Database Management Systems

Module 48: Transactions/3: Recoverability

Partha Pratim Das

Department of Computer Science and Engineering
Indian Institute of Technology, Kharagpur

ppd@cse.iitkgp.ac.in

Module Recap

- Understood the issues that arise when two or more transactions work concurrently
- Learnt the forms of serializability in terms of conflict and view serializability
- Acyclic precedence graph can ensure conflict serializability

Module Objectives

- What happens if system fails while a transaction is in execution? Can a consistent state be reached for the database? Recoverability attempts to answer issues in state and transaction recovery in the face of system failures
- Conflict serializability is a crisp concept for concurrent execution that guarantees ACID properties and has a simple detection algorithm. Yet only few schedules are Conflict serializable in practice. There is a need to explore – View Serializability – a weaker system for better concurrency

Module Outline

- Recoverability
- Transaction Definition in SQL
- View Serializability
- Complex Notions of Serializability

Recovery

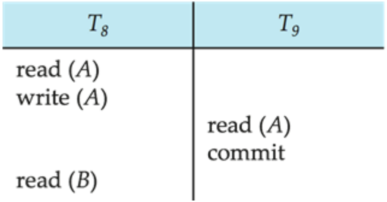
Recovery

What is Recovery?

- Serializability helps to ensure Isolation and Consistency of a schedule
- Yet, the Atomicity and Consistency may be compromised in the face of system failures
- Consider a schedule comprising a single transaction (obviously serial):
  1. **read**(A)
  2. $A := A - 50$
  3. **write**(A)
  4. **read**(B)
  5. $B := B + 50$
  6. **write**(B)
  7. **commit** // Make the changes permanent; show the results to the user
- What if system fails after Step 3 and before Step 6?
  - 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.
- The following schedule is not recoverable if T_9 commits immediately after the read(A) operation

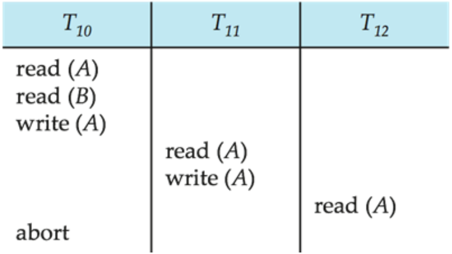


T_8	T_9
read (A)	
write (A)	
	read (A)
	commit
read (B)	

- If T_8 should abort, T_9 would have read (and possibly shown to the user) an inconsistent database state. Hence, database must ensure that schedules are recoverable

Cascading Rollbacks

- **Cascading rollback**: A single transaction failure leads to a series of transaction rollbacks. Consider the following schedule where none of the transactions has yet committed (so the schedule is recoverable)

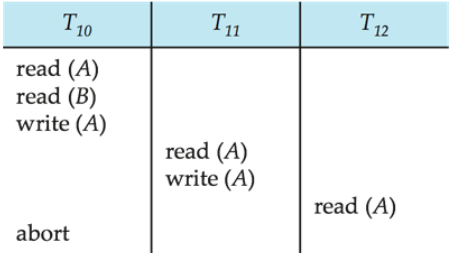


T_{10}	T_{11}	T_{12}
read (A)		
read (B)		
write (A)		
	read (A)	
	write (A)	
		read (A)
abort		

- If T_{10} fails, T_{11} and T_{12} must also be rolled back
- Can lead to the undoing of a significant amount of work

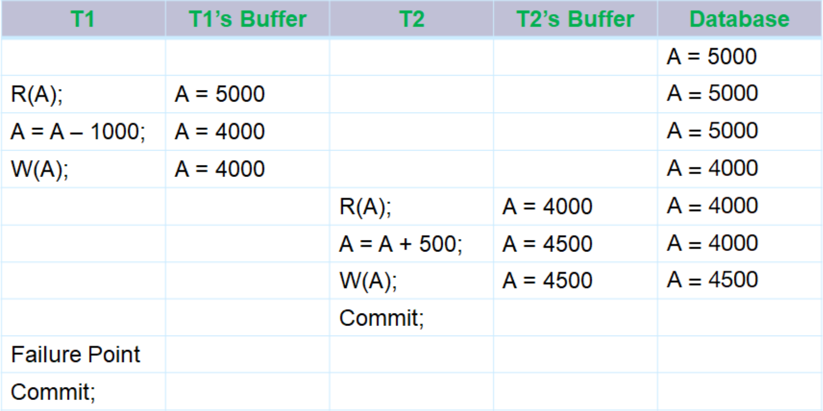
Cascadeless Schedules

- **Cascadeless schedules**: For each pair of transactions T_i and T_j such that T_j reads a data item previously written by T_i, the commit operation of T_i appears before the read operation of T_j
- Every cascadeless schedule is also recoverable
- It is desirable to restrict the schedules to those that are cascadeless
- Example of a schedule that is NOT cascadeless



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

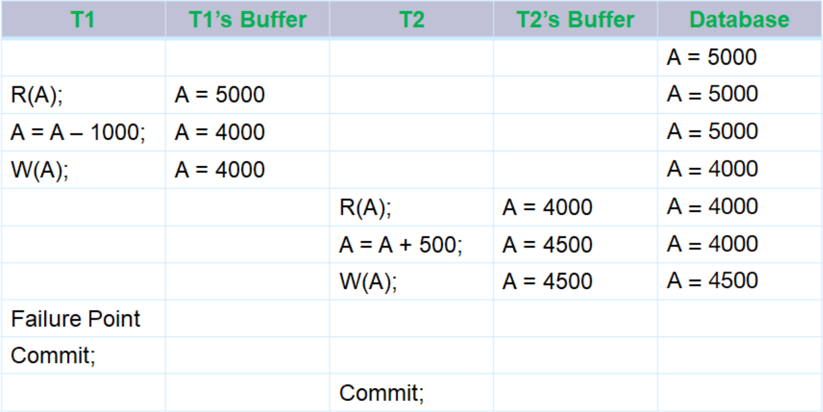
Example: Irrecoverable Schedule



T1	T1's Buffer	T2	T2's Buffer	Database
				A = 5000
R(A);	A = 5000			A = 5000
A = A – 1000;	A = 4000			A = 5000
W(A);	A = 4000			A = 4000
		R(A);	A = 4000	A = 4000
		A = A + 500;	A = 4500	A = 4000
		W(A);	A = 4500	A = 4500
		Commit;		
Failure Point				
Commit;				

Rollback is possible only till the end (commit) of T2. So the computation of A (4000) and write in T1 is lost.

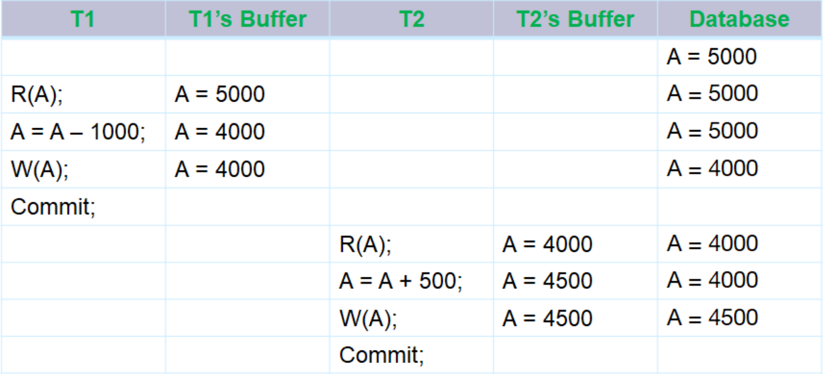
Example: Recoverable Schedule with Cascading Rollback



T1	T1's Buffer	T2	T2's Buffer	Database
				A = 5000
R(A);	A = 5000			A = 5000
A = A – 1000;	A = 4000			A = 5000
W(A);	A = 4000			A = 4000
		R(A);	A = 4000	A = 4000
		A = A + 500;	A = 4500	A = 4000
		W(A);	A = 4500	A = 4500
Failure Point				
Commit;				
		Commit;		

Rollback is possible as T2 has not committed yet. But T2 also need to be rolled back for rolling back T1.

Example: Recoverable Schedule without Cascading Rollback



T1	T1's Buffer	T2	T2's Buffer	Database
				A = 5000
R(A);	A = 5000			A = 5000
A = A – 1000;	A = 4000			A = 5000
W(A);	A = 4000			A = 4000
Commit;				
		R(A);	A = 4000	A = 4000
		A = A + 500;	A = 4500	A = 4000
		W(A);	A = 4500	A = 4500
		Commit;		

Rollback is possible without cascading - wherever failure occurs.

Transaction Definition in SQL

Transaction Definition in SQL

Transaction Definition in SQL

- Data manipulation language must include a construct for specifying the set of actions that comprise a transaction
  - In SQL, a transaction begins implicitly
  - A transaction in SQL ends by:
    - **Commit work**
      - Commits current transaction and begins a new one
    - **Rollback work**
      - Causes current transaction to abort
  - In almost all database systems, by default, every SQL statement also commits implicitly if it executes successfully
    - Implicit commit can be turned off by a database directive
      - For example in JDBC, connection.setAutoCommit(false);

Transaction Control Language (TCL)

- The following commands are used to control transactions
  - **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
- Transactional control commands are only used with the **DML Commands** such as
  - INSERT, UPDATE and DELETE only
  - They cannot be used while creating tables or dropping them because these operations are automatically committed in the database

Source: SQL - Transactions

TCL: COMMIT Command

- COMMIT is the transactional command used to save changes invoked by a transaction to the database
- COMMIT saves all the transactions to the database since the last COMMIT or ROLLBACK command
- The syntax for the COMMIT command is as follows:
  - `SQL> DELETE FROM Customers WHERE AGE = 25;`
  - `SQL> COMMIT;`

```
SQL> SELECT * FROM Customers;
```

Before DELETE

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
2	Khilan	25	Delhi	1500
3	kaushik	23	Kota	2000
4	Chaitali	25	Mumbai	6500
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

```
SQL> SELECT * FROM Customers;
```

After DELETE

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
3	kaushik	23	Kota	2000
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

Source: SQL - Transactions

TCL: ROLLBACK Command

- The ROLLBACK is the command used to undo transactions that have not already been saved to the database
- This can only be used to undo transactions since the last COMMIT or ROLLBACK command was issued
- The syntax for a ROLLBACK command is as follows:
  - ○ `SQL> DELETE FROM Customers WHERE AGE = 25;`
  - ○ `SQL> ROLLBACK;`

```
SQL> SELECT * FROM Customers;
```

Before DELETE

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
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6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

```
SQL> SELECT * FROM Customers;
```

After DELETE

ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
2	Khilan	25	Delhi	1500
3	kaushik	23	Kota	2000
4	Chaitali	25	Mumbai	6500
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

Source: SQL - Transactions

TCL: SAVEPOINT / ROLLBACK Command

- A SAVEPOINT is a point in a transaction when you can roll the transaction back to a certain point without rolling back the entire transaction
- The syntax for a SAVEPOINT command is:
  - `SAVEPOINT SAVEPOINT_NAME;`
- This command serves only in the creation of a SAVEPOINT among all the transactional statements.
- The ROLLBACK command is used to undo a group of transactions
- The syntax for rolling back to a SAVEPOINT is:
  - `ROLLBACK TO SAVEPOINT_NAME;`

Example:

- `SQL> SAVEPOINT SP1;`
  - Savepoint created.
- `SQL> DELETE FROM Customers WHERE ID=1;`
  - 1 row deleted.
- `SQL> SAVEPOINT SP2;`
  - Savepoint created.
- `SQL> DELETE FROM Customers WHERE ID=2;`
  - 1 row deleted.
- `SQL> SAVEPOINT SP3;`
  - Savepoint created.
- `SQL> DELETE FROM Customers WHERE ID=3;`
  - 1 row deleted.

Source: SQL - Transactions

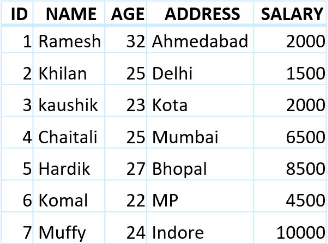
TCL: SAVEPOINT / ROLLBACK Command

- Three records deleted
- Undo the deletion of last two
- `SQL> ROLLBACK TO SP2;`
  - Rollback complete

```
SQL> SAVEPOINT SP1;
SQL> DELETE FROM Customers WHERE ID=1;
SQL> SAVEPOINT SP2;
SQL> DELETE FROM Customers WHERE ID=2;
SQL> SAVEPOINT SP3;
SQL> DELETE FROM Customers WHERE ID=3;
```

```
SQL> SELECT * FROM Customers
```

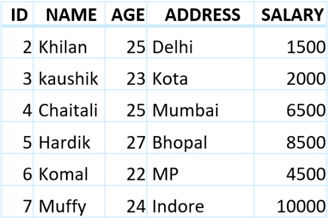
At the beginning



ID	NAME	AGE	ADDRESS	SALARY
1	Ramesh	32	Ahmedabad	2000
2	Khilan	25	Delhi	1500
3	kaushik	23	Kota	2000
4	Chaitali	25	Mumbai	6500
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

```
SQL> SELECT * FROM Customers;
```

After ROLLBACK



ID	NAME	AGE	ADDRESS	SALARY
2	Khilan	25	Delhi	1500
3	kaushik	23	Kota	2000
4	Chaitali	25	Mumbai	6500
5	Hardik	27	Bhopal	8500
6	Komal	22	MP	4500
7	Muffy	24	Indore	10000

Source: SQL - Transactions

TCL: RELEASE SAVEPOINT Command

- The RELEASE SAVEPOINT command is used to remove a SAVEPOINT that you have created
- The syntax for a RELEASE SAVEPOINT command is as follows
  - `RELEASE SAVEPOINT SAVEPOINT_NAME;`
- Once a SAVEPOINT has been released, you can no longer use the ROLLBACK command to undo transactions performed since the last SAVEPOINT

Source: SQL - Transactions

TCL: SET TRANSACTION Command

- The SET TRANSACTION command can be used to initiate a database transaction
- This command is used to specify characteristics for the transaction that follows
  - For example, you can specify a transaction to be read only or read write
- The syntax for a SET TRANSACTION command is as follows:
  - `SET TRANSACTION [ READ WRITE | READ ONLY ];`

Source: SQL - Transactions

View Serializability

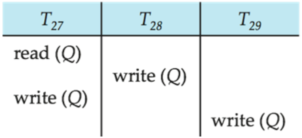
View Serializability

View Serializability

- Let S and S' be two schedules with the same set of transactions. S and S' are **view equivalent** if the following three conditions are met, for each data item Q,
  - **Initial Read**: If in schedule S, transaction T_i reads the initial value of Q, then in schedule S' also transaction T_i must read the initial value of Q
  - **Write-Read Pair**: If in schedule S transaction T_i executes **read**(Q), and that value was produced by transaction T_j (if any), then 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
  - **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'
- As can be seen, view equivalence is also based purely on **reads** and **writes** alone

View Serializability (2)

- A schedule S is **view serializable** if it is view equivalent to a serial schedule
- *Every conflict serializable schedule is also view serializable*
- Below is a schedule which is view-serializable but *not* conflict serializable



T_{27}	T_{28}	T_{29}
read (Q)		
	write (Q)	
write (Q)		
		write (Q)

- What serial schedule is above equivalent to?
  - $T_{27} - T_{28} - T_{29}$
  - The one read(Q) instruction reads the initial value of Q in both schedules and
  - T_{29} performs the final write of Q in both schedules
- T_{28} and T_{29} perform write(Q) operations called **blind writes**, without having performed a read(Q) operation
- *Every view serializable schedule that is not conflict serializable has* ***blind writes***

Test for View Serializability

- The precedence graph test for conflict serializability cannot be used directly to test for view serializability
  - Extension to test for view serializability has cost exponential in the size of the precedence graph
- The problem of checking if a schedule is view serializable falls in the class of *NP*-complete problems
  - Thus, existence of an efficient algorithm is *extremely* unlikely
- However, practical algorithms that just check some **sufficient conditions** for view serializability can still be used

View Serializability: Example 1

- Check whether the schedule is view serializable or not?
  - $S: R2(B); R2(A); R1(A); R3(A); W1(B); W2(B); W3(B);$
- Solution:
  - With 3 transactions, total number of schedules possible $= 3! = 6$
    - $< T_1 T_2 T_3 >$
    - $< T_1 T_3 T_2 >$
    - $< T_2 T_3 T_1 >$
    - $< T_2 T_1 T_3 >$
    - $< T_3 T_1 T_2 >$
    - $< T_3 T_2 T_1 >$

Source: *http://www.edugrabs.com/how-to-check-for-view-serializable-schedule/* (Accessed 12-Feb-18)

View Serializability: Example 1 (2)

- Check whether the schedule is view serializable or not?
  - $S : R2(B); R2(A); R1(A); R3(A); W1(B); W2(B); W3(B);$
- Solution:
  - Final update on data items:
    - ▷ $A : -$ (No write on A)
    - ▷ $B : T_1, \ T_2, \ T_3$ (All 3 transactions write B)
    - ▷ As the final update on B is made by T_3, $(T_1, T_2) \rightarrow T_3$. Now, Removing those schedules in which T_3 is not executing at last:
      - $< T_1 T_2 T_3 >$
      - $< T_2 T_1 T_3 >$

Source: *http://www.edugrabs.com/how-to-check-for-view-serializable-schedule/* (Accessed 12-Feb-18)

View Serializability: Example 1 (3)

- Check whether the schedule is view serializable or not?
  - $S : R2(B); R2(A); R1(A); R3(A); W1(B); W2(B); W3(B);$
- Solution:
  - Initial Read + Which transaction updates after read?
    - ▷ $A : T_2,\ T_1,\ T_3$ (initial read)
    - ▷ $B : T_2$ (initial read); T_1 (update after read)
    - ▷ The transaction T_2 reads B initially which is updated by T_1. So T_2 must execute before T_1. Hence, $T_2 \rightarrow T_1$. So only one schedule survives:
    - ▷ $< T_2\ T_1\ T_3 >$
  - Write Read Sequence (WR)
    - ▷ No need to check here
  - Hence, view equivalent serial schedule is:
    - ▷ $\boldsymbol{T}_2 \rightarrow \boldsymbol{T}_1 \rightarrow \boldsymbol{T}_3$

Source: *http://www.edugrabs.com/how-to-check-for-view-serializable-schedule/* (Accessed 12-Feb-18)

View Serializability: Example 2

- Check whether S is Conflict serializable and / or view serializable or not?
  - $S : R1(A); R2(A); R3(A); R4(A); W1(B); W2(B); W3(B); W4(B)$
- Solution is given in the next slide (hidden). First try to solve this and then check the solution.

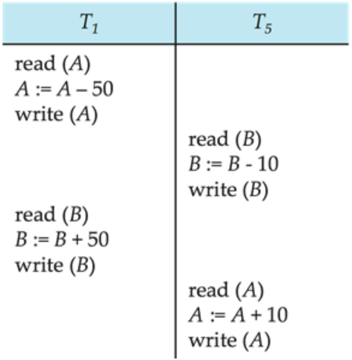
Source: Given in solution slides

Complex Notions of Serializability

Complex Notions of Serializability

More Complex Notions of Serializability

- The schedule below produces the same outcome as the serial schedule $< T1, T5 >$, yet is not conflict equivalent or view equivalent to it



T_1	T_5
read (A)	
$A := A - 50$	
write (A)	
	read (B)
	$B := B - 10$
	write (B)
read (B)	
$B := B + 50$	
write (B)	
	read (A)
	$A := A + 10$
	write (A)

- If we start with $A = 1000$ and $B = 2000$, the final result is 960 and 2040
- Determining such equivalence requires analysis of operations other than read and write

Module Summary

- With proper planning, a database can be recovered back to a consistent state from inconsistent state in the face of system failures. Such a recovery is done via cascaded or cascadeless rollback
- View Serializability is a weaker serializability system for better concurrency. However, testing for view serializability is NP complete

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