Two-Phase Locking

EECS 339

Lecture 16

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

View Serializability

- Schedules S1 and S2 are view equivalent if:
  - If Ti reads initial value of A in S1, then Ti also reads initial value of A in S2
  - If Ti reads value of A written by Tj in S1, then Ti also reads value of A written by Tj in S2
  - If Ti writes final value of A in S1, then Ti also writes final value of A in S2

T1:	R(A)		W(A)	
T2:		W(A)		
T3:				W(A)

T1:	R(A),W(A)		
T2:		W(A)	
T3:			W(A)

Two-Phase Locking (2PL)

- Two-Phase Locking Protocol
  - Each Xact must obtain a S (*shared*) lock on object before reading, and an X (*exclusive*) lock on object before writing.
  - A transaction can not request additional locks once it releases any locks.
  - 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

- *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 schedules whose precedence graph is acyclic

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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

Study Break: 2-Phase Locking

- Show the locks for the following schedule:

T1	T2
R1	
W1	
	R2
	W2
R2	
W2	

Is this a valid 2PL schedule?

Study Break: 2-Phase Locking Solution

- Show the locks for the following schedule:

T1	T2
R1	
W1	
	R2
	W2
R2	
W2	

T1	T2
S1	
X1	
	S2
	X2
S2	===Commit
X2	

Is this a valid 2PL schedule? Yes.

2PL Challenges

- Cascading aborts
- Deadlock
- Phantom problem

Cascading rollbacks

- Since transactions access overlapping datasets it is possible to create “chains” of transactions with dependent states
- If one aborts, the others may follow suit
- Cascadeless schedules are recoverable

Deadlocks

- Deadlock: Cycle of transactions waiting for locks to be released by each other.
- Two ways of dealing with deadlocks:
  - Deadlock prevention
  - Deadlock detection

Deadlock Prevention

- Assign priorities based on timestamps. Assume T_i wants a lock that T_j holds. Two policies are possible:
  - Wait-Die: It Ti has higher priority, Ti waits for Tj; otherwise Ti aborts
  - Wound-wait: If Ti has higher priority, Tj aborts; otherwise Ti waits
- If a transaction restarts, make sure it has its original timestamp

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)

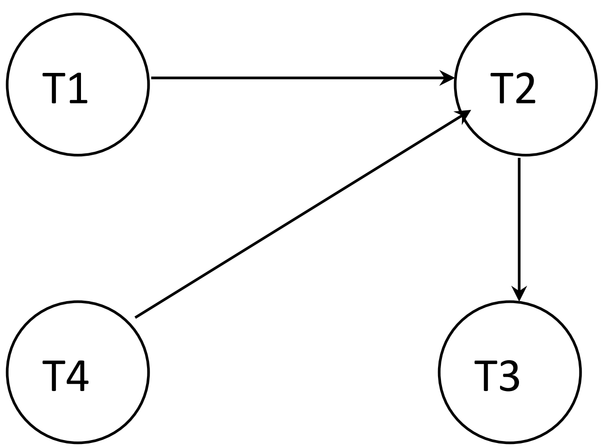
Example:

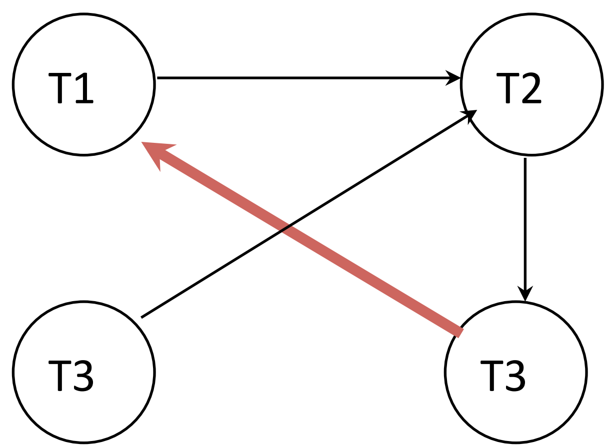
T1: S(A), R(A), S(B)

T2: X(B),W(B) X(C)

T3: S(C), R(C) X(A)

T4: X(B)





Dynamic Databases

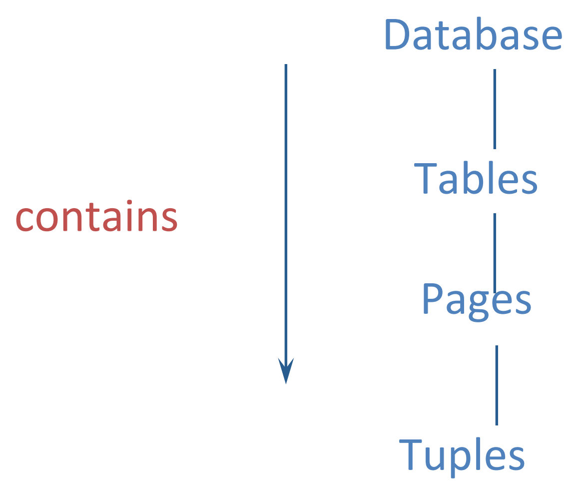
- If we relax the assumption that the DB is a fixed collection of objects, even Strict 2PL will not assure serializability:
  - T1 locks all pages containing sailor records with *rating* = 1, and finds oldest sailor (say, *age* = 71).
  - Next, T2 inserts a new sailor; *rating* = 1, *age* = 96.
  - T2 also deletes oldest sailor with rating = 2 (and, say, *age* = 80), and commits.
  - T1 now locks all pages containing sailor records with *rating* = 2, and finds oldest (say, *age* = 63).
- No consistent DB state where T1 is "correct"!

The Problem

- T1 implicitly assumes that it has locked the set of all sailor records with *rating* = 1.
  - Assumption only holds if no sailor records are added while T1 is executing!
  - Need some mechanism to enforce this assumption. (Index locking and predicate locking.)
- Example shows that conflict serializability guarantees serializability only if the set of objects is fixed!

Multiple-Granularity Locks

- Hard to decide what granularity to lock (tuples vs. pages vs. tables).
- Shouldn't have to decide!
- Data "containers" are nested:



Solution: New Lock Modes, Protocol

- Allow Xacts to lock at each level, but with a special protocol using new "intention" locks:

❖ Before locking an item, Xact must set "intention locks" on all its ancestors.

❖ For unlock, go from specific to general (i.e., bottom-up).

❖ SIX mode: Like S & IX at the same time.

	--	IS	IX	S	X
--	√	√	√	√	√
IS	√	√	√	√	
IX	√	√	√		
S	√	√		√	
X	√				

Multiple Granularity Lock Protocol

- Each Xact starts from the root of the hierarchy.
- To get S or IS lock on a node, must hold IS or IX on parent node.
  - What if Xact holds SIX on parent? S on parent?
- To get X or IX or SIX on a node, must hold IX or SIX on parent node.
- Must release locks in bottom-up order.

Protocol is correct in that it is equivalent to directly setting locks at the leaf levels of the hierarchy.

Examples

- T1 scans R, and updates a few tuples:
  - T1 gets an SIX lock on R, then repeatedly gets an S lock on tuples of R, and occasionally upgrades to X on the tuples.
- T2 uses an index to read only part of R:
  - T2 gets an IS lock on R, and repeatedly gets an S lock on tuples of R.
- T3 reads all of R:
  - T3 gets an S lock on R.
  - OR, T3 could behave like T2; can use lock escalation to decide which.

	--	IS	IX	S	X
--	√	√	√	√	√
IS	√	√	√	√	
IX	√	√	√		
S	√	√		√	
X	√				

Predicate Locking

- Grant lock on all records that satisfy some logical predicate, e.g. *age > 2*salary*.
- Index locking is a special case of predicate locking for which an index supports efficient implementation of the predicate lock.
  - What is the predicate in the sailor example?
- In general, predicate locking has a lot of overhead.

ACID, In Implementation

Database	Default Isolation	Maximum Isolation
Actian Ingres 10.0/10S	S	S
Aerospike	RC	RC
Akiban Persistit	SI	SI
Clustrix CLX 4100	RR	?
Greenplum 4.1	RC	S
IBM DB2 10 for z/OS	CS	S
IBM Informix 11.50	Depends	RR
MySQL 5.6	RR	S
MemSQL 1b	RC	RC
MS SQL Server 2012	RC	S
NuoDB	CR	CR
Oracle 11g	RC	SI
Oracle Berkeley DB	S	S
Oracle Berkeley DB JE	RR	S
Postgres 9.2.2	RC	S
SAP HANA	RC	SI
ScaleDB 1.02	RC	RC
VoltDB	S	S
Legend	*RC: read committed, RR: repeatable read, S: serializability, SI: snapshot isolation, CS: cursor stability, CR: consistent read*	

Source: http://www.bailis.org/blog/when-is-acid-acid-rarely/