15-721 Database Management Systems

Optimistic Concurrency Control

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Optimistic CC (Kung&Robinson)

- Assumption: conflicts are rare
- Optimize for the no-conflict case.
- All transactions consist of three phases
  - **Read:** Here, all writes are to private storage.
  - **Validation:** Make sure no conflicts have occurred.
  - **Write**: If Validation was successful, make writes public. (If not, abort!)

When Might this Make Sense?

- All transactions are readers
- Lots of transactions, each accessing/modifying only a small amount of data, large total amount of data
  - Low probability of conflict, so again locking is wasted
- Fraction of transaction execution in which conflicts "really take place" is small compared to total path length
  - Locks until end of Xact are way too restrictive most of the time

Validation Phase (1)

- Goal: guarantee only serializable schedules

(Intuitively: at validation, Tj checks its 'elders' for RW and WW conflicts)

- Validation technique:

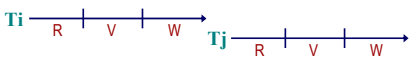
Assign each transaction a TN (transaction #)

(TN order is the serialization order)

If TN(Ti) < TN(Tj) ⇒ **ONE** of the following must hold:

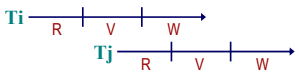
Validation Phase

1. Ti completes W before Tj starts R



Validation Phase (2)

2. WS(Ti) ∩ RS(Tj) = ∅ **and** Ti completes W before Tj starts W

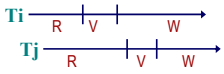


Comments:

- No problem with Tj reading values previous to Ti's writes (nothing in common there)
- No problem with Ti overwriting Tj's writes (no overlap in time)

Validation Phase (3)

3. WS(Ti) ∩ RS(Tj) = ∅ **and**
   WS(Ti) ∩ WS(Tj) = ∅ **and**
   Ti completes its R before Tj completes its R



Validation Phase (cont'd)

Comments:

- No problem with Tj getting (or missing) input from Ti, as there is nothing that Ti writes that Tj touches
- Since Ti finishes its R before Tj finishes its R, Ti won't read any output from Tj either
- No overwrite problems as write-sets are disjoint

Correctness

All of conflict types (WR, RW, WW) go one way

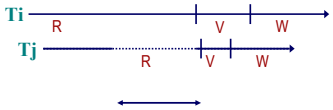
- Condition 1: true serial execution
- Condition 2
  - No W-R conflicts since WS(Ti) intersect RS(Tj) = NULL
  - In R-W conflicts, Ti precedes Tj, since Ti's W (and hence R) of Ti precedes that of Tj
  - In W-W conflicts, Ti precedes Tj by definition

Correctness (cont'd)

- Condition 3
  - No W-R conflicts since WS(Ti) intersect RS(Tj) = NULL
  - No W-W conflicts since WS(Ti) intersect WS(Tj) = NULL
  - In all R-W conflicts, Ti precedes Tj, since the Ti's R precedes Tj's W

Observations

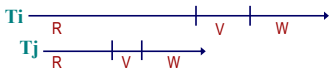
- When to better assign TN's?
- at beginning of read phase: Tj has to wait...



Tj has to wait
for V(Ti)!

Observations

- When to better assign TN's?
- at beginning of **validation** phase:
  - Tj can start
  - condition (3): automatic!



Tj takes TN before Ti

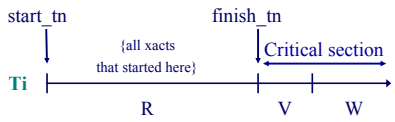
Observations (cont'd)

- BUT: subtle problem: T with very long R!
  - must check ALL T's within its lifetime!!!
  - Requires unbounded buffer space. Solution?
  - Bound buffer, toss out when full, abort possibly affected Ts
  - Starvation!
- Serial/Parallel validation – Pros & cons?

A Serial Validation Technique

Goal: to ensure conditions 1 and/or 2 above.

Requires that write phases be done serially.



Serial Validation Algorithm

1. Record ***start_tn*** when Xact starts (to identify active Xacts later)
2. Obtain the Xact's real Transaction Number (TN) at the start of validation phase
3. Record read set and write set while running and write into local copy
4. Do validation and write phase inside a critical section

Serial Validation: Critical Section

```
beginCriticalSection
finish_tn := currentTN;   /* tentatively assign tn */
valid := true;
for T from start_tn + 1 to finish_tn do
   if (write set of Xact T intersects read set)
      then valid := false;
if valid
   then { write phase; currentTN++; tn := currentTN }
endCriticalSection
if valid then cleanup() else backup();
```


Serial Validation (cont.)

Optimization: Do not assign TN (TID) unless success!

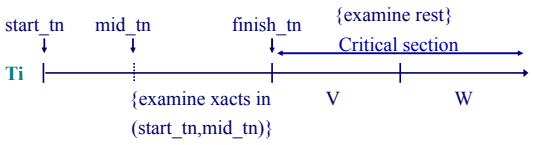
Informally,

1. check current TN;
2. check everything from start until current TN;
3. then enter critical region and do the rest.

Read-only Xacts are not assigned TNs; just check write sets of Xacts with ***start_tn*** < TN < ***finish_tn***

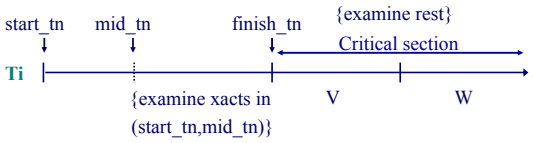
A Serial Validation Technique

Optimization: move some of the validation outside the critical section.



A Serial Validation Technique

This can be repeated for 2nd, 3rd etc time!



Parallel Validation

Only real difference:

now must check condition 3, using ***active***, the set of Xacts that have finished their read phase but have not yet completed their write phases.

Algorithm: in paper

Subtlety: A transaction may cause another transaction to abort, and then abort itself!

Opt CC vs. Locking

Locking:

- order is of first lock;
- wait
- on deadlock, abort

Optimistic cc

- order is of *t(i)*
- abort
- on starvation, lock

Conclusions

- Analysis [Agrawal, Carey, Livny, '87]:
  - dynamic locking performs very well, in most cases
- All vendors use locking
- optimistic cc: promising for OO systems, or when resource utilization is low.

Performance: Opt CC vs. Locking

- With optimistic CC, conflicts are
  - found when the transaction is basically done
  - resolved by aborts/restarts (that waste CPU & I/O resources)
- With locking, conflicts are resolved by waits
- With optimistic CC, updates incur a copy.
- With locking, updates are performed in place
- "Optimistic CC works well when conflicts are rare"
- In that case, smart locking works well too
- Optimistic CC incurs non-trivial cost of maintaining read and write sets.