CSE 444: Database Internals

Lecture 22
Replication

References

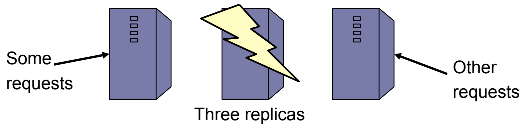
- Book Chapter 20.6
- **Database management systems.** Ramakrishnan and Gehrke. Third Ed. **Chapter 22.11** **(more info than our main book)**

Outline

- Goals of replication
- Three types of replication
  - Eager replication
  - Lazy replication
  - Two-tier replication

Goals of Replication

- Goal 1: availability
- Goal 2: performance



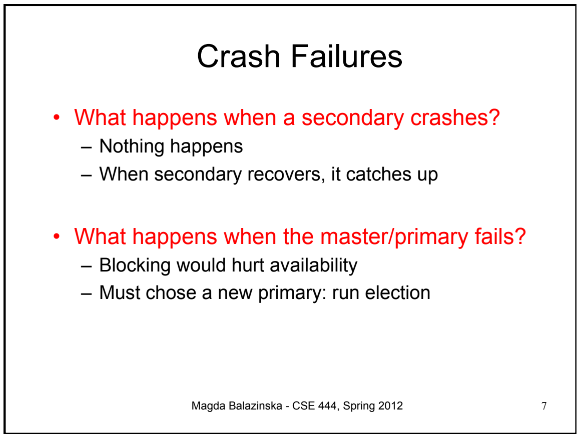
- But, it's easy to build a replicated system that reduces performance and availability

Eager Replication

- Also called synchronous replication
- All updates are applied to all replicas (or to a majority) as part of a single transaction (need two phase commit)
- 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
- Transactions must acquire global locks

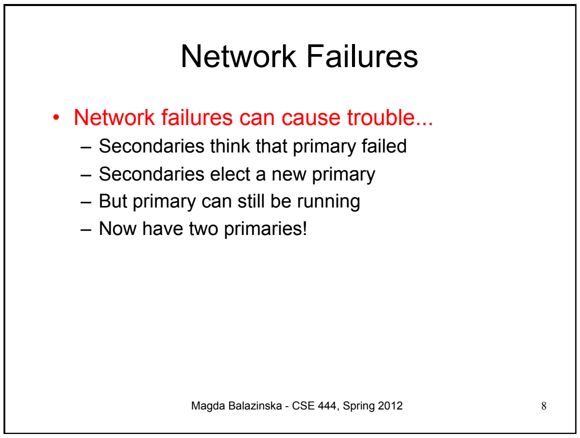
Eager Master

- One master for each object holds primary copy
  - To update object, transaction must acquire a lock at the master
  - Lock at the master is global lock



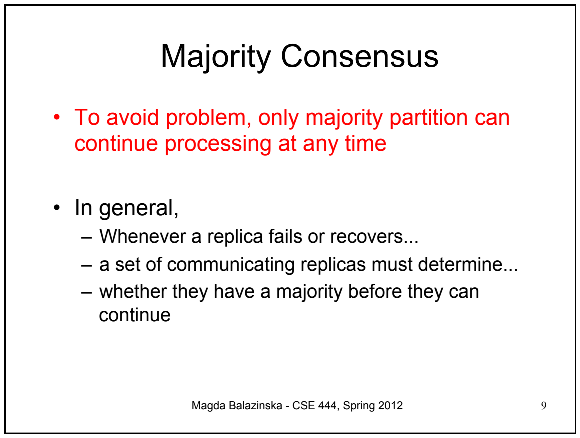
Crash Failures

- What happens when a secondary crashes?
  - Nothing happens
  - When secondary recovers, it catches up
- What happens when the master/primary fails?
  - Blocking would hurt availability
  - Must chose a new primary: run election



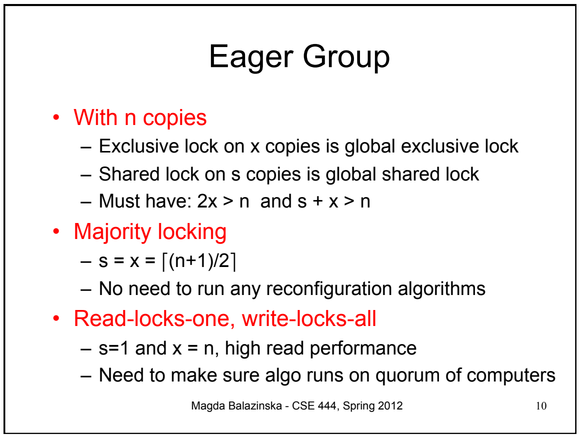
Network Failures

- 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!



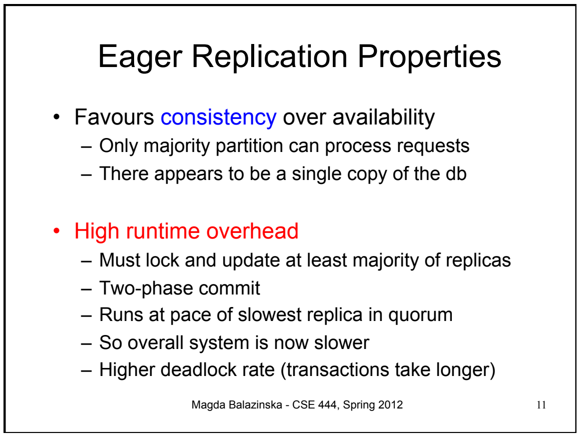
Majority Consensus

- 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



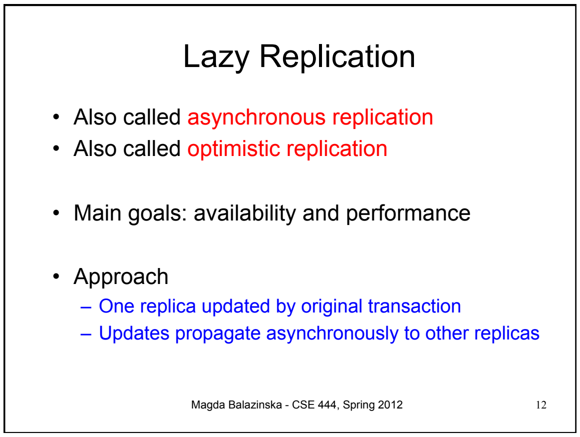
Eager Group

- 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 $s + x > n$
- Majority locking
  - $s = x = \lceil (n+1)/2 \rceil$
  - No need to run any reconfiguration algorithms
- Read-locks-one, write-locks-all
  - $s=1$ and $x = n$, high read performance
  - Need to make sure algo runs on quorum of computers



Eager 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)



Lazy Replication

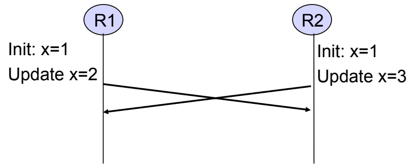
- Also called asynchronous replication
- Also called optimistic replication
- Main goals: availability and performance
- Approach
  - One replica updated by original transaction
  - Updates propagate asynchronously to other replicas

Lazy Master

- One master holds primary copy
  - Transactions update primary copy
  - Master asynchronously propagates updates to replicas, which process them in same order
  - 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

Lazy Group

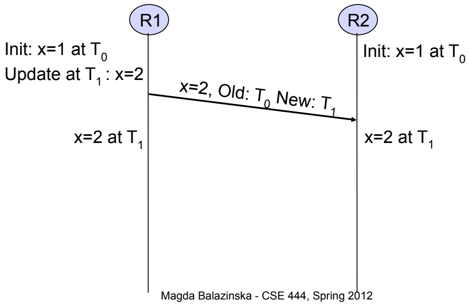
- Also called multi-master
- Best scheme for availability
- Cannot guarantee one-copy serializability!



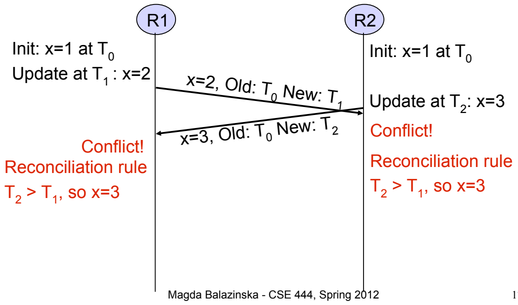
Lazy Group

- Cannot guarantee one-copy serializability!
- Instead guarantee convergence
  - Db state does not reflect any serial execution
  - But all replicas have the same state
- Detect conflicts and reconcile replica states
- Different reconciliation techniques are possible
  - Manual
  - Most recent timestamp wins
  - Site A wins over site B
  - User-defined rules, etc.

Detecting Conflicts Using Timestamps

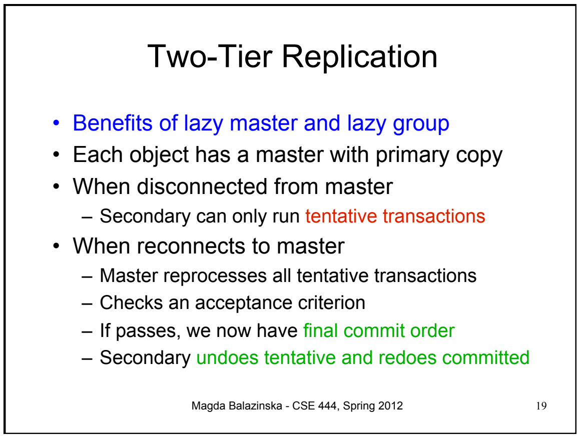


Detecting Conflicts Using Timestamps



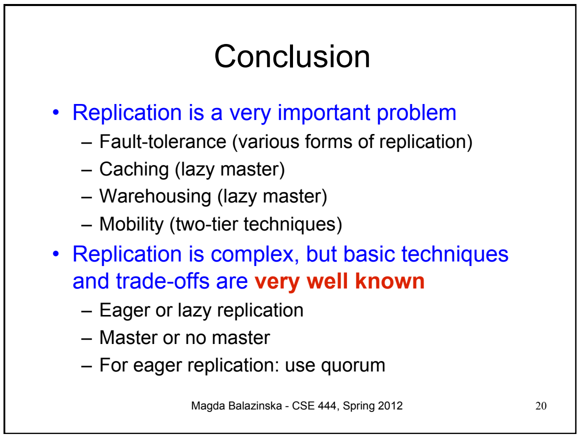
Lazy Group Replication Properties

- Favours availability over consistency
  - Can read and update any replica
  - High runtime performance
- Weak consistency
  - Conflicts and reconciliation



Two-Tier Replication

- Benefits of lazy master and lazy group
- Each object has a master with primary copy
- When disconnected from master
  - Secondary can only run tentative transactions
- When reconnects to master
  - Master reprocesses all tentative transactions
  - Checks an acceptance criterion
  - If passes, we now have final commit order
  - Secondary undoes tentative and redoes committed



Conclusion

- Replication is a very important problem
  - Fault-tolerance (various forms of replication)
  - Caching (lazy master)
  - Warehousing (lazy master)
  - Mobility (two-tier techniques)
- Replication is complex, but basic techniques and trade-offs are **very well known**
  - Eager or lazy replication
  - Master or no master
  - For eager replication: use quorum