[544] Cassandra Replication

Tyler Caraza-Harter

Learning Objectives

- walk a token ring (in Cassandra, or other consistent hashing implementation) to identify multiple nodes responsible for a given row (while potentially skipping duplicate nodes in the same "failure domain")
- tune read/write quorum requirements to achieve desired tradeoffs in availability, durability, and performance
- describe common approaches to eventual consistency and conflict resolution

Outline

Replication

Quorum Reads/Writes

Conflict Resolution

Cassandra Demos

Replication

We *replicate* (create multiple copies on different nodes) to improve *durability* -- meaning we don't want data to be lost when nodes die.

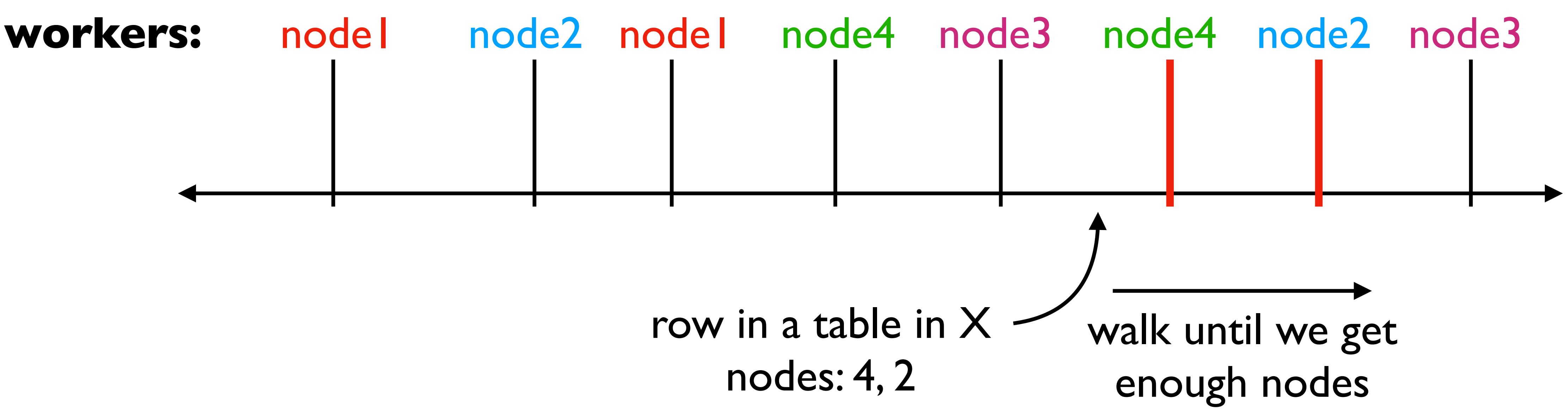
Cassandra lets us choose a different RF (replication factor) for each keyspace:

```
create keyspace X
with replication={'class': 'SimpleStrategy',
                  'replication_factor': 2};

create keyspace Y
with replication={'class': 'SimpleStrategy',
                  'replication_factor': 3};
```

Replication

Token Map:
token(node1) = {t1, t2}
token(node2) = {t3, t4}
token(node3) = {t5, t6}
token(node4) = {t7, t8}

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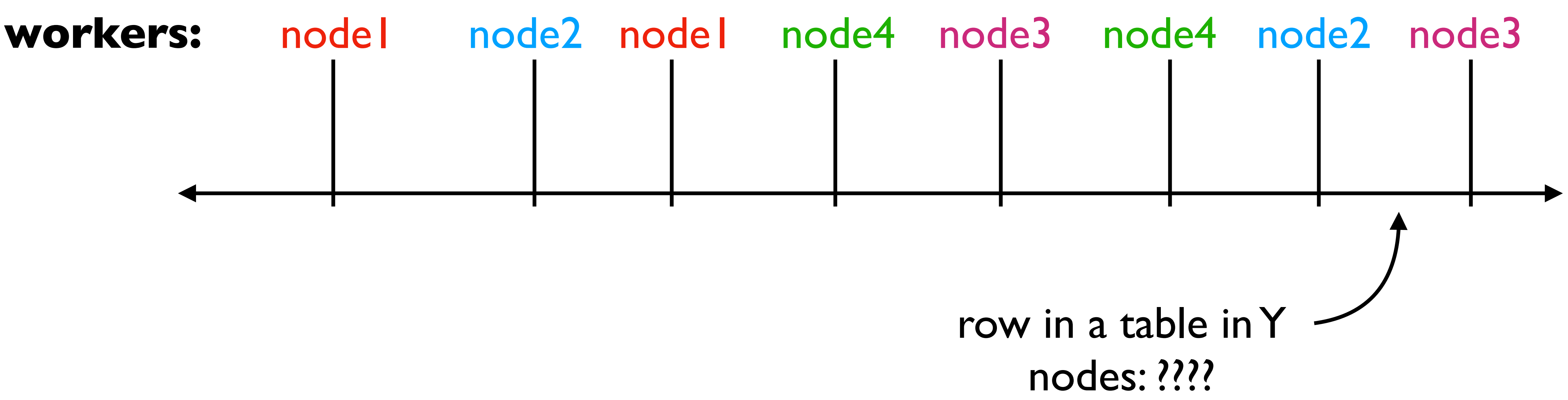


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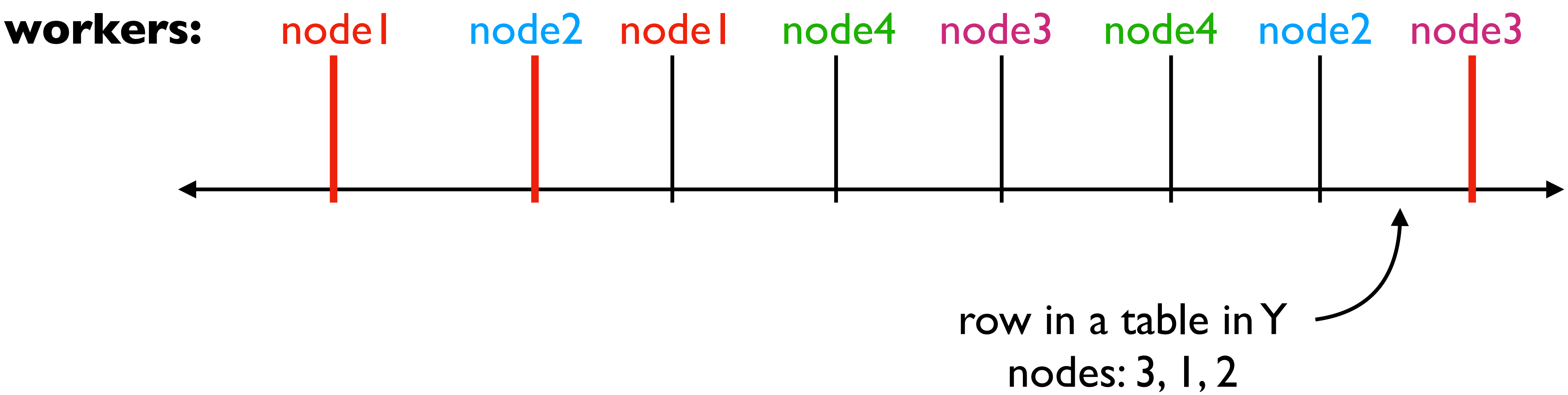


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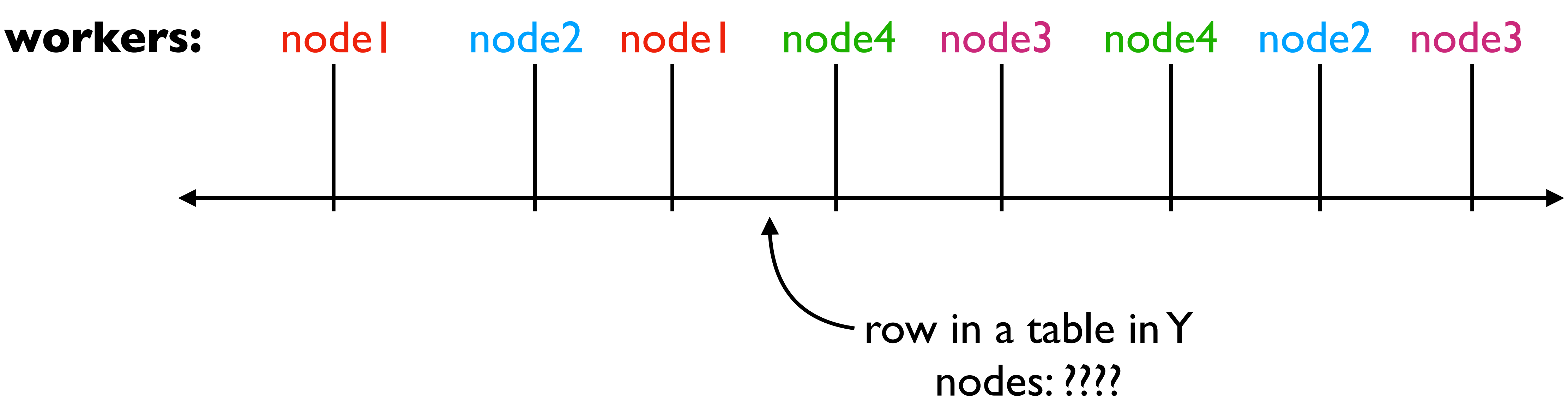


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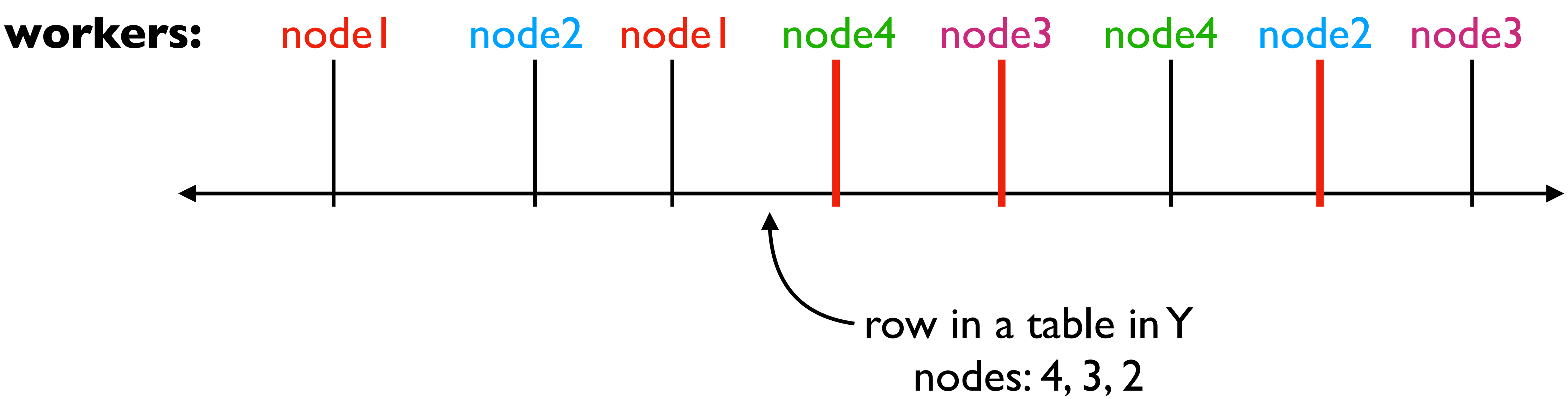
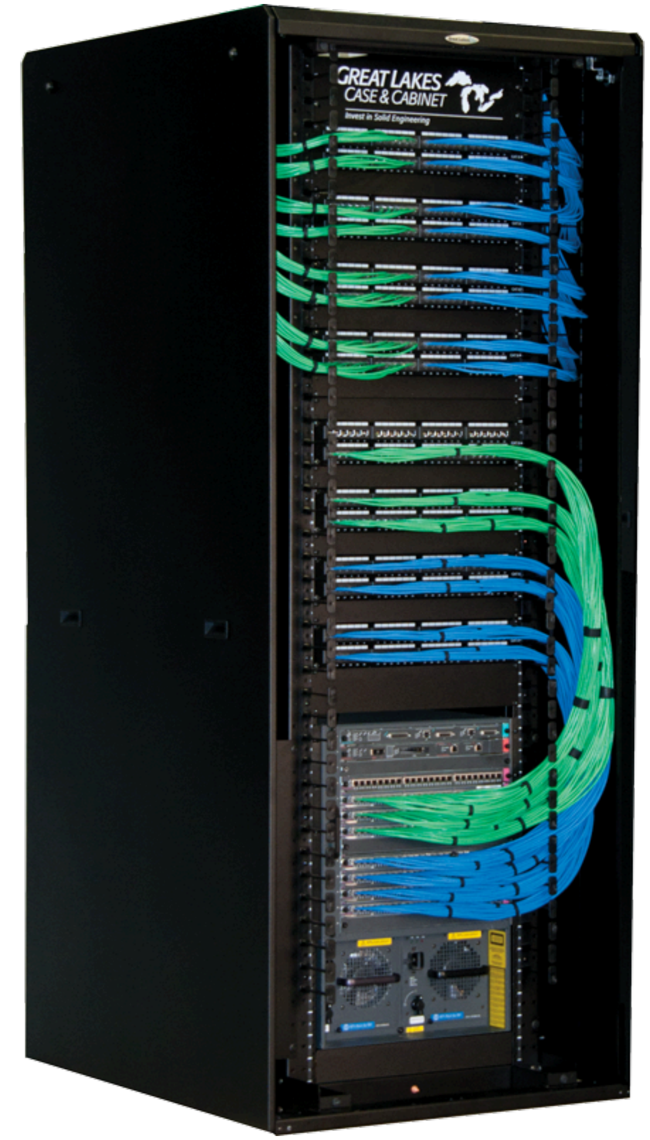


Important! Keeping multiple copies on vnodes on the same node provides little safety (when a node dies, all its vnodes die). Same "failure domain".

Cassandra can skip nodes as it "walks the ring".

Network Infrastructure

Server



Rack

Data Center

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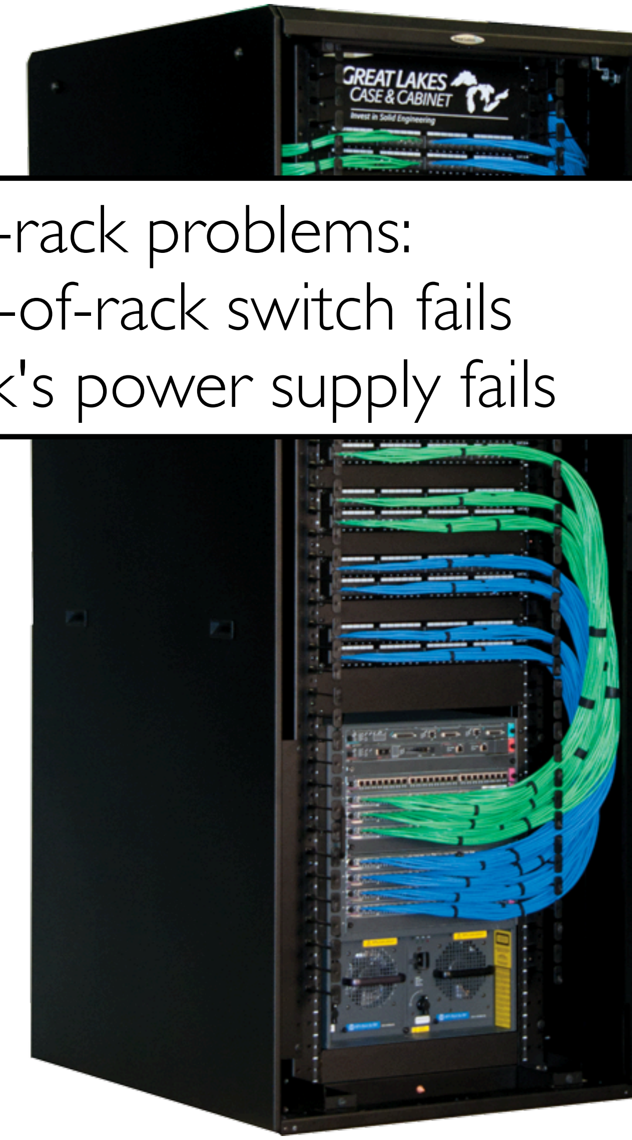
Correlated Failures

One server goes down, all of its vnodes are gone.

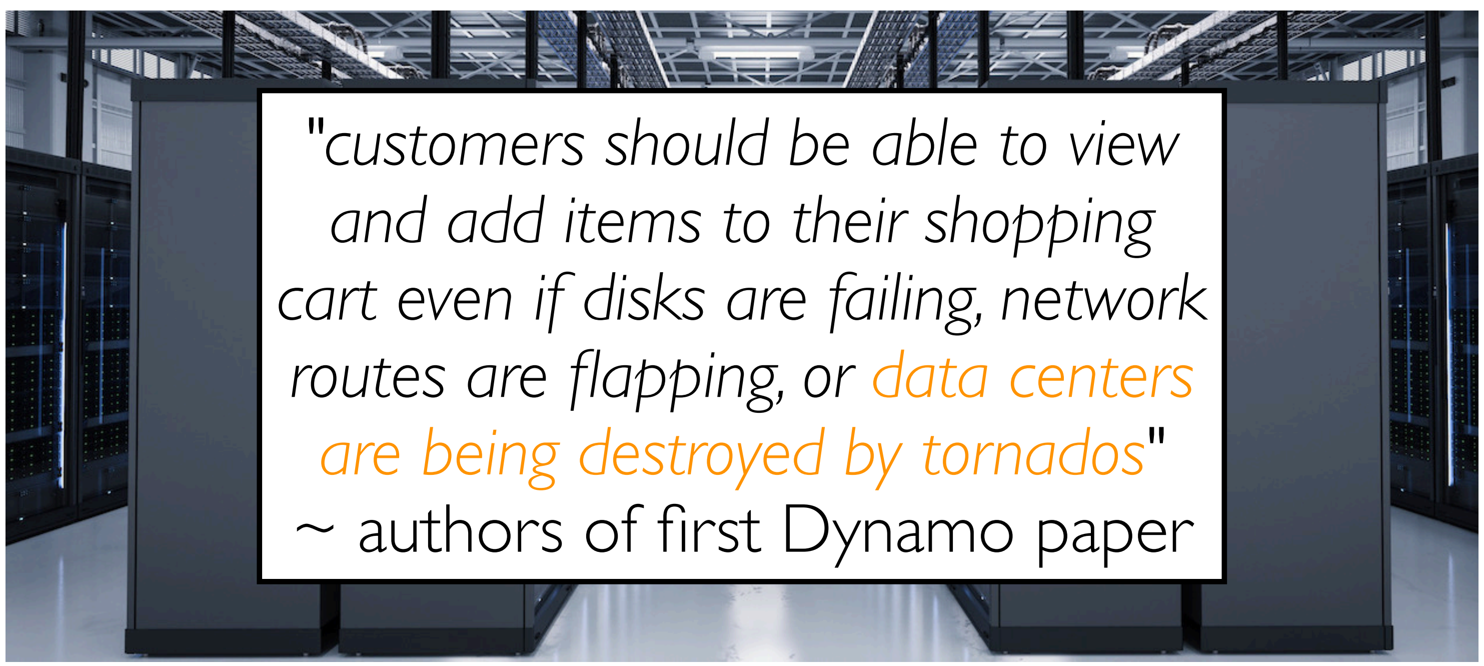
Server

Whole-rack problems:

- top-of-rack switch fails
- rack's power supply fails



Rack



"customers should be able to view and add items to their shopping cart even if disks are failing, network routes are flapping, or data centers are being destroyed by tornados"
~ authors of first Dynamo paper

Data Center

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Replication Policy

Cassandra replication strategies are "pluggable", with a couple built-in options.

SimpleStrategy

- all nodes are considered equal
- skips vnodes on same machine
- ignores rack and data center placement
- used in CS 544

NetworkTopologyStrategy

- considers data centers and racks
- when walking the ring, some vnodes may be skipped to protect against various kinds of correlated failure

Worksheet

Outline

Replication

Quorum Reads/Writes

Conflict Resolution

Cassandra Demos

Write Acks: WhatsApp Example

> **How to check read receipts** Copy link
>
> Android iPhone KaiOS
>
> Check marks will appear next to each message you send. Here's what each one indicates:
>
> - ✓ The message was successfully sent.
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> https://faq.whatsapp.com/665923838265756

these are examples of "acks" (acknowledgements)

In distributed storage systems/databases, an *ack* means our data is *committed*.

"Committed" means our data is "safe", even if bad things happen. The definition varies system to system, based on what bad things are considered. For example:

- a node could hang until rebooted; a node's disk could permanently fail
- a rack could lose power; a data center could be destroyed

Obviously, no data is ever completely safe against any circumstance (e.g., comet strikes earth, leading to destruction of humankind and all our data centers).

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stronger definition: **all** devices (in case one device fails)

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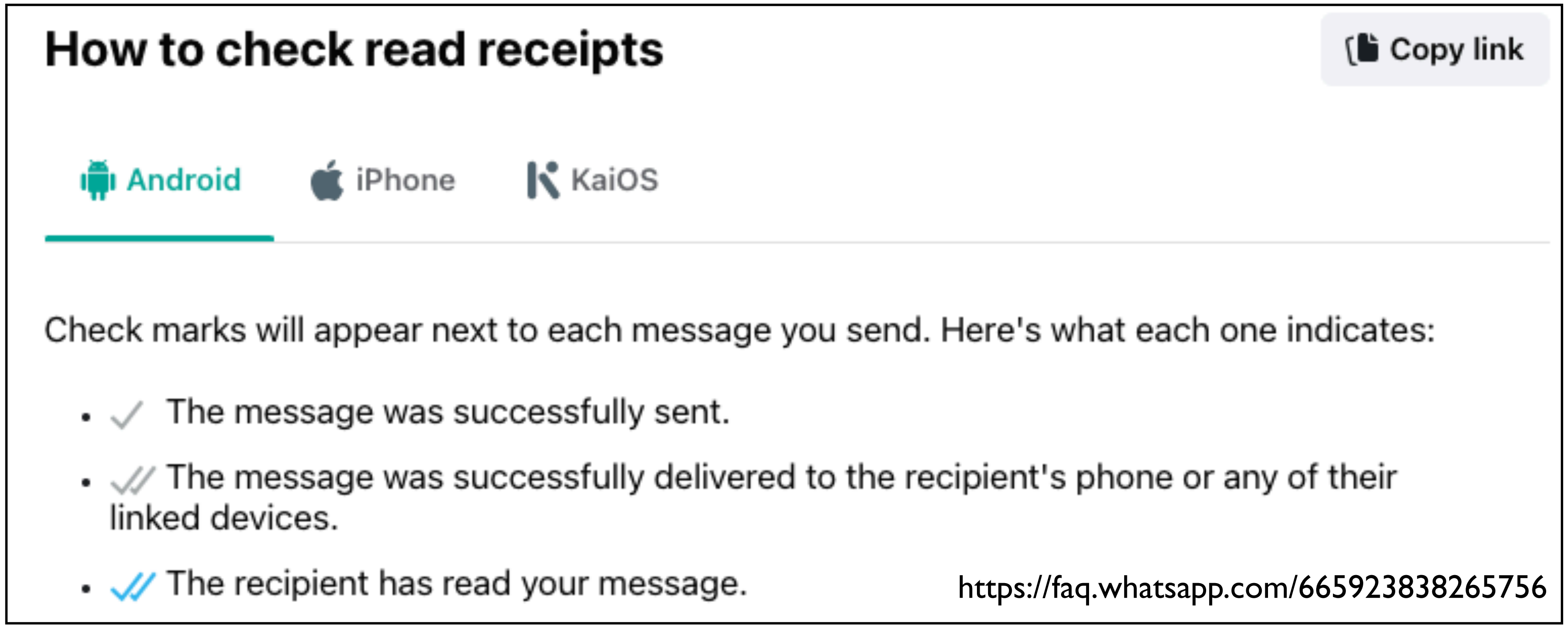

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Does only one check mean the message has NOT reached the destination?

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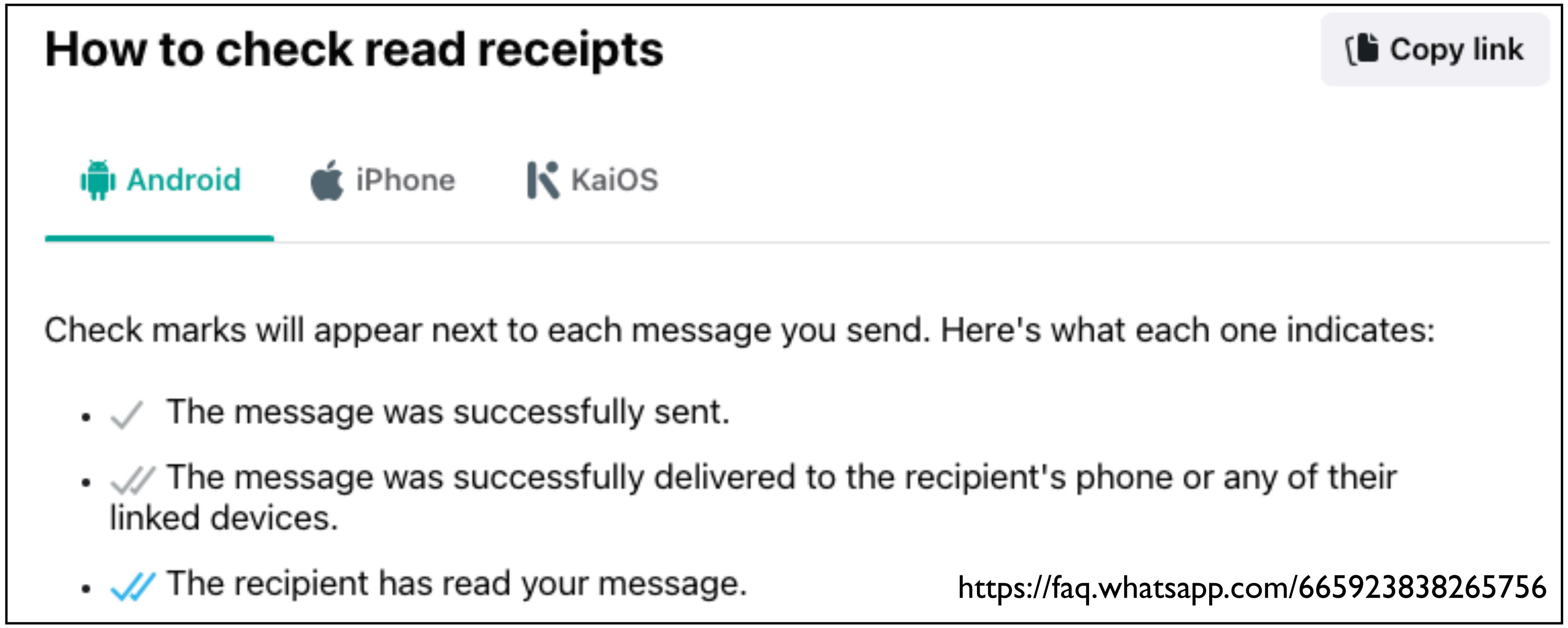

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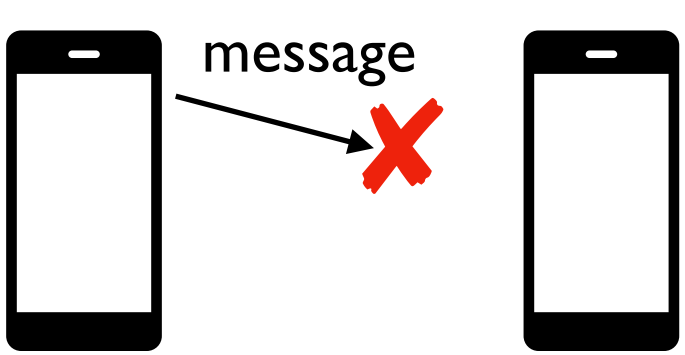
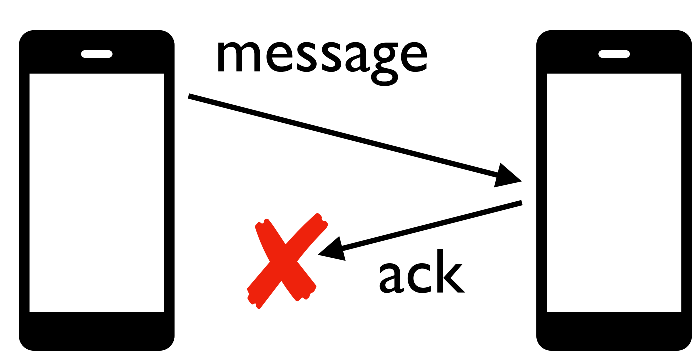
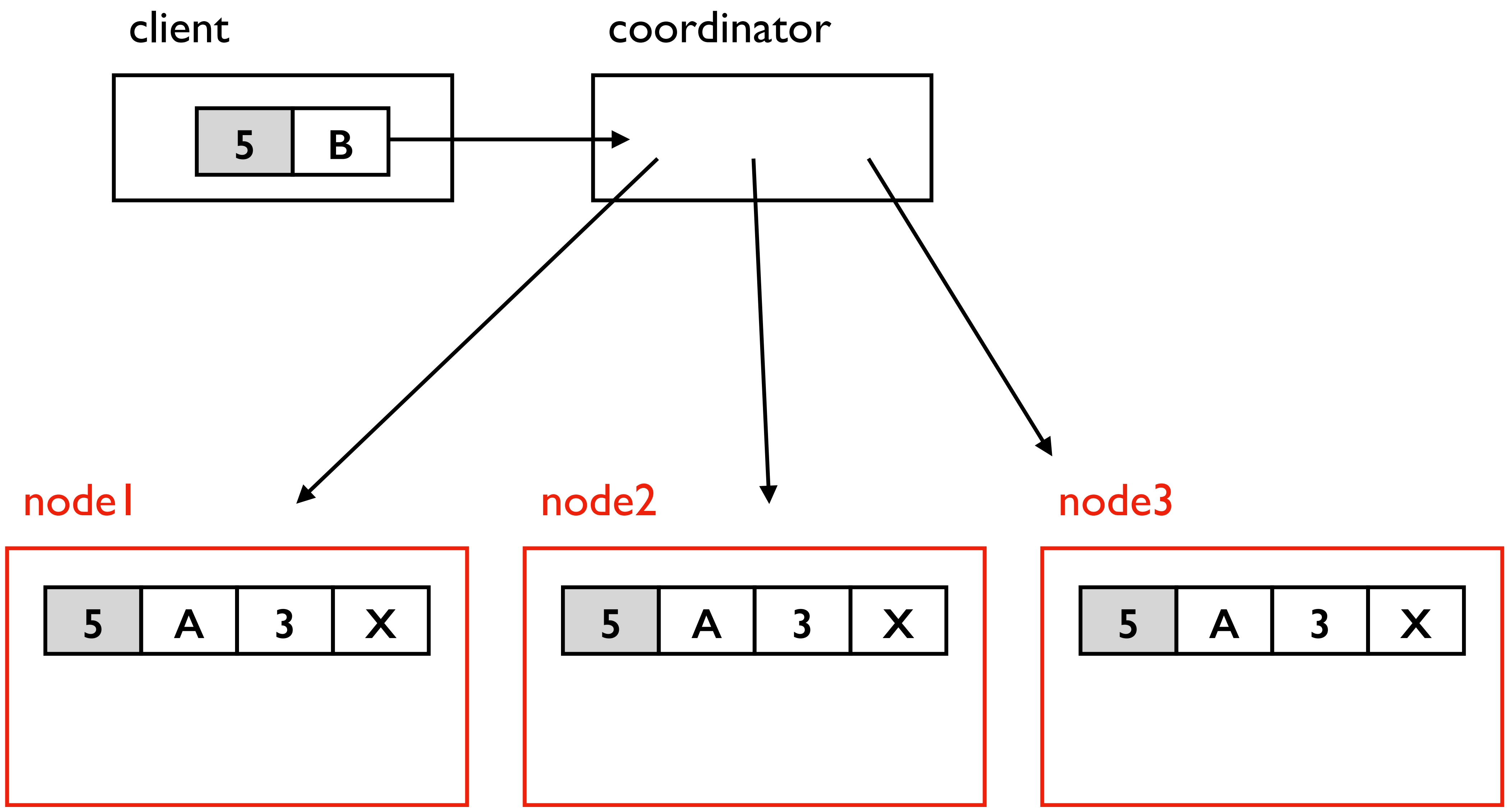


scenario 1



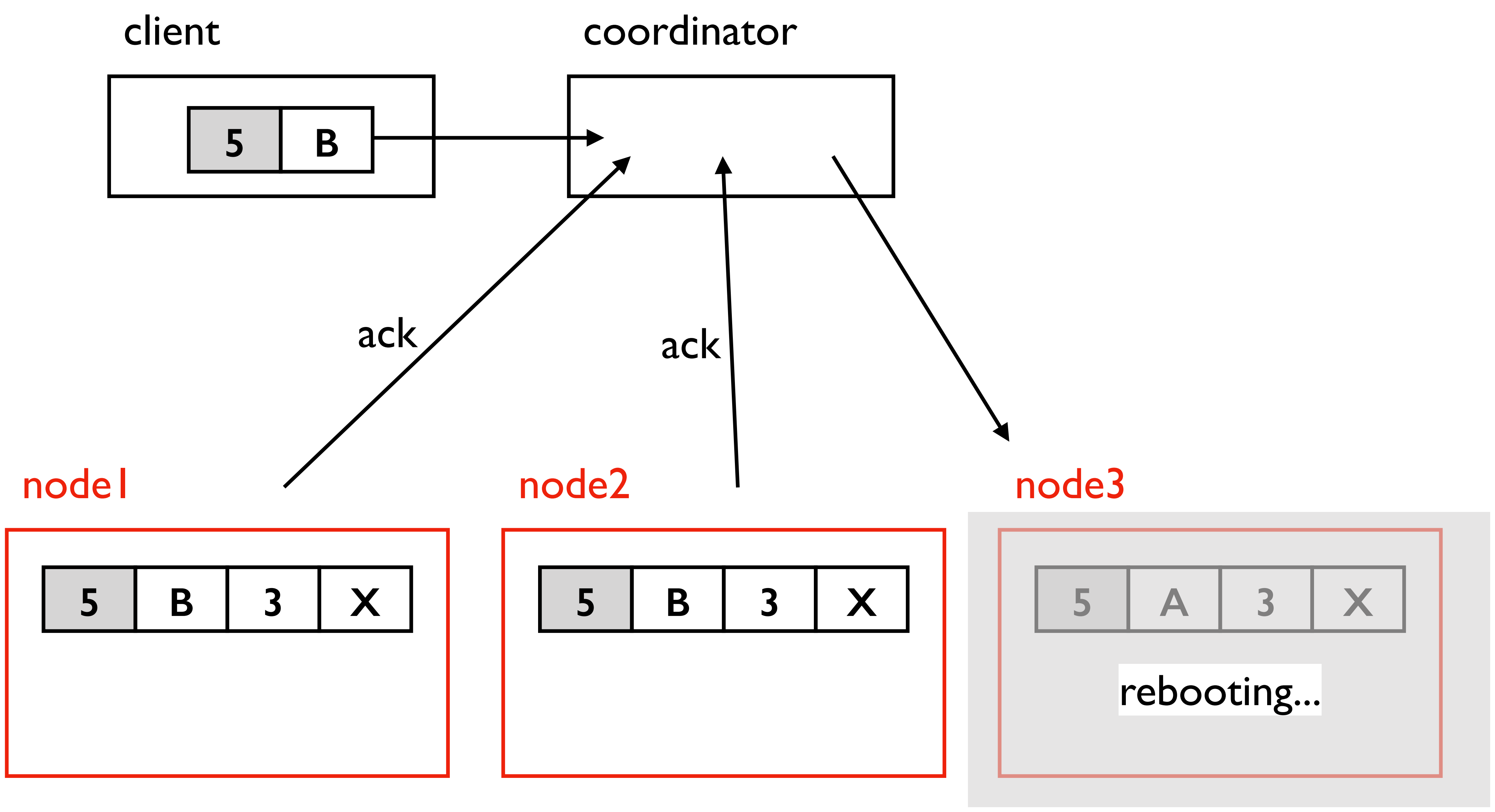
scenario 2

Cassandra Writes



Say RF=3. Coordinator will attempt to write data to all 3 replicas.

Cassandra Writes



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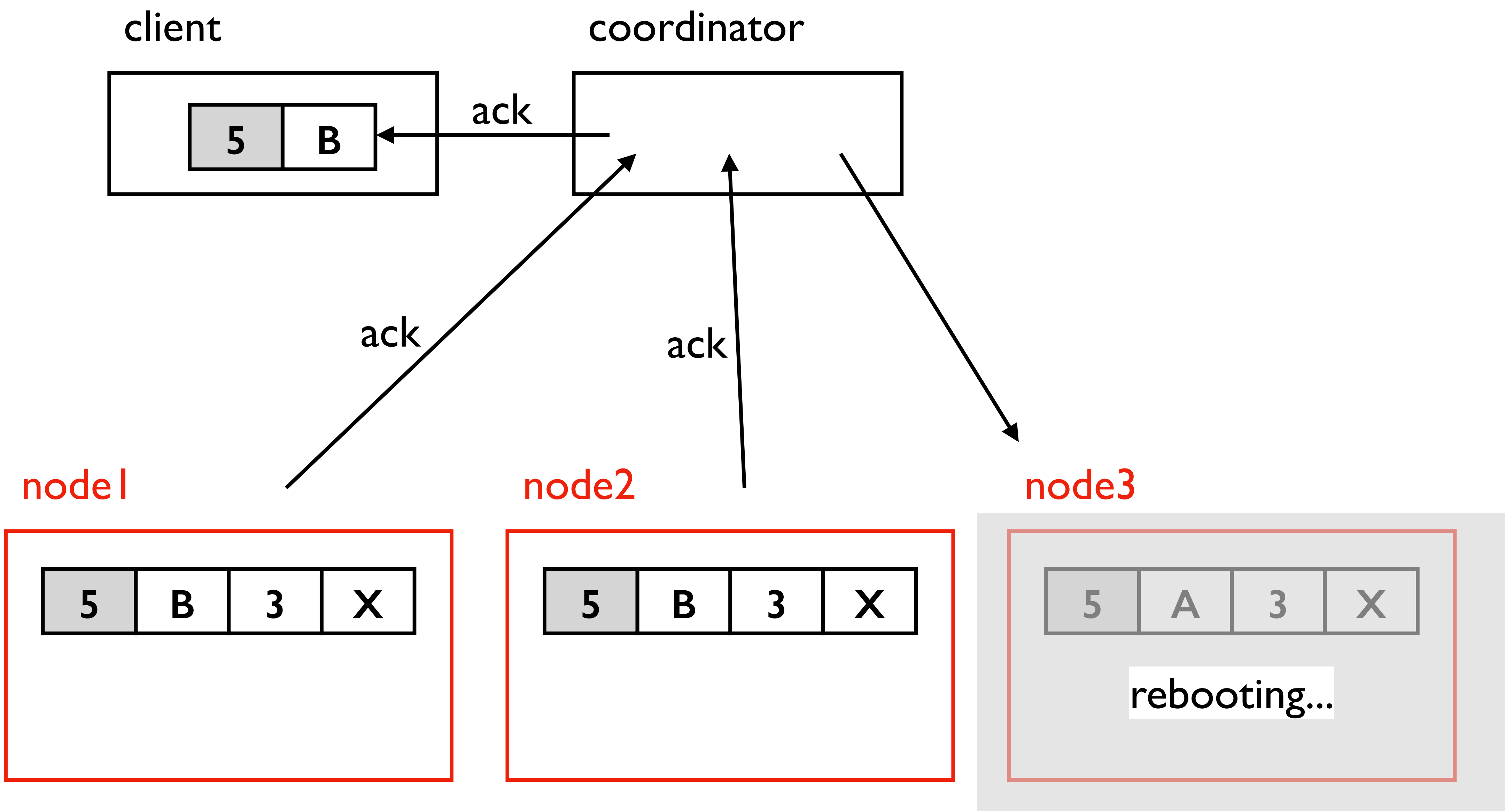
At what point should we send an ack to the client?

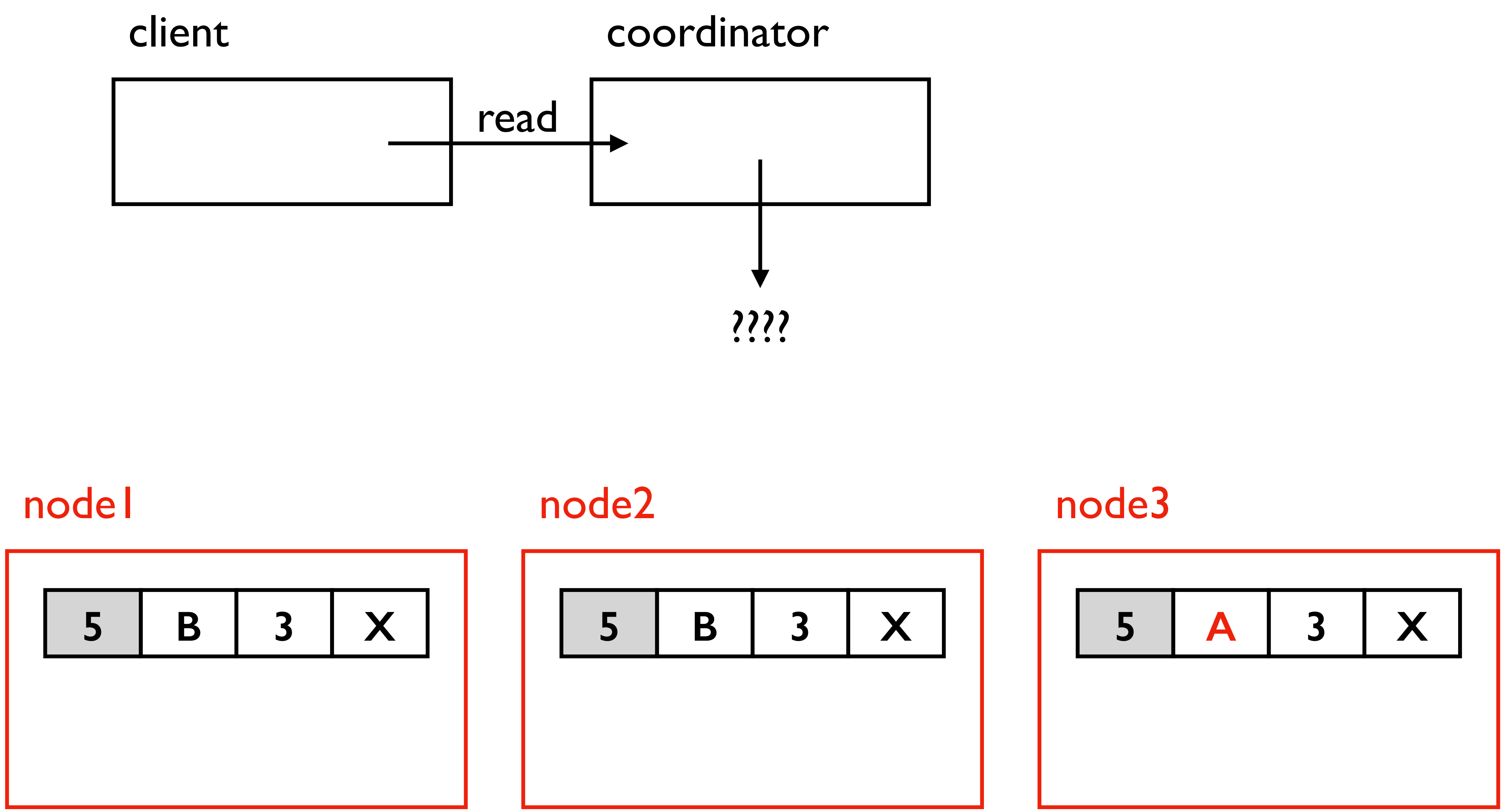
Cassandra Writes



Say RF=3. Coordinator will attempt to write data to all 3 replicas.

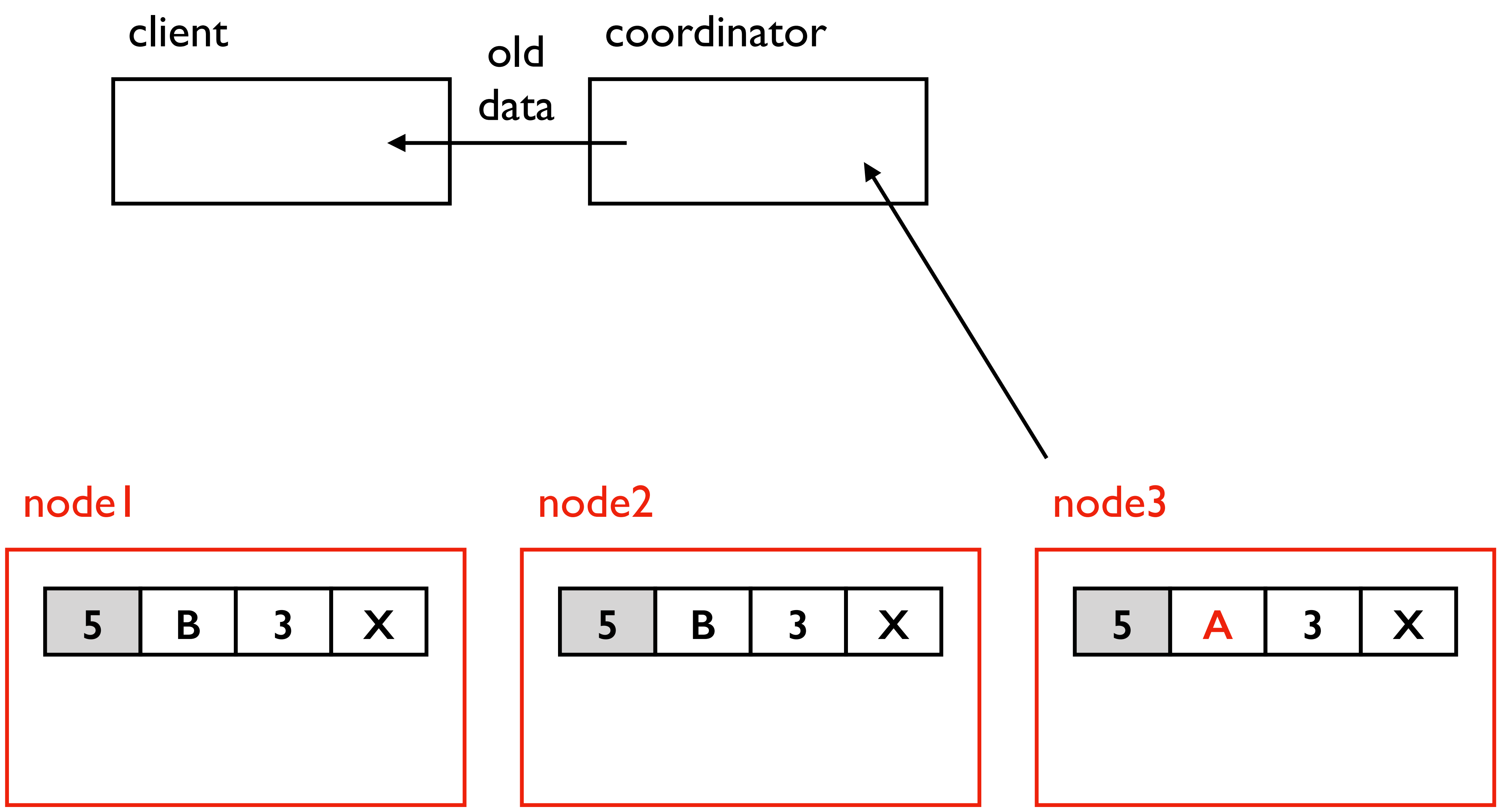
At what point should we send an ack to the client?
Configurable. W=2 lets coordinator ack now, and data is fairly safe.

Cassandra Reads



HDFS reads go to one replica. What if Cassandra tries that?

Cassandra Reads



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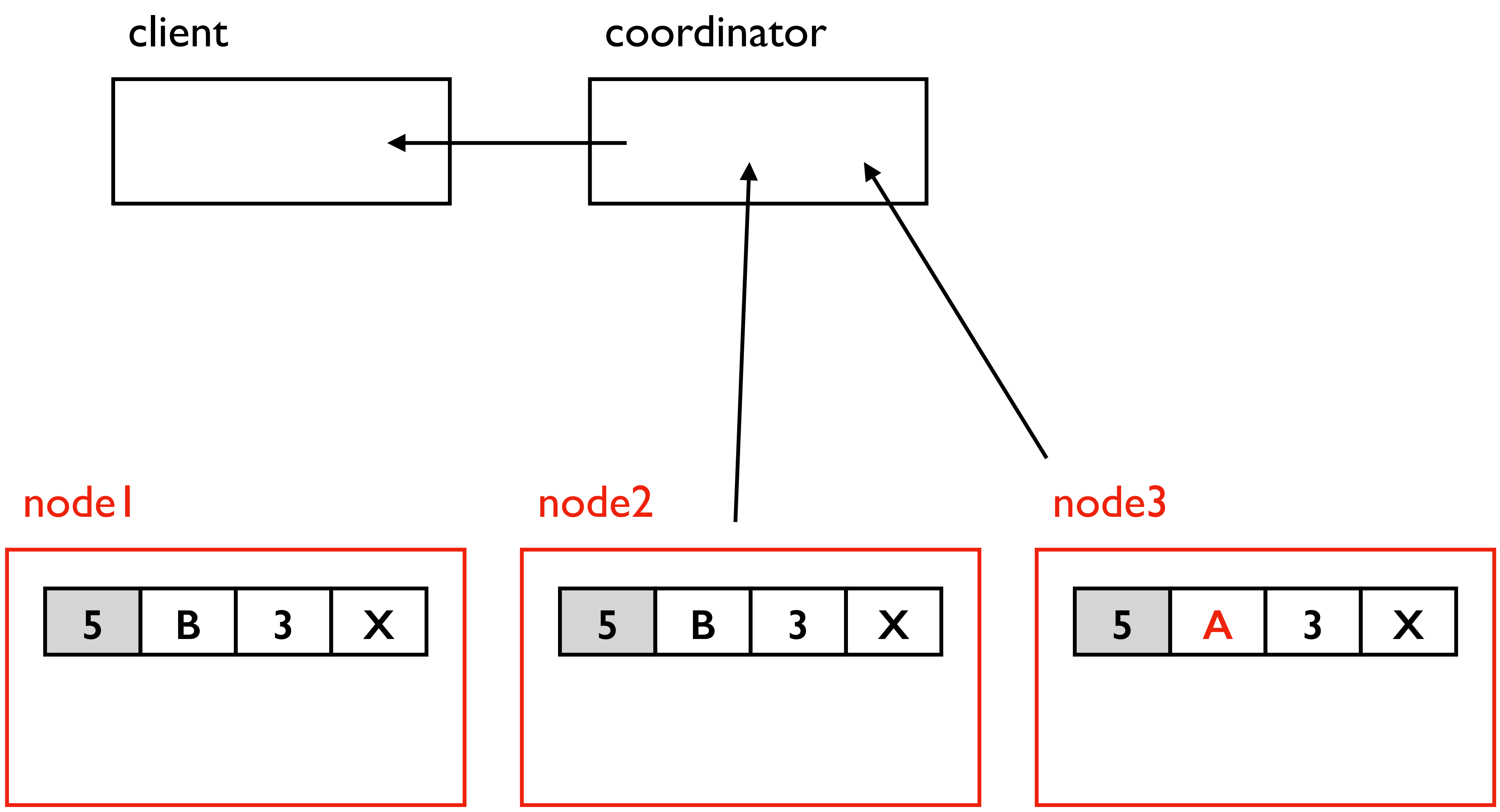
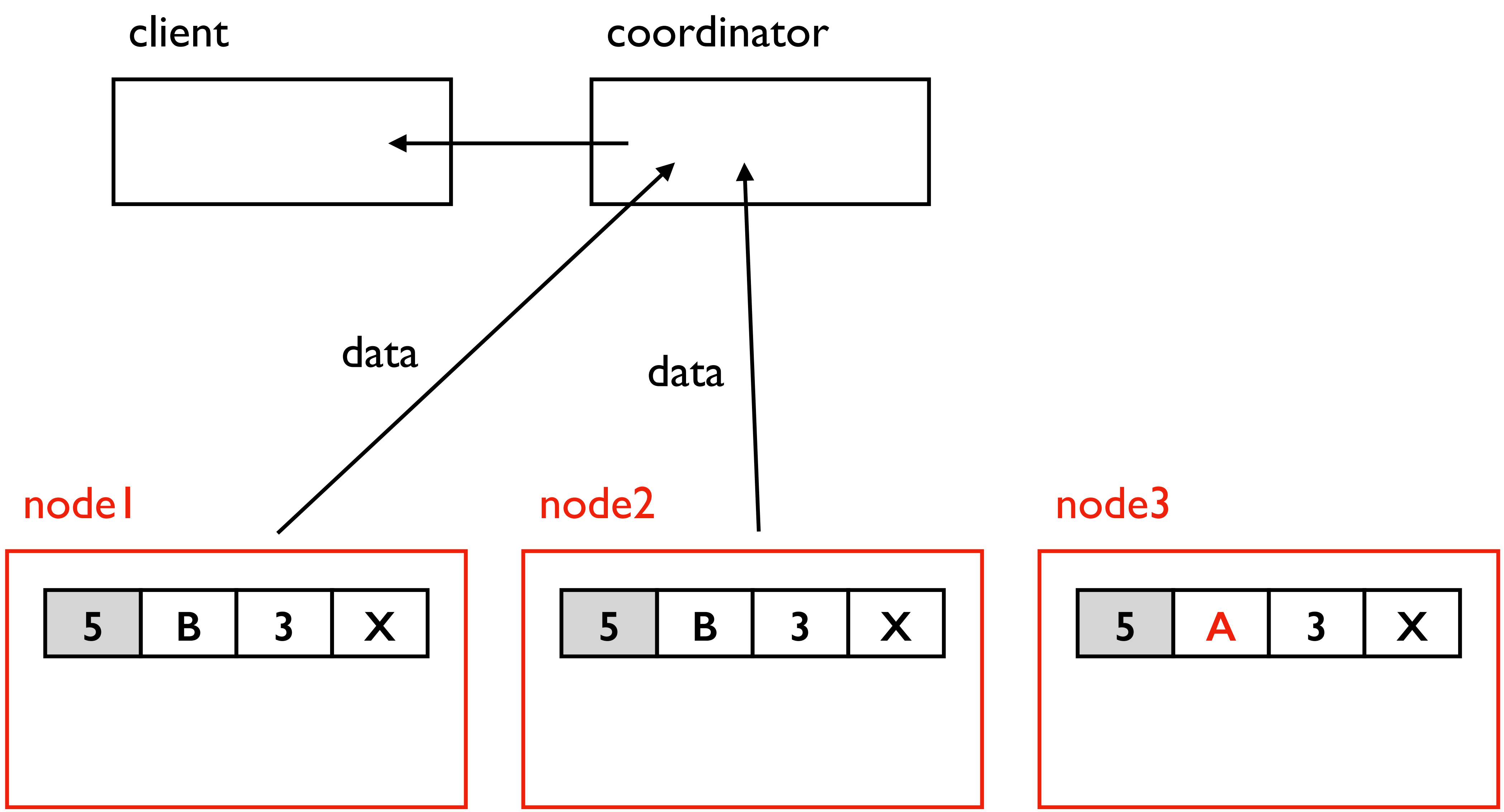


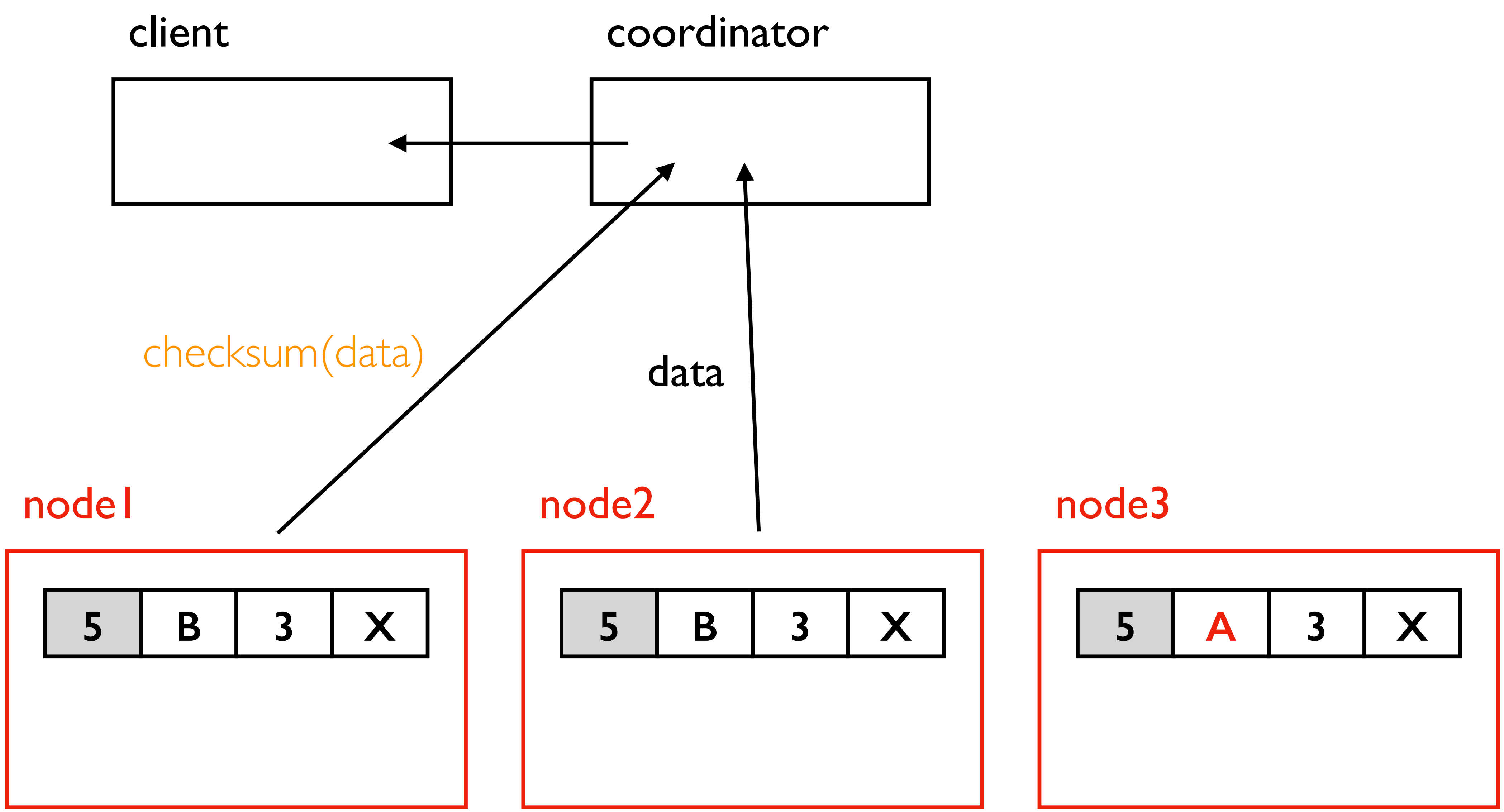
Read from R replicas (configurable). Here R=2.
Hopefully at least one of the replicas has new data.

Cassandra Reads



R=2 means we'll often read identical data from two replicas (wasteful!)

Cassandra Reads

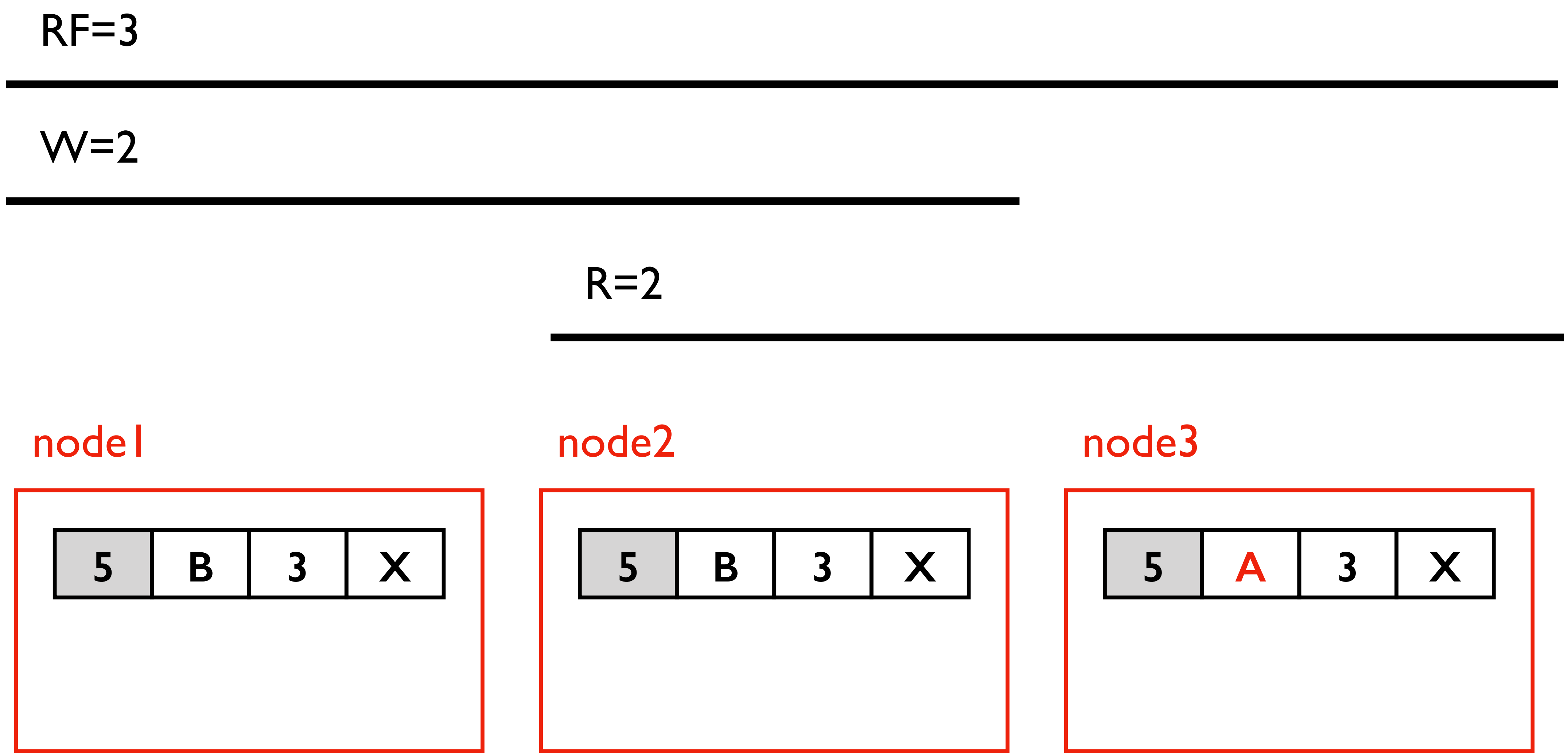


R=2 means we'll often read identical data from two replicas (wasteful!)

Improvement: read one copy, and only request checksum from others.

A *checksum* (like md5) is a hash function where collisions are extremely rare and hard to find.

When R+W > RF



When R+W > RF, the replicas read+written will overlap.

There are some caveats (related to ring membership and something called "hinted handoff") not covered in 544.

Tuning R and W

Say RF=3

W=3, R=1

- reads are highly available and fast -- only need one replica to respond before we can get back to the client!
- writes will not succeed (from the client's perspective) if even one node is down. But the data may still get recorded on some nodes.

W=1, R=3

- writes are highly available and fast -- only need one replica to respond before we can get back to the client!
- reads will not return data when even one node is down.
- risky: if the one node that took the write fails permanently, we'll lose committed data

W=2, R=2

- relatively balanced approach

W=1, R=1

- speed+availability more important that correct data

Worksheet

Outline

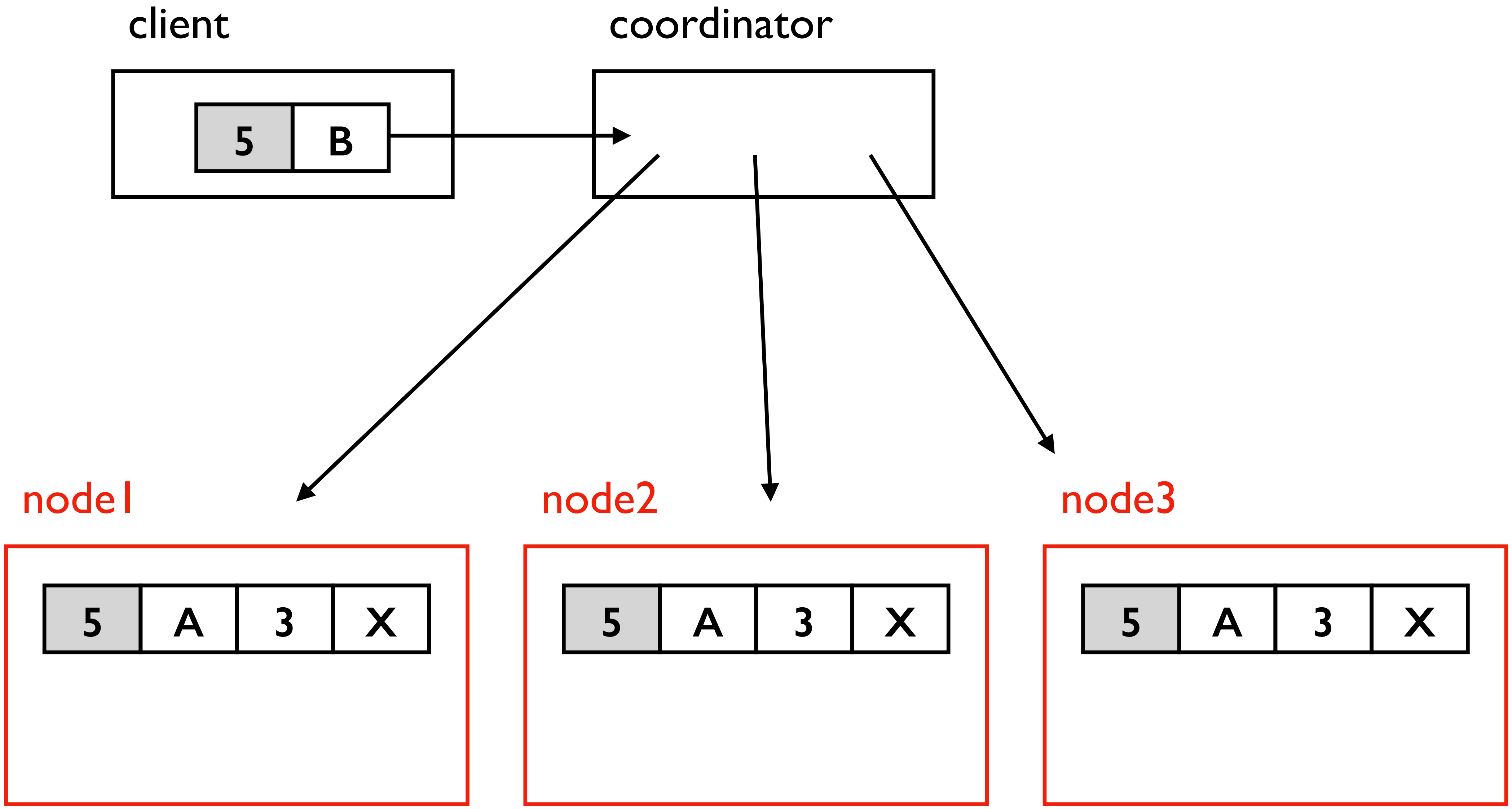
Replication

Quorum Reads/Writes

Conflict Resolution

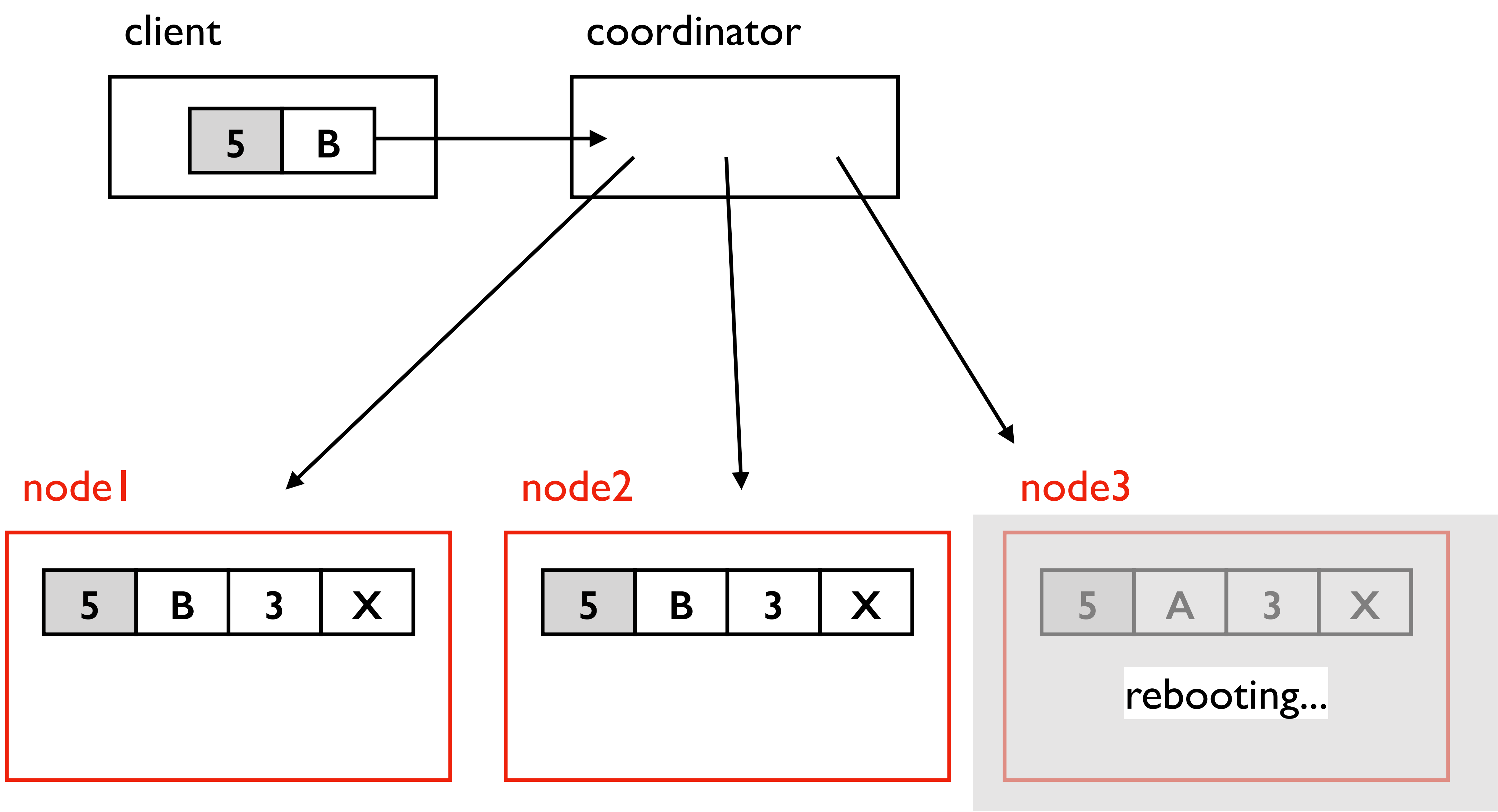
Cassandra Demos

Getting Conflicting Versions



Let RF=3, R=2, W=2

Getting Conflicting Versions



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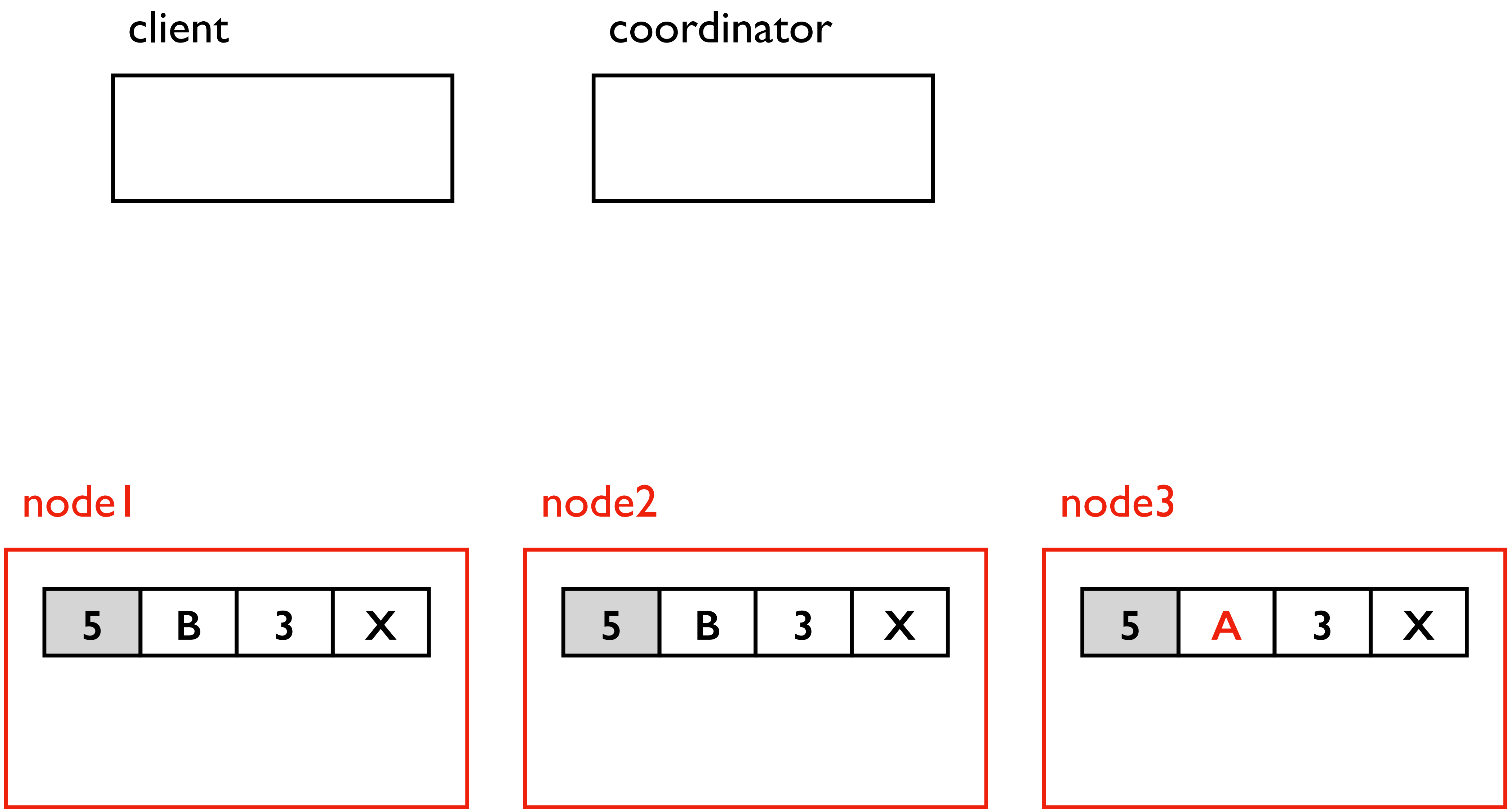

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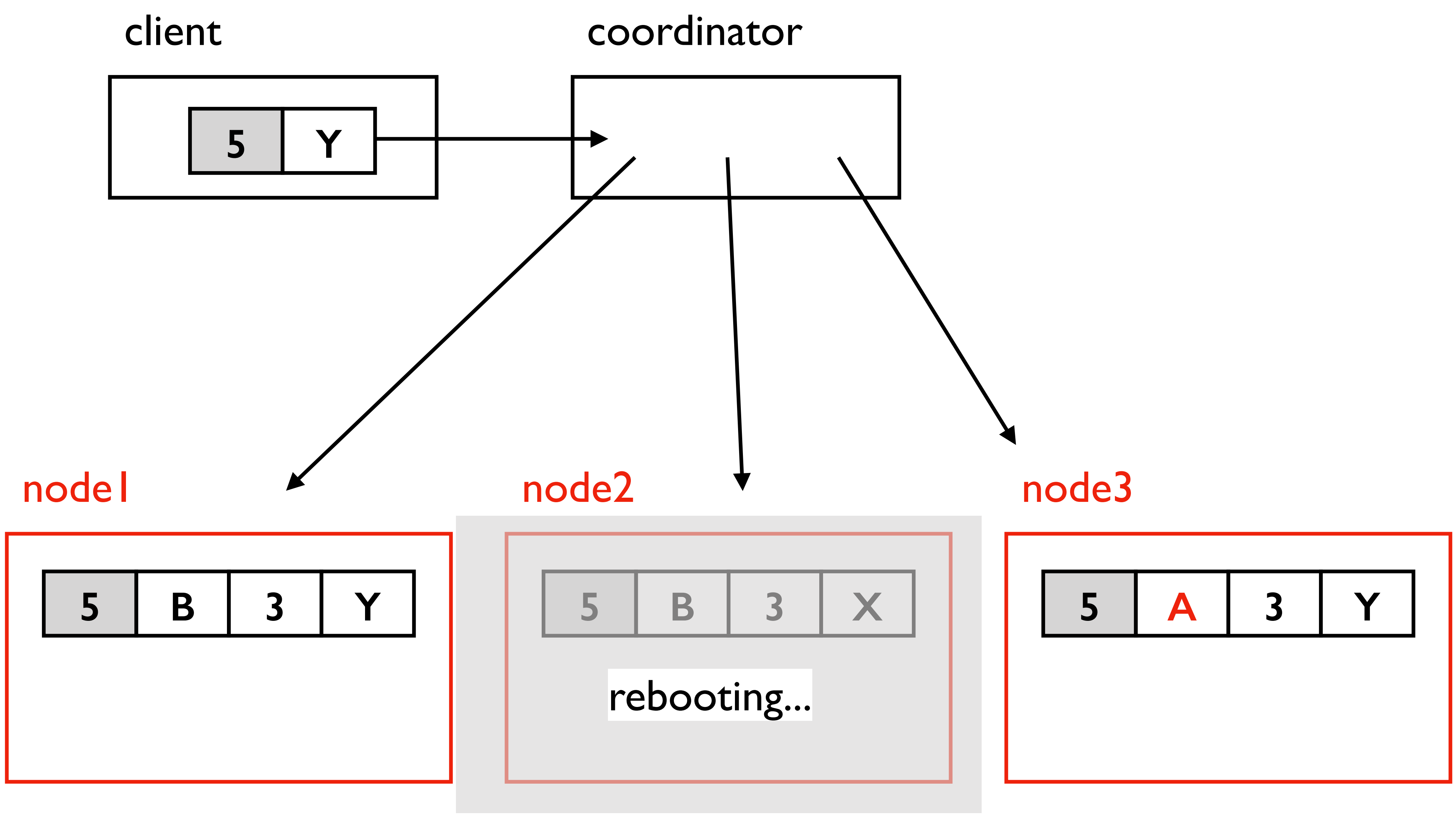

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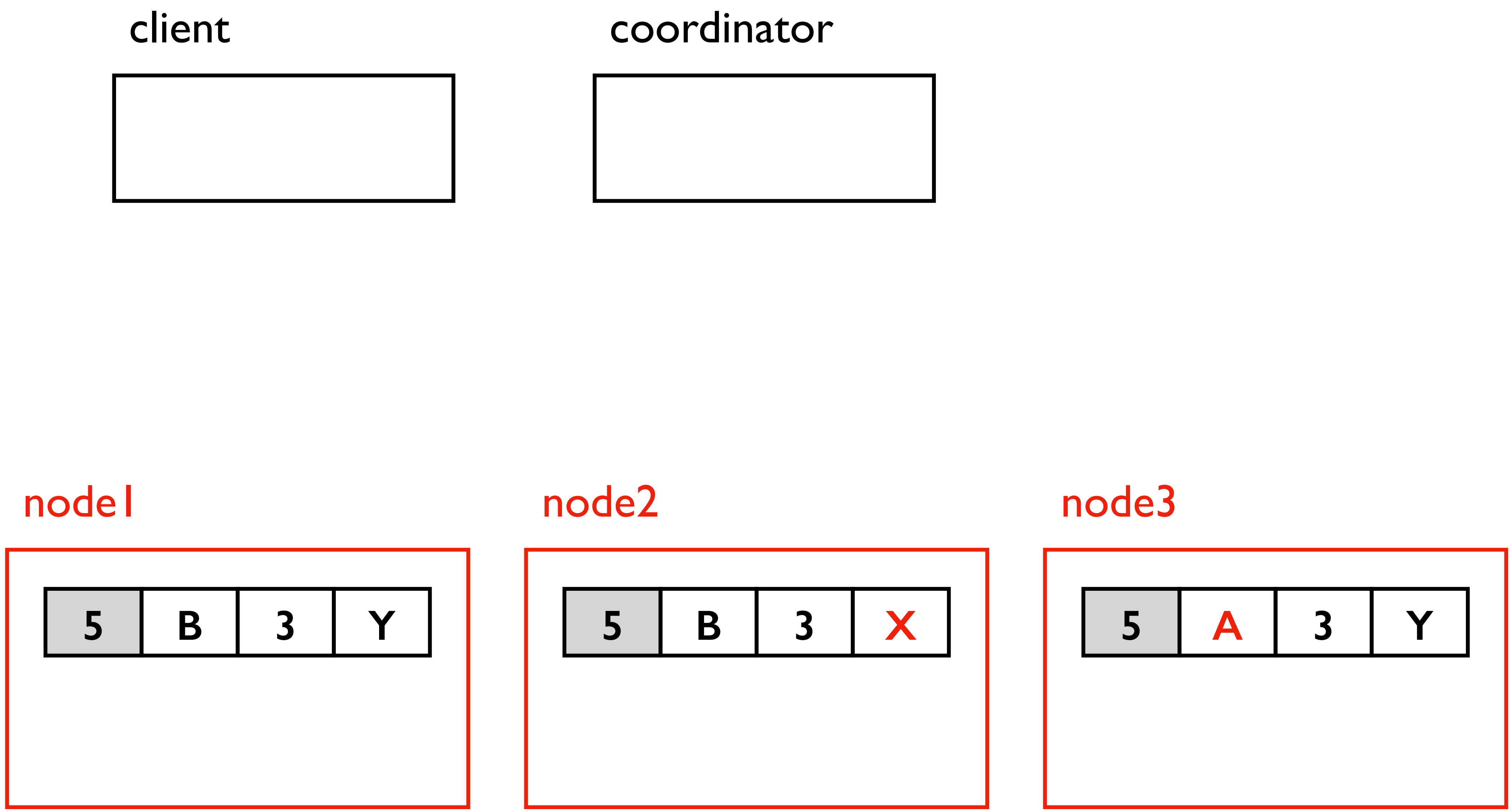

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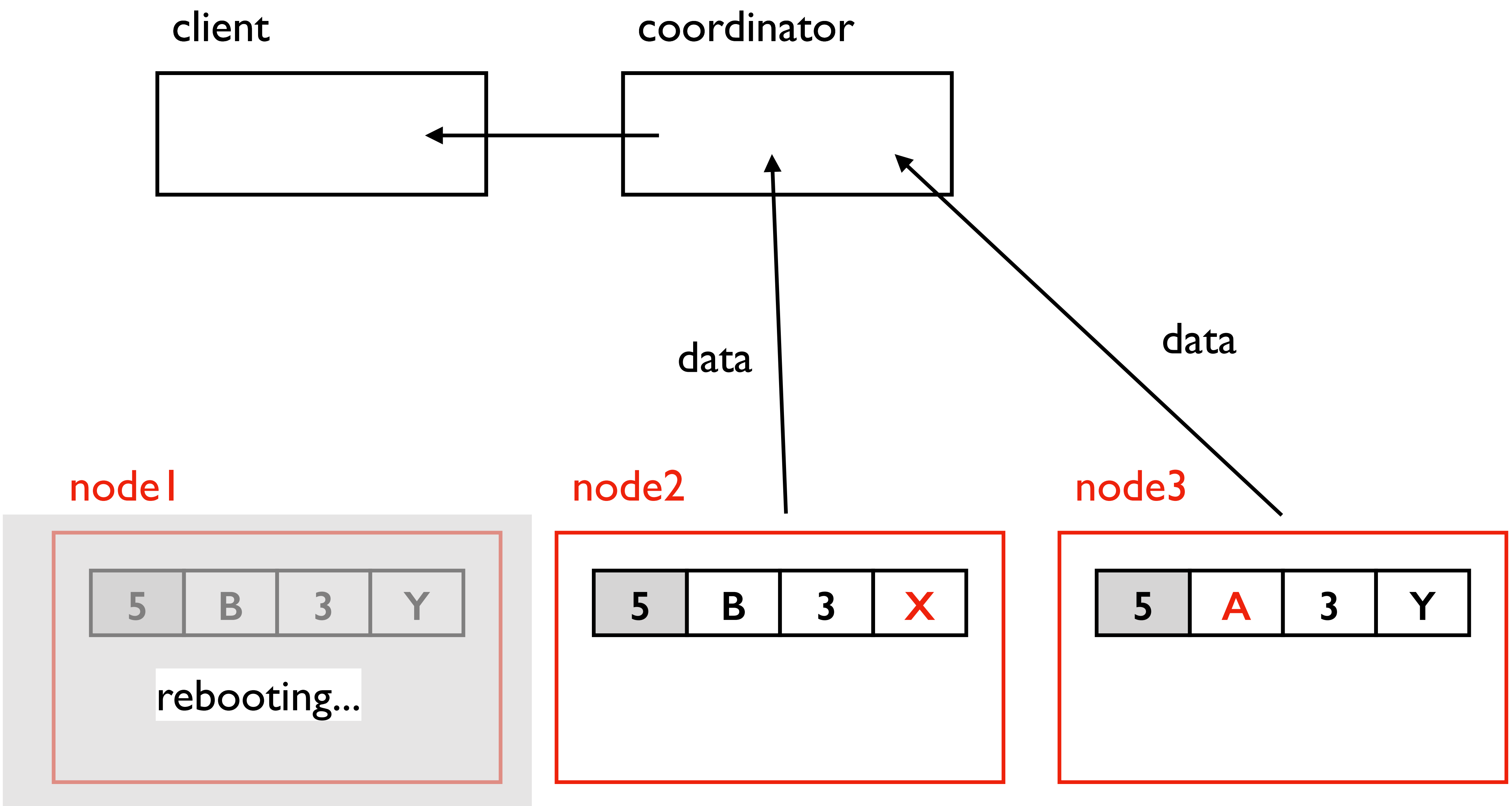
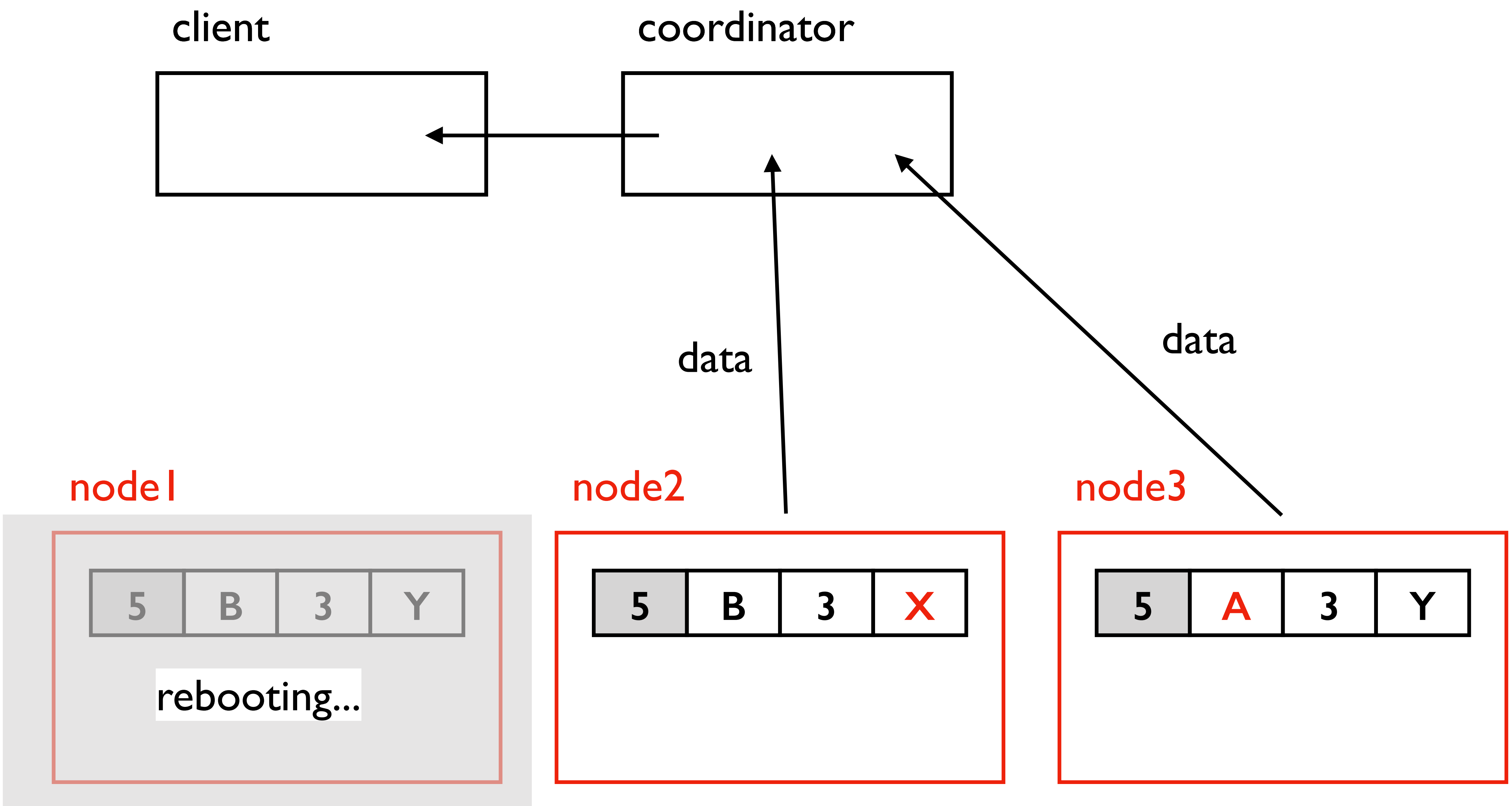


Which version of row 5 should be sent back?
Both contain some new data not contained by other.

Systems that allow conflicting versions to co-exist,
fixing it up later are "*eventually consistent*"

Getting Conflicting Versions

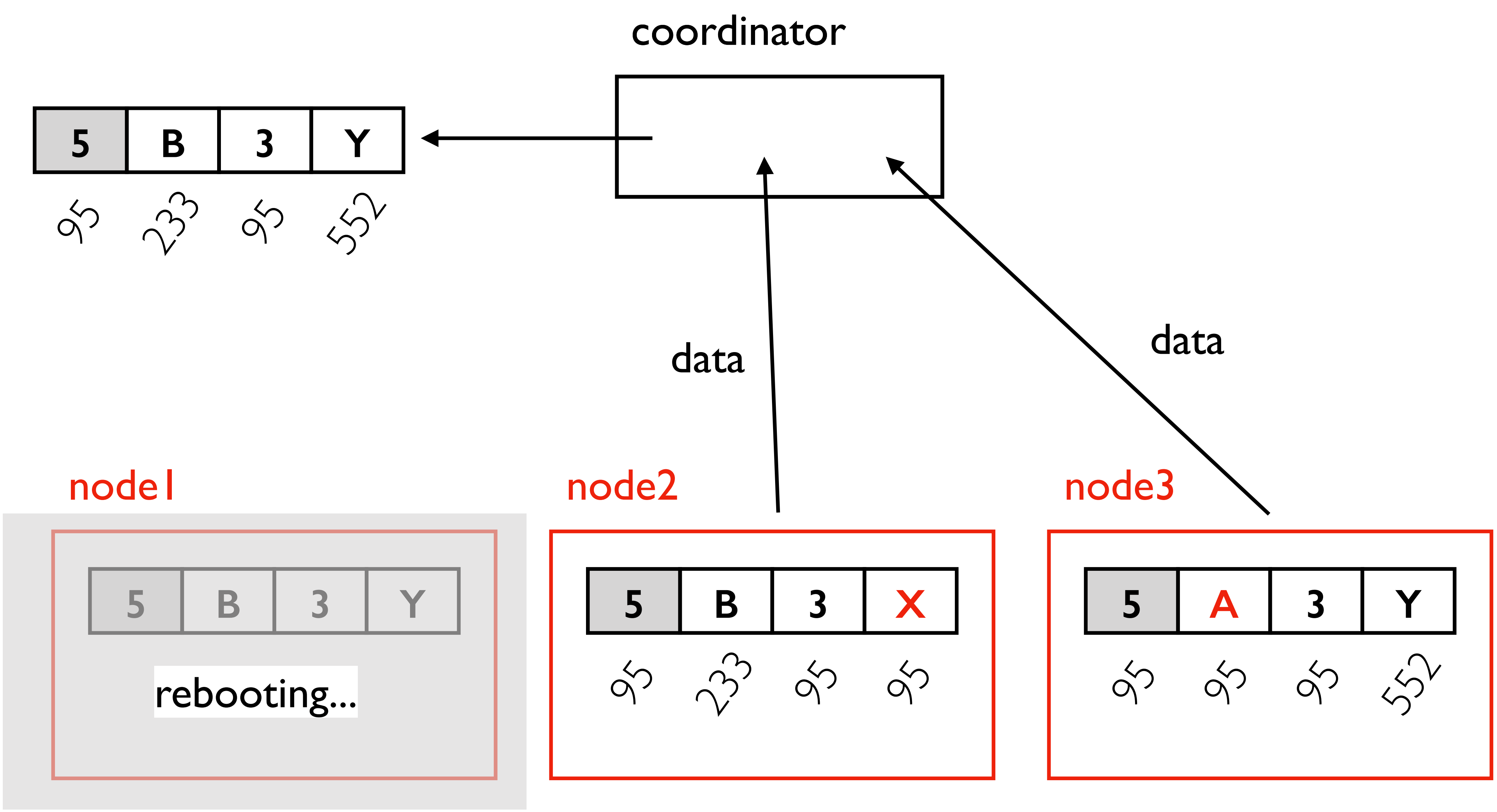


Approaches:

- send all version back to the client, which will need specialized conflict resolution code
- automatically combine them into a new row, and write that (if possible) to all replicas

Dynamo supports both. Cassandra uses second approach.

Timestamps



Every cell of every table has a timestamp:

- approximate (since clocks of nodes in a cluster are never perfectly in sync)
- policy is LWW (last writer wins), meaning prefer newer data
- Cassandra lets you query the timestamp of each cell

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