Concurrency Control and Recovery

Module 6, Lecture 1A

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 really understand the semantics of the data. (e.g., it does not understand how the interest on a bank account is computed).
- <u>*Issues:*</u> Effect of *interleaving* transactions, and *crashes*.

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 (Contd.)

- 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
```

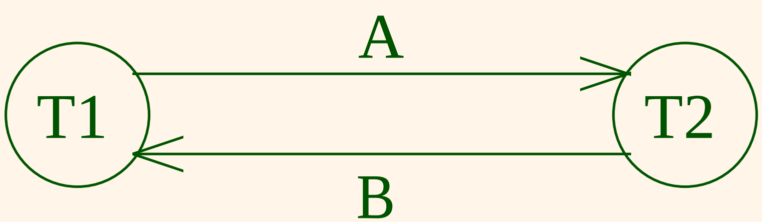
- The DBMS's view of the second schedule:

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

Example (Contd.)

- The DBMS must not allow schedules like this!

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



Dependency graph

- *Dependency graph*: One node per Xact; edge from *Ti* to *Tj* if *Tj* reads or writes an object last written by *Ti*.
- The cycle in the graph reveals the problem. The output of T1 depends on T2, and vice-versa.

Scheduling 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.
  - If the dependency graph of a schedule is *acyclic*, the schedule is called *conflict serializable*. Such a schedule is equivalent to a serial schedule.
  - This is the condition that is typically enforced in a DBMS (although it is not necessary for serializability).

Enforcing (Conflict) Serializability

- *Two-phase Locking (2PL) Protocol*:
  - Each Xact must obtain a S (*shared*) lock on object before reading, and an X (*exclusive*) lock on object before writing.
  - Once an Xact releases *any* lock, it cannot obtain new locks.
  - If an Xact holds an X lock on an object, no other Xact can get a lock (S or X) on that object.
- 2PL allows only conflict-serializable schedules.
- Potential problem of *deadlocks:* we could have a *cycle* of Xacts, T1, T2, ... , Tn, with each Ti waiting for its predecessor to release some lock that it needs.
  - Dealt with by killing one of them and releasing its locks.

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.
- This ensures that if each Xact preserves consistency, every serializable schedule preserves consistency.

Aborting a Transaction

- If a transaction *Ti* is aborted, all its actions have to be undone. Not only that, if *Tj* reads an object last written by *Ti*, *Tj* must be aborted as well!
- Most systems avoid such *cascading aborts* by releasing a transaction's locks only at commit time.
  - If *Ti* writes an object, *Tj* can read this only after *Ti* 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 commited Xacts seen.