

Database Management Systems

Lecture 2

Transactions. Concurrency Control

Conflict Serializability

- C – set of transactions
- $Sch(C)$ – the set of schedules for C
- $Op(C)$ – set of operations of the transactions in C
- consider schedule $S \in Sch(C)$
- the *conflict relation* of S is defined as:
 - $conflict(S) = \{(op_1, op_2) \mid op_1, op_2 \in Op(C), op_1 \text{ occurs before } op_2 \text{ in } S, op_1 \text{ and } op_2 \text{ are in conflict}\}$

Conflict Serializability

- C – set of transactions
- $Sch(C)$ – the set of schedules for C
- two schedules S_1 and $S_2 \in Sch(C)$ are conflict equivalent, written $S_1 \equiv_c S_2$, if $conflict(S_1) = conflict(S_2)$, i.e.:
 - S_1 and S_2 contain the same operations of the same transactions and
 - every pair of conflicting operations is ordered in the same manner in S_1 and S_2

Conflict Serializability

S1

T1	T2
Read(A)	
A := A – 100	
Write(A)	
Read(B)	
B := B + 200	
Write(B)	
	Read(A)
	A := A * 0.2
	Write(A)
	Read(B)
	B := B + 300
	Write(B)

S2

T1	T2
Read(A)	
A := A – 100	
Write(A)	
	Read(A)
	A := A * 0.2
	Write(A)
Read(B)	
B := B + 200	
Write(B)	
	Read(B)
	B := B + 300
	Write(B)

$$\text{conflict}(S1) = \text{conflict}(S2)$$

$$\Rightarrow S1 \equiv_c S2$$

$$\text{conflict}(S1) = \{(\text{Read}(T1, A), \text{Write}(T2, A)), (\text{Write}(T1, A), \text{Read}(T2, A)), (\text{Write}(T1, A), \text{Write}(T2, A)), (\text{Read}(T1, B), \text{Write}(T2, B)), (\text{Write}(T1, B), \text{Read}(T2, B)), (\text{Write}(T1, B), \text{Write}(T2, B))\}$$

Conflict Serializability

S1

T1	T2
Read(A)	
A := A - 100	
Write(A)	
Read(B)	
B := B + 200	
Write(B)	
	Read(A)
	A := A * 0.2
	Write(A)
	Read(B)
	B := B + 300
	Write(B)

S3

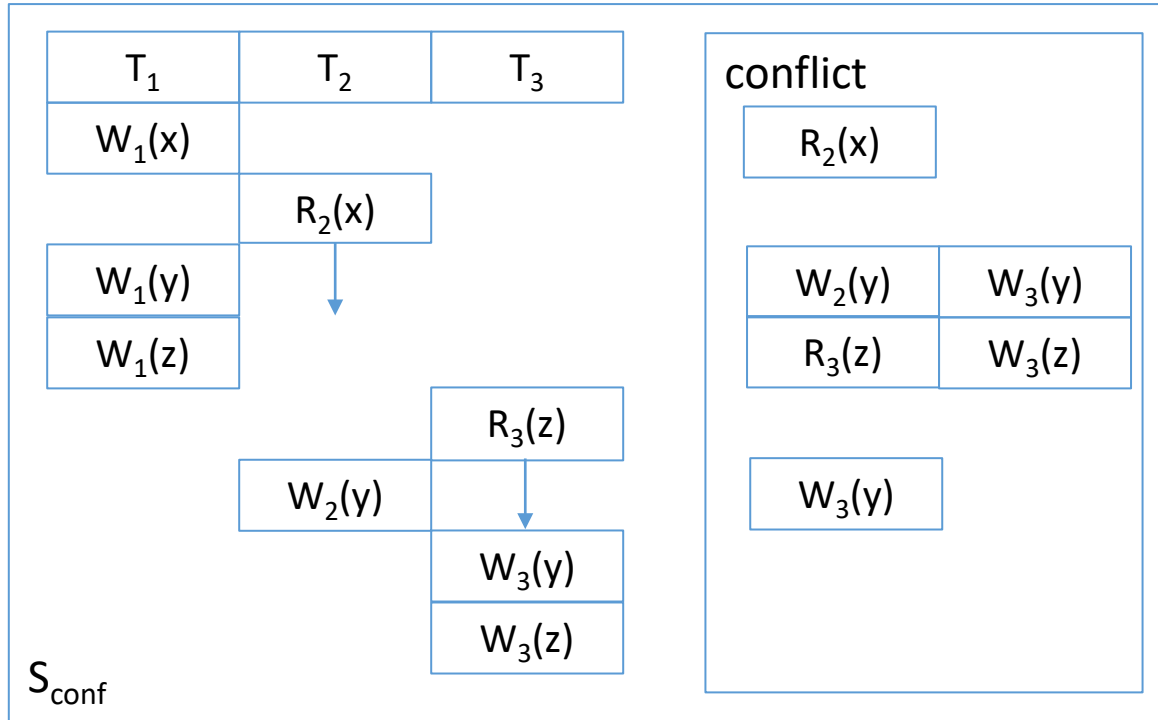
T1	T2
	Read(A)
	A := A * 0.2
	Write(A)
	Read(B)
	B := B + 300
	Write(B)
Read(A)	
A := A - 100	
Write(A)	
Read(B)	
B := B + 200	
Write(B)	

$\text{conflict}(S1) \neq \text{conflict}(S3)$
 $\Rightarrow S1 \not\equiv_c S3$

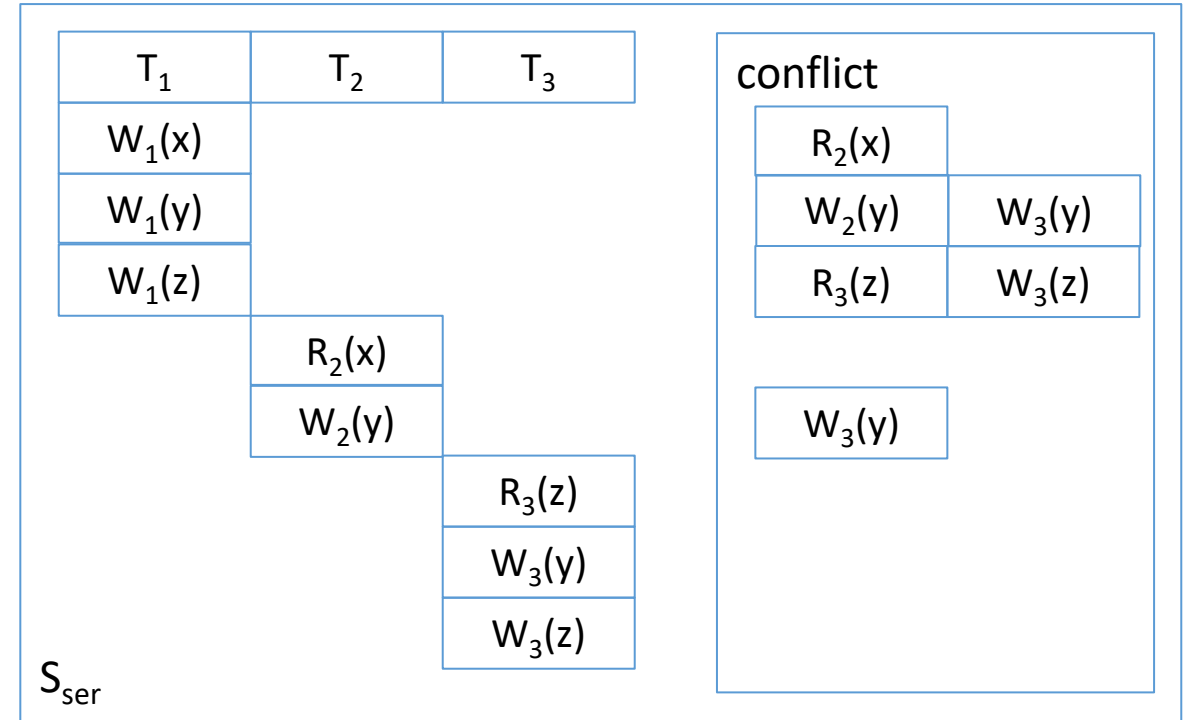
Conflict Serializability

- C – set of transactions
- $Sch(C)$ – the set of schedules for C
- let S be a schedule in $Sch(C)$
- schedule S is conflict serializable if there exists a serial schedule $S_0 \in Sch(C)$ such that $S \equiv_c S_0$, i.e., S is conflict equivalent to some serial schedule

Conflict Serializability



conflict serializable schedule



serial schedule

Conflict Serializability - Precedence Graph

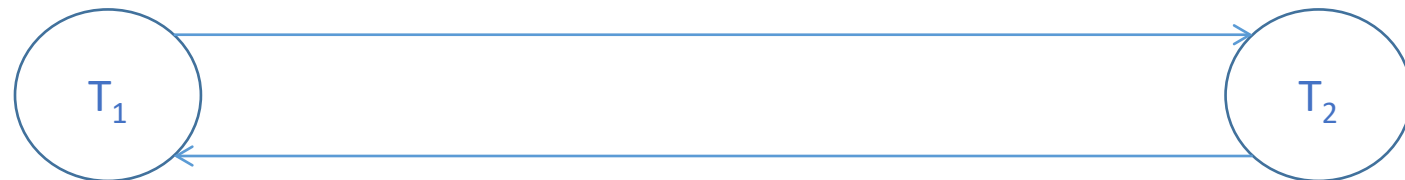
- let S be a schedule in $Sch(C)$
- the precedence graph (serializability graph) of S contains:
 - one node for every committed transaction in S
 - an arc from T_i to T_j if an action in T_i precedes and conflicts with one of the actions in T_j
- Theorem:
 - a schedule $S \in Sch(C)$ is conflict serializable if and only if its precedence graph is acyclic

Conflict Serializability - Precedence Graph

- example - a schedule that is not conflict serializable:



- the precedence graph has a cycle:

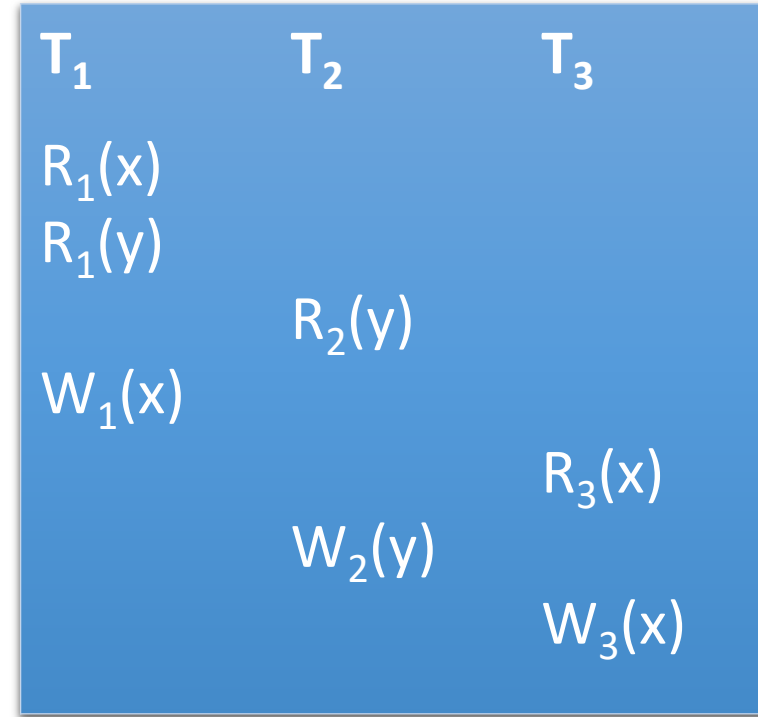


Conflict Serializability - Precedence Graph

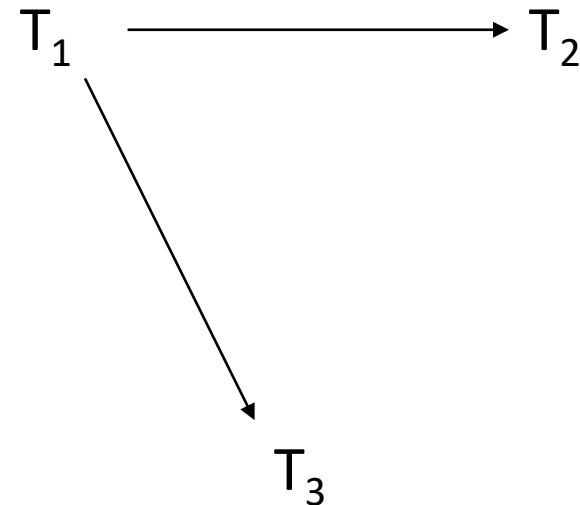
- algorithm to test the conflict serializability of a schedule $S \in Sch(C)$
 1. create a node labeled T_i in the precedence graph for every committed transaction T_i in the schedule
 2. create an arc (T_i, T_j) in the precedence graph if T_j executes a $Read(A)$ after a $Write(A)$ executed by T_i
 3. create an arc (T_i, T_j) in the precedence graph if T_j executes a $Write(A)$ after a $Read(A)$ executed by T_i
 4. create an arc (T_i, T_j) in the precedence graph if T_j executes a $Write(A)$ after a $Write(A)$ executed by T_i
 5. S is conflict serializable if and only if the resulting precedence graph has no cycles

Conflict Serializability - Precedence Graph

- examples
- let S_1 be a schedule over $\{T_1, T_2, T_3\}$:



- the precedence graph for S_1 :

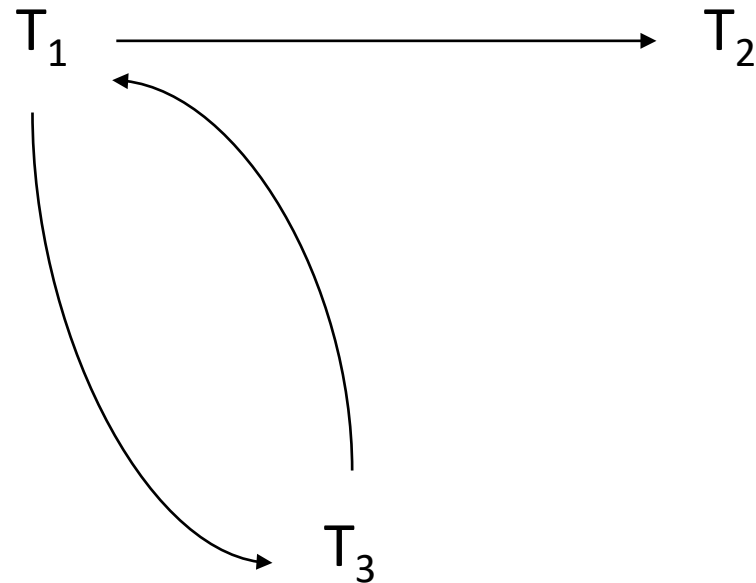


Conflict Serializability - Precedence Graph

- examples
- let S_2 be a schedule over $\{T_1, T_2, T_3\}$:

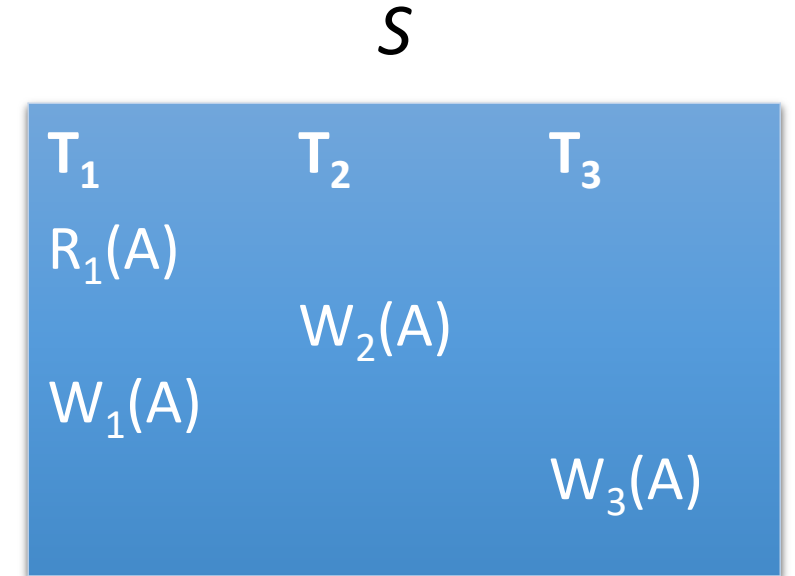
T_1	T_2	T_3
$R_1(x)$		
$R_1(y)$		
		$R_3(x)$
	$R_2(y)$	
$W_1(x)$		
	$W_2(y)$	
		$W_3(x)$

- the precedence graph for S_2 :



Conflict Serializability

- every conflict serializable schedule is serializable (in the absence of inserts / deletes, when items can only be updated)
- there are serializable schedules that are not conflict serializable
- S is serializable (it's equivalent to the serial execution of transactions T_1 , T_2 , T_3 – in this order), but it is not conflict serializable



View Serializability

- conflict serializability is a sufficient condition for serializability, but it is not a necessary one
- *view serializability*
 - a more general, sufficient condition for serializability
 - based on *view-equivalence*, a less stringent form of equivalence

View Serializability

- C – set of transactions
- $Sch(C)$ – the set of schedules for C
- let $T_i, T_j \in C, S_1, S_2 \in Sch(C)$; S_1 and S_2 are view equivalent, written $S_1 \equiv_v S_2$, if the following conditions are met:
 - if T_i reads the initial value of V in S_1 , then T_i also reads the initial value of V in S_2 ;
 - if T_i reads the value of V written by T_j in S_1 , then T_i also reads the value of V written by T_j in S_2 ;
 - if T_i writes the final value of V in S_1 , then T_i also writes the final value of V in S_2 .
- i.e.:
 - each transaction performs the same computation in S_1 and S_2
 - and
 - S_1 and S_2 produce the same final database state.

View Serializability

S1

T1	T2
Read(A)	
A := A - 100	
Write(A)	
Read(B)	
B := B + 200	
Write(B)	
	Read(A)
	A := A * 0.2
	Write(A)
	Read(B)
	B := B + 300
	Write(B)

S2

T1	T2
Read(A)	
A := A - 100	
Write(A)	
	Read(A)
	A := A * 0.2
	Write(A)
Read(B)	
B := B + 200	
Write(B)	
	Read(B)
	B := B + 300
	Write(B)

$S1 \equiv_v S2$

View Serializability

S1

T1	T2
Read(A)	
A := A - 100	
Write(A)	
Read(B)	
B := B + 200	
Write(B)	
	Read(A)
	A := A * 0.2
	Write(A)
	Read(B)
	B := B + 300
	Write(B)

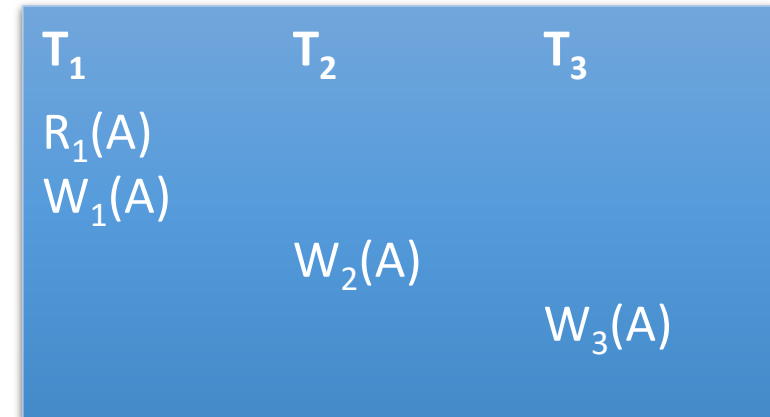
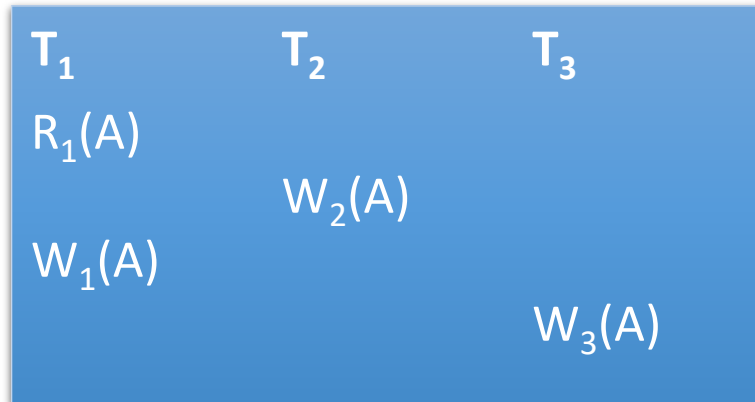
S3

T1	T2
	Read(A)
	A := A * 0.2
	Write(A)
	Read(B)
	B := B + 300
	Write(B)
Read(A)	
A := A - 100	
Write(A)	
Read(B)	
B := B + 200	
Write(B)	

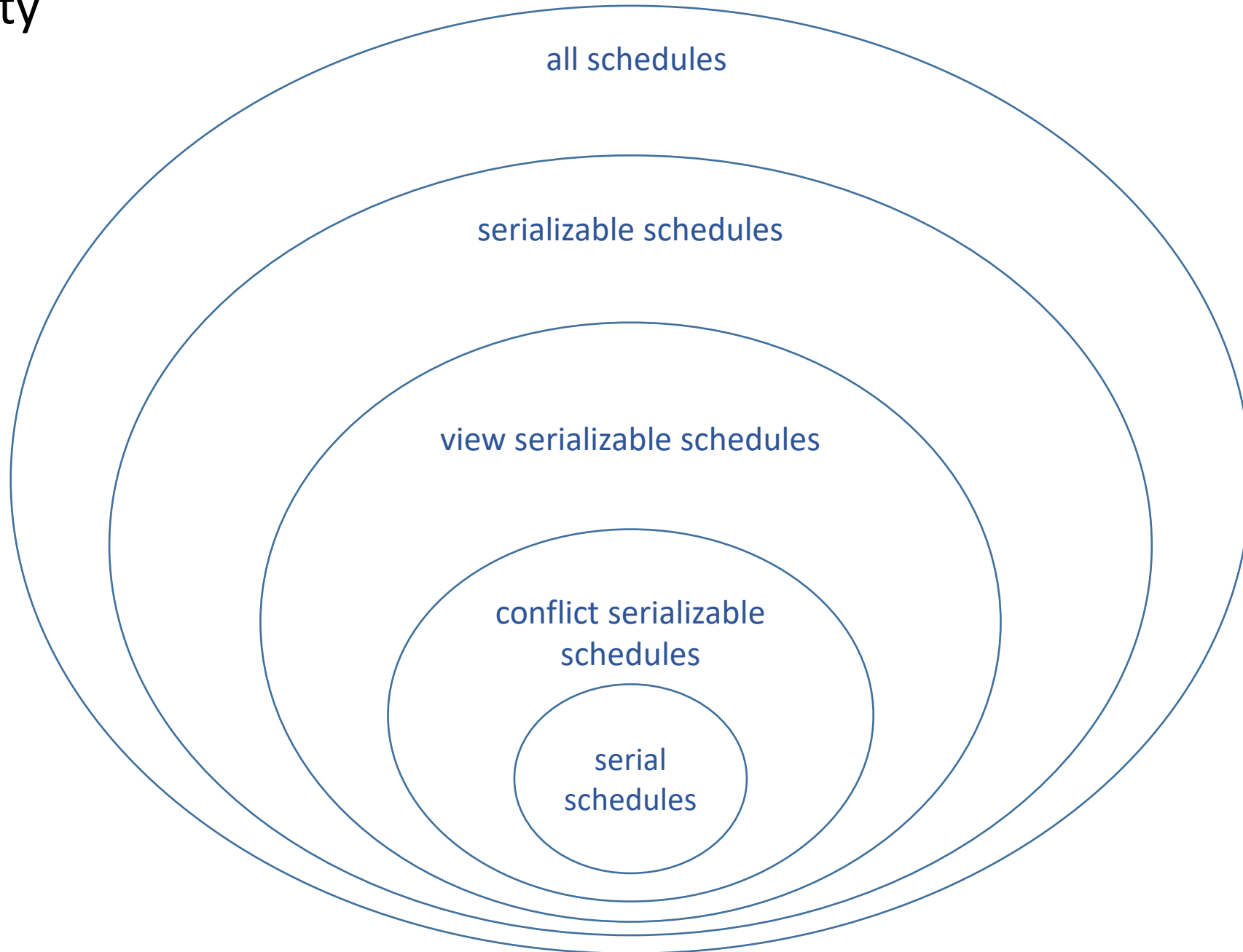
$S1 \not\equiv_v S3$

View Serializability

- C – set of transactions
- $Sch(C)$ – the set of schedules for C
- a schedule $S \in Sch(C)$ is view serializable if there exists a serial schedule $S_0 \in Sch(C)$ such that $S \equiv_v S_0$, i.e., S is view equivalent to some serial schedule



Serializability



Recoverable Schedules

- consider schedule S over $\{T_1, T_2\}$

T_1	T_2
Read(x)	
$x := x + 10$	
Write(x)	
	Read(x)
	$x := x * 5$
	Write(x)
	Read(y)
	$y := y * 5$
	Write(y)
	commit
abort	

- T_2 operates on a value of x that shouldn't have been there (T_1 aborts)

Recoverable Schedules

T_1	T_2
Read(x)	
$x := x + 10$	
Write(x)	
	Read(x)
	$x := x * 5$
	Write(x)
	Read(y)
	$y := y * 5$
	Write(y)
	commit
abort	

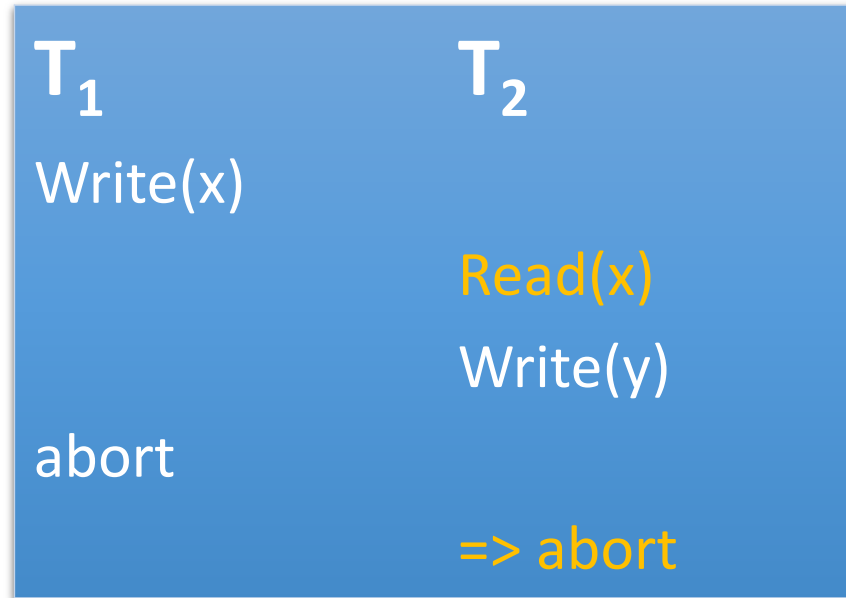
- cannot cascade the abort of T_1 , since T_2 has already committed
- schedule S is *unrecoverable*

Recoverable Schedules

- recoverable schedule

- a schedule in which a transaction T commits only after all transactions whose changes T read commit

Avoiding Cascading Aborts



- a schedule in which a transaction T is reading only changes of committed transactions is said to avoid cascading aborts
- avoiding cascading aborts => recoverable schedules

Lock-Based Concurrency Control

- technique used to guarantee serializable, recoverable schedules
- *lock*
 - a tool used by the transaction manager to control concurrent access to data
 - prevents a transaction from accessing a data object while another transaction is accessing the object
- *transaction protocol*
 - a set of rules enforced by the transaction manager and obeyed by all transactions
 - example – simple protocol: before a transaction can read / write an object, it must acquire an appropriate lock on the object
 - locks in conjunction with protocols allow interleaved executions

Lock-Based Concurrency Control

- SLock (*shared or read lock*)
 - if a transaction holds an SLock on an object, it can read the object, but it cannot modify it
- XLock (*exclusive or write lock*)
 - if a transaction holds an XLock on an object, it can both read and write the object
- if a transaction holds an SLock on an object, other transactions can be granted SLocks on the object, but they cannot acquire XLocks on it
- if a transaction holds an XLock on an object, other transactions cannot be granted either SLocks or XLocks on the object

	Shared	Exclusive
Shared	Yes	No
Exclusive	No	No

Lock-Based Concurrency Control

- *lock table*

- structure used by the lock manager to keep track of granted locks / lock requests
- entry in the lock table (corresponding to one data object):
 - number of transactions holding a lock on the data object
 - lock type (SLock / XLock)
 - pointer to a queue of lock requests

Lock-Based Concurrency Control

- *transaction table*
 - structure maintained by the DBMS
 - one entry / transaction
 - keeps a pointer to a list of locks held by the transaction
- lock upgrade
 - an SLock granted to a transaction can be upgraded to an XLock

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