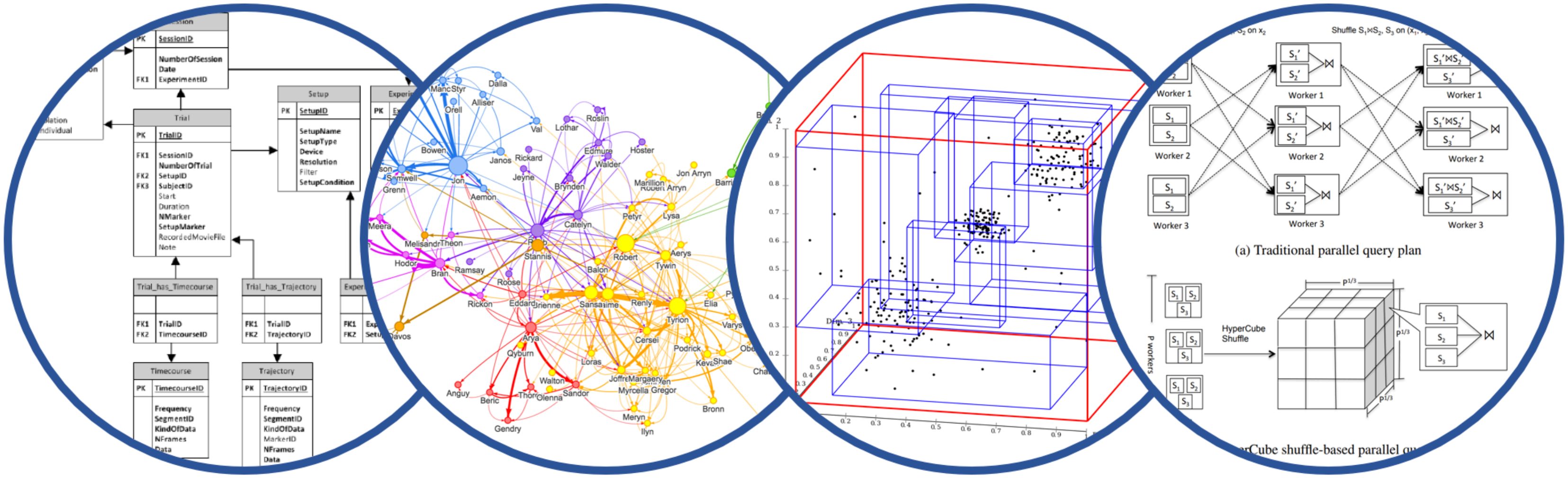
Course evals

Please take a few minutes to fill out the course evaluations:

https://uw.iasystem.org/survey/258581

And thank you all for your hard work this quarter!



Database System Internals

Replication

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Announcements

Almost done!

- HW6 due Monday
- Lab5 due on June 9. No late days
- No lab6 (we alternate with Lab5)

References

- Ullman Book Chapter 20.6

- Database management systems.
  Ramakrishnan and Gehrke.
  Third Ed. Chapter 22.11

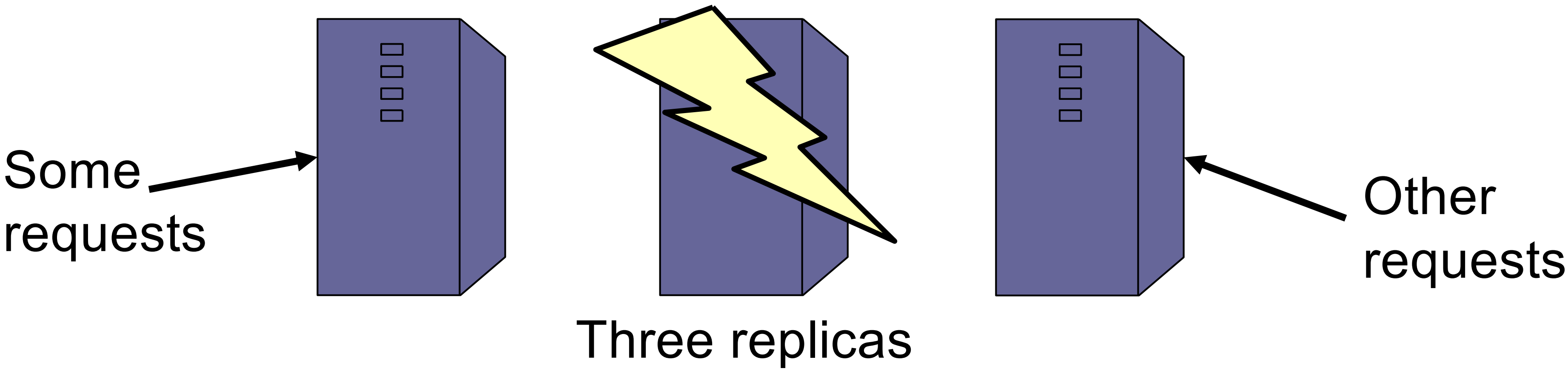
Outline

- Goals of replication

- Three types of replication
  - Synchronous (aka eager) replication
  - Asynchronous (aka lazy) replication
  - Two-tier replication

Goals of Replication

- Goal 1: consistency. Always read latest update
- Goal 2: availability. Every request → a response
- Goal 3: performance. Fast read/writes



Discussion: NoSQL

New problem in the early 2000's

- Startup company launces Website backed up by MySQL, works fine with 50 users
- Suddenly, they are successful and have 1M users
- MySQL cannot keep up

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NoSQL:

- Distributed database (replication, partition)
- Give up strong consistency in favor of availability and performance (as we'll see discuss next)

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NoSQL:

- Distributed database (replication, partition)
- Give up strong consistency in favor of availability and performance (as we'll see discuss next)

Today: strong consistency is standard requirement

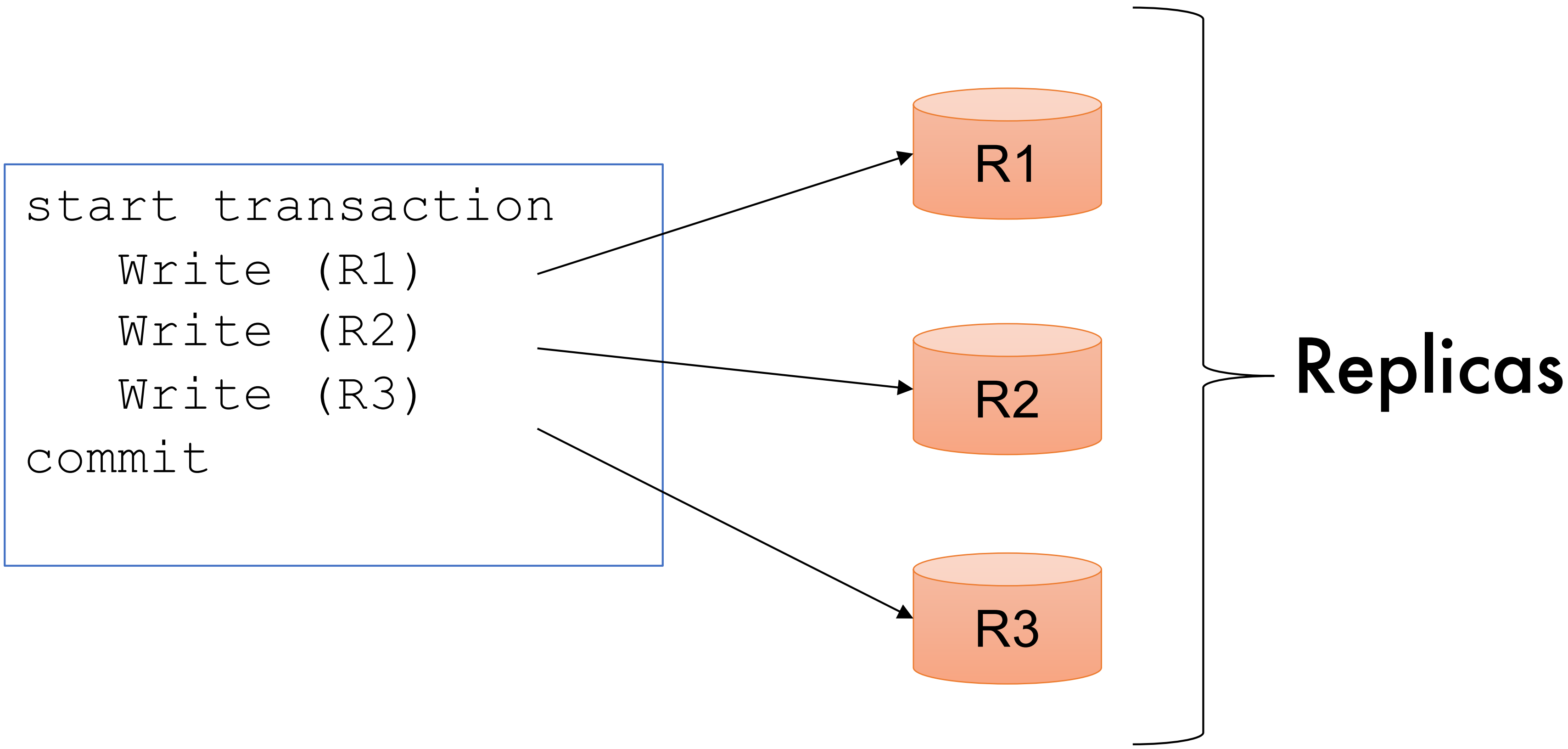
Types of Replication

	Master	Group
Synchronous	✓	
Asynchronous		

Synchronous Replication

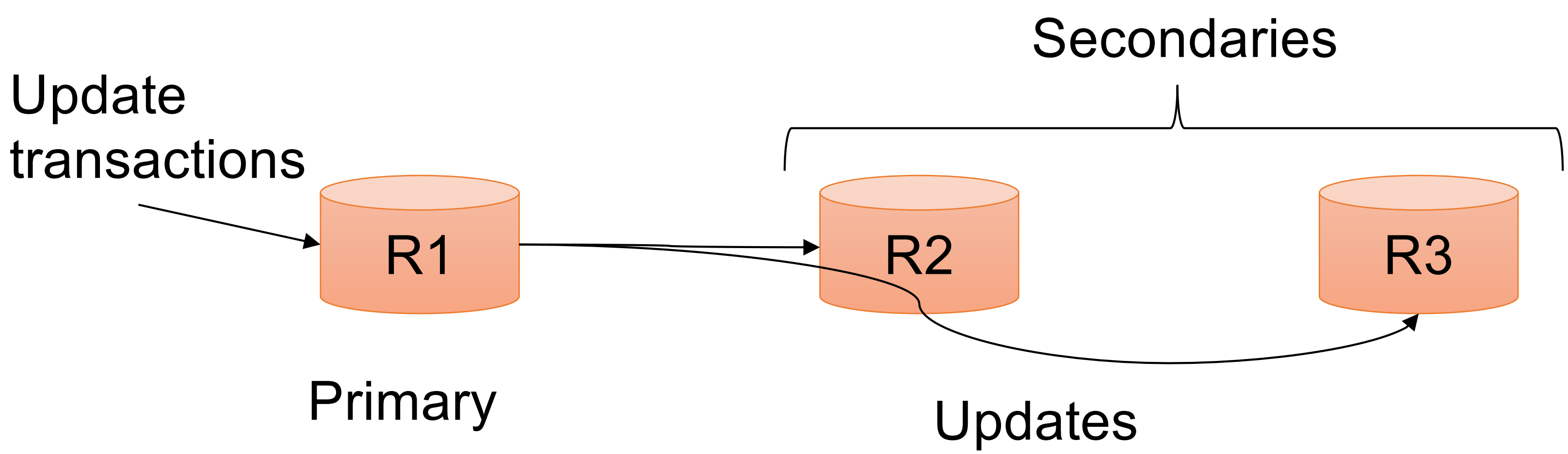
- Also called eager replication
- All updates are applied to all replicas (or to a majority) as part of a single transaction (need two phase commit)
- Transactions must acquire global locks
  - Nobody can read while we synchronize the replicas
- Main goal: as if there was only one copy
  - Maintain **consistency**
  - Maintain **one-copy serializability**
  - I.e., execution of transactions has same effect as an execution on a non-replicated db

Synchronous Replication



Synchronous Master Replication

- One master for each object holds primary copy
  - The "Master" is also called "Primary"
  - To update object, transaction must acquire a lock at the master
  - Lock at the master is global lock
- Master propagates updates to replicas synchronously
  - Updates propagate as part of the same distributed transaction
  - Need to run 2PC at the end



Crash Failures

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- What happens when the master/primary fails?
  - Blocking would hurt availability
  - Must chose a new primary: run election

Network Failures

- Network failures can cause trouble...
  - Secondaries think that primary failed
  - Secondaries elect a new primary
  - But primary can still be running
  - Now have two primaries!

Majority Consensus

- To avoid problem, only majority partition can continue processing at any time

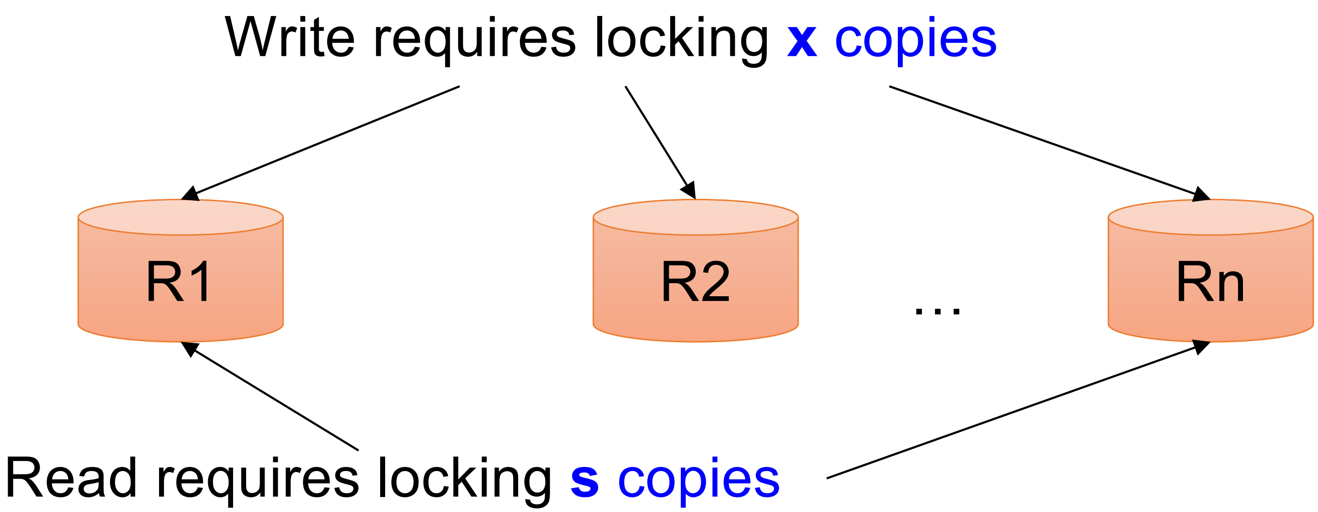
- In general,
  - Whenever a replica fails or recovers...
  - ...a set of communicating replicas must determine...
  - ...whether they have a majority before they can continue

Types of Replication

	Master	Group
Synchronous	✓	✓
Asynchronous		

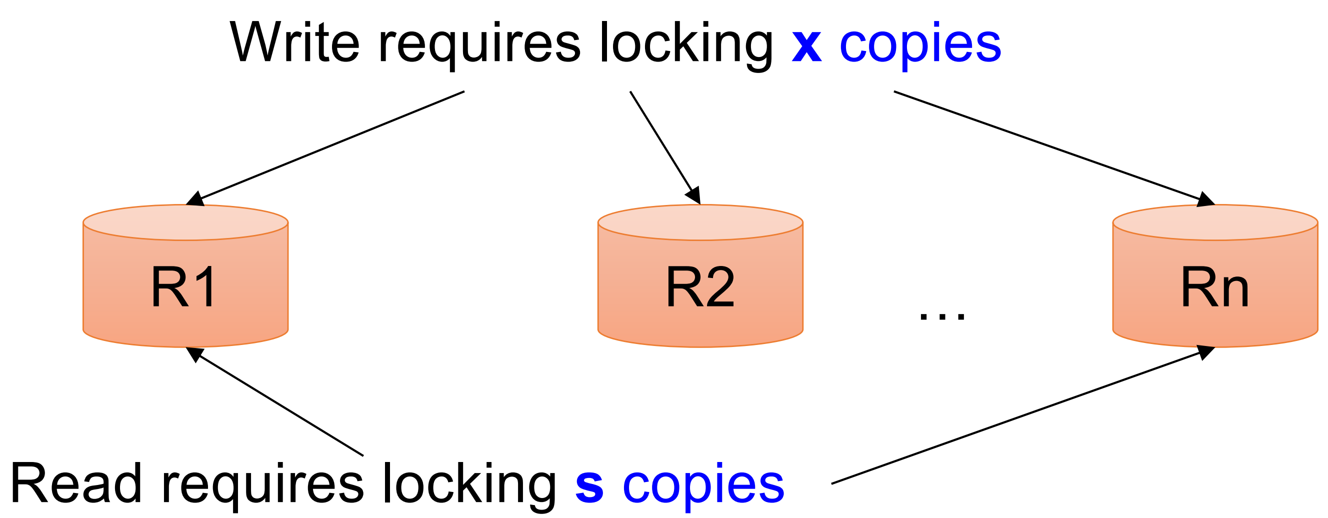
Synchronous Group Replication

- **Master-less**
  - Any node can initiate a transaction!
  - Need to gather a number of nodes that agree on a particular transaction
  - Each copy has its own lock



Synchronous Group Replication

- With n copies
  - Exclusive lock on x copies is global exclusive lock
  - Shared lock on s copies is global shared lock
  - Must have: 2x > n and s + x > n
  - Version numbers serve to identify current copy



Synchronous Group Replication

- Majority locking
  - $s = x = \lceil (n+1)/2 \rceil$ eg: 11 nodes: need 6 locked
  - Usually not attractive because reads are slowed down
- Read-locks-one, write-locks-all
  - $s=1$ and $x = n$, high read performance
  - Reads are very fast

Synchronous Replication Properties

- Favours consistency over availability
  - Only majority partition can process requests
  - There appears to be a single copy of the db
- High runtime overhead
  - Must lock and update at least majority of replicas
  - Two-phase commit
  - Runs at pace of slowest replica in quorum
  - So overall system is now slower
  - Higher deadlock rate (transactions take longer)

Types of Replication

	Master	Group
Synchronous	✓	✓
Asynchronous	✓	

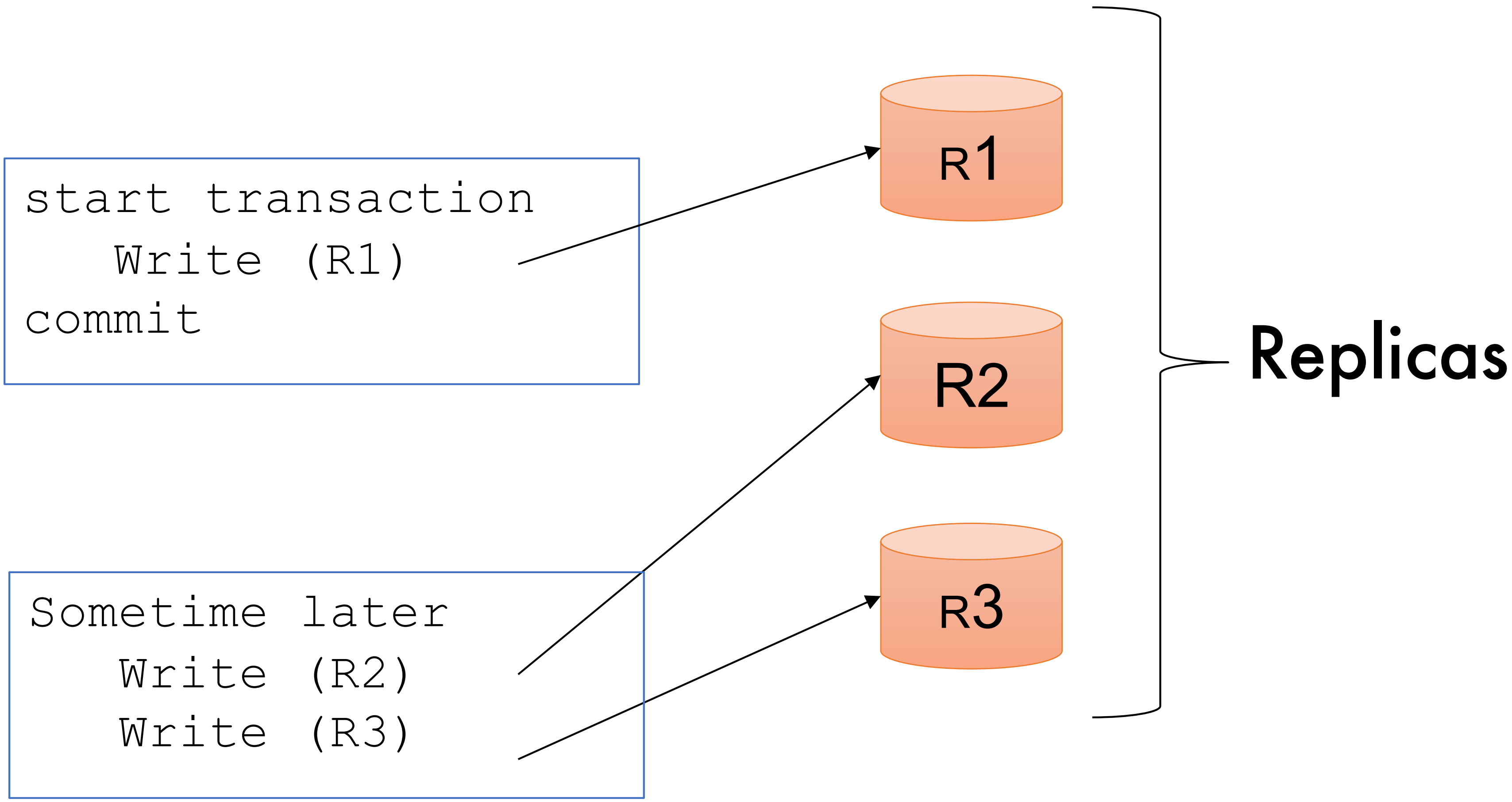
Asynchronous Replication

- Also called lazy replication
- Also called optimistic replication

- Main goals: availability and performance

- Approach
  - One replica updated by original transaction
  - Updates propagate asynchronously to other replicas

Asynchronous Replication



Asynchronous Master Replication

One master holds primary copy

- Transactions update primary copy
- Master asynchronously propagates updates to replicas, which process them in same order
  E.g. through log shipping
- Ensures single-copy serializability

What happens when master/primary fails?

- Can lose most recent transactions when primary fails!
- After electing a new primary, secondaries must agree who is most up-to-date

Discussion: Log Shipping

A general problem:

- A master operates on a database
- The DB needs to be replicated to one or several replicas (e.g. hot stand-by databases)

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- Log Shipping Technique:
  - Master node ships the tail of the log to the replicas E.g. when it flushes the log tail to disk
  - Replicas REDO the log; this is very efficient
  - Need very little systems development: we create the log anyway, and we have the REDO function anyway

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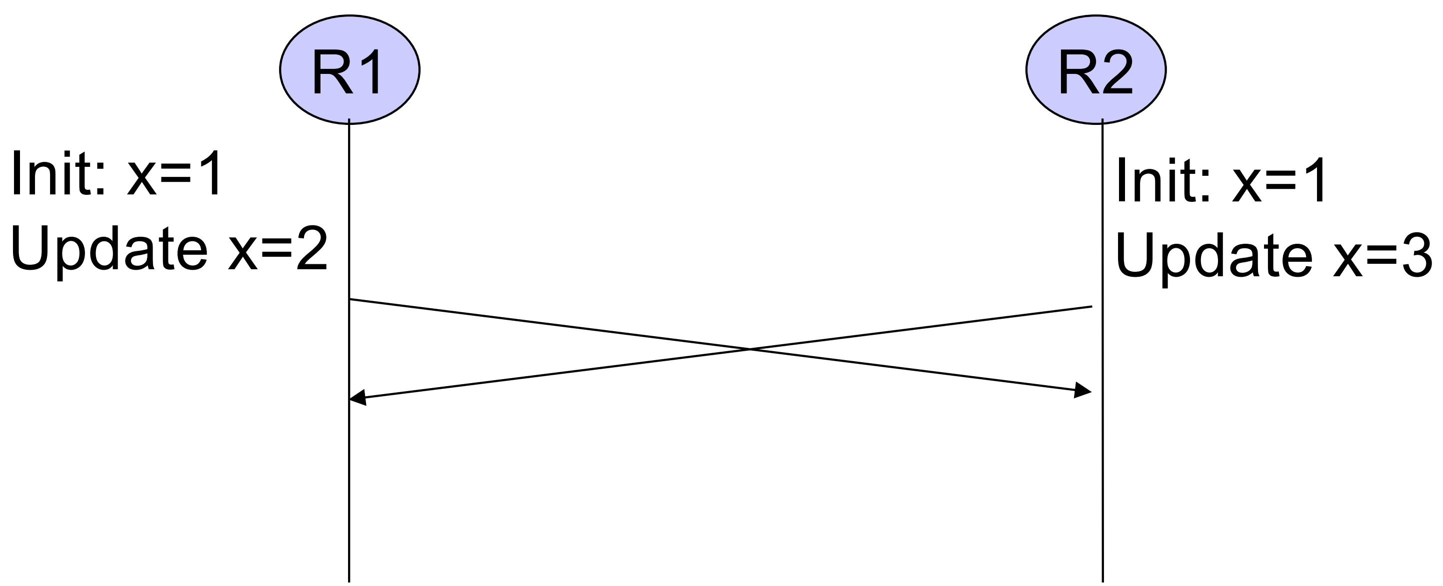
  - Replicas REDO the log; this is very efficient
  - Need very little systems development: we create the log anyway, and we have the REDO function anyway
  - Complications due to the need to "remove" updates of active transactions (they may later abort)

Types of Replication

	Master	Group
Synchronous	✓	✓
Asynchronous	✓	✓

Asynchronous Group Replication

- Also called multi-master
- Best scheme for availability
- Cannot guarantee one-copy serializability!



Asynchronous Group Replication

- Cannot guarantee one-copy serializability!
- Instead guarantee convergence
  - Db state does not reflect any serial execution
  - But all replicas have the same state
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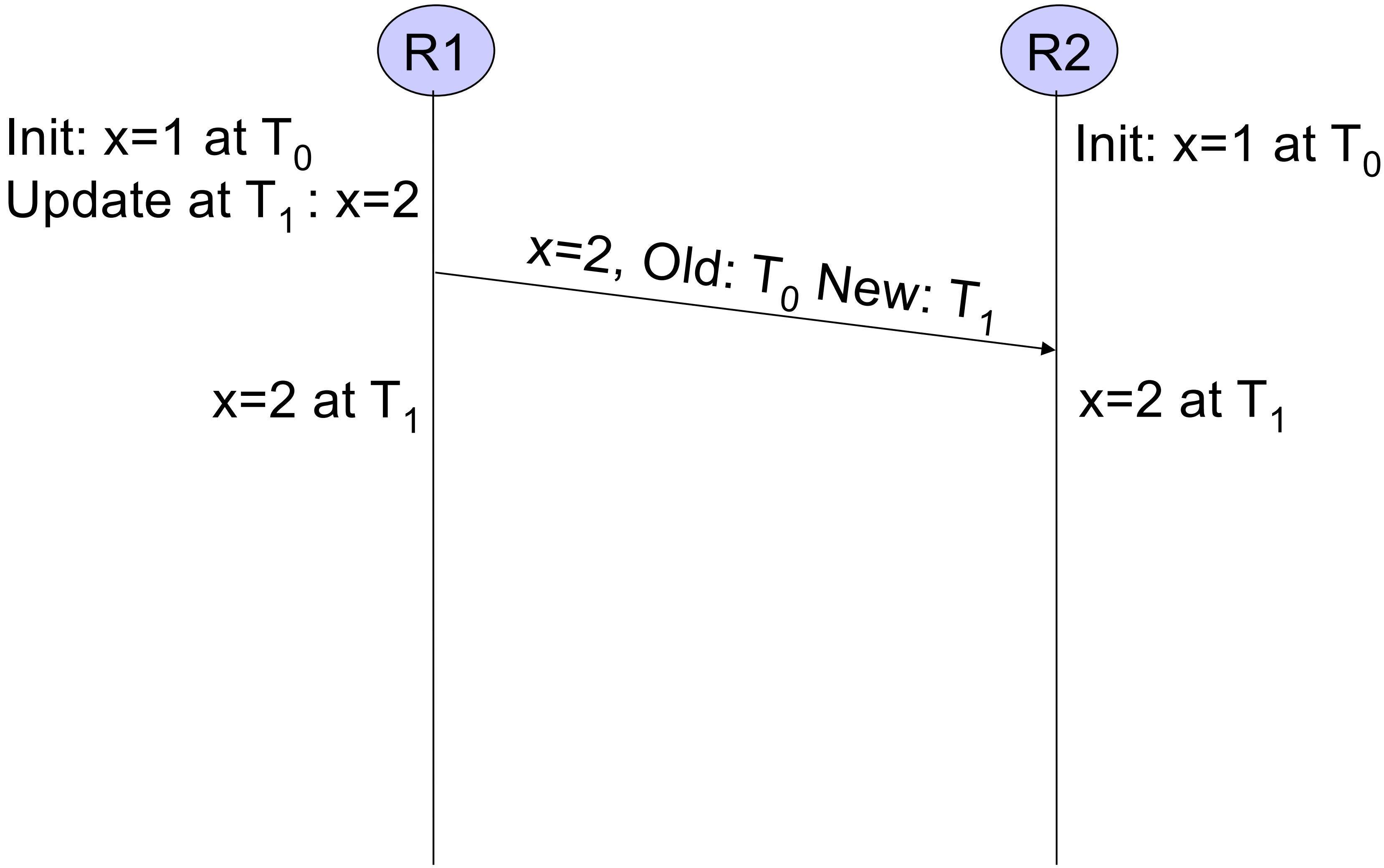
- Detect conflicts and reconcile replica states
- Reconciliation techniques:
  - Most recent timestamp wins
  - Site A wins over site B
  - But also: user-defined rules, or even manual

Detecting Conflicts Using Timestamps



Detecting Conflicts Using Timestamps