Concurrency Control

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 (graph-based protocol)

Deadlock Prevention

- 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

- Both in *wait-die* and in *wound-waits* schemes, a rolled back transactions is restarted with its original timestamp

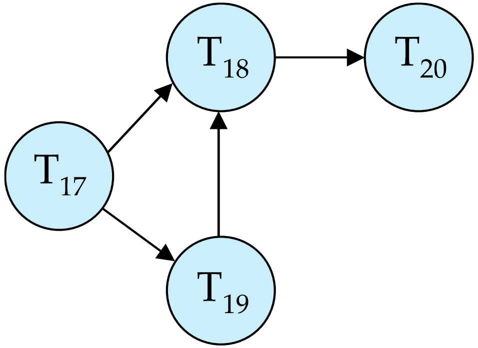
- Older transactions thus have precedence over newer ones, and starvation is hence avoided

- **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

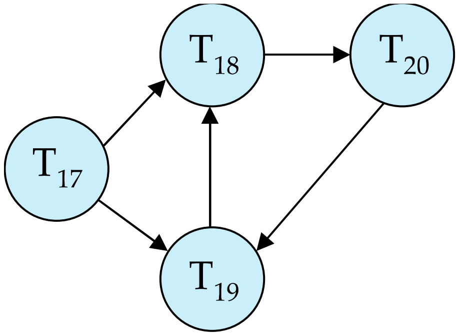
Deadlock Detection

- 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 cycle
  - 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

- 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

- 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)
  - 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

  - 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

- 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 T_i 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 T_i is rolled back
  - Otherwise, the **write** operation is executed, and **W**-timestamp(Q) is set to TS(T_i)

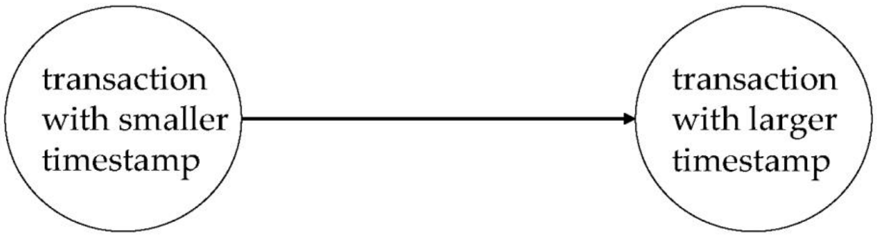
Example Use of the Protocol

- 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

Next Lecture

Recovery System

Thank you for your attention...

Any question?

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