Transaction

“Stop thinking, and end your problems.”
- Lao Tzu

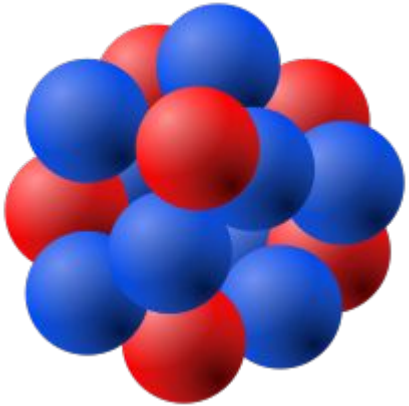
Outline

1. Introduction
    - Definition
    - ACID
    - Isolation Levels
2. How Transactions Work?
3. Common Problems

1. Introduction

1.1. Definition

- A transaction is **a group of SQL queries** that are treated **atomically**, as a single unit of work.
- All or Nothing
- Syntax:
    - START TRANSACTION / BEGIN: start transaction
    - a group of queries
    - COMMIT: Apply changes
    - ROLLBACK: Discard the changes



1.2. ACID

- ACID are properties of transaction in SQL DB
- **A**tomicity: a group of SQL queries is like a query. **all or nothing**.
- **C**onsistency:
  - Data should be valid according to all predefined rules.
  - The database should always move from one consistent state to the another, **maintaining all predefined rules, including SQL constraints, business rule,** data types
- **I**solation:
  - Multiple concurrent transactions do not affect each others.
  - The results of a transaction are usually **invisible** to other transactions until the transaction is complete.
- **D**urability: Committed data would be not lost, even after power failure.

1.3. Isolation Levels

1.3.1. Read Uncommitted

- Transactions can view the results of **uncommitted transactions**
- Problem: **Dirty Read** → Buggy
- Rarely used in practice
- Use case: A high-frequency logging system
    - Requirement: **performance is prioritized over the accuracy** of the log data

1.3.2. Read Committed

- Transactions can view the results of **committed transactions**
- Solve the Dirty Read problem
- In **Postgresql**, Read Committed is the **default** isolation level
- Use case: financial system
    - Requirement: each transaction must only see committed data to prevent anomalies but can tolerate non-repeatable reads.
- Problem: **Read Skew** (Non-repeatable read) - get different value on re-read of a row if another concurrent transaction updates the same row and commits.

1.3.3. Repeatable Read

- Repeatable Read guarantees that any rows a transaction reads will “look the **same” in subsequent reads within the same transaction**
- Solve the non-repeatable read problem
- In **MySQL**, Repeatable Read is the **default** isolation level
- Problem: **Phantom Read** - get different rows after re-execution of a range query if another transaction adds or removes some rows in the range and commits.
    - A new row appears without knowing where it comes from. It sounds like a phantom.
- Use case: An online retail system
    - Requirement: maintain a consistent view of item prices and availability throughout the session

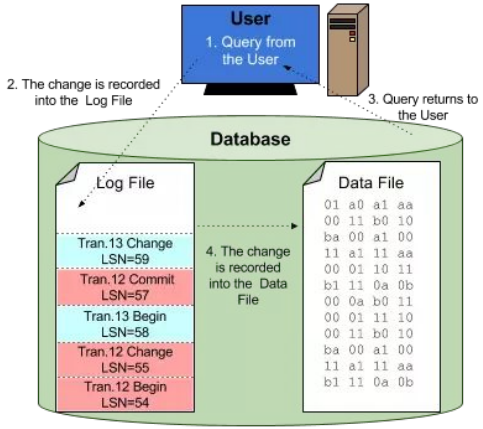
1.3.4. Serializable

- SERIALIZABLE solves the phantom read problem by forcing transactions to be ordered so that they can’t possibly conflict
- In a nutshell, **SERIALIZABLE places a lock on every row it reads**
- Problem: **Decreasing concurrency**
- Serializable is rarely used in practice.
- Use case: real estate system
    - Requirement: ensures full isolation, preventing phantom reads

2. How Transactions Work?

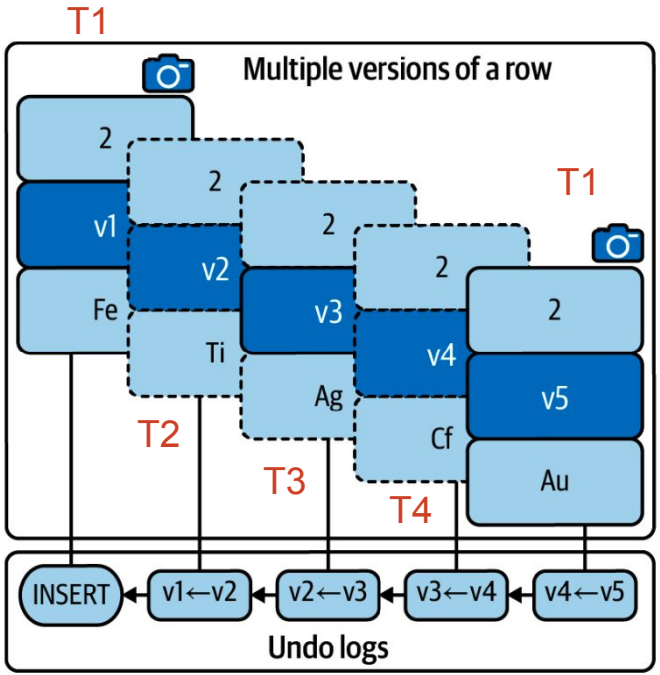
2.1. Transaction Logging

- Write Operation:
  - **Write-ahead logging**: The storage engine can then write a record of the change to the transaction log on disk (durable, sequential I/O).
  - The storage engine can change its **in-memory** copy of the data. This is very fast.
  - Later, storage engine update the real data on disk.



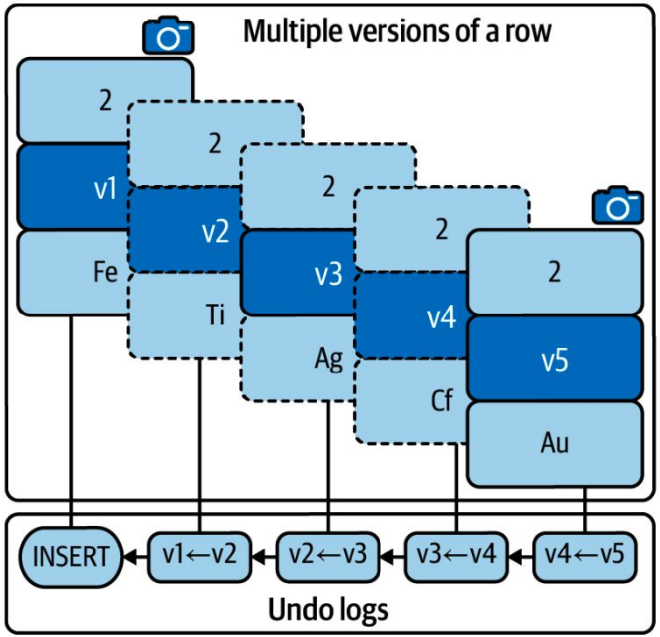
2.2. Multiversion Concurrency Control (MVCC)

- InnoDB uses multiversion concurrency control (MVCC) and undo logs to accomplish the A, C, and I properties of ACID
- Multiversion concurrency control means that **changes to a row create a new version** of the row.
  A version of the row is called Undo log.
- **Undo logs record how to reconstruct old row versions and used on REPEATABLE READ and ROLLBACK**
- A snapshot is created when SELECT



2.2. Multiversion Concurrency Control (MVCC)

- When the original transaction commits and no other active transaction are holding old snapshot, MySQL purges the related undo logs
- **Undo logs are saved in the InnoDB buffer pool**. Since undo logs reside in buffer pool pages, they use memory and are periodically flushed to disk.
- A transaction can hold many locks and undo logs → **performance impact**



2.2. Multiversion Concurrency Control (MVCC)

- MVVC in Postgres

2.3. History list length (HLL)

- History list length (HLL) gauges the amount of old row versions not purged or flushed.
- Monitor and keep HLL short

HLL	Response time (ms)	Baseline increase (%)
0	0.200 ms	
495	0.612 ms	206%
1,089	1.012 ms	406%
2,079	1.841 ms	821%
5,056	3.673 ms	1,737%
11,546	8.527 ms	4,164%

3. Common Problems

3.1. Large Transaction

- Problem: A transaction modifies too many rows
- Solution:
  - Find the large transaction query
  - **Why it’s modifying too many rows?**
  - Change them to modify fewer rows
  - Note: depend business logic

3.2. Long-Running Transactions

- Problem: A transaction takes too long to complete
- Causes:
  - The queries in the transaction are too slow
  - App executes too many queries in a transaction
- Solution:
  - (1) Find the root cause. **Maybe data locks**
  - (2) Limit fewer queries in the transaction

3.3. Stalled Transaction

- Problem: A transaction is waiting too long between queries in a transaction
- For example:

```
BEGIN;
SELECT FROM table1 … ;
– App takes it too long here
SELECT FROM table2 …;
COMMIT;
```

- Solution:
  - Depending on app logic
  - **Do these queries need to be a transaction?**
  - Can we use READ COMMITTED to disable gap locking?

3.4. Abandoned Transaction

- Problem: Client connection vanished during active transaction
- Causes:
  - App connection leaks
  - Half-closed connections: rarely
- Solution:
  - Fix app logic
  - Generate a report to find abandoned transactions

3.5. Notes

- Set transaction isolation level apply the next transaction only. After the next transaction, subsequent transactions use the default transaction isolation level.
- In MySQL, Autocommit is enabled by default.
- Alert on History List Length
- …

Recap

- Each isolation level solves the problem of the previous level.

  Read Committed and Repeatable Read are used in practice.
- Transaction works based on MVCC and undo logs. Optimize transaction.
- Transaction and Locking are 2 different mechanism solving 2 different problems

Homework

- Replay Isolation Level script

References

- https://blog.lawrencejones.dev/state-machines/index.html
- https://vladmihalcea.com/optimistic-vs-pessimistic-locking/
- https://faculty.kutztown.edu/schwesin/spring2022/csc343/lectures/Locking.pdf

Thank you 🙏