CONCURRENCY

Introduction to Database Systems

Mahdi Akhi
Sharif University of Technology

IN THIS LECTURE

- Concurrency control
- Serializability
  - Schedules of transactions
  - Serial & serializable schedules
- Locks
- 2 Phase Locking protocol (2PL)
- For more information
  - Connolly and Begg chapter 20
  - Ullman and Widom chapter 8.6

NEED FOR CONCURRENCY CONTROL

- Previous Lecture: Transactions running concurrently may interfere with each other, causing various problems (lost updates etc.)
- **Concurrency Control**: the process of managing simultaneous operations on the database without having them interfere with each other.

LOST UPDATE

This update
Is lost

T1	T2
Read(X)	
X = X - 5	
	Read(X)
	X = X + 5
Write(X)	
	Write(X)
COMMIT	
	COMMIT

Only this update succeeds

UNCOMMITTED UPDATE ("DIRTY READ")

T1	T2
Read(X)	
X = X - 5	
Write(X)	
	Read(X)
	X = X + 5
	Write(X)
	COMMIT
ROLLBACK	

This reads the value of X which it should not have seen

INCONSISTENT ANALYSIS

T1	T2
Read(X)	
X = X - 5	
Write(X)	
	Read(X)
	Read(Y)
	Sum = X+Y
Read(Y)	
Y = Y + 5	
Write(Y)	

Summing up data while it is being updated

SCHEDULES

- A **schedule** is a sequence of the operations by a set of concurrent transactions that preserves the order of operations in each of the individual transactions

- A **serial schedule** is a schedule where operations of each transaction are executed consecutively without any interleaved operations from other transactions (each transaction commits before the next one is allowed to begin)

SERIAL SCHEDULES

- Serial schedules are guaranteed to avoid interference and keep the database consistent

- However databases need concurrent access which means interleaving operations from different transactions

SERIALIZABILITY

- Two schedules are **equivalent** if they always have the same effect.
- A schedule is **serializable** if it is equivalent to some serial schedule.
- For example:
  - if two transactions only **read** some data items, then the order in which they do it is **not important**
  - If T1 **reads** and **updates X** and T2 **reads** and **updates** a different data item **Y**, then again they can be scheduled in any order.

SERIAL AND SERIALIZABLE

Interleaved Schedule

T1 Read(X)
T2 Read(X)
T2 Read(Y)
T1 Read(Z)
T1 Read(Y)
T2 Read(Z)

Serial Schedule

T2 Read(X)
T2 Read(Y)
T2 Read(Z)

T1 Read(X)
T1 Read(Z)
T1 Read(Y)

This schedule is serializable:

CONFLICT SERIALIZABLE SCHEDULE

Interleaved Schedule

T1 Read(X)
T1 Write(X)
T2 Read(X)
T2 Write(X)
T1 Read(Y)
T1 Write(Y)
T2 Read(Y)
T2 Write(Y)

This schedule is serializable, even though T1 and T2 read and write the same resources X and Y: they have a conflict

Serial Schedule

T1 Read(X)
T1 Write(X)
T1 Read(Y)
T1 Write(Y)

T2 Read(X)
T2 Write(X)
T2 Read(Y)
T2 Write(Y)

CONFLICT SERIALIZABILITY

- Two transactions have a conflict:
  - **NO** If they refer to different resources
  - **NO** If they are reads
  - **YES** If at least one is a write and they use the same resource
- A schedule is ***conflict serializable*** if transactions in the schedule have a conflict but the schedule is still serializable

CONFLICT SERIALIZABILITY

- Conflict serializable schedules are the main focus of concurrency control
- They allow for **interleaving** and at the same time they are guaranteed to **behave as** a serial schedule
- Important questions: how to determine whether a schedule is conflict serializable
- How to construct conflict serializable schedules

PRECEDENCE GRAPHS

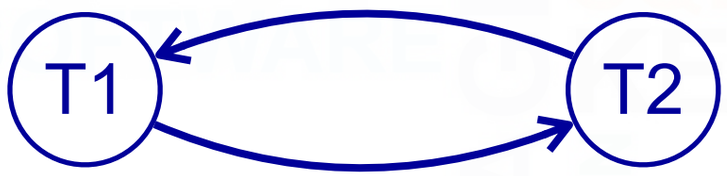
- To determine if a schedule is conflict serializable we use a **precedence graph**
  - Transactions are vertices of the graph
  - There is an edge from T1 to T2 if T1 must happen before T2 in any equivalent serial schedule
- Edge T1 → T2 if in the schedule we have:
  - T1 Read(R) followed by T2 Write(R) for the same resource R
  - T1 Write(R) followed by T2 Read(R)
  - T1 Write(R) followed by T2 Write(R)
- The schedule is serializable if there are **no cycles**

PRECEDENCE GRAPH EXAMPLE

- The lost update schedule has the precedence graph:

T1	T2
Read(X)	
X = X - 5	
	Read(X)
	X = X + 5
Write(X)	
	Write(X)
COMMIT	
	COMMIT

T1 Write(X) followed by T2 Write(X)



T2 Read(X) followed by T1 Write(X)

PRECEDENCE GRAPH EXAMPLE

- **No cycles**: conflict serializable schedule

T1 reads X before T2 writes X and
T1 writes X before T2 reads X and
T1 writes X before T2 writes X

T1	T2
Read(X)	
Write(X)	
	Read(X)
	Write(X)

LOCKING

- Locking is a procedure used to control concurrent access to data (to ensure serializability of concurrent transactions)
- In order to use a ‘resource’ (table, row, etc) a transaction must first acquire a **lock** on that resource
- This may deny access to other transactions to prevent incorrect results

TWO TYPES OF LOCKS

- Two types of lock
  - **Shared lock** (S-lock or read-lock)
  - **Exclusive lock** (X-lock or write-lock)
- Read lock allows several transactions simultaneously to read a resource (but no transactions can change it at the same time)
- Write lock allows one transaction exclusive access to write to a resource. No other transaction can read this resource at the same time.
- The lock manager in the DBMS assigns locks and records them in the data dictionary

LOCKING

- Before reading from a resource a transaction must acquire a read-lock
- Before writing to a resource a transaction must acquire a write-lock
- Locks are released on **Commit/Rollback**
- A transaction may not acquire a lock on any resource that is write-locked by another transaction
- A transaction may not acquire a write-lock on a resource that is locked by another transaction
- If the requested lock is not available, transaction waits

TWO-PHASE LOCKING

- A transaction follows the **two-phase locking protocol** (2PL) if all locking operations precede the first unlock operation in the transaction
- Two phases
  - **Growing phase** where locks are acquired on resources
  - **Shrinking phase** where locks are released

EXAMPLE

- T1 follows 2PL protocol
  - All of its locks are acquired before it releases any of them
- T2 does not
  - It releases its lock on X and then goes on to later acquire a lock on Y

T1	T2
read-lock(X)	read-lock(X)
Read(X)	Read(X)
write-lock(Y)	unlock(X)
unlock(X)	write-lock(Y)
Read(Y)	Read(Y)
Y = Y + X	Y = Y + X
Write(Y)	Write(Y)
unlock(Y)	unlock(Y)

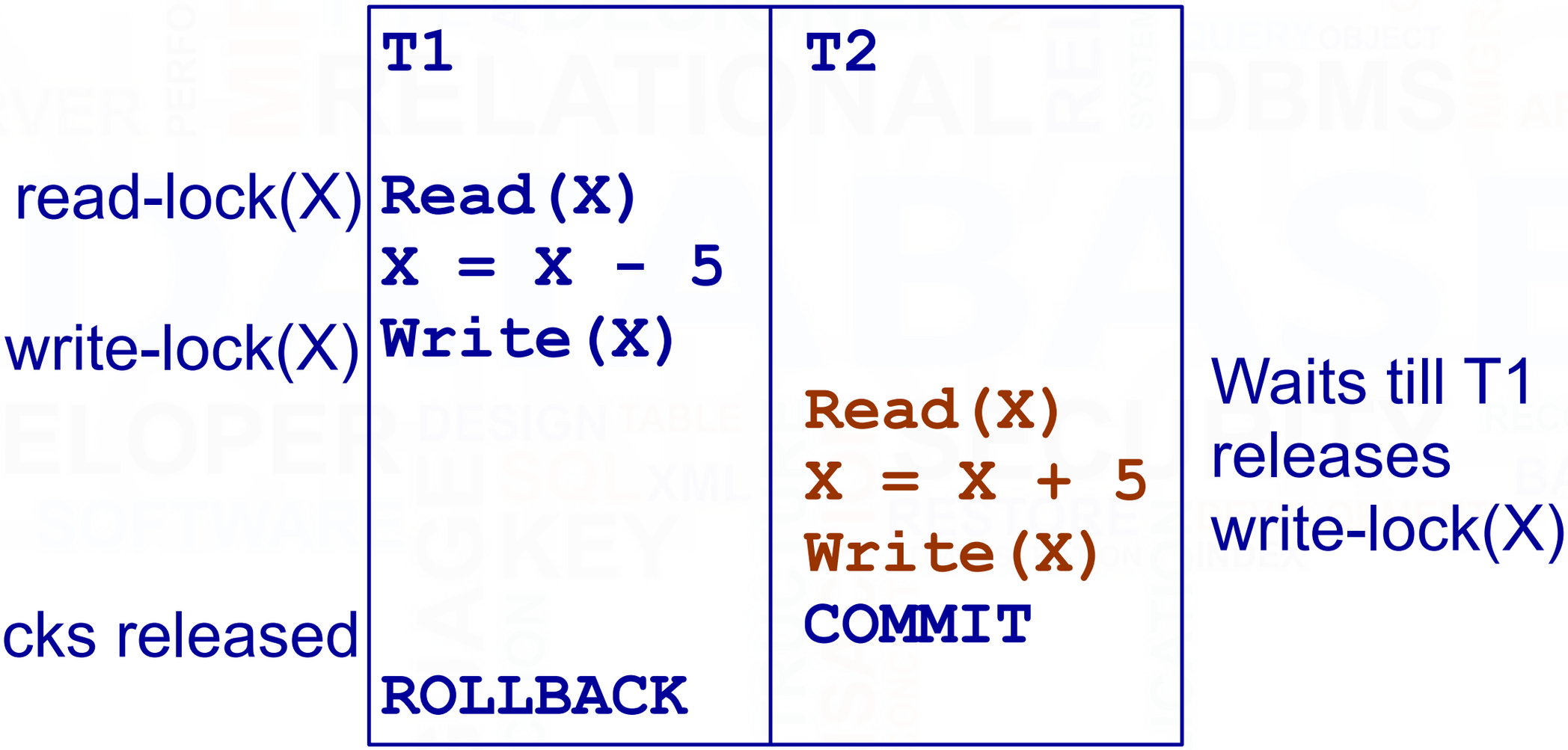
SERIALIZABILITY THEOREM

Any schedule of two-phased transactions is conflict serializable

LOST UPDATE CAN'T HAPPEN WITH 2PL

	T1	T2	
read-lock(X)	Read(X)		
	X = X - 5		
		Read(X)	read-lock(X)
		X = X + 5	
	Write(X)		
cannot acquire write-lock(X): T2 has read-lock(X)		Write(X)	cannot acquire write-lock(X): T1 has read-lock(X)
	COMMIT		
		COMMIT	

UNCOMMITTED UPDATE CANNOT HAPPEN WITH 2PL



INCONSISTENT ANALYSIS CANNOT HAPPEN WITH 2PL

	T1	T2	
read-lock(X)	Read(X)		
	X = X - 5		
write-lock(X)	Write(X)		
		Read(X)	Waits till T1 releases write-locks on X and Y
		Read(Y)	
		Sum = X+Y	
read-lock(Y)	Read(Y)		
	Y = Y + 5		
write-lock(Y)	Write(Y)		

NEXT LECTURE

- Deadlocks
  - Deadlock detection
  - Deadlock prevention
- Time-stamping
- For more information
  - Connolly and Begg chapter 20
  - Ullman and Widom chapter 8.6

END

This is Not! the End of the DB Course

The course will be next season!