

More Concurrency

Database Systems Lecture 17
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In This Lecture

- Deadlock detection
- Deadlock prevention
- Timestamping
- For more information
 - Connolly and Begg chapter 20

Deadlocks

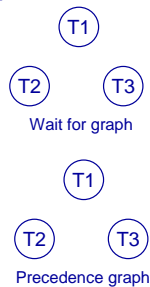
- A deadlock is an impasse that may result when two or more transactions are waiting for locks to be released which are held by each other.
 - For example: T1 has a lock on X and is waiting for a lock on Y, and T2 has a lock on Y and is waiting for a lock on X.
- Given a schedule, we can detect deadlocks which will happen in this schedule using a *wait-for graph* (WFG).

Precedence/Wait-For Graphs

- Precedence graph
 - Each transaction is a vertex
 - Arcs from T1 to T2 if
 - T1 reads X before T2 writes X
 - T1 writes X before T2 reads X
 - T1 writes X before T2 writes X
- Wait-for Graph
 - Each transaction is a vertex
 - Arcs from T2 to T1 if
 - T1 read-locks X then T2 tries to write-lock it
 - T1 write-locks X then T2 tries to read-lock it
 - T1 write-locks X then T2 tries to write-lock it

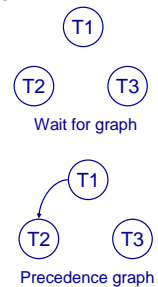
Example

T1 Read(X)
T2 Read(Y)
T1 Write(X)
T2 Read(X)
T3 Read(Z)
T3 Write(Z)
T1 Read(Y)
T3 Read(X)
T1 Write(Y)



Example

T1 Read(X)
T2 Read(Y)
T1 Write(X)
T2 Read(X)
T3 Read(Z)
T3 Write(Z)
T1 Read(Y)
T3 Read(X)
T1 Write(Y)



Example

T1 Read(X)
T2 Read(Y)
T1 Write(X)
T2 Read(X)
T3 Read(Z)
T3 Write(Z)
T1 Read(Y)
T3 Read(X)
T1 Write(Y)

Wait for graph

Precedence graph

Example

T1 Read(X)
T2 Read(Y)
T1 Write(X)
T2 Read(X)
T3 Read(Z)
T3 Write(Z)
T1 Read(Y)
T3 Read(X)
T1 Write(Y)

Wait for graph

Precedence graph

Example

T1 Read(X) read-locks(X)
T2 Read(Y) read-locks(Y)
T1 Write(X) **write-lock(X)**
T2 Read(X) **tries read-lock(X)**
T3 Read(Z)
T3 Write(Z)
T1 Read(Y)
T3 Read(X)
T1 Write(Y)

Wait for graph

Precedence graph

Example

T1 Read(X) read-locks(X)
T2 Read(Y) read-locks(Y)
T1 Write(X) **write-lock(X)**
T2 Read(X) tries read-lock(X)
T3 Read(Z) read-lock(Z)
T3 Write(Z) write-lock(Z)
T1 Read(Y) read-lock(Y)
T3 Read(X) **tries read-lock(X)**
T1 Write(Y)

Wait for graph

Precedence graph

Example

T1 Read(X) read-locks(X)
T2 Read(Y) **read-locks(Y)**
T1 Write(X) write-lock(X)
T2 Read(X) tries read-lock(X)
T3 Read(Z) read-lock(Z)
T3 Write(Z) write-lock(Z)
T1 Read(Y) read-lock(Y)
T3 Read(X) tries read-lock(X)
T1 Write(Y) **tries write-lock(Y)**

Wait for graph

Precedence graph

Deadlock Prevention

- Deadlocks can arise with 2PL
- Deadlock is less of a problem than an inconsistent DB
- We can detect and recover from deadlock
- It would be nice to avoid it altogether
- Conservative 2PL
 - All locks must be acquired before the transaction starts
 - Hard to predict what locks are needed
 - Low 'lock utilisation' - transactions can hold on to locks for a long time, but not use them much

Deadlock Prevention

- We impose an ordering on the resources
 - Transactions must acquire locks in this order
 - Transactions can be ordered on the last resource they locked
- This prevents deadlock
 - If T1 is waiting for a resource from T2 then that resource must come after all of T1's current locks
 - All the arcs in the wait-for graph point 'forwards' - no cycles

Example of resource ordering

- Suppose resource order is: $X < Y$
- This means, if you need locks on X and Y, you first acquire a lock on X and only after that a lock on Y
 - (even if you want to write to Y before doing anything to X)
- It is impossible to end up in a situation when T1 is waiting for a lock on X held by T2, and T2 is waiting for a lock on Y held by T1.

Timestamping

- Transactions can be run concurrently using a variety of techniques
- We looked at using locks to prevent interference
- An alternative is timestamping
 - Requires less overhead in terms of tracking locks or detecting deadlock
 - Determines the order of transactions before they are executed

Timestamping

- Each transaction has a timestamp, TS, and if T1 starts before T2 then $TS(T1) < TS(T2)$
 - Can use the system clock or an incrementing counter to generate timestamps
- Each resource has two timestamps
 - $R(X)$, the largest timestamp of any transaction that has read X
 - $W(X)$, the largest timestamp of any transaction that has written X

Timestamp Protocol

- If T tries to read X
 - If $TS(T) < W(X)$ T is rolled back and restarted with a later timestamp
 - If $TS(T) \geq W(X)$ then the read succeeds and we set $R(X)$ to be $\max(R(X), TS(T))$
- T tries to write X
 - If $TS(T) < W(X)$ or $TS(T) < R(X)$ then T is rolled back and restarted with a later timestamp
 - Otherwise the write succeeds and we set $W(X)$ to $TS(T)$

Timestamping Example

- Given T1 and T2 we will assume
 - The transactions make alternate operations
 - Timestamps are allocated from a counter starting at 1
 - T1 goes first

T1	T2
Read(X)	Read(X)
Read(Y)	Read(Y)
$Y = Y + X$	$Z = Y - X$
Write(Y)	Write(Z)

Timestamp Example

T1
 Read(X)
 Read(Y)
 $Y = Y + X$
 Write(Y)

T2
 Read(X)
 Read(Y)
 $Z = Y - X$
 Write(Z)

	X	Y	Z
R			
W			

	T1	T2
TS		

Timestamp Example

T1
 → Read(X)
 Read(Y)
 $Y = Y + X$
 Write(Y)

T2
 Read(X)
 Read(Y)
 $Z = Y - X$
 Write(Z)

	X	Y	Z
R	1		
W			

	T1	T2
TS	1	

Timestamp Example

T1
 → Read(X)
 Read(Y)
 $Y = Y + X$
 Write(Y)

T2
 → Read(X)
 Read(Y)
 $Z = Y - X$
 Write(Z)

	X	Y	Z
R	2		
W			

	T1	T2
TS	1	2

Timestamp Example

T1
 Read(X)
 → Read(Y)
 $Y = Y + X$
 Write(Y)

T2
 → Read(X)
 Read(Y)
 $Z = Y - X$
 Write(Z)

	X	Y	Z
R	2	1	
W			

	T1	T2
TS	1	2

Timestamp Example

T1
 Read(X)
 → Read(Y)
 $Y = Y + X$
 Write(Y)

T2
 Read(X)
 → Read(Y)
 $Z = Y - X$
 Write(Z)

	X	Y	Z
R	2	2	
W			

	T1	T2
TS	1	2

Timestamp Example

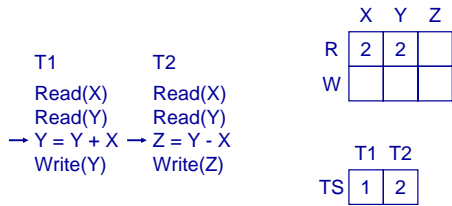
T1
 Read(X)
 Read(Y)
 → $Y = Y + X$
 Write(Y)

T2
 Read(X)
 → Read(Y)
 $Z = Y - X$
 Write(Z)

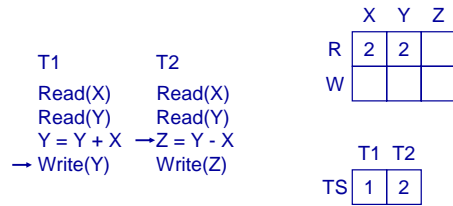
	X	Y	Z
R	2	2	
W			

	T1	T2
TS	1	2

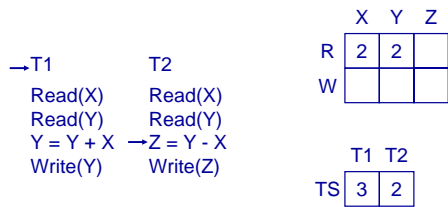
Timestamp Example



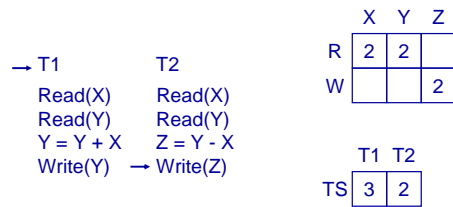
Timestamp Example



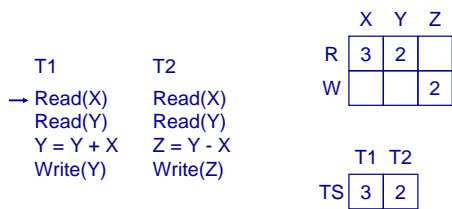
Timestamp Example



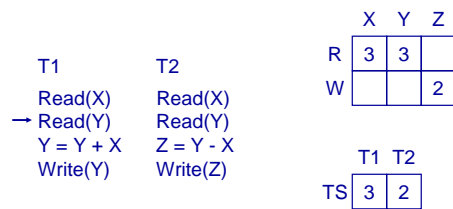
Timestamp Example



Timestamp Example



Timestamp Example



Timestamp Example

T1	T2	X	Y	Z
Read(X)	Read(X)	R	3	3
Read(Y)	Read(Y)	W		
→ Y = Y + X	Z = Y - X			2
Write(Y)	Write(Z)			
		T1	T2	
		TS	3	2

Timestamp Example

T1	T2	X	Y	Z
Read(X)	Read(X)	R	3	3
Read(Y)	Read(Y)	W		
Y = Y + X	Z = Y - X			2
→ Write(Y)	Write(Z)			
		T1	T2	
		TS	3	2

Timestamping

- The protocol means that transactions with higher times take precedence
 - Equivalent to running transactions in order of their final time values
 - Transactions don't wait - no deadlock
- Problems
 - Long transactions might keep getting restarted by new transactions - starvation
 - Rolls back old transactions, which may have done a lot of work

Next Lecture

- After the break:
 - Java and SQL (not in the exam, just for information)
 - Feedback on coursework 5 (normalisation)
 - Exam revision