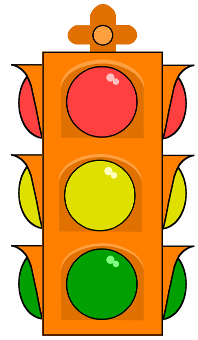
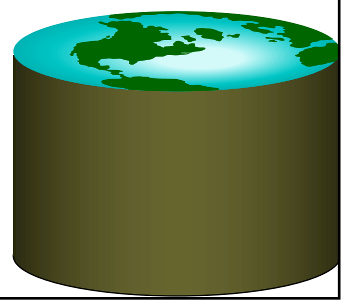
Concurrency Control More !

Chapter 17



Smile, it is the key that fits the lock of everybody's heart.

Anthony J. D'Angelo,
The College Blue Book



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Review: Two-Phase Locking (2PL)

- **Two-Phase Locking Protocol**
  - Each Xact must obtain a S (*shared*) lock on object before reading, and an X (*exclusive*) lock on object before writing.
  - A transaction can not request additional locks once it releases any locks.
  - If a Xact holds an X lock on an object, no other Xact can get a lock (S or X) on that object.
- **Can result in Cascading Aborts!**
  - STRICT (!!) 2PL "Avoids Cascading Aborts" (ACA)

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Lock Management

- **Lock and unlock requests are handled by the lock manager**
- **Lock table entry:**
  - Number of transactions currently holding a lock
  - Type of lock held (shared or exclusive)
  - Pointer to queue of lock requests
- **Locking and unlocking have to be atomic operations**
  - requires latches ("semaphores"), which ensure that the process is not interrupted while managing lock table entries
  - see OS course for implementations of semaphores
- **Lock upgrade: transaction that holds a shared lock can be upgraded to hold an exclusive lock**
  - Can cause deadlock problems

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Deadlocks

- **Deadlock: Cycle of transactions waiting for locks to be released by each other.**
- **Two ways of dealing with deadlocks:**
  - Deadlock prevention
  - Deadlock detection

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Deadlock Prevention

- **Assign priorities based on timestamps. Assume Ti wants a lock that Tj holds. Two policies are possible:**
  - Wait-Die: If Ti has higher priority, Ti waits for Tj; otherwise Ti aborts
  - Wound-wait: If Ti has higher priority, Tj aborts; otherwise Ti waits
- **If a transaction re-starts, make sure it gets its original timestamp**
  - Why?

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Deadlock Detection

- **Create a waits-for graph:**
  - Nodes are transactions
  - There is an edge from Ti to Tj if Ti is waiting for Tj to release a lock
- **Periodically check for cycles in the waits-for graph**

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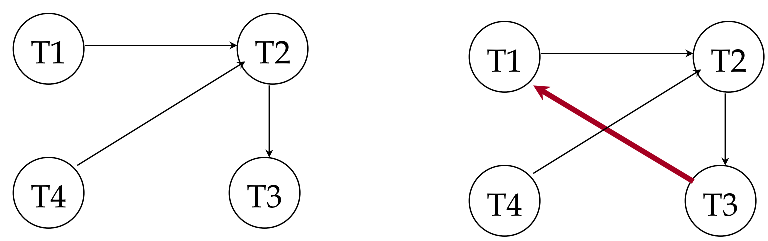
Deadlock Detection (Continued)

Example:

T1: S(A), S(D), S(B)
T2: X(B) X(C)
T3: S(D), S(C), X(A)
T4: X(B)



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Deadlock Detection (cont.)

- **In practice, most systems do detection**
  - Experiments show that most waits-for cycles are length 2 or 3
  - Hence few transactions need to be aborted
  - Implementations can vary
    - Can construct the graph and periodically look for cycles
      - When is the graph created ?
        - Either continuously or at cycle checking time
      - Which process checks for cycles ?
        - Separate deadlock detector
    - Can do a “time-out” scheme: if you’ve been waiting on a lock for a long time, assume you’re deadlock and abort

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Summary

- **Correctness criterion for isolation is "serializability".**
  - In practice, we use "conflict serializability", which is somewhat more restrictive but easy to enforce.
- **There are several lock-based concurrency control schemes (Strict 2PL, 2PL). Locks directly implement the notions of conflict.**
  - The lock manager keeps track of the locks issued. Deadlocks can either be prevented or detected.

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Conflict serializability

- **A transaction schedule is conflict serializable if it can be transformed into a serial schedule by swapping non conflicting operations**
- **S1: $R_1(A)$, $W_1(A)$, $R_2(A)$, $W_2(A)$, $R_1(B)$, $W_1(B)$, $R_2(B)$, $W_2(B)$**
- **T1: $R_1(A)$, $W_1(A)$, $R_1(B)$, $W_1(B)$**
- **T2: $R_2(A)$, $W_2(A)$, $R_2(B)$, $W_2(B)$**
- **Possible Serial Schedules are: T1->T2 or T2->T1**

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Conflict Serializability

- **Swapping non-conflicting operations $R_2(A)$ and $R_1(B)$ in S1, the schedule becomes,**
- **S11: $R_1(A)$, $W_1(A)$, $R_1(B)$, $W_2(A)$, $R_2(A)$, $W_1(B)$, $R_2(B)$, $W_2(B)$**
- **Similarly, swapping non-conflicting operations $W_2(A)$ and $W_1(B)$ in S11, the schedule becomes,**
- **S12: $R_1(A)$, $W_1(A)$, $R_1(B)$, $W_1(B)$, $R_2(A)$, $W_2(A)$, $R_2(B)$, $W_2(B)$**

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Things We' re Glossing Over

- **What should we lock?**
  - We assume tuples here, but that can be expensive!
  - If we do table locks, that' s too conservative
  - *Multi-granularity* locking
- **Mechanisms**
  - Locks and Latches
- **Repeatability**
  - In a Xact, what if a query is run again ?
  - Are more records (phantoms) tolerable ?

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Multiple-Granularity Locks

- **Hard to decide what granularity to lock (tuples vs. pages vs. tables).**
- **Shouldn't have to make same decision for all transactions!**
- **Data "containers" are nested:**

contains ↓

Database

Tables

Pages

Tuples

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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?

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

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Multiple Granularity Lock Protocol

- **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 SIX on parent? S 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.

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Examples – 2 level hierarchy

- **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

Tables
|
Tuples

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

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Locks and Latches

- **What's common ?**
  - Both used to synchronize concurrent tasks
- **What's different ?**
  - Locks are used for *logical consistency*
  - Latches are used for *physical consistency*
- **Why treat 'em differently ?**
  - Database people like to *reason* about our data
- **Where are latches used ?**
  - In a lock manager !
  - In a shared memory buffer manager
  - In a B+ Tree index
  - In a log/transaction/recovery manager

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Locks vs Latches

	Latches	**Locks**
Ownership	Processes	Transactions
Duration	Very short	Long (Xact duration)
Deadlocks	No detection - code carefully !	Checked for deadlocks
Overhead	Cheap - 10s of instructions (latch is directly addressable)	Costly - 100s of instructions (got to search for lock)
Modes	S, X	S, X, IS, IX, SIX
Granularity	Flat - no hierarchy	Hierarchical

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Dynamic Databases – The "Phantom" Problem

- **If we relax the assumption that the DB is a fixed collection of objects, even Strict 2PL (on individual items) will not assure serializability:**
- **Consider T1 – "Find oldest sailor for each rating"**
  - T1 locks all pages containing sailor records with *rating* = 1, and finds oldest sailor (say, *age* = 71).
  - Next, T2 inserts a new sailor; *rating* = 1, *age* = 96.
  - T2 also deletes oldest sailor with rating = 2 (and, say, *age* = 80), and commits.
  - T1 now locks all pages containing sailor records with *rating* = 2, and finds oldest (say, *age* = 63).
- **No serial execution where T1's result could happen!**
  - Let's try it and see!

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The Problem

- **T1 implicitly assumes that it has locked the set of all sailor records with *rating* = 1.**
  - Assumption only holds if no sailor records are added while T1 is executing!
  - Need some mechanism to enforce this assumption. (Index locking and predicate locking.)
- **Example shows that conflict serializability guarantees serializability only if the set of objects is fixed!**
  - e.g. table locks

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Predicate Locking

- **Grant lock on all records that satisfy some logical predicate, e.g. *age > 2*salary*.**
- **Index locking is a special case of predicate locking for which an index supports efficient implementation of the predicate lock.**
  - What is the predicate in the sailor example?
- **In general, predicate locking has a lot of locking overhead.**
  - too expensive!

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Instead of predicate locking

- **Table scans lock entire tables**
- **Index lookups do "next-key" locking**
  - physical stand-in for a logical range!

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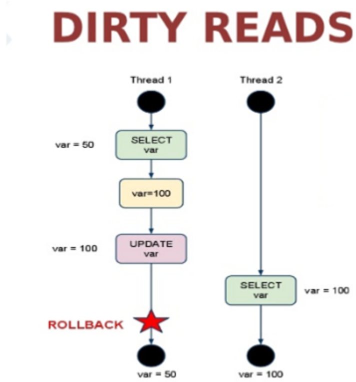
SQL ISOLATION LEVELS

- **READ UNCOMMITED (allows dirty reads, phantoms)**



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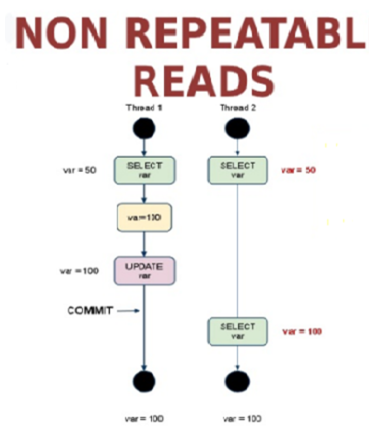
SQL ISOLATION LEVELS

- **READ COMMITTED (non repeatable reads, phantoms)**



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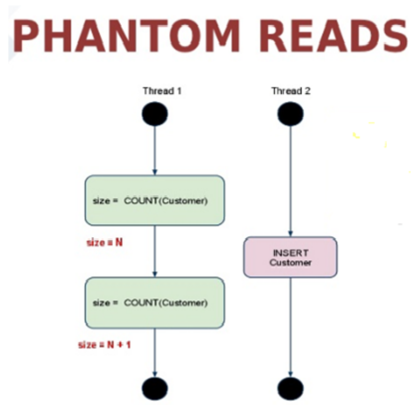
SQL ISOLATION LEVELS

- **REPEATABLE READS (phantom reads)**



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SQL ISOLATION LEVELS

- **SERIALIZABLE (complete isolation)**
- **Like repeatable reads but no phantoms**

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