

# Transaction Management

## Overview

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## 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.

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## 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).
- Issues: Effect of *interleaving* transactions, and *crashes*.

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## 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.

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## 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.

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## 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)	

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## 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. )

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## 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), C	

- Unrepeatable Reads (RW Conflicts):

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

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## Anomalies (Continued)

- Overwriting Uncommitted Data (WW Conflicts):

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

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## 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
  - 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.

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## 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 transaction'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.

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## The Log

- The following actions are recorded in the log:
  - $T_i$  writes an object: the old value and the new value.
    - Log record must go to disk *before* the changed page!
  - $T_i$  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.

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## 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!)

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## 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.

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