CSE 344

MARCH 25TH – ISOLATION

ADMINISTRIVIA

- **HW8 Due Friday, June 1**
- **OQ7 Due Wednesday, May 30**
- **Course Evaluations**
  - Out tomorrow

TRANSACTIONS

We use database transactions everyday

- Bank $$$ transfers
- Online shopping
- Signing up for classes

For this class, a transaction is a series of DB queries

- Read / Write / Update / Delete / Insert
- Unit of work issued by a user that is independent from others

KNOW YOUR TRANSACTIONS: ACID

Atomic

- State shows either all the effects of txn, or none of them

Consistent

- Txn moves from a DBMS state where integrity holds, to another where integrity holds
  - remember integrity constraints?

Isolated

- Effect of txns is the same as txns running one after another (i.e., looks like batch mode)

Durable

- Once a txn has committed, its effects remain in the database

IMPLEMENTING A SCHEDULER

Major differences between database vendors

Locking Scheduler

- Aka "pessimistic concurrency control"
- SQLite, SQL Server, DB2

Multiversion Concurrency Control (MVCC)

- Aka "optimistic concurrency control"
- Postgres, Oracle: Snapshot Isolation (SI)

We discuss only locking schedulers in this class

LOCKING SCHEDULER

Simple idea:

Each element has a unique lock

Each transaction must first acquire the lock before reading/writing that element

If the lock is taken by another transaction, then wait

The transaction must release the lock(s)

By using locks scheduler ensures conflict-serializability

SCHEDULE ANOMALIES

What could go wrong if we didn’t have concurrency control:

- Dirty reads (including inconsistent reads)
- Unrepeatable reads
- Lost updates

Many other things can go wrong too

MORE NOTATIONS

$L_i(A)$ = transaction T_i acquires lock for element A

$U_i(A)$ = transaction T_i releases lock for element A

TWO PHASE LOCKING (2PL)

The 2PL rule:

> In every transaction, all lock requests
> must precede all unlock requests

EXAMPLE: 2PL TRANSACTIONS

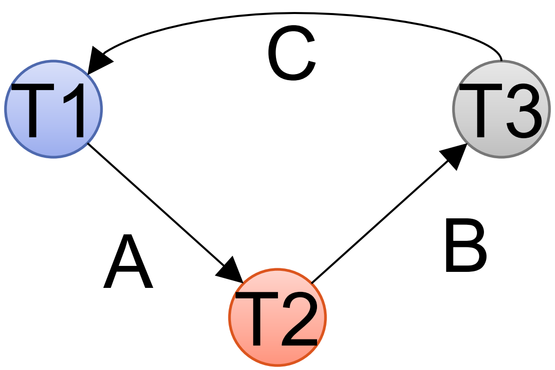
T1	T2
$L_1(A)$; $L_1(B)$; READ(A)	
A := A+100	
WRITE(A); $U_1(A)$	
	$L_2(A)$; READ(A)
	A := A*2
	WRITE(A);
	$L_2(B)$; BLOCKED…
READ(B)	
B := B+100	
WRITE(B); $U_1(B)$;	
	…GRANTED; READ(B)
	B := B*2
	WRITE(B); $U_2(A)$; $U_2(B)$;

Now it is conflict-serializable

TWO PHASE LOCKING (2PL)

Theorem: 2PL ensures conflict serializability

Proof. Suppose not: then there exists a cycle in the precedence graph.



Then there is the following **temporal** cycle in the schedule:

$U_1(A) \rightarrow L_2(A)$

$L_2(A) \rightarrow U_2(B)$

$U_2(B) \rightarrow L_3(B)$

$L_3(B) \rightarrow U_3(C)$

$U_3(C) \rightarrow L_1(C)$

$L_1(C) \rightarrow U_1(A)$

Cycle in time: Contradiction

A NEW PROBLEM: NON-RECOVERABLE SCHEDULE

T1	T2
$L_1(A)$; $L_1(B)$; READ(A)	
A :=A+100	
WRITE(A); $U_1(A)$	
	$L_2(A)$; READ(A)
	A := A*2
	WRITE(A);
	$L_2(B)$; BLOCKED…
READ(B)	
B :=B+100	
WRITE(B); $U_1(B)$;	
	…GRANTED; READ(B)
	B := B*2
	WRITE(B); $U_2(A)$; $U_2(B)$;
	Commit
Rollback	

Dirty reads of A, B lead to incorrect writes.

Elements A, B written by T1 are restored to their original value.

Can no longer undo!

STRICT 2PL

The Strict 2PL rule:

All locks are held until commit/abort:
All unlocks are done together with commit/abort.

With strict 2PL, we will get schedules that
are both conflict-serializable and recoverable

STRICT 2PL

T1	T2
L_1(A); READ(A)	
A :=A+100	
WRITE(A);	
	L_2(A); BLOCKED…
L_1(B); READ(B)	
B :=B+100	
WRITE(B);	
Rollback & U_1(A);U_1(B);	
	…GRANTED; READ(A)
	A := A*2
	WRITE(A);
	L_2(B); READ(B)
	B := B*2
	WRITE(B);
	Commit & U_2(A); U_2(B);

STRICT 2PL

Lock-based systems always use strict 2PL

Easy to implement:

- Before a transaction reads or writes an element A, insert an L(A)
- When the transaction commits/aborts, then release all locks

Ensures both conflict serializability and recoverability

ANOTHER PROBLEM: DEADLOCKS

T_1: R(A), W(B)

T_2: R(B), W(A)

T_1 holds the lock on A, waits for B

T_2 holds the lock on B, waits for A

This is a deadlock!

ANOTHER PROBLEM: DEADLOCKS

To detect a deadlocks, search for a cycle in the waits-for graph:

T_1 waits for a lock held by T_2;

T_2 waits for a lock held by T_3;

. . .

T_n waits for a lock held by T_1

Relatively expensive: check periodically, if deadlock is found, then abort one TXN;
re-check for deadlock more often (why?)

LOCK MODES

S = shared lock (for READ)

X = exclusive lock (for WRITE)

Lock compatibility matrix:

	None	S	X
None			
S			
X			

LOCK MODES

S = shared lock (for READ)

X = exclusive lock (for WRITE)

Lock compatibility matrix:

	None	S	X
None	✔	✔	✔
S	✔	✔	✖
X	✔	✖	✖

LOCK GRANULARITY

Fine granularity locking (e.g., tuples)

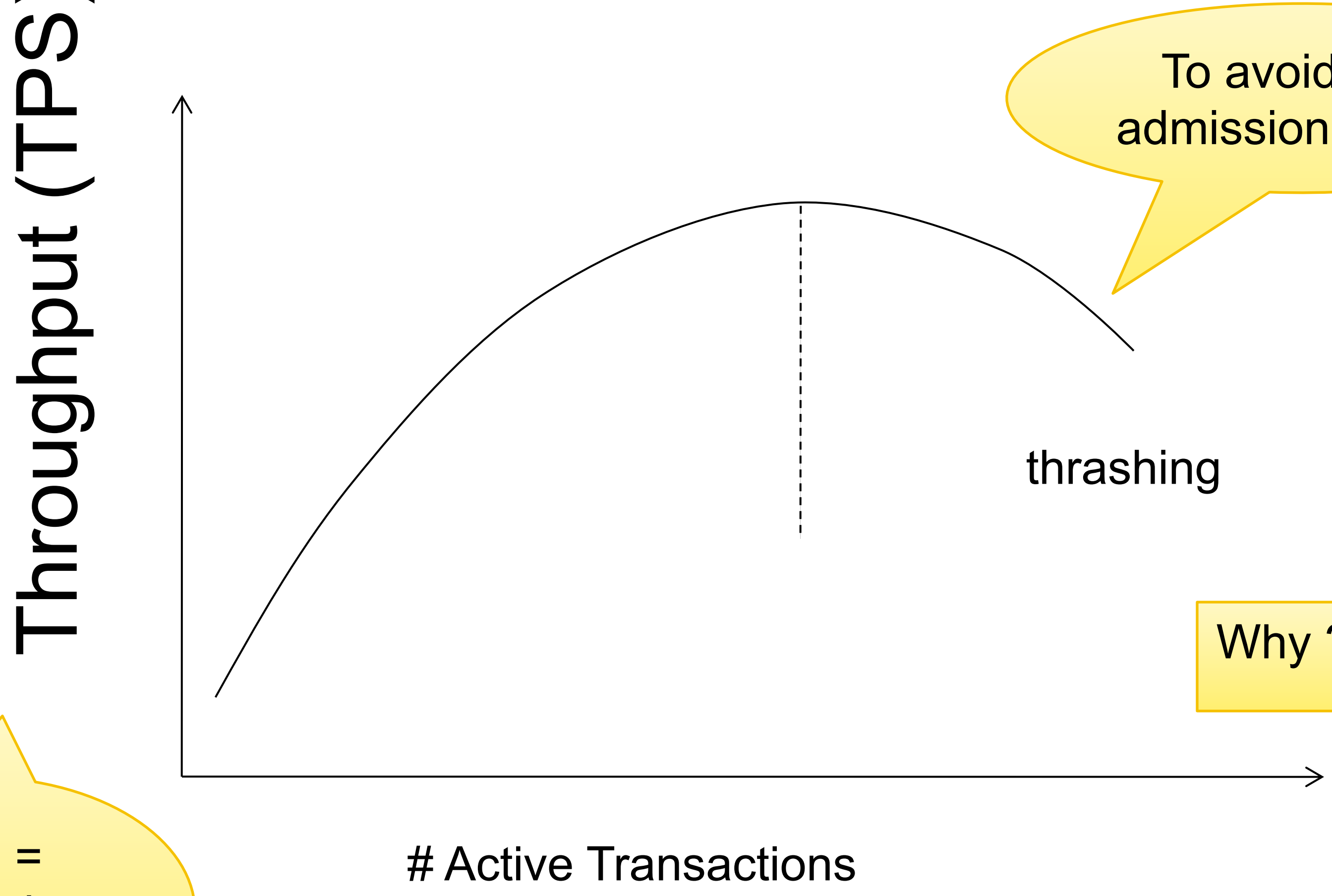
- High concurrency
- High overhead in managing locks
- E.g., SQL Server

Coarse grain locking (e.g., tables, entire database)

- Many false conflicts
- Less overhead in managing locks
- E.g., SQL Lite

Solution: lock escalation changes granularity as needed

LOCK PERFORMANCE



To avoid, use admission control

Why ?

TPS = Transactions per second

PHANTOM PROBLEM

So far we have assumed the database to be a *static* collection of elements (=tuples)

If tuples are inserted/deleted then the *phantom problem* appears

Suppose there are two blue products, A1, A2:

PHANTOM PROBLEM

T1	T2
SELECT * FROM Product WHERE color='blue'	
	INSERT INTO Product(name, color) VALUES ('A3','blue')
SELECT * FROM Product WHERE color='blue'	

Is this schedule serializable ?

Suppose there are two blue products, A1, A2:

PHANTOM PROBLEM

T1	T2
SELECT * FROM Product WHERE color=‘blue’	
	INSERT INTO Product(name, color) VALUES (‘A3’,’blue’)
SELECT * FROM Product WHERE color=‘blue’	

$R_1(A1);R_1(A2);W_2(A3);R_1(A1);R_1(A2);R_1(A3)$

Suppose there are two blue products, A1, A2:

PHANTOM PROBLEM

T1	T2
SELECT * FROM Product WHERE color=‘blue’	
	INSERT INTO Product(name, color) VALUES (‘A3’,’blue’)
SELECT * FROM Product WHERE color=‘blue’	

$R_1(A1);R_1(A2);W_2(A3);R_1(A1);R_1(A2);R_1(A3)$

$W_2(A3);R_1(A1);R_1(A2);R_1(A1);R_1(A2);R_1(A3)$

PHANTOM PROBLEM

A "phantom" is a tuple that is invisible during part of a transaction execution but not invisible during the entire execution

In our example:

- T1: reads list of products
- T2: inserts a new product
- T1: re-reads: a new product appears !

DEALING WITH PHANTOMS

Lock the entire table

Lock the index entry for ‘blue’

- If index is available

Or use predicate locks

- A lock on an arbitrary predicate

Dealing with phantoms is expensive !

SUMMARY OF SERIALIZABILITY

Serializable schedule = equivalent to a serial schedule

(strict) 2PL guarantees *conflict serializability*

- What is the difference?

Static database:

- *Conflict serializability* implies serializability

Dynamic database:

- This no longer holds

ISOLATION LEVELS IN SQL

1. **“Dirty reads”**

   SET TRANSACTION ISOLATION LEVEL READ UNCOMMITTED

2. **“Committed reads”**

   SET TRANSACTION ISOLATION LEVEL READ COMMITTED

3. **“Repeatable reads”**

   SET TRANSACTION ISOLATION LEVEL REPEATABLE READ

4. **Serializable transactions**

   ACID

   SET TRANSACTION ISOLATION LEVEL SERIALIZABLE

1. ISOLATION LEVEL: DIRTY READS

"Long duration" WRITE locks

- Strict 2PL

No READ locks

- Read-only transactions are never delayed

Possible problems: dirty and inconsistent reads

2. ISOLATION LEVEL: READ COMMITTED

“Long duration” WRITE locks

- Strict 2PL

“Short duration” READ locks

- Only acquire lock while reading (not 2PL)

Unrepeatable reads:
When reading same element twice,
may get two different values

3. ISOLATION LEVEL: REPEATABLE READ

"Long duration" WRITE locks

- Strict 2PL

"Long duration" READ locks

- Strict 2PL

Why ?

This is not serializable yet !!!

4. ISOLATION LEVEL SERIALIZABLE

“Long duration” WRITE locks

- Strict 2PL

“Long duration” READ locks

- Strict 2PL

Predicate locking

- To deal with phantoms

BEWARE!

In commercial DBMSs:

Default level is often NOT serializable

Default level differs between DBMSs

Some engines support subset of levels!

Serializable may not be exactly ACID

- Locking ensures isolation, not atomicity

Also, some DBMSs do NOT use locking and different isolation levels can lead to different problems

Bottom line: Read the doc for your DBMS!

CONCLUSION

- **May different elements can be “tuned”**
- **ACID constraints may not always be totally necessary**
- **HW8**
  - Simple implementation
  - Prioritizing throughput

NEXT WEEK

- **Wednesday**
  - Brief survey of topics in applied usage
  - Not on final exam
- **Friday**
  - Exam review
  - June 6th 8:30a