Comp 5311 Database Management Systems

15. Timestamp-based Protocols

Timestamps

- Each transaction is issued a timestamp when it enters the system. If an old transaction T_i has time-stamp TS(T_i), a new transaction T_j is assigned time-stamp TS(T_j) such that TS(T_i) <TS(T_j).
- The protocol manages concurrent execution such that the time-stamps determine the serializability order.
- In order to assure such behavior, the protocol maintains for each data Q two timestamp values:
  - **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 – Read operation

- The timestamp ordering protocol ensures that any conflicting **read** and **write** operations are executed in timestamp order.

Suppose a transaction T_i issues a **read**(Q)

1. If TS(T_i) < **W**-timestamp(Q), then T_i needs to read a value of Q that was already overwritten. Hence, the **read** operation is rejected, and T_i is rolled back.
   - T_i will restart with a new (larger) timestamp $TS'(T_i)$
2. If TS(T_i)≥ **W**-timestamp(Q), then the **read** operation is executed, and R-timestamp(Q) is set to the maximum of R-timestamp(Q) and TS(T_i).

Timestamp-Based Protocols – Write operation

Suppose that transaction T_i issues **write**(Q).

If TS(T_i) < R-timestamp(Q), then the value of Q that T_i is producing was needed previously, and the system assumed that that value would never be produced. Hence, the **write** operation is rejected, and T_i is rolled back.

If TS(T_i) < W-timestamp(Q), then T_i is attempting to write an obsolete value of Q. Hence, this **write** operation is rejected, and T_i is rolled back.

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

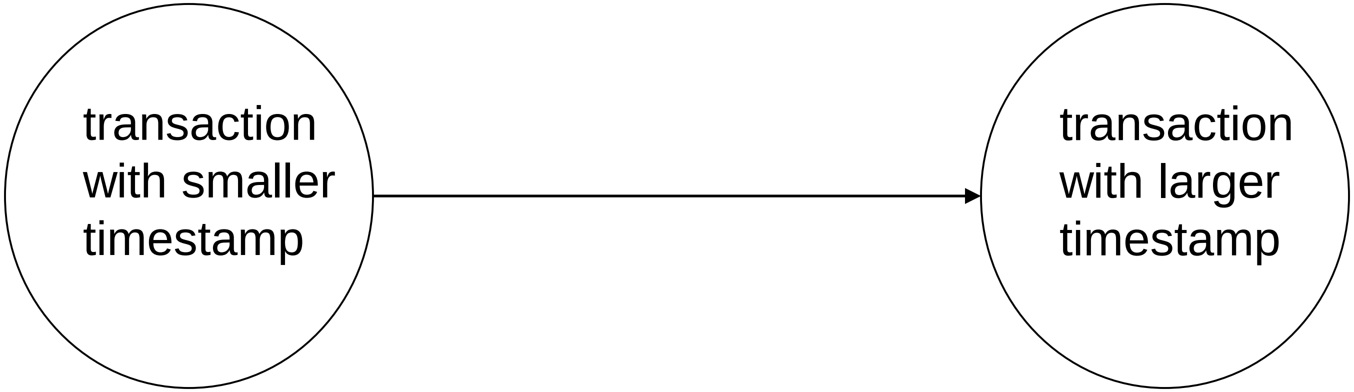
Example of TS Protocol

A partial schedule for several data items for transactions with timestamps 1, 2, 3, 4, 5

T_1=1	T_2=2	T_3=3	T_4=4	T_5=5
				read(*X*) RTS(*X*)=5
	read(*Y*)- RTS(*Y*)=2			
read(*Y*) RTS(*Y*)=2				
		write(*Y*) W/RTS(*Y*)=3		
		write(*Z*) W/RTS(*Z*)=3		
				read(***Z***) RTS(*Z*)=5
	read(*Z or Y*) abort			
read(*X*) RTS(*X*)=5				
		write(*Z*) abort		
				write(*Y*)
				write(*Z*)

Correctness of Timestamp-Ordering Protocol

- The timestamp-ordering protocol guarantees serializability since all the arcs in the precedence graph are of the form:



- Thus, there will be no cycles in the precedence graph
- Timestamp protocol ensures freedom from deadlock as no transaction ever waits.
- But the schedule may not recoverable.

Recoverability and Cascade Freedom

- Problem with timestamp-ordering protocol:
  - Suppose T_i aborts, but T_j has read a data item written by T_i
  - Then T_j must abort; if T_j had been allowed to commit earlier, the schedule is not recoverable.
  - Further, any transaction that has read a data item written by T_j must abort
  - This can lead to cascading rollback --- that is, a chain of rollbacks
- Solution:
  - A transaction is structured such that its writes are all performed at the end of its processing
  - All writes of a transaction form an atomic action; no transaction may execute while a transaction is being written
  - A transaction that aborts is restarted with a new timestamp

Multiversion Schemes

- Multiversion schemes keep old versions of data item to increase concurrency.
  - Multiversion Timestamp Ordering
  - Multiversion Two-Phase Locking
- Each successful **write** results in the creation of a new version of the data item written.
- Use timestamps to label versions.
- When a **read**(Q) operation is issued, select an appropriate version of Q based on the timestamp of the transaction, and return the value of the selected version.
- **reads** never fail as an appropriate version can always be found.

Multiversion Timestamp Ordering

- Each data item Q has a sequence of versions $<Q_1, Q_2, \ldots, Q_m>$. Each version Q_k contains three data fields:
  - **Content** -- the value of version Q_k.
  - **W-timestamp**(Q_k) -- timestamp of the transaction that created (wrote) version Q_k
  - **R-timestamp**(Q_k) -- largest timestamp of a transaction that successfully read version Q_k
- when a transaction T_i creates a new version Q_k of Q, Q_k's W-timestamp and R-timestamp are initialized to TS(T_i).
- R-timestamp of Q_k is updated whenever a transaction T_j reads Q_k, and TS(T_j) > R-timestamp(Q_k).

Multiversion Timestamp Ordering Read and Write

Suppose that transaction T_i issues a **read**(Q) or **write**(Q) operation. Let Q_k be the version of Q whose write timestamp is the largest write timestamp less than or equal to TS(T_i).

1. If transaction T_i issues a **read**(Q), then the value returned is the content of version Q_k. Reads always succeed.

2. If transaction T_i issues a **write**(Q),
   if TS(T_i) < R-timestamp(Q_k), then transaction T_i is rolled back. Some other transaction T_j that (in the serialization order defined by the timestamp values) should read T_i's write, has already read a version created by a transaction older than T_i.
   If TS(T_i) = W-timestamp(Q_k), the contents of Q_k are overwritten; Q_k was written before also by T_i.
   If TS(T_i) > W-timestamp(Q_k) a new version of Q is created.

Conflicts are resolved through aborting transactions.

Summary

- All protocols that we have seen (e.g., 2PL, TS Ordering, Multiversion protocols) ensure correctness.
- However, a correct schedule may not be permitted by a protocol.
- The more correct schedules allowed by a protocol, the more the degree of concurrency
- Multiversion TS protocols also allow schedules that are not conflict serializable, but generate correct results.
- The protocols also differ on the way they handle conflicts: (i) Lock-based protocols make transactions wait (thus they can result in deadlocks); (ii) TS ordering protocols make transactions abort (thus there are no deadlocks but aborting a transaction may be more expensive).

Summary (cont)

- **Recoverability** is a necessary property of a schedule, which means that a transaction that has committed should not be rolled back.
- In order to ensure recoverability, a transaction T_i can commit only after all transactions that wrote items which T_i read have committed.
- A cascading rollback happens when an *uncommitted* transaction must be rolled back because it read an item written from a transaction that failed.
- It is desirable to have cascadeless schedules. In order to achieve this property a transaction should only be allowed to read items written by committed operations.

Summary (cont)

- If a schedule is cascadeless, it is also recoverable.
- Strict 2PL ensures cascadeless schedules by releasing all exclusive locks of transaction T_i after T_i commits (therefore other transactions cannot read the items locked by T_i at the same time)
- TS ordering protocols can also achieve cascadeless schedules by performing all the writes at the end of the transaction as an atomic operation.