

Cassandra - “Advanced” Topics

Big Data Systems

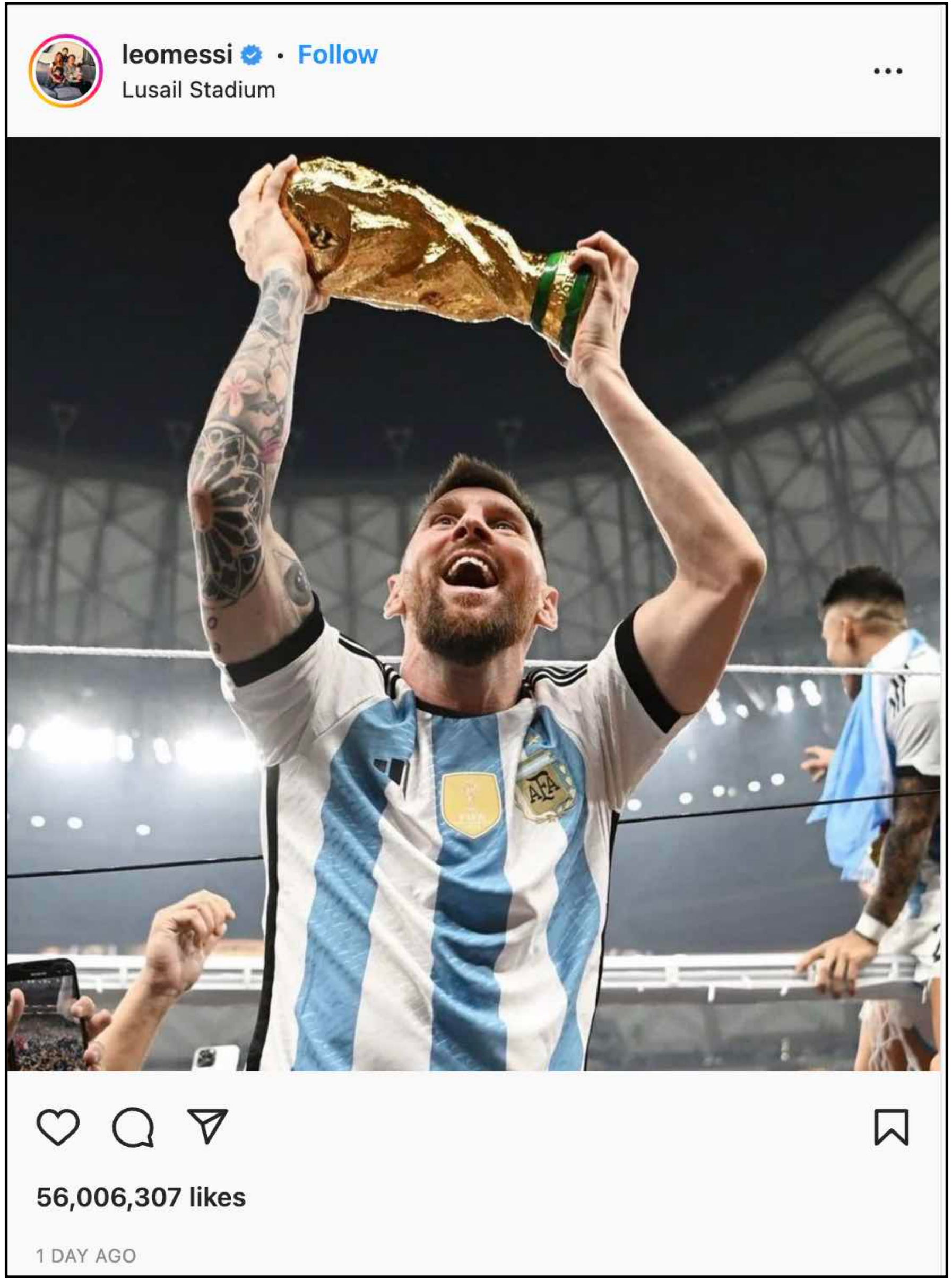
Dr. Rubi Boim

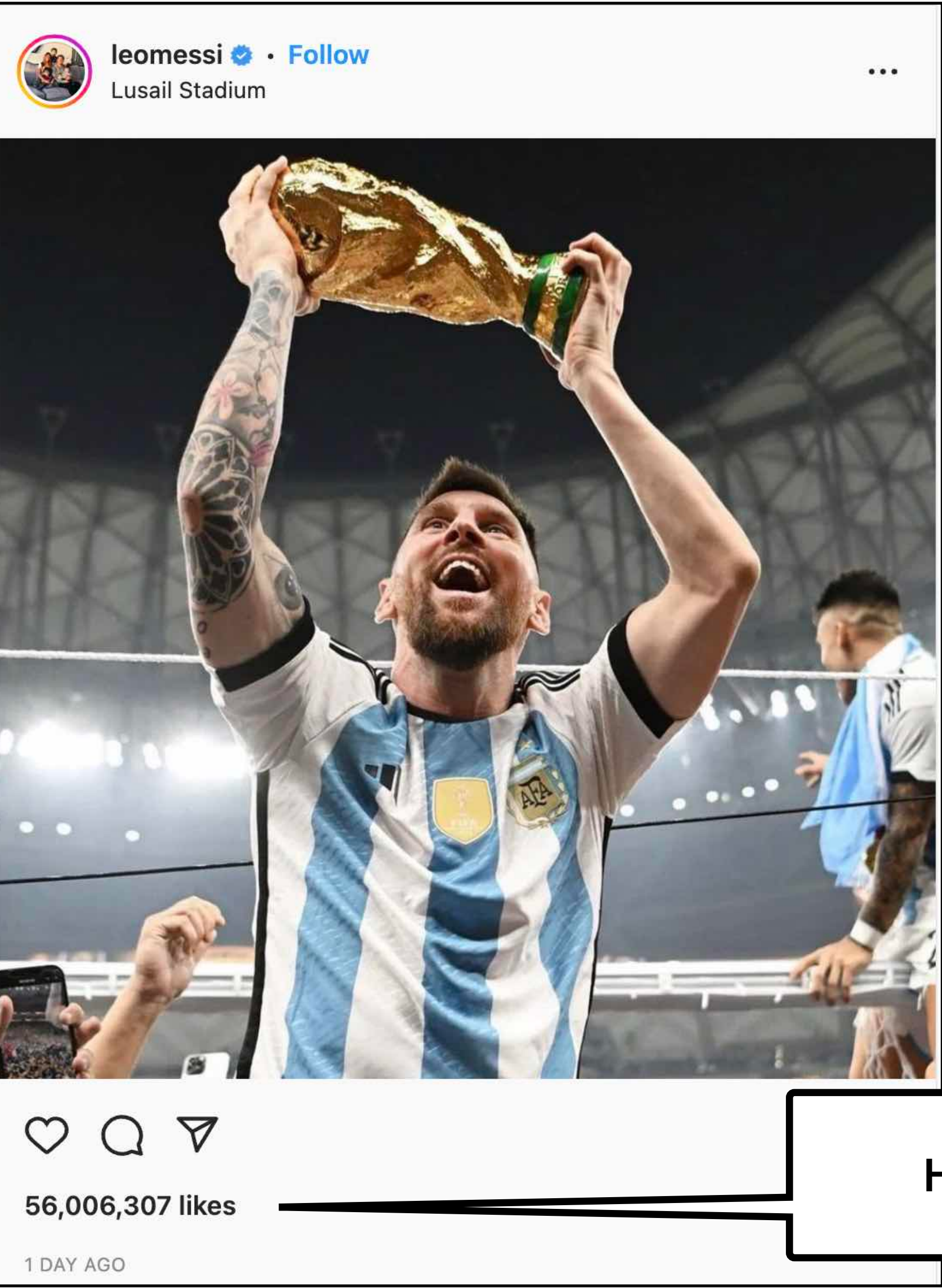
Cassandra advanced topics

- Counters
- Collections
- UDTs
- Batches
- Lightweight transactions
- Tunable consistency
- Deletes & tombstones

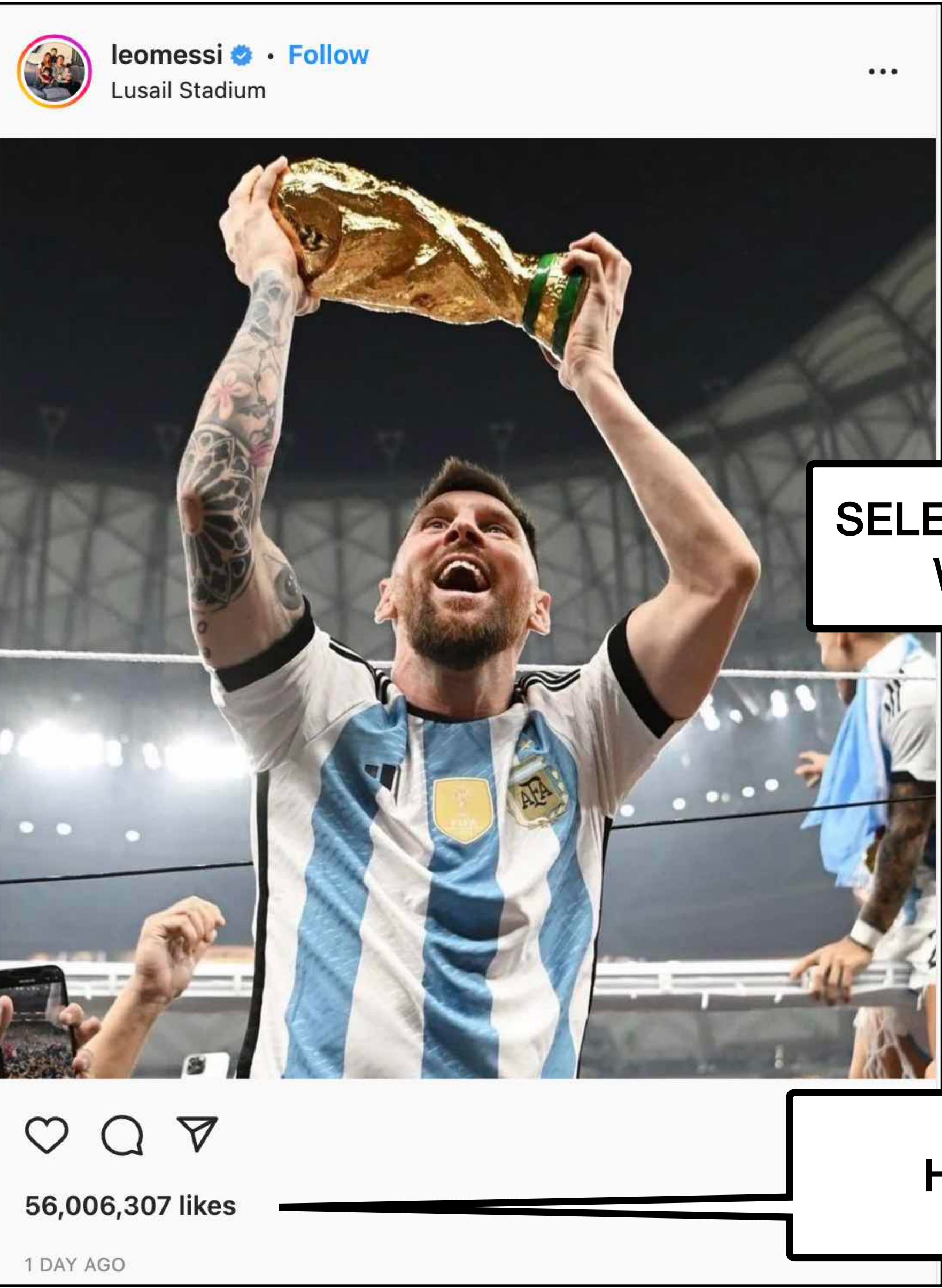
Cassandra advanced topics

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- Collections
- UDTs
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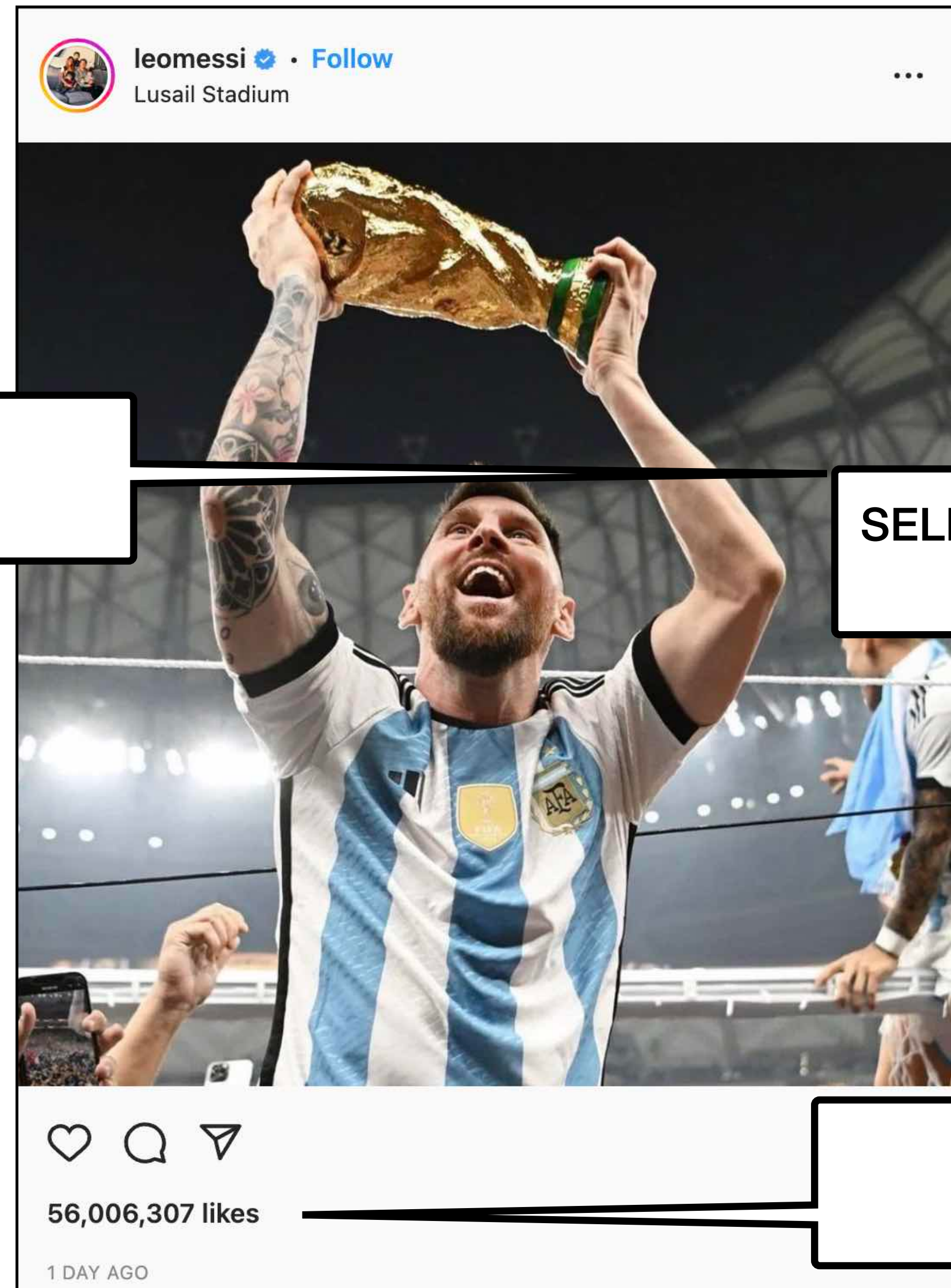


How can we calculate this?



```
SELECT count(*) FROM likes_by_item  
WHERE itemID = 123456789
```

How can we calculate this?



What is the problem?

```
SELECT count(*) FROM likes_by_item  
WHERE itemID = 123456789
```

How can we calculate this?



What is the problem?

```
SELECT count(*) FROM likes_by_item  
WHERE itemID = 123456789
```

The “like” data is probably saved on several partitions.
Will take too much time to read all data from all
partitions and count all.

We need this data in 1ms, not 10 seconds

How can we calculate this?

Cassandra counters

- A special (powerful) data type
- 64bit signed integer (long)
- Cannot be set - only increment/decrement
(initial value == 0)
- Used with “UPDATE”

Cassandra counters - example

```
CREATE TABLE movie_view_counts (  
    movie_id      BIGINT,  
    view_count    COUNTER,  
    PRIMARY KEY  (movie_id)  
);
```

```
UPDATE movie_view_counts  
SET view_count = view_count + 1  
WHERE movie_id = 123
```

```
SELECT view_count FROM movie_view_counts  
WHERE movie_id = 123
```

Cassandra counters - example

```
CREATE TABLE movie_view_counts (  
    movie_id      BIGINT,  
    view_count    COUNTER,  
    PRIMARY KEY  (movie_id)  
);
```

You can also use “-“ and values different than 1

```
UPDATE movie_view_counts  
SET view_count = view_count + 1  
WHERE movie_id = 123
```

```
SELECT view_count FROM movie_view_counts  
WHERE movie_id = 123
```

Cassandra counters - limitations

- Counter cannot be part of the primary key
- A table that contains a counter can only contain counters
either all the columns of a table outside the PRIMARY KEY have the counter type, or none of them have it
- Counters does not support expiration (TTL)
- Not idempotent by nature
- Slight consistency issues in distributed scenarios
due to in-memory and speed optimizations to deal with “read before write”
- Counters can be deleted, but not reused
can you think of an example this might cause a problem?

Cassandra counters - limitations

- Counter cannot be part of the primary key
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either all the columns of a table outside the PRIMARY KEY have the counter type, or none of them have it
- Counters does not support expiration
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due to in-memory and speed optimizations to deal with “read before write”
- Counters can be deleted, but not reused
can you think of an example this might cause a problem?

Think about an eCommerce store which saves a counter for the number of views for a specific item. The item is removed from the dataset and after a few months it is added again with the same id (key)

Question on the example

- Previous implementation counted the total views
- How can we support the query “views per day”?

```
CREATE TABLE movie_view_counts (  
    movie_id      BIGINT,  
    view_count    COUNTER,  
    PRIMARY KEY  (movie_id)  
);
```

(previous implementation)

Question on the example - answer

- Add a timestamp column to the key
- Describe a day by rounding (down) to 00:00:00 UTC

```
// a quick version instead of using calendar...
public static long getTSDayRound(long timestamp) {
    long portion = timestamp % MILLISECONDS_IN_DAY;
    return timestamp - portion;
}
```

```
// returns the round day for the current time
return getTSDayRound(System.currentTimeMillis());
```

Question on the example - answer

```
CREATE TABLE movie_view_counts_by_day (  
    movie_id      BIGINT,  
    ts            TIMESTAMP,  
    view_count    COUNTER,  
    PRIMARY KEY  (movie_id, ts)  
);
```

```
UPDATE movie_view_counts  
SET view_count = view_count + 1  
WHERE movie_id = 123 AND  
      ts = 1627344000000
```

```
SELECT view_count FROM movie_view_counts  
WHERE movie_id = 123 AND  
      ts = 1627344000000
```

July 27 2021



Question on the example (2)

- How can we support the query “views per day” and “views per month”?

```
CREATE TABLE movie_view_counts_by_day (  
    movie_id      BIGINT,  
    ts            TIMESTAMP,  
    view_count    COUNTER,  
    PRIMARY KEY (movie_id, ts)  
);
```

(previous implementation)

Question on the example (2)

- How can we support the query “views per day” and “views per month”?

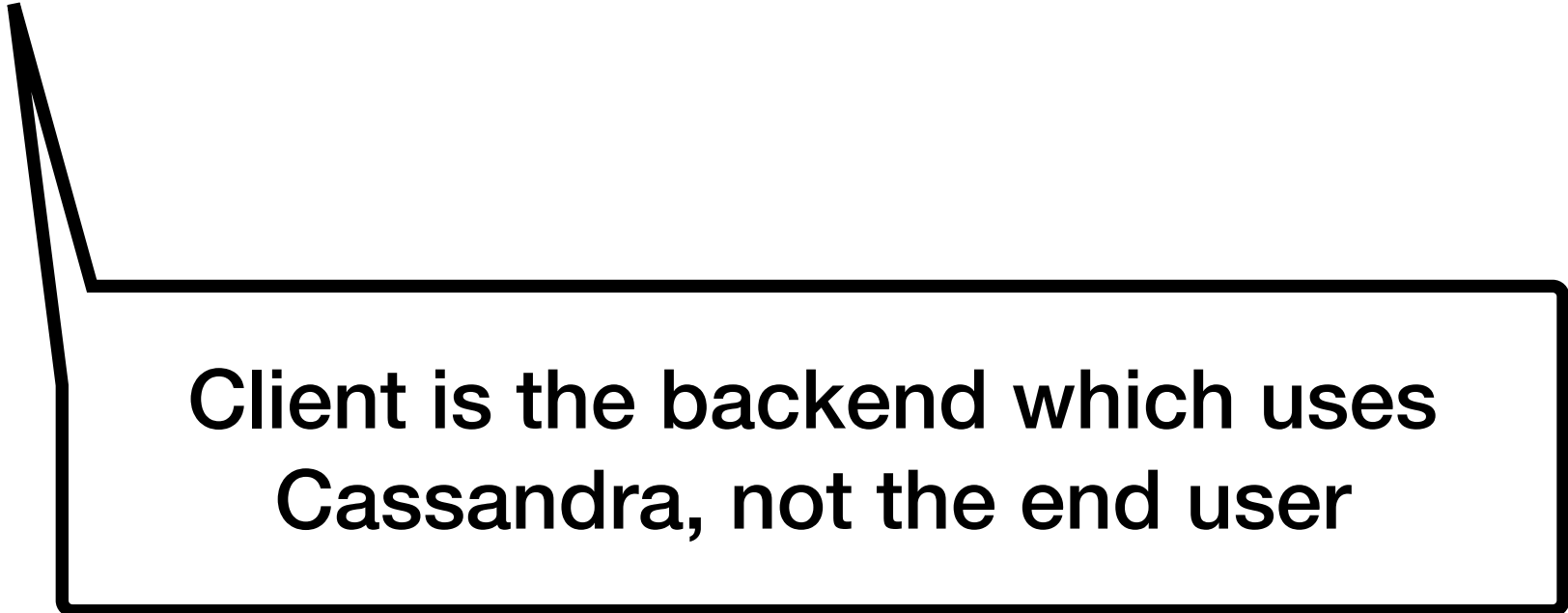
```
CREATE TABLE movie_view_counts_by_day (  
    movie_id      BIGINT,  
    ts            TIMESTAMP,  
    view_count    COUNTER,  
    PRIMARY KEY  (movie_id, ts)  
);
```

(previous implementation)

NOTE - we set the ts as a clustering column and not as a partition key - why?

Question on the example (2) - answer

- Use the same table
- Use the same “day rounding (down)”
- Use a different query
- Group and sum results on **client side**



Client is the backend which uses
Cassandra, not the end user

Question on the example (2) - answer

July 01 2021

July 31 2021

```
SELECT ts, view_count FROM movie_view_counts
WHERE movie_id = 123 AND
      ts >= 1625097600000 AND
      ts <= 1627689600000
```

Query result

ts	view_count
1625097600000	50,023
1625184000000	78,288
...	...
1627689600000	28,052

Client is the backend which uses
Cassandra, not the end user

final result - sum of all values (on client)

Question on the example (3)

- How can we support the query “views per day”, “views per month” **AND** “views per hour”?

```
CREATE TABLE movie_view_counts_by_day (  
    movie_id      BIGINT,  
    ts            TIMESTAMP,  
    view_count    COUNTER,  
    PRIMARY KEY  (movie_id, ts)  
);
```

(previous implementation)

Question on the example (3) - answer

- Use the same table
- Use the a different rounding function:
“hour rounding (down)”

```
// a quick version instead of using calendar...
public static long getTSHourRound(long timestamp) {
    long portion = timestamp % MILLISECONDS_IN_HOUR;
    return timestamp - portion;
}
```

Discussion (1)

- What is the partition key in the examples?
why is this super important here?

```
CREATE TABLE movie_view_counts_by_day (  
    movie_id      BIGINT,  
    ts            TIMESTAMP,  
    view_count    COUNTER,  
    PRIMARY KEY  (movie_id, ts)  
);
```

Discussion (1)

- What is the partition key in the examples?
why is this super important here?

```
CREATE TABLE movie_view_counts_by_day (  
    movie_id      BIGINT,  
    ts            TIMESTAMP,  
    view_count    COUNTER,  
    PRIMARY KEY  (movie_id, ts)  
);
```

We need to read a range of data and we want to do it in a single (read) call

Discussion (2)

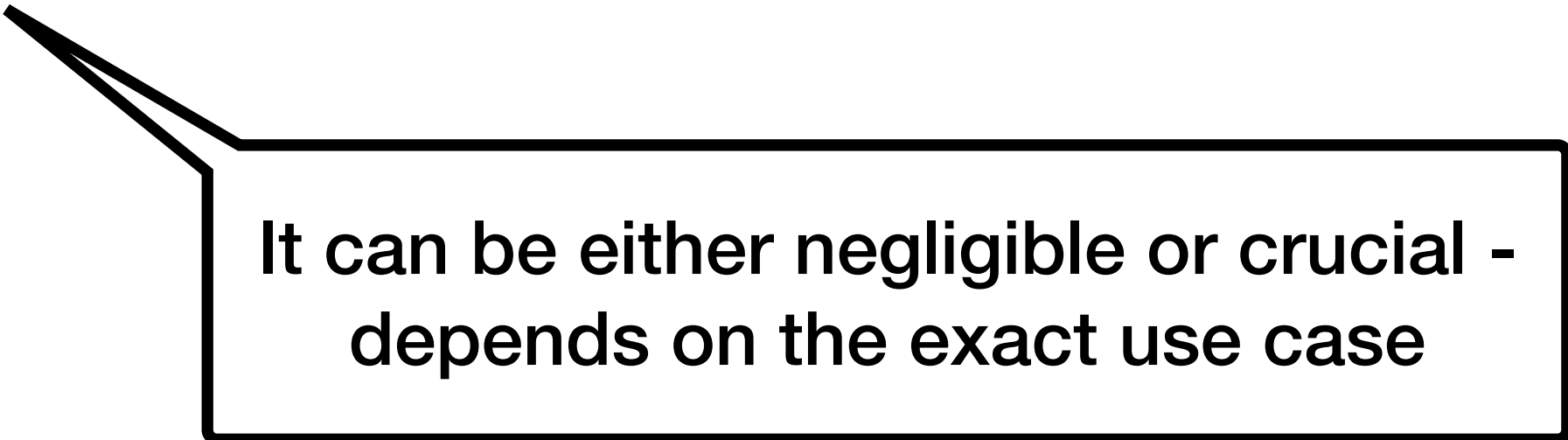
- Are there any performance differences between using “round by hour” vs “round by day”?

Discussion (2)

- Are there any performance differences between using “round by hour” vs “round by day”?
 - The number of events should be the same (unless you allow a daily event to be saved several times during the day)
 - The number of counters can be X24
 - Query / client runtime
 - storage

Discussion (2)

- Are there any performance differences between using “round by hour” vs “round by day”?
 - The number of events should be the same (unless you allow a daily event to be saved several times during the day)
 - The number of counters can be X24
 - Query / client runtime
 - storage



It can be either negligible or crucial - depends on the exact use case

Cassandra advanced topics

- Counters
- **Collections**
- UDTs
- Batches
- Lightweight transactions
- Tunable consistency
- Deletes & tombstones

Cassandra collections

- Multi value columns
Set / List / Map
- Designed for relatively small amount of data
- Retrieved all together
no paging / indexes
- Type is fixed for all elements
- Cannot nest (*only FROZEN)
more on FROZEN later



SET

- Unique, unordered, returned sorted

```
CREATE TABLE movies (  
    movie_id      BIGINT,  
    title         TEXT,  
    genres        SET<text>  
    PRIMARY KEY (movie_id)  
);
```

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Action", "Comedy"})
```

```
UPDATE movies  
SET genres = {"Action", "Comedy", "Teen"}  
WHERE id = 123
```

```
UPDATE movies  
SET genres = genres + {"Teen"}  
WHERE id = 123
```

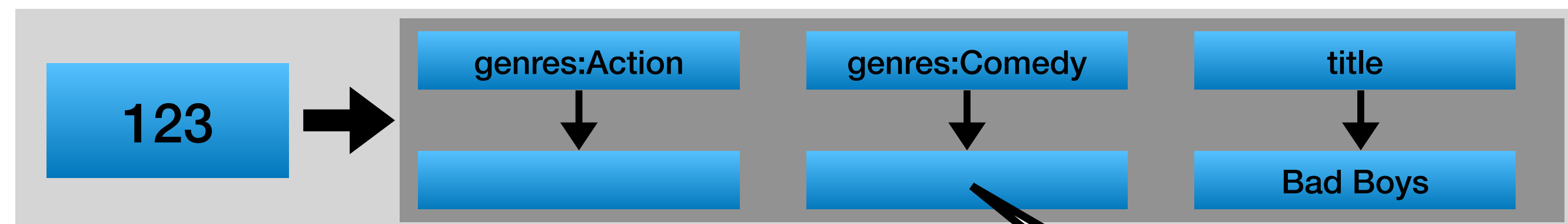
```
UPDATE movies  
SET genres = genres - {"Teen"}  
WHERE id = 123
```

SET

- In practice

```
CREATE TABLE movies (  
  movie_id      BIGINT,  
  title         TEXT,  
  genres        SET<text>  
  PRIMARY KEY (movie_id)  
);
```

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Action", "Comedy"})
```

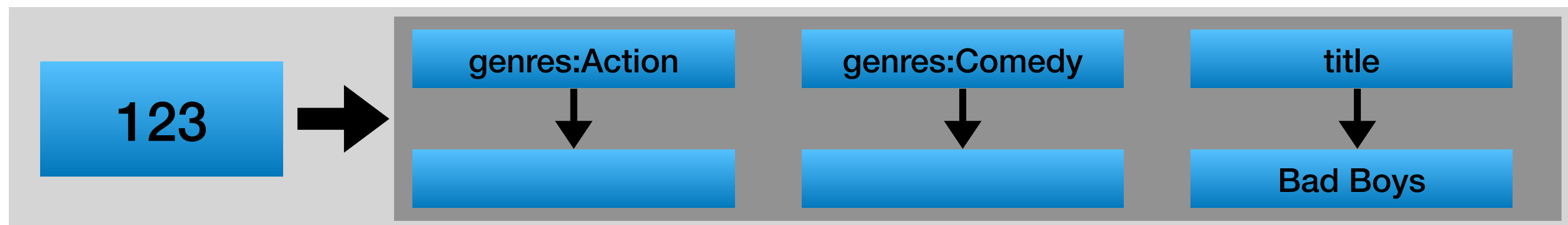


There are no values for the set columns

SET

- In practice

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Action", "Comedy"})
```



```
UPDATE movies  
SET genres = genres + {"Teen"}  
WHERE id = 123
```

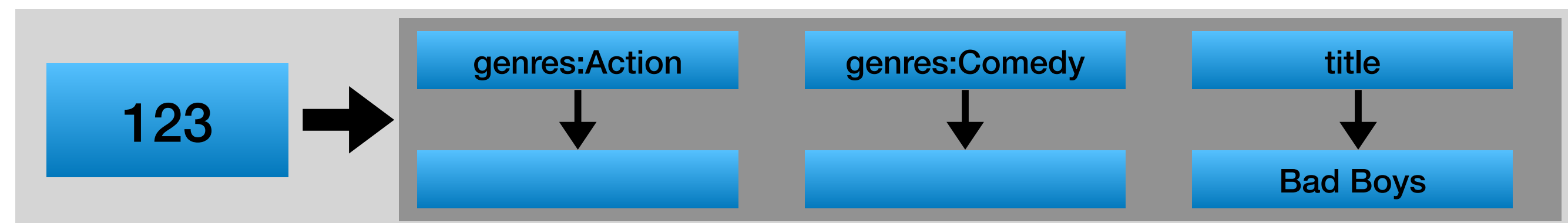
```
CREATE TABLE movies (  
    movie_id      BIGINT,  
    title         TEXT,  
    genres        SET<text>  
    PRIMARY KEY (movie_id)  
);
```

SET

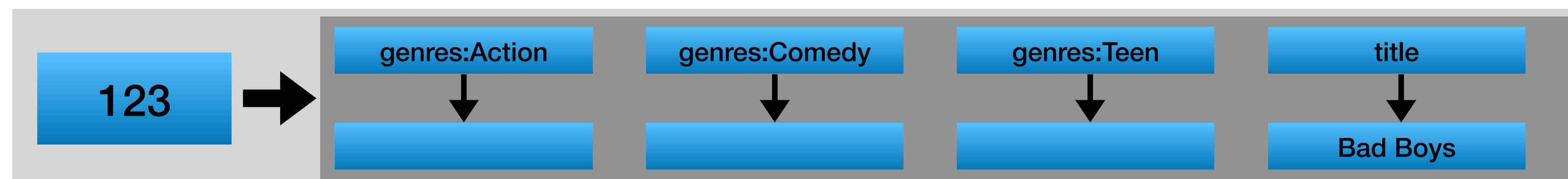
- In practice

```
CREATE TABLE movies (  
    movie_id      BIGINT,  
    title         TEXT,  
    genres        SET<text>  
    PRIMARY KEY (movie_id)  
);
```

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Action", "Comedy"})
```



```
UPDATE movies  
SET genres = genres + {"Teen"}  
WHERE id = 123
```



LIST

- Duplicated, ordered
- (may) requires read before write

```
CREATE TABLE movies (  
    movie_id      BIGINT,  
    title         TEXT,  
    cast          LIST<text>  
    PRIMARY KEY (movie_id)  
);
```

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Will Smith", "Martin Lawrence"})
```

```
UPDATE movies  
SET cast = cast - {"Martin Lawrence"} // all matching elements  
WHERE id = 123                       NOT thread-safe
```

```
UPDATE movies  
SET cast[1] = {"Martin Lawrence"}  
WHERE id = 123
```

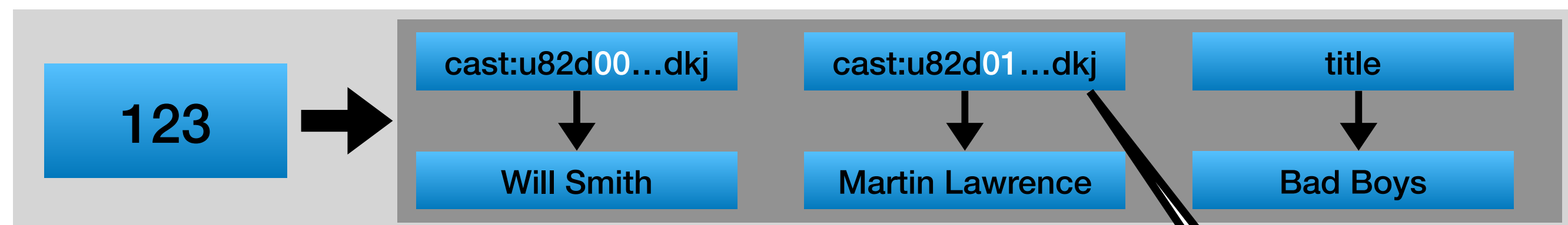
```
DELETE cast[1] FROM movies WHERE id = 123
```

LIST

- In practice

```
CREATE TABLE movies (  
    movie_id      BIGINT,  
    title         TEXT,  
    cast          LIST<text>  
    PRIMARY KEY (movie_id)  
);
```

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Will Smith", "Martin Lawrence"})
```



List values are column values

Column name is added with unique String
based on the list order

LIST

- In practice

```
CREATE TABLE movies (  
  movie_id      BIGINT,  
  title         TEXT,  
  cast          LIST<text>  
  PRIMARY KEY (movie_id)  
);
```

```
INSERT INTO m  
VALUES (123,
```

Again - list may required read before write.
Do NOT use unless you know what you are doing



List values are column values

Column name is added with unique String
based on the list order

MAP

- Key-Value pair, ordered by keys

```
CREATE TABLE movies (  
    movie_id      BIGINT,  
    title         TEXT,  
    cast          MAP<BIGINT, text>  
    PRIMARY KEY (movie_id)  
);
```

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {44: "Will Smith", 45: "Martin Lawrence"})
```

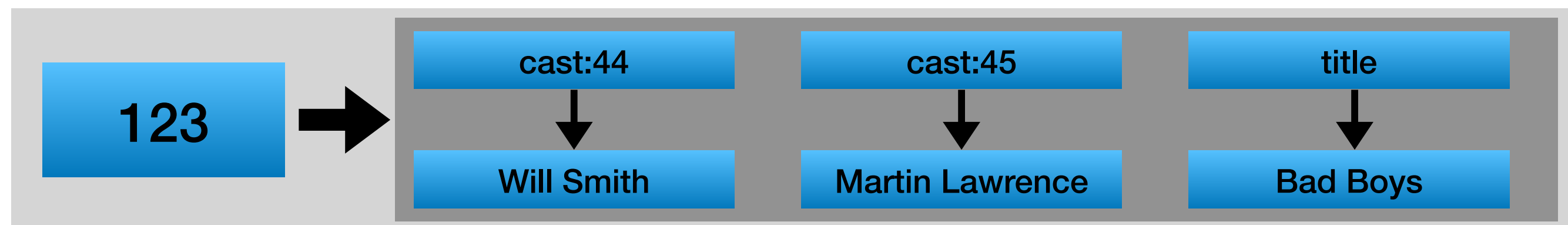
```
UPDATE movies  
SET cast = cast - {44}  
WHERE id = 123
```

MAP

- In practice

```
CREATE TABLE movies (  
  movie_id      BIGINT,  
  title         TEXT,  
  cast          MAP<BIGINT, text>  
  PRIMARY KEY (movie_id)  
);
```

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {44: "Will Smith", 45: "Martin Lawrence"})
```



Cassandra advanced topics

- Counters
- Collections
- **UDTs**
- Batches
- Lightweight transactions
- Tunable consistency
- Deletes & tombstones

User defined types

frozen == blob for Cassandra
—> all data needs to be set at once

- Attach multiple data fields to a single column
- Any type of field is valid (UDT, Collections)
- Use with FROZEN
new versions can support non frozen UDT without collections



```
CREATE TYPE full_name (  
    first_name TEXT,  
    last_name TEXT  
);
```

```
CREATE TYPE address (  
    country TEXT,  
    city TEXT,  
    street TEXT,  
    phones SET<TEXT>  
);
```

User defined types - example

```
CREATE TYPE full_name (  
    first_name TEXT,  
    last_name TEXT  
);
```

```
CREATE TABLE users (  
    user_id BIGINT,  
    name FROZEN <full_name>,  
    age INT  
);
```

```
INSERT INTO user  
VALUES (123, {first_name: "Lebron", last_name: "James"}, 36)
```

User defined types - notes

- You can love them or hate them
- Useful with collections

```
CREATE TYPE address (  
    country      TEXT,  
    city         TEXT,  
    street       TEXT,  
    phones       SET<TEXT>  
) ;
```

```
CREATE TABLE users (  
    user_id      BIGINT,  
    addresses    SET<FROZEN <ADDRESS>>  
) ;
```

Cassandra advanced topics

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Important note

- Batches in Cassandra are different from relational databases
- TLDR; they are “half” relational transactions
batch is isolate and atomic in a single partition

In relational databases

- Batches & Transactions are collections of commands (Insert/Update/Delete) sent together to the server
- Batch
 - NO rollback / ACID
 - used to increase performance by reducing server calls
- Transaction
 - full ACID

In relational databases

No ACID

```
"DRIVER START BATCH"  
  INSERT INTO users VALUES ("Rubi") ;  
  ...  
  INSERT INTO users VALUES ("Tova") ;  
"DRIVER END BATCH"
```

Atomicity
Consistency
Isolation
Durability

If "Tova" fails, "Rubi" is still added

ACID

```
START TRANSACTION  
  INSERT INTO flights VALUES ("Rubi", "TLV-NY") ;  
  ...  
  INSERT INTO hotels VALUES ("Rubi", "Hilton-NY") ;  
COMMIT
```

If "Hilton-NY" fails, the flight is NOT added

Cassandra Batch

- Executes several commands
- If statement apply to the same partition:
atomic & isolated

BEGIN BATCH

`INSERT INTO users_by_country VALUES ("Israel",123, "Rubi") ;`

`...`

`INSERT INTO users_by_country VALUES ("Israel",123, "Tova") ;`

APPLY BATCH

Same partition

If "Tova" Fails, "Rubi" will not be added

Isolation - can NOT read "Rubi" until "Tova" is added

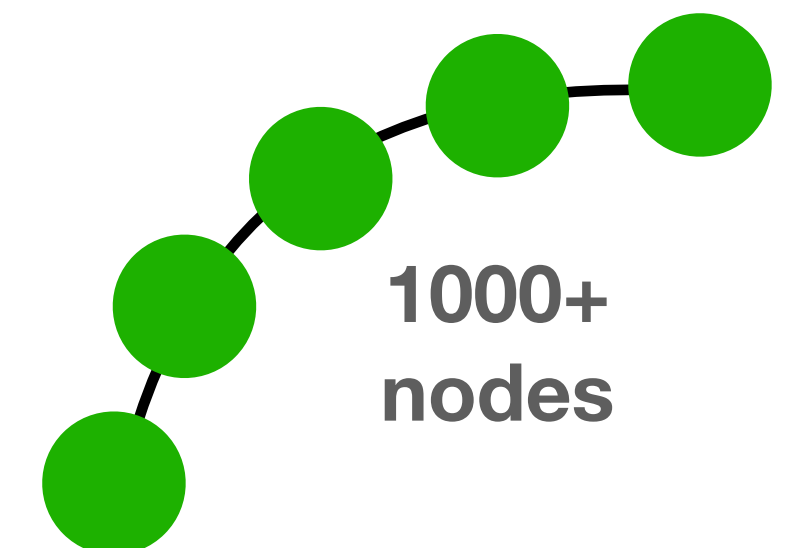
Cassandra Batch - performance?

users	
user_id	K
name	

- Each batch is sent to a single coordinator (node), logged and then executed
- What happens in each scenario?

- ```
BEGIN BATCH
 INSERT INTO users VALUES (123, "Rubi");
 ...
 INSERT INTO users VALUES (456, "Tova");
APPLY BATCH
```

- ```
INSERT INTO users VALUES (123, "Rubi");
...
INSERT INTO users VALUES (456, "Tova");
```



Cassandra Batch - performance?

users	
user_id	K
name	

- Each batch is send to a single coordinator (node), logged and then executed

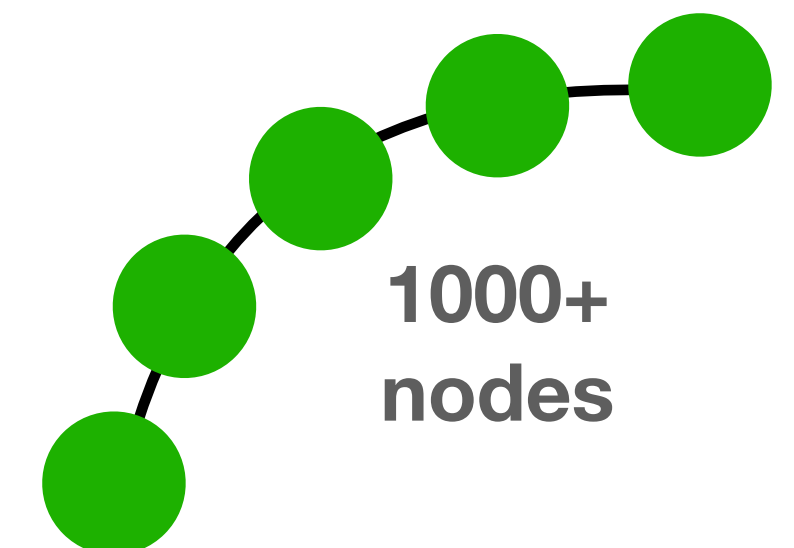
- What happens in each scenario?

- ```
BEGIN BATCH
 INSERT INTO users VALUES (123, "Rubi");
 ...
 INSERT INTO users VALUES (456, "Tova");
APPLY BATCH
```

Contact the node of the first partition key (123) and log the batch.

Then that node contacts the node of partition 456

- ```
INSERT INTO users VALUES (123, "Rubi");
...
INSERT INTO users VALUES (456, "Tova");
```



Cassandra Batch - performance?

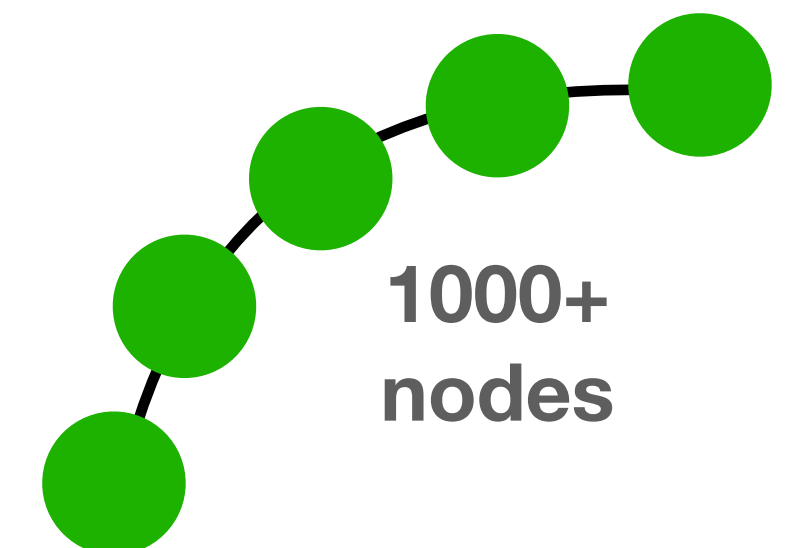
users	
user_id	K
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- Each batch is send to a single coordinator (node), logged and then executed
- What happens in each scenario?

- ```
BEGIN BATCH
 INSERT INTO users VALUES (123, "Rubi");
 ...
 INSERT INTO users VALUES (456, "Tova");
APPLY BATCH
```

- ```
INSERT INTO users VALUES (123, "Rubi");
...
INSERT INTO users VALUES (456, "Tova");
```

Each insert calls directly the relevant node



Cassandra Batch - performance?

users	
user_id	K
name	

- Each batch is sent to a single node (node),
logged

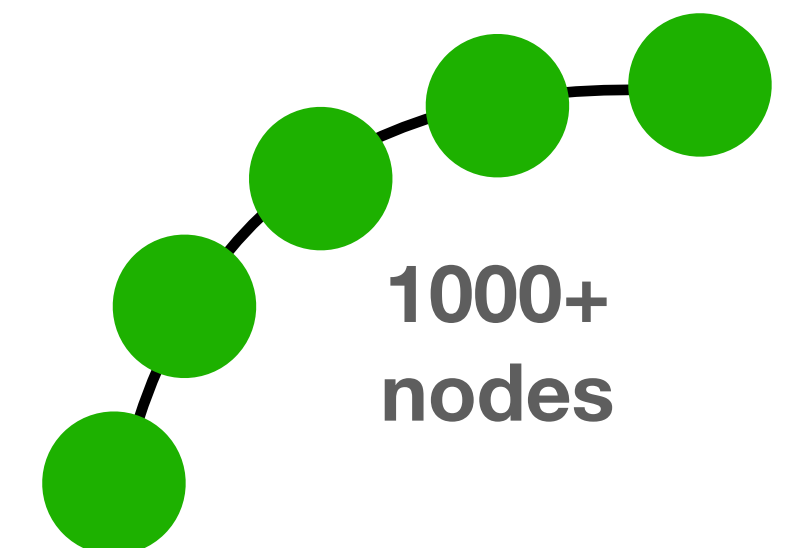
- What happens?

Batches in Cassandra almost always do not help
with performance

Use it only if you need single partition isolation

- ```
BEGIN BATCH
 INSERT INTO users VALUES (123, 'Rubi');
 ...
 INSERT INTO users VALUES (456, 'Tova');
APPLY BATCH
```

- ```
INSERT INTO users VALUES (123, 'Rubi');
...
INSERT INTO users VALUES (456, 'Tova');
```



Cassandra advanced topics

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- UDTs
- Batches
- **Lightweight transactions**
- Tunable consistency
- Deletes & tombstones

Lightweight Transactions

- Checks a condition prior to Insert/Update/Delete
- Expensive (more than a read and write)
- An “ACID Transaction” at the partition level

Lightweight Transactions - examples

```
INSERT INTO movies  
VALUES (3, "American Pie", 1999, 96)  
IF NOT EXISTS
```

```
UPDATE movies  
SET duration = 96  
WHERE id = 3  
IF year = 1999
```

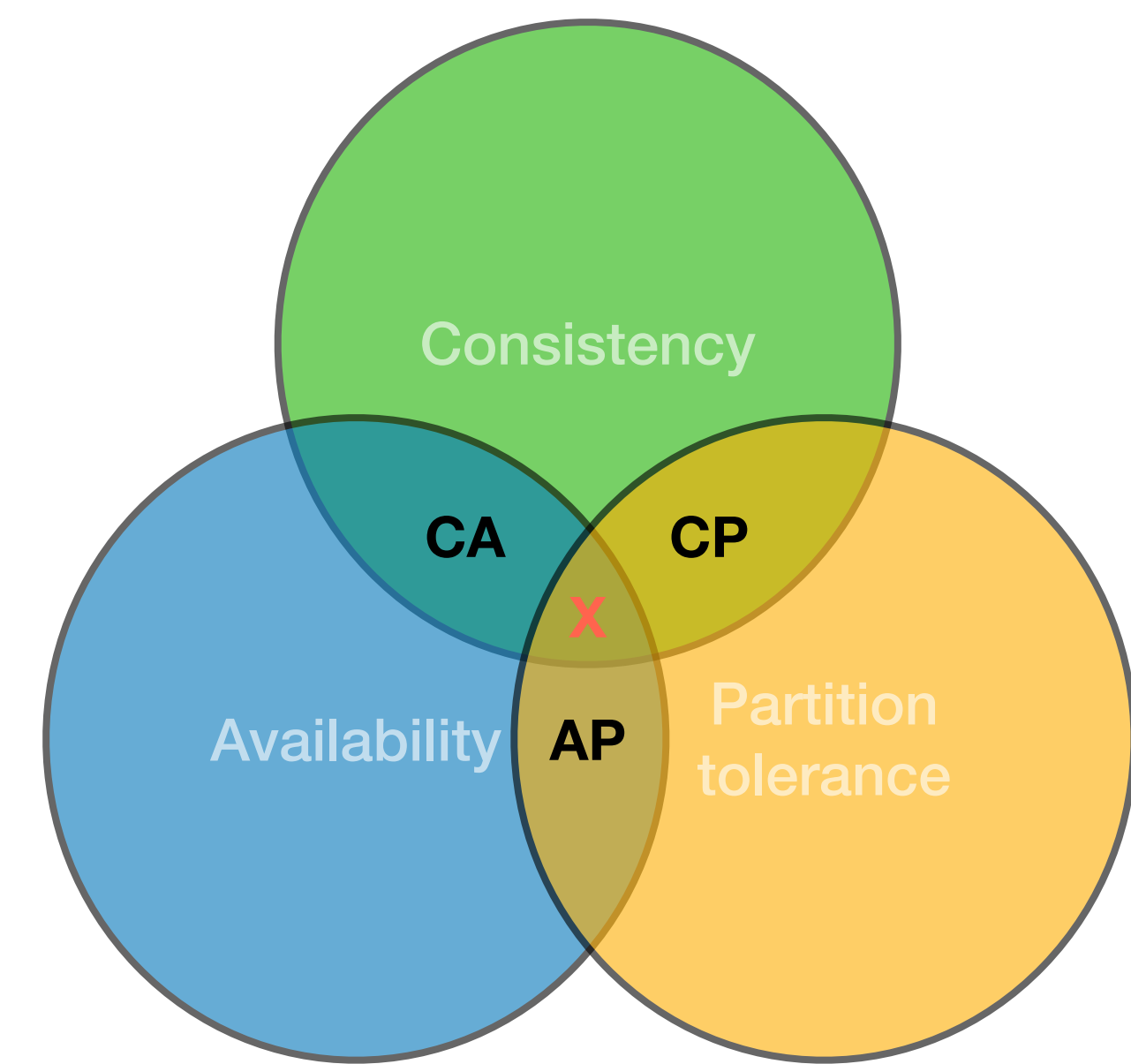
movies	
id	K
title	
year	
duration	

Cassandra advanced topics

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- **Tunable consistency**
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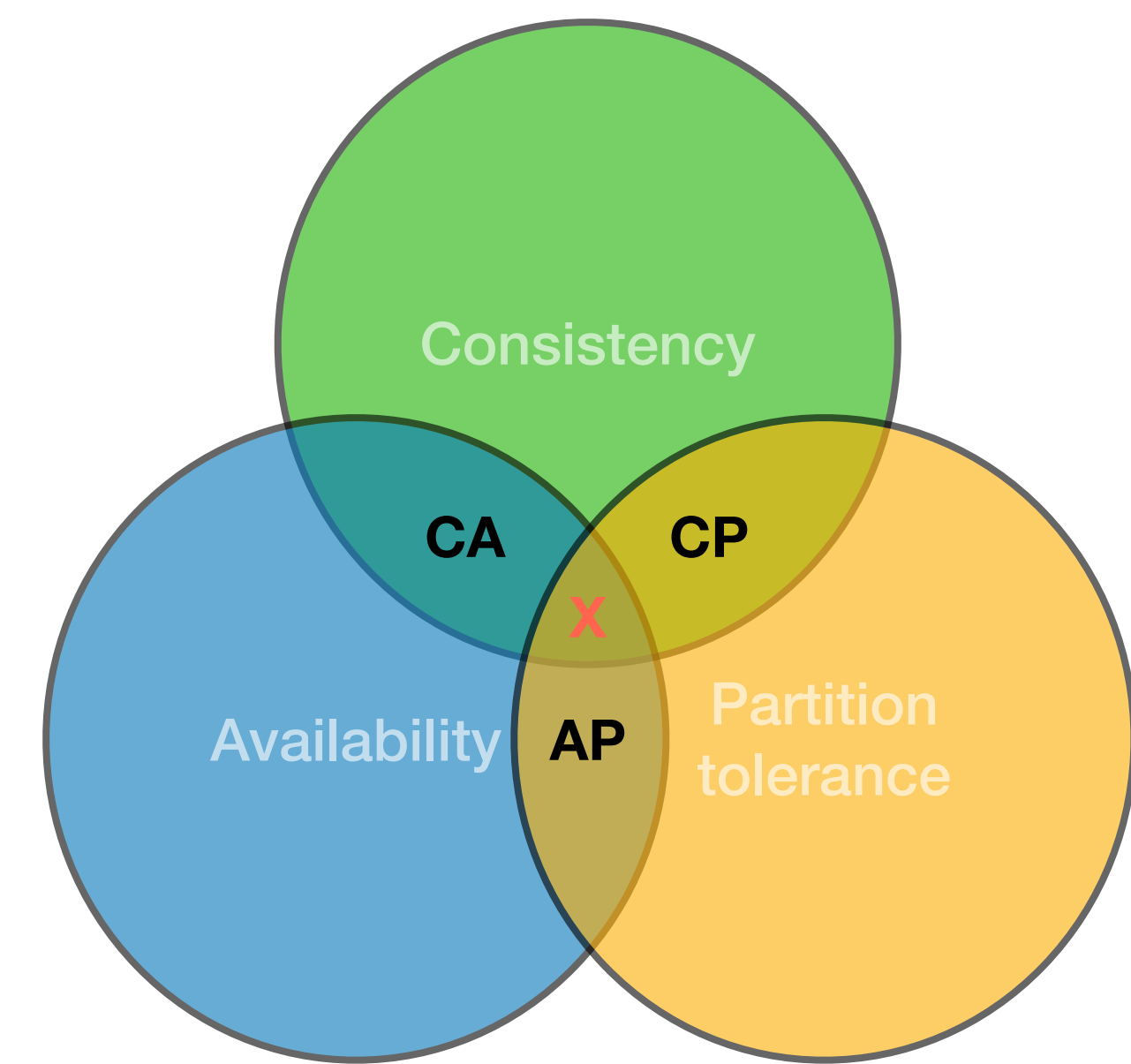
Recap - CAP

- **Consistency**
Every read receives the most recent write or an error
- **Availability**
Every request receives a (non-error) response, without the guarantee that it contains the most recent write
- **Partition tolerance**
The system continues to operate despite an arbitrary number of messages being dropped (or delayed) by the network



Recap - CAP

- TLDR; If a node is down/unreachable
 - Cancel the operation (CP)
 - Return result with (maybe) inconsistency (AP)



Tunable consistency in Cassandra

- When performing read/write, consistency level can be specified

Consistency level = # of nodes (replicas) needs to response

- ONE / TWO / QUORUM / LOCAL_QUORUM / ALL / ...

Tunable consistency in Cassandra

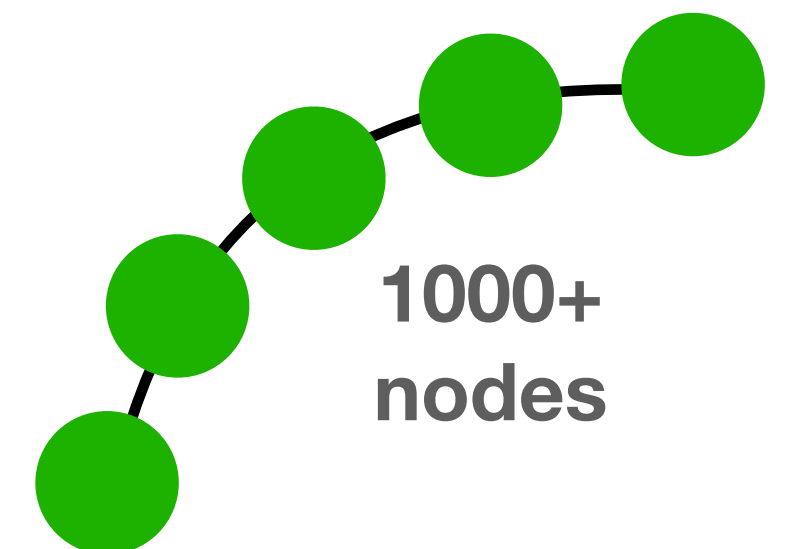
```
// within cqlsh session  
CONSISTENCY QUORUM  
INSERT INTO movies VALUES (3, "American Pie", 1999, 96)
```

When to use which level?

- A function of application logic & resources (money)

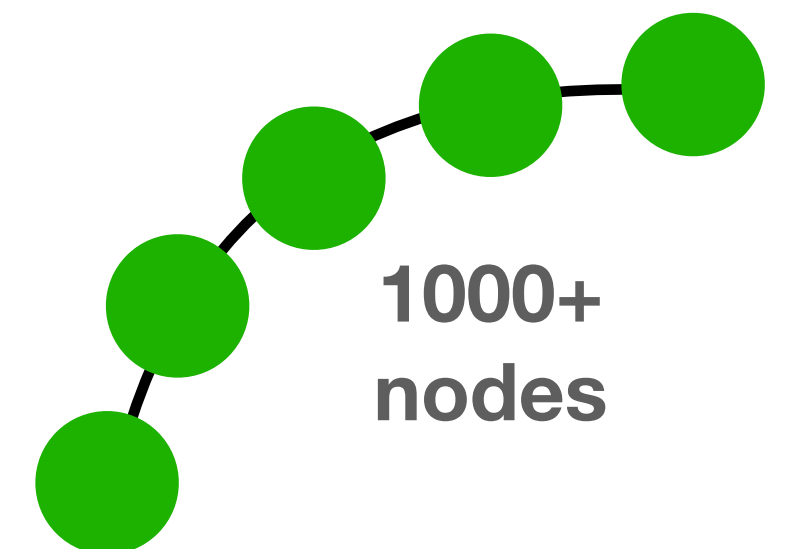
When to use which level?

- A function of application logic & resources (money)
- For example:
 - A “like” event should get ONE or QUORUM?



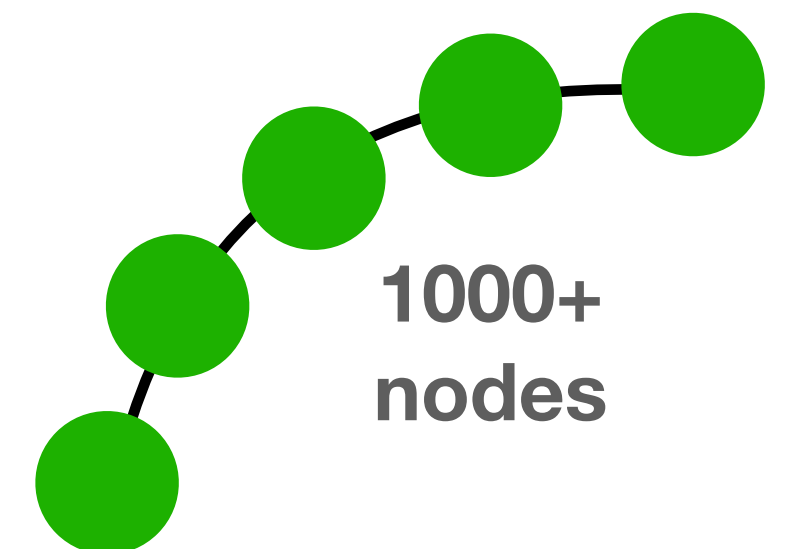
When to use which level?

- A function of application logic & resources (money)
- For example:
 - A “like” event should get ONE or QUORUM?
 - A “buy” event should get ONE or QUORUM?



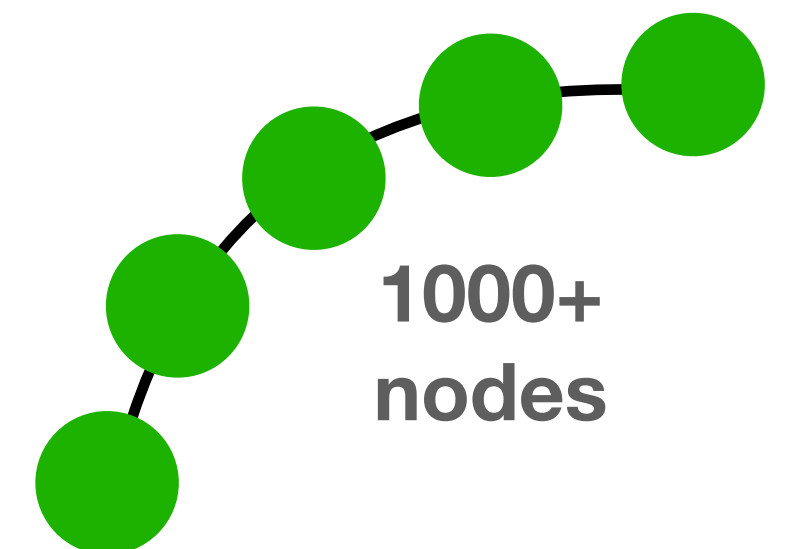
When to use which level?

- A function of application logic & resources (money)
- For example:
 - A “like” event should get ONE or QUORUM?
 - A “buy” event should get ONE or QUORUM?
 - # of available rooms in a hotel should get ONE or QUORUM?



When to use which level?

- A function of application logic & resources (money)
- For example:
 - A “like” event should get ONE or QUORUM?
 - A “buy” event should get ONE or QUORUM?
 - # of available rooms in a hotel should get ONE or QUORUM?
- Critical for performance on large scale



Cassandra advanced topics

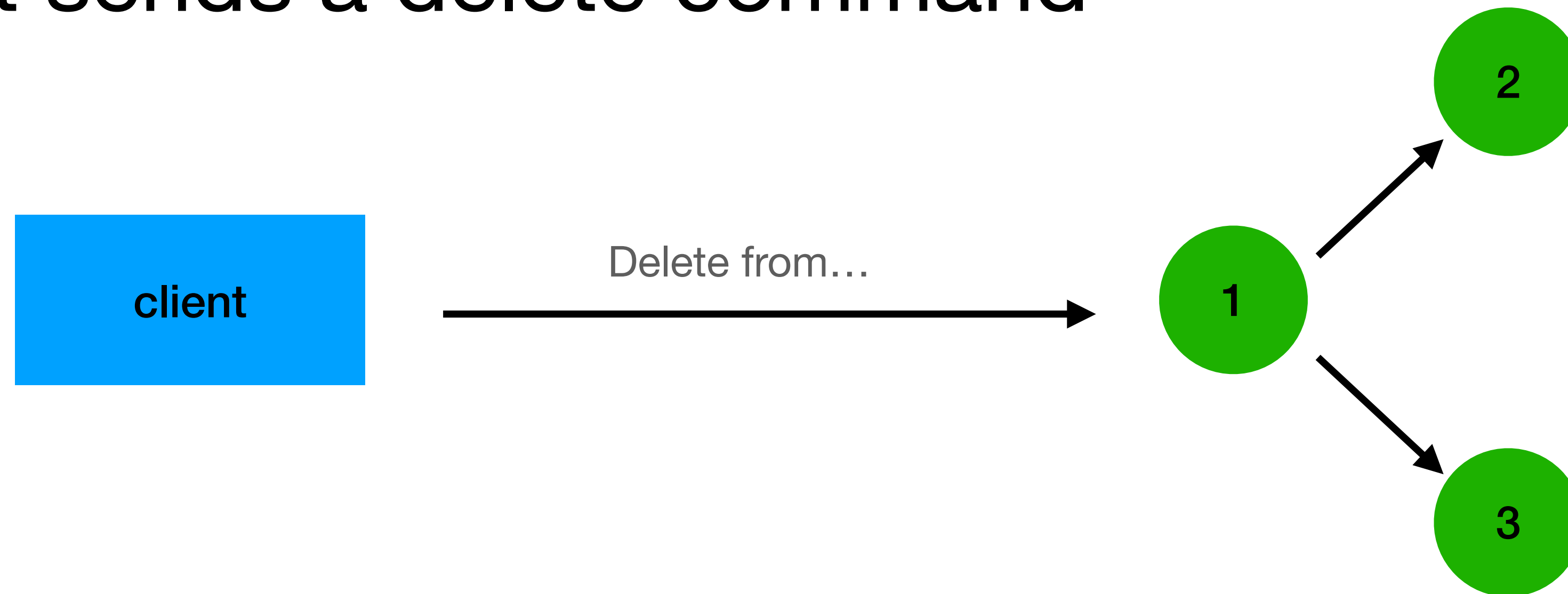
- Counters
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- Lightweight transactions
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- **Deletes & tombstones**

Deletes in a distributed system

- A hard problem.
Why?

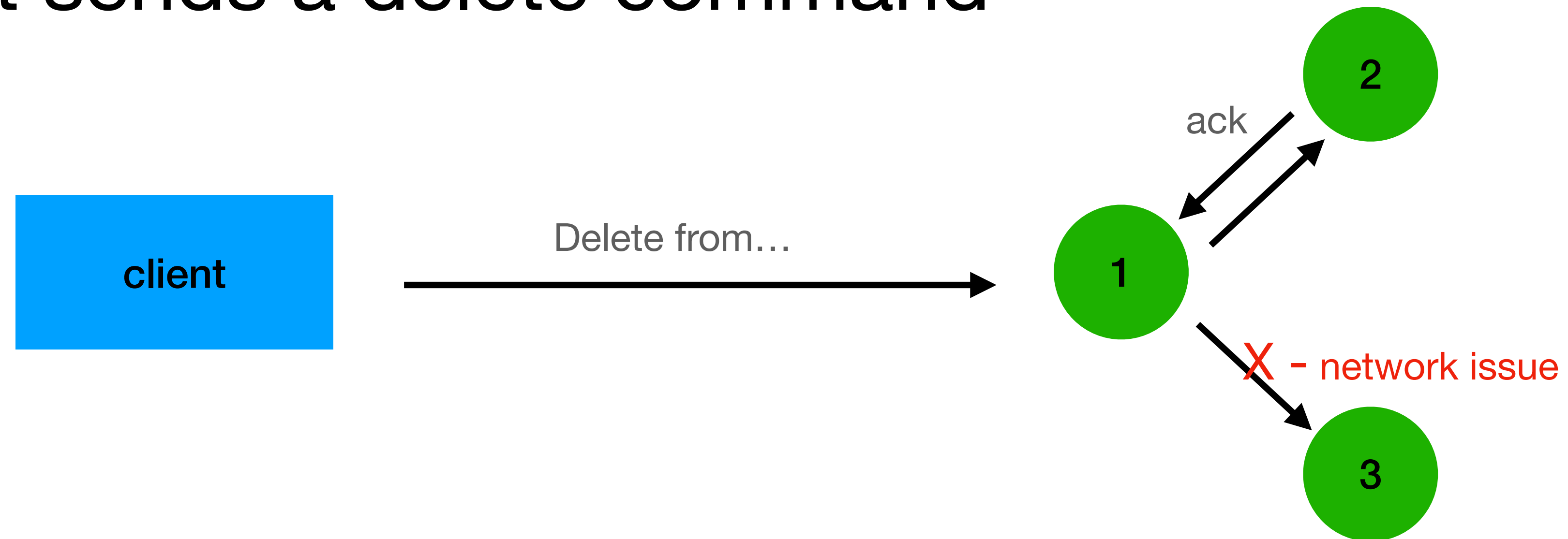
Delete example - distributed system

- 3 nodes, replication factor = 3, consistency=quorum
- A client sends a delete command



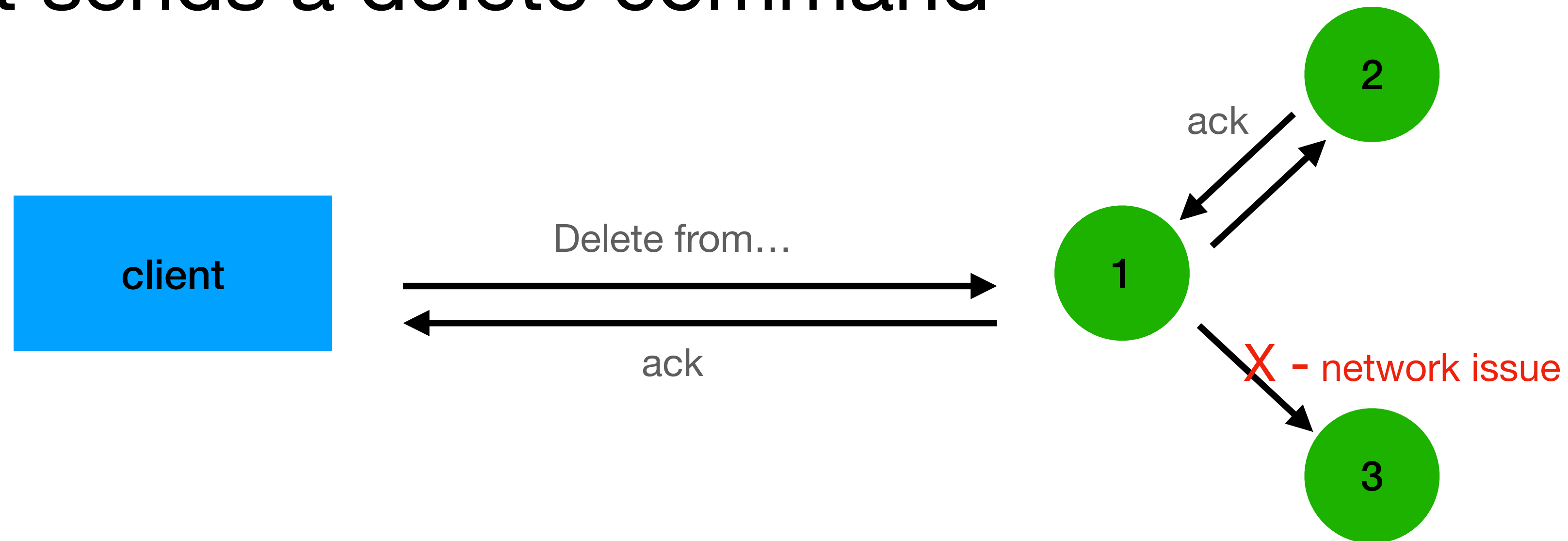
Delete example - distributed system

- 3 nodes, replication factor = 3, consistency=quorum
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Delete example - distributed system

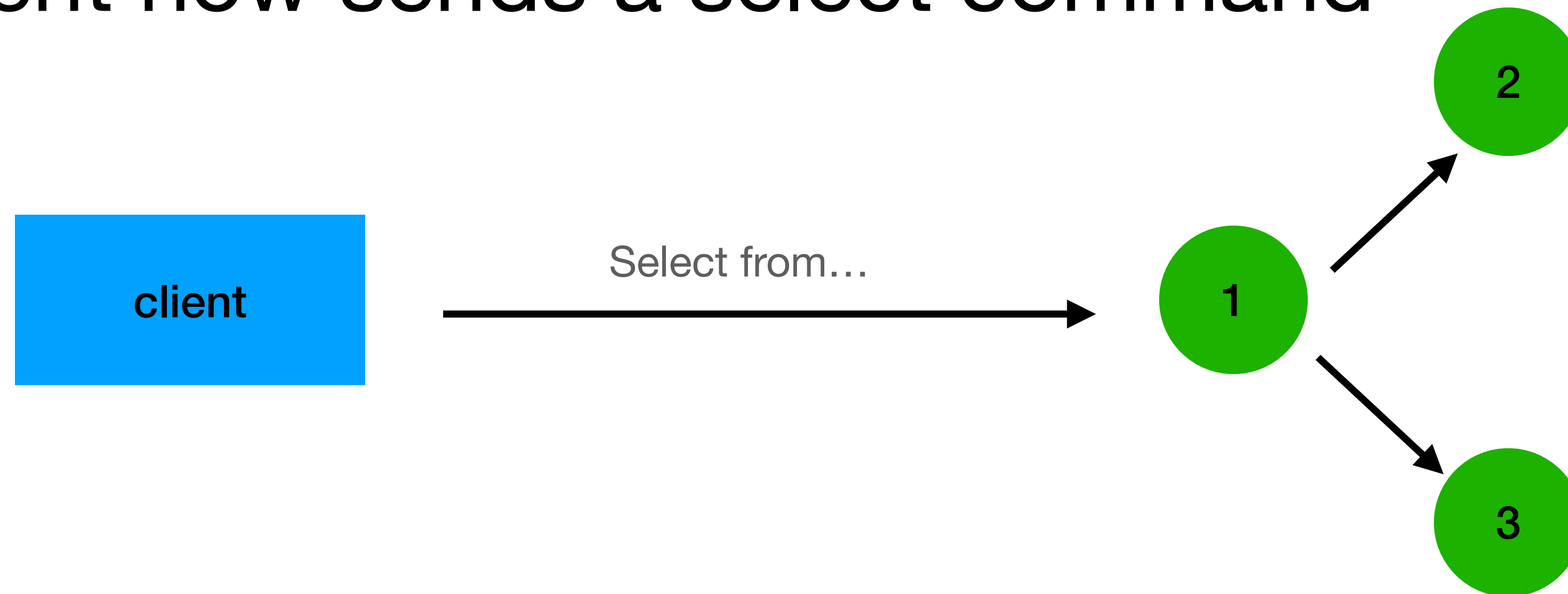
- 3 nodes, replication factor = 3, consistency=quorum
- A client sends a delete command



- Client receives success (2 out of 3)

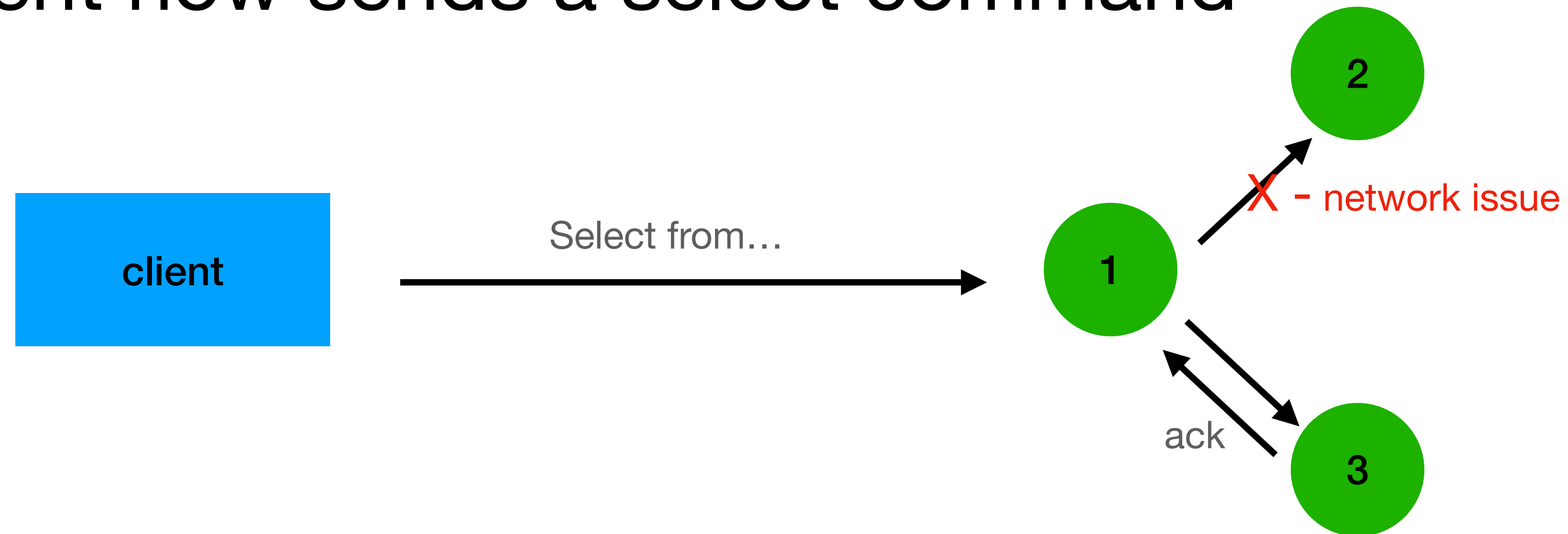
Delete example - distributed system

- 3 nodes, replication factor = 3, consistency=quorum
- The client now sends a select command



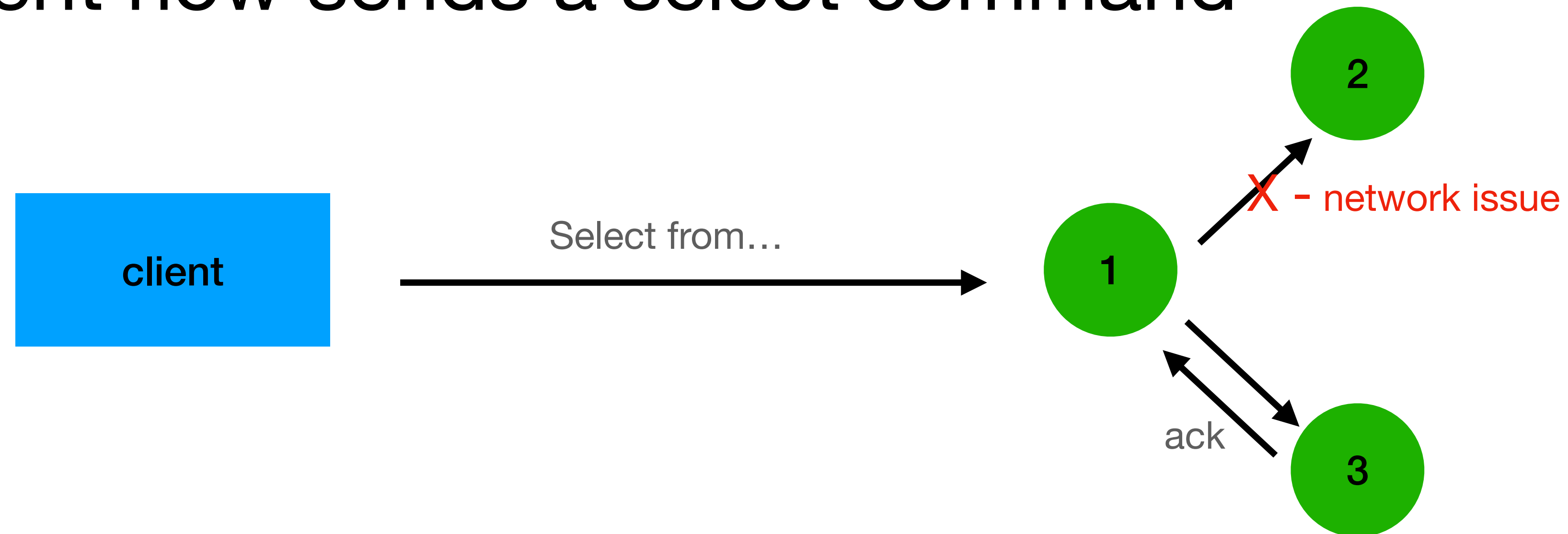
Delete example - distributed system

- 3 nodes, replication factor = 3, consistency=quorum
- The client now sends a select command



Delete example - distributed system

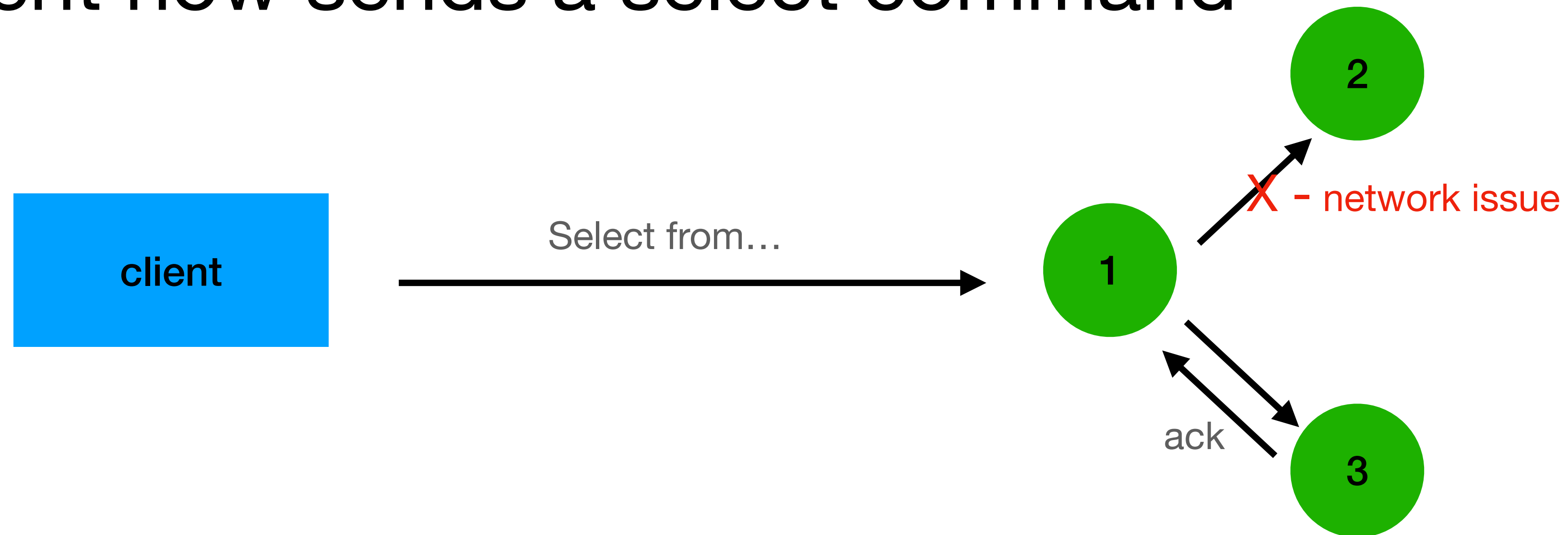
- 3 nodes, replication factor = 3, consistency=quorum
- The client now sends a select command



- Conflict! Node 3 contains data, Node 1 does not

Delete example - distributed system

- 3 nodes, replication factor = 3, consistency=quorum
- The client now sends a select command



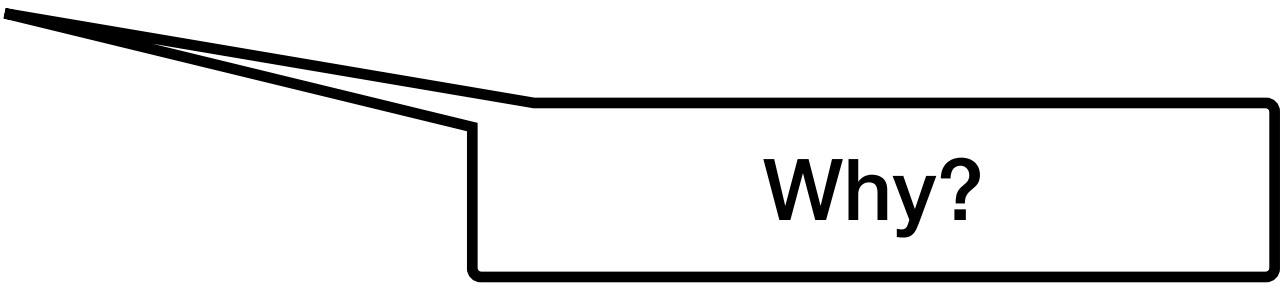
- Conflict! Node 3 contains data, Node 1 does not
—> Cassandra will return “zombie” / “ghost” data

Cassandra solution (simplified)

- When deleting, create a “delete entry” - **tombstone**
- Solves 2 problems:
 - the “ambiguous read”
 - immutable storage (SSTables)
- Before reads - Cassandra checks for relevant tombstones

Tombstones

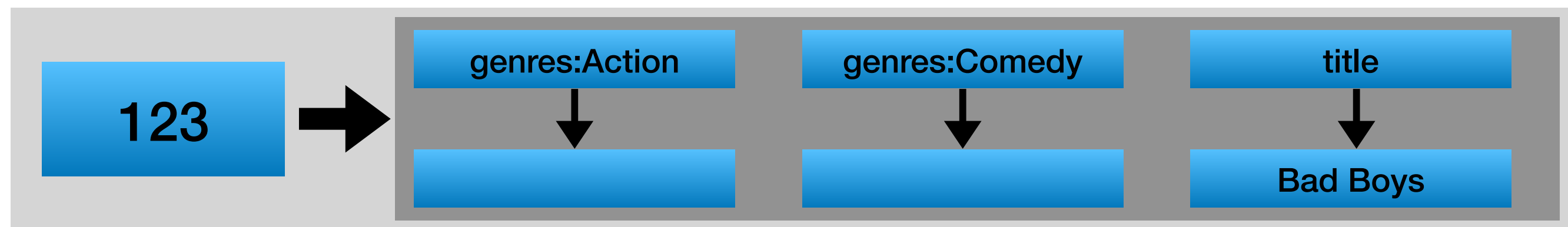
- Created when
 - DELETE
 - Setting TTLs
 - Inserting NULLs (avoid!)
 - Inserting data into a collection
when inserting the entire collection



Why?

Tombstone & SET

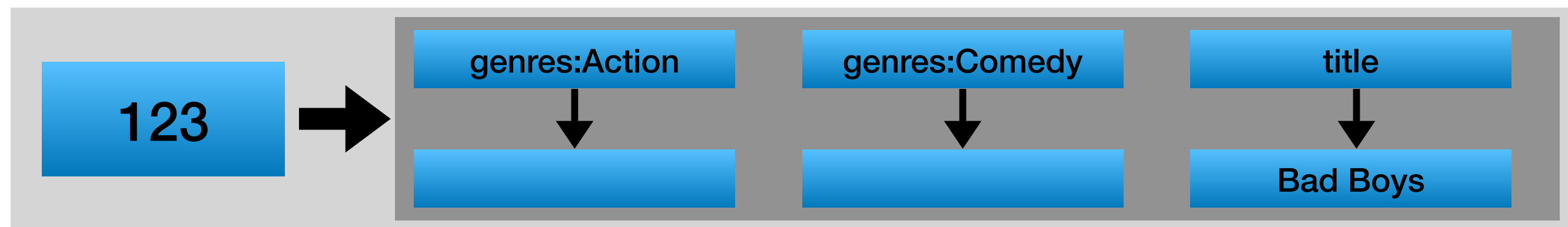
```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Action", "Comedy"})
```



```
CREATE TABLE movies (  
    movie_id      BIGINT,  
    title         TEXT,  
    genres        SET<text>  
    PRIMARY KEY (movie_id)  
);
```

Tombstone & SET

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Action", "Comedy"})
```

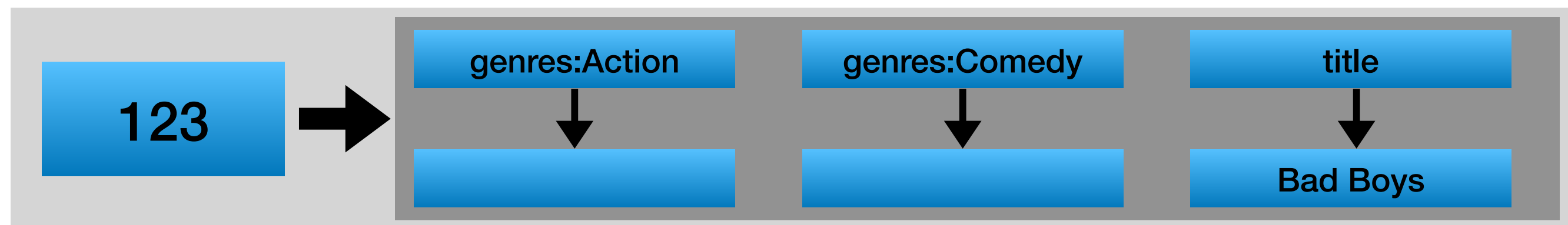


```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Teen", "Drama"})
```

```
CREATE TABLE movies (  
    movie_id      BIGINT,  
    title         TEXT,  
    genres        SET<text>  
    PRIMARY KEY (movie_id)  
);
```

Tombstone & SET

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Action", "Comedy"})
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CREATE TABLE movies (  
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  PRIMARY KEY (movie_id)  
);
```

```
INSERT INTO movies  
VALUES (123, "Bad Boys", {"Teen", "Drama"})
```

As data is stored in separate columns, we need to delete all previous existing columns

Tombstones - how long do we keep them?

Any ideas?

Tombstones - how long do we keep them?

Tombstones can be removed once:

- Creation time is longer than `gc_grace_seconds`
default is 10 days
- A repair should run at least once every `gc_grace_seconds`
repairs assures consistency among all nodes
- All sstables that could contain the relevant data are involved in the compaction

Tombstones - problem

- Tombstones had performance hit for queries
- Warning in 1k tombstones per partition query
- Error in 100k tombstones per partition query

Tombstones - problem - SOLUTION

- It all comes down to the data model
- Adjusting and `gc_grace_seconds` and Repairs
if you are doing this —> probably problems in production :(
- More on this later...
modeling multi tenants for example