CS315: Database Systems
Concurrency Control

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2nd semester, 2022-23
Tue 10:30-11:45, Thu 12:00-13:15

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- Concurrency control manager decides whether and when to grant locks
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  2. Shared (S) mode: Data item can only be read
- A lock can be granted based on the compatibility matrix
- Lock compatibility matrix or conflict matrix

	S	X
S	yes	no
X	no	no

- If a lock cannot be granted, it must *wait*

Locking Protocol

- A schedule must specify all locking and unlocking operations and their modes
  - $lx(a)$ requests an exclusive lock on data item a; $ux(a)$ releases it
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- Starvation may also happen
- A locking protocol specifies the rules of how a transaction can acquire and release locks

Two-Phase Locking Protocol (2PL)

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- Two phases
- Phase 1: Growing (locking) phase
  - Transaction may obtain locks
  - Transaction cannot release locks
- Phase 2: Shrinking (unlocking) phase
  - Transaction may release locks
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  - $lx_1(a); r_1(a); w_1(a); ls_2(b); r_2(b); ls_2(a); lx_1(b)$
- May suffer from *cascading rollbacks*
  - $lx_1(a); r_1(a); w_1(a); ux_1(a); lx_2(a); r_2(a); w_2(a); ux_2(a);$
    $ls_3(a); r_3(a); a_1$

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- Rigorous 2PL
  - A transaction must hold *all* its locks till it commits or aborts
  - Transactions can be serialized in the order of their commits
- Conservative (static) 2PL
  - All locks are acquired atomically before a transaction begins
  - Each transaction declares its read set and write set
  - Deadlock-free

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- Protocols using timestamps *cannot* deadlock

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- Is *not recoverable*

Modifications

- To make it recoverable
  - Use commit dependency
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- To make it recoverable and cascadeless
  - Wait for data to be committed before allowing read
- Strict timestamp ordering: to make it strict
  - Wait for data to be committed before reading or writing

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- Improves concurrency and recoverability
- Allows some *view-serializable schedules* that are not conflict-serializable
  - $r_1(a) w_2(a) w_1(a) w_3(a)$

Validation (Certification)-Based Protocol

- Three phases of a transaction T
- Read and execution phase: T writes only to local temporary variables
- Validation phase: T performs validation test to determine if local variables can be written without violating serializability
- Write phase: If T is validated, it updates the database; otherwise it is rolled back (actually nothing needs to be done)
- Also known as optimistic concurrency control since transaction executes fully in the hope that all is well

Validation Timestamp

- Three timestamps for each transaction
  - *start(T)*: start of execution phase
  - *validation(T)*: start of validation phase
  - *finish(T)*: end of write phase
- Timestamp of T is set to validation timestamp: ts(T) = validation(T)
- Serialized using this timestamp
  - Increases concurrency

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- Starvation
- No deadlock

Validation Test

- For a transaction T_i, check two conditions for all transactions T_j with $\mathrm{ts}(T_j) < \mathrm{ts}(T_i)$
  - $\mathrm{finish}(T_j) < \mathrm{start}(T_i)$
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- Justification
  - First condition ensures serial schedules
  - Writes of T_i cannot affect reads of T_j

Validation Test

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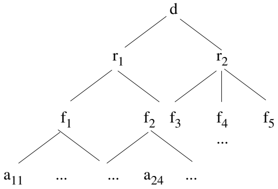
- If either of these conditions is true, validation succeeds; otherwise, it fails
- Justification
  - First condition ensures serial schedules
  - Writes of T_i cannot affect reads of T_j
  - Writes of T_j do not affect reads of T_i as they are disjoint

Mutliple Granularity

- Hierarchy of data items
  - DB, Relation, Tuple, Attribute
- Locking can be done at different levels
- Locking a node *explicitly* locks all its descendants *implicitly*
  - Explicit locks
  - Implicit locks
- Granularity of locking
  - *Fine granularity*: lower in tree, high concurrency, high locking overhead
  - *Coarse granularity*: higher in tree, low concurrency, low locking overhead

Problems of Simple Locking



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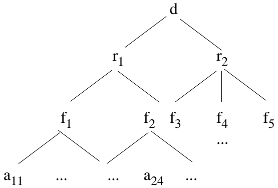

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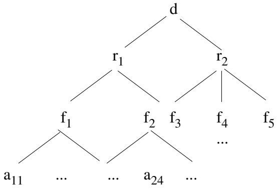

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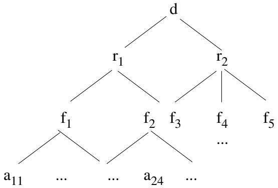

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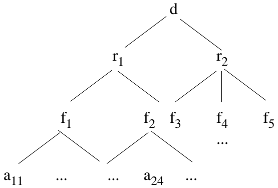

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  - It cannot since that would lock f_2 implicitly
  - Find out by searching entire subtree under r_1
- Thus, for efficiency, intention lock modes are used
  - Ancestors of an explicitly locked node are in intention mode

Intention Lock Modes

- In addition to shared (S) and exclusive (X) locks, three additional locks
- Intention-shared (IS): at least one descendant has a S lock
- Intention-exclusive (IX): at least one descendant has a X lock
- Shared and intention-exclusive (SIX): node is locked in S mode *and* at least one descendant has X lock

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- Locks are released in leaf-to-root order
- Compatibility matrix

	IS	IX	S	SIX	X
IS	yes	yes	yes	yes	no
IX	yes	yes	no	no	no
S	yes	no	yes	no	no
SIX	yes	no	no	no	no
X	no	no	no	no	no

Multiple Granularity Locking Scheme

- Transaction T wants to lock a node x:
  - Lock compatibility matrix is observed
  - In S or IS mode: only if parent of x is locked by T in IX or IS mode
  - In X, SIX or IX mode: only if parent of x is locked by T in IX or SIX mode
  - Maintains 2PL, i.e., has not unlocked anything

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Multiple Granularity Locking Scheme

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- Ensures conflict serializability

SIX Lock

- Suppose T_1 wants to read r_1 but only modify a_{24}
- Locking r_1 in IX mode will allow other transactions to lock r_1 in IX mode
  - Unsafe as T_1 is reading r_1
- Locking r_1 in S mode will allow other transactions to lock r_1 in S mode and read everything
  - Unsafe as T_1 is modifying a_{24}
- SIX lock compromises and is safer

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- Wound-wait has fewer rollbacks than wait-die
  - Less likely for old transactions to not finish and want a lock from a young transaction

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- Starvation happens when the same transaction is repeatedly chosen as the victim
  - Factor number of rollbacks when choosing victim

Insert and Delete

- insert(x): inserts the data item x
- delete(x): deletes the data item x
- Logical errors
  - read(x), write(x) before insert(x)
  - read(x), write(x) after delete(x)
  - delete(x) after delete(x)
  - insert(x) after insert(x)
- Conflicts
  - Similar to write(x)
  - Conflicts with operations on relation

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- Exclusive lock on relation solves this
- Multi-granularity locking
- If index structure is used, index locking protocol improves concurrency by locking index nodes
  - Avoids phantom phenomenon since every transaction needs to lock all accessed nodes