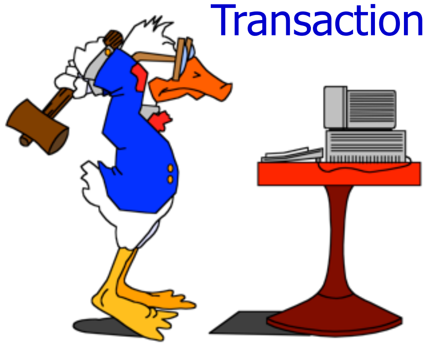
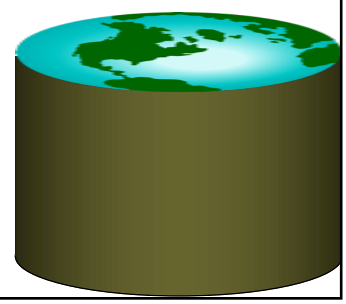
Transaction Management Overview



Chapter 16



There are three side effects of acid.
Enhanced long term memory,
decreased short term memory,
and I forget the third.
- Timothy Leary

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Concurrency Control & Recovery

- **Concurrency Control**
  – Provide correct and highly available access to data in the presence of concurrent access by large and diverse user populations
- **Recovery**
  – Ensures database is fault tolerant, and not corrupted by software, system or media failure
  – 7x24 access to mission critical data
- **Existence of CC&R allows applications to be written without explicit concern for concurrency and fault tolerance**

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Roadmap

- **Overview (Today)**
- **Concurrency Control**
- **Recovery**

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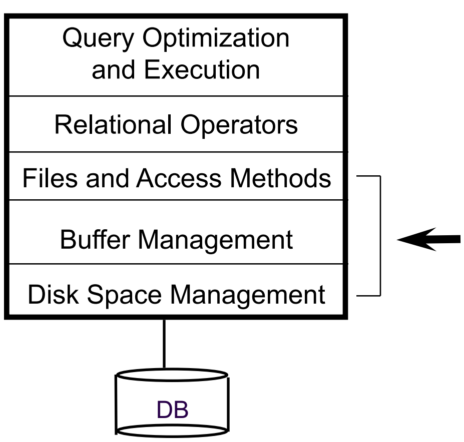
Structure of a DBMS



These layers must consider concurrency control and recovery (Transaction, Lock, Recovery Managers)

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Transactions and Concurrent Execution

- ***Transaction*** **- DBMS's abstract view of a user program (or activity):**
  - A sequence of reads and writes of database objects.
  - Unit of work that must commit and abort as a single atomic unit
- **Transaction Manager controls the execution of transactions.**
- **User 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.**
- **Concurrent execution of multiple transactions essential for good performance.**
  - Disk is the bottleneck (slow, frequently used)
  - Must keep CPU busy w/many queries
  - Better response time

ACID properties of Transaction Executions

- **A tomicity: All actions in the Xact happen, or none happen.**
- **C onsistency: If each Xact is consistent, and the DB starts consistent, it ends up consistent.**
- **I solation: Execution of one Xact is isolated from that of other Xacts.**
- **D urability: If a Xact commits, its effects persist.**

Atomicity and Durability

- **A transaction might *commit* after completing all its actions, or it could *abort* (or be aborted by the DBMS) after executing some actions. Also, the system may crash while the transaction is in progress.**
- **Important properties:**
  - *Atomicity* : Either executing all its actions, or none of its actions.
  - *Durability* : The effects of committed transactions must survive failures.
- **DBMS ensures the above by *logging* all actions:**
  - *Undo* the actions of aborted/failed transactions.
  - *Redo* actions of committed transactions not yet propagated to disk when system crashes.

Transaction Consistency

- **A transaction performed on a database that is internally consistent will leave the database in an internally consistent state.**
- **Consistency of database is expressed as a set of declarative Integrity Constraints**
  - CREATE TABLE/ASSERTION statements
    - E.g. Each CSC434 student can only register in one project group. Each group must have 2 students.
  - Application-level
    - E.g. Bank account of each customer must stay the same during a transfer from savings to checking account
- **Transactions that violate ICs are aborted.**

Isolation (Concurrency)

- **Concurrency is achieved by DBMS, which interleaves actions (reads/writes of DB objects) of various transactions.**
- **DBMS ensures transactions do not step onto one another.**
- **Each transaction executes as if it was running by itself.**
  - Transaction's behavior is not impacted by the presence of other transactions that are accessing the same database concurrently.
  - Net effect *must be* identical to executing all transactions for some serial order.
  - Users understand a transaction without considering the effect of other concurrently executing 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

- 1st xact transfers \$100 from B's account to A's
- 2nd credits both accounts with 6% interest.
- Assume at first A and B each have \$1000. What are the legal outcomes of running T1 and T2?
  - T1 ; T2 (**A=1166,B=954)**
  - T2 ; T1 (**A=1160,B=960)**
  - In either case, A+B = \$2000 *1.06 = \$2120
  - There is no guarantee that T1 will execute before T2 or vice-versa, if both are submitted together.

Example (Contd.)

- **Consider a possible interleaved *schedule*:**

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

- This is OK (same as T1;T2). But what about:

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

- **Result: A=1166, B=960; A+B = 2126, bank loses $6 !**
- **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), C	

- **Unrepeatable Reads (RW Conflicts):**

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

Anomalies (Continued)

- **Overwriting Uncommitted Data (WW Conflicts):**

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

Lock-Based Concurrency Control

- **Here's a simple way to allow concurrency but avoid the anomalies just described…**
- ***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.
  - If an Xact holds an X lock on an object, no other Xact can get a lock (S or X) on that object.
  - System can obtain these locks *automatically*
  - Two phases: acquiring locks, and releasing them
    - No lock is ever acquired after one has been released
    - "Growing phase" followed by "shrinking phase".
- **Lock Manager keeps track of request for locks and grants locks on database objects when they become available.**

Strict 2PL

- **2PL allows only serializable schedules but is subjected to cascading aborts.**
- **Example: rollback of T1 requires rollback of T2!**

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

- **To avoid Cascading aborts, use Strict 2PL**
- **Strict Two-phase Locking (Strict 2PL) Protocol:**
  - Same as 2PL, except:
  - All locks held by a transaction are released only when the transaction completes

Introduction to Crash Recovery

- **Recovery Manager**
  - When a DBMS is restarted after crashes, the recovery manager must bring the database to a consistent state
  - Ensures transaction atomicity and durability
  - Undos actions of transactions that do not commit
  - Redos actions of committed transactions during system failures and media failures (corrupted disk).
- **Recovery Manager maintains log information during normal execution of transactions for use during crash recovery**

The Log

- **Log consists of "records" that are written sequentially.**
  - Typically chained together by Xact id
  - Log is often *duplexed* and *archived* on stable storage.
- **Log stores modifications to the database**
  - *if Ti writes an object*, write a log record with:
  - If UNDO required need "before image"
  - IF REDO required need "after image".
  - *Ti commits/aborts*: a log record indicating this action.
- **Need for UNDO and/or REDO depend on Buffer Mgr.**
  - UNDO required if uncommitted data can overwrite stable version of committed data (STEAL buffer management).
  - REDO required if xact can commit before all its updates are on disk (NO FORCE buffer management).

Logging Continued

- **Write Ahead Logging (WAL) protocol**
  - Log record must go to disk *before* the changed page!
    - implemented via a handshake between log manager and the buffer manager.
  - All log records for a transaction (including it's commit record) must be written to disk before the transaction is considered "Committed".
- **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.**

ARIES Recovery

- **There are 3 phases in ARIES recovery:**
  - *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, as found in the log), working backwards in the log.
- **At the end --- all committed updates and only those updates are reflected in the database.**
- **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.**
- **Concurrency control is automatic.**
  - 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) and the recovery protocol are used to undo the actions of aborted transactions and to restore the system to a consistent state after a crash.**