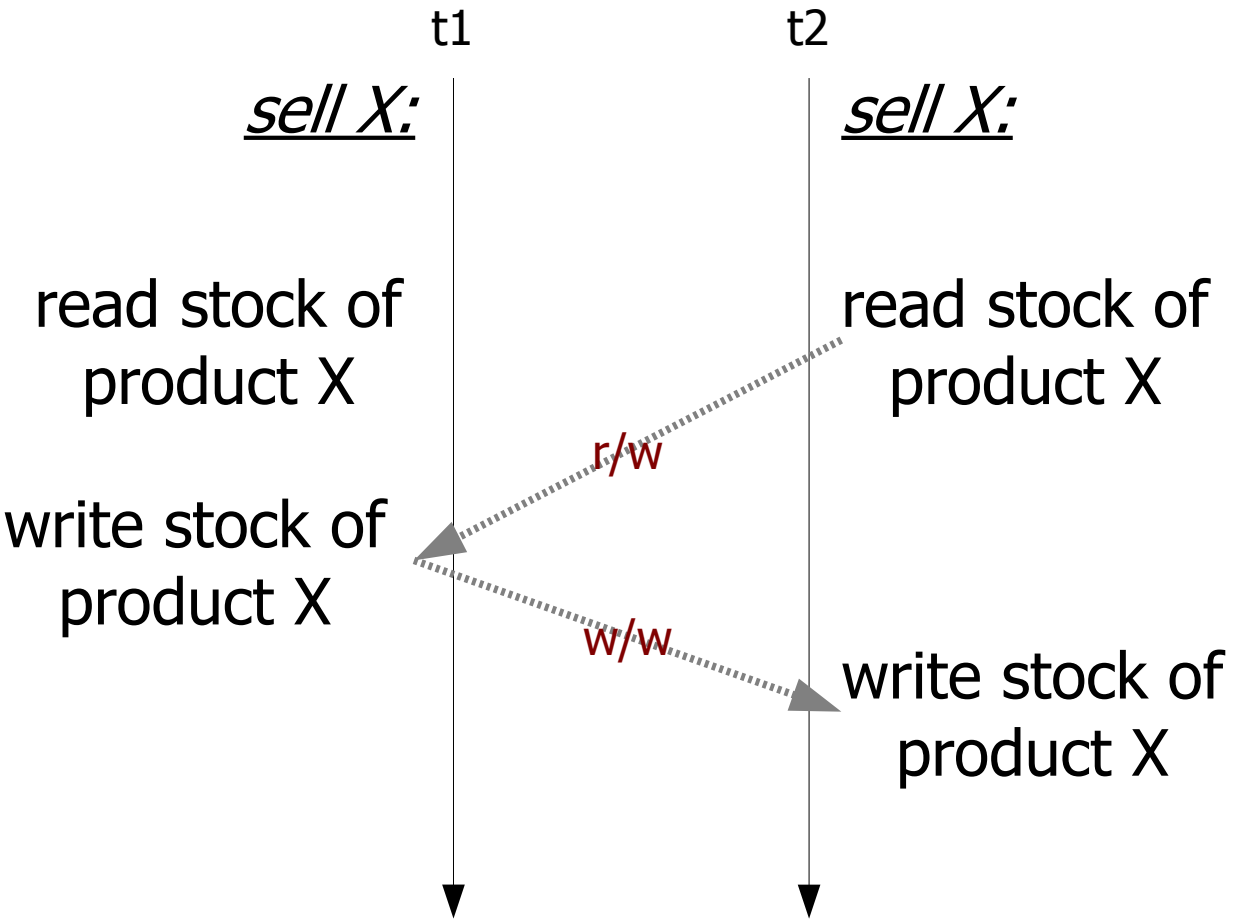
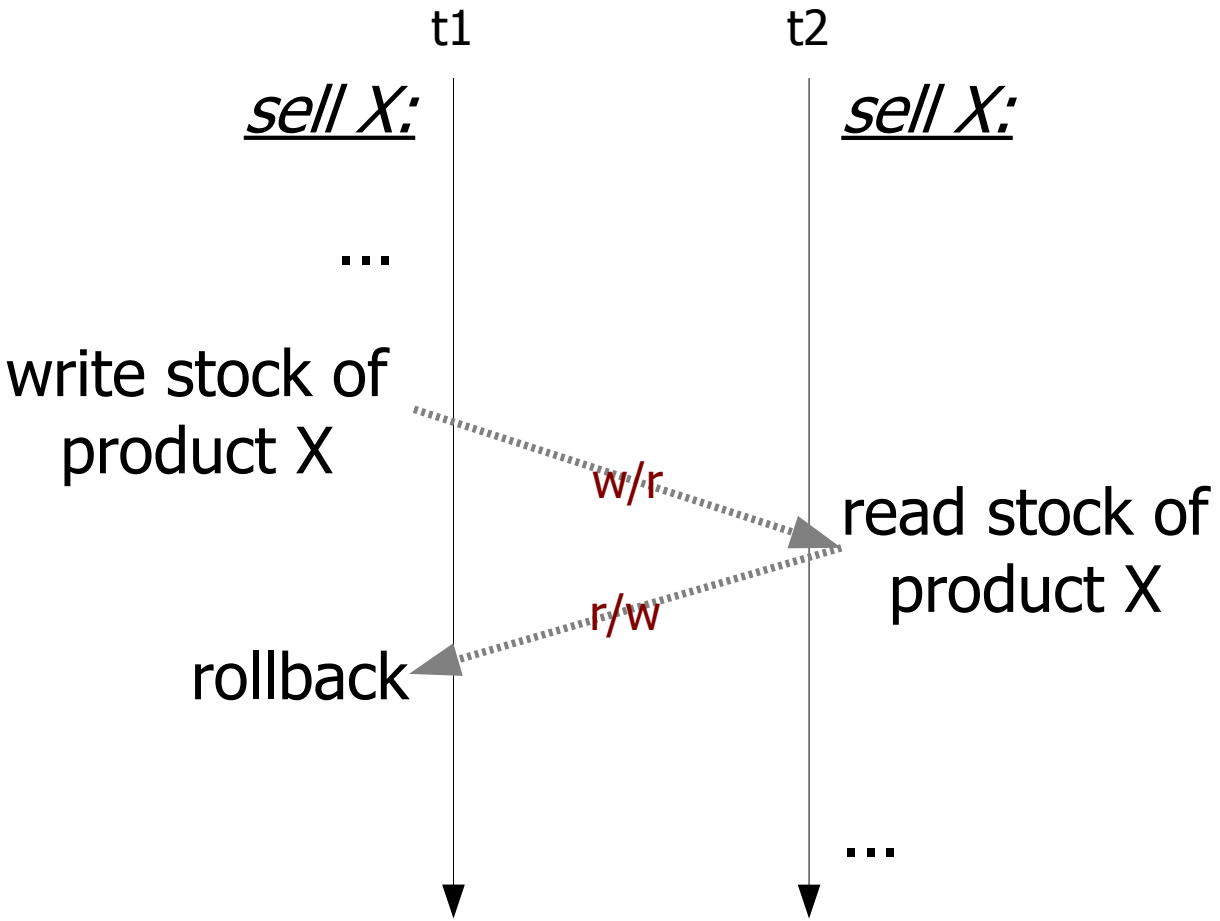
Motivation

- First, implement each operation assuming that no two operations run concurrently
- Then, assume that any operations can run concurrently
- What can go wrong?

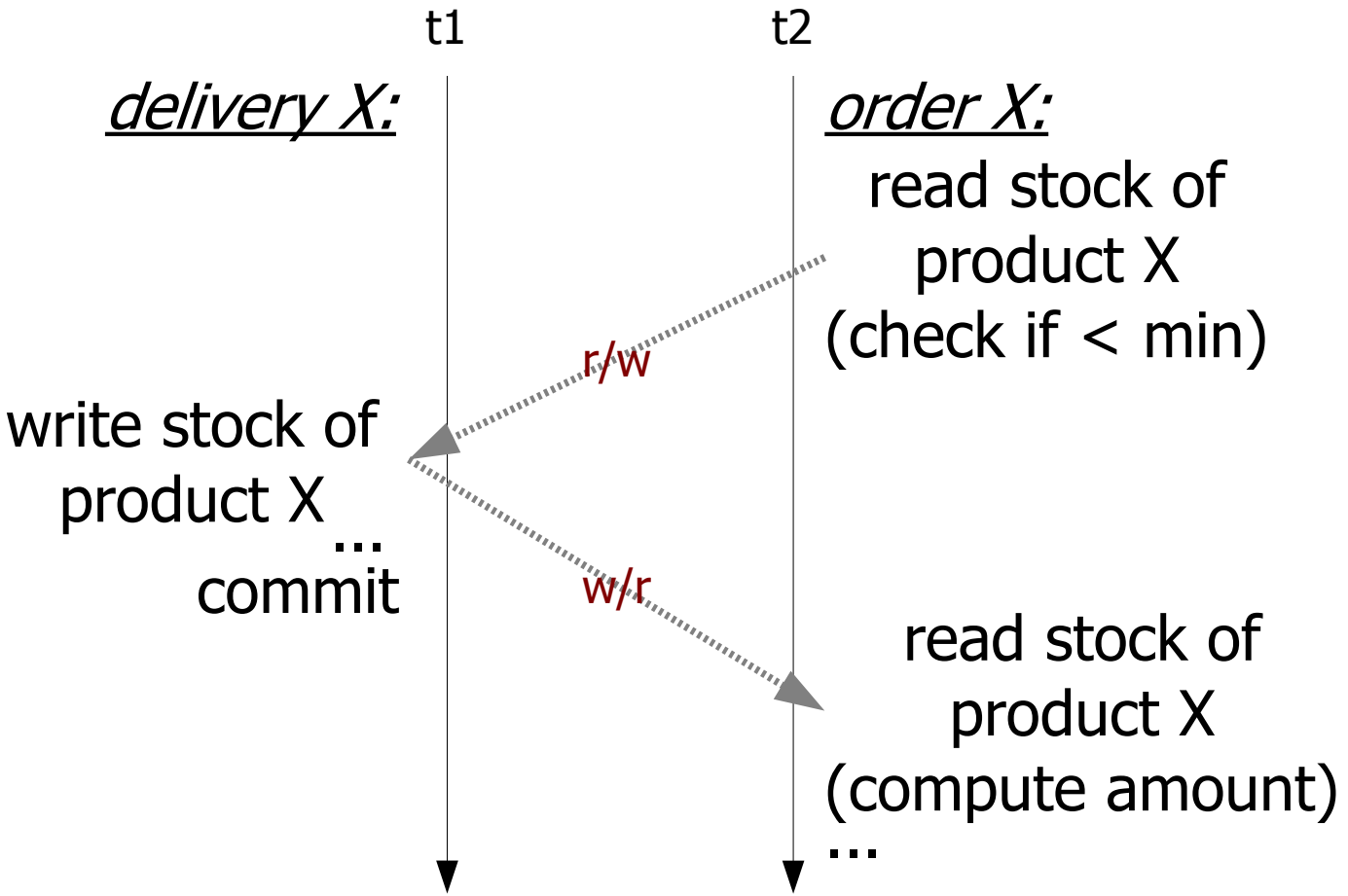
Lost update (RWW)



Dirty read (WRW)



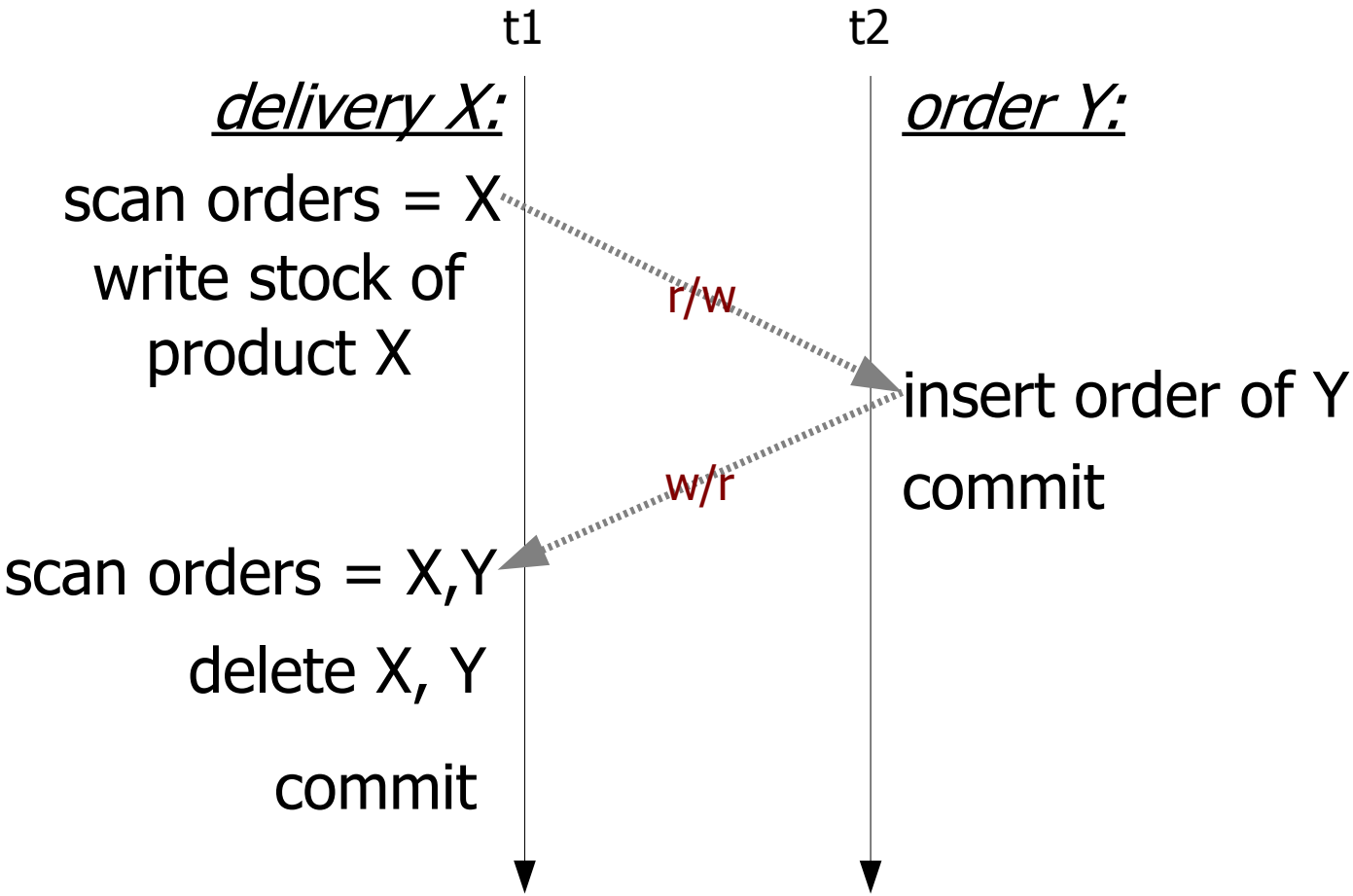
Non-repeatable read (RWR)



Other anomalies?

- Read after read is not a problem
  - Thus no RRW, WRR...
- Why no WWR?
  - Assume no “blind writes”
  - Actually a **R**WWR (lost update)

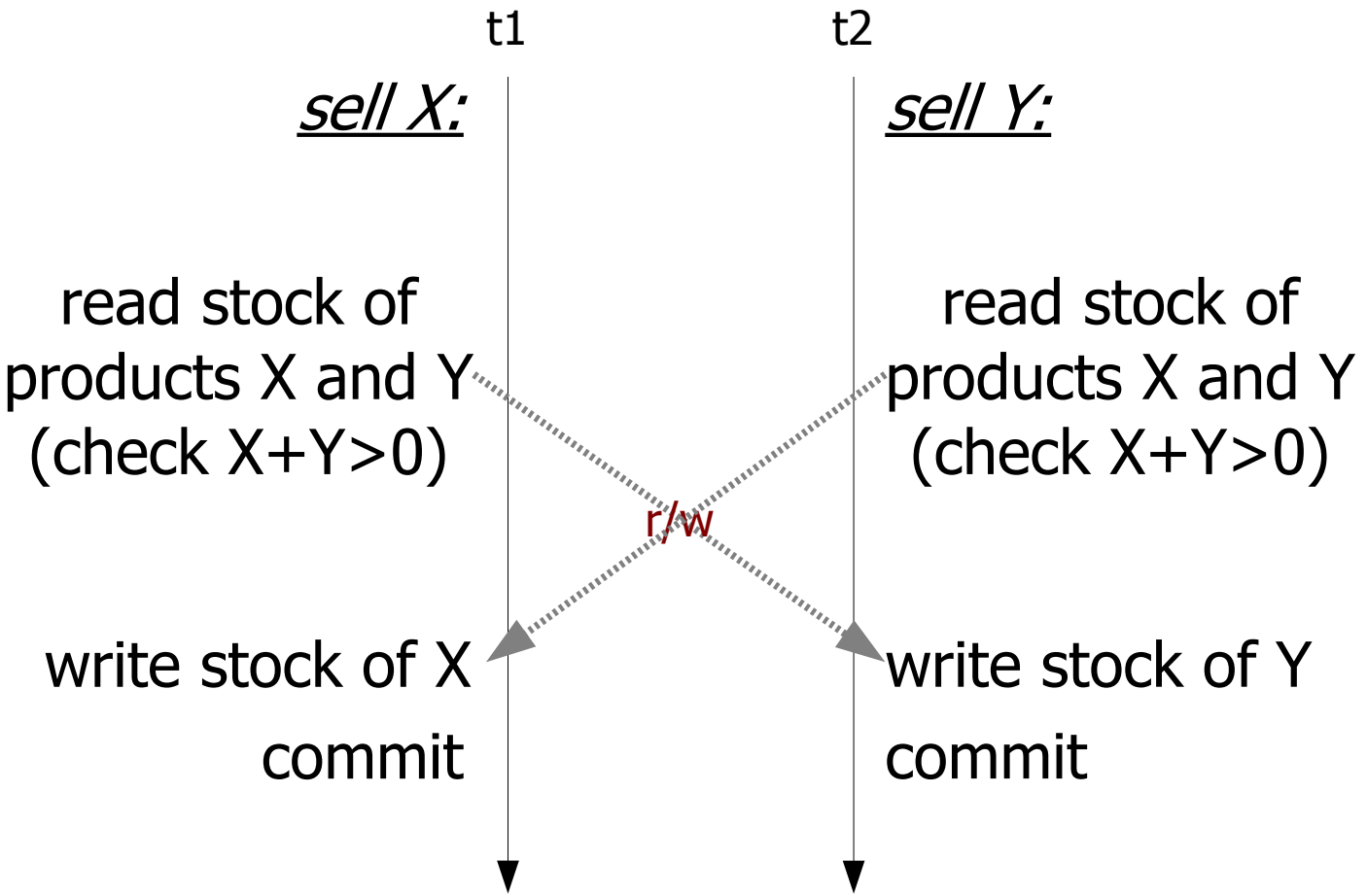
Phantoms


t1
t2
delivery X:
order Y:
scan orders = X
write stock of product X
r/w
insert order of Y
commit
w/r
scan orders = X,Y
delete X, Y
commit

Phantoms

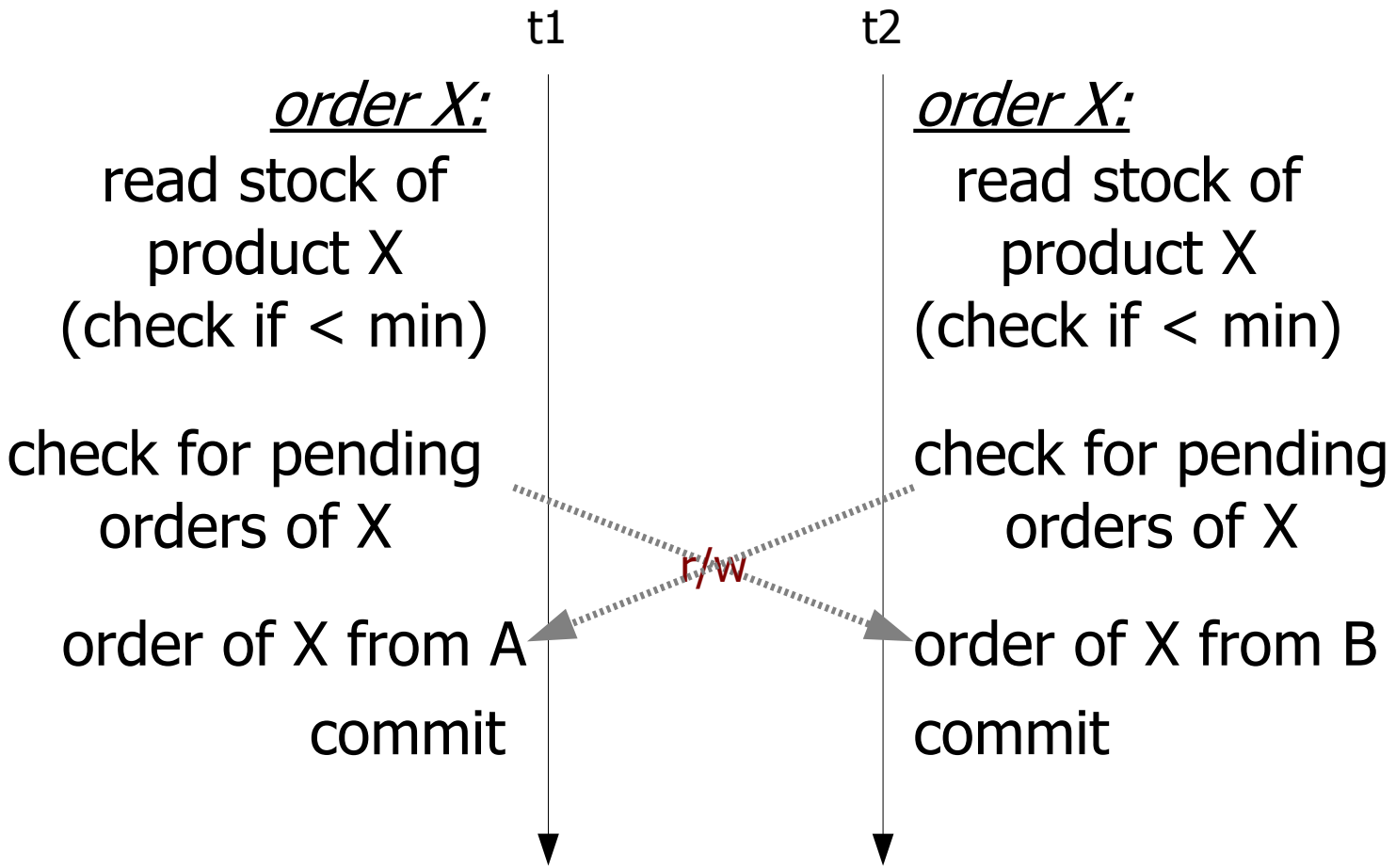
- It is actually a non-repeatable read (RWR) on the collection
- Why no dirty read (WRW) for collections?
  - Solved by having no dirty reads on the item
- Why no RWW (lost update) for collections?
  - Means allocating the same physical space for two records!
  - Very dangerous: corruption, etc...

Write skew (aka “short fork”)



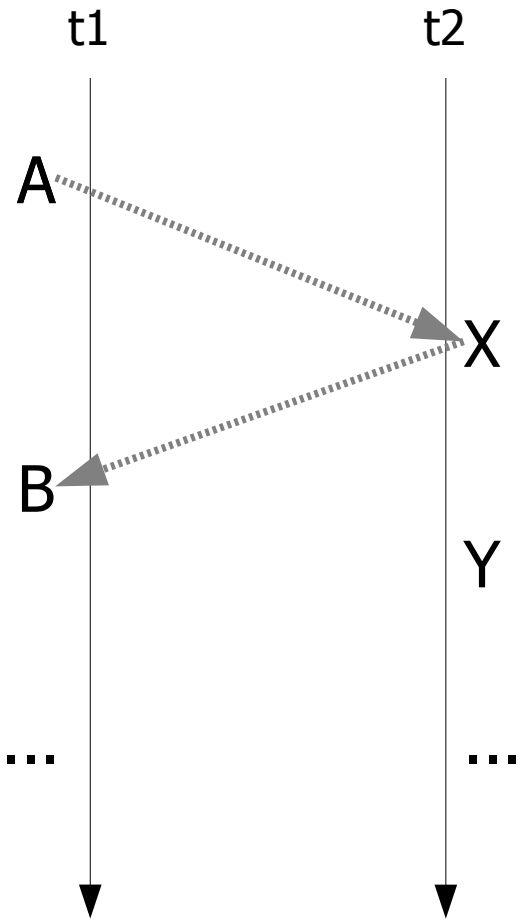
(assume X is backup for Y and vice-versa)

Write skew on collections



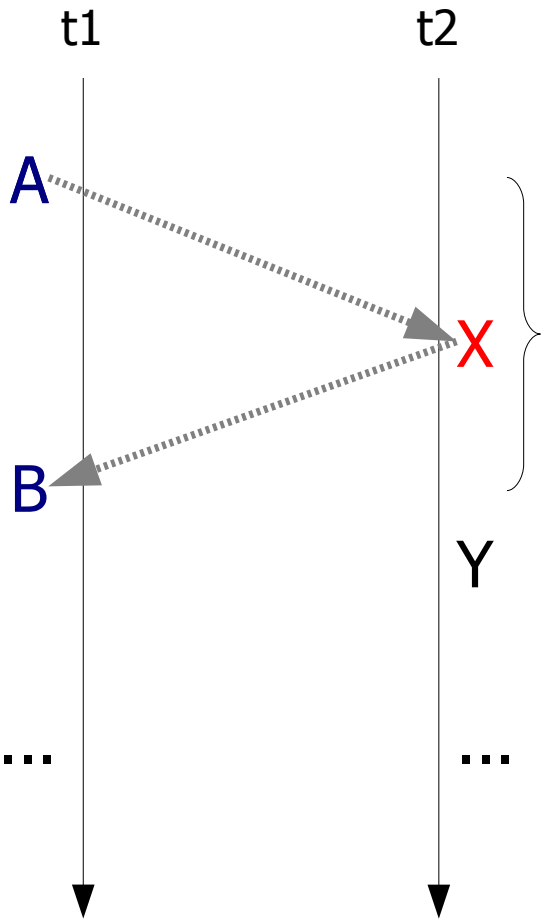
General problem

- No serial execution is conceivable:
  - Some t1 must be ordered after t2
  - But t2 must be ordered after t1
- The user cannot be fooled into thinking that transactions execute serially (i.e. serialized)



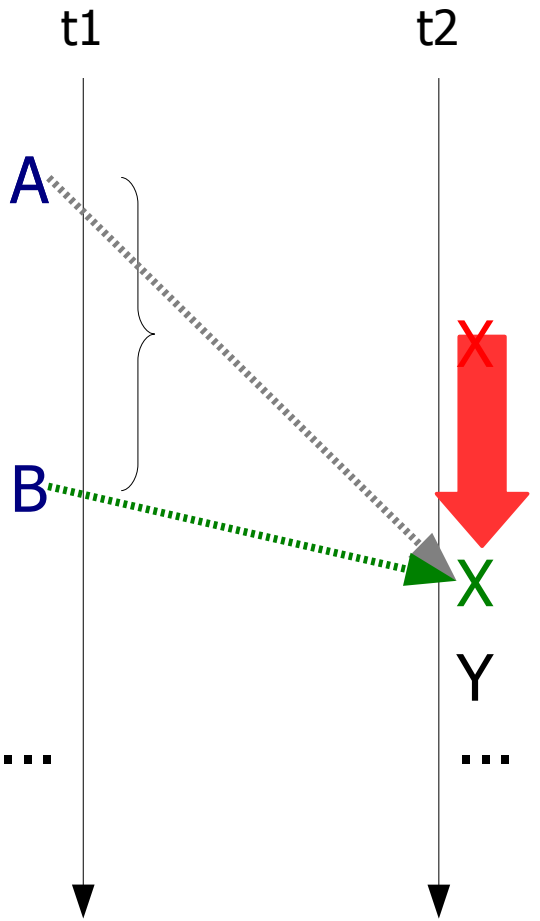
General problem

- In detail, some operation X should not be happening between A and B...



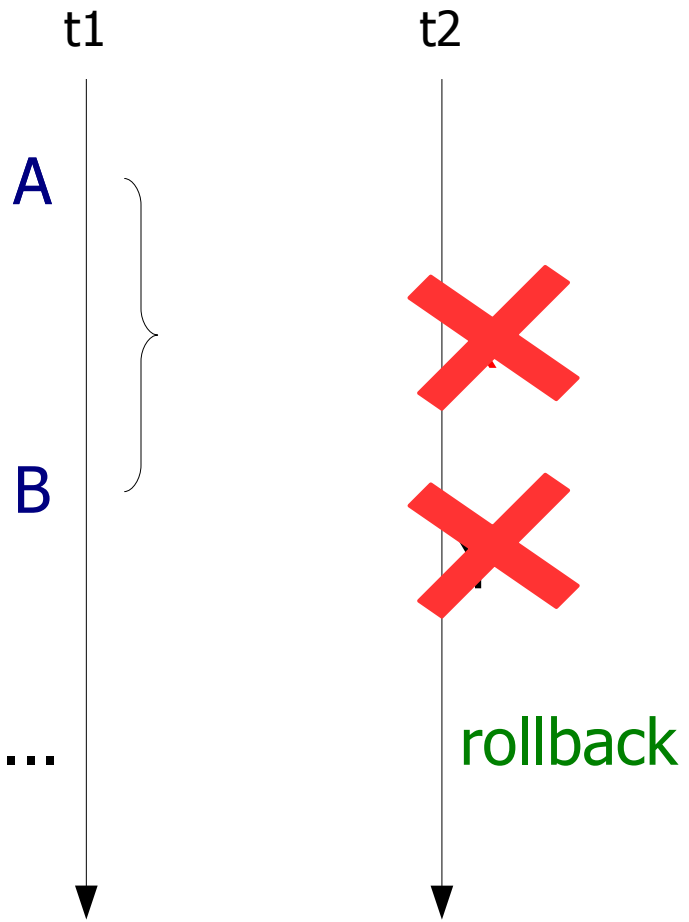
General approach

- Delay X (and all its consequences) until B
  - t1 precedes t2



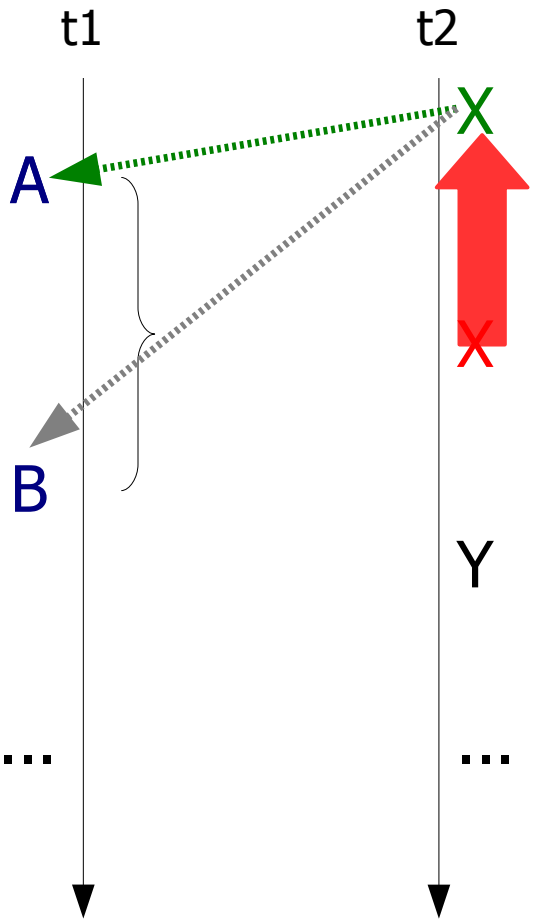
General approach

- Remove X and related operations
  - t1 executes alone



General approach

- Anticipate X (i.e. execute X before the application has requested it!)
  - t2 precedes t1
- (Can you propose a mechanism to do this!?)



Roadmap

- How to implement each solution?
- What solution for each problem?

2-Phase Locking

- Acquire a lock for an item before reading or writing it
- All lock requests precede all unlock requests
  - This means unlocking only on transaction commit
- Equivalent to acquiring all locks upfront

Deadlocks

- Cannot easily be avoided:
  - Interactive transactions
  - Plan selected by the optimizer
- Can be detected:
  - Wait-for graph
  - Time-out
- Resolved by aborting one transaction

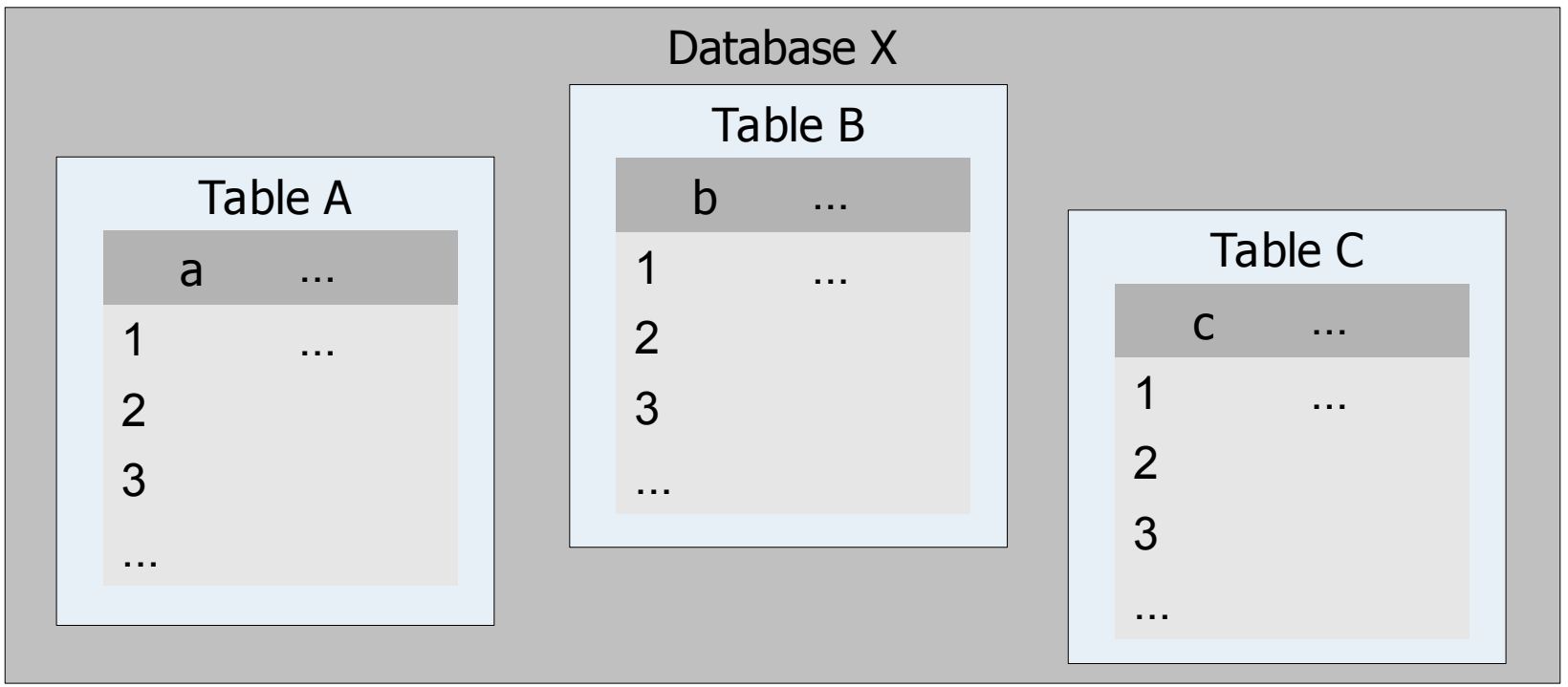
Shared vs exclusive

Compatible?	Shared	Exclusive
Shared	**Yes**	No
Exclusive	No	No

- As read/read does not cause anomalies:
  - Exclusive locks for writing
  - Shared locks for reading
- More concurrency is possible

Multi-level locking

- Row locks vs table locks



Locking Protocols

- Multiple dimensions:
  - 2-phase locking
  - Shared vs exclusive
  - Granularity
- What combinations?
- How to select them?

Read uncommitted (aka “browse”)

- Protocol:
  - Exclusive locks on INSERT/UPDATE/DELETE until transaction complete
  - No shared locks
- Allows:
  - ~~Lost update~~ (in a single UPDATE statement)
  - Dirty read
  - Non-repeatable read
  - Phantoms
  - Write skew

Read committed (aka “cursor stability”)

- Protocol:
  - Exclusive locks on INSERT/UPDATE/DELETE until transaction complete
  - Shared locks on each SELECT statement
- Allows:
  - ~~Lost update~~
  - ~~Dirty read~~
  - Non-repeatable read
  - Phantoms
  - Write skew

Repeatable read

- Protocol:
  - Exclusive locks on INSERT/UPDATE/DELETE until transaction complete
  - Shared locks on SELECT until transaction complete
- Allows:
  - ~~Lost update~~
  - ~~Dirty read~~
  - ~~Non-repeatable read~~
  - Phantoms
  - Write skew (on collections)

Serializable

- Protocol:
  - Exclusive locks on INSERT/UPDATE/DELETE until transaction complete
  - Shared range/table locks on SELECT until trans. complete
- Allows:
  - ~~Lost update~~
  - ~~Dirty read~~
  - ~~Non-repeatable read~~
  - ~~Phantoms~~
  - ~~Write skew~~

Serializable

- A lot of trouble to avoid phantoms:
  - Table locking has has a large impact in concurrency
  - Predicate locking or range locking using indexes adds complexity/overhead

Multi-version

- Never overwrite, always create a new version
- Example transaction 1:
  - insert (aa,11)
  - insert (bb,22)

k	v	from	to
aa	11	1	
bb	22	1	

Multi-version

- Transaction 2:
  - insert (cc,33)
  - update (bb,44)

k	v	from	to
aa	11	1	
bb	22	1	2
cc	33	2	
bb	44	2	

Multi-version

- Transaction 3:
  - delete (aa)

k	v	from	to
aa	11	1	3
bb	22	1	2
cc	33	2	
bb	44	2	

Snapshot isolation

- Protocol:
  - Read from version that existed when the transaction started (or local writes)
  - On I/U/D, lock exclusive and first committer wins, others rollback
- Allows:
  - ~~Lost update~~
  - ~~Dirty read~~
  - ~~Non-repeatable read~~
  - ~~Phantoms~~
  - Write skew

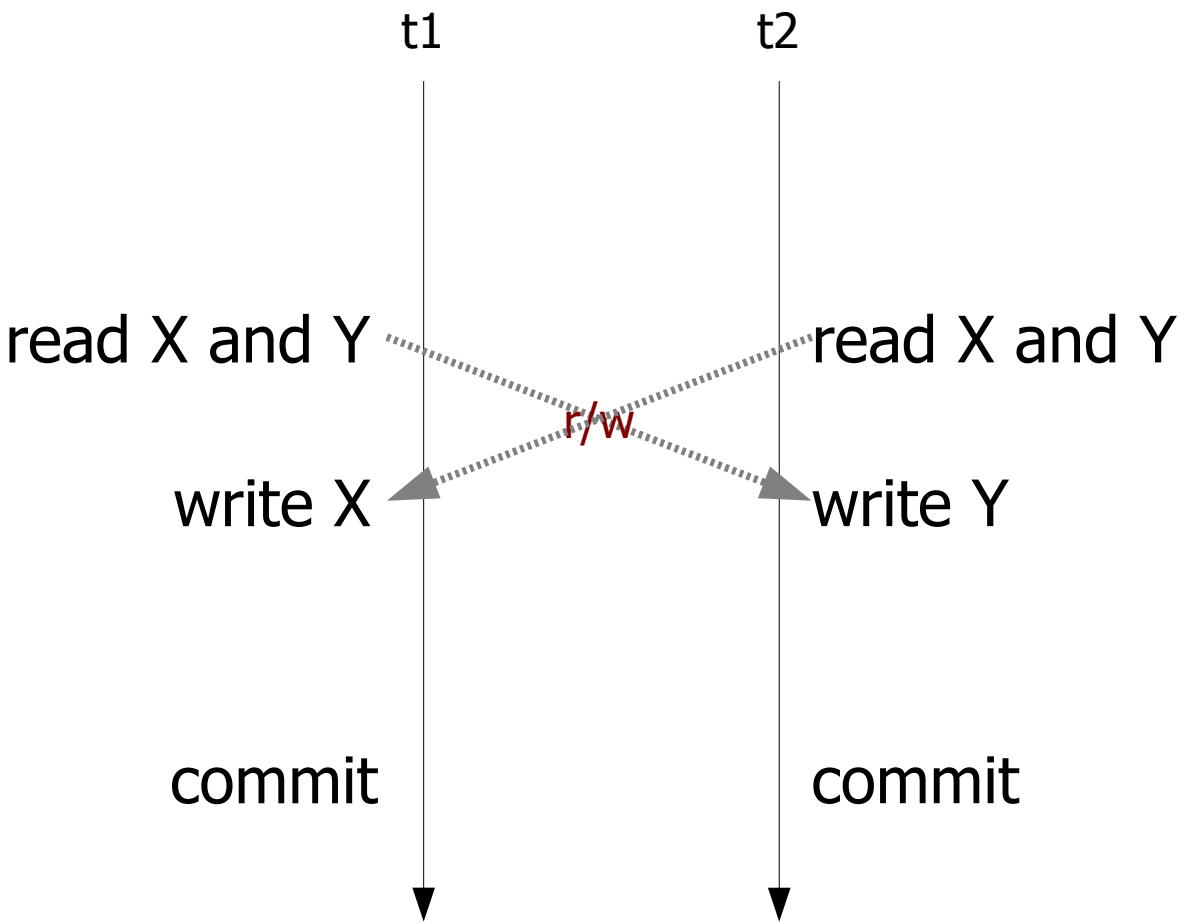
Snapshot isolation

- To avoid that two transactions execute concurrently:
  - Use explicit locking (SELECT FOR UPDATE)
  - Make them write on the same data item
- If two transactions update the same item, they cannot execute concurrently:
  - Prefer inserts to updates
  - Be careful with:
    - Counters
    - Materialized views of aggregates

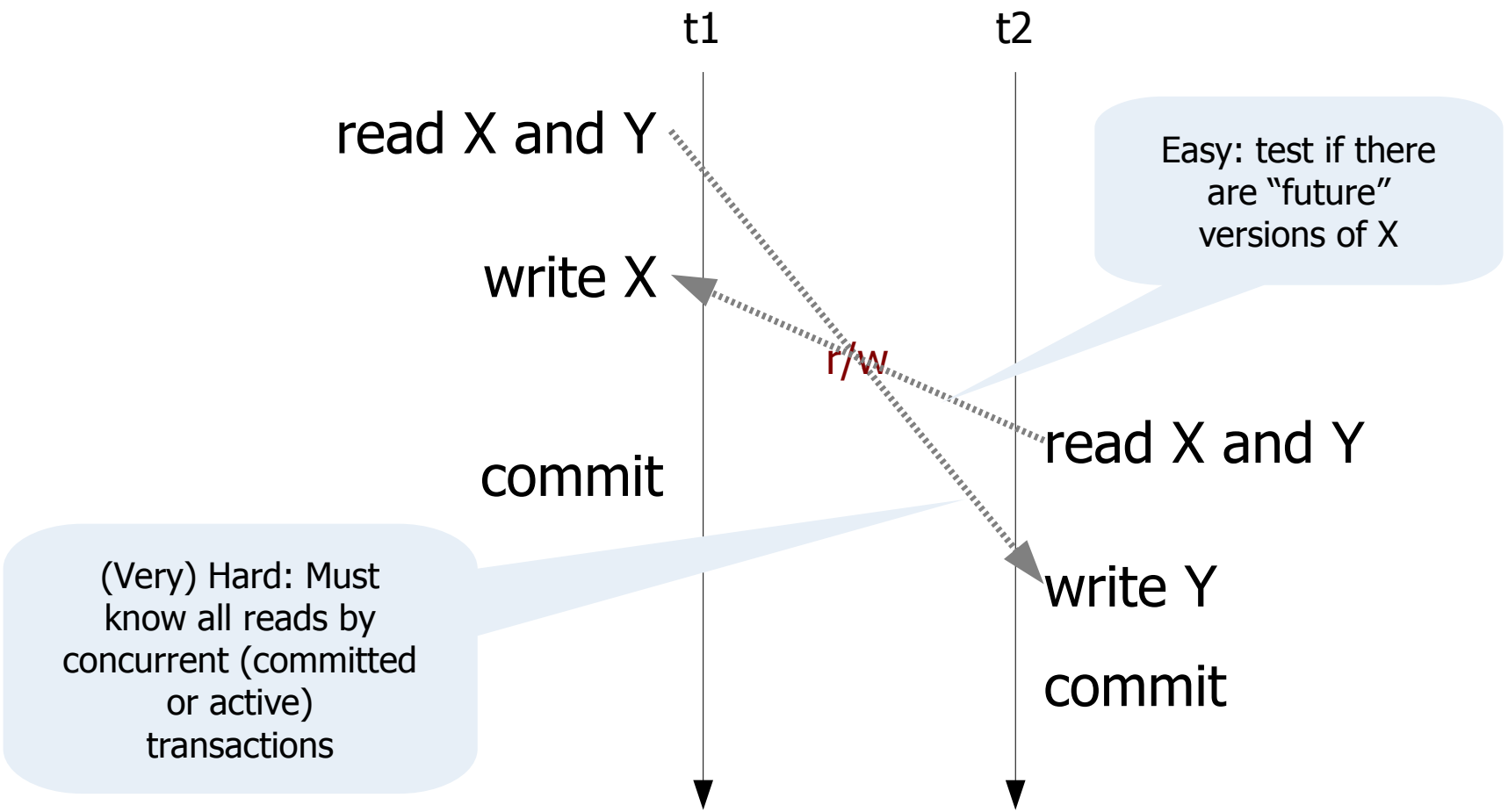
Serializable snapshot isolation

- Protocol:
  - Everything in SI plus...
  - Detect RW dependencies and abort transactions when two consecutive found (might not be a cycle: false positive!)
- Allows:
  - ~~Lost update~~
  - ~~Dirty read~~
  - ~~Non-repeatable read~~
  - ~~Phantoms~~
  - ~~Write skew~~

Serializable snapshot isolation



Serializable snapshot isolation



Conclusions

- Rollback is not a convenience!
- Snapshot isolation combines all approaches
- Snapshot isolation is now preferred:
  - Never blocks reads
  - Easily becomes serializable
- Must avoid update hot-spots