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Chapter 15 : Concurrency Control

CSR IS TOO COSTLY FOR PRACTICAL USE. HERE, WE ARE GOING TO DISCUSS SOME ALTERNATIVES BASED ON LOCKS

Database System Concepts, 6th Ed.

Lock-Based Protocols

- A lock is a mechanism to control concurrent access to a data item
- Data items can be locked in two modes :
  1. *exclusive (X) mode*. Data item can be both read as well as written. X-lock is requested using **lock-X** instruction.
  2. *shared (S) mode*. Data item can only be read. S-lock is requested using **lock-S** instruction.
- Lock requests are made to the concurrency-control manager by the programmer. Transaction can proceed only after request is granted.

Lock-Based Protocols (Cont.)

- **Lock-compatibility matrix**

	S	X
S	true	false
X	false	false

- A transaction may be granted a lock on an item if the requested lock is compatible with locks already held on the item by other transactions
- Any number of transactions can hold shared locks on an item,
  - But if any transaction holds an exclusive on the item no other transaction may hold any lock on the item.
- If a lock cannot be granted, the requesting transaction is made to wait till all incompatible locks held by other transactions have been released. The lock is then granted.

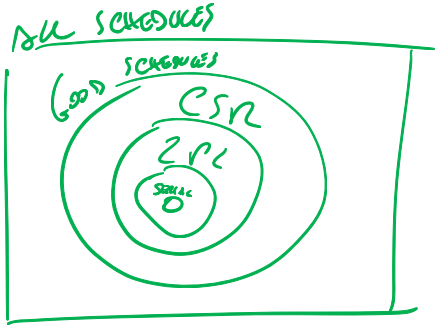
Lock-Based Protocols (Cont.)

- Example of a transaction performing locking:

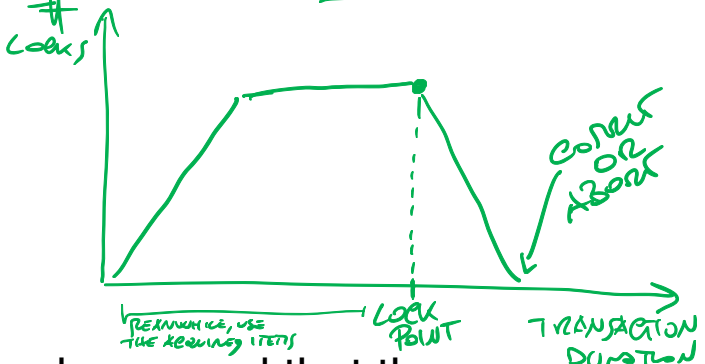
  T_2: **lock-S**(*A*);
  read (*A*);
  unlock(*A*);
  lock-S(*B*);
  read (*B*);
  unlock(*B*);
  display(*A*+*B*)

- Locking as above is not sufficient to guarantee serializability — if *A* and *B* get updated in-between the read of *A* and *B*, the displayed sum would be wrong.
- A **locking protocol** is a set of rules followed by all transactions while requesting and releasing locks. Locking protocols restrict the set of possible schedules.

The Two-Phase Locking Protocol



- This protocol ensures conflict-serializable schedules.
- Phase 1: Growing Phase
  - Transaction may obtain locks
  - Transaction may not release locks
- Phase 2: Shrinking Phase
  - Transaction may release locks
  - Transaction may not obtain locks
- The protocol assures serializability. It can be proved that the transactions can be serialized in the order of their **lock points** (i.e., the point where a transaction acquired its final lock).



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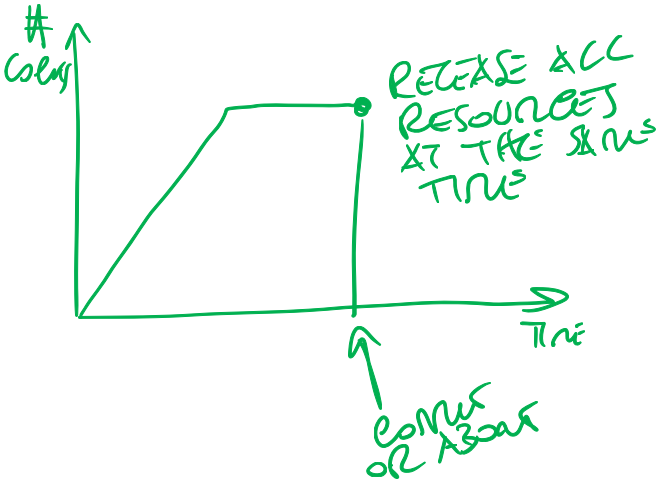
The Two-Phase Locking Protocol (Cont.)

- There can be conflict serializable schedules that cannot be obtained if two-phase locking is used.

VARIANT: STRICT 2PL:

PROBLEM WITH PLAIN 2PL:



T_1 IS RELEASING ITS LOCK OVER TIME. T_2 ACQUIRES SOME OF ITS RELEASED LOCKS AND STARTS ITS EXECUTION, SO IT IS WORKING ON INFO. MODIFIED BY T_1. THEN T_1 ENCOUNTERS A PROBLEM, AND IS ABORTED. BUT T_2 HAS ALREADY STARTED TO WORK ON SOME DATA AFFECTED BY T_1, SO IT HAS TO BE ROLLED BACK AS WELL.

Lock Conversions

- Two-phase locking with lock conversions:
  - First Phase:
    - can acquire a lock-S on item
    - can acquire a lock-X on item
    - can convert a lock-S to a lock-X (upgrade)
  - Second Phase:
    - can release a lock-S
    - can release a lock-X
    - can convert a lock-X to a lock-S (downgrade)
- This protocol assures serializability. But still relies on the programmer to insert the various locking instructions.

Automatic Acquisition of Locks

- A transaction T_i issues the standard read/write instruction, without explicit locking calls.
- The operation **read**(*D*) is processed as:

```
if Ti has a lock on D
  then
      read(D)
  else begin
      if necessary wait until no other
         transaction has a lock-X on D
      grant Ti a lock-S on D;
      read(D)
  end
```

Automatic Acquisition of Locks (Cont.)

- **write**(*D*) is processed as:

```
if Ti has a lock-X on D
  then
    write(D)
  else begin
    if necessary wait until no other transaction has any lock on D,
    if Ti has a lock-S on D
      then
        upgrade lock on D to lock-X
      else
        grant Ti a lock-X on D
      write(D)
  end;
```

Does somebody of you spot a problem with this policy of waiting/granting/releasing locks?

- All locks are released after commit or abort

(If we consider strict 2-P L)

NOW CONSIDER THIS SITUATION

Deadlocks

- Consider the partial schedule

T_3	T_4
lock-x (B)	
read (B)	
$B := B - 50$	
write (B)	
	lock-s (A)
	read (A)
	lock-s (B)
lock-x (A)	

WAIT

WAIT

- Neither T_3 nor T_4 can make progress — executing **lock-S**(B) causes T_4 to wait for T_3 to release its lock on B, while executing **lock-X**(A) causes T_3 to wait for T_4 to release its lock on A.
- Such a situation is called a **deadlock**.
  - To handle a deadlock one of T_3 or T_4 must be rolled back and its locks released.

Deadlocks (Cont.)

- Two-phase locking *does not* ensure freedom from deadlocks.
- In addition to deadlocks, there is a possibility of **starvation.**
- **Starvation** occurs if the concurrency control manager is badly designed. For example:
  - A transaction may be waiting for an X-lock on an item, while a sequence of other transactions request and are granted an S-lock on the same item.
  - The same transaction is repeatedly rolled back due to deadlocks.
- Concurrency control manager can be designed to prevent starvation.

AGEING

FOR INSTANCE, IT MAY PREFER TO GRANT SHARED LOCKS SINCE THEY ARE LESS "COSTLY"

Strategies to deal with deadlocks:
- deadlock prevention
- deadlock detection

Deadlock Handling

- System is deadlocked if there is a set of transactions such that every transaction in the set is waiting for another transaction in the set.
- ***Deadlock prevention*** protocols ensure that the system will *never* enter into a deadlock state. Some prevention strategies :
  - Require that each transaction locks all its data items before it begins execution (predeclaration). → TOO RESTRICTIVE, MAY NEVER FIND ALL OF THEM AVAILABLE
  - Impose partial ordering of all data items and require that a transaction can lock data items only in the order specified by the partial order.

THEN WE BREAK CYCLES

A TRANSACTION MAY PREFER A DIFFERENT ORDER...

More Deadlock Prevention Strategies

- Following schemes use transaction timestamps for the sake of deadlock prevention alone.
- **wait-die** scheme — non-preemptive

IF T_i WAITS ON A RESOURCE HELD BY T_j, WHICH IS YOUNGER THAN T_i, THEN T_i KILLS T_j —

  - older transaction may wait for younger one to release data item. (older means smaller timestamp)
    Younger transactions never wait for older ones; they are rolled back instead.
  - a transaction may die several times before acquiring needed data item
- **wound-wait** scheme — preemptive
  - older transaction *wounds* (forces rollback of) younger transaction instead of waiting for it. Younger transactions may wait for older ones.

KILLING A TRANSACTION IS NOT A TRAGEDY, SINCE ALL OPERATIONS IT HAS DONE UP TO THAT POINT ARE UNDONE, AND THE ENTIRE TRANSACTION IS THEN RESTARTED —

Deadlock prevention (Cont.)

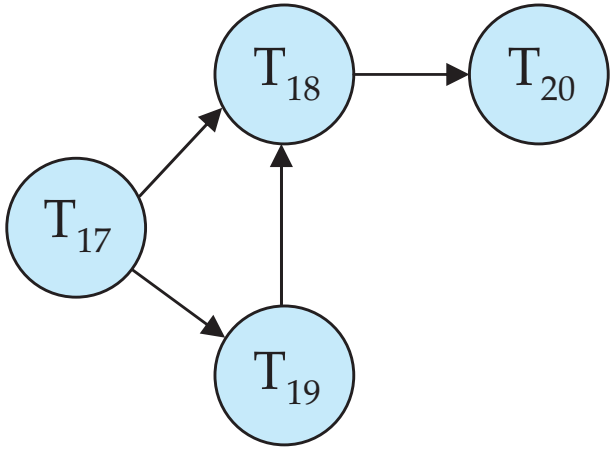
- Both in *wait-die* and in *wound-wait* schemes, a rolled back transactions is restarted with its original timestamp. Older transactions thus have precedence over newer ones, and starvation is hence avoided.
- **Timeout-Based Schemes:**
  - a transaction waits for a lock only for a specified amount of time. If the lock has not been granted within that time, the transaction is rolled back and restarted,
  - Thus, deadlocks are not possible
  - simple to implement; but starvation is possible. Also difficult to determine good value of the timeout interval.

MOST USED AMONG DEADLOCK PREVENTION STRATEGIES - KIND OF SUICIDE BY THE TRANSACTION -

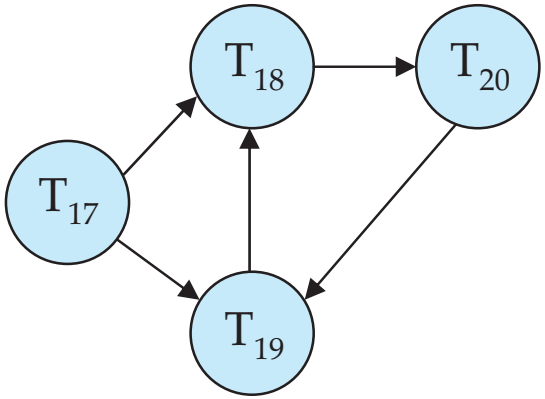
Deadlock Detection

- Deadlocks can be described as a *wait-for graph*, which consists of a pair $G = (V,E)$,
  - V is a set of vertices (all the transactions in the system)
  - E is a set of edges; each element is an ordered pair $T_i \rightarrow T_j$.
- If $T_i \rightarrow T_j$ is in E, then there is a directed edge from T_i to T_j, implying that T_i is waiting for T_j to release a data item.
- When T_i requests a data item currently being held by T_j, then the edge $T_i \rightarrow T_j$ is inserted in the wait-for graph. This edge is removed only when T_j is no longer holding a data item needed by T_i.
- The system is in a deadlock state if and only if the wait-for graph has a cycle. Must invoke a deadlock-detection algorithm periodically to look for cycles.

Deadlock Detection (Cont.)



Wait-for graph without a cycle



Wait-for graph with a cycle

MOST USED SOLUTIONS

- TIMEOUT-BASED DEADLOCK PREVENTION
- DEADLOCK DETECTION WITH GRAPHS