Chapter 15 : Concurrency Control

Database System Concepts, 6th Ed.

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Concurrency Control

- A database must provide a mechanism that will ensure that all possible schedules are
  - either conflict or view serializable, and
  - are recoverable and preferably cascadeless
- A policy in which only one transaction can execute at a time generates serial schedules, but provides a poor degree of concurrency
- Testing a schedule for serializability *after* it has executed is a little too late
- **Goal** – to develop concurrency control protocols that will assure serializability
  - Concurrency-control schemes tradeoff between the amount of concurrency they allow and the amount of overhead that they incur

Lock-Based Protocols

- A lock is a mechanism to control concurrent access to a data item
- Data items can be locked in two modes:
  1. ***exclusive*** *(X) mode*. Data item can be both read as well as written. X-lock is requested using **lock-X** instruction.
  2. ***shared*** *(S) mode*. Data item can only be read. S-lock is requested using **lock-S** instruction.
- Lock requests are made to concurrency-control manager
- Transaction can proceed only after request is granted

Granting of Locks

- **Lock-compatibility matrix**

	S	X
S	true	false
X	false	false

- 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
- Any number of transactions can hold shared locks on an item
- If any transaction holds an exclusive lock on the item no other transaction may hold any lock on the item
- If a lock cannot be granted, the requesting transaction is made to wait till all incompatible locks held by other transactions have been released

Transaction with Locking

- Example of a transaction performing locking:

  T_2: **lock-S**(*A*);
  read (*A*);
  unlock(*A*);
  lock-S(*B*);
  read (*B*);
  unlock(*B*);
  display(*A+B*)

- A **locking protocol** is a set of rules followed by all transactions while requesting and releasing locks
- Locking protocols restrict the set of possible schedules

Pitfalls of Lock-Based Protocols

- Consider the partial schedule

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)	

- Neither T_3 nor T_4 can make progress
  - Executing **lock-S**(*B*) causes T_4 to wait for T_3 to release its lock on *B*
  - Executing **lock-X**(*A*) causes T_3 to wait for T_4 to release its lock on *A*
- Such a situation is called a **deadlock**
  - To handle a deadlock one of T_3 or T_4 must be rolled back and its locks released

Pitfalls of Lock-Based Protocols (Cont.)

- The potential for deadlock exists in most locking protocols
  - Deadlocks are a necessary evil
- **Starvation** is also possible if concurrency control manager is badly designed
- 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

Two-Phase Locking Protocol (2PL)

- This is a protocol which ensures conflict-serializable schedules
- 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
- The protocol assures (conflict) serializability
  - The transactions can be serialized in the order of their **lock points** (i.e., the point where a transaction acquired its final lock)
  - There can be conflict serializable schedules that cannot be obtained if two-phase locking is used

Partial Schedule Under 2PL

T_5	T_6	T_7
lock-X(A)		
read(A)		
lock-S(B)		
read(B)		
write(A)		
unlock(A)		
	lock-X(A)	
	read(A)	
	write(A)	
	unlock(A)	
		lock-S(A)
		read(A)

Strict / Rigorous 2PL

- Two-phase locking *does not* ensure freedom from deadlocks
- Cascading roll-back is possible under two-phase locking

- **Strict two-phase locking**
  - Here a transaction must hold all its exclusive locks till it commits/aborts
  - No cascading rollback
- **Rigorous two-phase locking**
  - Here *all* locks(shared and exclusive) are held till commit/abort
  - No cascading rollback (of course)
  - In this protocol transactions can be serialized in the order in which they commit

Lock Conversions

- The original lock mode with (lock-X, lock-S)
  - assign lock-X on a data D when D is both read and written
- Two-phase locking with lock conversions:
  - First 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:
    - can release a lock-S
    - can release a lock-X
    - can convert a lock-X to a lock-S (downgrade)
- This protocol assures serializability
- The refined 2PL gets more concurrency than the original 2PL

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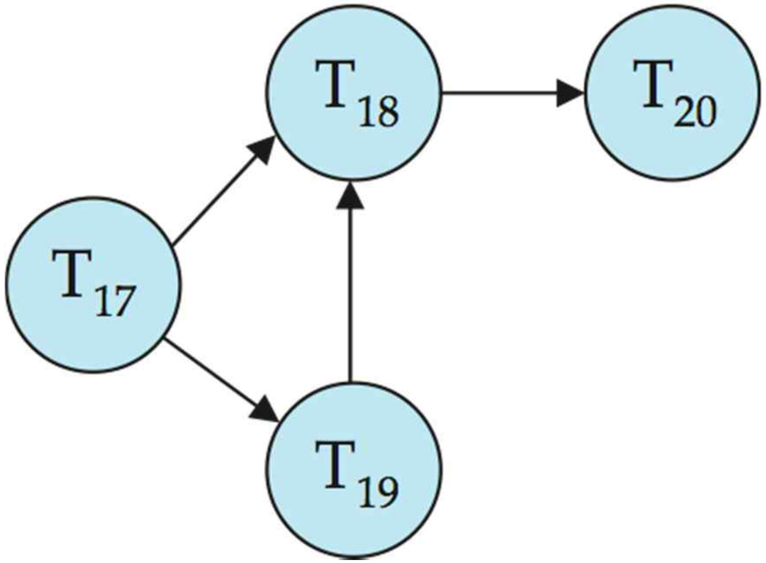
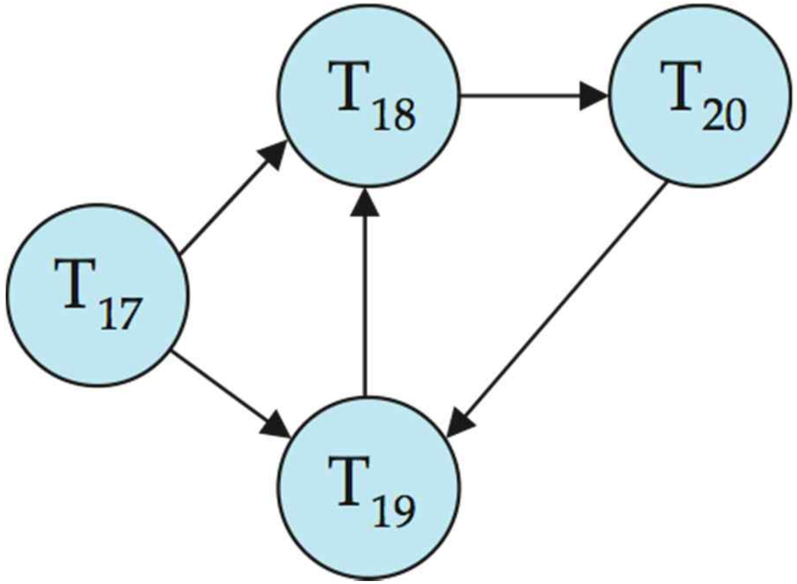
Deadlock Detection

- 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
- When T_i requests a data item currently being held by T_j, then the edge $T_i \rightarrow T_j$ is inserted in the wait-for graph
  - This edge is removed only when T_j is no longer holding a data item needed by T_i
- The system is in a deadlock state if and only if the wait-for graph has a cycle
  - Must invoke a deadlock-detection algorithm periodically to look for cycles

Deadlock Detection (Cont.)



Wait-for graph without a cycle



Wait-for graph with a cycle

Multiversion Two-Phase Locking

- Motivation: Decision support queries that read large amounts of data have concurrency conflicts with OLTP transactions that update a few rows
  - Poor performance results
- Multiversion schemes keep old versions of data item to increase concurrency
  - Differentiates between read-only transactions and update transactions
  - Ts-counter is a global time-stamp clock
    - This is incremented during commit processing
- ***Update transactions*** acquire read and write locks, and hold all locks up to the end of the transaction
  - Each successful **write** results in the creation of a new version of the data item written
  - Each version of a data item has a single timestamp whose value is obtained from **ts-counter**
- ***Read-only transactions*** are assigned a timestamp by reading the current value of **ts-counter** before they start execution

Multiversion Two-Phase Locking (Cont.)

- Creation of multiple versions increases storage overhead
  - Extra tuples
  - Extra space in each tuple for storing version information
- Versions can, however, be garbage collected
  - E.g., if Q has two versions Q5 and Q9, and the oldest active transaction has timestamp > 9, than Q5 will never be required again
- Problem: works well, but how does system know a transaction is read only?

Snapshot Isolation

- A transaction T2 executing with Snapshot Isolation
  - takes snapshot of committed data at start
  - always reads/modifies data in its own snapshot
  - updates of concurrent transactions are not visible to T2
  - writes of T2 complete when it commits
  - **First-committer-wins rule**:
    - Commits only if no other concurrent transaction has already written data that T2 intends to write

T1	T2	T3
W(Y := 1) Commit		
	Start R(X) → 0 R(Y)→ 1	
		W(X:=2) W(Z:=3) Commit
	R(Z) → 0 R(Y) → 1 W(X:=3) Commit-Req Abort	

Concurrent updates not visible

Own updates are visible

Not first-committer of X

Serialization error, T2 is rolled back

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Benefits of Snapshot Isolation

- Reading is *never* blocked
  - and also doesn't block other txs activities
- Performance similar to Read Committed
- Avoids the usual anomalies
  - No dirty read
  - No lost update
  - No non-repeatable read
  - Predicate based selects are repeatable
- Problems with SI
  - SI does not always give serializable executions
    - Serializable: among two concurrent txs, one sees the effects of the other
    - SI: neither sees the effects of the other
  - Result: integrity constraints can be violated
- Variants implemented in many database systems
  - E.g., Oracle, PostgreSQL, SQL Server 2005

Weak Levels of Consistency in SQL

- SQL allows non-serializable executions
  - **Serializable**: is the default
  - **Repeatable read**: allows only committed records to be read, and repeating a read should return the same value (so read locks should be retained)
    - However, the phantom phenomenon need not be prevented
      - T1 may see some records inserted by T2, but may not see others inserted by T2
  - **Read committed**: only committed records can be read, but successive reads of record may return different (but committed) values
  - **Read uncommitted:** even uncommitted records may be read
- In many database systems, read committed is the default consistency level
  - has to be explicitly changed to serializable when required
    - **set isolation level serializable**

End of Chapter 15

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