MC302 – DBMS: Concurrency Control 2

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Timestamp Allocation

- Each transaction T_i is assigned a unique fixed timestamp that is monotonically increasing.
  - Let **TS(**Ti**)** be the timestamp allocated to transaction Ti
  - Different schemes assign timestamps at different times during the transaction.
- Multiple implementation strategies:
  - System Clock.
  - Logical Counter.
  - Hybrid.

Timestamp Ordering Concurrency Control

- Use these timestamps to determine the serializability order.
- If **TS(**Ti**)** < **TS(**Tj**)**, then the DBMS must ensure that the execution schedule is equivalent to a serial schedule where Ti appears before Tj.

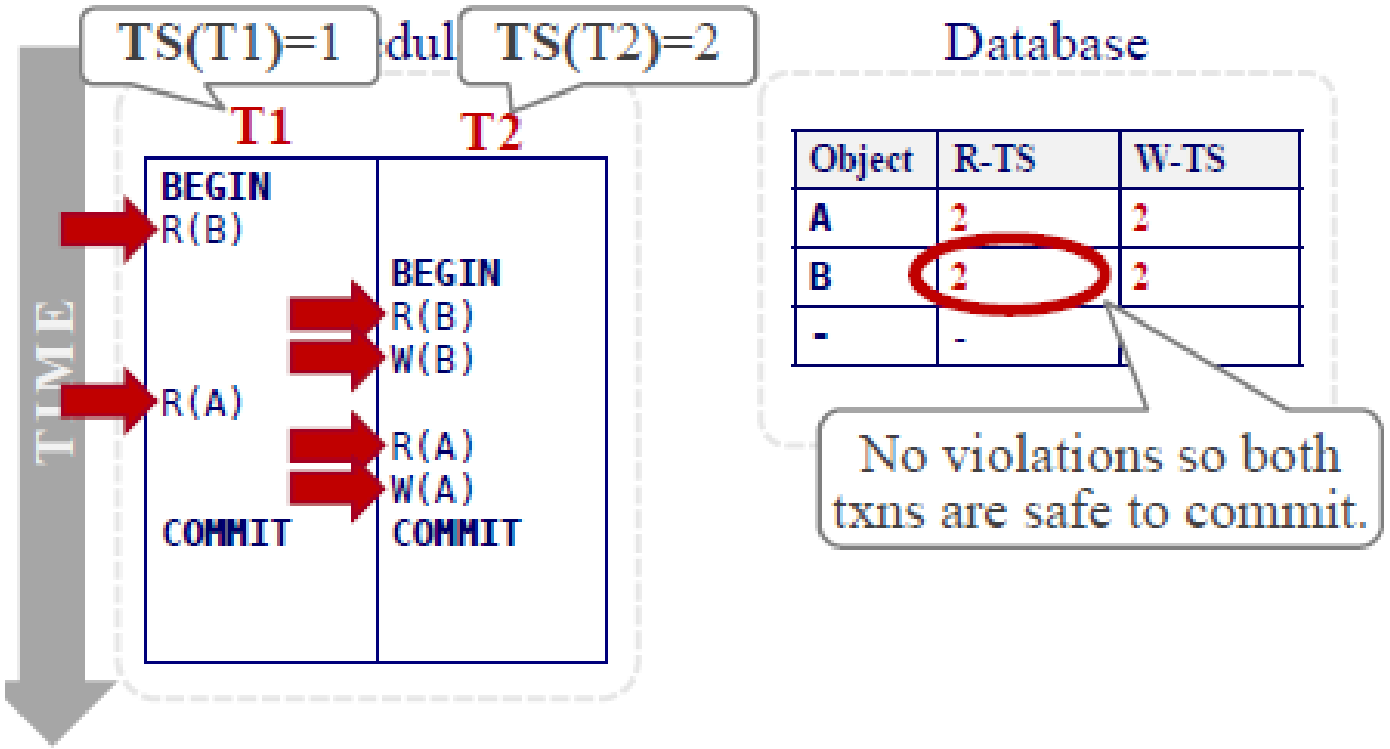
Basic T/O

- Transactions read and write objects without locks.
- Every object X is tagged with timestamp of the last transaction that successfully did read/write:
  - **W-TS(**X**)** – Write timestamp on X
  - **R-TS(**X**)** – Read timestamp on X
- Check timestamps for every operation:
  - If transaction tries to access an object “from the future”, it aborts and restarts.

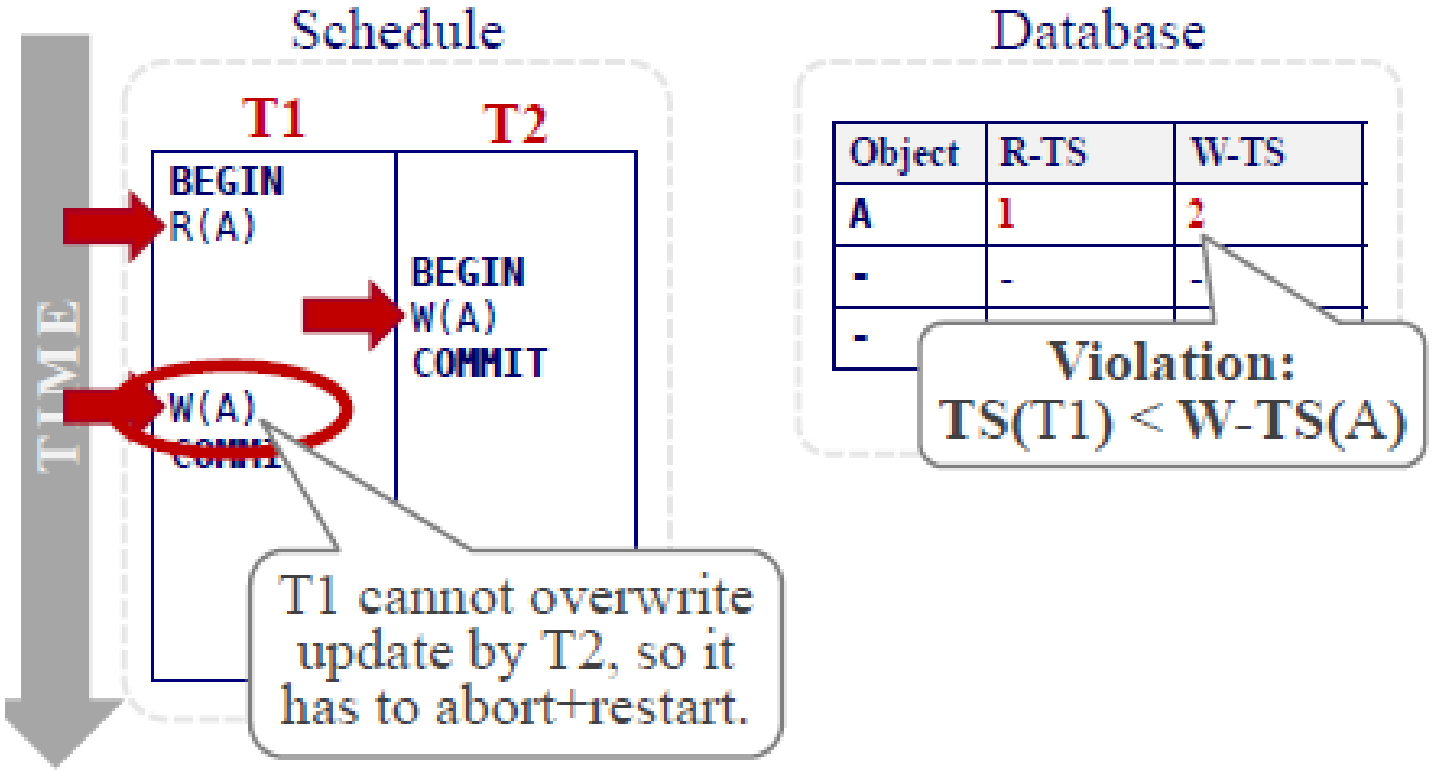
Basic T/O – Reads and Writes

- Reads
- If **TS(**Ti**)** < **W-TS(**X**)**, this violates timestamp order of Ti w.r.t. writer of X.
  - Abort Ti and restart it (with same TS? why?)
- Else:
  - Allow Ti to read X.
  - Update **R-TS(**X**)** to **max(R-TS(**X**)**, **TS(**Ti**))**
  - Have to make a local copy of X to ensure repeatable reads for Ti.
- Writes
- If **TS(**Ti**)** < **R-TS(**X**)** or **TS(**Ti**)** < **W-TS(**X**)**
  - Abort and restart Ti.
- Else:
  - Allow Ti to write X and update **W-TS(**X**)**
  - Also have to make a local copy of X to ensure repeatable reads for Ti.

Basic T/O Example



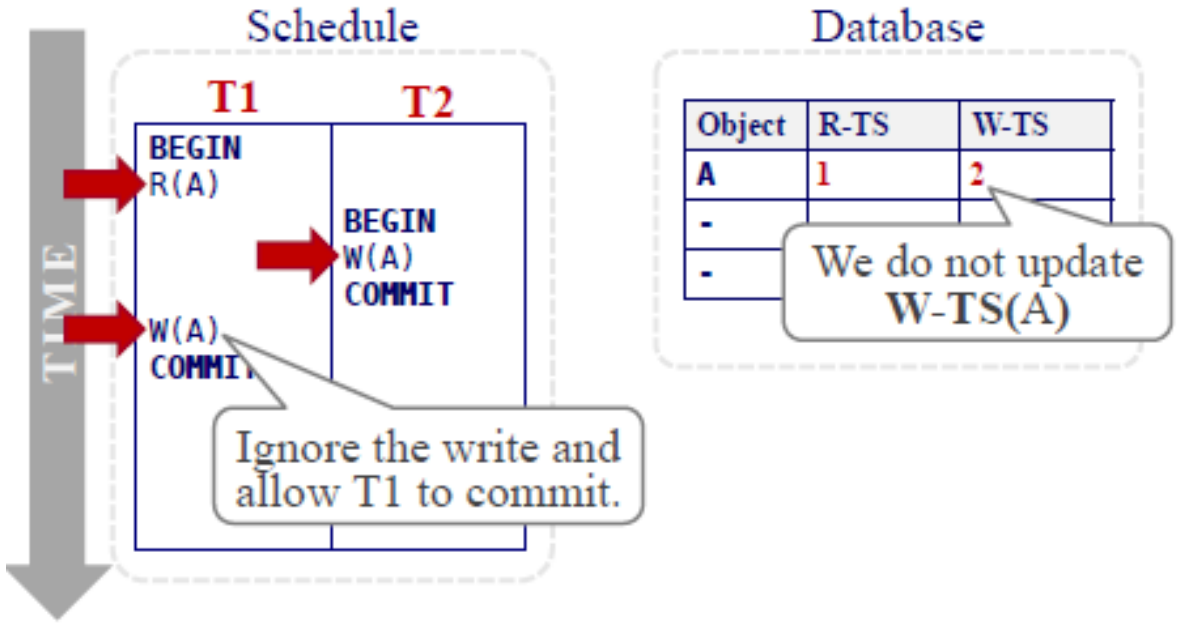
Basic T/O Example 2



Basic T/O: Thomas Write Rule

- If **TS(**Ti**)** < **R-TS(**X**)**:
  - Abort and restart Ti.
- If **TS(**Ti**)** < **W-TS(**X**)**:
  - **Thomas Write Rule:** Ignore the write and allow the txn to continue.
  - This violates timestamp order of Ti
- Else:
  - Allow Ti to write X and update **W-TS(**X**)**

Basic T/O: Thomas Write Rule

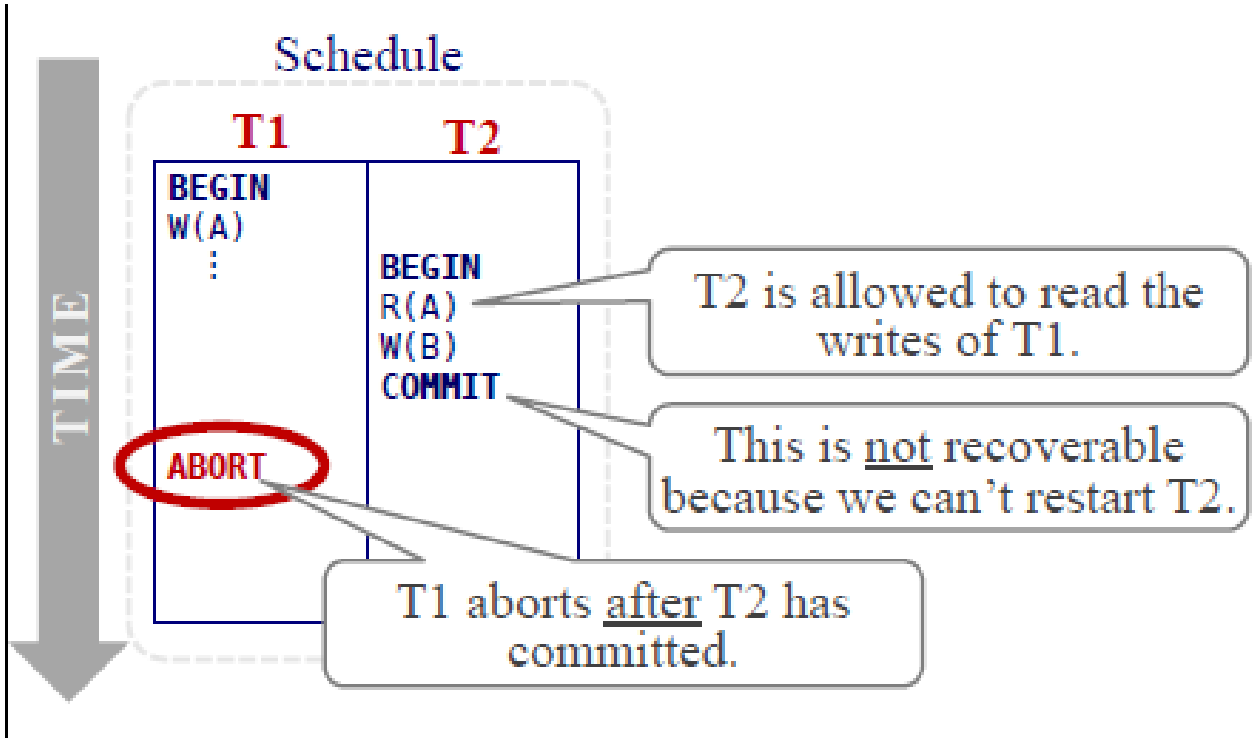


Basic T/O

- Ensures conflict serializability if you don’t use the Thomas Write Rule.
- No deadlocks because no transaction ever waits.
- Possibility of starvation for long transactions if short transactions keep causing conflicts.
- Permits schedules that are not ***recoverable***.

Recoverable Schedules

- Transactions commit only after all transactions whose changes they read, commit.



Basic T/O: Performance Issues

- High overhead from copying data to transaction's workspace and from updating timestamps.
- Long running transactions can get starved.
- Suffers from timestamp bottleneck.

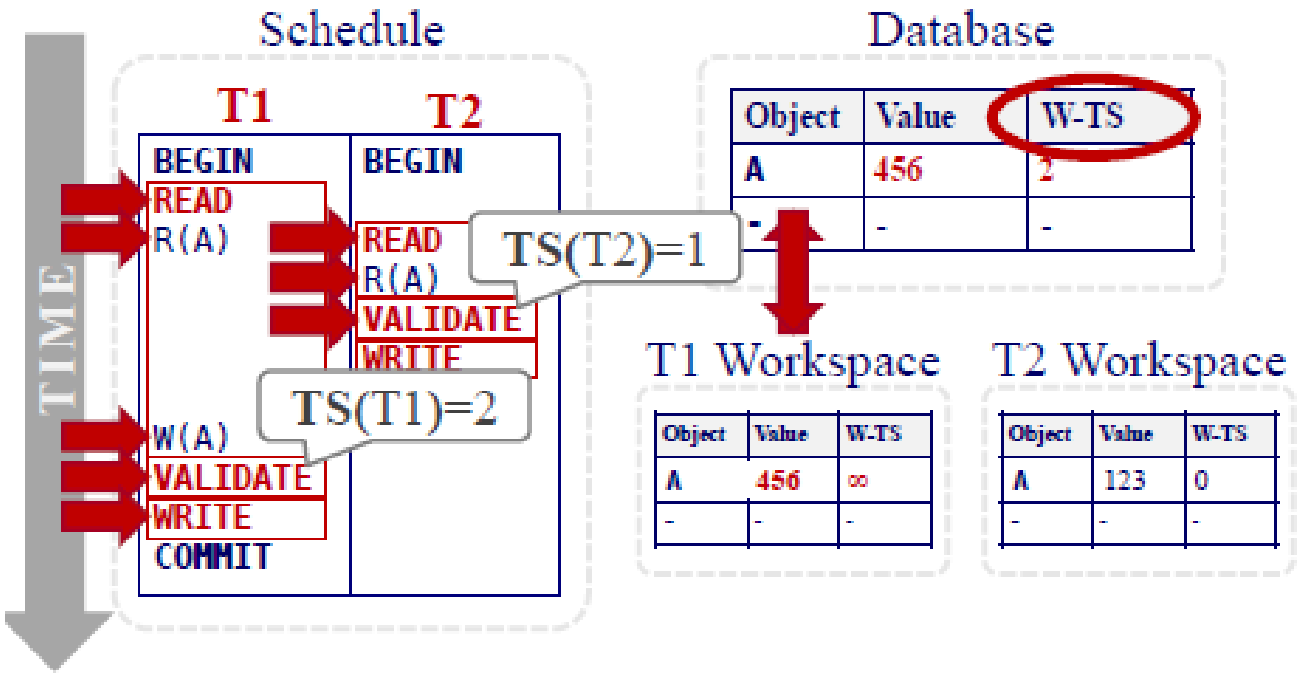
Optimistic Concurrency Control

- Assumption: Conflicts are rare
- Forcing transactions to wait to acquire locks adds a lot of overhead.
- Optimize for the no-conflict case.

OCC Phases:

- **Read:** Track the read/write sets of transactions and store their writes in a private workspace.
- **Validation:** When a transaction commits, check whether it conflicts with other transactions.
- **Write:** If validation succeeds, apply private changes to database. Otherwise abort and restart the transaction.

OCC Example


Schedule
Database
T1
T2
BEGIN
BEGIN
READ
R(A)
READ
R(A)
VALIDATE
WRITE
TS(T2)=1
TS(T1)=2
W(A)
VALIDATE
WRITE
COMMIT
TIME
Object
Value
W-TS
A
456
2
-
-
-
T1 Workspace
Object
Value
W-TS
A
456
∞
-
-
-
T2 Workspace
Object
Value
W-TS
A
123
0
-
-
-

OCC: Validation Phase

- Need to guarantee only serializable schedules are permitted.
- At validation, Ti checks other txns for RW and WW conflicts and makes sure that all conflicts go one way (from older txns to younger txns).

OCC: Serial Validation

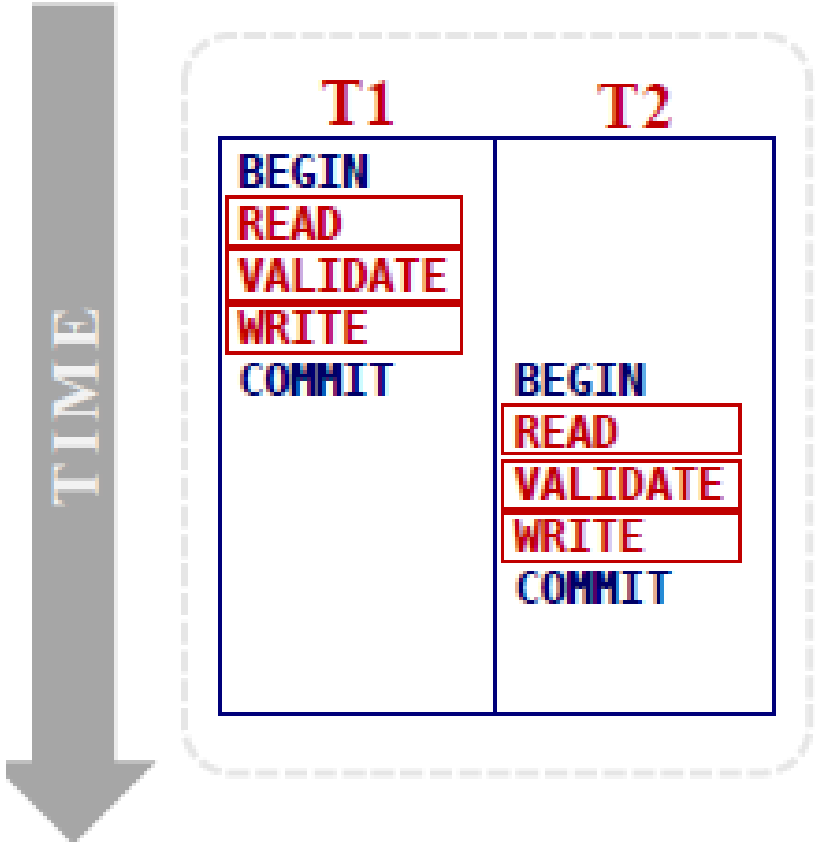
- Maintain global view of all active transactions.
- Record read set and write set while transactions are running and write into private workspace.
- Execute **Validation** and **Write** phase inside a protected critical section.

OCC: Validation Phase

- Each transaction's timestamp is assigned at the beginning of the validation phase.
- Check the timestamp ordering of the committing transaction with all other running transactions.
- If **TS(**Ti**)** < **TS(**Tj**)**, then one of the following three conditions must hold…

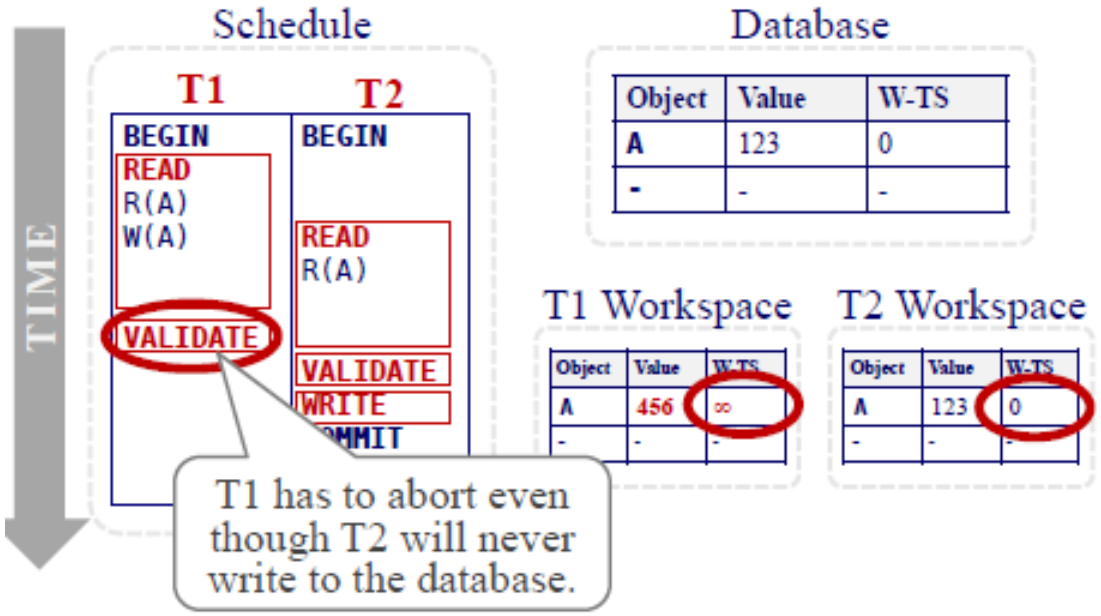
OCC Validation #1

- Ti completes all three phases before Tj begins.

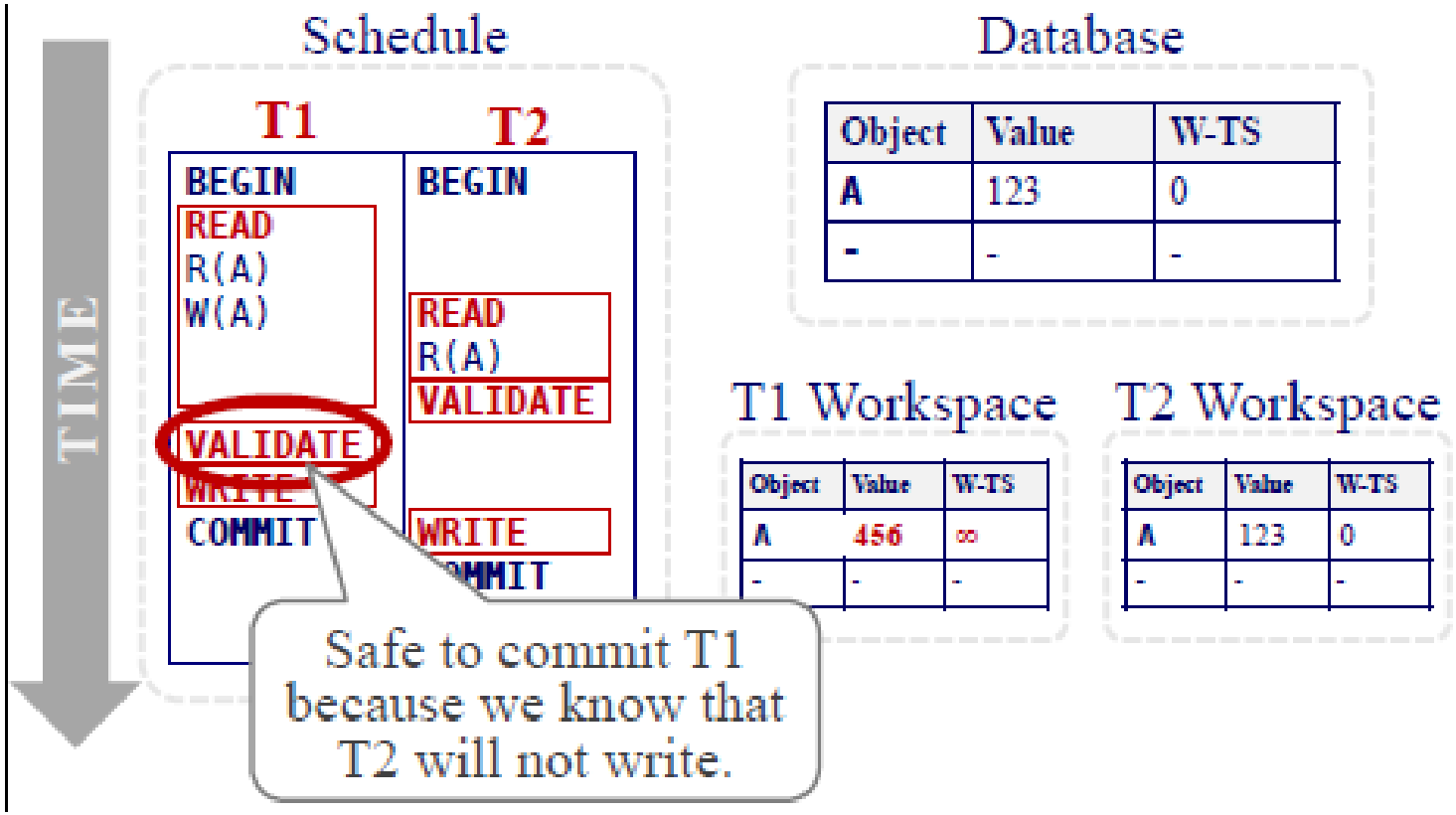


OCC – Validation#2

- Ti completes before Tj starts its **Write** phase, and Ti does not write to any object read by Tj.
  - WriteSet(Ti) ∩ ReadSet(Tj) = Ø

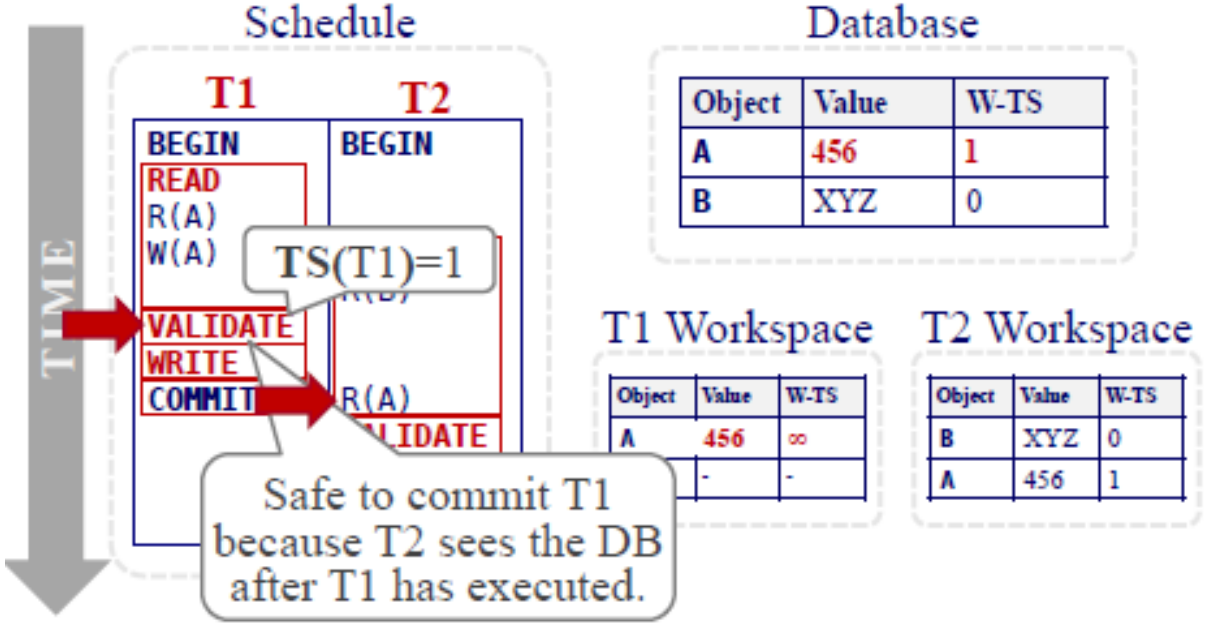


OCC-Validation #2



OCC-Validation#3

- Ti completes its **Read** phase before Tj completes its **Read** phase
- And Ti does not write to any object that is either read or written by Tj:
  - WriteSet(Ti) ∩ ReadSet(Tj) = Ø
  - WriteSet(Ti) ∩ WriteSet(Tj) = Ø



OCC-Observations

- **Q:** When does OCC work well?
- **A:** When # of conflicts is low:
  - All transactions are read-only (ideal).
  - Transactions access disjoint subsets of data.
- If the database is large and the workload is not skewed, then there is a low probability of conflict, so again locking is wasteful.

OCC Performance Issues

- High overhead for copying data locally.
- **Validation/Write** phase bottlenecks.
- Aborts are more wasteful because they only occur *after* a txn has already executed.
- Suffers from timestamp allocation bottleneck.

Multi-Version Concurrency Control

- Writes create new versions of objects instead of in-place updates:
  - Each successful write results in the creation of a new version of the data item written.
- Use write timestamps to label versions.
  - Let X_k denote the version of X where for a given trnasaction T_i: **W-TS(**X_k**)** ≤ **TS(**T_i**)**

MVCC – Reads and Writes

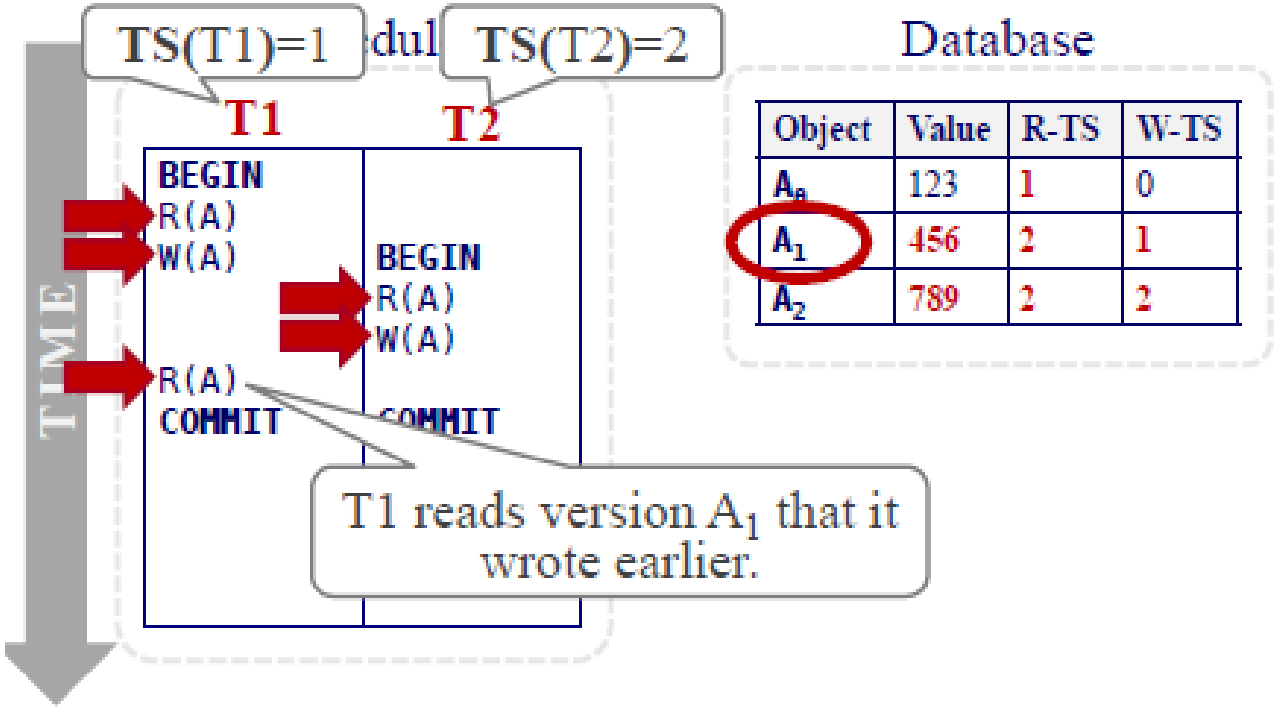
Reads

- Any read operation sees the latest version of an object from right before that transaction started.
- Every read request can be satisfied without blocking the transaction.
- If **TS(**T_i**)** > **R-TS(**X_k**)**:
  - Set **R-TS(**X_k**) = TS(**T_i**)**

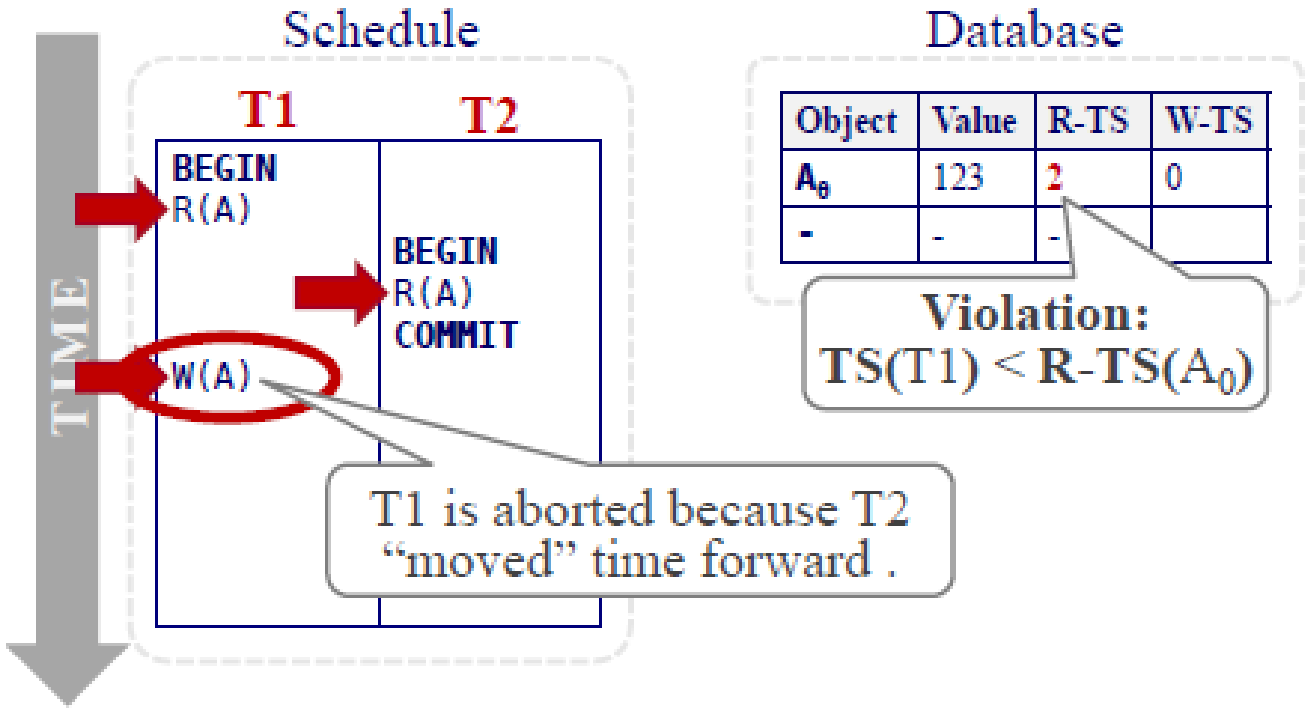
Writes

- If **TS(**T_i**)** < **R-TS(**X_k**)**:
  - Abort and restart T_i.
- If **TS(**T_i**)** = **W-TS(**X_k**)**:
  - Overwrite the contents of X_k.
- Else:
  - Create a new version of X_{k+1} and set its write timestamp to **TS(**T_i**)**.

MVCC – Example #1



MVCC – Example #2



MVCC

- Can still incur cascading aborts because a transaction sees uncommitted versions from transactions that started before it did.
- Old versions of tuples accumulate.
- The DBMS needs a way to remove old versions to reclaim storage space.