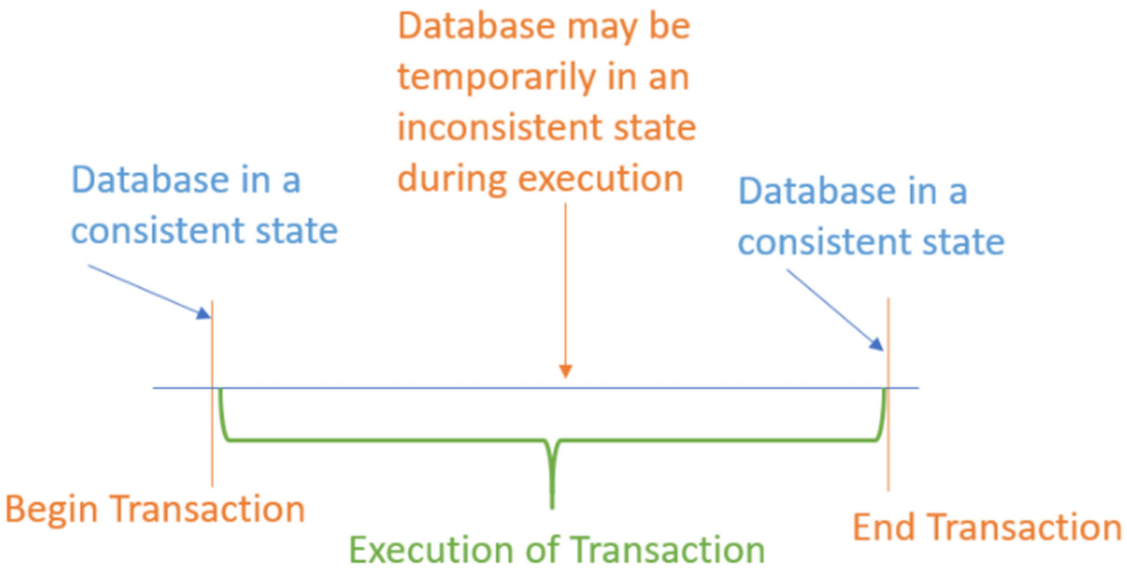
Basic concept of Transaction

What is a Transaction?

A **TRANSACTION** is a logical unit of processing in a DBMS which entails one or more database access operation. In a nutshell, database transactions represent real-world events of any enterprise.

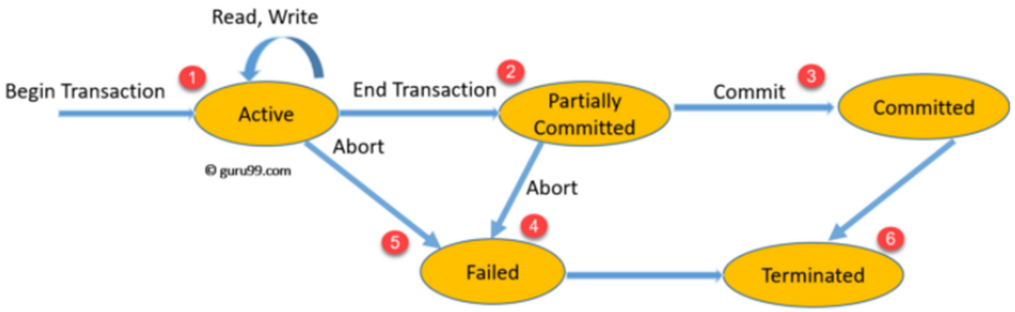
All types of database access operation which are held between the beginning and end transaction statements are considered as a single logical transaction. During the transaction the database is inconsistent. Only once the database is committed the state is changed from one consistent state to another.



- A transaction is a program unit whose execution may or may not change the contents of a database.
- The transaction is executed as a single unit
- If the database operations do not update the database but only retrieve data, this type of transaction is called a read-only transaction.
- A successful transaction can change the database from one CONSISTENT STATE to another
- DBMS transactions must be **Atomic**, **Consistent**, **Isolated** and **Durable**
- If the database were in an inconsistent state before a transaction, it would remain in the inconsistent state after the transaction.

State of a Transaction

A transaction in a database can be in one of the following states



State Transition Diagram for a Database Transaction

Active State

As we have discussed in the DBMS transaction introduction that a transaction is a sequence of operations. If a transaction is in execution then it is said to be in active state. It doesn't matter which step is in execution, until unless the transaction is executing, it remains in active state.

Failed State

If a transaction is executing and a failure occurs, either a hardware failure or a software failure then the transaction goes into failed state from the active state.

Partially Committed State

As we can see in the above diagram that a transaction goes into "partially committed" state from the active state when there are read and write operations present in the transaction.

A transaction contains number of read and write operations. Once the whole transaction is successfully executed, the transaction goes into partially committed state where we have all the read and write operations performed on the main memory (local memory) instead of the actual database.

The reason why we have this state is because a transaction can fail during execution so if we are making the changes in the actual database instead of local memory, database may be left in an inconsistent state in case of any failure. This state helps us to rollback the changes made to the database in case of a failure during execution.

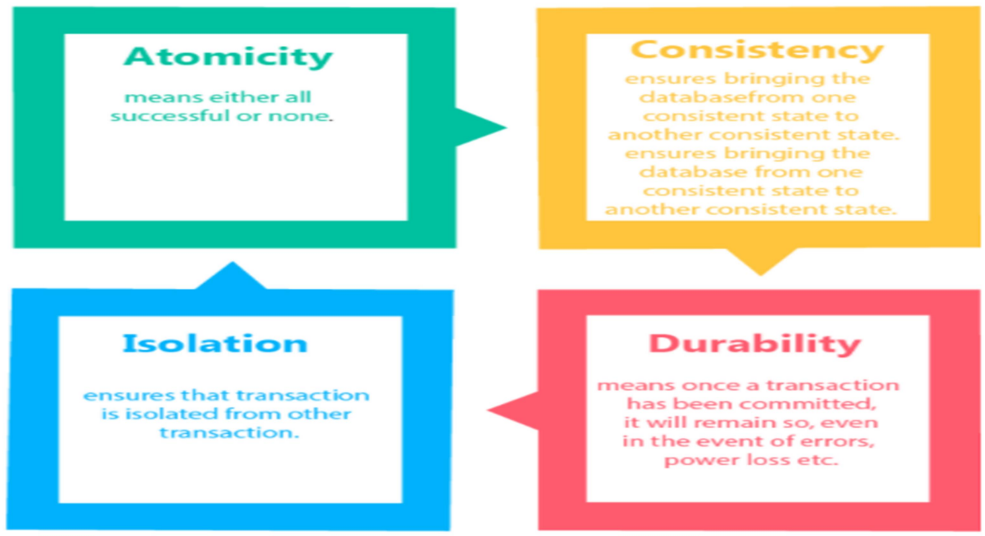
Committed State

If a transaction completes the execution successfully then all the changes made in the local memory during partially committed state are permanently stored in the database. You can also see in the above diagram that a transaction goes from partially committed state to committed state when everything is successful.

Aborted State

As we have seen above, if a transaction fails during execution then the transaction goes into a failed state. The changes made into the local memory (or buffer) are rolled back to the previous consistent state and the transaction goes into aborted state from the failed state. Refer the diagram to see the interaction between failed and aborted state.

A transaction is a very small unit of a program and it may contain several low level tasks. A transaction in a database system must maintain **A**tomicity, **C**onsistency, **I**solation, and **D**urability – commonly known as ACID properties – in order to ensure accuracy, completeness, and data integrity.



Implementation of Atomicity and Durability

Atomicity

By this, we mean that either the entire transaction takes place at once or doesn't happen at all. There is no midway i.e. transactions do not occur partially. Each transaction is considered as one unit and either runs to completion or is not executed at all. It involves the following two operations.

—Abort: If a transaction aborts, changes made to database are not visible.

—Commit: If a transaction commits, changes made are visible.

Atomicity is also known as the 'All or nothing rule'.

Consider the following transaction **T** consisting of **T1** and **T2**: Transfer of 100 from account **X** to account **Y**.

Before: X : 500	Y: 200
Transaction T	
T1	**T2**
Read (X) X: = X − 100 Write (X)	Read (Y) Y: = Y + 100 Write (Y)
After: X : 400	Y : 300

Durability

This property ensures that once the transaction has completed execution, the updates and modifications to the database are stored in and written to disk and they persist even if a system failure occurs. These updates now become permanent and are stored in non-volatile memory. The effects of the transaction, thus, are never lost.

Implementation

The recovery-management component of a database system can support atomicity and durability by a variety of schemes.

Here we are going to learn about one of the simplest scheme called Shadow copy.

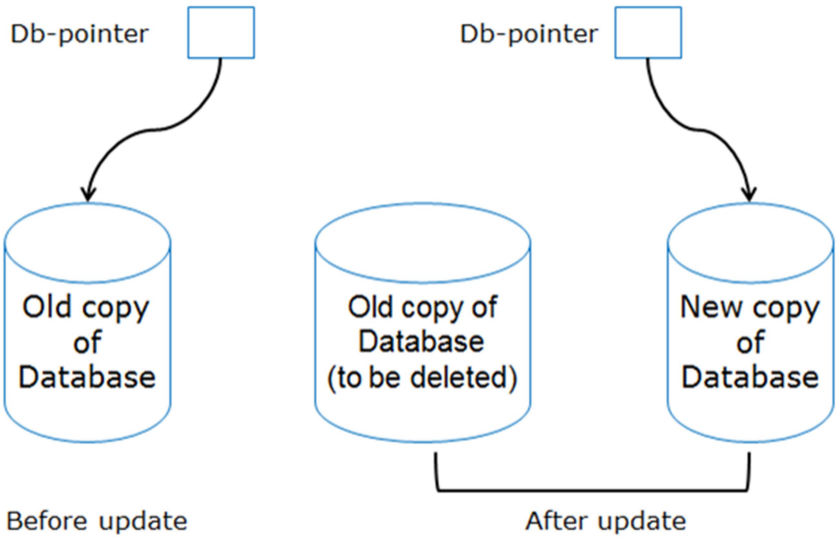
Shadow copy:

- In the shadow-copy scheme, a transaction that wants to update the database first creates a complete copy of the database. All updates are done on the new database copy, leaving the original copy, the shadow copy, untouched. If at any point the transaction has to be aborted, the system merely deletes the new copy. The old copy of the database has not been affected.
- This scheme is based on making copies of the database, called shadow copies, assumes that only one transaction is active at a time. The scheme also assumes that the database is simply a file on disk. A pointer called db-pointer is maintained on disk; it points to the current copy of the database.

If the transaction completes, it is committed as follows:

- First, the operating system is asked to make sure that all pages of the new copy of the database have been written out to disk. (Unix systems use the flush command for this purpose.)
- After the operating system has written all the pages to disk, the database system updates the pointer db-pointer to point to the new copy of the database; the new copy then becomes the current copy of the database. The old copy of the database is then deleted.

Figure below depicts the scheme, showing the database state before and after the update.



Shadow-copy technique for atomicity and durability

The transaction is said to have been committed at the point where the updated db pointer is written to disk.

How the technique handles transaction failures:

- If the transaction fails at any time before db-pointer is updated, the old contents of the database are not affected.
- We can abort the transaction by just deleting the new copy of the database.
- Once the transaction has been committed, all the updates that it performed are in the database pointed to by db pointer.
- Thus, either all updates of the transaction are reflected, or none of the effects are reflected, regardless of transaction failure.

How the technique handles system failures:

- Suppose that the system fails at any time before the updated db-pointer is written to disk. Then, when the system restarts, it will read db-pointer and will thus see the original contents of the database, and none of the effects of the transaction will be visible on the database.
- Next, suppose that the system fails after db-pointer has been updated on disk. Before the pointer is updated, all updated pages of the new copy of the database were written to disk.
- Again, we assume that, once a file is written to disk, its contents will not be damaged even if there is a system failure. Therefore, when the system restarts, it will read db-pointer and will thus see the contents of the database after all the updates performed by the transaction.

Concurrent Executions

Multiple transactions are allowed to run concurrently in the system.

Advantages are:

Increased processor and disk utilization, leading to better transaction throughput

E.g. One transaction can be using the CPU while another is reading from or writing to the disk

Reduced average response time for transactions: Short transactions need not wait behind long ones.

Concurrency control schemes– Mechanisms to achieve Isolation

That is, to control the interaction among the concurrent transactions in order to prevent them from destroying the consistency of the database

Serializability

When multiple transactions are being executed by the operating system in a multiprogramming environment, there are possibilities that instructions of one transactions are interleaved with some other transaction.

- **Schedule** − A chronological execution sequence of a transaction is called a schedule. A schedule can have many transactions in it, each comprising of a number of instructions/tasks.
- **Serial Schedule** − It is a schedule in which transactions are aligned in such a way that one transaction is executed first. When the first transaction completes its cycle, then the next transaction is executed. Transactions are ordered one after the other. This type of schedule is called a serial schedule, as transactions are executed in a serial manner.

In a multi-transaction environment, serial schedules are considered as a benchmark. The execution sequence of an instruction in a transaction cannot be changed, but two transactions can have their instructions executed in a random fashion. This execution does no harm if two transactions are mutually independent and working on different segments of data; but in case these two transactions are working on the same data, then the results may vary. This ever-varying result may bring the database to an inconsistent state.

To resolve this problem, we allow parallel execution of a transaction schedule, if its transactions are either serializable or have some equivalence relation among them.

Equivalence Schedules

An equivalence schedule can be of the following types −

Result Equivalence

If two schedules produce the same result after execution, they are said to be result equivalent. They may yield the same result for some value and different results for another set of values. That's why this equivalence is not generally considered significant.

View Equivalence

Two schedules would be view equivalence if the transactions in both the schedules perform similar actions in a similar manner.

For example −

- If T reads the initial data in S1, then it also reads the initial data in S2.
- If T reads the value written by J in S1, then it also reads the value written by J in S2.
- If T performs the final write on the data value in S1, then it also performs the final write on the data value in S2.

Conflict Equivalence

Two schedules would be conflicting if they have the following properties −

- Both belong to separate transactions.
- Both accesses the same data item.
- At least one of them is "write" operation.

Two schedules having multiple transactions with conflicting operations are said to be conflict equivalent if and only if −

- Both the schedules contain the same set of Transactions.
- The order of conflicting pairs of operation is maintained in both the schedules.

View equivalent schedules are view serializable and conflict equivalent schedules are conflict serializable. All conflict serializable schedules are view serializable too

Recoverability

A transaction may not execute completely due to hardware failure, system crash or software issues. In that case, we have to roll back the failed transaction. But some other transaction may also have used values produced by the failed transaction. So we have to roll back those transactions as well.

Let's understand the same with examples and we will also discuss the types of recovery schedules

Recoverable Schedule –
A schedule is said to be recoverable if it is recoverable as name suggest. Only reads are allowed before write operation on same data. Only reads (Ti->Tj) is permissible.

T1	T1's buffer space	T2	T2's buffer space	Database
				A = 6500
Read(A);	A = 6500			A = 6500
A = A - 500;	A = 6000			A = 6500
Write(A);	A = 6000			A = 6000
		Read(A);	A = 6000	A = 6000
		A =A + 1000;	A = 7000	A = 6000
		Write(A);	A = 7000	A = 7000
Failure Point				
Commit;				
		Commit;		

The above table shows a schedule with two transactions. Transaction T1 reads and writes A, and that value is read and written by transaction T2. But later on, T1 fails. Due to this, we have to rollback T1. T2 should be rollback because T2 has read the value written by T1. As it has not committed before T1 commits so we can rollback transaction T2 as well. So it is recoverable with cascade rollback.

Given schedule follows order of **Ti->Tj => C1->C2**. Transaction T1 is executed before T2 hence there is no chances of conflict occur. R1(x) appears before W1(x) and transaction T1 is committed before T2 i.e. completion of first transaction performed first update on data item x, hence given schedule is recoverable.

Irrecoverable schedule: The schedule will be irrecoverable if Tj reads the updated value of Ti and Tj committed before Ti commit.

T1	T1's buffer space	T2	T2's buffer space	Database
				A = 6500
Read(A);	A = 6500			A = 6500
A = A - 500;	A = 6000			A = 6500
Write(A);	A = 6000			A = 6000
		Read(A);	A = 6000	A = 6000
		A =A + 1000;	A = 7000	A = 6000
		Write(A);	A = 7000	A = 7000
		Commit;		
Failure Point				
Commit;				

The above shows a schedule which has two transactions. T1 reads and writes the value of A and that value is read and written by T2. T2 commits but later on, T1 fails. Due to the failure, we have to rollback T1. T2 should also be rollback because it reads the value written by T1, but T2 can't be rollback because it already committed. So this type of schedule is known as irrecoverable schedule.

Implementation of Isolation

Isolation determines how transaction integrity is visible to other users and systems. It means that a transaction should take place in a system in such a way that it is the only transaction that is accessing the resources in a database system.
Isolation levels define the degree to which a transaction must be isolated from the data modifications made by any other transaction in the database system. A transaction isolation level is defined by the following phenomena –

- **Dirty Read –** A Dirty read is the situation when a transaction reads a data that has not yet been committed. For example, Let's say transaction 1 updates a row and leaves it uncommitted, meanwhile, Transaction 2 reads the updated row. If transaction 1 rolls back the change, transaction 2 will have read data that is considered never to have existed.

- **Non Repeatable read –** Non Repeatable read occurs when a transaction reads same row twice, and get a different value each time. For example, suppose transaction T1 reads data. Due to concurrency, another transaction T2 updates the same data and commit, Now if transaction T1 rereads the same data, it will retrieve a different value.

- **Phantom Read –** Phantom Read occurs when two same queries are executed, but the rows retrieved by the two, are different. For example, suppose transaction T1 retrieves a set of rows that satisfy some search criteria. Now, Transaction T2 generates some new rows that match the search criteria for transaction T1. If transaction T1 re-executes the statement that reads the rows, it gets a different set of rows this time.

Based on these phenomena, The SQL standard defines four isolation levels :

1. **Read Uncommitted –** Read Uncommitted is the lowest isolation level. In this level, one transaction may read not yet committed changes made by other transaction, thereby allowing dirty reads. In this level, transactions are not isolated from each other.

2. **Read Committed –** This isolation level guarantees that any data read is committed at the moment it is read. Thus it does not allows dirty read. The transaction holds a read or write lock on the current row, and thus prevent other transactions from reading, updating or deleting it.

3. **Repeatable Read –** This is the most restrictive isolation level. The transaction holds read locks on all rows it references and writes locks on all rows it inserts, updates, or deletes. Since other transaction cannot read, update or delete these rows, consequently it avoids non-repeatable read.

4. **Serializable –** This is the Highest isolation level. A *serializable* execution is guaranteed to be serializable. Serializable execution is defined to be an execution of operations in which concurrently executing transactions appears to be serially executing.

Transaction in SQL

A transaction is a logical unit of work that contains one or more SQL statements. A transaction is an atomic unit. The effects of all the SQL statements in a transaction can be either all committed (applied to the database) or all rolled back (undone from the database).

A transaction begins with the first executable SQL statement. A transaction ends when it is committed or rolled back, either explicitly with a COMMIT or ROLLBACK statement or implicitly when a DDL statement is issued.

A transaction in DB begins when the first executable SQL statement is encountered. An **executable SQL statement** is a SQL statement that generates calls to an instance, including DML and DDL statements.

When a transaction begins, DB assigns the transaction to an available undo tablespace to record the rollback entries for the new transaction.

A transaction ends when any of the following occurs:

- A user issues a COMMIT or ROLLBACK statement without a SAVEPOINT clause.
- A user runs a DDL statement such as CREATE, DROP, RENAME, or ALTER. If the current transaction contains any DML statements, DB first commits the transaction, and then runs and commits the DDL statement as a new, single statement transaction.
- A user disconnects from DB. The current transaction is committed.

- A user process terminates abnormally. The current transaction is rolled back.

After one transaction ends, the next executable SQL statement automatically starts the following transaction.

Note:

Applications should always explicitly commit or undo transactions before program termination.

Commit Transactions

Committing a transaction means making permanent the changes performed by the SQL statements within the transaction.

Before a transaction that modifies data is committed, the following has occurred:

- DB has generated undo information. The undo information contains the old data values changed by the SQL statements of the transaction.
- DB has generated redo log entries in the redo log buffer of the SGA. The redo log record contains the change to the data block and the change to the rollback block. These changes may go to disk before a transaction is committed.
- The changes have been made to the database buffers of the SGA. These changes may go to disk before a transaction is committed.

Note:

The data changes for a committed transaction, stored in the database buffers of the SGA, are not necessarily written immediately to the datafiles by the database writer (DBW*n*) background process. This writing takes place when it is most efficient for the database to do so. It can happen before the transaction commits or, alternatively, it can happen some time after the transaction commits.

When a transaction is committed, the following occurs:

1. The internal transaction table for the associated undo tablespace records that the transaction has committed, and the corresponding unique system change number (SCN) of the transaction is assigned and recorded in the table.
2. The log writer process (LGWR) writes redo log entries in the SGA's redo log buffers to the redo log file. It also writes the transaction's SCN to the redo log file. This atomic event constitutes the commit of the transaction.
3. DB releases locks held on rows and tables.
4. DB marks the transaction complete.

Rollback of Transactions

Rolling back means undoing any changes to data that have been performed by SQL statements within an uncommitted transaction. DB uses undo tablespaces (or rollback segments) to store old values. The redo log contains a record of changes.

DB lets you roll back an entire uncommitted transaction. Alternatively, you can roll back the trailing portion of an uncommitted transaction to a marker called a savepoint.

All types of rollbacks use the same procedures:

- Statement-level rollback (due to statement or deadlock execution error)
- Rollback to a savepoint
- Rollback of a transaction due to user request
- Rollback of a transaction due to abnormal process termination
- Rollback of all outstanding transactions when an instance terminates abnormally
- Rollback of incomplete transactions during recovery

In rolling back **an entire transaction**, without referencing any savepoints, the following occurs:

1. DB undoes all changes made by all the SQL statements in the transaction by using the corresponding undo tablespace.
2. DB releases all the transaction's locks of data.
3. The transaction ends.

Savepoints In Transactions

You can declare intermediate markers called **savepoints** within the context of a transaction. Savepoints divide a long transaction into smaller parts.

Using savepoints, you can arbitrarily mark your work at any point within a long transaction. You then have the option later of rolling back work performed before the current point in the transaction but after a declared savepoint within the transaction. For example, you can use savepoints throughout a long complex series of updates, so if you make an error, you do not need to resubmit every statement.

Savepoints are similarly useful in application programs. If a procedure contains several functions, then you can create a savepoint before each function begins. Then, if a function fails, it is easy to return the data to its state before the function began and re-run the function with revised parameters or perform a recovery action.

After a rollback to a savepoint, DB releases the data locks obtained by rolled back statements. Other transactions that were waiting for the previously locked resources can proceed. Other transactions that want to update previously locked rows can do so.

When a transaction is rolled back to a savepoint, the following occurs:

1. DB rolls back only the statements run after the savepoint.
2. DB preserves the specified savepoint, but all savepoints that were established after the specified one are lost.
3. DB releases all table and row locks acquired since that savepoint but retains all data locks acquired previous to the savepoint.

The transaction remains active and can be continued.

Whenever a session is waiting on a transaction, a rollback to savepoint does not free row locks. To make sure a transaction does not hang if it cannot obtain a lock, use FOR UPDATE ... NOWAIT before issuing UPDATE or DELETE statements. (This refers to locks obtained before the savepoint to which has been rolled back. Row locks obtained after this savepoint are released, as the statements executed after the savepoint have been rolled back completely.)