CS460: Intro to Database Systems

Class 21: Transactional Management Overview

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https://bu-disc.github.io/CS460/

Administrativia – what lies ahead

WA5b (Bonus) – on indexing & LSM (deadline 11/17)

uploaded last week

WA6 – on Query Optimization (deadline 11/23)

coming on 11/17

PA2.1 – Query Optimization (deadline 11/30)

uploaded last week

PA2.2 – Row-stores vs. Column-stores (completion in the labs)

coming next week

WA7 (last WA) – on Transaction Processing (deadline 12/6)

coming next week

Final: in HAR 208 (this room) on Wednesday 12/15 3pm-5pm

Transaction Management

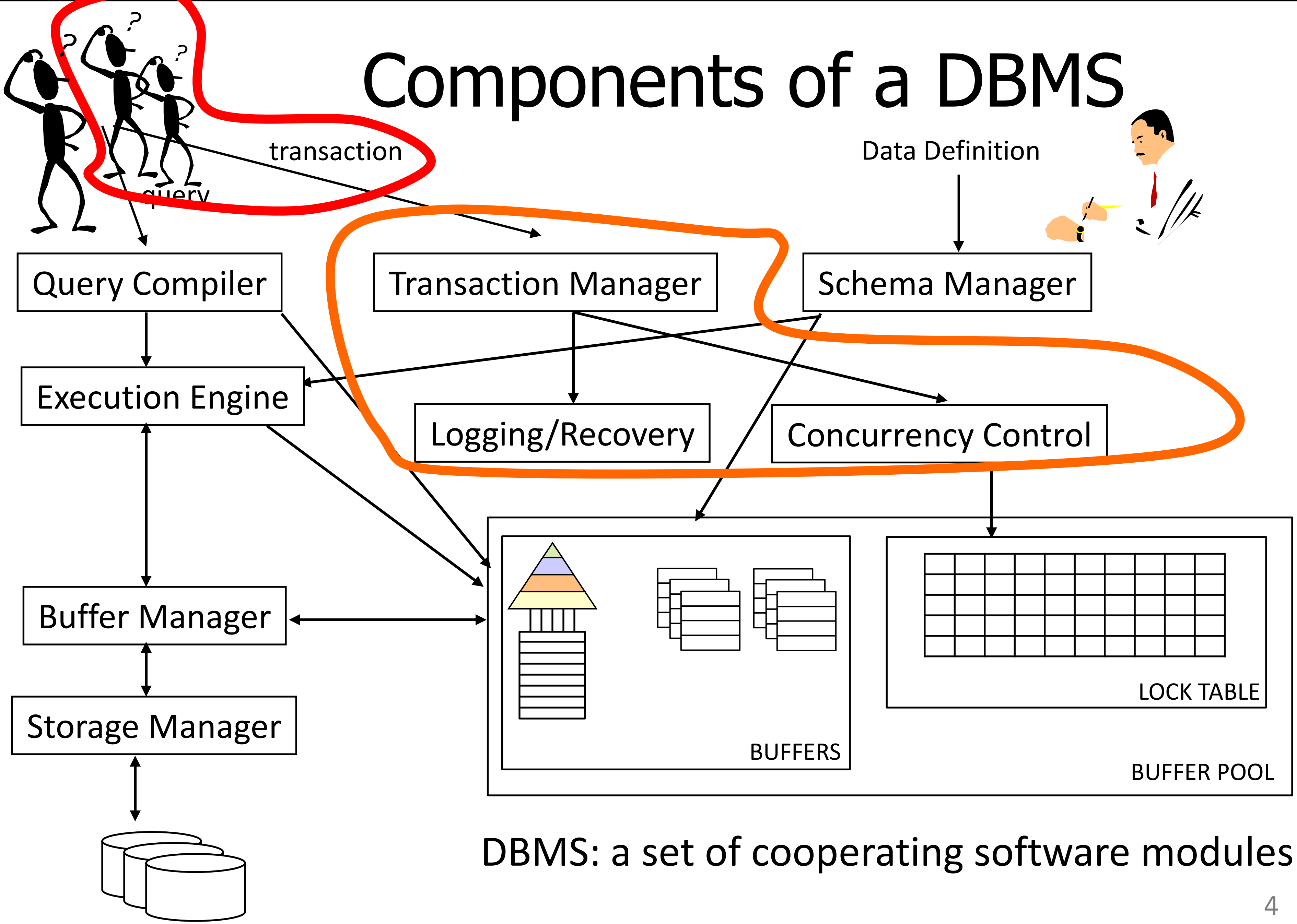
Overview of ACID

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

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

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

Transaction Management

Overview of ACID

Concurrency control

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:

consistent database S1 $\xrightarrow{\text{transaction T}}$ consistent database S2

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

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

2nd 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

Overview of ACID

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Logging and recovery

Readings: Chapter 16.7

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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

- (ask me after class if you’re curious)

Logging used by modern systems, because of the need for audit trail and for efficiency

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 *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

- <u>UNDO required if</u>: uncommitted data can overwrite committed data (STEAL buffer management)
- <u>REDO required if</u>: 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"
- *Ti 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

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

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!*