[544] Cassandra Replication

Meenakshi Syamkumar

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.

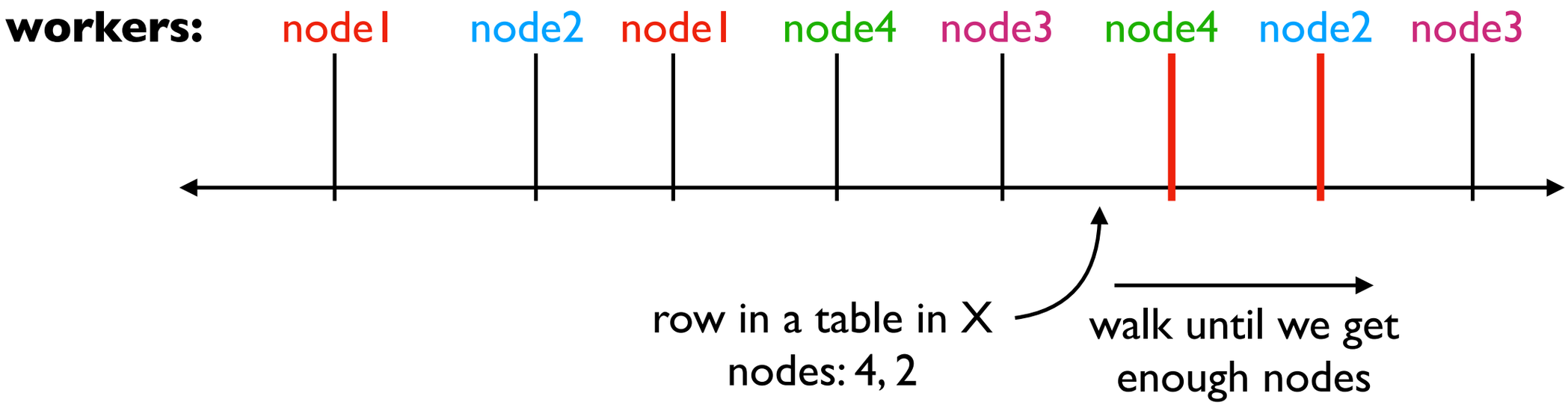
Cassandra lets us choose a different RF (replication factor) for each keyspace:

```
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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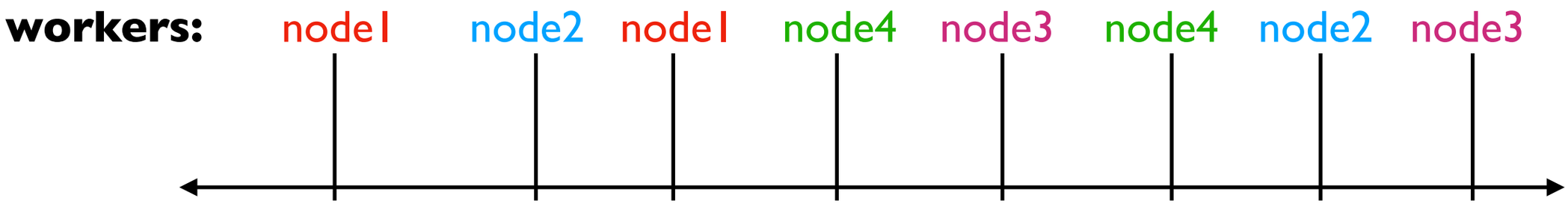

row in a table in Y
nodes: ????

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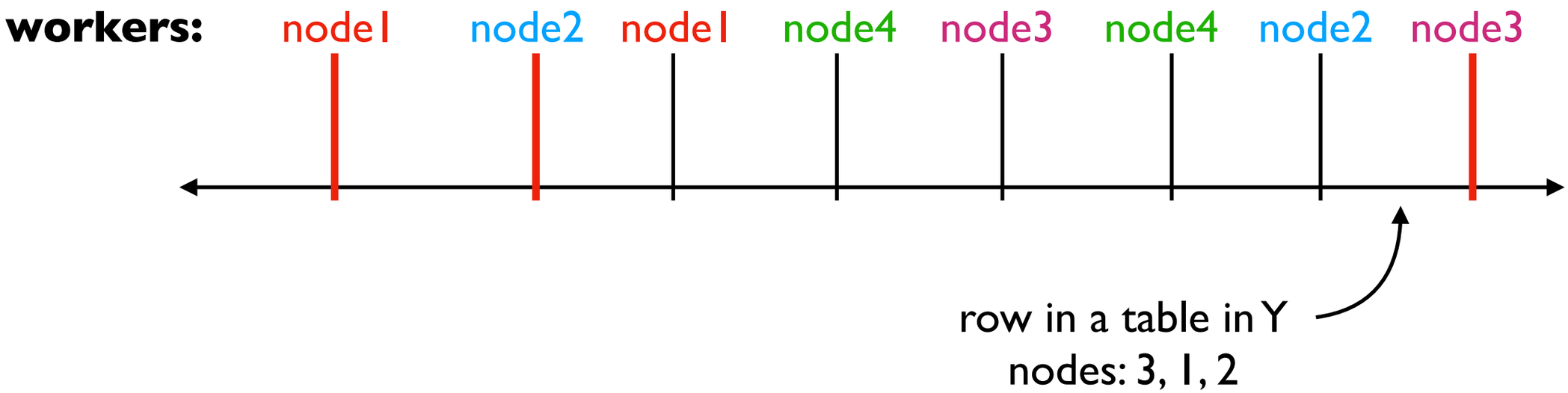


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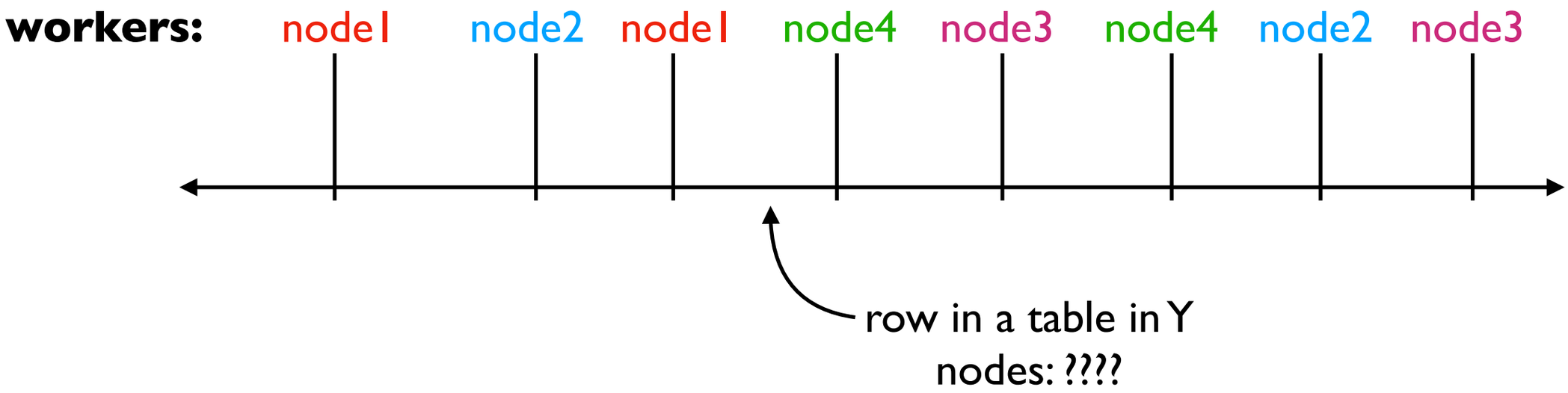


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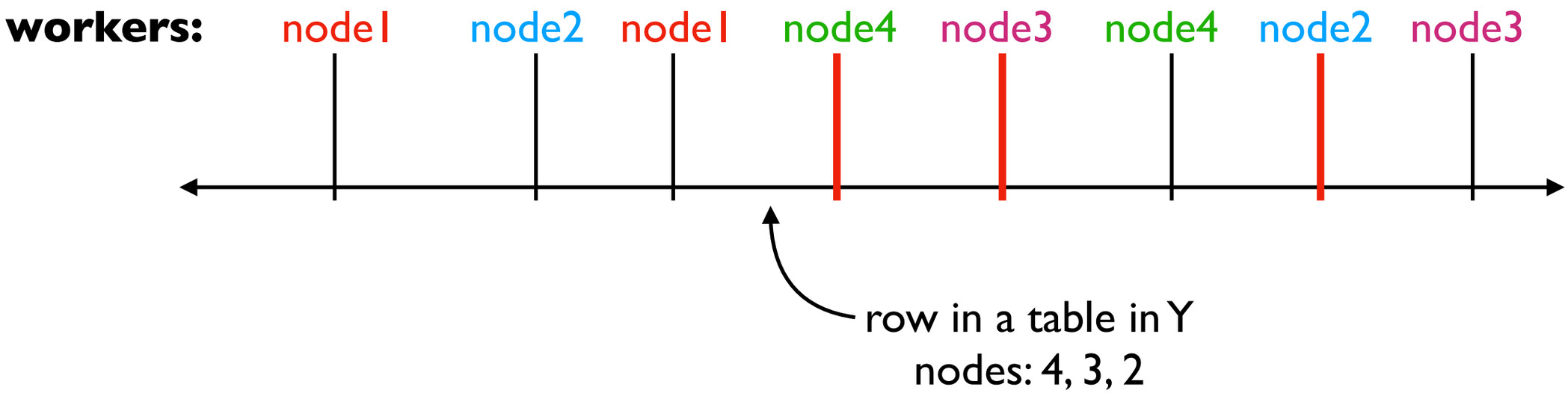


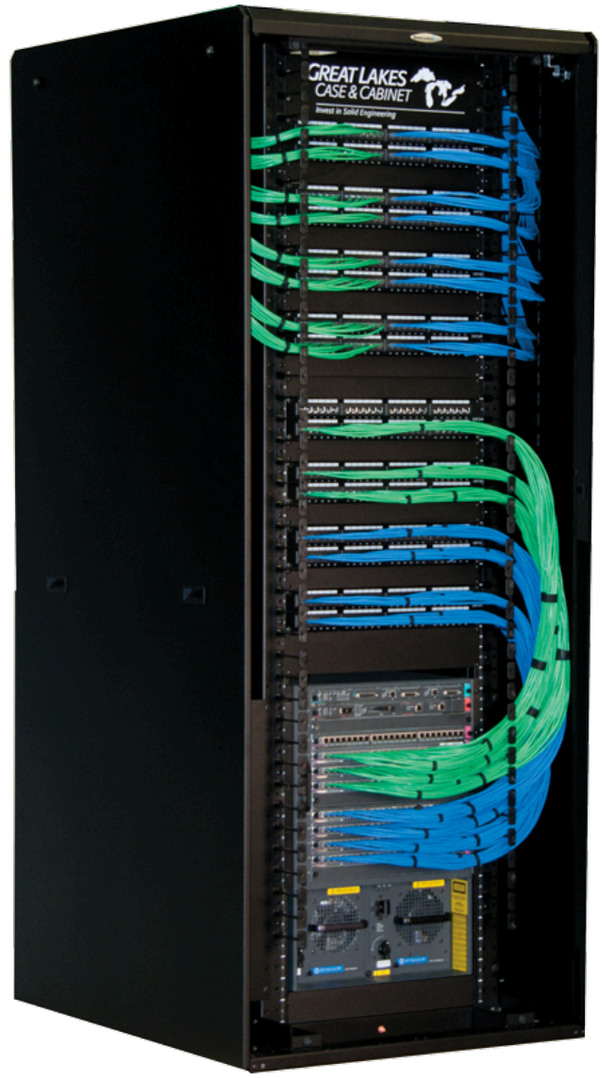
Important! Keeping multiple copies on vnodes on the same node provides little safety (when a node dies, all its vnodes die). Same "failure domain".

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

Network Infrastructure

Server

Data Center



Rack

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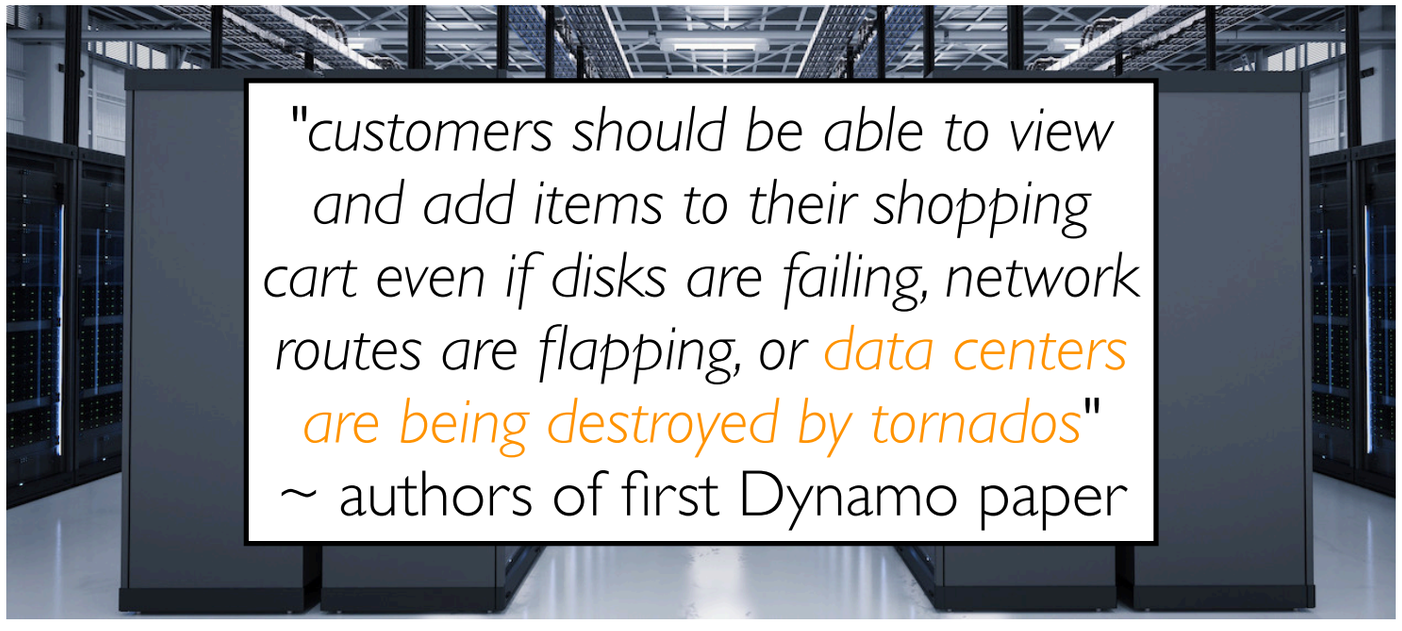
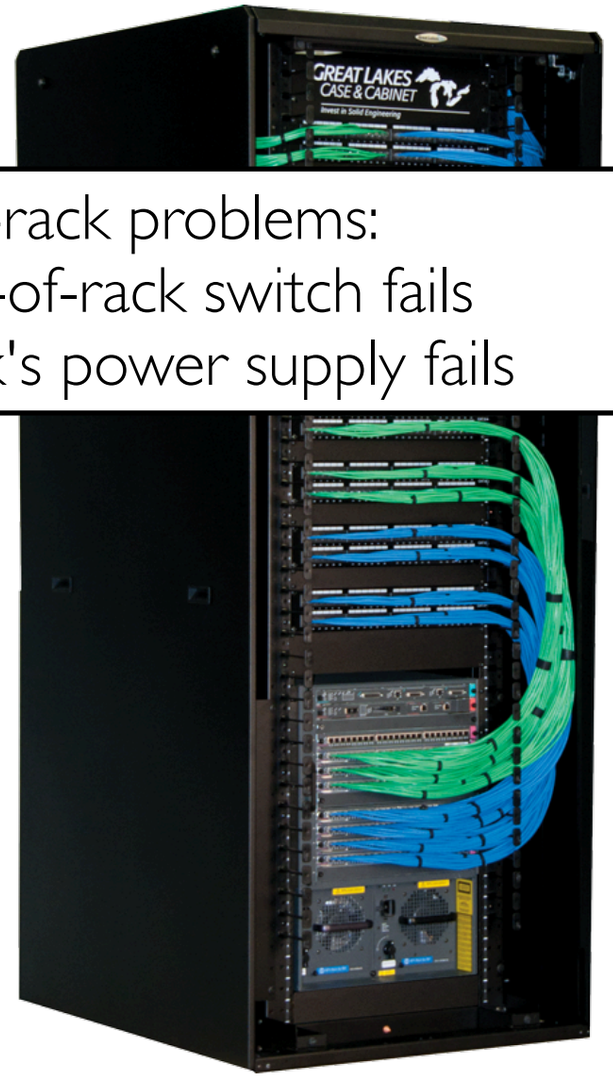
Correlated Failures

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

Server



Data Center



Whole-rack problems:

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

Rack

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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

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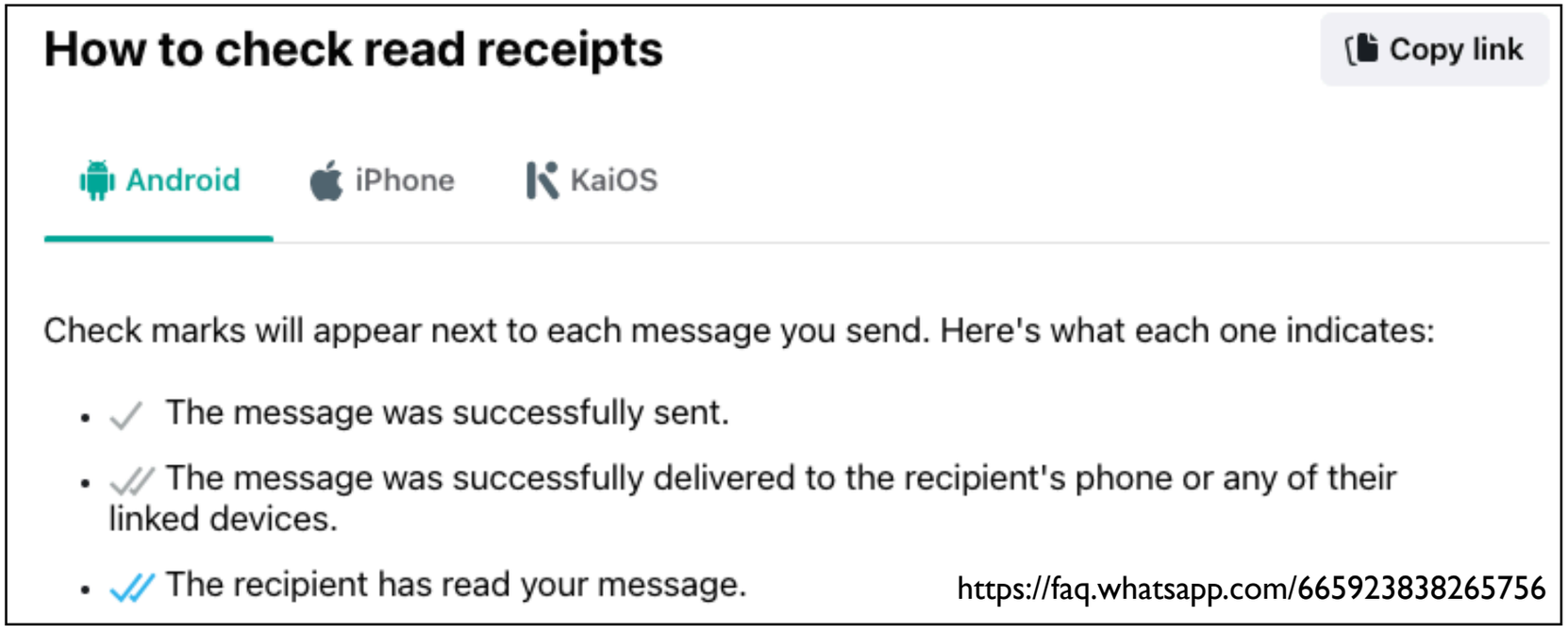
Write Acks: WhatsApp Example



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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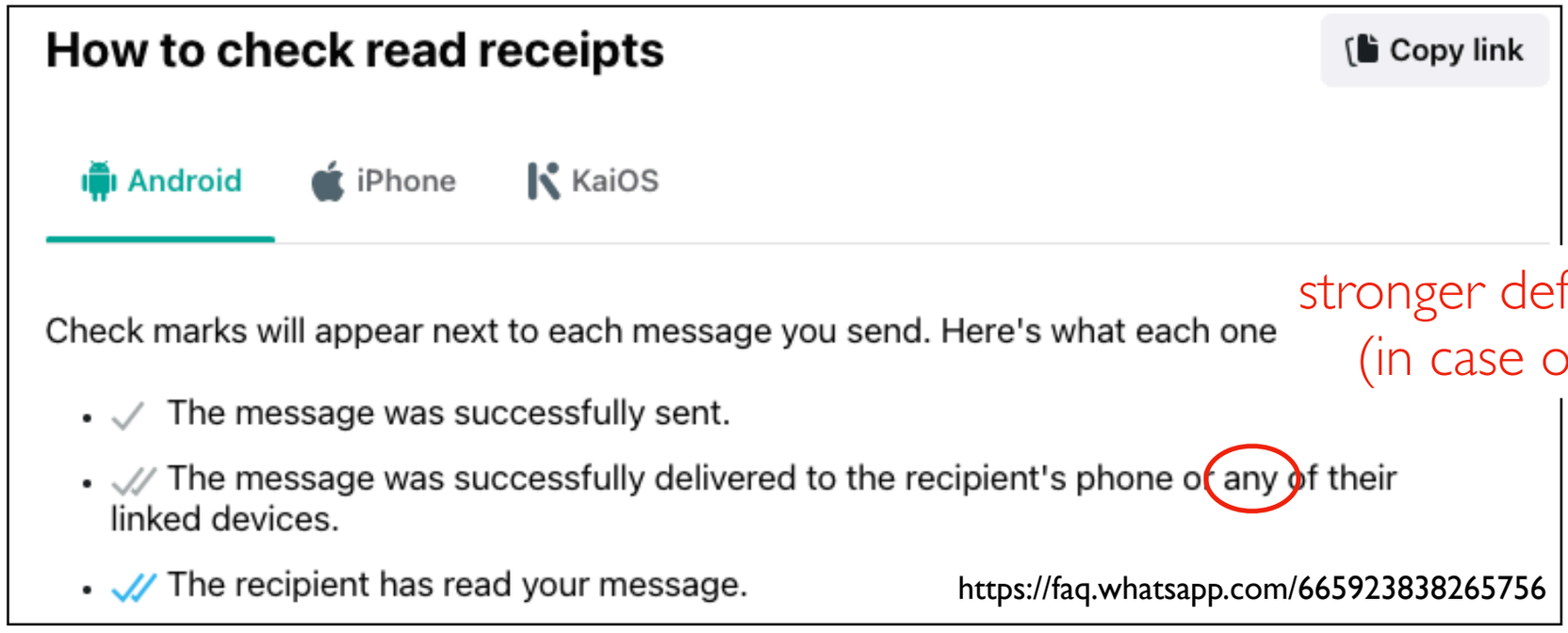

stronger definition: **all** devices (in case one device fails)

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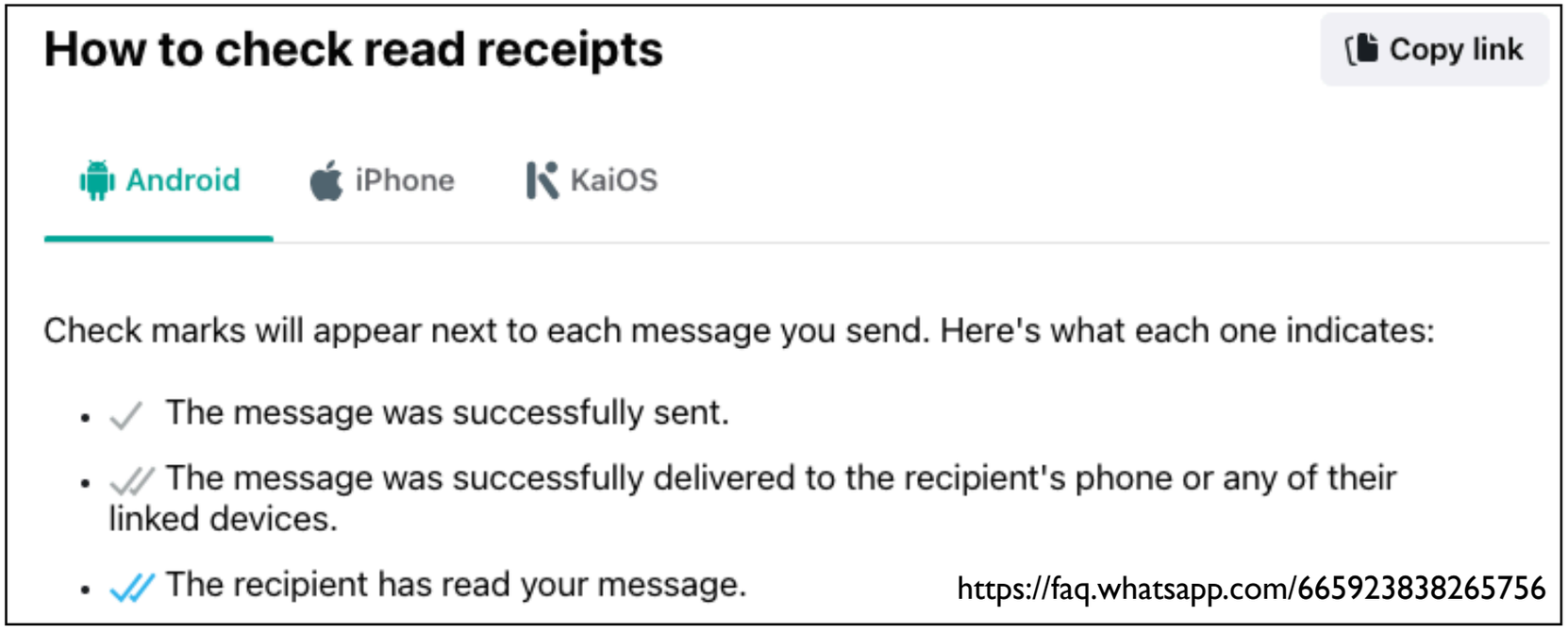

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two checks (in WhatsApp) mean the message reached the destination.

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

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.
- ✓✓ The message was successfully delivered to the recipient's phone or any of their linked devices.
- ✓✓ The recipient has read your message.

https://faq.whatsapp.com/665923838265756

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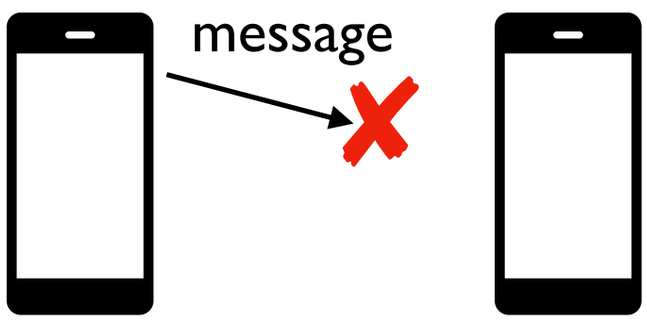
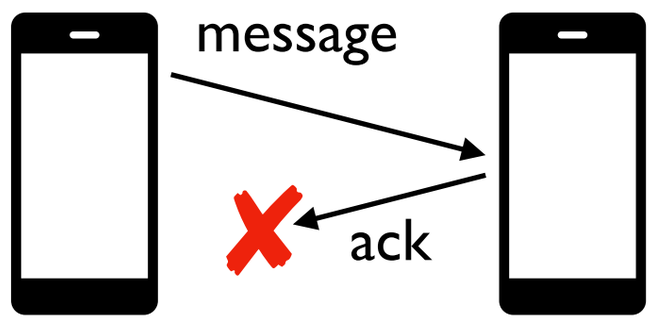
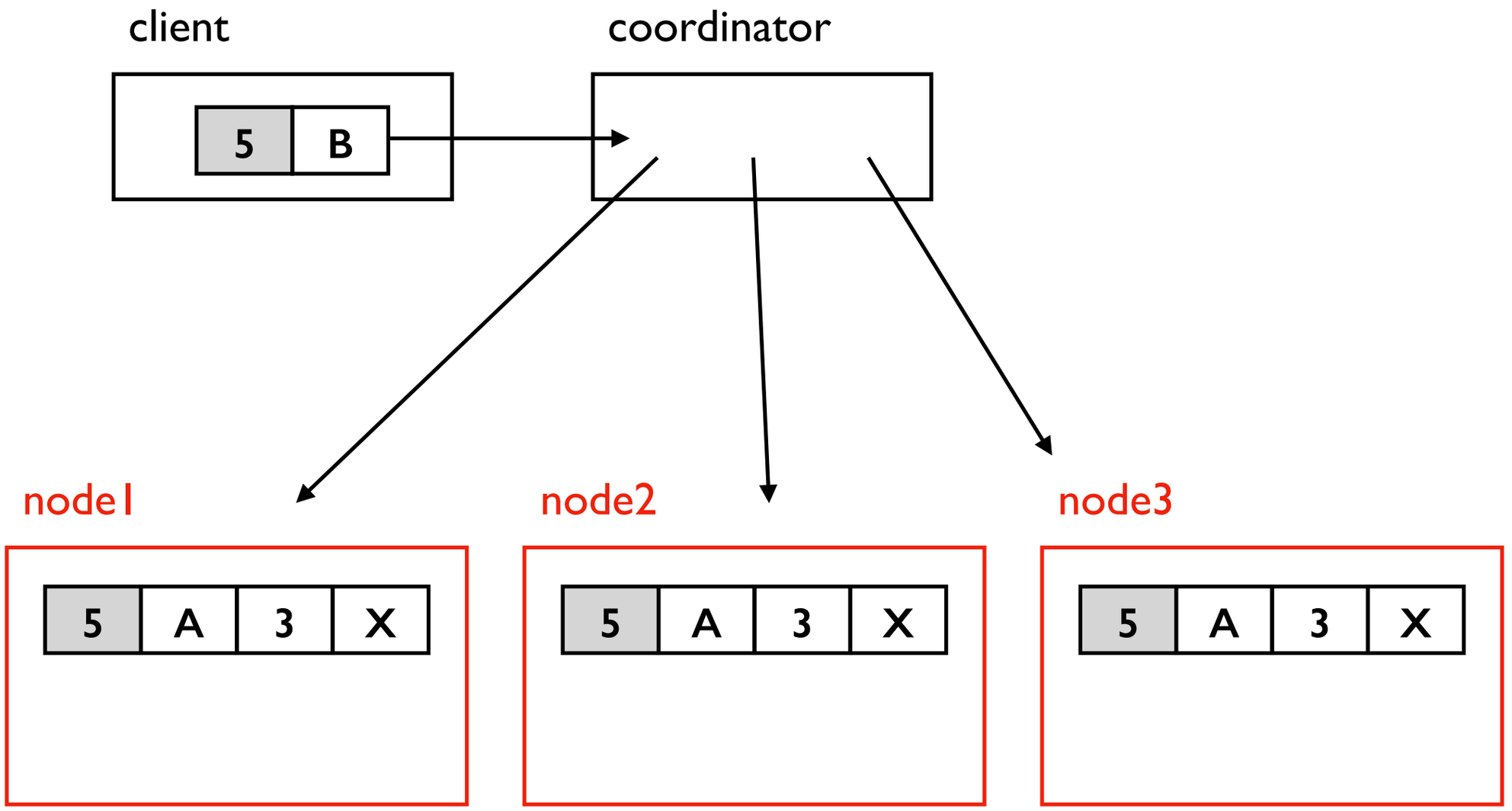


scenario 1



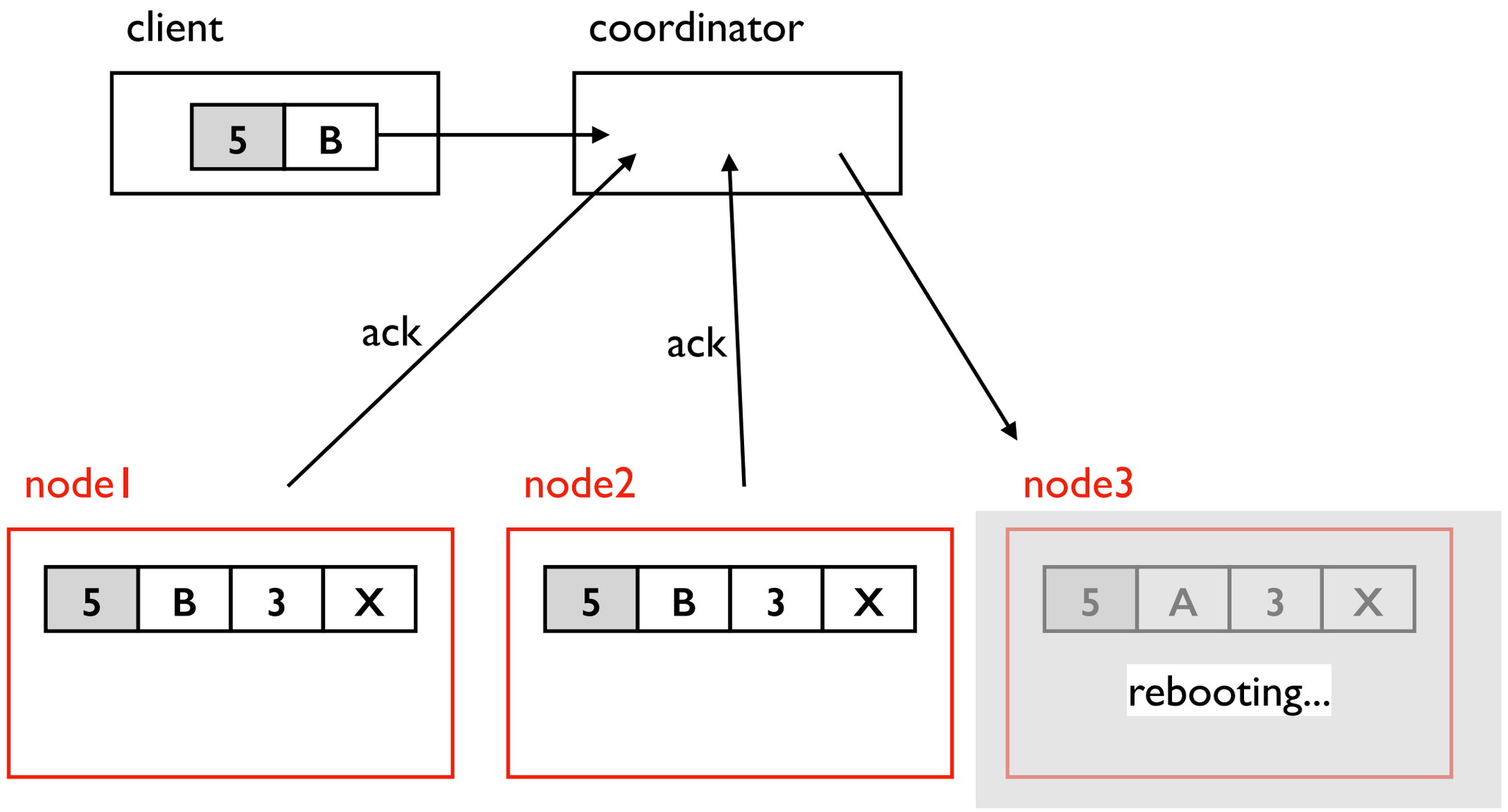
scenario 2

Cassandra Writes



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

Cassandra Writes



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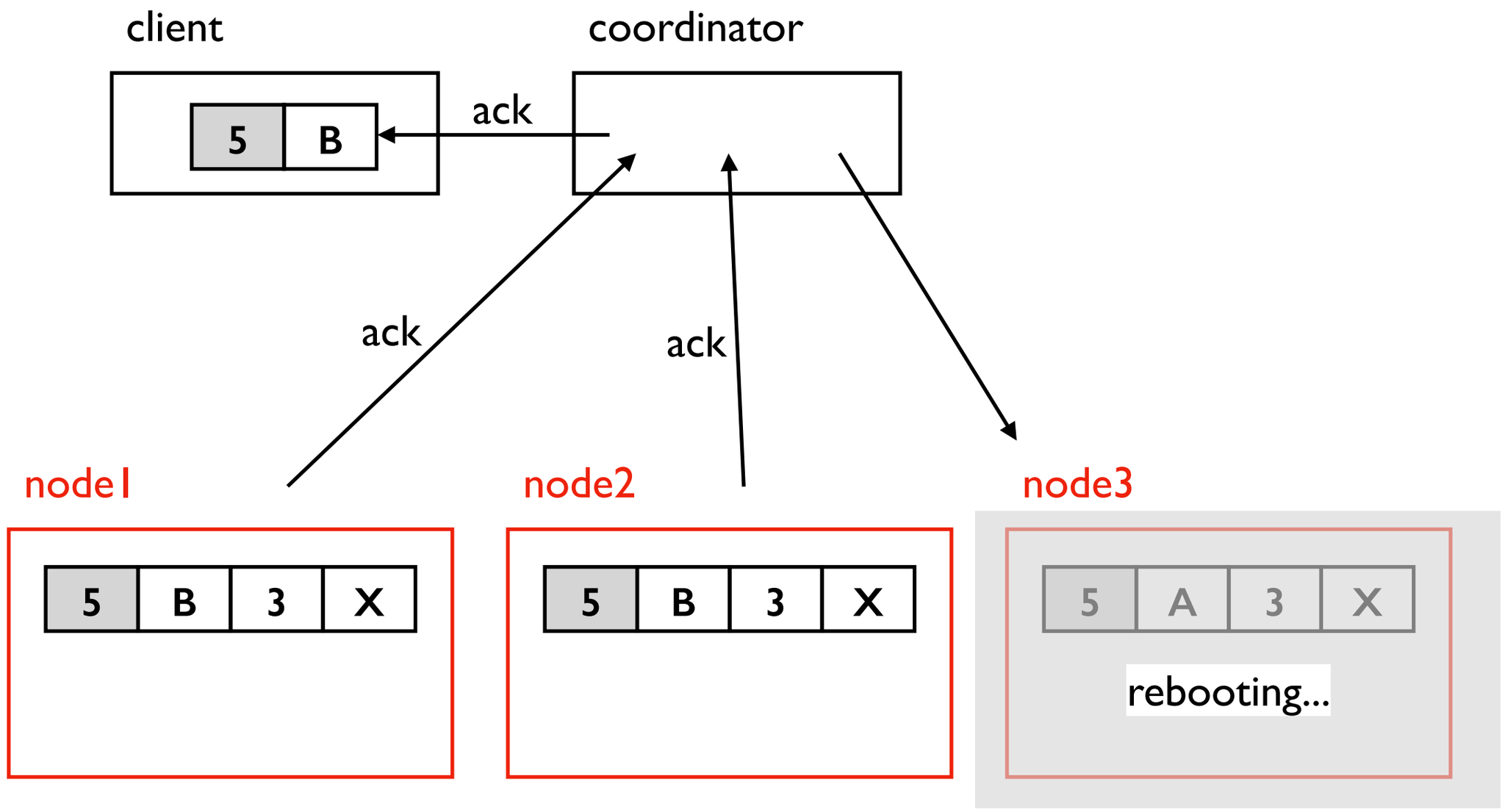
At what point should we send an ack to the client?

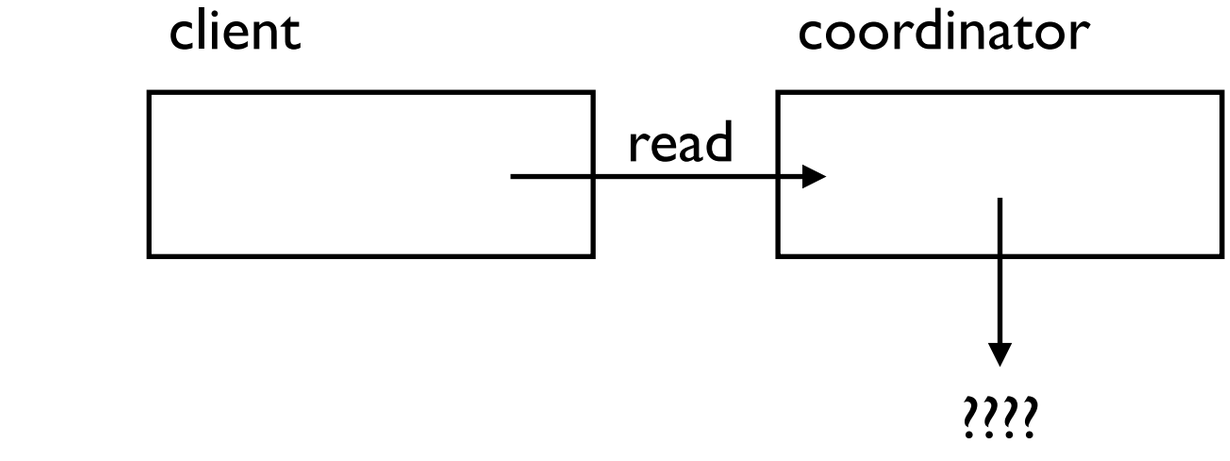
Cassandra Writes

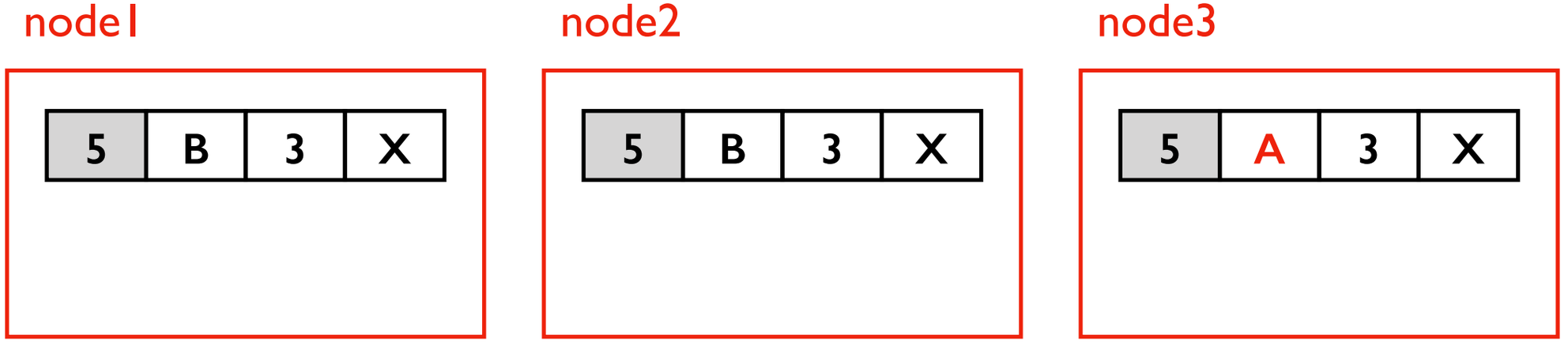


Say RF=3. Coordinator will attempt to write data to all 3 replicas.

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

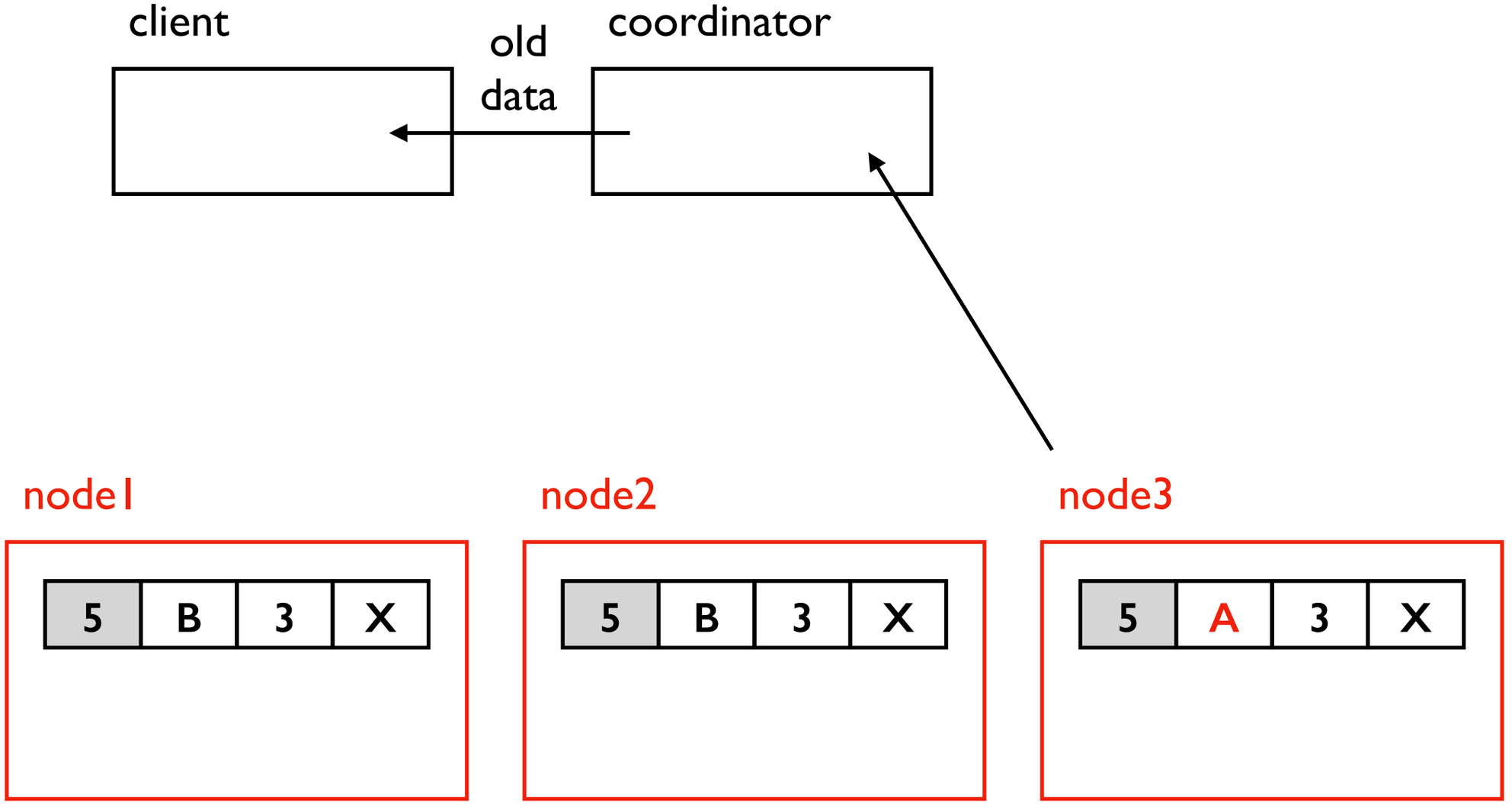
Cassandra Reads





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

Cassandra Reads



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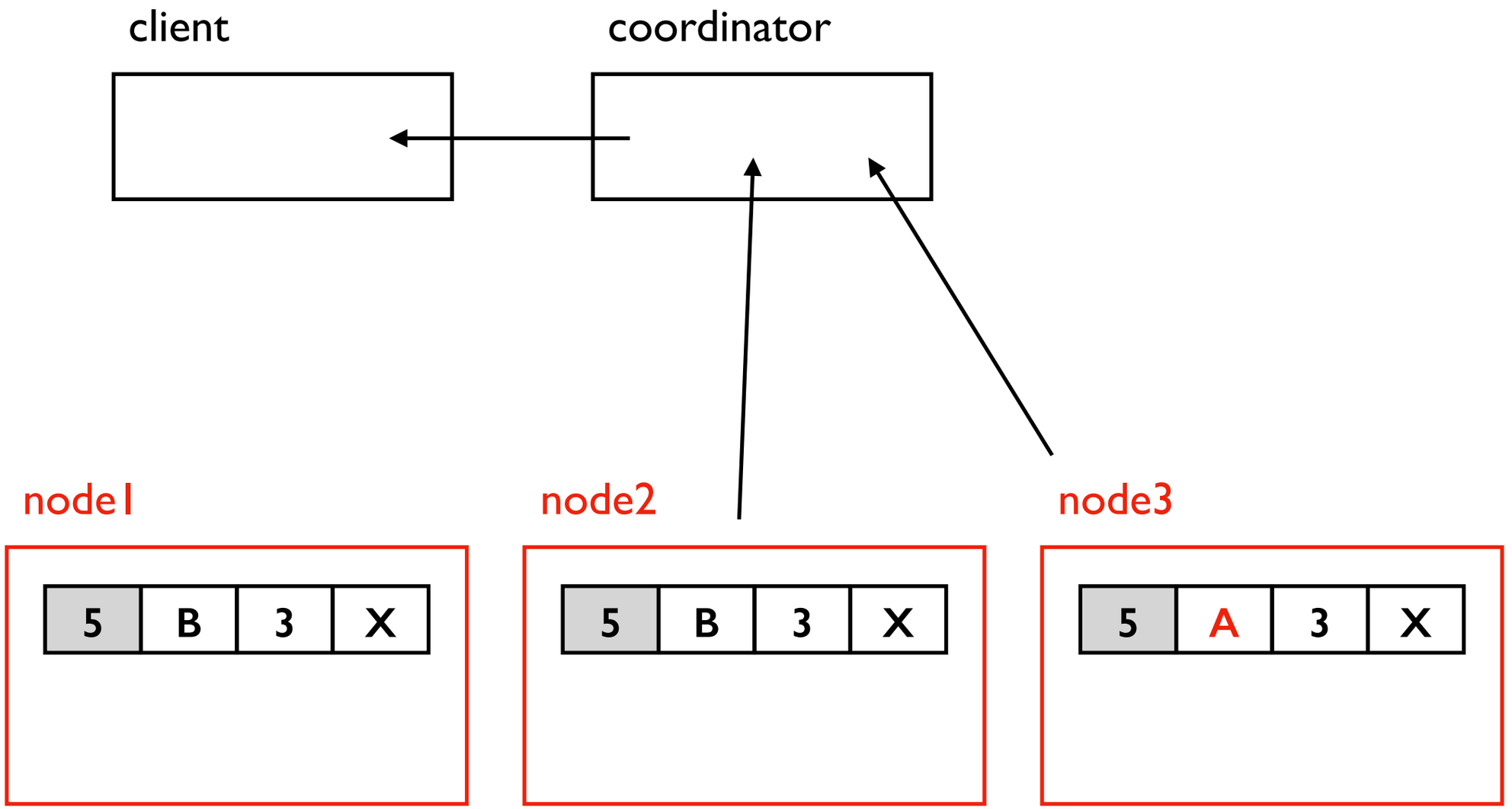
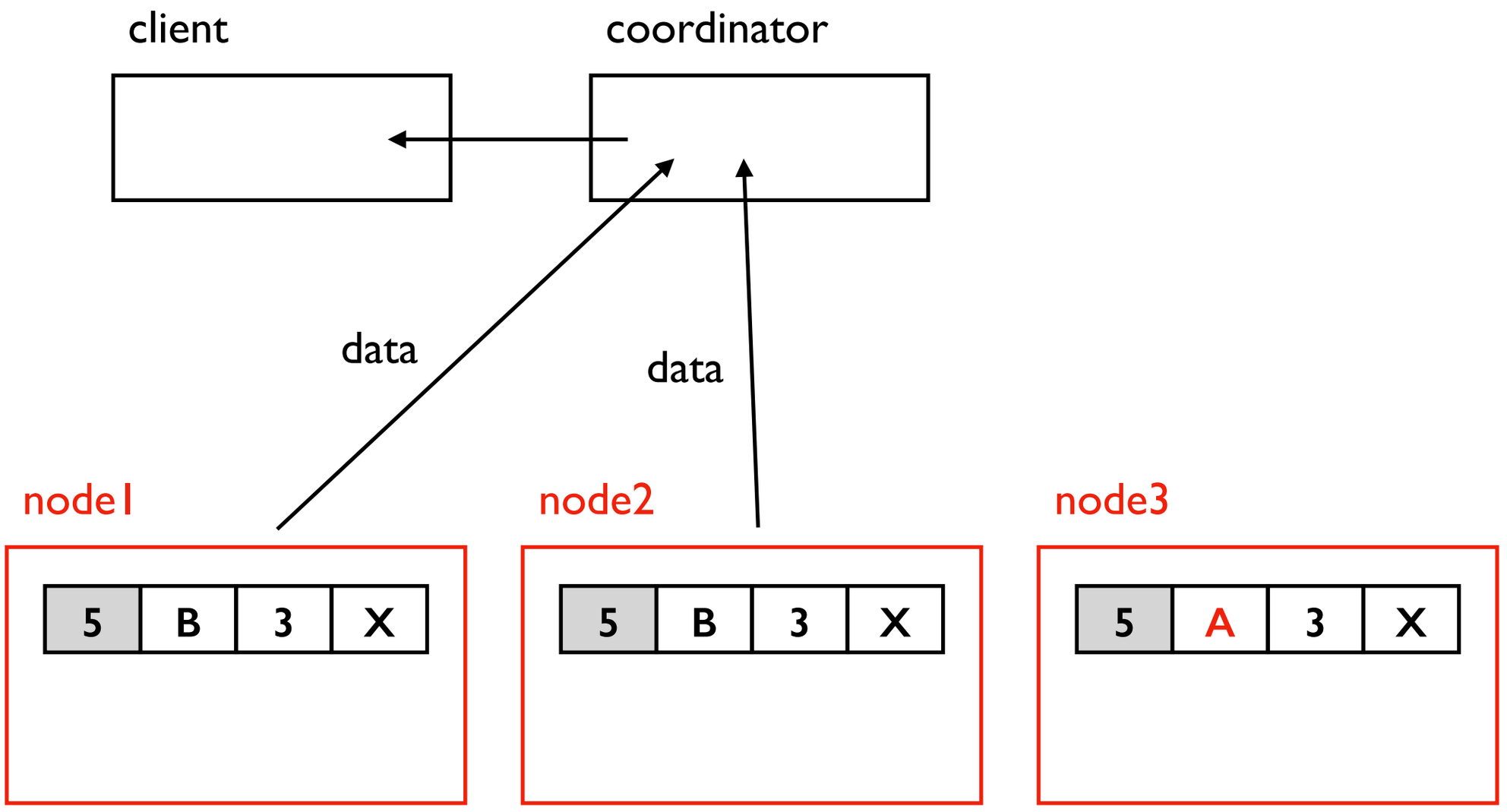


Read from R replicas (configurable). Here R=2.
Hopefully at least one of the replicas has new data.

Cassandra Reads



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

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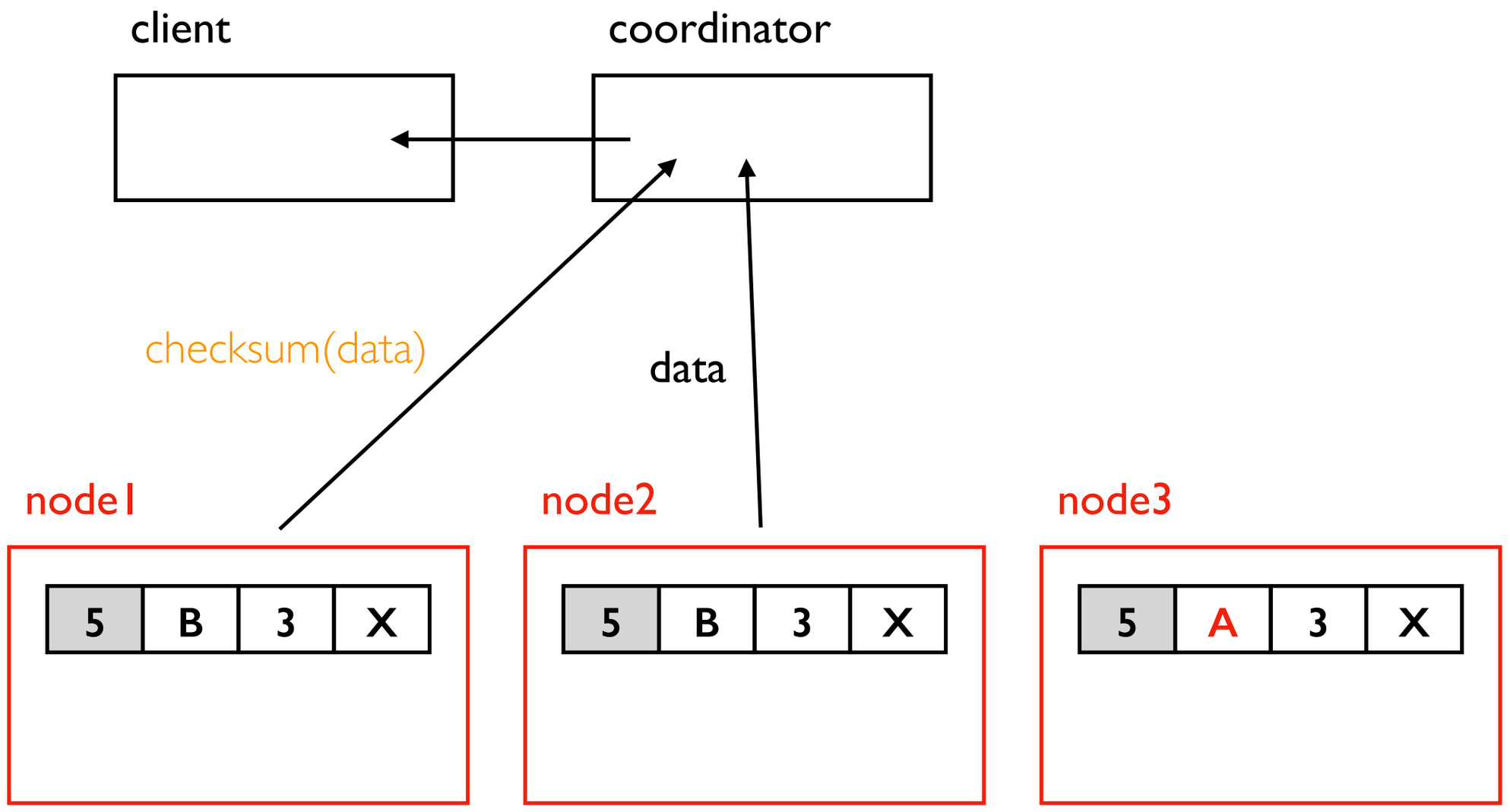

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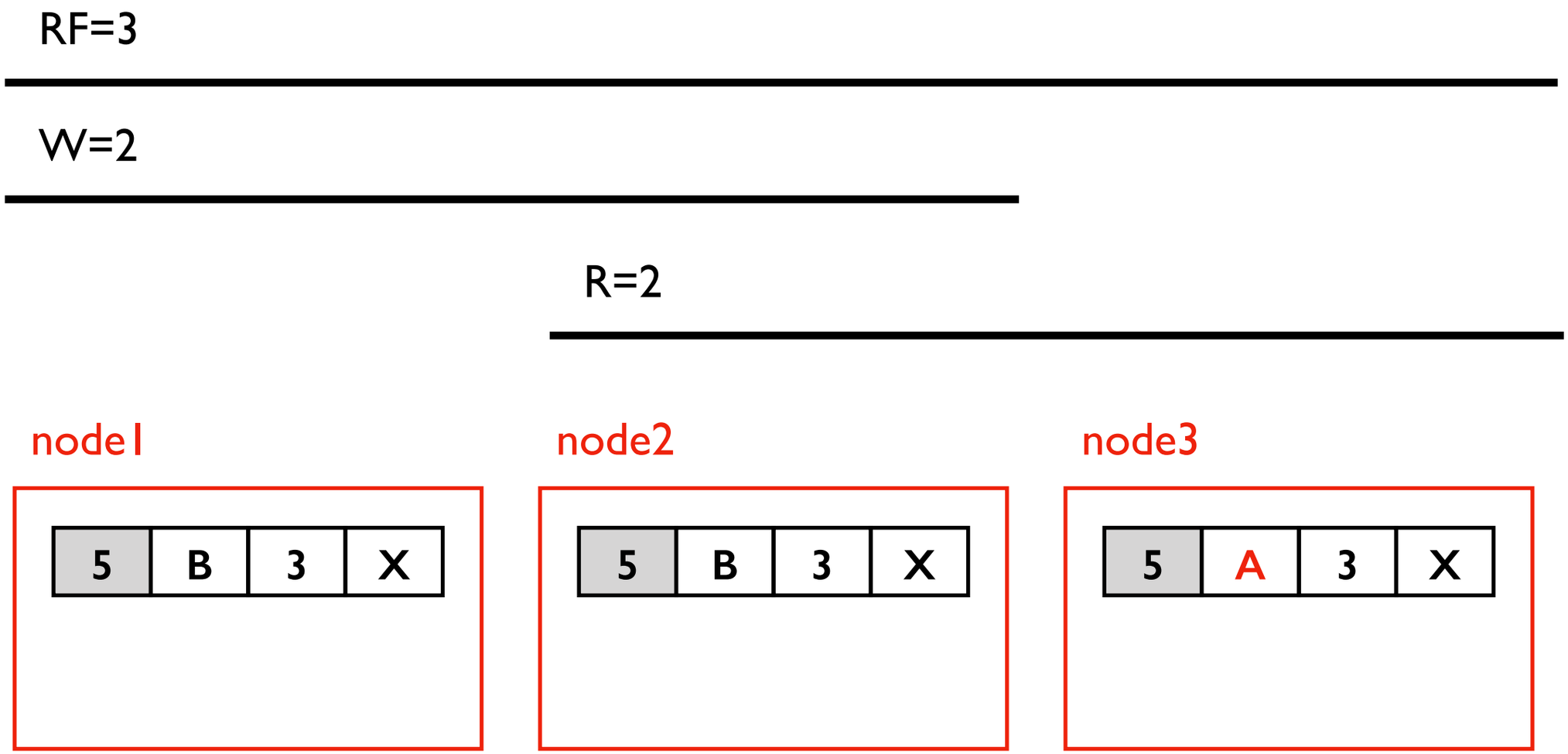
Improvement: read one copy, and only request checksum from others.

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

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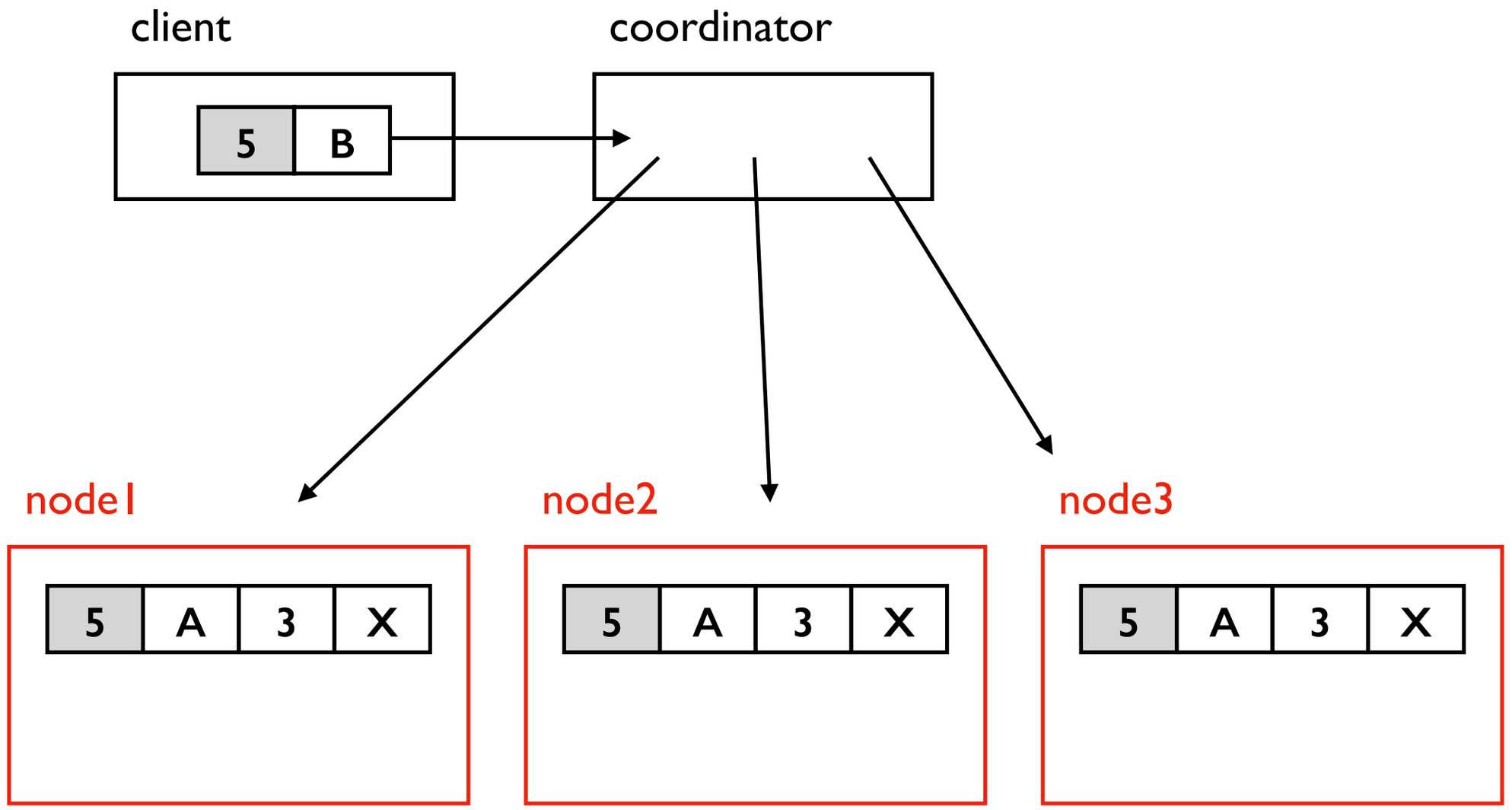
Getting Conflicting Versions



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

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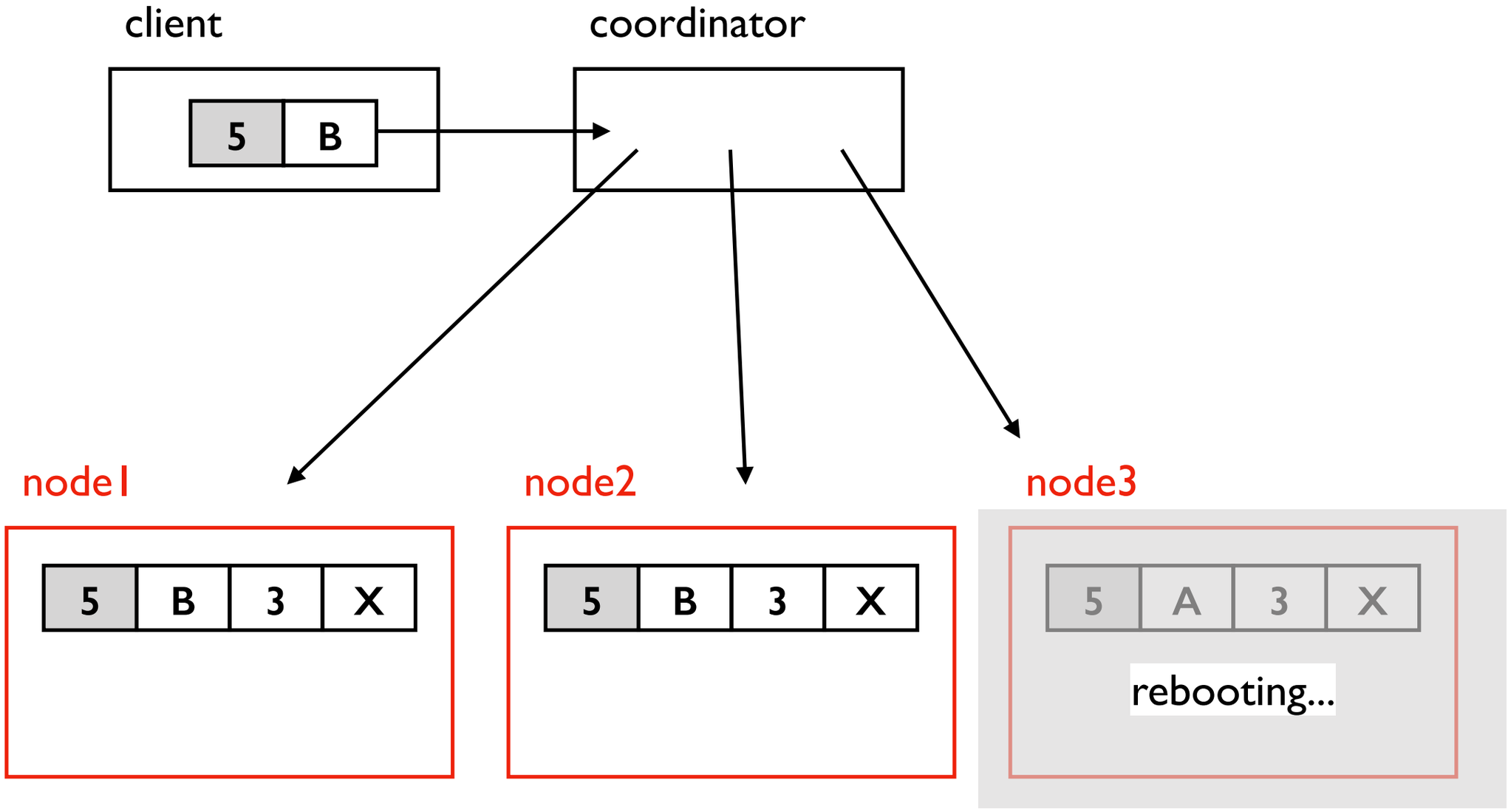

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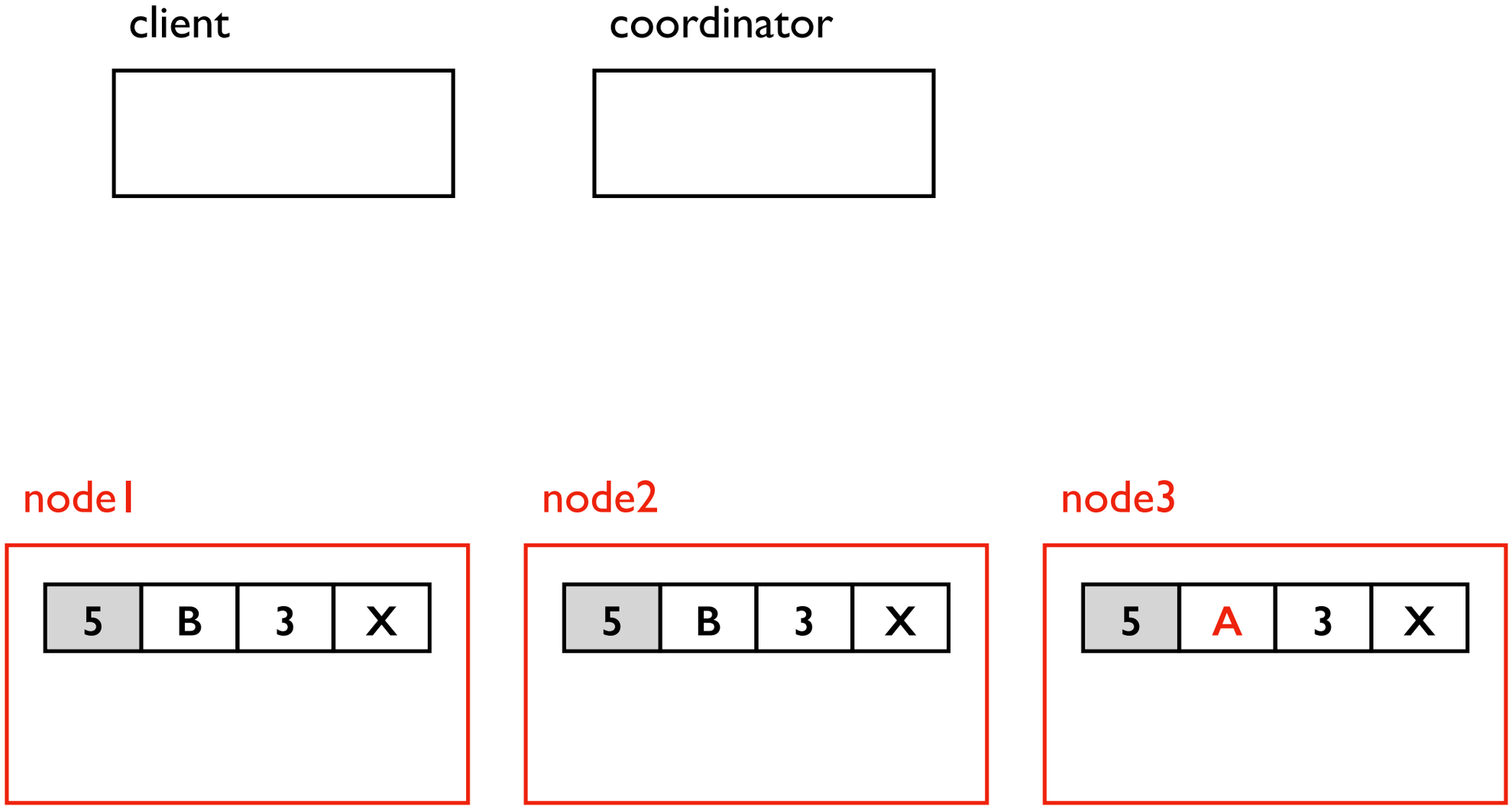

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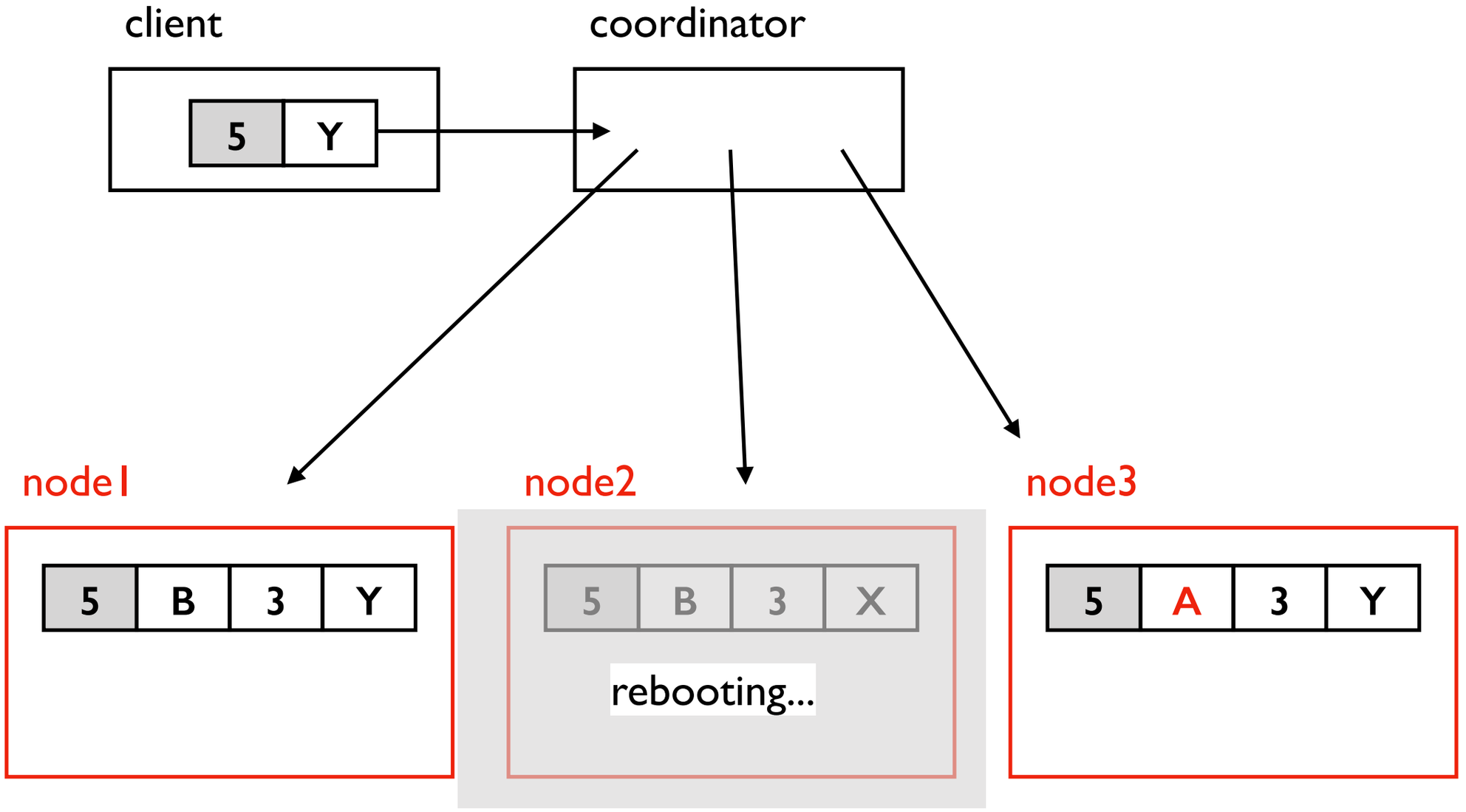

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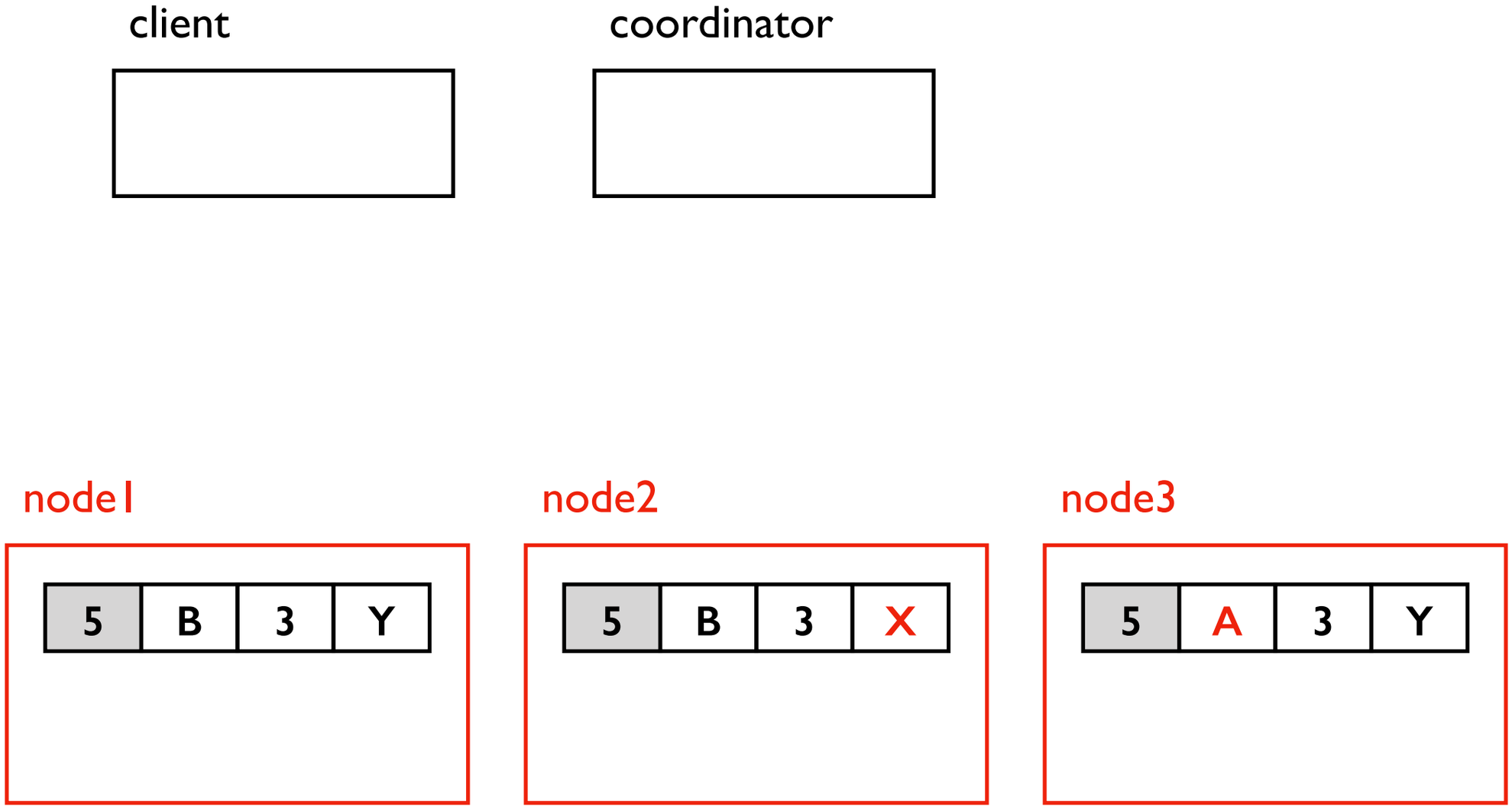

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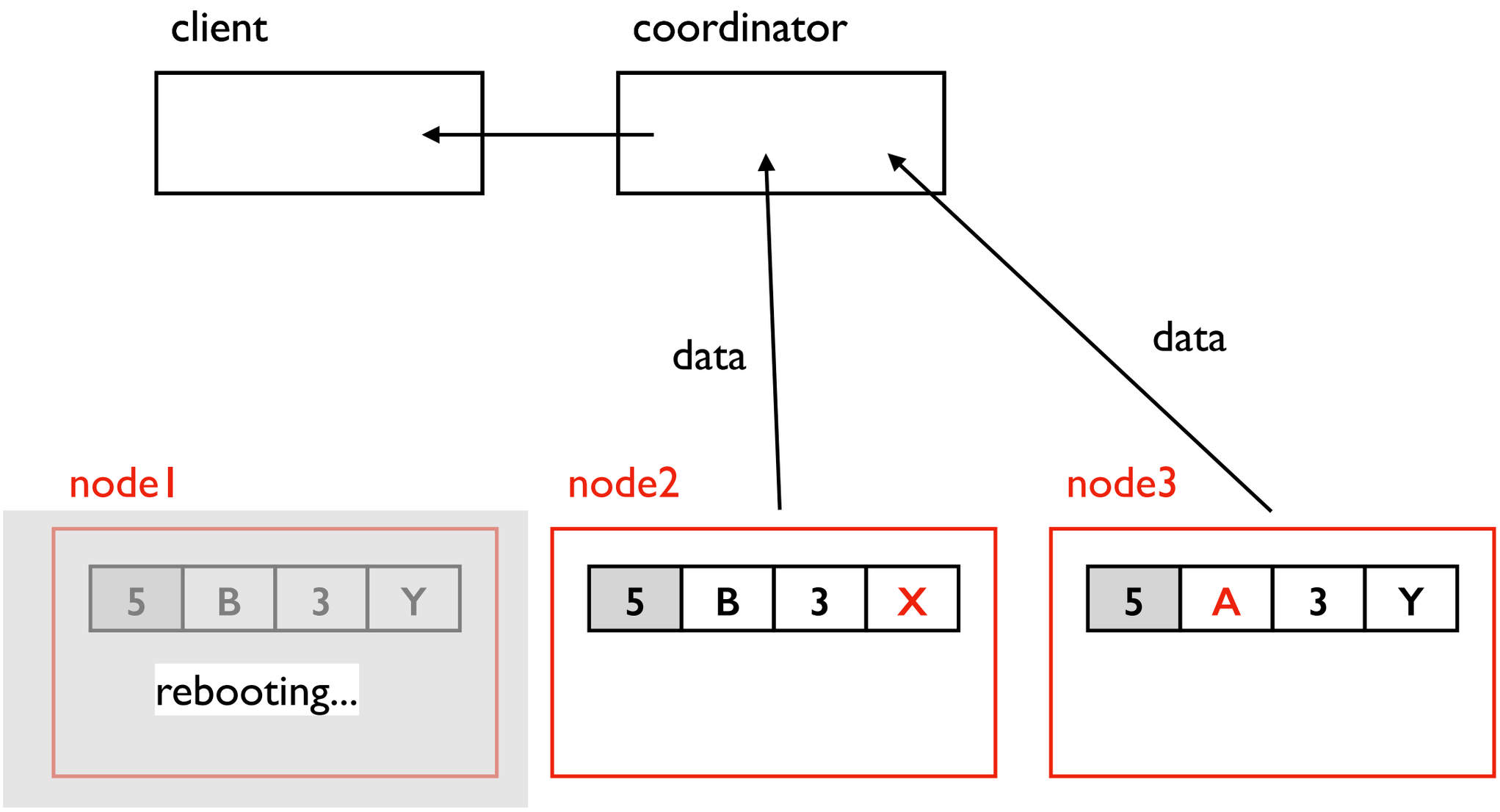
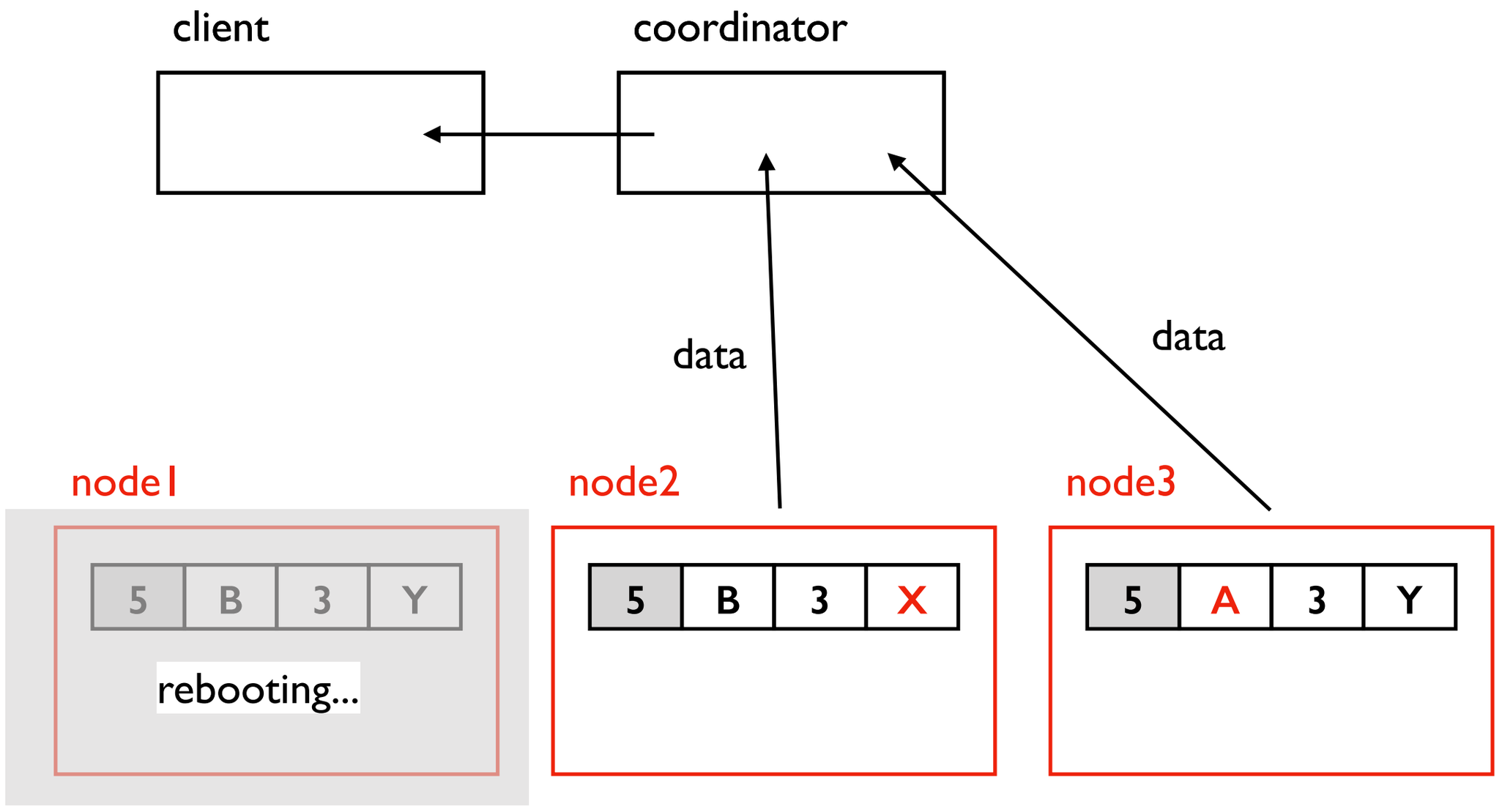


Which version of row 5 should be sent back?
Both contain some new data not contained by other.

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

Getting Conflicting Versions

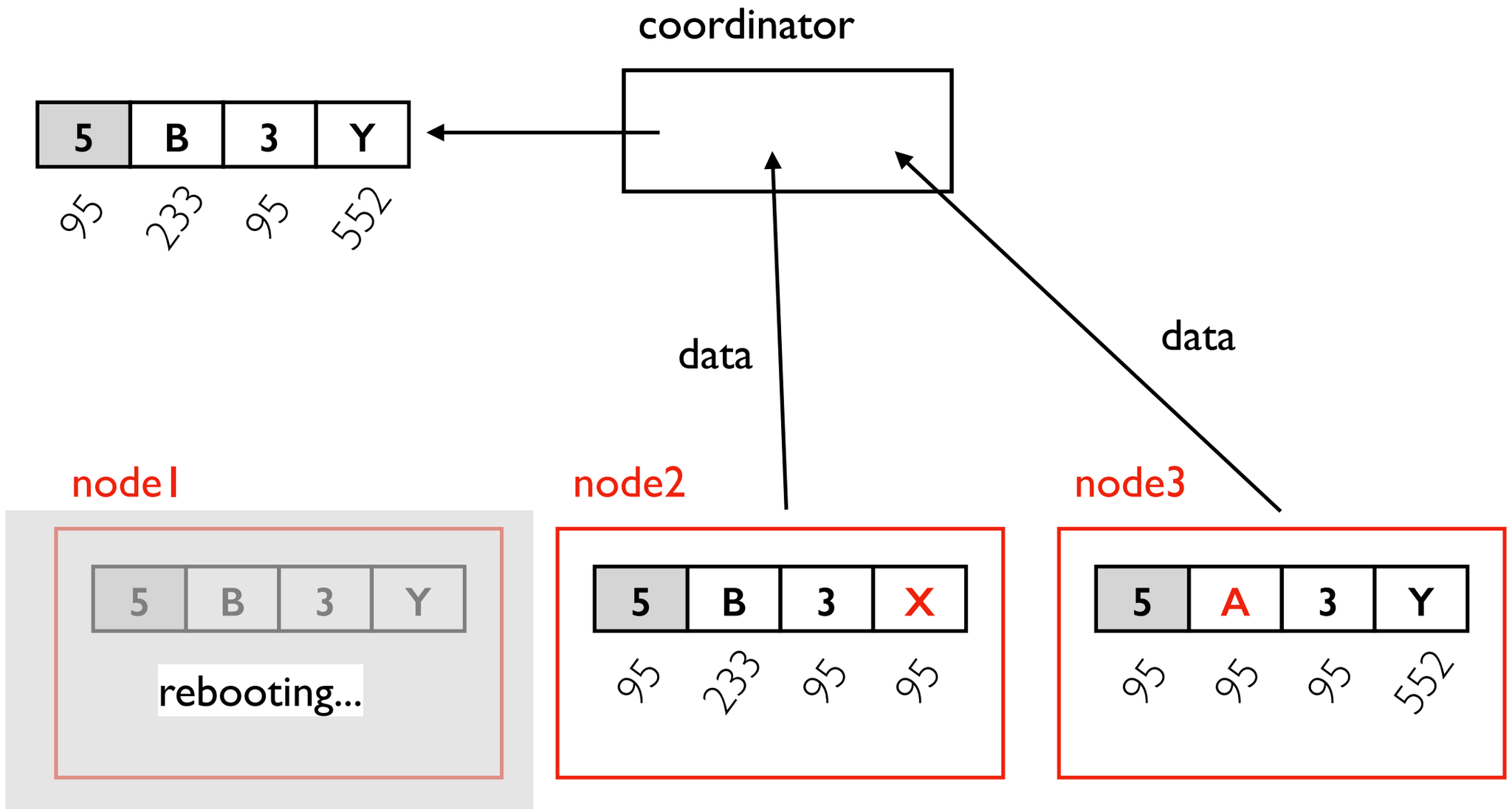


Approaches:

- 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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