CS315: Principles of Database Systems
Concurrency Control Protocols

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- Concurrency control manager decides whether and when to grant locks
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- 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
  - $ls(a)$ requests a shared lock on data item a; $us(a)$ releases it
- Example: $lx_1(a); r_1(a); w_1(a); ls_2(b); r_2(b); ux_1(a); us_2(b)$

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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)

- Two phases
- Phase 1: Growing (locking) phase
  - Transaction may obtain locks
  - Transaction may not release locks
- Phase 2: Shrinking (unlocking) phase
  - Transaction may release locks
  - Transaction may not obtain locks

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- 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

Timestamps

- Each transaction is assigned a timestamp when it starts
  - Transaction T_i starting earlier has a lower timestamp than T_j starting later
- For each data item x, two timestamps are maintained
- write-timestamp(x) is the largest timestamp of any transaction that executed write successfully
- read-timestamp(x) is the largest timestamp of any transaction that executed read successfully
- Protocols using timestamps *cannot* deadlock

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- Is not cascadeless
- Is not recoverable

Modifications

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

Thomas' write rule

- Obsolete writes may be ignored
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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
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- No deadlock

Validation test

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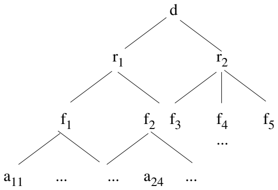
  - Writes of T_j do not affect reads of T_i as they are disjoint

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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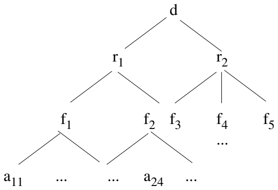

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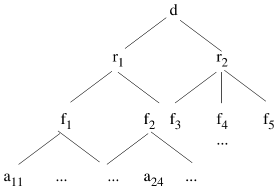

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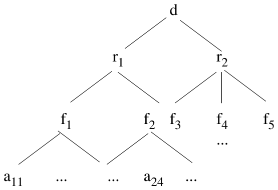

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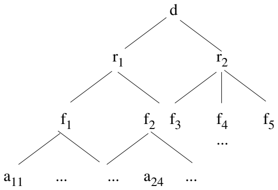

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  - Find out by searching entire subtree under r_1
- Thus, for efficiency, intention lock modes are used
  - Ancestors of an explicitly locked node are in intention mode

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

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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
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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

Example

- T_1 wants to read a_{12}

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  - Locks d, r_1, f_1 in IS mode and a_{12} in S mode
- T_2 wants to write a_{14}

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  - Locks d, r_1, f_1 in IX mode and a_{12} in X mode
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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)

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- 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