PURDUE UNIVERSITY | Department of Computer Science

CS 44800: Introduction To Relational Database Systems

Lock Management

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31 March 2021

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Multiple Granularity

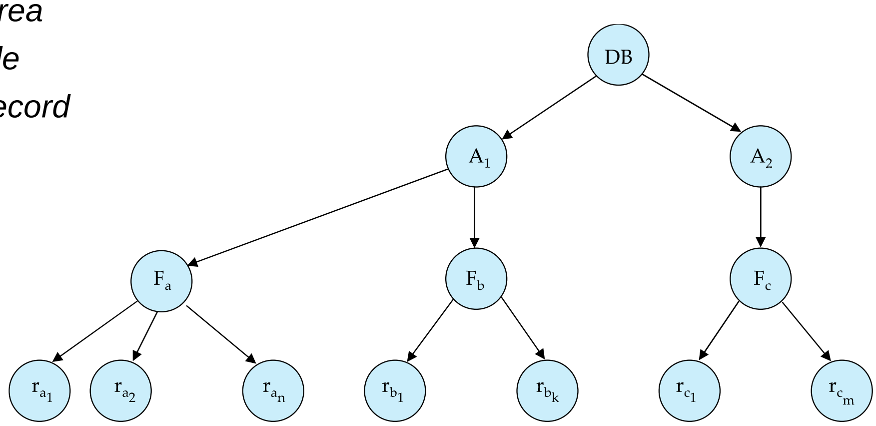
- Allow data items to be of various sizes and define a hierarchy of data granularities, where the small granularities are nested within larger ones
- Can be represented graphically as a tree (but don't confuse with tree-locking protocol)
- When a transaction locks a node in the tree *explicitly*, it *implicitly* locks all the node's descendants in the same mode.
- Granularity of locking (level in tree where locking is done):
  - **Fine granularity** (lower in tree): high concurrency, high locking overhead
  - **Coarse granularity** (higher in tree): low locking overhead, low concurrency

Database System Concepts - 7th Edition 19.55 ©Silberschatz, Korth and Sudarshan

Example of Granularity Hierarchy

The levels, starting from the coarsest (top) level are

- *database*
- *area*
- *file*
- *record*



Compatibility Matrix with Intention Lock Modes

- The compatibility matrix for all lock modes is:

	IS	IX	S	SIX	X
IS	true	true	true	true	false
IX	true	true	false	false	false
S	true	false	true	false	false
SIX	true	false	false	false	false
X	false	false	false	false	false

Multiple Granularity Locking Scheme

- Transaction T_i can lock a node Q, using the following rules:
  1. The lock compatibility matrix must be observed.
  2. The root of the tree must be locked first, and may be locked in any mode.
  3. A node Q can be locked by T_i in S or IS mode only if the parent of Q is currently locked by T_i in either IX or IS mode.
  4. A node Q can be locked by T_i in X, SIX, or IX mode only if the parent of Q is currently locked by T_i in either IX or SIX mode.
  5. T_i can lock a node only if it has not previously unlocked any node (that is, T_i is two-phase).
  6. T_i can unlock a node Q only if none of the children of Q are currently locked by T_i.
- Observe that locks are acquired in root-to-leaf order, whereas they are released in leaf-to-root order.
- **Lock granularity escalation**: in case there are too many locks at a particular level, switch to higher granularity S or X lock

Insert/Delete Operations and Predicate Reads

- Locking rules for insert/delete operations
  - An exclusive lock must be obtained on an item before it is deleted
  - A transaction that inserts a new tuple into the database I automatically given an X-mode lock on the tuple
- Ensures that
  - reads/writes conflict with deletes
  - Inserted tuple is not accessible by other transactions until the transaction that inserts the tuple commits

Phantom Phenomenon

- Example of **phantom phenomenon**.
  - A transaction T1 that performs **predicate read** (or scan) of a relation
    - **select count**(*)
      from *instructor*
      where *dept_name* = 'Physics'
  - and a transaction T2 that inserts a tuple while T1 is active but after predicate read
    - **insert into** *instructor* **values** ('11111', 'Feynman', 'Physics', 94000)

  (conceptually) conflict in spite of not accessing any tuple in common.
- If only tuple locks are used, non-serializable schedules can result
  - E.g. the scan transaction does not see the new instructor, but may read some other tuple written by the update transaction
- Can also occur with updates
  - E.g. update Wu's department from Finance to Physics

Insert/Delete Operations and Predicate Reads

- **Another Example**: T1 and T2 both find maximum instructor ID in parallel, and create new instructors with ID = maximum ID + 1
  - Both instructors get same ID, not possible in serializable schedule
- Schedule

T1	T2
Read(instructor where dept_name='Physics')	
	Insert Instructor in Physics
	Insert Instructor in Comp. Sci.
	Commit
Read(instructor where dept_name='Comp. Sci.')	

Handling Phantoms

- There is a conflict at the data level
  - The transaction performing predicate read or scanning the relation is reading information that indicates what tuples the relation contains
  - The transaction inserting/deleting/updating a tuple updates the same information.
  - The conflict should be detected, e.g. by locking the information.
- One solution:
  - Associate a data item with the relation, to represent the information about what tuples the relation contains.
  - Transactions scanning the relation acquire a shared lock in the data item,
  - Transactions inserting or deleting a tuple acquire an exclusive lock on the data item. (Note: locks on the data item do not conflict with locks on individual tuples.)
- Above protocol provides very low concurrency for insertions/deletions.

Index Locking To Prevent Phantoms

- **Index locking protocol** to prevent phantoms
  - Requires that every relation must have at least one index.
  - A transaction can access tuples only after finding them through one or more indices on the relation
  - A transaction T_i that performs a lookup must lock all the index leaf nodes that it accesses, in S-mode
    - Even if the leaf node does not contain any tuple satisfying the index lookup (e.g. for a range query, no tuple in a leaf is in the range)
  - A transaction T_i that inserts, updates or deletes a tuple t_i in a relation r
    - Must update all indices to r
    - Must obtain exclusive locks on all index leaf nodes affected by the insert/update/delete
  - The rules of the two-phase locking protocol must be observed
- Guarantees that phantom phenomenon won't occur

Next-Key Locking to Prevent Phantoms

- Index-locking protocol to prevent phantoms locks entire leaf node
  - Can result in poor concurrency if there are many inserts
- **Next-key locking protocol**: provides higher concurrency
  - Lock all values that satisfy index lookup (match lookup value, or fall in lookup range)
  - Also lock next key value in index
    - even for inserts/deletes
  - Lock mode: S for lookups, X for insert/delete/update
- Ensures detection of query conflicts with inserts, deletes and updates

Consider B+-tree leaf nodes as below, with query predicate $7 \leq X \leq 16$.
Check what happens with next-key locking when inserting: (i) 15 and (ii) 7