CSE 412 / 598 : Database Management

Lecture 12

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Transaction Management Overview

Transactions

Concurrent execution of user programs is essential for good DBMS performance.

Why ?

Transactions

- Concurrent execution of user programs is essential for good DBMS performance.

- 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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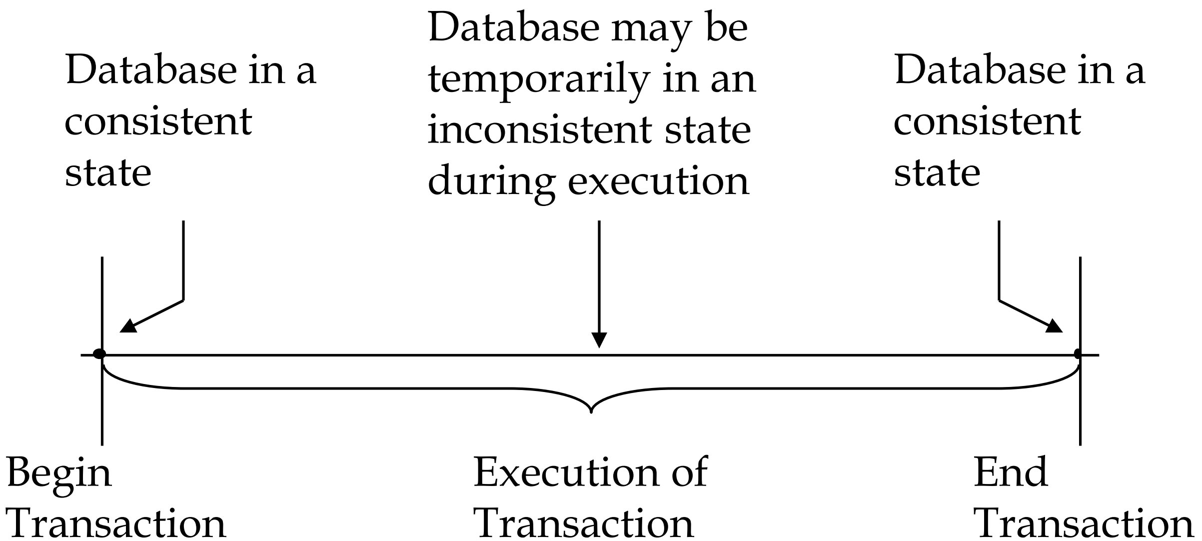
Transaction

A transaction is a collection of actions that make consistent transformations of system states while preserving system consistency.



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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Principles of Transactions

ATOMICITY
- all or nothing

CONSISTENCY
- no violation of integrity constraints

ISOLATION
- concurrent changes invisible $\Rightarrow$ serializable

DURABILITY
- committed updates persist

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.

Consistency

- Internal consistency
  - A transaction which executes alone against a consistent database leaves it in a consistent state.
  - Transactions do not violate database integrity constraints.
- Transactions are correct programs

Isolation

- Serializability
  - If several transactions are executed concurrently, the results must be the same as if they were executed serially in some order.
- Incomplete results
  - An incomplete transaction cannot reveal its results to other transactions before its commitment.
  - Necessary to avoid cascading aborts.

Durability

- Once a transaction commits, the system must guarantee that the results of its operations will never be lost, in spite of subsequent failures.
- Database recovery

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)	

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.

Interleaved Execution

S1

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

S2

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

S3

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

Identify Anomalies ?

Anomalies (Continued)

- Overwriting Uncommitted Data (WW Conflicts):

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

Anomalies (Continued)

- Overwriting Uncommitted Data (WW Conflicts):

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

Conflict Serializable Schedules

- Two schedules are conflict equivalent if:
  - Involve the same actions of the same transactions
  - Every pair of conflicting actions is ordered the same way
- Schedule S is conflict serializable if S is conflict equivalent to some serial schedule

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

Conflict Serializable?

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

Conflict Serializable?

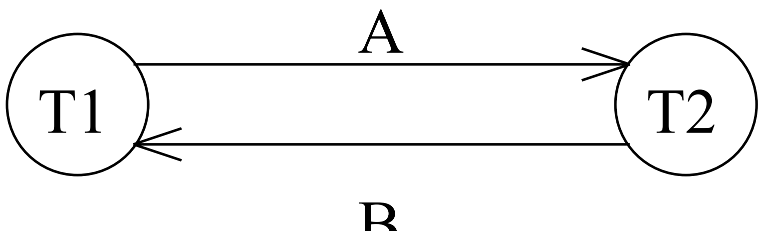
T1:	R(A), W(A), R(B), W(B)	
T2:		R(A), W(A), R(B), W(B)

Conflict Serializable?

Example

- A schedule that is not conflict serializable:

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



Dependency graph

- The cycle in the graph reveals the problem. The output of T1 depends on T2, and vice-versa.

Dependency Graph

- *Dependency graph*: One node per Xact; edge from *Ti* to *Tj* if *Tj* reads/writes an object last written by *Ti*.
- Theorem: Schedule is conflict serializable if and only if its dependency graph is acyclic

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

Lock Management

- Lock and unlock requests are handled by the lock manager
- Lock table entry:
  - Number of transactions currently holding a lock
  - Type of lock held (shared or exclusive)
  - Pointer to queue of lock requests
- Locking and unlocking have to be atomic operations
- Lock upgrade: transaction that holds a shared lock can be upgraded to hold an exclusive lock

Deadlocks

- Deadlock: Cycle of transactions waiting for locks to be released by each other.

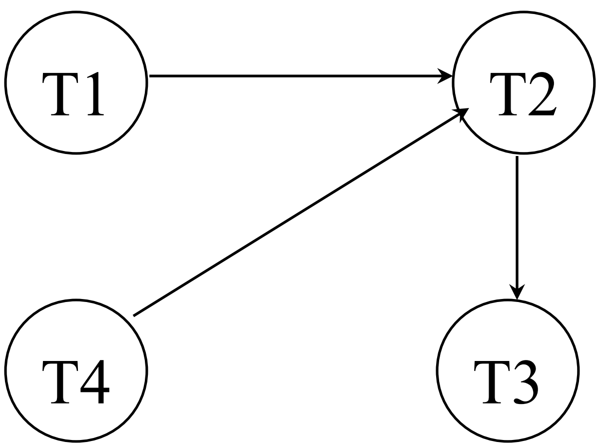
Deadlock Detection

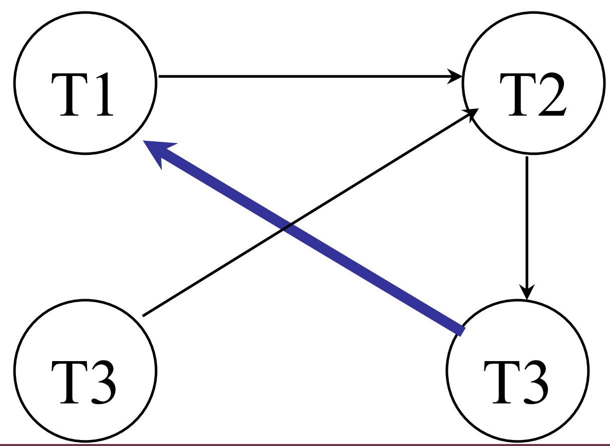
- Create a waits-for graph:
  - Nodes are transactions
  - There is an edge from Ti to Tj if Ti is waiting for Tj to release a lock
- Periodically check for cycles in the waits-for graph

Deadlock Detection (Continued)

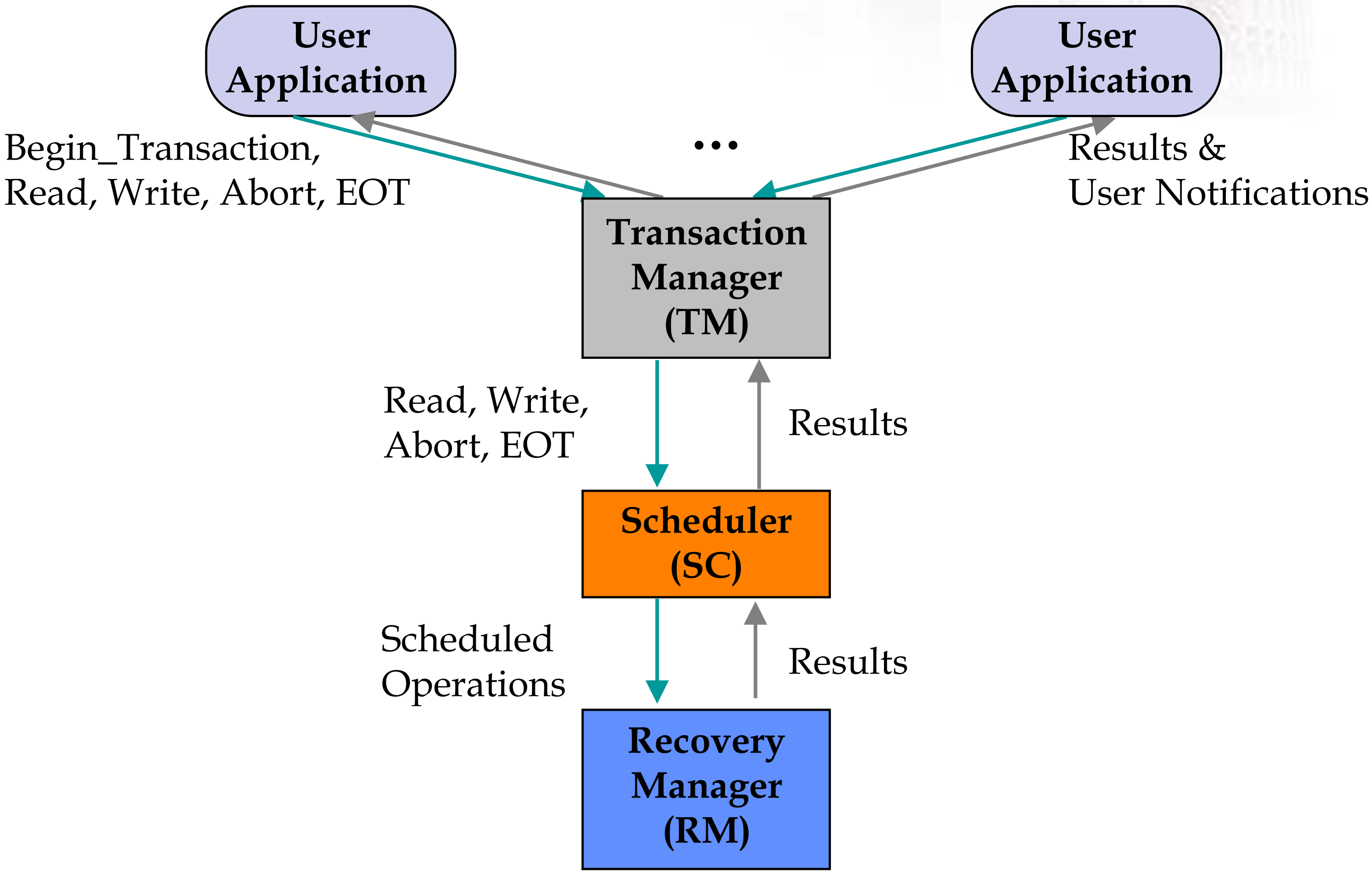
Example:

T1: S(A), R(A), S(B)
T2: X(B),W(B) X(C)
T3: S(C), R(C) X(A)
T4: X(B)

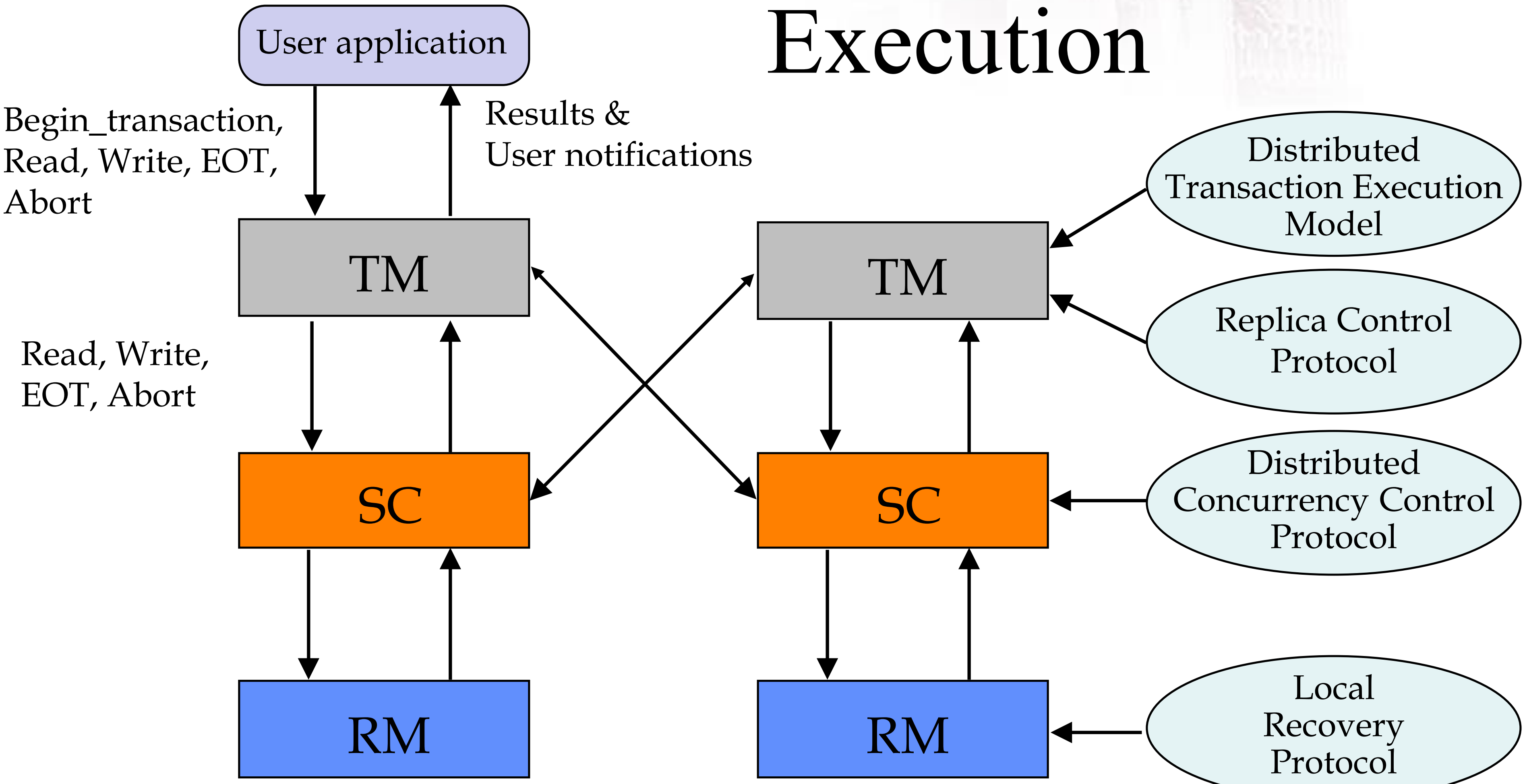




Centralized Transaction Execution



Distributed Transaction Execution



Questions