Database Management Systems

Module 50: Concurrency Control/2

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Module Recap

- Understood the locking mechanism and protocols
- Realized that deadlock is a peril of locking and needs to be handled through rollback

Module Objectives

- Deadlocks are perils of locking. We need to understand how to detect, prevent and recover from deadlock
- Introduce a simple time-based protocol that avoids deadlocks

Module Outline

- Deadlock Handling
- Timestamp-Based Protocols

Deadlock Handling

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 (pre-declaration)
  - 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

Deadlock Prevention

- **Transaction Timestamp**: Timestamp is a unique identifier created by the DBMS to identify the relative starting time of a transaction. Timestamping is a method of concurrency control in which each transaction is assigned a transaction timestamp
- Following schemes use transaction timestamps for the sake of deadlock prevention alone
  - **wait-die** scheme: non-preemptive
    - ▷ 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
    - ▷ May be fewer rollbacks than *wait-die* scheme

Deadlock Prevention (2): Wait-Die Scheme

- It is a **non-preemptive** technique for deadlock prevention
- When transaction T_n requests a data item currently held by T_k, T_n is allowed to wait only if it has a timestamp *smaller* than that of T_k (That is, T_n is older than T_k), otherwise T_n is killed ("die")
- If a transaction requests to lock a resource (data item), which is already held with a conflicting lock by another transaction, then one of the two possibilities may occur:
  - **Timestamp**(T_n) $<$ **Timestamp**(T_k): T_n, which is requesting a conflicting lock, is older than T_k, then T_n is allowed to "wait" until the data-item is available.
  - **Timestamp**(T_n) $>$ **Timestamp**(T_k): T_n is younger than T_k, then T_n is killed ("dies"). *T_n is restarted later with a random delay but with the same timestamp(n)*
- This scheme allows the older transaction to "wait" but kills the younger one ("die")
- Example
  - Suppose that transaction T_5, T_{10}, T_{15} have time-stamps 5, 10 and 15 respectively
  - If T_5 requests a data item held by T_{10} then T_5 will "wait"
  - If T_{15} requests a data item held by T_{10}, then T_{15} will be killed ("die")

Source: *What is the difference between "wait-die" and "wound-wait" deadlock prevention algorithms?*

Deadlock Prevention (3): Wound-Wait Scheme

- It is a **preemptive** technique for deadlock prevention
- When transaction T_n requests a data item currently held by T_k, T_n is allowed to wait only if it has a timestamp *larger* than that of T_k, otherwise T_k is killed (wounded by T_n)
- If a transaction requests to lock a resource (data item), which is already held with a conflicting lock by another transaction, then one of the two possibilities may occur:
  - **Timestamp(** T_n **)** $<$ **Timestamp(** T_k **)**: T_n forces T_k to be killed ("wounds"). *T_k is restarted later with a random delay but with the same timestamp(k)*
  - **Timestamp(** T_n **)** $>$ **Timestamp(** T_k **)**: T_n "wait"s until the resource is free
- This scheme allows the younger transaction requesting a lock to "wait" if the older transaction already holds a lock, but forces the younger one to be suspended ("wound") if the older transaction requests a lock on an item already held by the younger one
- Example
  - Suppose that transaction T_5, T_{10}, T_{15} have time-stamps 5, 10 and 15 respectively
  - If T_5 requests a data item held by T_{10}, then it will be preempted from T_{10} and T_{10} will be suspended ("wounded")
  - If T_{15} requests a data item held by T_{10}, then T_{15} will "wait"

Source: *What is the difference between "wait-die" and "wound-wait" deadlock prevention algorithms?*

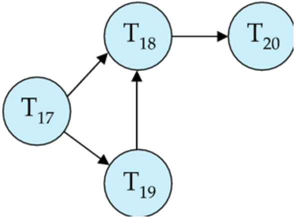
Deadlock Prevention

- Both in *wait-die* and in *wound-wait* schemes, a rolled back transaction 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

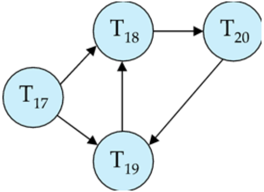
Deadlock Detection

- 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: Example



Wait-for graph without a cycle



Wait-for graph with a cycle

Deadlock Recovery

- When deadlock is detected:
  - Some transaction will have to rolled back (made a victim) to break deadlock. Select that transaction as victim that will incur minimum cost
  - Rollback – determine how far to roll back transaction
    - Total rollback: Abort the transaction and then restart it
    - More effective to roll back transaction only as far as necessary to break deadlock
  - Starvation happens if same transaction is always chosen as victim. Include the number of rollbacks in the cost factor to avoid starvation

Timestamp-Based Protocols

Timestamp-Based Protocols

- Each transaction is issued a timestamp when it enters the system. If an old transaction T_i has time-stamp TS(T_i), a new transaction T_j is assigned time-stamp $TS(T_j)$ such that $TS(T_i) < TS(T_j)$.
- The protocol manages concurrent execution such that the time-stamps determine the serializability order
- In order to assure such behavior, the protocol maintains for each data Q two timestamp values:
  - **W-timestamp(Q)** is the largest time-stamp of any transaction that executed **write**(Q) successfully
  - **R-timestamp(Q)** is the largest time-stamp of any transaction that executed **read**(Q) successfully

Timestamp-Based Protocols (2)

- The timestamp ordering protocol ensures that any conflicting **read** and **write** operations are executed in timestamp order
- Suppose a transaction T_i issues a **read**(Q)
  a) If $TS(T_i) \leq$ **W**-timestamp(Q), then T_i needs to **read** a value of Q that was already overwritten
     - Hence, the **read** operation is rejected, and T_i is rolled back.

  b) If $TS(T_i) \geq$ **W**-timestamp(Q), then the **read** operation is executed, and **R**-timestamp(Q) is set to **max**(**R**-timestamp(Q), $TS(T_i)$).

Timestamp-Based Protocols (3)

- Suppose that transaction T_i issues **write**(Q).
  - If $TS(T_i) < $ **R**-timestamp(Q), then the value of Q that T_i is producing was needed previously, and the system assumed that that value would never be produced
    - Hence, the **write** operation is rejected, and Ti is rolled back
  - If $TS(T_i) < $ **W**-timestamp(Q), then T_i is attempting to write an obsolete value of Q
    - Hence, this **write** operation is rejected, and Ti is rolled back
  - Otherwise, the **write** operation is executed, and **W**-timestamp(Q) is set to $TS(T_i)$

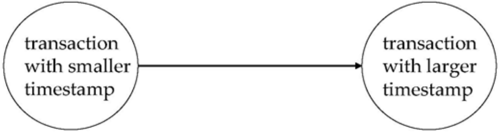
Example Use of the Protocol

A partial schedule for several data items for transactions with timestamps 1, 2, 3, 4, 5

T_1	T_2	T_3	T_4	T_5
				read (X)
	read (Y)			
read (Y)				
		write (Y)		
		write (Z)		
				read (Z)
	read (Z)			
	abort			
read (X)				
			read (W)	
		write (W)		
		abort		
				write (Y)
				write (Z)

Correctness of Timestamp-Ordering Protocol

- The timestamp-ordering protocol guarantees serializability since all the arcs in the precedence graph are of the form:



  Thus, there will be no cycles in the precedence graph
- Timestamp protocol ensures freedom from deadlock as no transaction ever waits
- But the schedule may not be cascade-free, and may not even be recoverable

Module Summary

- Explained how to detect, prevent and recover from deadlock
- Introduced a time-based protocol that avoids deadlocks

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