Transaction Management: Concurrency Control, part 3

CS634
Class 19, Apr 11, 2016

Slides based on "Database Management Systems" 3rd ed, Ramakrishnan and Gehrke

Lock Management

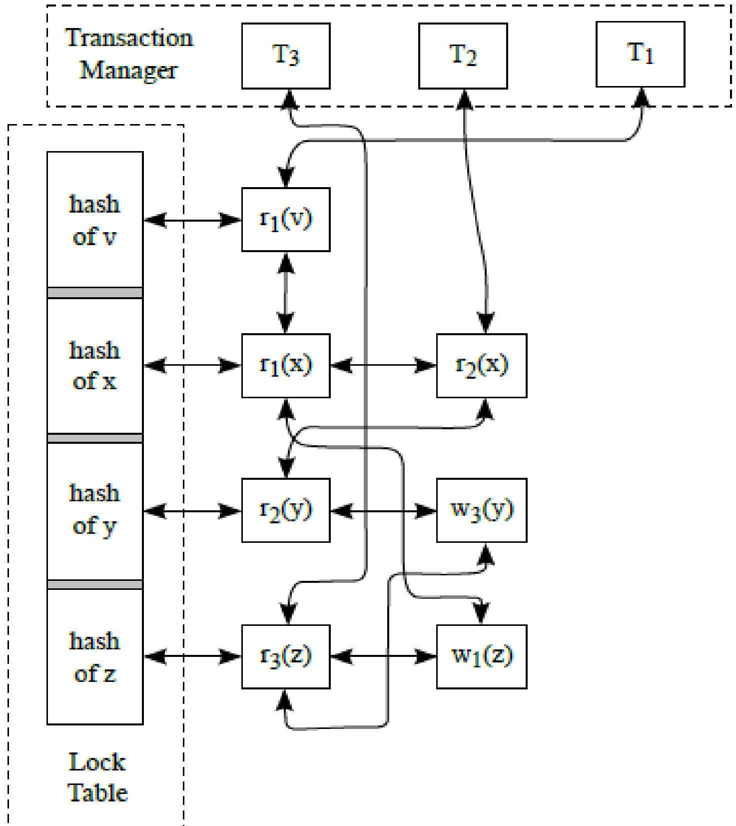
- Lock and unlock requests are handled by the lock manager (see Sec. 17.2.1)

- Lock table entry:
  - Lock name/identifier
  - 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 (need mutex protection)

- Lock table entries are kept in order, to prevent starvation (lots of reads preventing a writer from ever getting a lock, etc.)

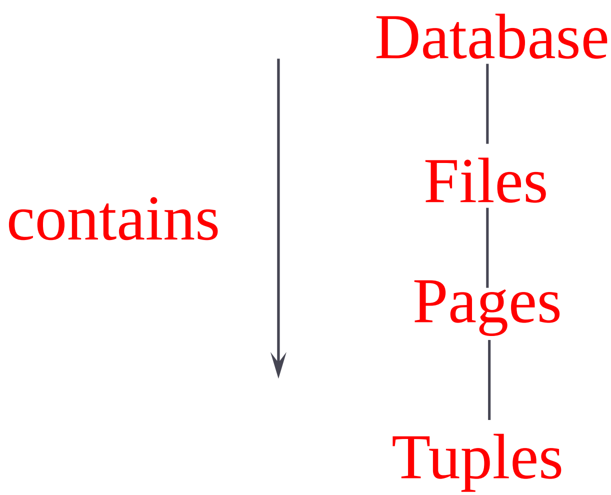
Lock Manager Data structure: a multilist



- Need access to lock entry by lock name or transaction id
- Some of these transactions are blocked on the lock

Multiple-Granularity Locks

- Hard to decide what granularity to lock
  - tuples vs. pages vs. files
  - Inefficient to have a million row locks to scan a relation
- Shouldn't have to decide once and for all!
- Data containers are nested:



New Lock Modes, Protocol

- Allow transactions to lock at each level, but with a special protocol using new **intention locks**

- Before locking an item, must set intention locks on ancestors
- To lock an item with an S lock (X lock), need an IS (IX) lock or stronger on 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	√				

New Lock Modes, Protocol

- Lock manager doesn't care: just make up lock names with table name or item id, use new lock compatibility table
- Protocol makes client check higher level(s) first, then target level, so lock manager itself (or its kernel part) has no responsibility to know relationship between locks

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

New Lock Modes, strength of locks

- Before locking an item, must set intention locks (IS/IX) on ancestors, or stronger locks
- IS is the weakest lock: it only blocks an X-locker (of a different transaction)
- IX is stronger than IS because it blocks an S-locker or an X-locker
- X is stronger than any other lock: it blocks all locks attempts by other transactions
- IX and S are not comparable this way
- SIX: blocks all but IS locks

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

Multiple Granularity Lock Protocol

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

Examples: two levels, relation and tuples

- 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. If overlapping with T1, gets the IS lock on R, but may block on X-locked tuples.
- T3 reads all of R:
  - T3 gets an S lock on R. If overlapping with T1, will block until T1's SIX lock is released
  - OR, T3 could behave like T2; can use lock escalation to decide which.

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

Isolation Levels in Practice

- Databases default to RC, read-committed, so many apps run that way, can have their read data changed, and phantoms
- Web apps (JEE, anyway) have a hard time overriding RC, so most are running at RC
- The 2PL locking scheme we studied was for RR, repeatable read: transaction takes long term read and write locks
- Long term = until commit of that transaction

Read Committed (RC) Isolation

- 2PL can be modified for RC: take long-term write locks but not long term read locks
- Reads are atomic as operations, but that's it
- Lost updates can happen in RC: system takes 2PC locks only for the write operations:

  R1(A)R2(A)W2(B)C2W1(B)C1

  R1(A)R2(A)X2(B)W2(B)C2X1(B)W1(B)C1 (RC isolation)
- Update statements are atomic, so that case of read-then-write is safe even at RC
- Update T set A = A + 100 (safe at RC isolation)
- Remember to use update when possible!

Syntax for SQL

SET TRANSACTION ISOLATION LEVEL
SERIALIZABLE READ WRITE

SET TRANSACTION ISOLATION LEVEL
REPEATABLE READ READ ONLY

- Note:
  - READ UNCOMITTED cannot be READ WRITE

More on setting transaction properties

Embedded SQL

```
EXEC SQL SET TRANSACTION ISOLATION LEVEL SERIALIZABLE
```

JDBC

```
conn.setAutoCommit(false);
conn.setTransactionIsolation
        (Connection.TRANSACTION_ISOLATION_SERIALIZABLE);
```

Snapshot Isolation (SI)

- Multiversion Concurrency Control Mechanism (MVCC)
- This means the database holds more than one value for a data item at the same time

- Used in Oracle, PostgreSQL (as option), MS SQL Server (as option), others

- Readers never conflict with writers unlike traditional DBMS (e.g., IBM DB2)! Read-only transactions run fast.

- Does not guarantee "real" serializability, unless fixed up, i.e., has anomalies. "Serializable Snapshot Isolation" available now in Postgres. Oracle allows SI anomalies.
- <u>But: avoids all anomalies in the ANSI table, so seems OK.</u>
- We found in use at Microsoft in 1993, published as example of MVCC

Snapshot Isolation - Basic Idea:

- Every transaction reads from its own snapshot (copy) of the database (will be created when the transaction starts, or reconstructed from the undo log).
- Writes are collected into a writeset (WS), not visible to concurrent transactions.
- Two transactions are considered to be concurrent if one starts (takes a snapshot) while the other is in progress.

First Committer Wins Rule of SI

- At the commit time of a transaction its WS is compared to those of concurrent committed transactions.
- If there is no conflict (overlapping), then the WS can be applied to stable storage and is visible to transactions that begin afterwards.
- However, if there is a conflict with the WS of a concurrent, already committed transaction, then the transaction must be aborted.
- That's the "First Committer Wins Rule"
- Actually Oracle uses first updater wins, basically same idea, but doesn't require separate WS

Write Skew Anomaly of SI

- In MVCC, data items need subscripts to say which version is being considered
  - Zero version: original database value
  - T1 writes new value of X, X_1
  - T2 writes new value of Y, Y_2
- Write skew anomaly schedule:

$R_1(X_0)\ R_2(X_0)\ R_1(Y_0)\ R_2(Y_{0},)\ W_1(X_1)\ C_1\ W_2(Y_2)\ C_2$

- Writesets WS(T1) = {X}, WS(T2) = {Y}, do not overlap, so both commit.
- So what's wrong—where's the anomaly?

Write Skew Anomaly of SI

$R_1(X_0)\ R_2(X_0)\ R_1(Y_0)\ R_2(Y_0,)\ W_1(X_1)\ C_1\ W_2(Y_2)\ C_2$

- Scenario:
  - X = husband's balance, orig 100,
  - Y = wife's balance, orig 100.
  - Bank allows withdrawals up to combined balance
  - Rule: X + Y >= 0
  - Both withdraw 150, thinking OK, end up with -50 and -50.
- Easy to make this happen in Oracle at "Serializable" isolation.
- See conflicts, cycle in PG, can't happen with full 2PL
- Can happen with RC/locking

How can an Oracle app handle this?

- If X+Y >= 0 is needed as a constraint, it can be "materialized" as sum in another column value.
- Old program: R(X)R(X-spouse)W(X)C
- New program: R(X)R(X-spouse) W(sum) W(X)C
- So schedule will have W(sum) in both transactions, and sum will be in both Writesets, so second committer aborts.

Oracle, Postgres: new failure to handle

- Recall deadlock-abort handling: retry the aborted transaction
- With SI, get "can't serialize access“
  - ORA-08177: can't serialize access for this transaction
  - Means another transaction won for a contended write
- App handles this error like deadlock-abort: just retry transaction, up to a few times
- This only happens when you set serializable isolation level

Other anomalies under SI

- Oldest sailors example
  - Both concurrent transactions see original sailor data in snapshots, plus own updates
  - Updates are on different rows, so both commit
  - Neither sees the other's update
  - So not serializable: one should see one update, other should see two updates.
- Task Registry example:
  - Both concurrent transactions see original state with 6 hours available for Joe
  - Both insert new task for Joe
  - Inserts involve different rows, so both commit

Fixing the task registry phantom problem

- Following the idea of the simple write skew, we can materialize the constraint "workhours <= 8"
- Add a workhours column to worker table
- Old program:
- if sum(hours-for-x)+newhours<=8
-    insert new task
- New program:
- if workhours-for-x + newhours <=8
- { update worker set workhours = workhours + newhours…
-   insert new task
- }

Fixing the Oldest sailor example

- If the oldest sailor is important to the app, materialize it!

Create table oldestsailor (rating int primary key, sid int)

Oracle Read Committed Isolation

- READ COMMITTED is the default isolation level for both Oracle and PostgreSQL.
- A new snapshot is taken for every issued SQL statement (every statement sees the latest committed values).
- If a transaction T2 running in READ COMMITTED mode tries to update a row which was already updated by a concurrent transaction T1, then T2 gets blocked until T1 has either committed or aborted
- Nearly same as 2PL/RC, though all reads occur effectively at the same time for the statement.

Transaction Management: Crash Recovery

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ACID Properties

Transaction Management must fulfill four requirements:

1. Atomicity: either all actions within a transaction are carried out, or none is
   - Only actions of committed transactions must be visible
2. Consistency: concurrent execution must leave DBMS in consistent state
3. Isolation: each transaction is protected from effects of other concurrent transactions
   - Net effect is that of **some sequential execution**
4. Durability: once a transaction commits, DBMS changes will persist
   - Conversely, if a transaction aborts/is aborted, there are no effects

Recovery Manager

- Crash recovery
  - Ensure that atomicity is preserved if the system crashes while one or more transactions are still incomplete
  - Main idea is to keep a log of operations; every action is logged before its page updates reach disk (Write-Ahead Log or WAL)

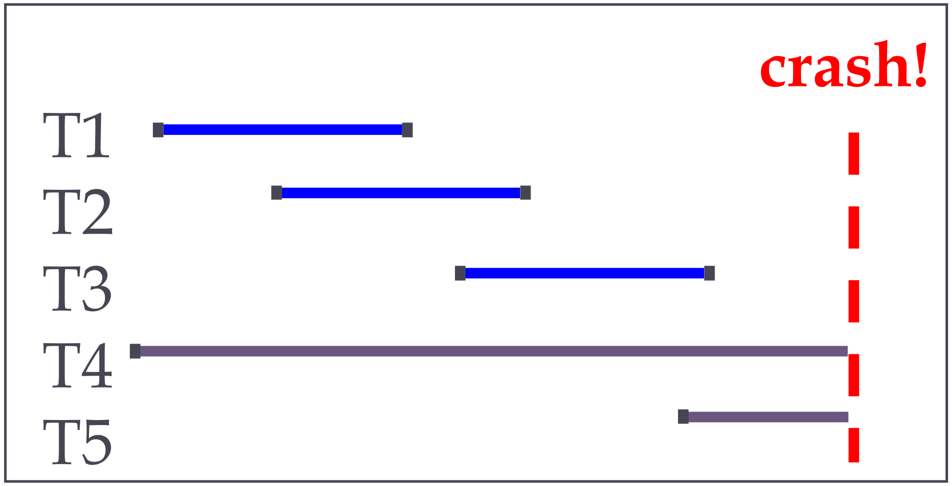
- The **Recovery Manager** guarantees Atomicity & Durability

Motivation

- **Atomicity:**
  - Transactions may abort – must rollback their actions
- **Durability:**
  - What if DBMS stops running – e.g., power failure?

Desired Behavior after system restarts:

- T1, T2 & T3 should be durable
- T4 & T5 should be aborted (effects not seen)



Assumptions

- Concurrency control is in effect
  - Strict 2PL
- Updates are happening "in place"
  - Data overwritten on (deleted from) the disk
- A simple scheme is needed
  - A protocol that is too complex is difficult to implement
  - Performance is also an important issue