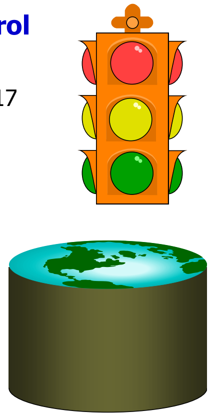
Concurrency Control Part 2

R&G - Chapter 17



The sequel was far better than the original!

-- Nobody

Outline

- Last time:
  - Theory: conflict serializability, view serializability
  - Two-phase locking (2PL)
  - Strict 2PL
  - Dealing with deadlocks (prevention, detection)
- Today: "advanced" locking issues…
  - Locking granularity
  - Optimistic Concurrency Control

Locking Granularity

- Hard to decide what granularity to lock (tuples vs. pages vs. tables).
- ***why?***

Multiple-Granularity Locks

- Shouldn't have to make same decision for all transactions!
- Data "containers" are nested:

contains

Database
Tables
Pages
Tuples

Solution: New Lock Modes, Protocol

- Allow Xacts to lock at each level, but with a special protocol using new "intention" locks:
- Still need S and X locks, but before locking an item, Xact must have proper intension locks on all its ancestors in the granularity hierarchy.

Database
Tables
Pages
Tuples

- IS – Intent to get S lock(s) at finer granularity.
- IX – Intent to get X lock(s) at finer granularity.
- SIX mode: Like S & IX at the same time. Why useful?

Multiple Granularity Lock Protocol

Database
Tables
Pages
Tuples

- 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 S on parent? SIX 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.

Lock Compatibility Matrix

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

Database
Tables
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Tuples

- IS – Intent to get S lock(s) at finer granularity.
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Examples – 2 level hierarchy

Tables
Tuples

- T1 scans R, and updates a few tuples:
  - T1 gets an SIX lock on R, then get X lock on tuples that are updated.
- 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.
  - Lock escalation dynamically asks for coarser-grained locks when too many low level locks acquired

	IS	IX	SIX	S	X
IS	√	√	√	√	
IX	√	√			
SIX	√				
S	√			√	
X					

Just So You're Aware: Indexes

- 2PL on B+-tree pages is a rotten idea.
  - Why?
- Instead, do short locks (latches) in a clever way
  - Idea: Upper levels of B+-tree just need to direct traffic correctly. Don't need to be serializably handled!
  - Different tricks to exploit this
    - Including the "rightlink" trick you peeked at in GiST
- Note: this is pretty complicated!

Just So You're Aware: Phantoms

- Suppose you query for sailors with rating between 10 and 20, using a B+-tree
  - Tuple-level locks in the Heap File
- I insert a Sailor with rating 12
- You do your query again
  - Yikes! A phantom!
  - Problem: Serializability assumed a static DB!
- What we want: lock the *logical* range 10-20
  - Imagine that lock table!
- What is done: set locks in indexes cleverly

Roadmap

- So far:
  - Correctness criterion: serializability
  - Lock-based CC to enforce serializability
    - Strict 2PL
    - Deadlocks
    - Hierarchical Locking
    - Tree latching
    - Phantoms
- Next:
  - Alternative CC mechanism: Optimistic

Optimistic CC (Kung-Robinson)

Locking is a conservative approach in which conflicts are prevented.

- Disadvantages:
  - Lock management overhead.
  - Deadlock detection/resolution.
  - Lock contention for heavily used objects.
- Locking is "pessimistic" because it assumes that conflicts will happen.
- What if conflicts are rare?
  - We might get better performance by not locking, and instead checking for conflicts at commit time.

Kung-Robinson Model

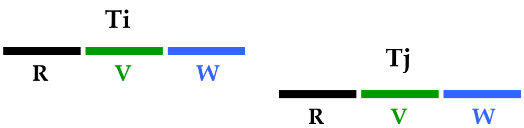
- Xacts have three phases:
  - READ: Xacts read from the database, but make changes to private copies of objects.
  - VALIDATE: Check for conflicts.
  - WRITE: Make local copies of changes public.

Validation

- *Idea:* test conditions that are sufficient to ensure that no conflict occurred.
- Each Xact assigned a numeric id.
  - Just use a **timestamp**.
  - Assigned at end of READ phase.
- ReadSet(Ti): Set of objects read by Xact Ti.
- WriteSet(Ti): Set of objects modified by Ti.

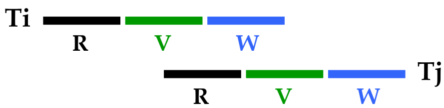
Test 1

- For all i and j such that Ti < Tj, check that Ti completes before Tj begins.



Test 2

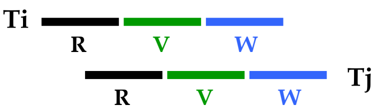
- For all i and j such that Ti < Tj, check that:
  - Ti completes before Tj begins its Write phase **AND**
  - WriteSet(Ti) ∩ ReadSet(Tj) is empty.



Does Tj read dirty data? Does Ti overwrite Tj's writes?

Test 3

- For all i and j such that Ti < Tj, check that:
  - Ti completes Read phase before Tj does **AND**
  - WriteSet(Ti) ∩ ReadSet(Tj) is empty **AND**
  - WriteSet(Ti) ∩ WriteSet(Tj) is empty.



Does Tj read dirty data? Does Ti overwrite Tj's writes?

Applying Tests 1 & 2: Serial Validation

- To validate Xact T:

```
valid = true;
// S = set of Xacts that committed after Begin(T)
//    (above defn implements Test 1)
//The following is done in critical section
< foreach  Ts in S do {
  if ReadSet(T) intersects WriteSet(Ts)
       then valid = false;
  }
  if valid then { install updates; // Write phase
                  Commit T } >
         else Restart T
```

start of critical section

end of critical section

Comments on Serial Validation

- Applies Test 2, with T playing the role of Tj and each Xact in Ts (in turn) being Ti.
- Assignment of Xact id, validation, and the Write phase are inside a **critical section**!
  - Nothing else goes on concurrently.
  - So, no need to check for Test 3 --- can't happen.
  - If Write phase is long, major drawback.
- Optimization for Read-only Xacts:
  - Don't need critical section (because there is no Write phase).

Overheads in Optimistic CC

- Record xact activity in ReadSet and WriteSet
  - Bookkeeping overhead.
- Check for conflicts during validation
  - Critical section can reduce concurrency.
- Private writes have to go somewhere arbitrary
  - Can impact sequential I/Os on read & write.
- Restart xacts that fail validation.
  - Work done so far is wasted; requires clean-up.

Optimistic CC vs. Locking

- Despite its own overheads, Optimistic CC can be better if conflicts are rare
  - Special case: mostly read-only xacts
- What about the case in which conflicts are not rare?
  - The choice is less obvious …

Optimistic CC vs. Locking (for xacts that tend to conflict)

- Locking:
  - Delay xacts involved in conflicts
  - Restart xacts involved in deadlocks
- Optimistic CC:
  - Delay other xacts during critical section (validation+write)
  - Restart xacts involved in conflicts
- Observations:
  - Locking tends to delay xacts longer (duration of X locks usually longer than critical section for validation+write)
    - → could decrease *throughput*
  - Optimistic CC tends to restart xacts more often
    - → more "wasted" resources
    - → decreased throughput if resources are scarce

Rule of thumb: locking wins unless you have lots of spare resources. E.g. distributed system.

Just So You've Heard of Them

- Two more CC techniques
  - Timestamp CC
    - Each xact has a timestamp. It marks it on data it touches. Restart a xact if it tries to mess with a data item from "the future".
  - Multiversion CC
    - Allow objects from many timestamps to coexist.
    - Restart a transaction if it tries to "slip in a version" that should have been seen by somebody that ran previously.

Summary

- Locking, cont
  - Hierarchical Locking a critical extension to 2PL
  - Tree latches a critical issue in practice
  - Phantom handling important in practice
- Optimistic CC using end-of-xact "validation"
  - Good if:
    - Read-dominated workload
    - System has lots of extra resources
- Most DBMSs use locking
  - OCC used in some distributed systems, since restart resources are cheap, latency of locks expensive.