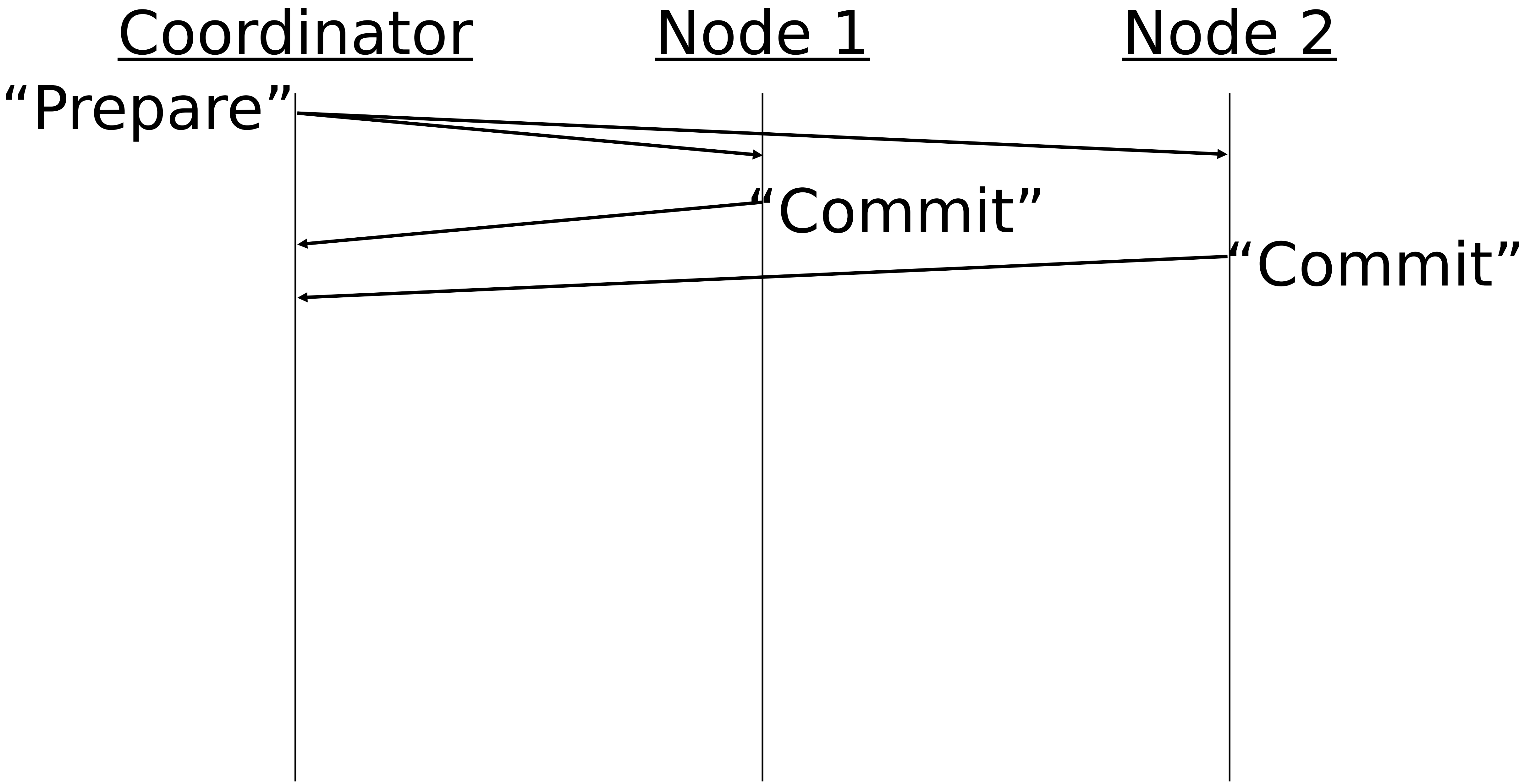
Phase 1 - Prepare

Coordinator | Node 1 | Node 2

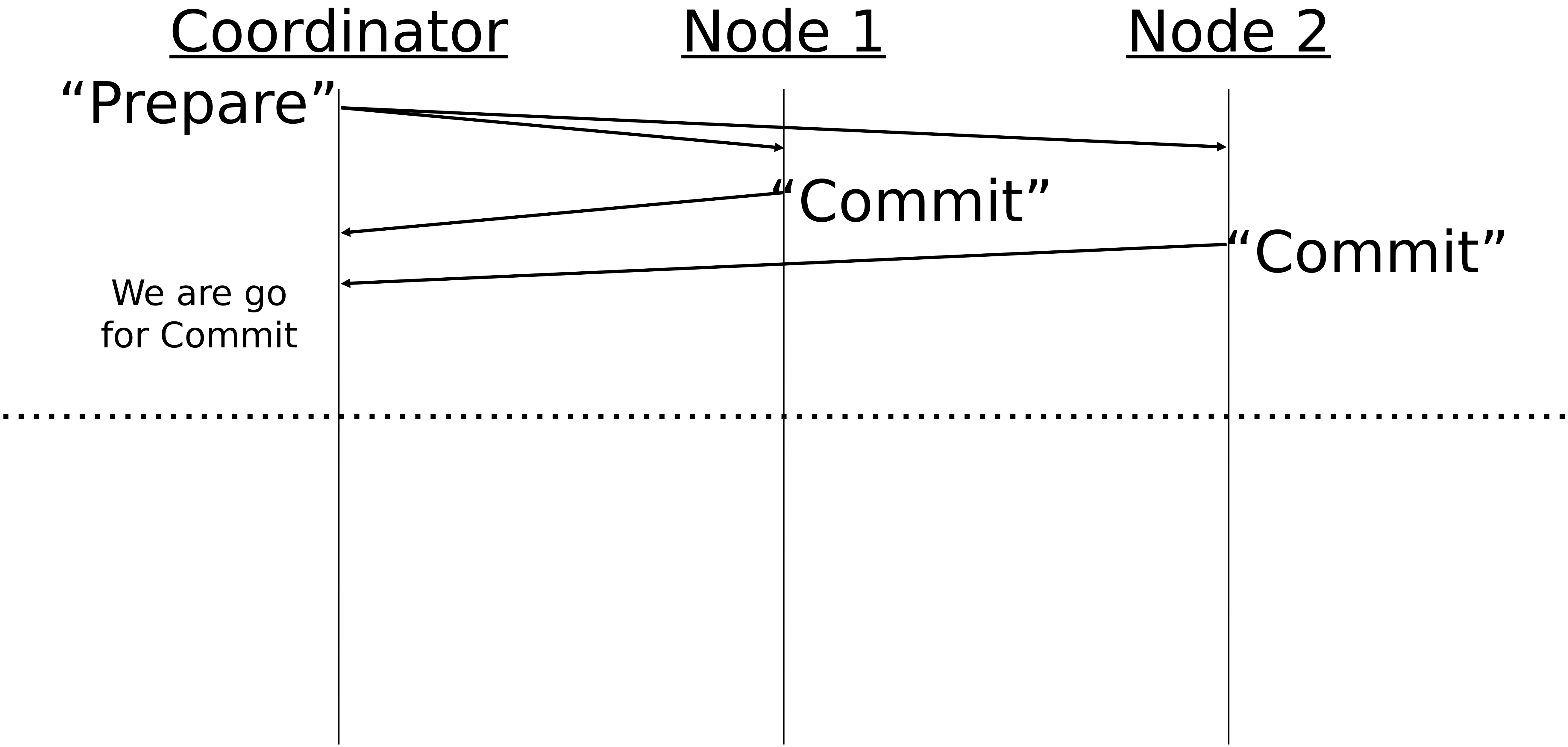
Phase 1 - Prepare



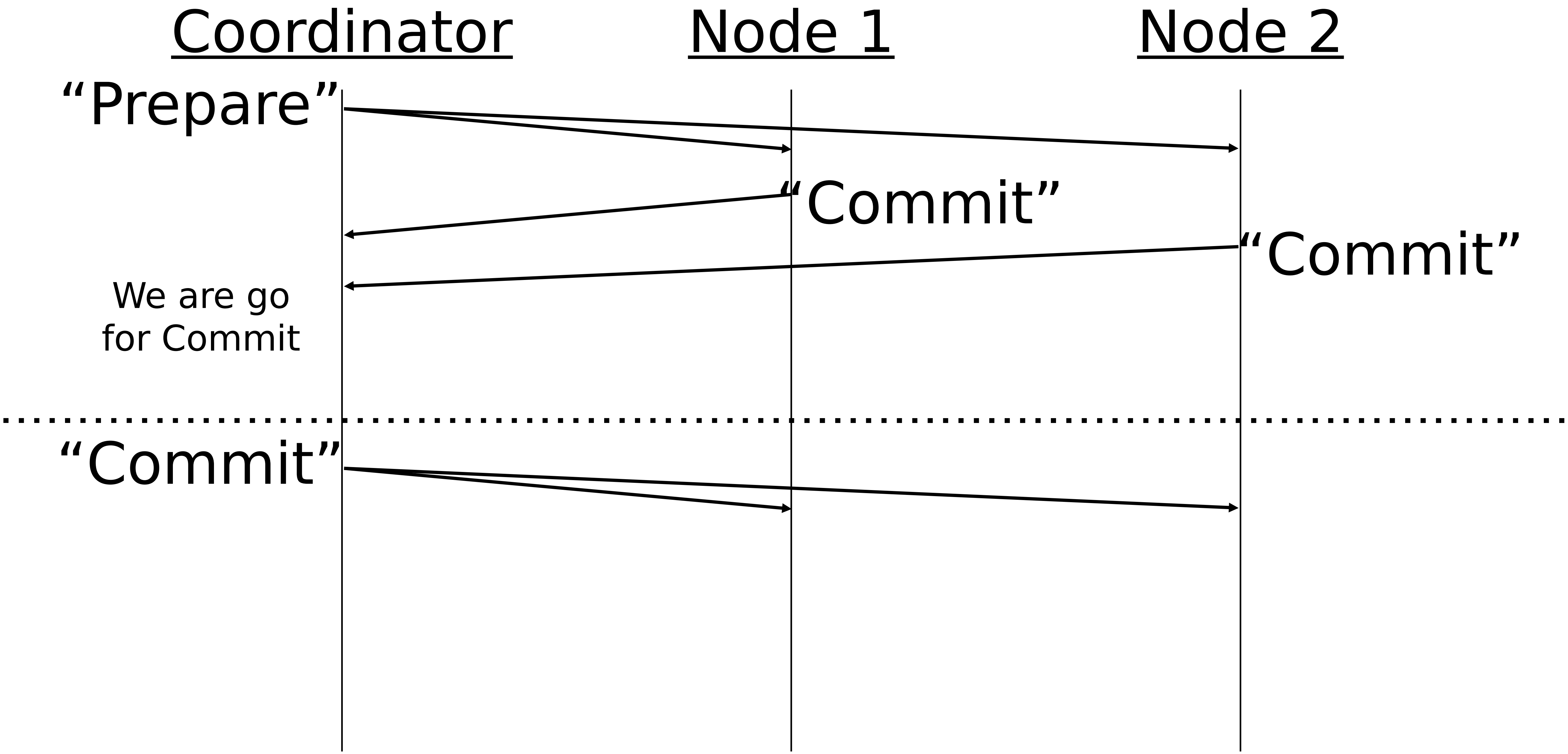
Phase 1 - Prepare



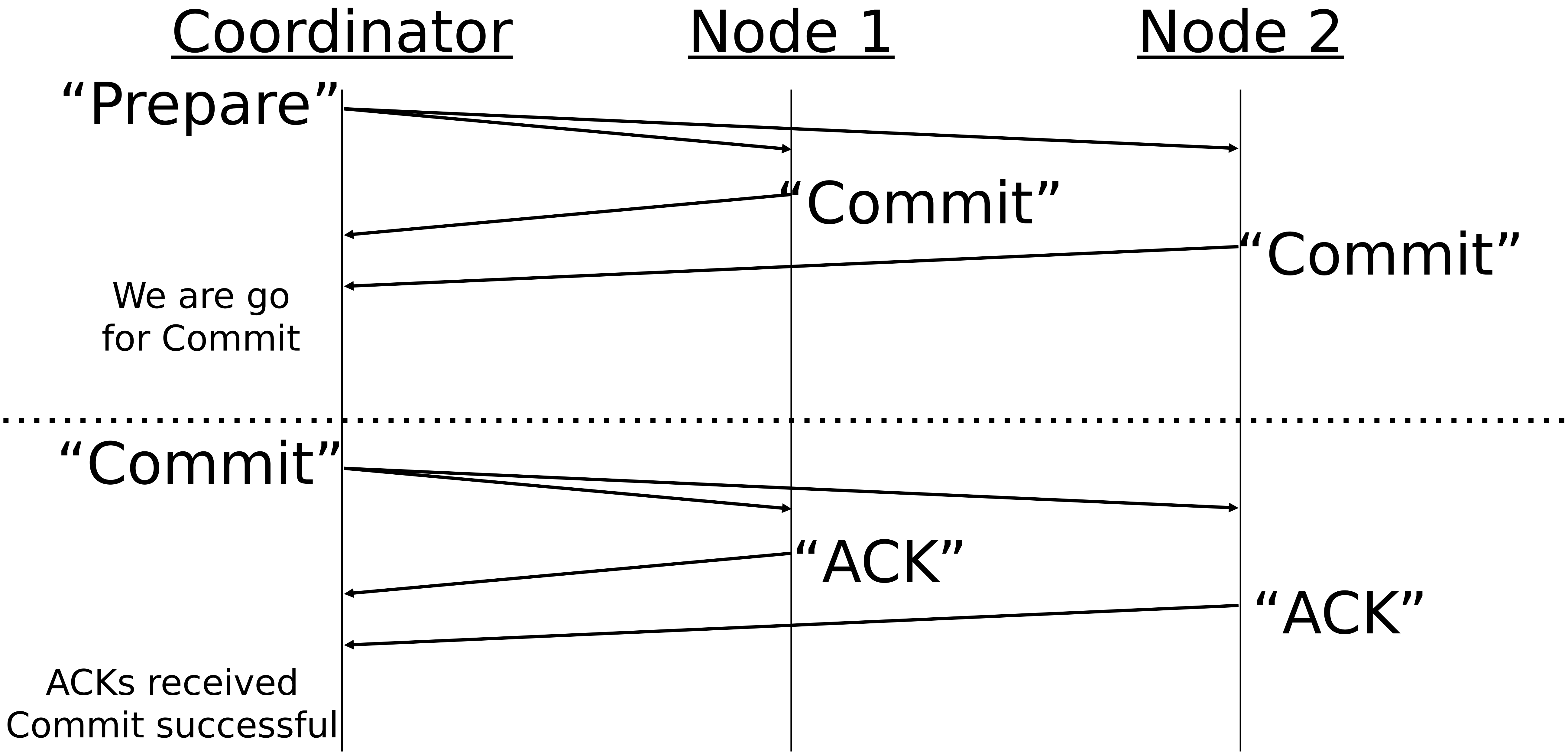
Phase 1 - Prepare



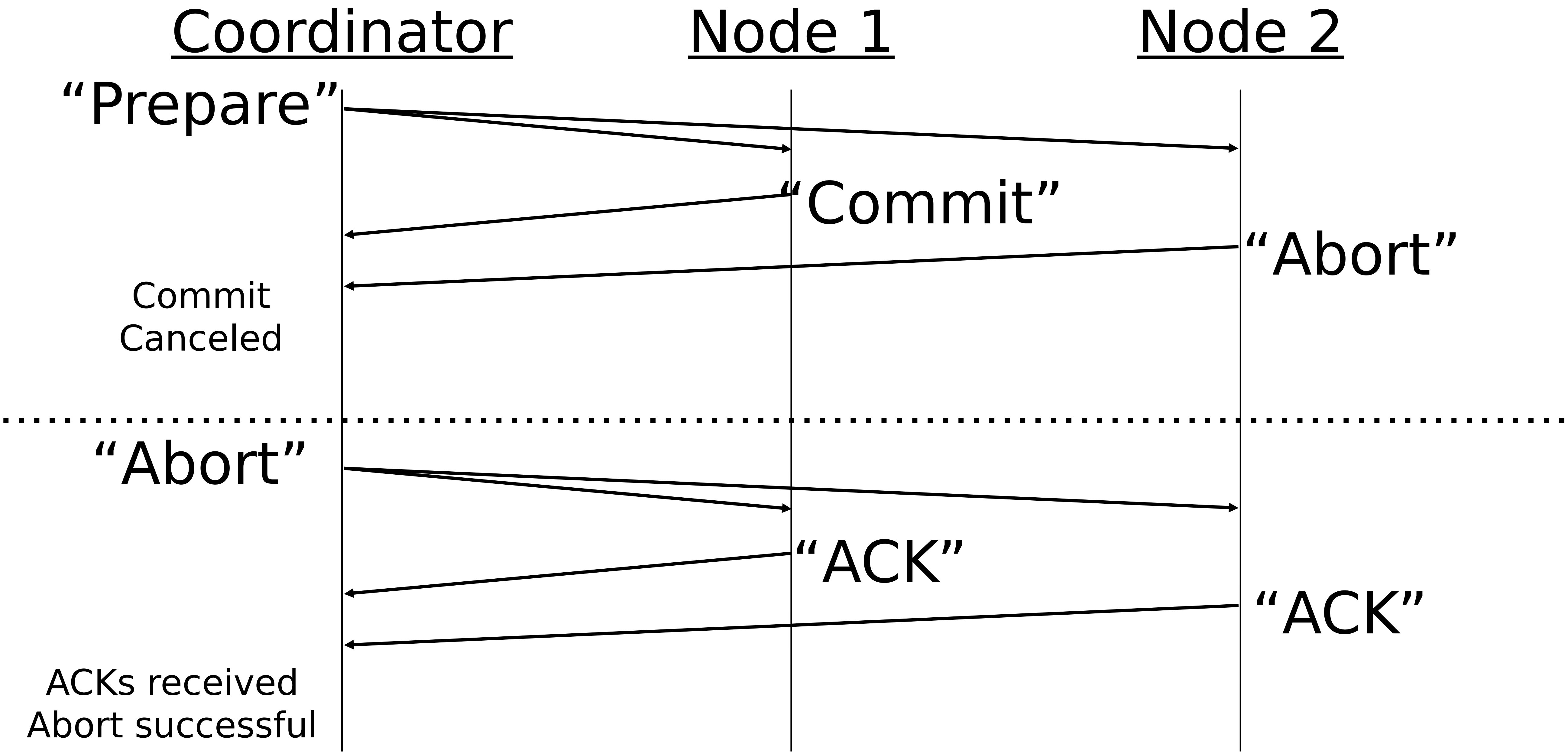
Phase 2 - Commit



Phase 2 - Commit

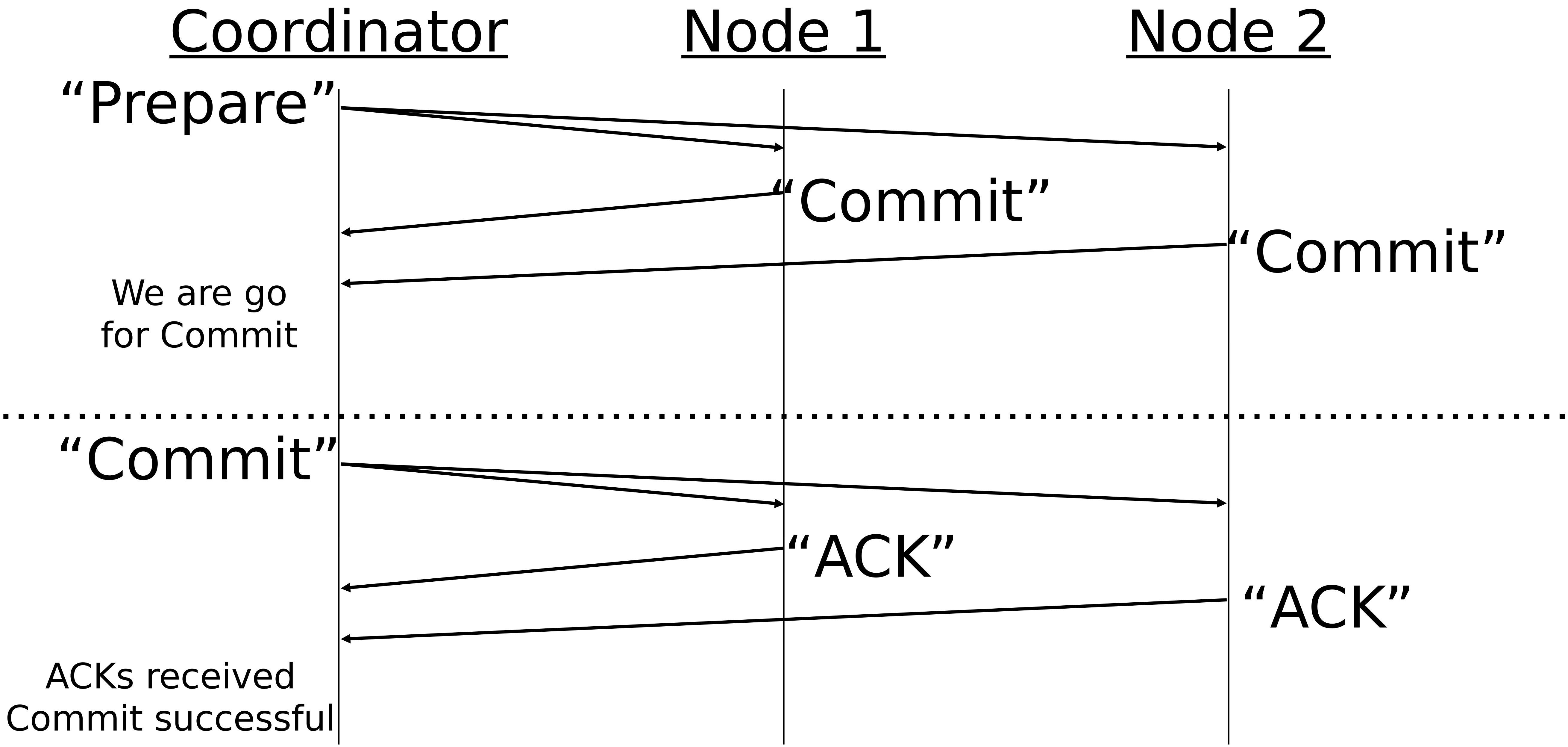


Aborting



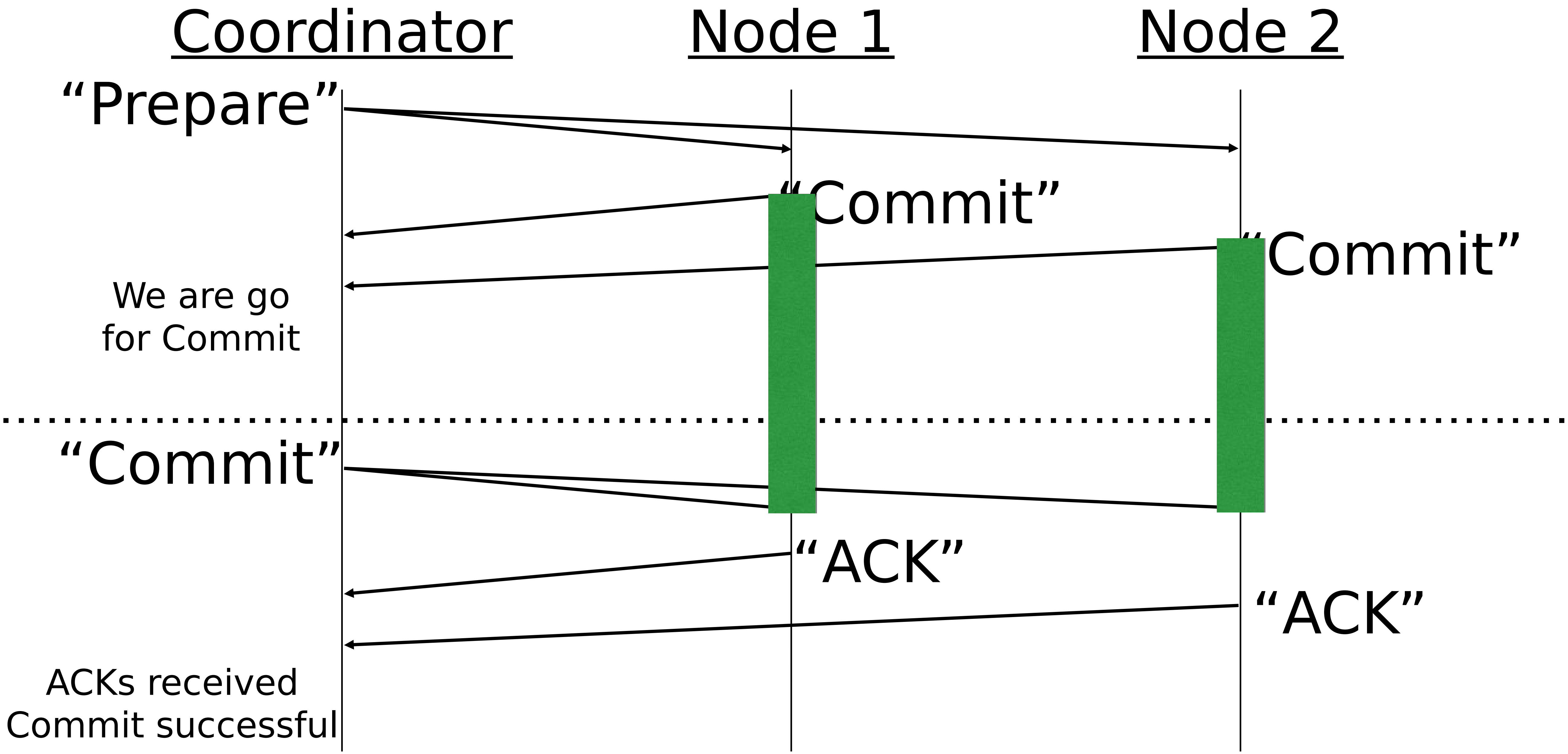
If <u>any</u> participant aborts in Phase 1, <u>everyone</u> aborts.

Guarantees



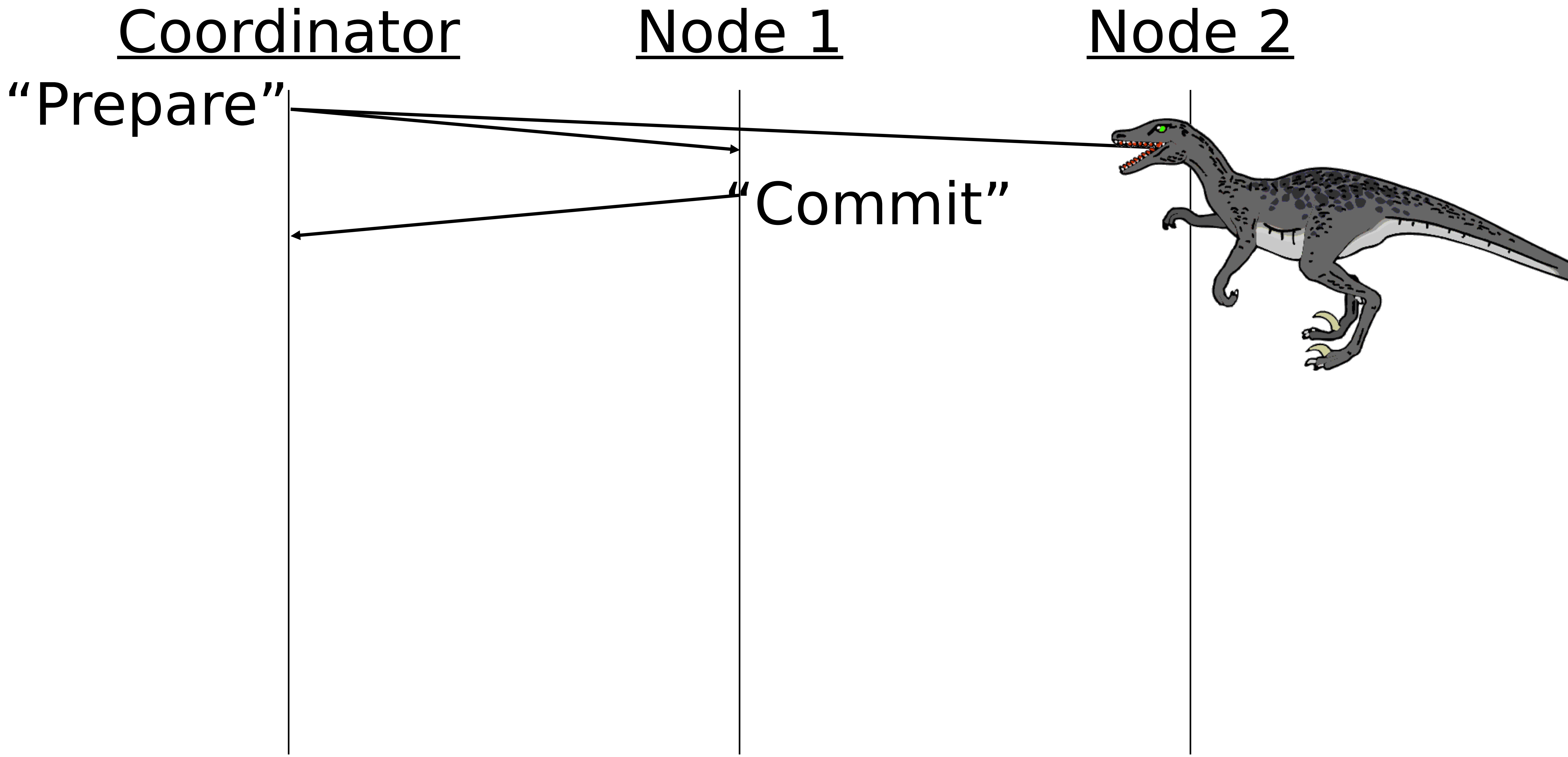
A Node “Commit” means the node is <u>able</u> to commit.
A Coordinator “Commit” means the transaction <u>must</u> commit.

Guarantees



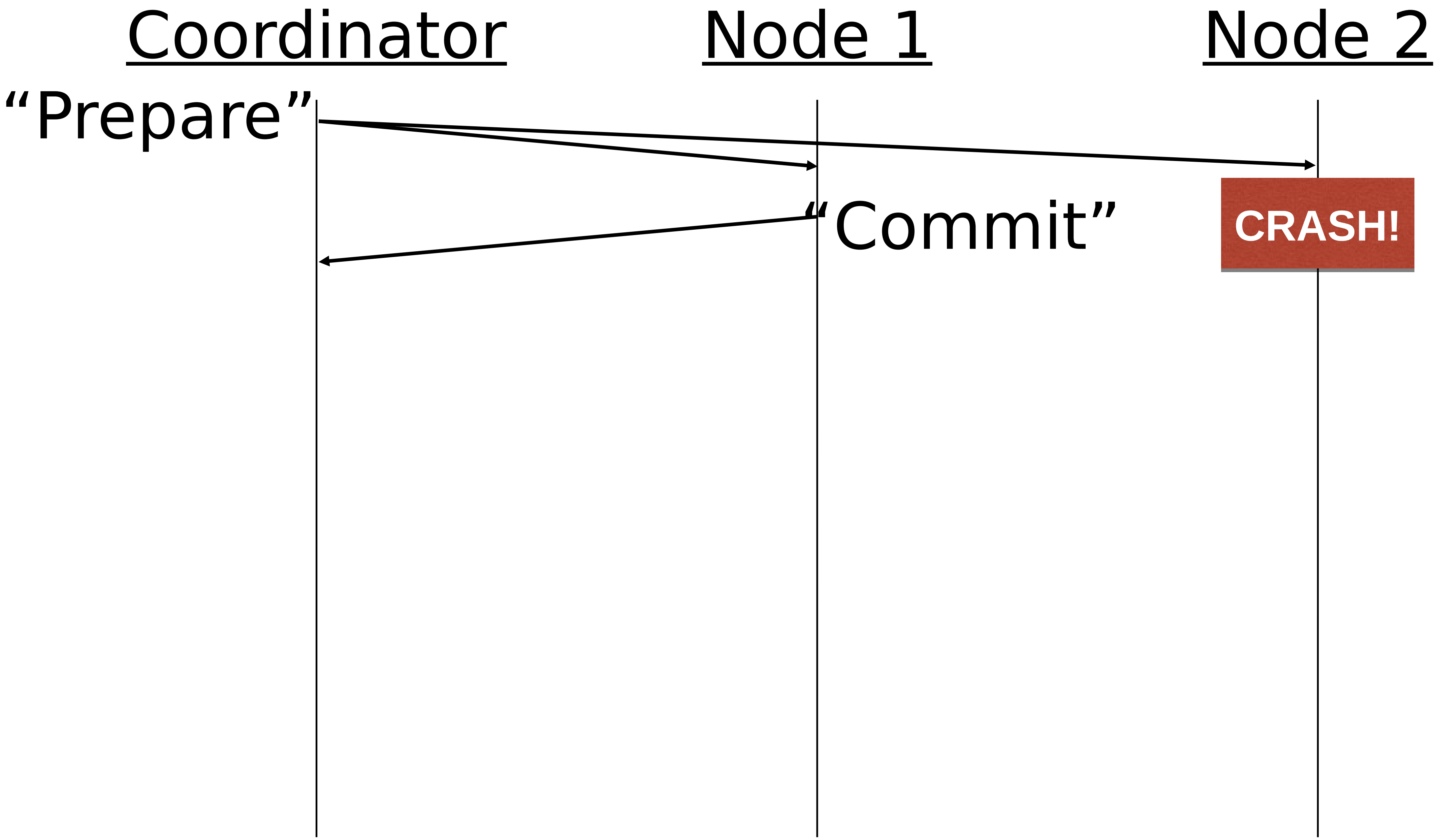
Once a node commits, the xact is still not committed yet.
However the node must avoid breaking the commit.

Failure Modes



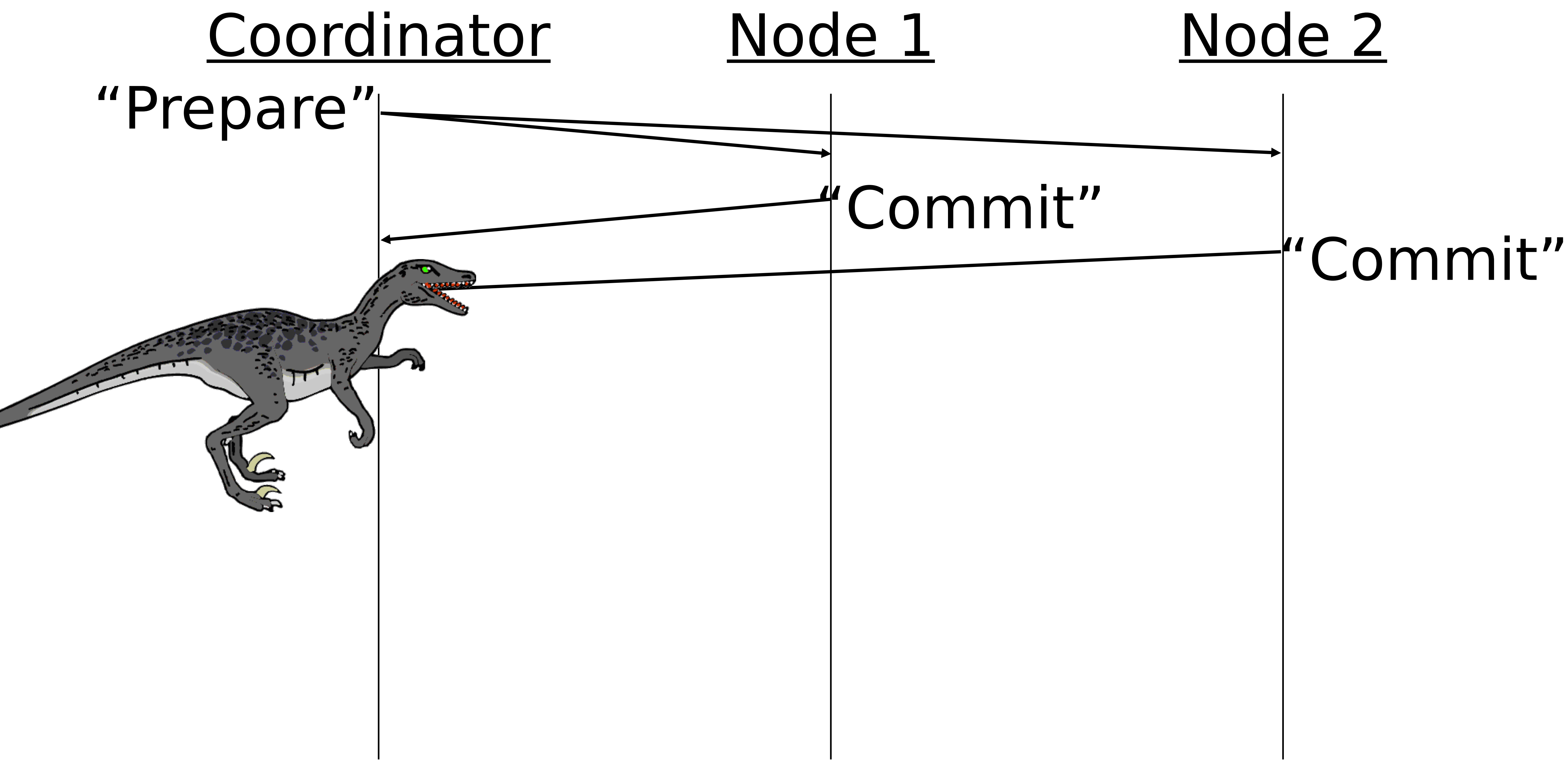
Prepare unreceived and unacknowledged: Coordinator (1) Retries, or (2) Aborts

Failure Modes



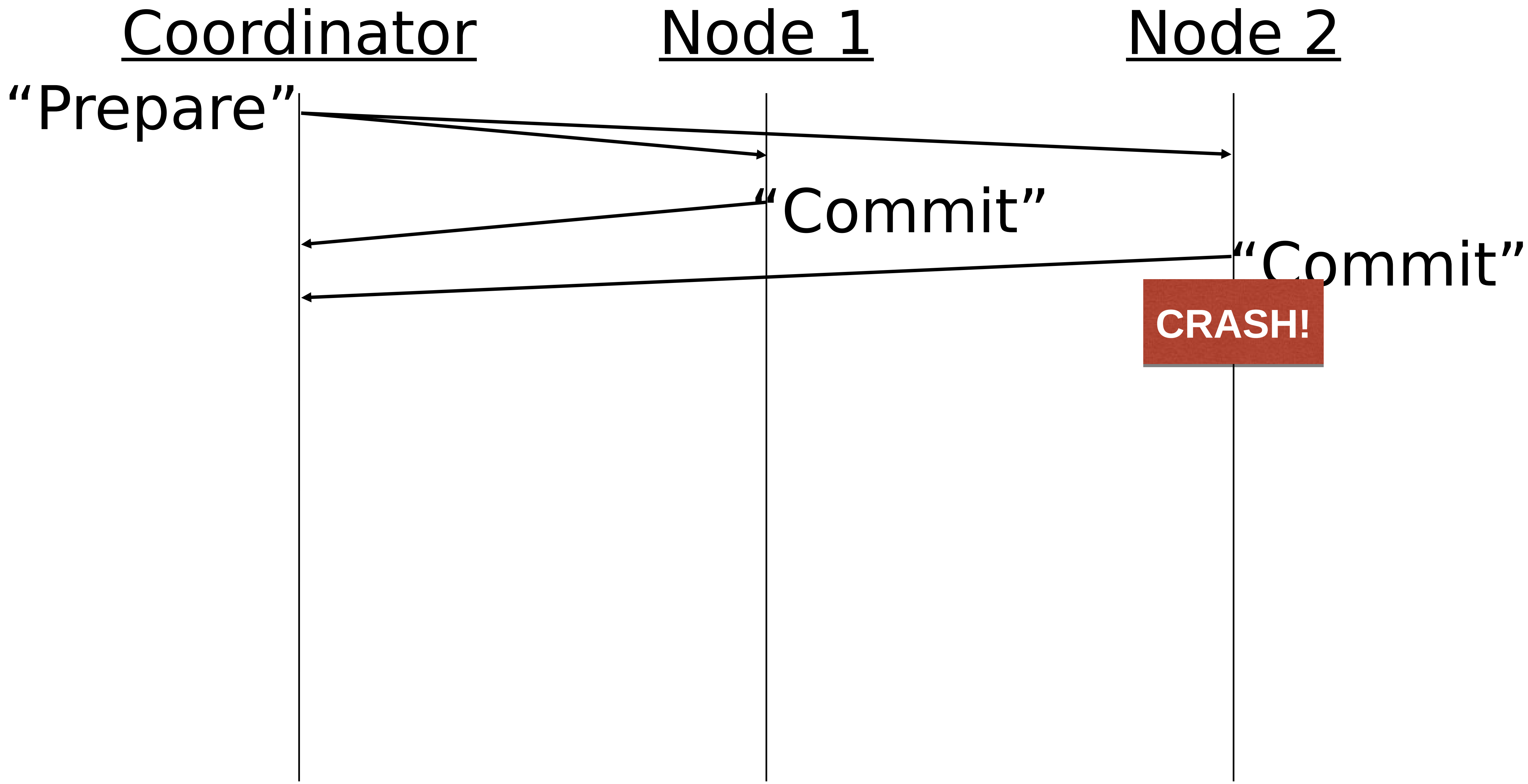
Node 2 crashes before responding: Restart and continue as a dropped packet

Failure Modes



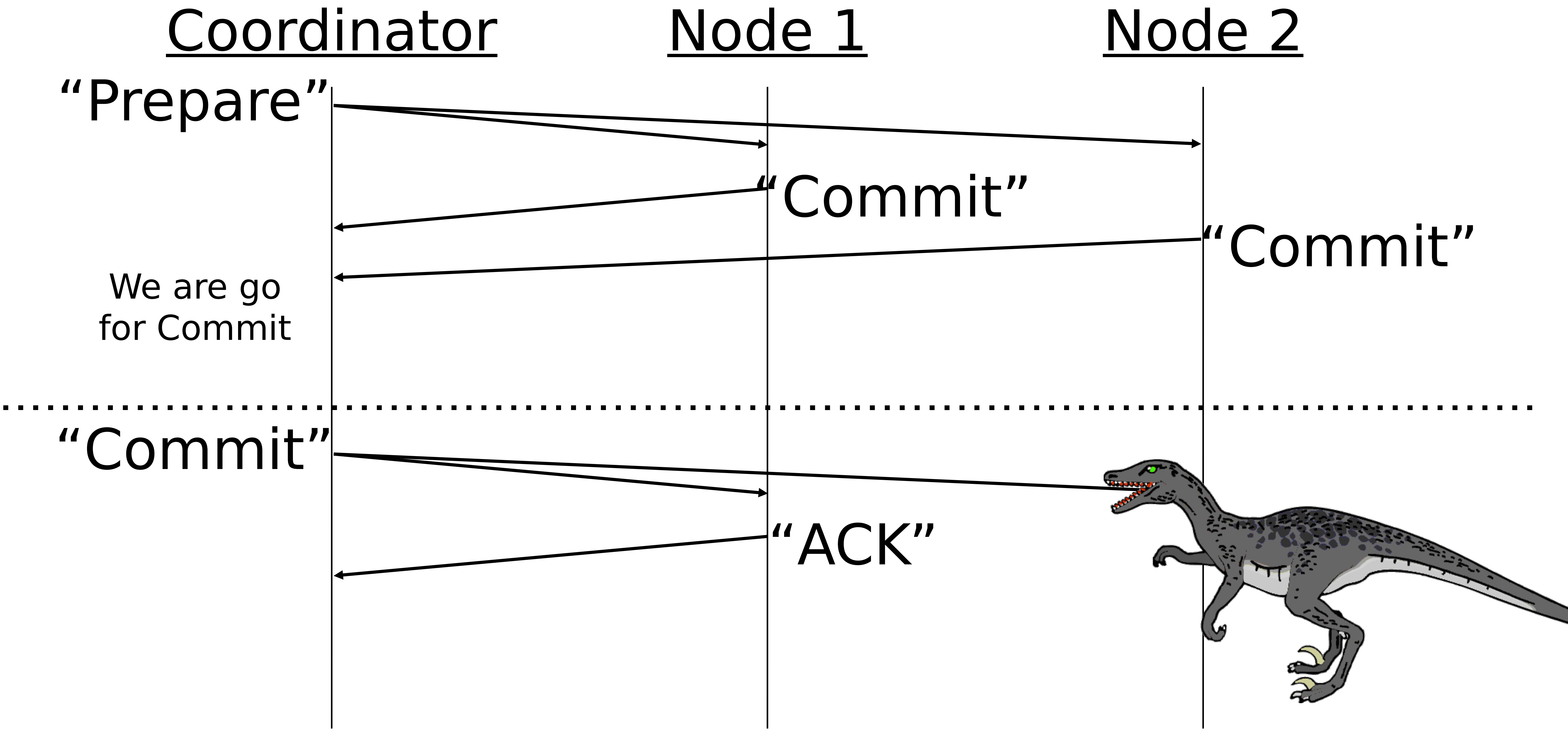
Node “Commit” unreceived: (1) Re-sent “Prepare” can be ignored. (2) Node still able to abort.

Failure Modes



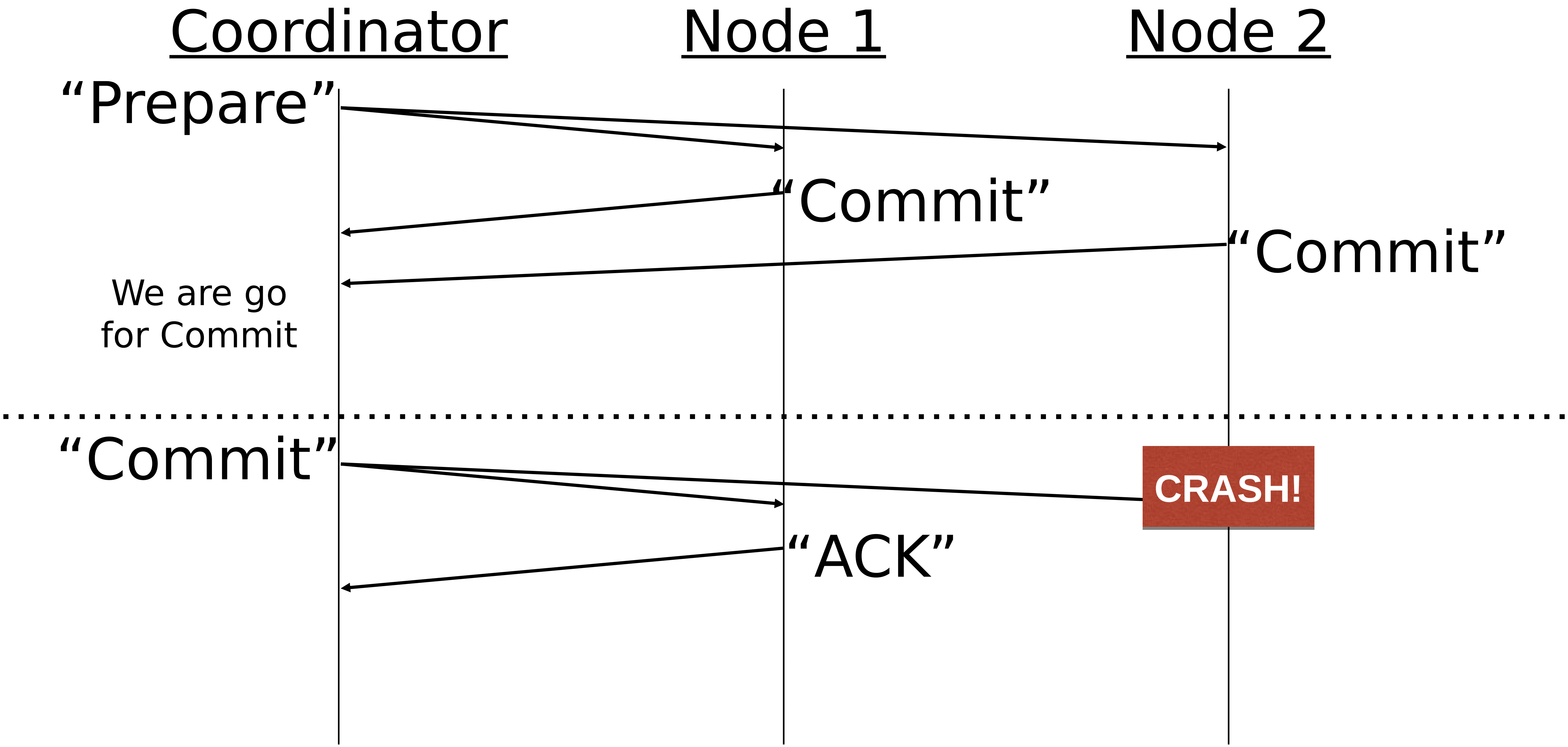
Node 2 crashes after responding: Restart from log

Failure Cases



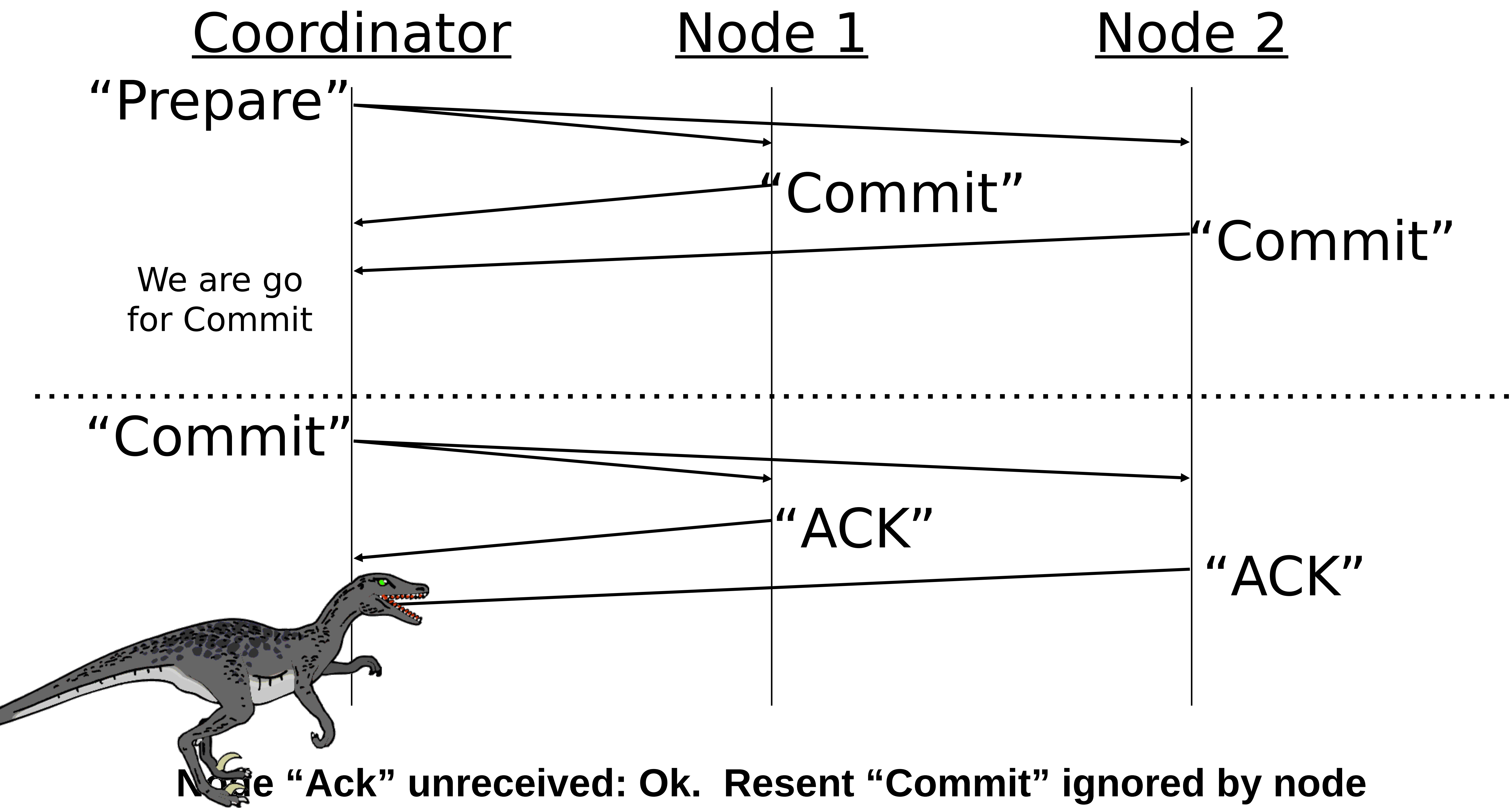
Coordinator “Commit” unreceived: Commit <u>must</u> happen, coordinator resends

Failure Cases



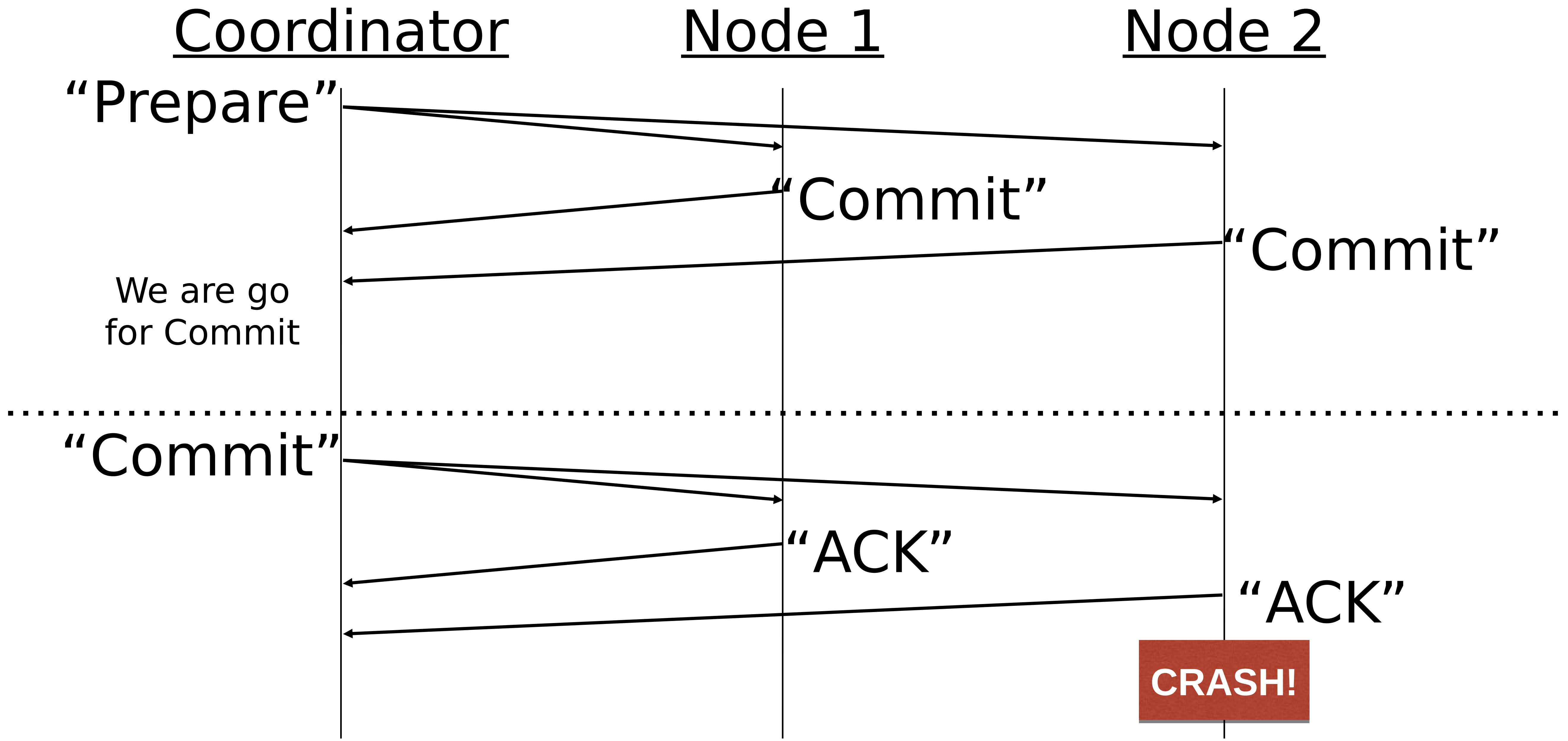
Node 2 crash: Restart. Already logged “Commit” message, so all is well.

Failure Cases



Node “Ack” unreceived: Ok. Resent “Commit” ignored by node

Failure Cases



Node crash after “Ack”: Ok. Log already recorded commit

Replication

- **Mode 1**: Periodic Backups
  - Copy the replicated data nightly/hourly.
- **Mode 2**: Log Shipping
  - Only send changes (replica serves as the log).

Replication

- Ensuring durability
- Ensuring write-consistency under 2PC
- Ensuring read-consistency without 2PC

Ensuring Durability

When is a replica write durable?

Ensuring Durability

Never.

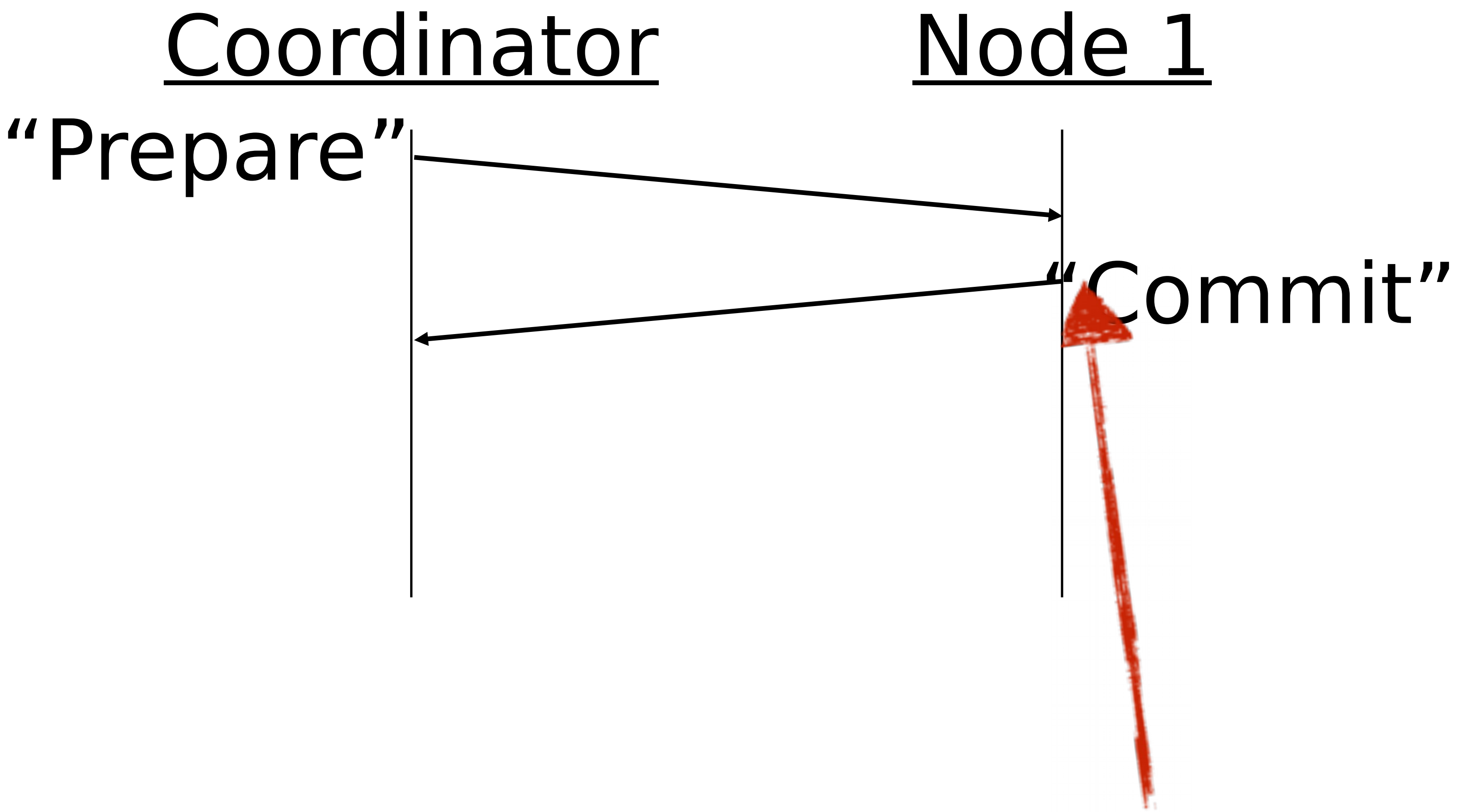
What you should be asking is how much durability do you need?

Ensuring Durability

For **N** Failures
N+1 Replicas

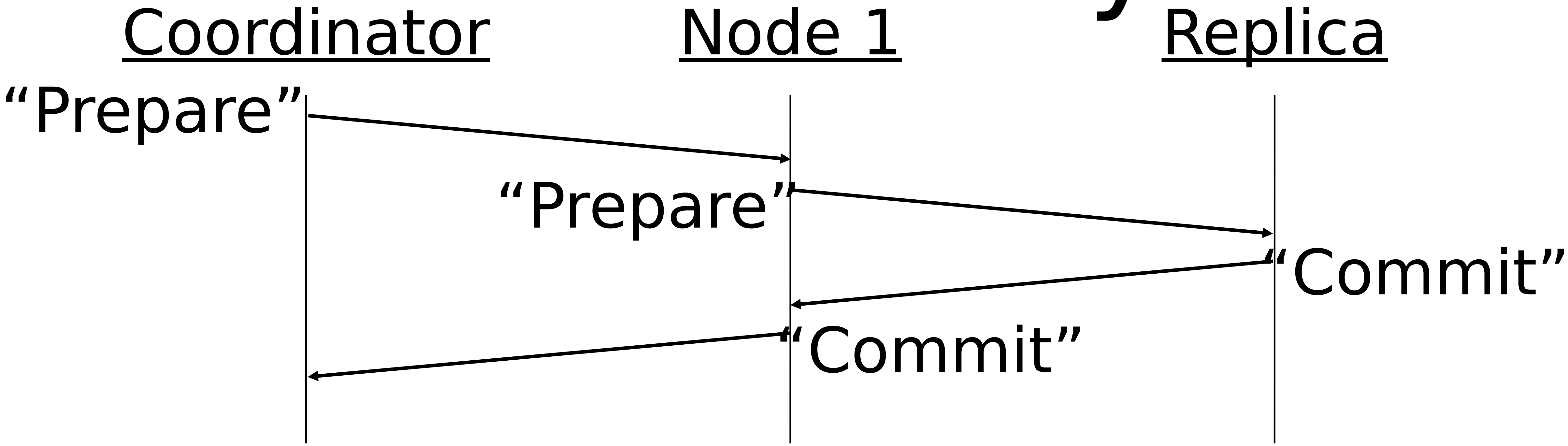
(Assuming Failure = Crash)

Ensuring Write Consistency



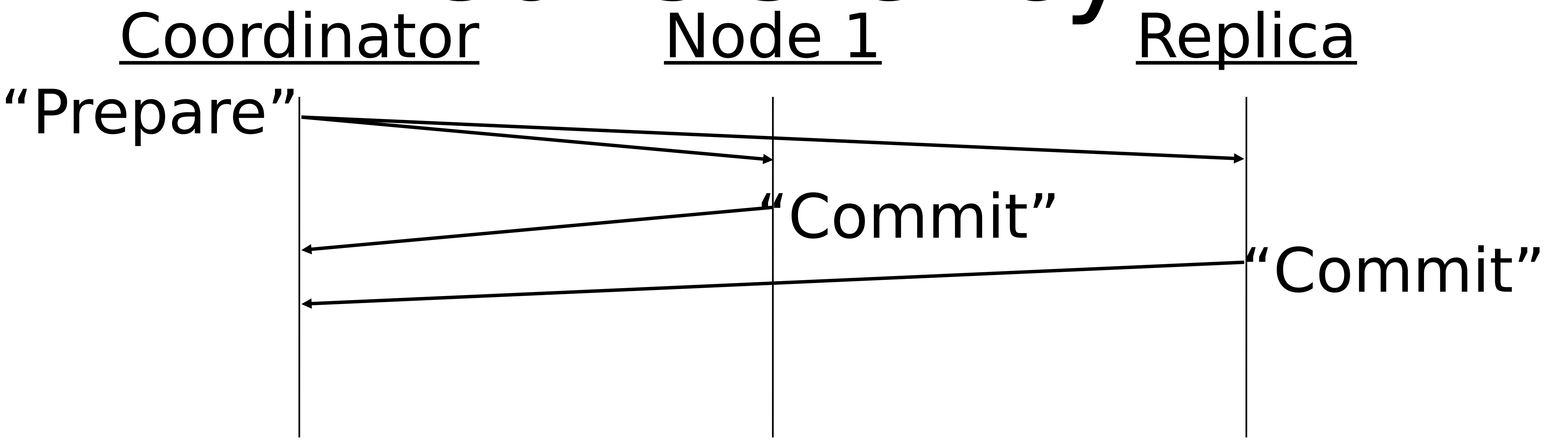
Node 1 asserts that the commit is durable!
What if Node 1 fails?

Ensuring Write Consistency



Waiting for Node 1 to replicate is slooooow!
Let the coordinator take over!

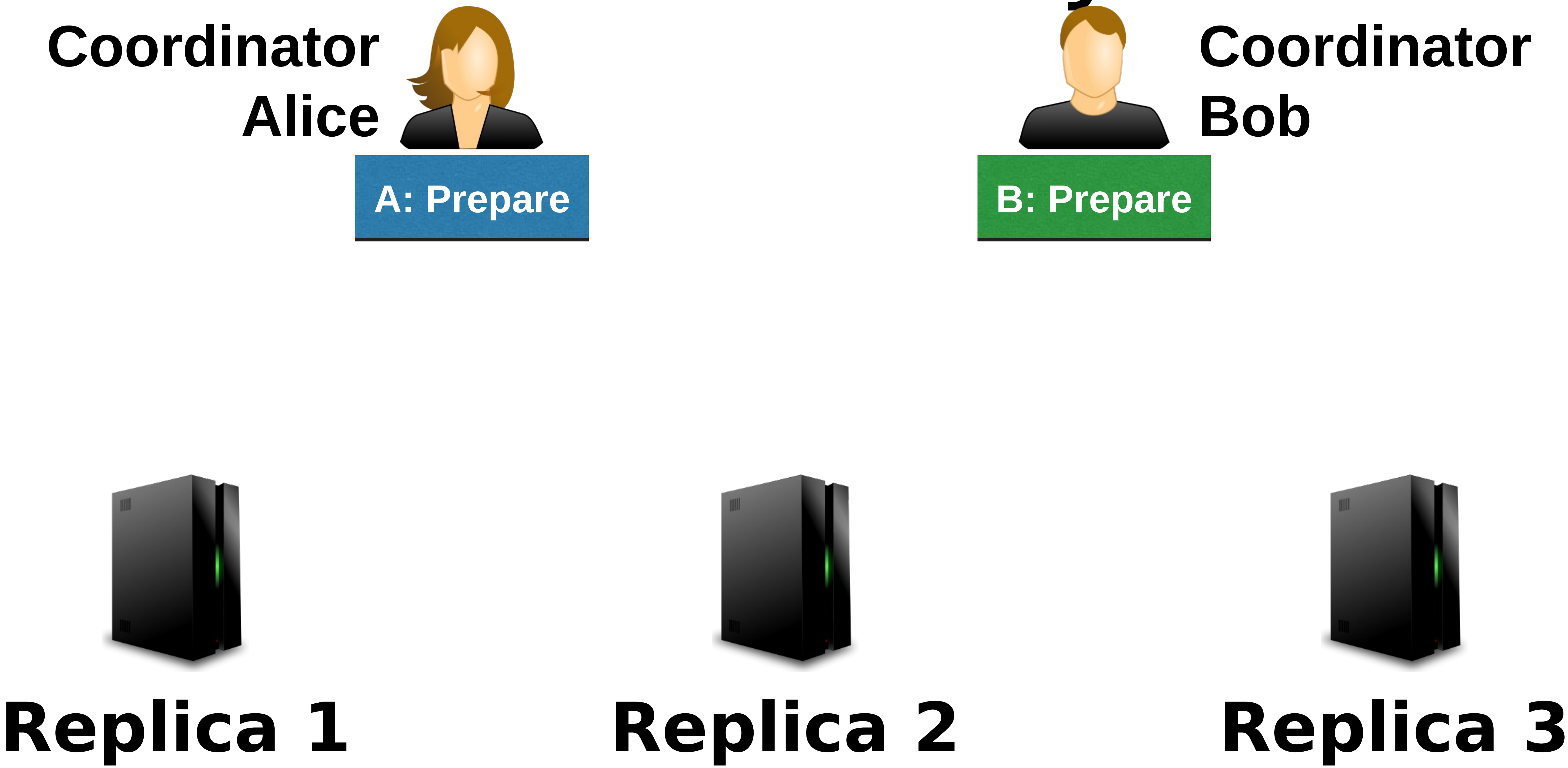
Ensuring Write Consistency



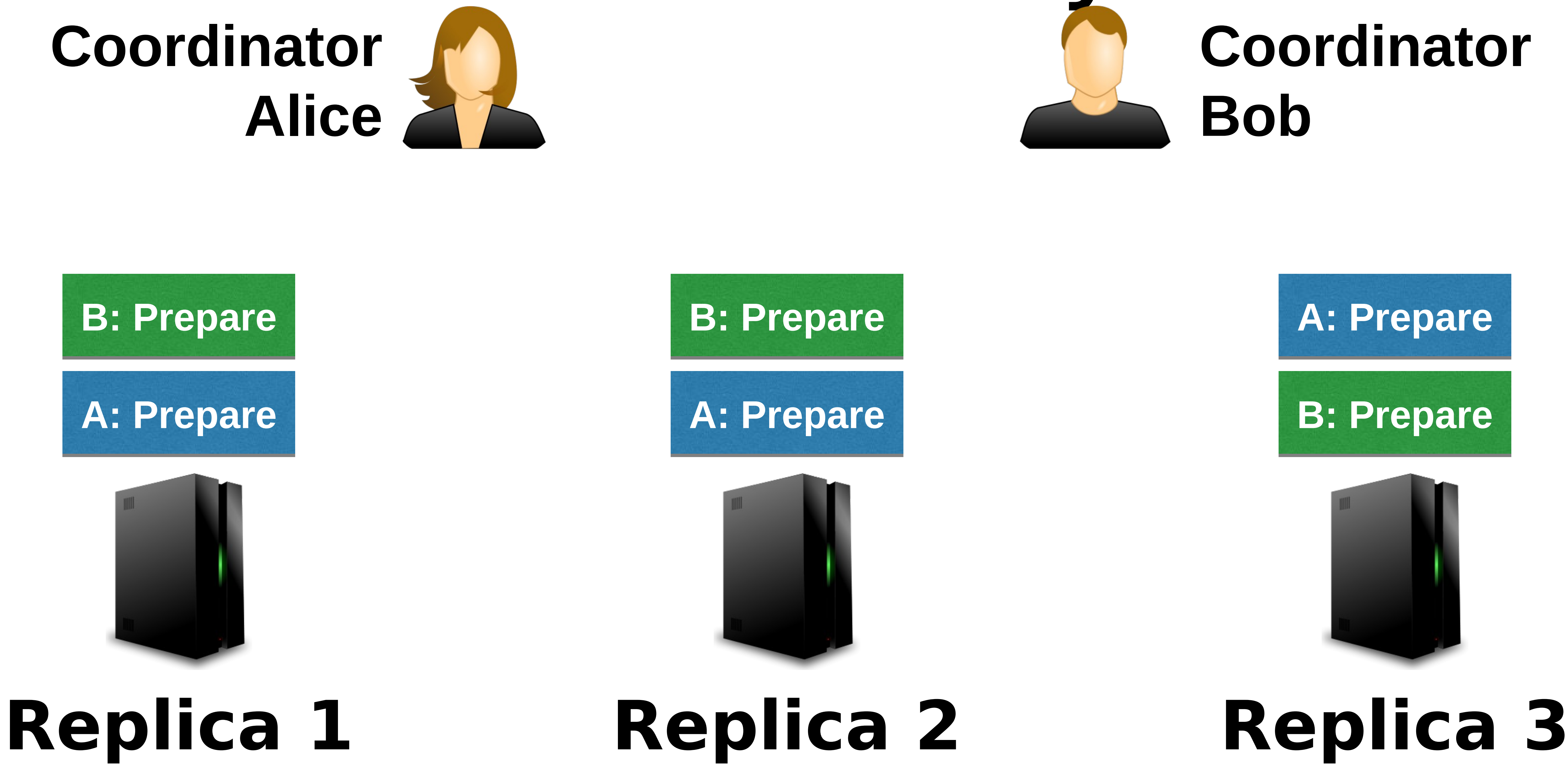
Like 2PC…

… but better. We may not need to wait for the replica

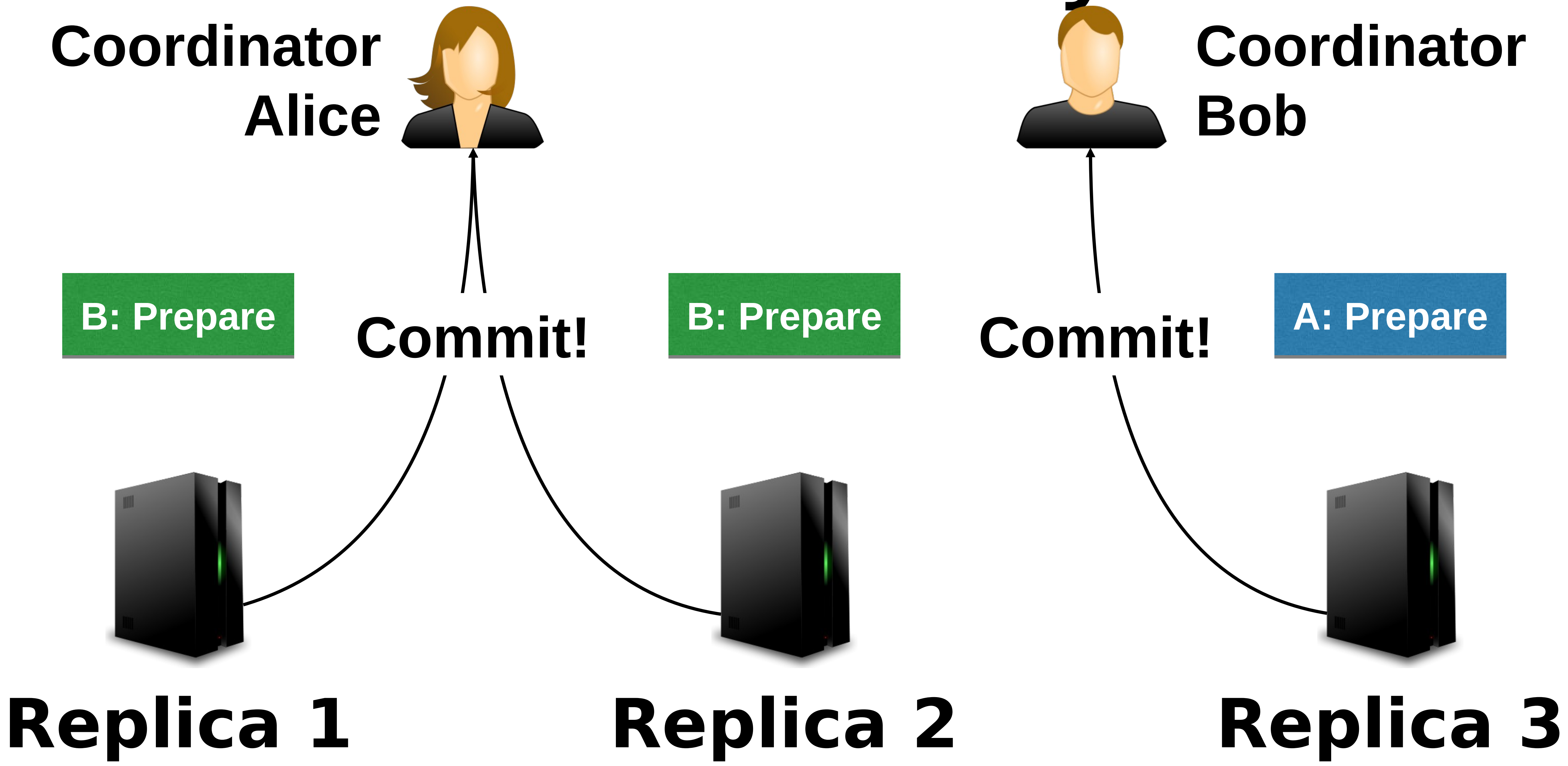
Ensuring Write-Consistency



Ensuring Write-Consistency



Ensuring Write-Consistency



Ensuring Write-Consistency

Majority Vote

N Replicas

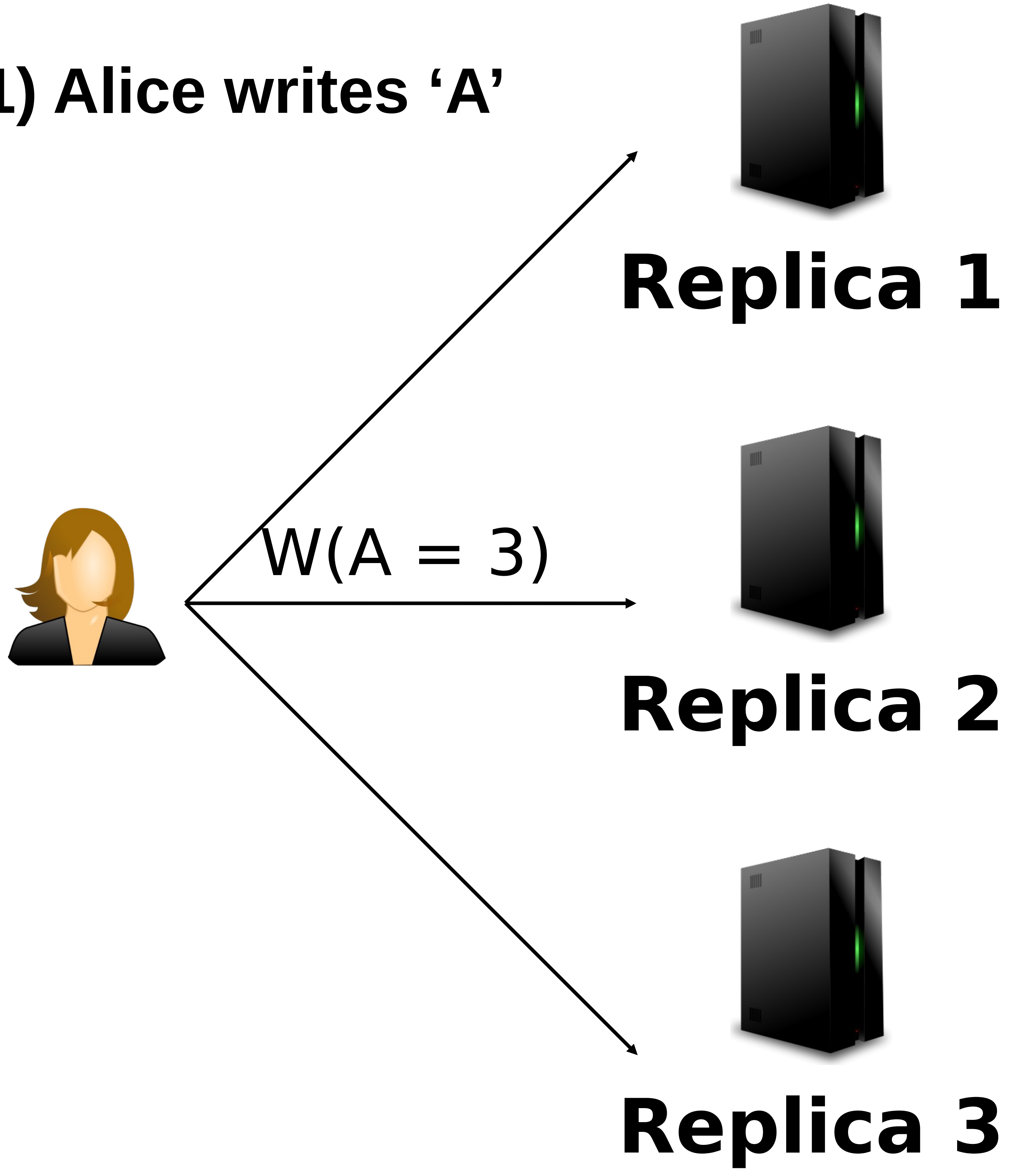
($^{N}/_{2}$)+1 Votes Needed

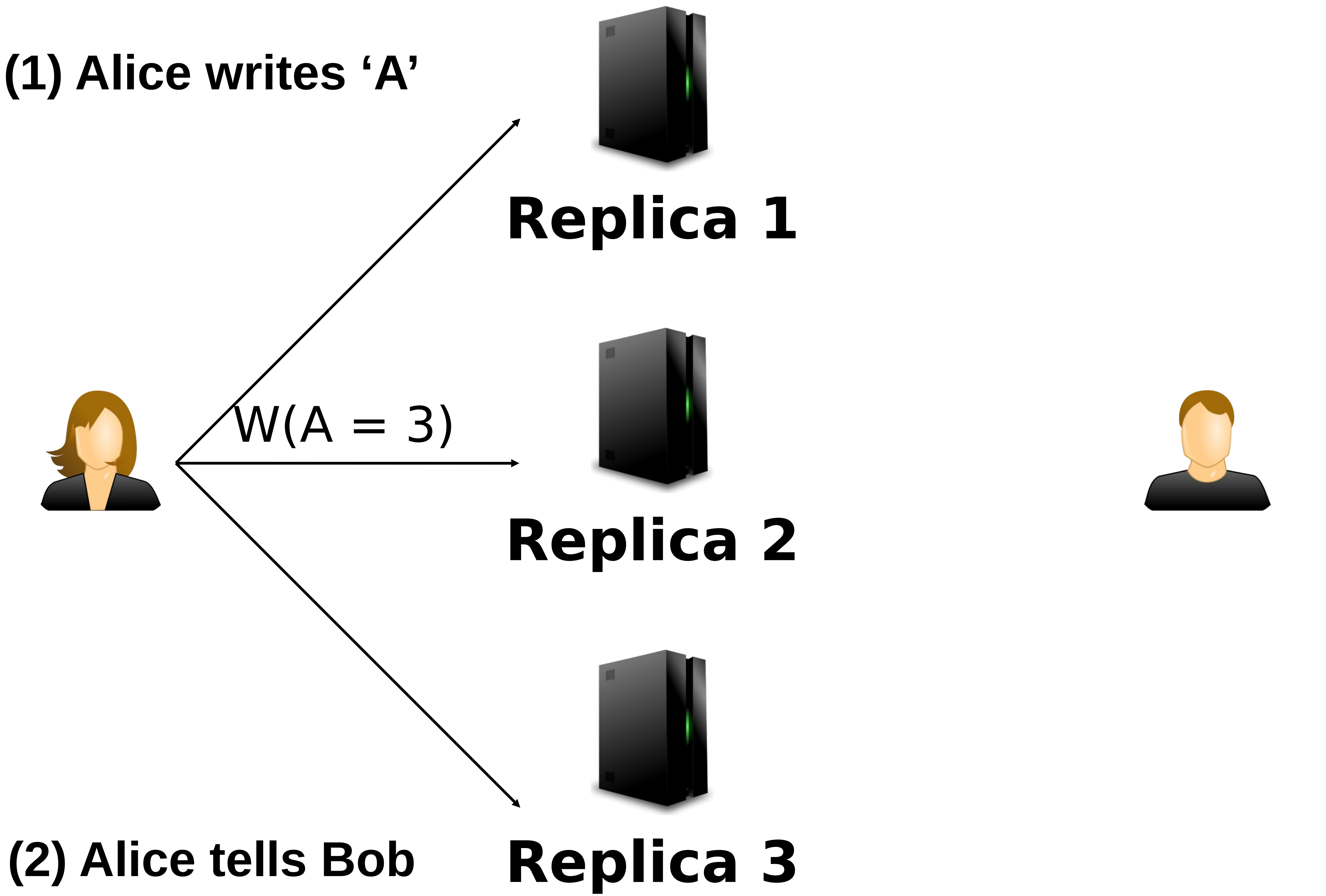
Ensuring Read Consistency

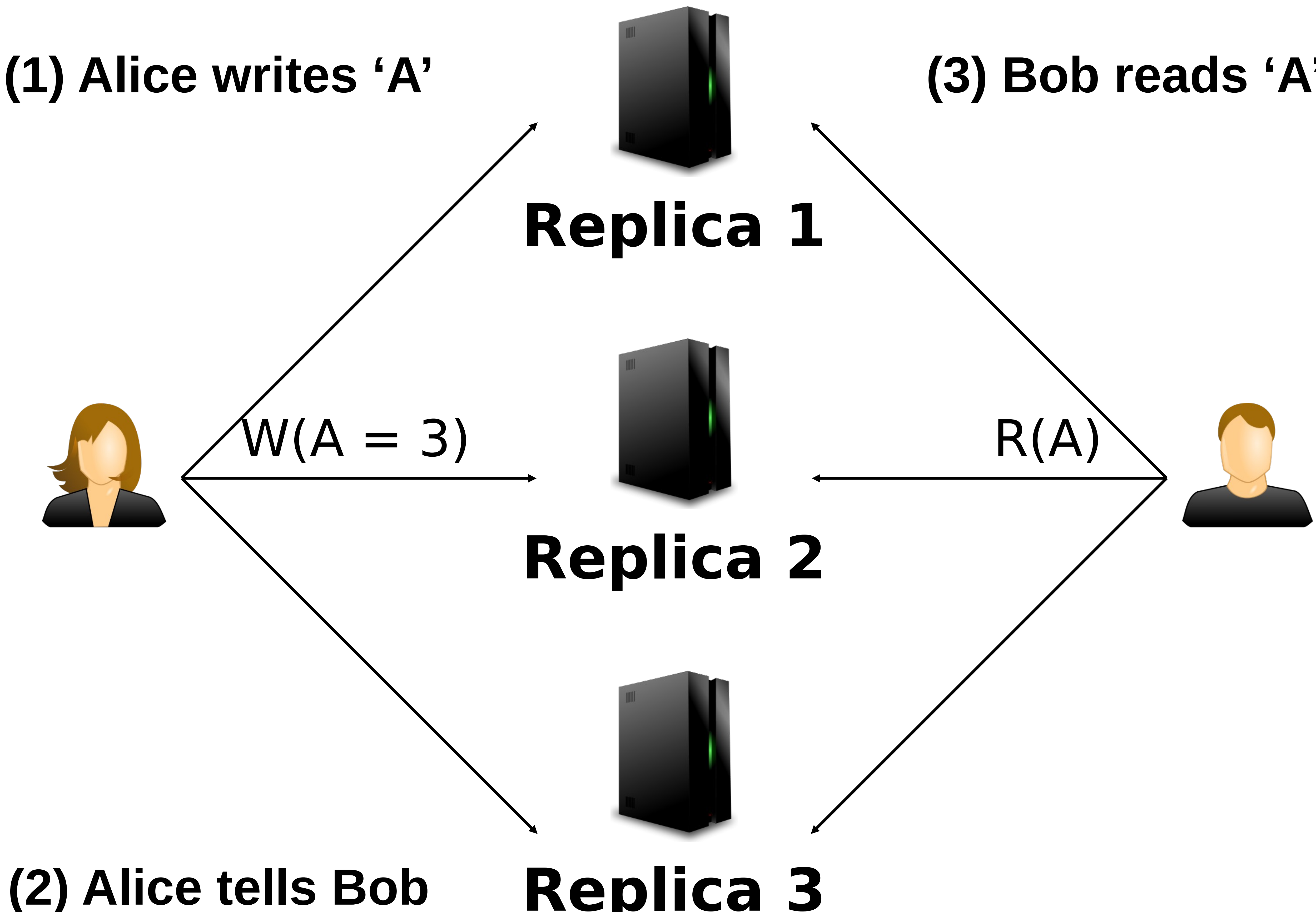
Forget transactions, let’s go back to reads & writes

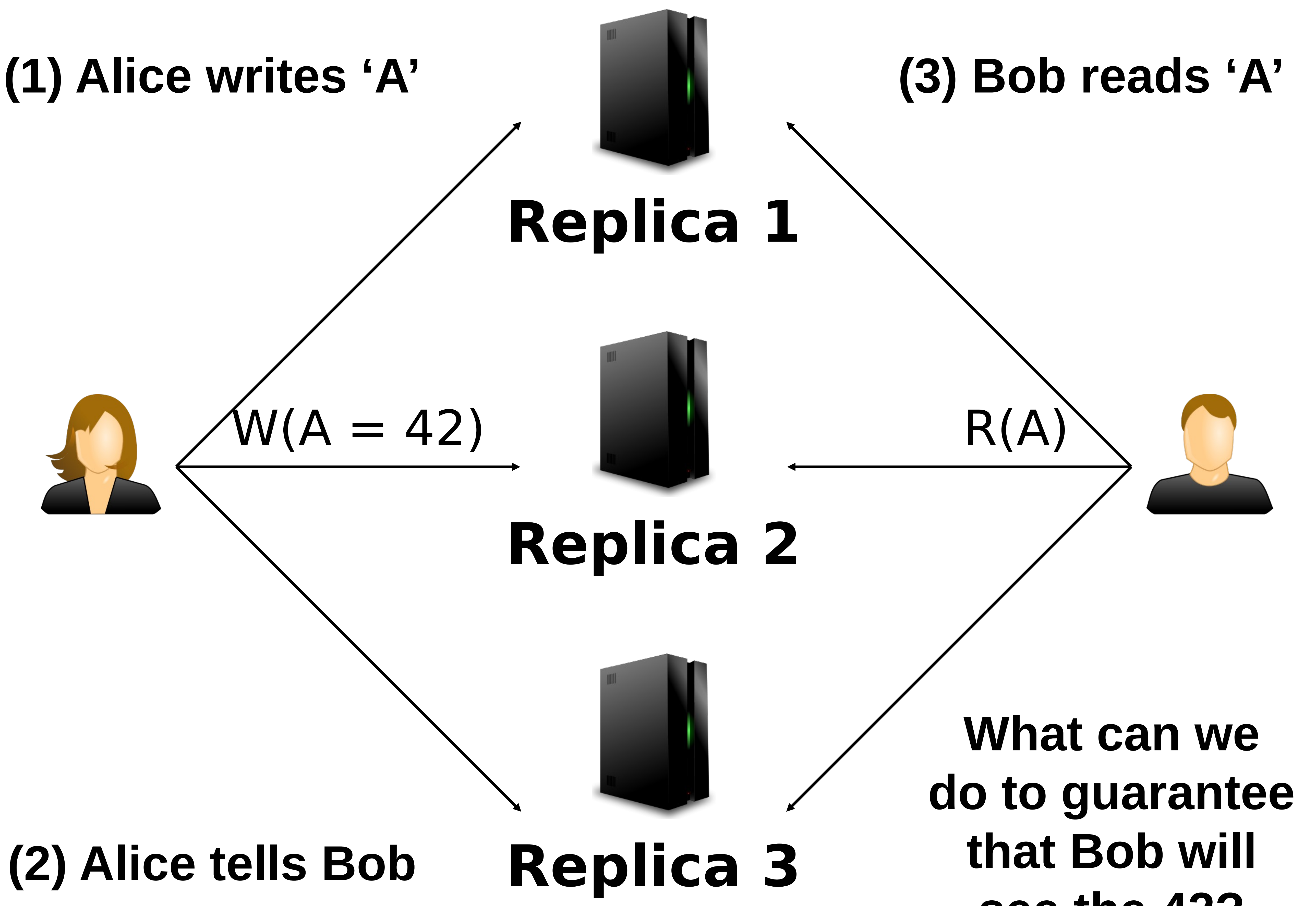
Can we do better than 2PC if we don’t need xacts?

(1) Alice writes ‘A’




(1) Alice writes ‘A’
Replica 1
W(A = 3)
Replica 2
Replica 3
(2) Alice tells Bob


(1) Alice writes ‘A’
(3) Bob reads ‘A’
Replica 1
W(A = 3)
R(A)
Replica 2
Replica 3
(2) Alice tells Bob

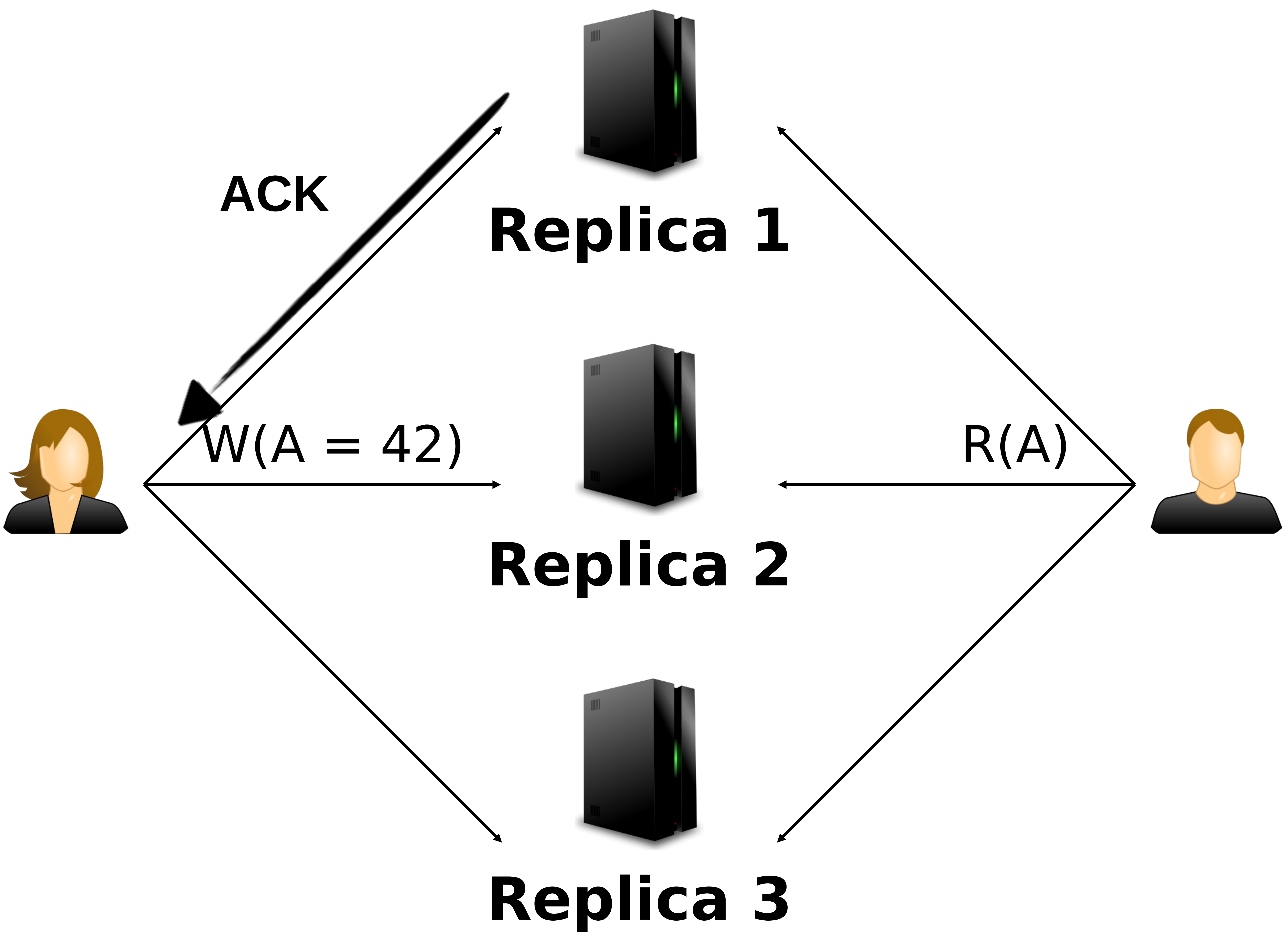

(1) Alice writes ‘A’
(3) Bob reads ‘A’
Replica 1
W(A = 42)
R(A)
Replica 2
Replica 3
(2) Alice tells Bob
What can we do to guarantee that Bob will see the 42?

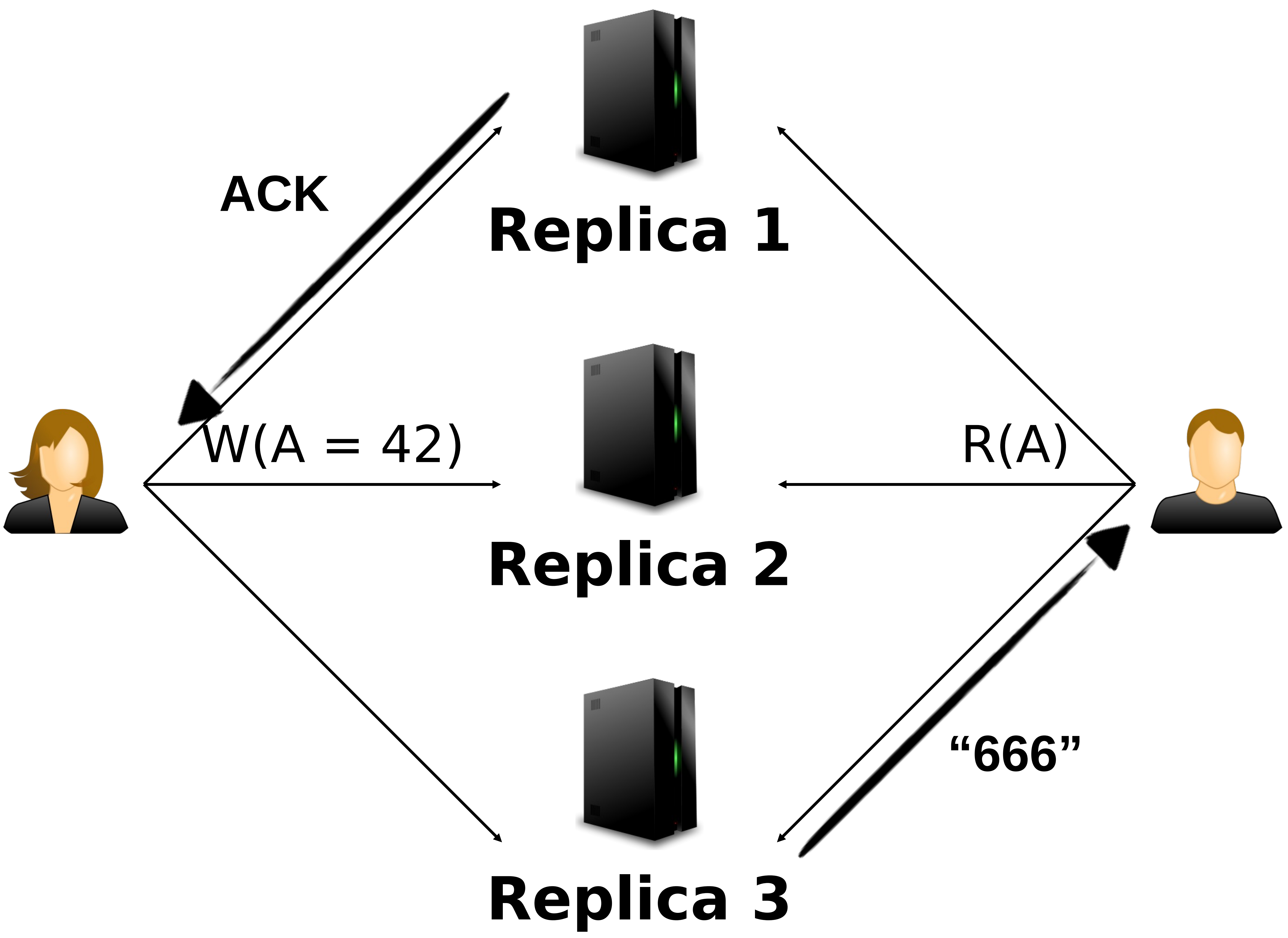
Ensuring Read Consistency

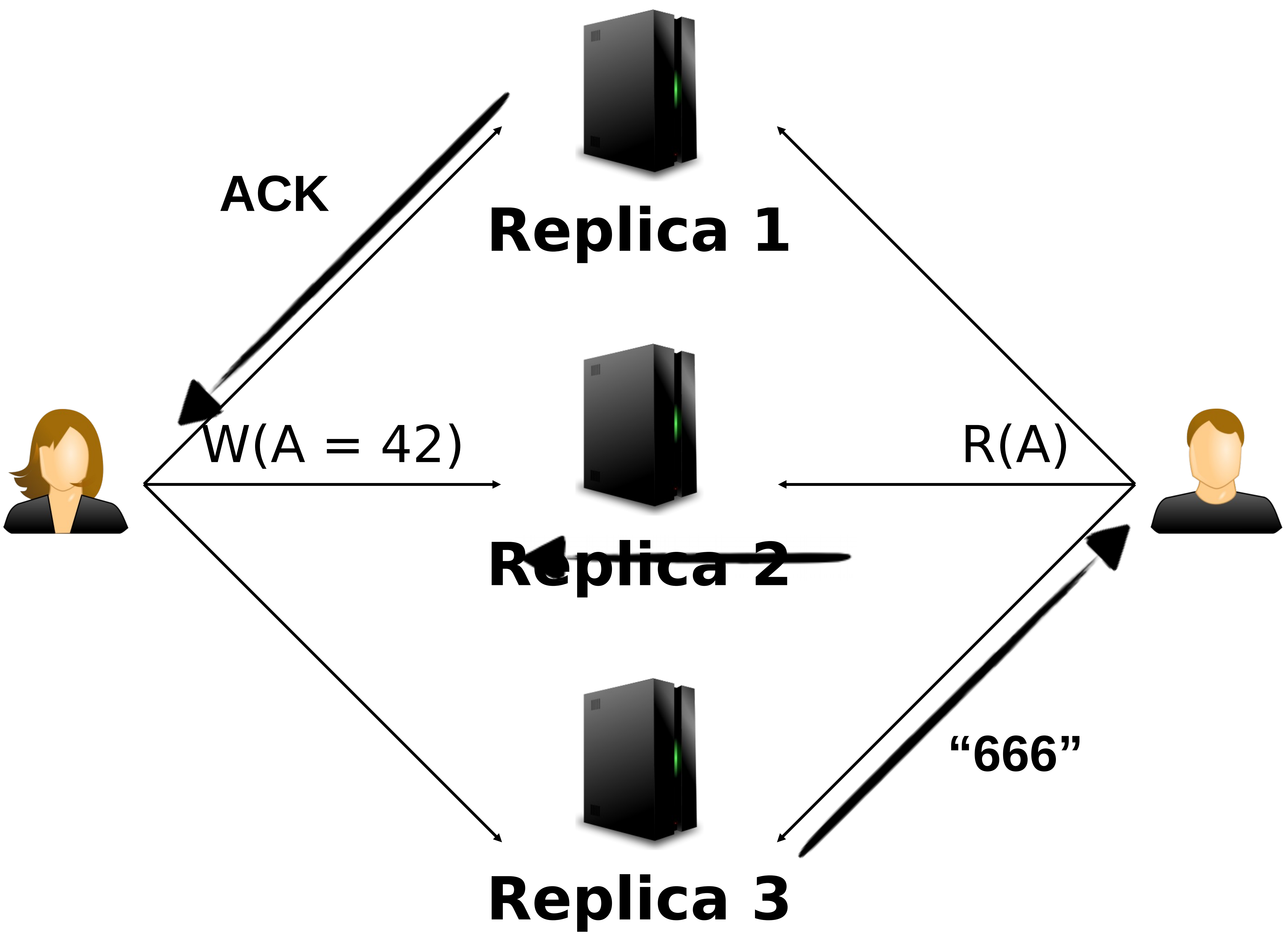
Approach: Alice and Bob each wait for multiple responses

Alice waits for ‘ack’s
Bob waits for read responses.

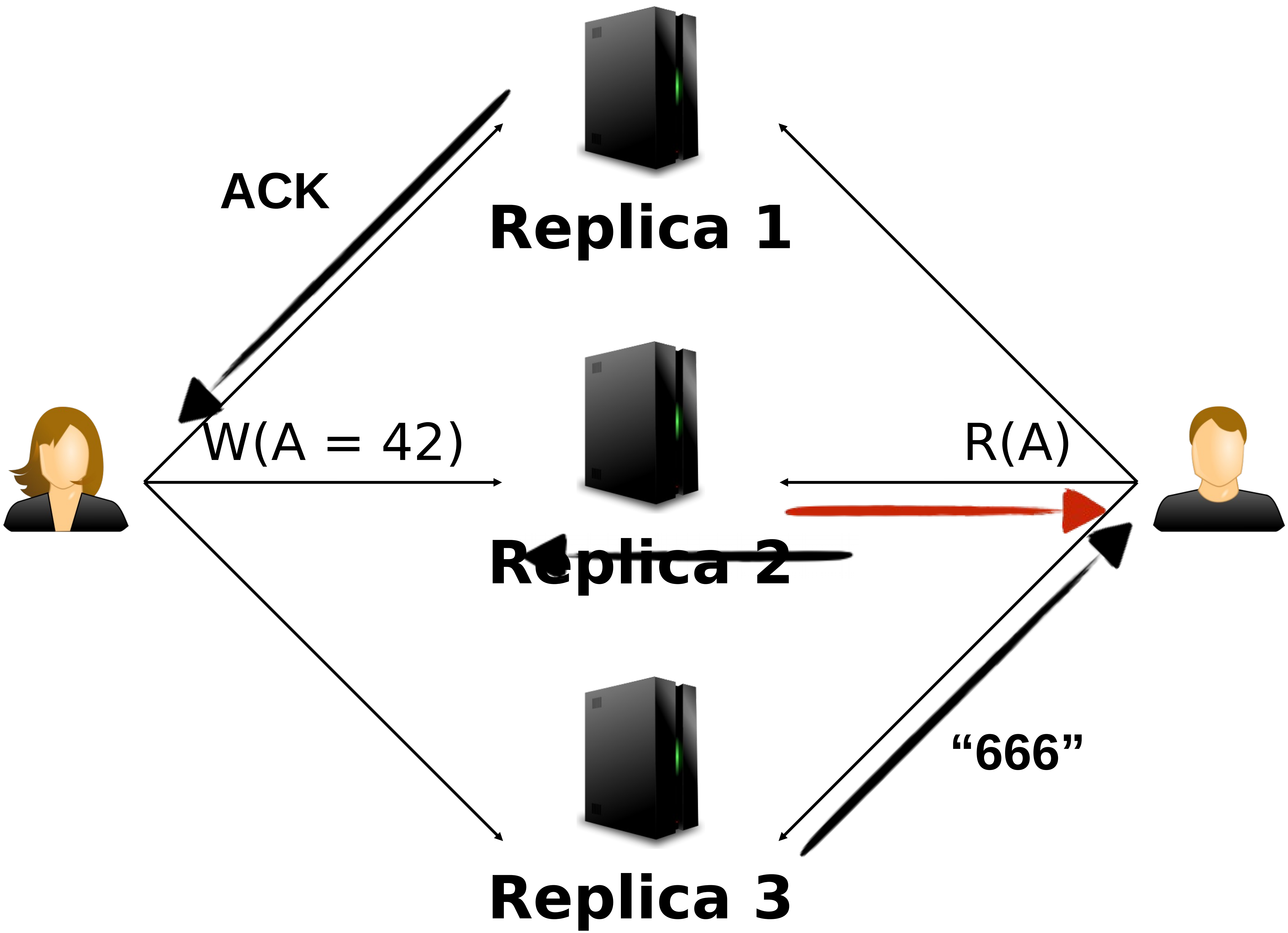
How many responses are required for each?


ACK
Replica 1
W(A = 42)
Replica 2
R(A)
Replica 3


ACK
Replica 1
W(A = 42)
Replica 2
R(A)
"666"
Replica 3



ACK
Replica 1
W(A = 42)
R(A)
Replica 2
"666"
Replica 3


ACK
Replica 1
W(A = 42)
R(A)
Replica 2
"666"
Replica 3

Ensuring Read-Consistency

Like Majority Vote

N Replicas
R Replica Reads Needed
W Writer Acks Needed
R + W > N