

Transaction Management Overview

Chapter 16

Transactions

- ❖ Concurrent execution of user programs is essential for good DBMS performance.
 - Because disk accesses are frequent, and relatively slow, it is important to keep the CPU humming by working on several user programs concurrently.
- ❖ A user's program may carry out many operations on the data retrieved from the database, but the DBMS is only concerned about what data is read/written from/to the database.
- ❖ A transaction is the DBMS's abstract view of a user program: a sequence of reads and writes.

Concurrency in a DBMS

- ❖ Users submit transactions, and can think of each transaction as executing by itself.
 - Concurrency is achieved by the DBMS, which interleaves actions (reads/writes of DB objects) of various transactions.
 - Each transaction must leave the database in a consistent state if the DB is consistent when the transaction begins.
 - DBMS will enforce some ICs, depending on the ICs declared in CREATE TABLE statements.
 - Beyond this, the DBMS does not understand the semantics of the data. (e.g., it does not understand how the interest on a bank account is computed).
- ❖ Issues: Effect of *interleaving* transactions, and of *crashes*.

Atomicity of Transactions

- ❖ A transaction might *commit* after completing all its actions, or it could *abort* (or be aborted by the DBMS) after executing some actions.
- ❖ A very important property guaranteed by the DBMS for all transactions is that they are *atomic*. That is, a user can think of a Xact as always executing all its actions in one step, or not executing any actions at all.
 - DBMS *logs* all actions so that it can *undo* the actions of aborted transactions.

Example

- ❖ Consider two transactions (*Xacts*):

```
T1:  BEGIN  A=A+100,  B=B-100  END
T2:  BEGIN  A=1.06*A,  B=1.06*B  END
```

- ❖ Intuitively, the first transaction is transferring \$100 from B's account to A's account. The second is crediting both accounts with a 6% interest payment.
- ❖ There is no guarantee that T1 will execute before T2 or vice-versa, if both are submitted together. However, the net effect *must* be equivalent to these two transactions running serially in some order.

Example (Cont.)

- ❖ Consider a possible interleaving (schedule):

T1:	$A=A+100,$	$B=B-100$
T2:	$A=1.06*A,$	$B=1.06*B$

- ❖ This is OK. But what about:

T1:	$A=A+100,$	$B=B-100$
T2:	$A=1.06*A,$	$B=1.06*B$

- ❖ The DBMS's view of the second schedule:

T1:	$R(A), W(A),$	$R(B), W(B)$
T2:	$R(A), W(A), R(B), W(B)$	

Scheduling Transactions

- ❖ Serial schedule: Schedule that does not interleave the actions of different transactions.
- ❖ Equivalent schedules: For any database state, the effect (on the set of objects in the database) of executing the first schedule is identical to the effect of executing the second schedule.
- ❖ Serializable schedule: A schedule that is equivalent to some serial execution of the transactions.
(Note: If each transaction preserves consistency, every serializable schedule preserves consistency.)

Anomalies with Interleaved Execution

- ❖ Reading Uncommitted Data (WR Conflicts, "dirty reads"):

T1: R(A), W(A),	R(B), W(B), Abort
T2:	R(A), W(A), Commit

- ❖ Unrepeatable Reads (RW Conflicts):

T1: R(A),	R(A), W(A), Commit
T2:	R(A), W(A), Commit

Anomalies (Cont.)

❖ Overwriting Uncommitted Data (WW Conflicts):

T1:	W(A),	W(B), Commit
T2:	W(A), W(B), Commit	

Lock-Based Concurrency Control

❖ Strict Two-phase Locking (Strict 2PL) Protocol:

- Each Xact must obtain a **S (shared) lock** on object before reading, and an **X (exclusive) lock** on object before writing.
- All locks held by a transaction are released when the transaction completes
 - **(Non-strict) 2PL Variant:** Release locks anytime, but cannot acquire locks after releasing any lock.
- If an Xact holds an X lock on an object, no other Xact can get a lock (S or X) on that object.

❖ Strict 2PL allows only serializable schedules.

- Additionally, it simplifies transaction aborts
- **(Non-strict) 2PL** also allows only serializable schedules, but involves more complex abort processing

Aborting a Transaction

- ❖ If a transaction T_i is aborted, all its actions have to be undone. Not only that, if T_j reads an object last written by T_i , T_j must be aborted as well!
- ❖ Most systems avoid such *cascading aborts* by releasing a Xact's locks only at commit time.
 - If T_i writes an object, T_j can read this only after T_i commits.
- ❖ In order to *undo* the actions of an aborted transaction, the DBMS maintains a *log* in which every write is recorded. This mechanism is also used to recover from system crashes: all active Xacts at the time of the crash are aborted when the system comes back up.

The Log

- ❖ The following actions are recorded in the log:
 - *Ti writes an object*: the old value and the new value.
 - Log record must go to disk before the changed page!
 - *Ti commits/aborts*: a log record indicating this action.
- ❖ Log records are chained together by Xact **id**, so it's easy to undo a specific Xact.
- ❖ Log is often *duplexed* and *archived* on stable storage.
- ❖ All log related activities (and in fact, all CC related activities such as lock/unlock, dealing with deadlocks etc.) are handled transparently by the DBMS.

Recovering From a Crash

- ❖ There are 3 phases in the *Aries* recovery algorithm:
 - Analysis: Scan the log forward (from the most recent *checkpoint*) to identify all Xacts that were active, and all dirty pages in the buffer pool at the time of the crash.
 - Redo: Redoes all updates to dirty pages in the buffer pool, as needed, to ensure that all logged updates are in fact carried out and written to disk.
 - Undo: The writes of all Xacts that were active at the crash are undone (by restoring the *before value* of the update, which is in the log record for the update), working backwards in the log. (Some care must be taken to handle the case of a crash occurring during the recovery process!)

Summary

- ❖ Concurrency control and recovery are among the most important functions provided by a DBMS.
- ❖ Users need not worry about concurrency.
 - System automatically inserts lock/unlock requests and schedules actions of different Xacts in such a way as to ensure that the resulting execution is equivalent to executing the Xacts one after the other in some order.
- ❖ Write-ahead logging (WAL) is used to undo the actions of aborted transactions and to restore the system to a consistent state after a crash.
 - *Consistent state*: Only the effects of committed Xacts seen.