CS660: Graduate Intro to Database Systems

Class 19: Transactional Management Overview

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https://bu-disc.github.io/CS660/

Transaction Management

Overview of ACID

Concurrency control

Logging and recovery

Transaction Management

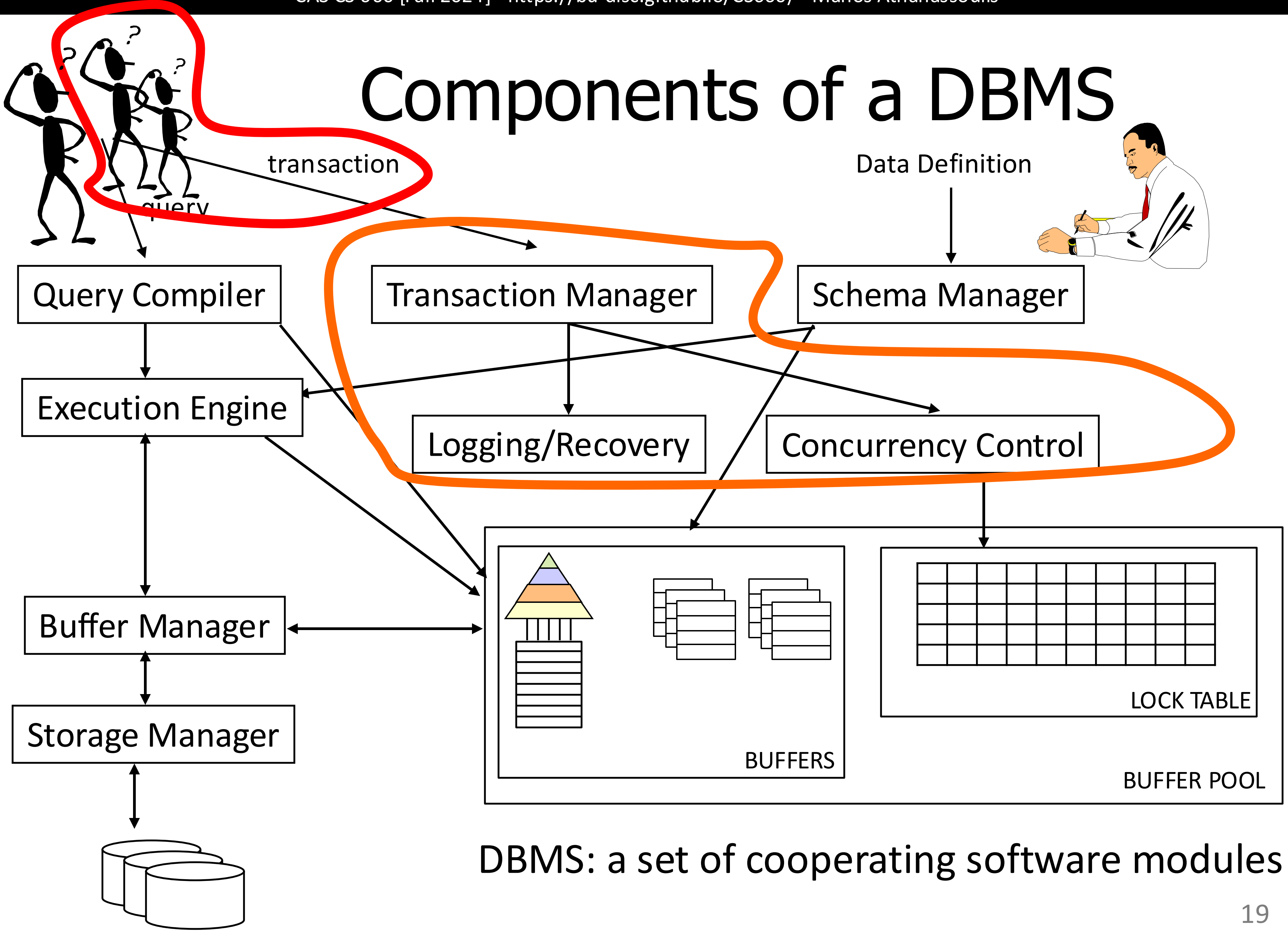
Overview of ACID

Readings: Chapter 16.1

Concurrency control

Logging and recovery

Components of a DBMS



DBMS: a set of cooperating software modules

Problem Statement

Goal: concurrent execution of independent transactions

- utilization/throughput ("hide" waiting for I/Os)
- response time
- fairness

Example:

	T1:	T2:
t0:	tmp1 := read(X)	
t1:		tmp2 := read(X)
t2:	~~tmp1 := tmp1 – 20~~	
t3:		tmp2 := tmp2 + 10
t4:	write tmp1 into X	
t5:		write tmp2 into X

Arbitrary interleaving can lead to inconsistencies

Definitions

A program may carry out many operations on the data retrieved from the database

The DBMS is only concerned about what data is read/written from/to the database

database

a fixed set of named data objects *(A, B, C, …)*

transaction

an atomic sequence of read and write operations *(read(A), write(B), …)*

Transaction - Example

```
BEGIN;     --BEGIN TRANSACTION

UPDATE accounts SET balance = balance - 100.00
  WHERE name = 'Alice';

UPDATE branches SET balance = balance - 100.00
  WHERE name = (SELECT branch_name FROM accounts
                WHERE name = 'Alice');

UPDATE accounts SET balance = balance + 100.00
  WHERE name = 'Bob';

UPDATE branches SET balance = balance + 100.00
  WHERE name = (SELECT branch_name FROM accounts
                WHERE name = 'Bob');

COMMIT;    --COMMIT WORK
```

Transaction Example (with Savepoint)

```
BEGIN;
UPDATE accounts SET balance = balance - 100.00
    WHERE name = 'Alice';

SAVEPOINT my_savepoint;
UPDATE accounts SET balance = balance + 100.00
    WHERE name = 'Bob’;

-- oops ... forget that and use Wally's account
ROLLBACK TO my_savepoint;

UPDATE accounts SET balance = balance + 100.00
    WHERE name = 'Wally';
COMMIT;
```

Correctness: The **ACID** properties

A tomicity: All actions in the transaction happen, or none happen

C onsistency: If each transaction is consistent, and the DB starts consistent, it ends up consistent

I solation: Execution of one transaction is isolated from that of other transactions

D urability: If a transaction commits, its effects persist

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Readings: Chapter 16.2-16.6

Logging and recovery

C Transaction Consistency

Consistency - data in DBMS is accurate in modeling real world and follows integrity constraints

User must ensure that transaction is consistent

Key point:

C Transaction Consistency (cont.)

Recall: Integrity constraints

- must be true for DB to be considered consistent
- **Examples:**
  1. FOREIGN KEY R.sid REFERENCES S
  2. ACCT-BAL >= 0

System checks integrity constraints and if they fail, the transaction rolls back (i.e., is aborted)

- Beyond this, DBMS does not understand data semantics
- e.g., how interest on a bank account is computed

I Isolation of Transactions

Users submit transactions, and

Each xact executes as if it was running by itself

- Concurrency is achieved by DBMS, which interleaves actions (reads/writes of DB objects) of various transactions.

Techniques for achieving isolation:

- Pessimistic – don't let problems arise in the first place
- Optimistic – assume conflicts are rare, deal with them *after* they happen.

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Example

Consider two transactions:

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

1^{st} xact transfers $100 from B's account to A's

2^{nd} xact 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?

$2000 *1.06 = $2120

There is no guarantee that T1 will execute before T2 or vice-versa, if both are submitted together. But, the net effect *must* be equivalent to these two transactions running serially in some order

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Example (Cont.)

Remember: correct outcome: A+B=$2120

Legal outcomes: A=1166,B=954 or A=1160,B=960

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)	

I 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	

A gets its value from T2

B gets its values from T1

A correct execution would take both values from T2 or both from T1

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Concurrency Control

How to avoid such anomalies?
“lock” data

Strict Two-phase Locking (Strict 2PL) Protocol

obtain an S (*shared*) lock on object before reading
obtain an X (*exclusive*) lock on object before writing

(i) obtain locks automatically
(ii) if a xact holds an X lock on object no other xact can acquire S or X
(iii) if a xact holds an S lock, no other xact can acquire X (but only S)

2 phases: first acquire and then release all at the end
important: no lock is ever acquired after one has been released

Transaction Management

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A Atomicity of Transactions

Two possible outcomes of executing a transaction:

- Transaction might *commit* after completing all its actions
- or it could *abort* (or be aborted by the DBMS) after executing some actions

DBMS guarantees that transactions are *atomic.*

- From user's point of view: transaction always either executes all its actions, or executes no actions at all

A Mechanisms for Ensuring Atomicity

One approach: LOGGING

– DBMS *logs* all actions so that it can *undo* the actions of aborted transactions

Another approach: SHADOW PAGES

– DBMS creates additional copies of updated pages which replace old pages at commit time, or are discarded at abort time

Logging used because they support audit and for efficiency

Shadow Pages used when underlying OS can be leveraged

Aborting a Transaction (i.e., Rollback)

If a xact T_i is aborted, all its actions must be undone

If T_j reads object last written by T_i, T_j must be aborted!

- Most systems avoid such *cascading aborts* by releasing locks only at end of the transaction (i.e., strict locking)
- If T_i writes an object, T_j can read it only after T_i finishes

To *undo* actions of an aborted transaction, DBMS maintains a *log* which records every write

Log is also used to recover from system crashes:

- All active Xacts at time of crash are aborted when system comes back up

why?

to ensure atomicity!

The Log

Log consists of "records" that are written sequentially

- Typically chained together by transaction id
- Log is often *archived* on stable storage

Need for UNDO and/or REDO depends on Buffer Manager

- UNDO required if: uncommitted data can overwrite committed data (STEAL buffer management)
- REDO required if: transaction can commit before all its updates are on disk (NO FORCE buffer management)

The Log (cont.)

The following actions are recorded in the log:

- *if T_i writes an object*, write a log record with:
  - If UNDO required need "before image"
  - IF REDO required need "after image"
- *T_i commits/aborts*: a log record indicating this action

Logging (cont.)

Write-Ahead Logging protocol

- Log record must go to disk ***before*** the changed page!
- All log records for a transaction (including its commit record) must be written to disk before the transaction is considered "Committed"

All logging and CC-related activities are handled transparently by the DBMS

(Review) Goal: The **ACID** properties

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D urability: If a transaction commits, its effects persist

What happens if system **crashes** between
commit and *flushing modified data to disk* ?

D Durability - Recovering From a Crash

Three phases:

- *Analysis*: Scan the log (forward from the most recent *checkpoint*) to identify all transactions that were active at the time of the crash
- *Redo*: Redo updates as needed to ensure that all logged updates are in fact carried out and written to disk
- *Undo*: Undo writes of all transactions that were active at the crash, 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
- Property ensured: 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:

1. undo the actions of aborted transactions, and
2. restore the system to a consistent state after a crash

next: *concurrency control in detail!*