MC302 – DBMS: Transaction Processing Concepts

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Overview

- Transaction Overview
- Concurrency
- Recovery

Motivation

- Lost Updates → Two people change the same record ("Rajan"); how to avoid "race condition"? (Concurrency control)
- Durability → You transfer Rs. 100 from account -> processing; power failure – what happens? (Durability)

DBMSs automatically handle both issues: **Transactions**

Transactions

- Transaction - execution of a sequence of one or more operations (e.g., SQL queries) on a shared database to perform some higher-level function.
- Basic unit of change in a DBMS:
  – Partial transactions are not allowed!
- Example: Transfer Rs. 10,000 from Rajan’s account to his travel agent’s account
- Transaction:
  - Check if Rajan has Rs.10,000 in his account
  - Deduct Rs. 10,000 from his account
  - Credit Rs. 10,000 to his travel agent’s account

Approaches

- First – Strawman System
  - Execute transactions serially – one at a time
  - Make a local copy of DB
    - If the transaction completes successfully – overwrite the local DB with the new one
    - If transaction fails, remove the dirty copy
- Better - allow concurrent execution of independent transactions
- Why?
  - Higher utilization/throughput
  - Increased response time to users
- Essentials:
  - Correctness
  - Fairness

Transactions – Formal Definitions

- Database: A fixed set of named data objects (A, B, C, …)
  - Data object – an entire DB, a set of tables, a table, a set of rows, a single row etc.
- Transaction: A sequence of read and write operations (R(A), W(B), …)
  – DBMS’s abstract view of a user program

Transactions in SQL

- A new transaction starts with the begin command.
- The transaction stops with either commit or abort:
  - If commit, all changes are saved.
  - If abort, all changes are undone so that it's like as if the transaction never executed at all.
- The transaction ends with a end command

Correctness Criteria: **ACID**

- **Atomicity:** All actions in the transaction happen, or none happen.

  “all or nothing”
- **Consistency:** If each transaction is consistent and the DB starts consistent, then it ends up consistent.

  “it looks correct”
- **Isolation:** Execution of one transaction is isolated from that of other transactions.

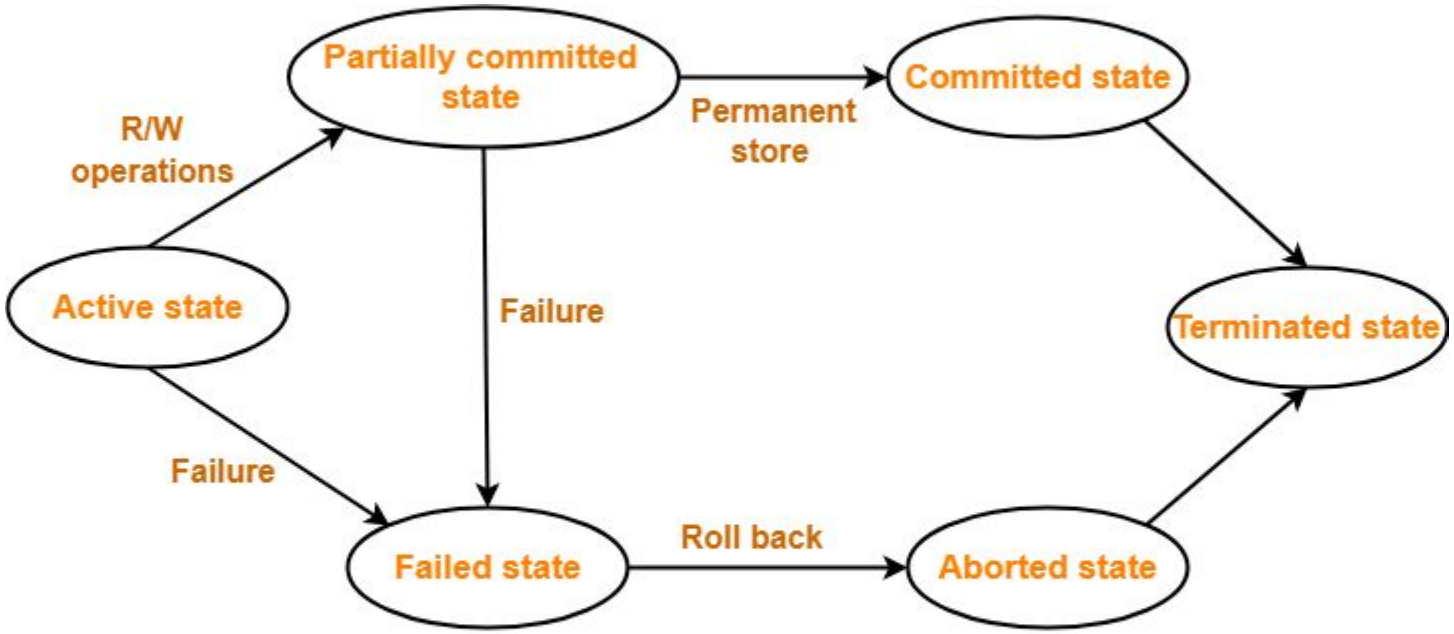
  “as if alone”
- **Durability:** If a transaction commits, its effects persist.

  “survive failures”

Atomicity of Transactions

- DBMS guarantees that transactions are atomic.
  - From user's point of view: transaction always either executes all its actions, or executes no actions at all.
- We take Rs. 10,000 out of Rajan's account but then there is a power failure before we transfer it to his travel agent.
- When the database comes back on-line, what should be the correct state of Rajan's account?
- To ensure atomicity – Logging
  - DBMS logs all actions so that it can undo the actions of aborted transactions.

Transaction States



Transaction States in DBMS

Transaction States

- Active –while executing
- Partially committed – after final statement gets executed
- Failed – after discovery that cannot proceed with the normal execution
- Aborted – after transaction has been rolled back and the DB has been restored to its state prior to the start of the transaction
- Committed – after successful completion

Consistency

- DB Consistency - Data in the DBMS is accurate in modeling the real world and follows integrity constraints
- Transaction Consistency - if the database is consistent before the txn starts (running alone), it will be after also.
- In a distributed DBMS, the consistency level determines when other nodes see new data in the database:
  - **Strong**: Guaranteed to see all writes immediately, but transactions are slower.
  - **Weak/Eventual**: Will see writes at some later point in time, but transactions are faster.

Isolation of Transactions

- Users submit transactions, and each transaction executes *as if it* was running *by itself*.
- Concurrency is achieved by DBMS, which interleaves actions (reads/writes of DB objects) of various transactions.
- Two Main strategies:
  - **Pessimistic** – Don’t let problems arise in the first place.
  - **Optimistic** – Assume conflicts are rare, deal with them after they happen.

Example

- Consider two transactions:
  - T1 – transfers Rs. 2000 from B's account to A's account
  - T2 – credits both accounts with 5% interest
- Assume that both have Rs. 10,000 each.
- What are the legal outcomes of running T1 and T2?

T1

```
BEGIN
A = A+2000
B = B-2000
COMMIT
```

T2

```
BEGIN
A = A*1.05
B = B*1.05
COMMIT
```

Example

- **Q**: What are the possible outcomes of running T1 and T2 together?
- **A**: Many! But A+B should be:

  Rs. 20,000*1.05=Rs. 21,000

- There is no guarantee that T1 will execute before T2 or vice-versa, if both are submitted together. But, the net effect must be equivalent to these two transactions running **serially** in some order.
- Legal outcomes:
  - A=12,600, B=8,400 → 21,000
  - A=12,500, B=8,500 → 21,000
- The outcome depends on whether T1 executes before T2 or vice versa.

Example

- Legal outcomes – S1: A=12,600, B=8,400;
  S2: A=12,500, B=8,500

S1

T1	T2
A= A+2000	
B = B-2000	
	A = A *1.05
	B = B * 1.05

S2

T1	T2
	A = A *1.05
	B = B * 1.05
A= A+2000	
B = B-2000	

Interleaving Transactions - Schedule

- Interleave the transactions in order to maximize concurrency.
  - Slow disk/network I/O.
  - Multi-core CPUs.
- Legal outcomes - A=12,600, B=8,400; A=12,500, B=8,500

S1

T1	T2
A= A+2000	
	A = A *1.05
B = B-2000	
	B = B * 1.05

Good

S2

T1	T2
A= A+2000	
	A = A *1.05
	B = B * 1.05
B = B-2000	

Bad

Interleaving Transactions - Schedule

Schedule S

T1	T2
A= A+2000	
	A = A *1.05
	B = B * 1.05
B = B-2000	

DBMS View of Schedule

T1	T2
R(A)	
W(A)	
	R(A)
	W(A)
	R(B)
	W(B)
R(B)	
W(B)	

Schedule

- Q: How would you judge that a schedule is ‘correct’?
- A: if it is equivalent to **some** serial execution

- Formal Properties of Schedules
  - *Serial schedule:* does not interleave the actions of different transactions.
  - *Equivalent schedules*: For any database state, the effect of executing the first schedule is identical to the effect of executing the second schedule.
  - *Serializable schedule*: A schedule that is equivalent to some serial execution of the transactions.

Anomalies with Interleaved Execution

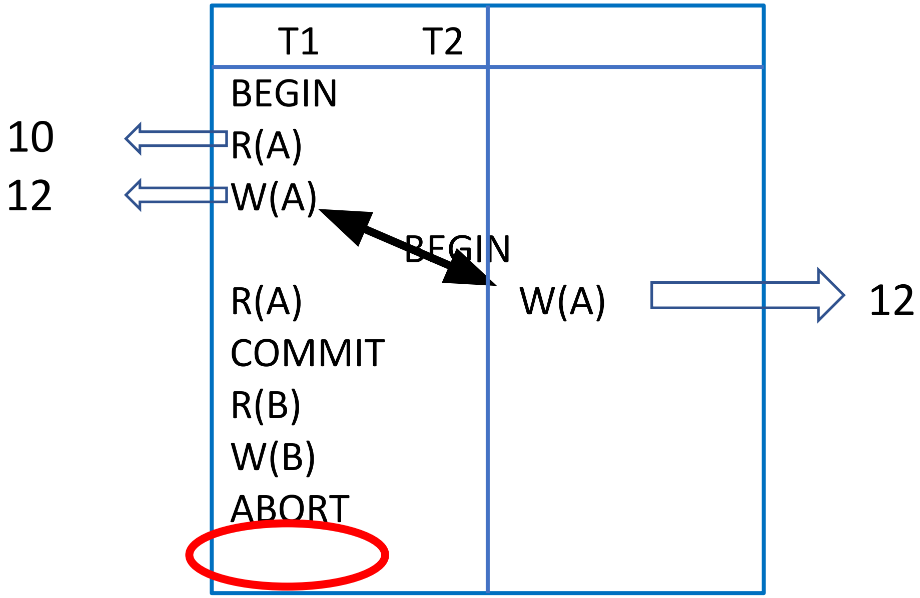
- Read-Write conflicts (R-W)
- Write-Read conflicts (W-R)
- Write-Write conflicts (W-W)

- Q – Why not Read-Read (R-R) conflicts?

Write-Read conflicts

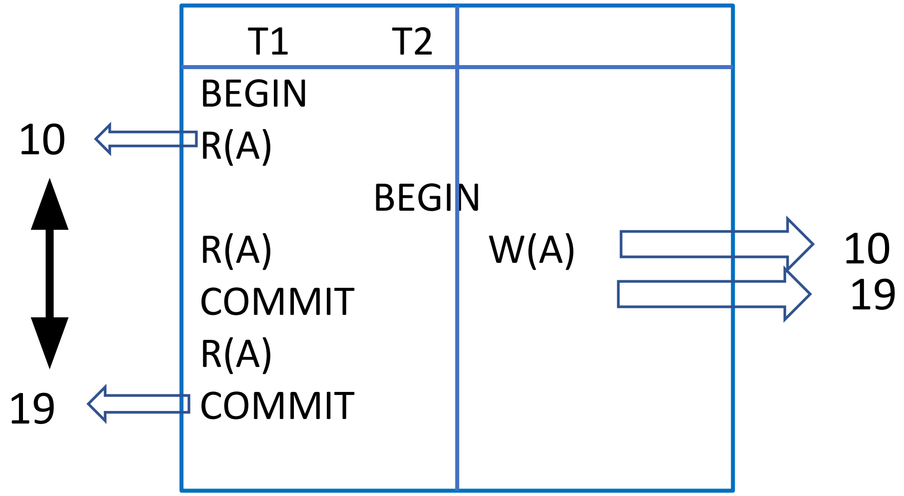
- Reading uncommitted data, “Dirty Reads”

- **Q:** Why is avoiding “dirty reads” important?
- **A:** If a transaction aborts, all actions must be undone. Any transaction that read modified data must also be aborted.



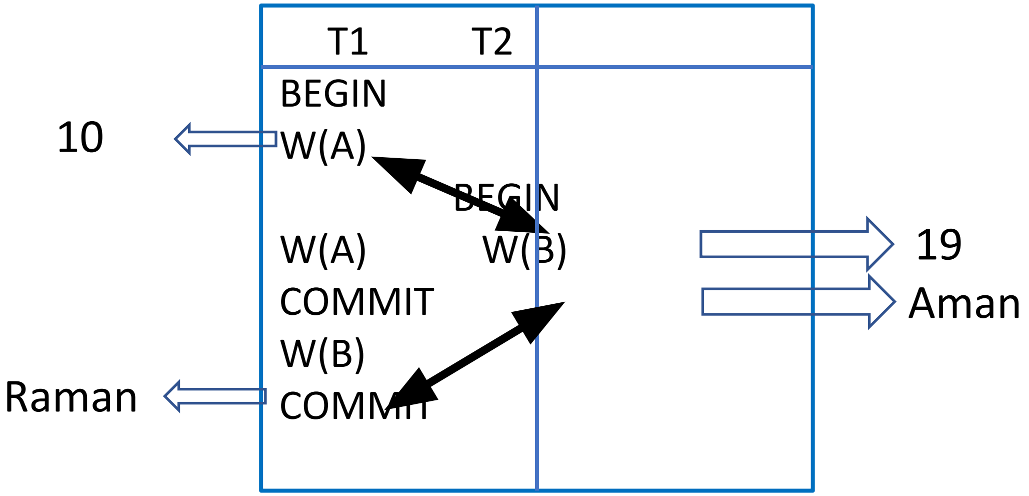
Read-Write conflicts

- “Unrepeatable Reads”



Write-Write conflicts

- “Lost update problem”
- Overwriting uncommitted data



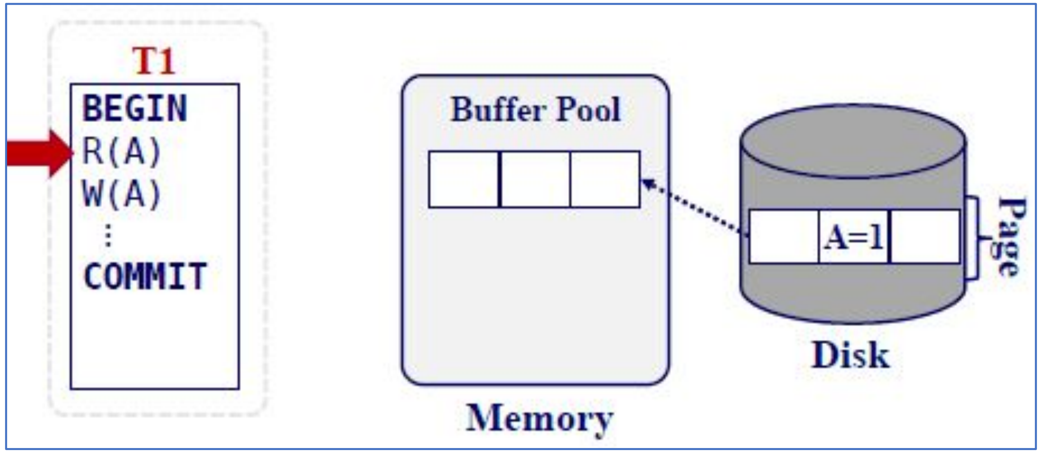
Solutions

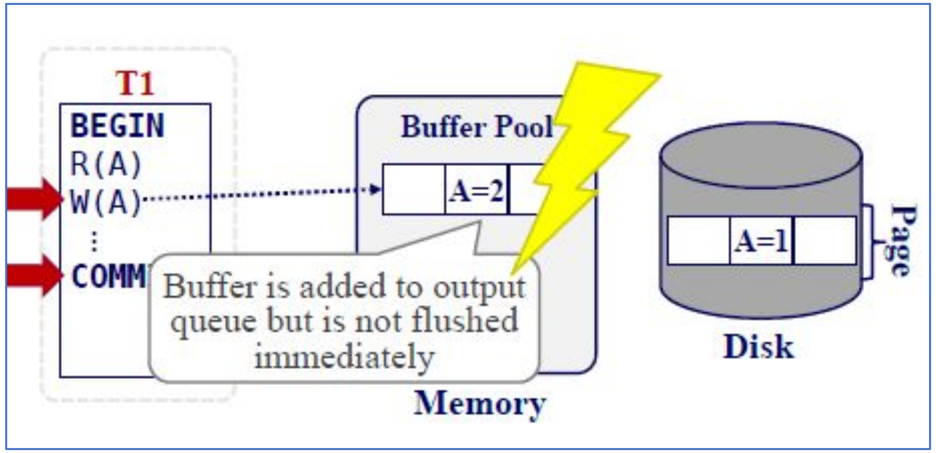
- **Q:** How could you guarantee that all resulting schedules are correct (i.e., serializable)?
- **A:** Use locks! – part of the answer

  Use locks; keep them until commit – full answer

Transaction Durability

- Records are stored on disk.
- For updates, they are copied into memory and flushed back to disk at the discretion of the O.S.





Write-Ahead Log

- Record the changes made to the database in a log ***before*** the change is made.
- Assume that the log is on stable storage.
- Log record format:
  - **<txnId, objectId, beforeValue, afterValue>**
  - Each transaction writes a log record first, before doing the change
- When a transaction finishes, the DBMS will:
  - Write a **<commit>** record on the log
  - Make sure that all log records are flushed before it returns an acknowledgement to application.
- After a failure, DBMS “replays” the log:
  - Undo uncommitted transactions
  - Redo the committed ones

Write-Ahead Log

before

<T1 start>

<T1, W, 1000, 2000>

<T1, Z, 5, 10>

<T1 commit>

crash

REDO T1

before

<T1 start>

<T1, W, 1000, 2000>

<T1, Z, 5, 10>

UNDO T1