DBMS Week 10 TA Session

Transaction

- A transaction is a unit of program execution that accesses and, possibly updates, various data items.

Two main issues to deal with:

- Failures of various kinds, such as hardware failures and system crashes
- **Concurrent execution** of multiple transactions

ACID Properties

- **Atomicity** - All or Nothing Transactions
- **Consistency** - Guarantees committed transaction state
- **Isolation** - Transactions are independent (Ensures Concurrent Transaction)
- **Durability** - Committed Data is never lost

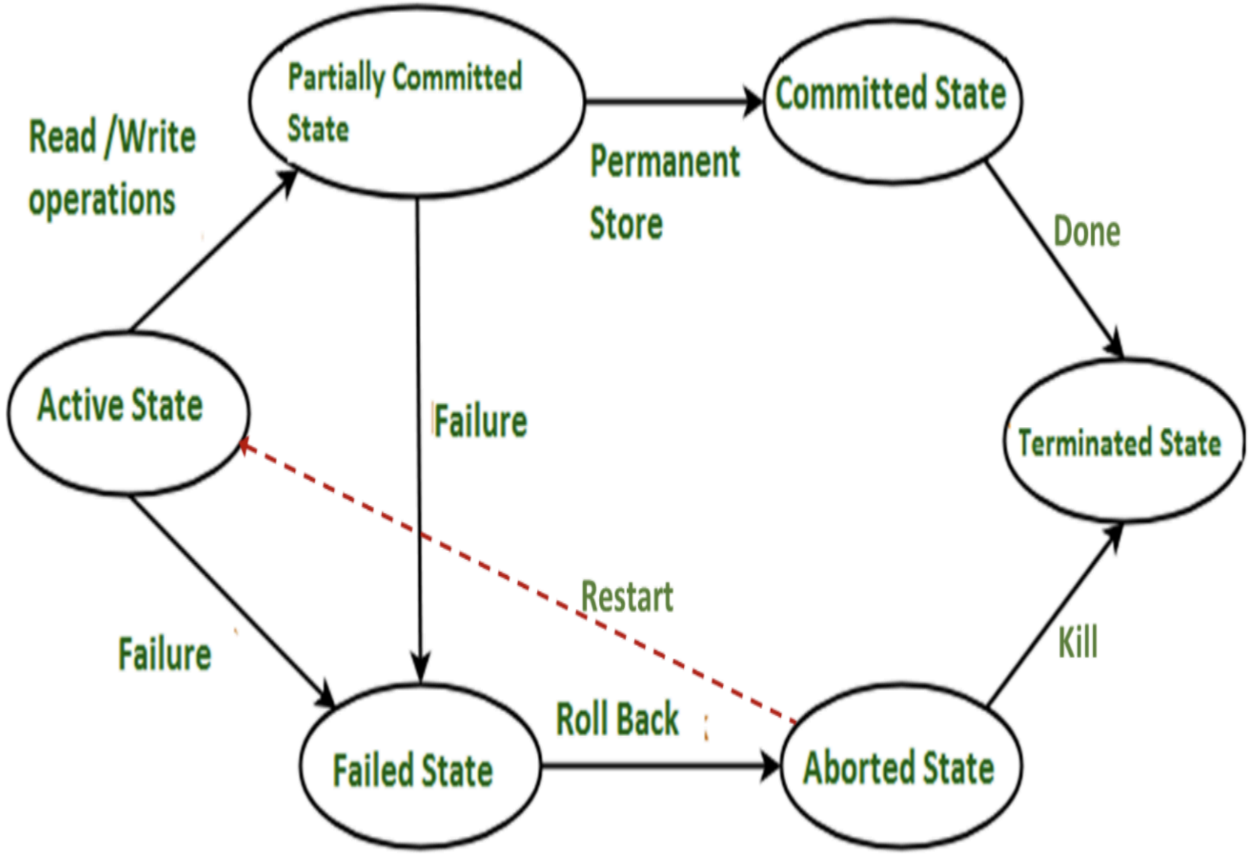
Transaction to transfer $50 from account A to account B:

	T1
1	read(A)
2	A := A – 50
3	write(A)
4	read(B)
5	B := B + 50
6	write(B)

Transaction States

Every transaction can be in one of the following states

- Active
- Partially committed
- Failed
- Aborted
- Committed
- Terminated



Schedule

A sequence of instructions that specify the chronological order in which instructions of concurrent transactions are executed.

- A schedule for a set of transactions must consist of all instructions of those transactions
- Must preserve the order in which the instructions appear in each individual transaction

Serializability

- Each Transaction preserves database consisitency
- A schedule is serializable if it it is equivalent serial schedule

Types of Serializability

1. **Conflict Serializability**
2. **View Serializability**

Example of Schedule and Serializable

Let T1 and T2 be the transactions. The following schedule is not a serial schedule, but it is equivalent to Schedule 1

Schedule 3

T_1	T_2
read (A) $A := A - 50$ write (A)	
	read (A) $temp := A * 0.1$ $A := A - temp$ write (A)
read (B) $B := B + 50$ write (B) commit	
	read (B) $B := B + temp$ write (B) commit

Schedule 1

T_1	T_2
read (A) $A := A - 50$ write (A) read (B) $B := B + 50$ write (B) commit	
	read (A) $temp := A * 0.1$ $A := A - temp$ write (A) read (B) $B := B + temp$ write (B) commit

A	B	A+B	Transaction	Remarks
100	200	300	@ Start	
50	200	250	T1, write A	
45	200	245	T2, write A	
45	250	295	T1, write B	@ Commit
45	255	300	T2, write B	@Commit

Consistent @ Commit
Inconsistent @ Transit
Inconsistent @ Commit

Conflicting Instructions

Let I_i and I_j be two Instructions from transactions T_i and T_j respectively

- I_i = read(Q), I_j = read(Q) - I_i and I_j don't conflict
- I_i = read(Q), I_i = write(Q) - They conflict
- I_i = write(Q), I_j = read(Q) - They conflict
- I_i = write(Q), I_j = write(Q) - They conflict

Conflict Serializable

- If a schedule S can be transformed into a schedule $S^{'}$ by a series of swaps of non-conflicting instructions, we say that S and $S^{'}$ are conflict equivalent.
- We say that a schedule S is conflict serializable if it is conflict equivalent to a serial schedule.

Note

- All conflict-serializable schedules are equivalent serializable but the reverse is not true.

Example

Schedule 3 can be transformed into Schedule 6, a serial schedule where T2 follows T1, by a series of swaps of non-conflicting instructions:

- Swap T1.read(B) and T2.write(A)
- Swap T1.read(B) and T2.read(A)
- Swap T1.write(B) and T2.write(A)
- Swap T1.write(B) and T2.read(A)

T_1	T_2
read (A)	
write (A)	
	read (A)
	write (A)
read (B)	
write (B)	
	read (B)
	write (B)

T_1	T_2
read(A)	
write(A)	
	read(A)
read(B)	
	write(A)
write(B)	
	read(B)
	write(B)

T_1	T_2
read (A)	
write (A)	
read (B)	
write (B)	
	read (A)
	write (A)
	read (B)
	write (B)

Precedence Graph

- A direct graph where the vertices are the transactions (names)
- We draw an arc from T_i to T_j if the two transactions conflict, and T_i accessed the data item on which the conflict arose earlier.

Note

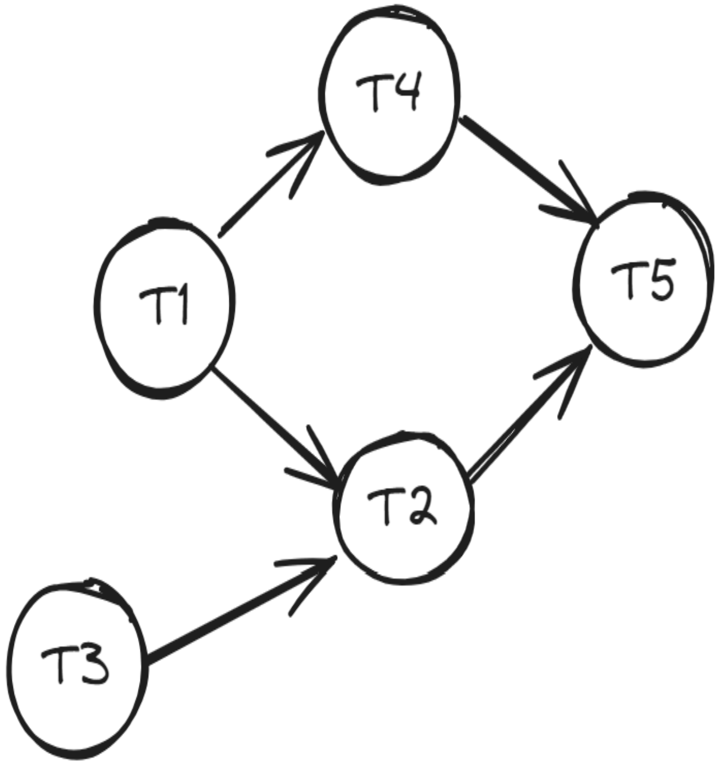
- A schedule is conflict serializable if and only if its precedence graph is **acyclic**
- If precedence graph is acyclic, the serializability order can be obtained by a **topological sorting** of the graph

Example

Consider the following schedule:

w1(A), r2(A), w1(B), w3(C),r2(C),r4(B), w2(D), w4(E), r5(D), w5(E)

T1	T2	T3	T4	T5
w1(A)				
	r2(A)			
w1(B)				
		w3(C)		
	r2(C)			
			r4(B)	
	w2(D)			
			w4(E)	
				r5(D)
				w5(E)



Recovery

- Serializability helps to ensure Isolation and Consistency of a schedule.

If the system fails in intermediate steps of the transaction,

- Leads to inconsistent state
- Need to rollback update of A

This is known as **Recovery**

Recoverable Schedules

If a transaction T_j reads a data item previously written by a transaction T_i, then the commit operation of T_i must appear before the commit operation of T_j.

T_8	T_9
read (A)	
write (A)	
	read (A)
	commit
read (B)	

- The following schedule is not recoverable if T9 commits immediately after the read(A) operation
- If T8 should abort, T9 would have read (and possibly shown to the user) an inconsistent database state.

Cascading Rollbacks

- A single transaction failure leads to a series of transaction rollbacks.

T_{10}	T_{11}	T_{12}
read (A)		
read (B)		
write (A)		
	read (A)	
	write (A)	
		read (A)
abort		

- The following schedule is recoverable
- If T10 fails, T11 and T12 must also be rolled back
- Can lead to the undoing of a significant amount of work

Cascadeless Schedules

- For each pair of transactions T_i and T_j such that T_j reads a data item previously written by Ti, the commit operation of T_i appears before the read operation of T_j
- Every cascadeless schedule is also recoverable

T_{10}	T_{11}	T_{12}
read (A)		
read (B)		
write (A)		
	read (A)	
	write (A)	
		read (A)
abort		

- The shown schedule is **not cascadeless**

TCL (Transaction Control Language)

- `COMMIT` - To save the changes
- `ROLLBACK` - To roll back the changes
- `SAVEPOINT` - Creates points within the groups of transactions in which to ROLLBACK
- `SET TRANSACTION` - Places a name on a transaction

Example

```
SQL> SAVEPOINT SP1;
SQL> UPDATE Employee SET EName="Janie" WHERE EID="E06";
SQL> SAVEPOINT SP2;
SQL> DELETE FROM Employee WHERE EID='E02';
SQL> SAVEPOINT SP3;
SQL> UPDATE Employee SET EName="Raina" WHERE EID="E04";
SQL> ROLLBACK TO SP1
```

EID	EName
E01	Arthur
E02	Raina
E03	Meena
E04	Arthur
E06	Joey

View Serializability

Let S and $S^{'}$ be two schedules with the same set of transactions.S and $S^{'}$ view equivalent if the following conditions met

1. **Initial Read**
    - In S, T_i reads initial value of Q, then in $S^{'}$ also T_i also read initial value of Q.
2. **Write-Read Pair**
    - If in schedule S, T_i executes read(Q), and that value was produced by transaction T_j(if any), in schedule $S^{'}$ also transaction T_i must read the value of Q that was produced by the same write(Q) operation of transaction T_j
3. **Final write**
    - The transaction (if any) that performs the final write(Q) operation in schedule S must also perform the final write(Q) operation in schedule $S^{'}$

View Serializability (Continued)

- A schedule S is view serializable if it is view equivalent to a serial schedule

Note

- Every conflict serializable schedule is also view serializable
- Every view serializable schedule that is not conflict serializable has blind writes

Example

T1	T2	T3
read(Q)		
	write(Q)	
write(Q)		
		write(Q)

T1	T2	T3
read(Q)		
write(Q)		
	write(Q)	
		write(Q)

- T_{28} and T_{29} perform write(Q) operations called **blind writes**, without having performed a read(Q) operation.

Concurrency Control

A database must provide a mechanism that will ensure that all possible schedule are both:

- **Conflict serializable**
- **Recoverable and, preferably, Cascadeless**

Concurrency-control schemes tradeoff between the amount of concurrency they allow and the amount of overhead that they incur

Lock Based Protocol

A lock is a mechanism to control concurrent access to a data item
Data items can be locked in two modes:

- **exclusive (X) mode:**
  - Data item can be both read as well as written
  - X-lock is requested using lock-X instruction
- **shared (S) mode:**
  - Data item can only be read
  - S-lock is requested using lock-S instruction
- A transaction can unlock a data item Q by the unlock(Q) Instruction
- Transaction can proceed only after request is granted

Lock-Compatibility Matrix

A lock compatibility matrix is used which states whether a data item can be locked by two transactions at the same time

Lock request type

State of the lock	**Shared**	**Exclusive**
Shared	Yes	No
Exclusive	No	No

Lock Based Protocol

Requesting for / Granting of a Lock

- A transaction may be granted a lock on an item if the requested lock is compatible with locks already held on the item by other transactions

Sharing a Lock

- Any number of transactions can hold shared locks on an item
- But if any transaction holds an exclusive lock on the item no other transaction may hold any lockon the item

Lock Based Protocol (Continued)

Waiting for a Lock

- If a lock cannot be granted, the requesting transaction is made to wait till all incompatible locks held by other transactions have been released

Holding a Lock

- A transaction must hold a lock on a data item as long as it accesses that item

Unlocking / Releasing a Lock

- Transaction Ti may unlock a data item that it had locked at some earlier point.

Example: Concurrent Schedule (Bad)

In this case, transaction T2 displays $250, which is incorrect. The reason for this mistake is that

- The transaction T1 unlocked data item B too early, as a result of which T2 saw an inconsistent state.

T_1	T_2	concurrency contr
lock-X(B)		
		grant-X(B, T_1)
read(B)		
$B := B - 50$		
write(B)		
unlock(B)		
	lock-S(A)	
		grant-S(A, T_2)
	read(A)	
	unlock(A)	
	lock-S(B)	
		grant-S(B, T_2)
	read(B)	
	unlock(B)	
	display($A + B$)	
lock-X(A)		
		grant-X(A, T_1)
read(A)		
$A := A + 50$		
write(A)		
unlock(A)		

Deadlock

- A state where neither of these transactions can ever proceed with its normal execution.
- This situation is called **deadlock**
- When deadlock occurs, the system must roll back one of the two transactions
- Once a transaction has been rolled back, the data items that were locked by that transaction are unlocked.

T_3	T_4
lock-x (B)	
read (B)	
$B := B - 50$	
write (B)	
	lock-s (A)
	read (A)
	lock-s (B)
lock-x (A)	

Two Phase Locking Protocol

Phase 1: Growing Phase

- Transaction may obtain locks
- Transaction may not release locks

Phase 2: Shrinking Phase

- Transaction may release locks
- Transaction may not obtain locks

Lock Conversions

Two-phase locking with lock conversions

First Phase (Growing Phase):

- can acquire a **lock-S** on item
- can acquire a **lock-X** on item
- can convert a **lock-S** to a **lock-X** (upgrade)

Second Phase (Shrinking Phase):

- can release a **lock-S**
- can release a **lock-X**
- can convert a **lock-X** to a **lock-S** (downgrade)

Starvation

In addition to deadlocks, there is a possibility of Starvation

Starvation occurs if the concurrency control manager is badly designed. For example:

- A transaction may be waiting for an X-lock on an item, while a sequence of other transactions request and are granted an S-lock on the same item.
- The same transaction is repeatedly rolled back due to deadlocks.

Concurrency control manager can be designed to prevent starvation

More Two Phase Locking Protocols

To avoid Cascading roll-back, follow a modified protocol called **strict two-phase locking**

- A transaction must hold all its exclusive locks till it commits/aborts

Rigorous two-phase locking is even stricter

- All locks are held till commit/abort. In this protocol transactions can be serialized in the order in which they commit.

Note

- Concurrency goes down as we move to more and more strict locking protocol

Deadlock Prevention

Transaction Timestamp:

Timestamp is a unique identifier created by the database to identify the relative starting time of a transaction.

wait-die scheme: **non-preemptive**

- Older transaction wait for younger transaction.

wound-wait scheme: **preemptive**

- Younger transaction waits for older transaction.

Note

- older means smaller timestamp, younger means larger timestamp

Wait-Die Scheme

- It is a non-preemptive technique for deadlock prevention
- When transaction T_n requests a data item currently held by T_k, T_n is allowed to wait only if it has a timestamp smaller than that of T_k (That is, T_n is older than T_k), otherwise Tn is killed ("die")

$Timestamp(T_n) < Timestamp(T_k)$:

- T_n, which is requesting a conflicting lock, is older than T_k , then T_n is allowed to "wait" until the data-item is available.

$Timestamp(T_n) > Timestamp(T_k)$:

- T_n is younger than T_k , then T_n is killed ("dies").

Wound-Wait Scheme

- It is a preemptive technique for deadlock prevention.
- When transaction Tn requests a data item currently held by T_k , T_n is allowed to wait only if it has a timestamp larger than that of T_k , otherwise T_k is killed (wounded by T_n)

$Timestamp(T_n) > Timestamp(T_k)$:

- T_n "wait"s until the resource is free

$Timestamp(T_n) < Timestamp(T_k)$:

- T_n forces T_k to be killed ("wounds"). T_k is restarted later with a random delay but with the same $timestamp(k)$

Deadlock Detection

Deadlocks can be described as a wait-for graph, which consists of a pair G = (V, E),

- V is a set of vertices (all the transactions in the system)
- E is a set of edges; each element is an ordered pair $T_i \rightarrow T_j$
- If $T_i \rightarrow T_j$ is in E, then there is a directed edge from T_i to T_j, implying that T_i is waiting for T_j to release a data item
- The system is in a deadlock state if and only if the wait-for graph has a cycle

Timestamp Based Protocols

- **W-timestamp(Q)** is the largest time-stamp of any transaction that executed write(Q) successfully
- **R-timestamp(Q)** is the largest time-stamp of any transaction that executed read(Q) successfully

Timestamp Based Protocols (2)

Suppose a transaction T_i issues a read(Q)

$$TS(T_i) \leq W - timestamp(Q)$$

- Read Operation is rejected, T_i is rolled back

$$TS(T_i) \geq W - timestamp(Q)$$

- Read Operation is executed

Timestamp Based Protocols (3)

Suppose a transaction T_i issues a write(Q)

$$TS(T_i) < R-timestamp(Q)$$

- Write Operation is rejected, T_i is rolled back

$$TS(T_i) < W-timestamp(Q)$$

- Write Operation is rejected, T_i is rolled back

Otherwise, the write operation is executed, and $W-timestamp(Q)$ is set to $TS(T_i)$

Correctness of Timestamp-Ordering Protocol

- The timestamp-ordering protocol guarantees serializability
- Timestamp protocol ensures freedom from deadlock as no transaction ever waits
- But the schedule may not be cascade-free, and may not even be recoverable