COMP 3311
DATABASE MANAGEMENT SYSTEMS

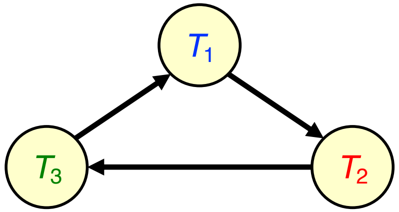
LECTURE 22 EXERCISES
CONCURRENCY CONTROL:
TIMESTAMP-BASED PROTOCOLS

EXERCISE 1

Recall that this schedule is not serializable because there is a cycle T_1, T_2, T_3, T_1. Therefore, the schedule will fail under any protocol that aims at conflict serializability.

T_1	T_2	T_3
read(X)		
	read(Y)	
	write(Y)	
		write(Z)
write(X)		
	read(X)	
	write(X)	
		read(Y)
		write(Y)
write(Z)		

Precedence Graph



EXERCISE 1 (CONT'D)

Use the single-version, timestamp-ordering protocol, to complete the following non-serializable schedule assuming the timestamps 1, 2, and 3 for transactions T_1, T_2, and T_3, respectively. Show where the protocol will fail. Assume initial R/W timestamp of all items is 0.

Read
If TS(T_i) < WTS(Q) **rollback**
If TS(T_i) ≥ WTS(Q)
RTS(Q) = max(TS(T_i), RTS(Q))

Write
If TS(T_i) < RTS(Q) **rollback**
If TS(T_i) < WTS(Q) **rollback**
Otherwise WTS(Q) = TS(T_i)

RTS(X)=2	WTS(X)=2	RTS(Y)=3	WTS(Y)=3	RTS(Z)=0	WTS(Z)=3

T_1 [TS=1]	T_2 [TS=2]	T_3 [TS=3]
read(X) ✓ TS(T_1)=1 ≥ WTS(X)=0; **set** RTS(X)=1		
	read(Y) ✓ TS(T_2)=2 ≥ WTS(Y)=0; **set** RTS(Y)=2	
	write(Y) ✓ TS(T_2)=2 ≥ RTS(Y)=2 & ≥ WTS(Y)=0; **set** WTS(Y)=2	
		write(Z) ✓ TS(T_3)=3 ≥ RTS(Z)=0 & ≥ WTS(Z)=0; **set** WTS(Z)=3
write(X) ✓ TS(T_1)=1 ≥ RTS(X)=1 & ≥ WTS(X)=0; **set** WTS(X)=1		
	read(X) ✓ TS(T_2)=2 ≥ WTS(X)=1; **set** RTS(X)=2	
	write(X) ✓ TS(T_2)=2 ≥ RTS(X)=2 & ≥ WTS(X)=1; **set** WTS(X)=2	
		read(Y) ✓ TS(T_3)=3 ≥ WTS(Y)=2; **set** RTS(Y)=3
		write(Y) ✓ TS(T_3)=3 ≥ RTS(Y)=3 & ≥ WTS(Y)=2; **set** WTS(Y)=3
write(Z) TS(T_1)=1 < WTS(Z)=3 ⇒ **rollback**		

EXERCISE 1 (CONT'D)

Use the single-version, timestamp-ordering protocol, to complete the following non-serializable schedule assuming the timestamps 1, 2, and 3 for transactions T_1, T_2, and T_3, respectively. Show where the protocol will fail. Assume initial R/W timestamp of all items is 0.

Read
If TS(T_i) < WTS(Q) **rollback**
If TS(T_i) ≥ WTS(Q)
RTS(Q) = max(TS(T_i), RTS(Q))

Write
If TS(T_i) < RTS(Q) **rollback**
If TS(T_i) < WTS(Q) **ignore**
Otherwise WTS(Q) = TS(T_i)

RTS(X)=2	WTS(X)=2	RTS(Y)=3	WTS(Y)=3	RTS(Z)=0	WTS(Z)=3

T_1 [TS=1]	T_2 [TS=2]	T_3 [TS=3]
read(X) ✓ TS(T_1)=1 ≥ WTS(X)=0; **set** RTS(X)=1		
	read(Y) ✓ TS(T_2)=2 ≥ WTS(Y)=0; **set** RTS(Y)=2	
	write(Y) ✓ TS(T_2)=2 ≥ RTS(Y)=2 & ≥ WTS(Y)=0; **set** WTS(Y)=2	
		write(Z) ✓ TS(T_3)=3 ≥ RTS(Z)=0 & ≥ WTS(Z)=0; **set** WTS(Z)=3
write(X) ✓ TS(T_1)=1 ≥ RTS(X)=1 & ≥ WTS(X)=0; **set** WTS(X)=1		
	read(X) ✓ TS(T_2)=2 ≥ WTS(X)=1; **set** RTS(X)=2	
	write(X) ✓ TS(T_2)=2 ≥ RTS(X)=2 & ≥ WTS(X)=1; **set** WTS(X)=2	
		read(Y) ✓ TS(T_3)=3 ≥ WTS(Y)=2; **set** RTS(Y)=3
		write(Y) ✓ TS(T_3)=3 ≥ RTS(Y)=3 & ≥ WTS(Y)=2; **set** WTS(Y)=3
write(Z) TS(T_1)=1 < WTS(Z)=3 ⟹ **ignore**		

EXERCISE 2

Use the multi-version, timestamp-ordering protocol to complete the schedule of Exercise 1 assuming the timestamps 1, 2, and 3 for transactions T_1, T_2, and T_3, respectively. Assume initial R/W timestamp of X_0, Y_0 and Z_0 is 0. ☞ Timestamps are used to label versions.

$RTS(X_0)=1$	$WTS(X_0)=0$
$RTS(X_1)=2$	$WTS(X_1)=1$
$RTS(X_2)=2$	$WTS(X_2)=2$

$RTS(Y_0)=2$	$WTS(Y_0)=0$
$RTS(Y_1)=3$	$WTS(Y_1)=2$
$RTS(Y_2)=3$	$WTS(Y_2)=3$

$RTS(Z_0)=0$	$WTS(Z_0)=0$
$RTS(Z_1)=3$	$WTS(Z_1)=3$

T_1 [TS=1]	T_2 [TS=2]	T_3 [TS=3]
read(X_0) ✓ set $RTS(X_0)=1$		
	read(Y_0) ✓ set $RTS(Y_0)=2$	
	write(Y_1) ✓ $TS(T_2)=2 > WTS(Y_0)=0$; create Y_1; set $R/WTS(Y_1)=2$	
		write(Z_1) ✓ $TS(T_3)=3 > WTS(Z_0)=0$; create Z_1; set $R/WTS(Z_1)=3$
write(X_1) ✓ $TS(T_1)=1 > WTS(X_0)=0$; create X_1; set $R/WTS(X_1)=1$		
	read(X_1) ✓ set $RTS(X_1)=2$	
	write(X_2) ✓ $TS(T_2)=2 > WTS(X_1)=1$; create X_2; set $R/WTS(X_2)=2$	
		read(Y_1) ✓ set $RTS(Y_1)=3$
		write(Y_2) ✓ $TS(T_3)=3 > WTS(Y_1)=2$; create Y_2; set $R/WTS(Y_2)=3$
write(Z) $TS(T_1)=1 > WTS(Z_0)=0$; create Z_2; set $R/WTS(Z_2)=1$ ⇒ **ignore!**		

Read

Reads always succeed

set $RTS(Q) = \max(TS(T_i), RTS(Q_k))$

Write

If $TS(T_i) < RTS(Q)$ **rollback**

If $TS(T_i) = WTS(Q)$
overwrite contents

If $TS(T_i) > WTS(Q)$
create new version
set $R/WTS(Q') = TS(T_i)$

EXERCISE 2 (CONT'D)

Multi-version timestamp-ordering protocol assuming the timestamps 2, 1 and 3 for transactions T_1, T_2 and T_3 respectively.

RTS(X_0)=2	WTS(X_0)=0	RTS(Y_0)=1	WTS(Y_0)=0	RTS(Z_0)=0	WTS(Z_0)=0
RTS(X_1)=2	WTS(X_1)=2	RTS(Y_1)=1	WTS(Y_1)=1	RTS(Z_1)=3	WTS(Z_1)=3

T_1 [TS=2]	T_2 [TS=1]	T_3 [TS=3]
read(X_0) ✓ **set** RTS(X_0)=2		
	read(Y_0) ✓ **set** RTS(Y_0)=1	
	write(Y_1) ✓ TS(T_2)=1 > WTS(Y_0)=0; **create** Y_1; **set** R/WTS(Y_1)=1	
		write(Z_1) ✓ TS(T_3)=3 > WTS(Z_0)=0; **create** Z_1; **set** R/WTS(Z_1)=3
write(X_1) ✓ TS(T_1)=2 > WTS(X_0)=0; **create** X_1; **set** R/WTS(X_1)=2		
	read(X_1) ✓ RTS(X_1)=2	
	write(X) TS(T_2)=1 < RTS(X_0)=2	**⟹ rollback**
		read(Y)
		write(Y)
write(Z)		

Read

Reads always succeed

set RTS(Q) = max(TS(T_i), RTS(Q_k))

Write

If TS(T_i) < RTS(Q) **rollback**

If TS(T_i) = WTS(Q)

overwrite contents

If TS(T_i) > WTS(Q)

create new version

set R/WTS(Q')=TS(T_i)

Any other timestamp ordering of the transactions, as in this example, will lead to a rollback.

EXERCISE 3

The following schedule is conflict serializable.

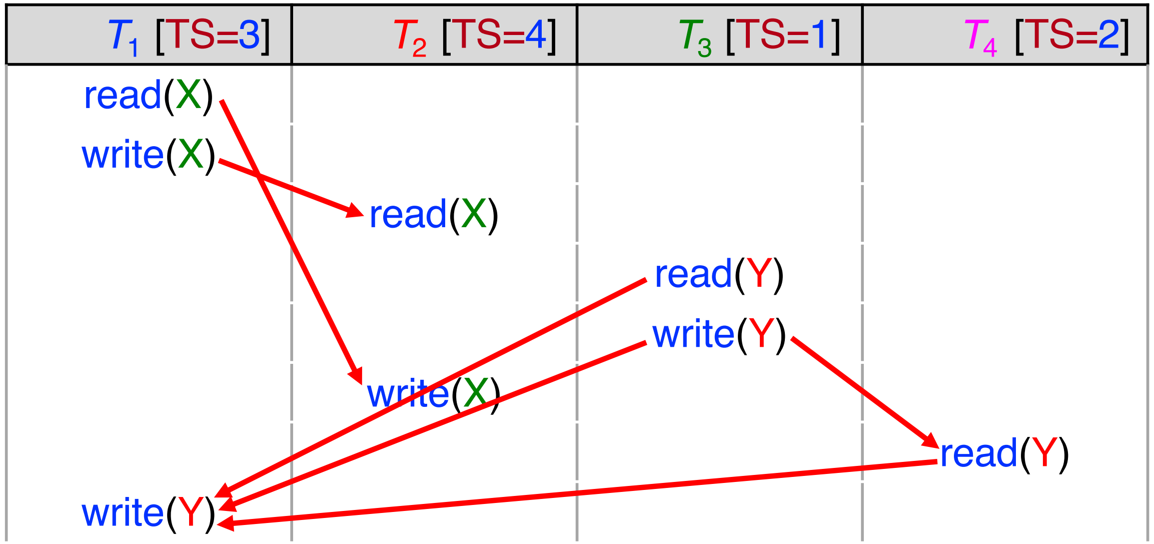
(a) What is the equivalent serial schedule?

(b) Assign appropriate timestamps to the transactions T_1, T_2, T_3 and T_4 so that the schedule is conflict serializable according to the single version, timestamp-based protocol. Assume initial R/W timestamp of all items is 0.

T_1	T_2	T_3	T_4
read(X)			
write(X)			
	read(X)		
		read(Y)	
		write(Y)	
	write(X)		
			read(Y)
write(Y)			

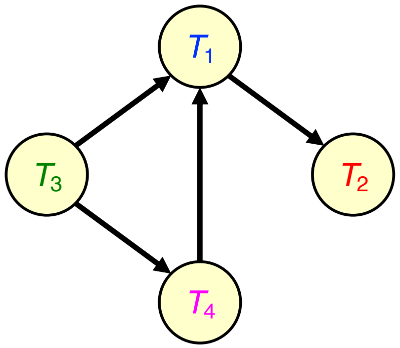
EXERCISE 3 (CONTD)

(a) What is the equivalent serial schedule?



T_1 [TS=3]	T_2 [TS=4]	T_3 [TS=1]	T_4 [TS=2]
read(X)			
write(X)			
	read(X)		
		read(Y)	
		write(Y)	
	write(X)		
			read(Y)
write(Y)			

Precedence Graph



The equivalent serial schedule is T_3, T_4, T_1, T_2

(b) Assign appropriate timestamps to the transactions T_1, T_2, T_3 and T_4 so that the schedule is conflict serializable according to the single version, timestamp-based protocol. Assume initial R/W timestamp of all items is 0.

EXERCISE 3 (CONTD)

We note that, for this schedule, any other order of timestamps will fail according to the single version timestamp-ordering protocol as shown below for the order T_1, T_2, T_3, T_4.

Read

If TS(T_i) < WTS(Q) **rollback**

If TS(T_i) ≥ WTS(Q)

RTS(Q) = max(TS(T_i), RTS(Q))

Write

If TS(T_i) < RTS(Q) **rollback**

If TS(T_i) < WTS(Q) **ignore**

Otherwise WTS(Q) = TS(T_i)

T_1 [TS=1]	T_2 [TS=2]	T_3 [TS=3]	T_4 [TS=4]
read(X) ✓ TS(T_1)=1 ≥ WTS(X)=0; set RTS(X)=1			
write(X) ✓ TS(T_1)=1 ≥ RTS(X)=1 & ≥ WTS(X)=0; **set** WTS(X)=1			
	read(X) ✓ TS(T_2)=2 ≥ WTS(X)=1; **set** RTS(X)=2		
		read(Y) ✓ TS(T_3)=3 ≥ WTS(Y)=0; **set** RTS(Y)=3	
		write(Y) ✓ TS(T_3)=3 ≥ RTS(Y)=3 & ≥ WTS(Y)=0; **set** WTS(Y)=3	
	write(X) ✓ TS(T_2)=2 ≥ RTS(X)=2 & ≥ WTS(X)=1; **set** WTS(X)=2		
			read(Y) ✓ TS(T_4)=4 ≥ WTS(Y)=3; **set** RTS(Y)=4
write(Y) TS(T_1)=1 < RTS(Y)=4 ⇒ **rollback**			

EXERCISE 4

Use the multi version, timestamp-ordering protocol, to complete the conflict serializable schedule of **Exercise 3** assuming the timestamps 1, 2, 3, and 4 for transactions T_1, T_2, T_3 and T_4, respectively. Show where the protocol will fail. Assume initial R/W timestamp of all items is 0.

Read
Reads always succeed
set RTS(Q) = max(TS(T_i), RTS(Q_k))

Write
If TS(T_i) < RTS(Q) **rollback**
If TS(T_i) = WTS(Q)
overwrite contents
If TS(T_i) > WTS(Q)
create new version
set R/WTS(Q')=TS(T_i)

T_1 [TS=1]	T_2 [TS=2]	T_3 [TS=3]	T_4 [TS=4]
read(X_0) ✓ **set** RTS(X_0)=1			
write(X_1) ✓ TS(T_1)=1 ≥ RTS(X_0)=1 & > WTS(X_0)=0; **create** X_1; **set** R/WTS(X_1)=1			
	read(X_1) ✓ **set** RTS(X_1)=2		
		read(Y_0) ✓ **set** RTS(Y_0)=3	
		write(Y_1) ✓ TS(T_3)=3 ≥ RTS(Y_0)=3 & > WTS(Y_0)=0; **create** Y_1; **set** R/WTS(Y_1)=3	
	write(X_2) ✓ TS(T_2)=2 ≥ RTS(X_1)=2 & > WTS(X_1)=1; **create** X_2; **set** R/WTS(X_2)=2		
			read(Y_1) ✓ **set** RTS(Y_1)=4
write(Y) TS(T_1)=1 < RTS(Y_1)=4	⟹ **rollback**		

Note that this is not a blind write since T_3 read Y_0 setting its RTS to 3 before writing Y_1. Therefore, T_1 can no longer read Y_0 since its RTS is greater than that of T_1 (i.e., T_1 cannot find a version whose TS is less than or equal to its timestamp.