Lecture 17: Concurrency Control

Friday, February 17, 2006

Outline

- Serial and Serializable Schedules (18.1)
- Conflict Serializability (18.2)
- Locks (18.3)
- Multiple lock modes (18.4)
- The tree protocol (18.7)

The Problem

- Multiple transactions are running concurrently T_1, T_2, …
- They read/write some common elements A_1, A_2, …
- How can we prevent unwanted interference ?

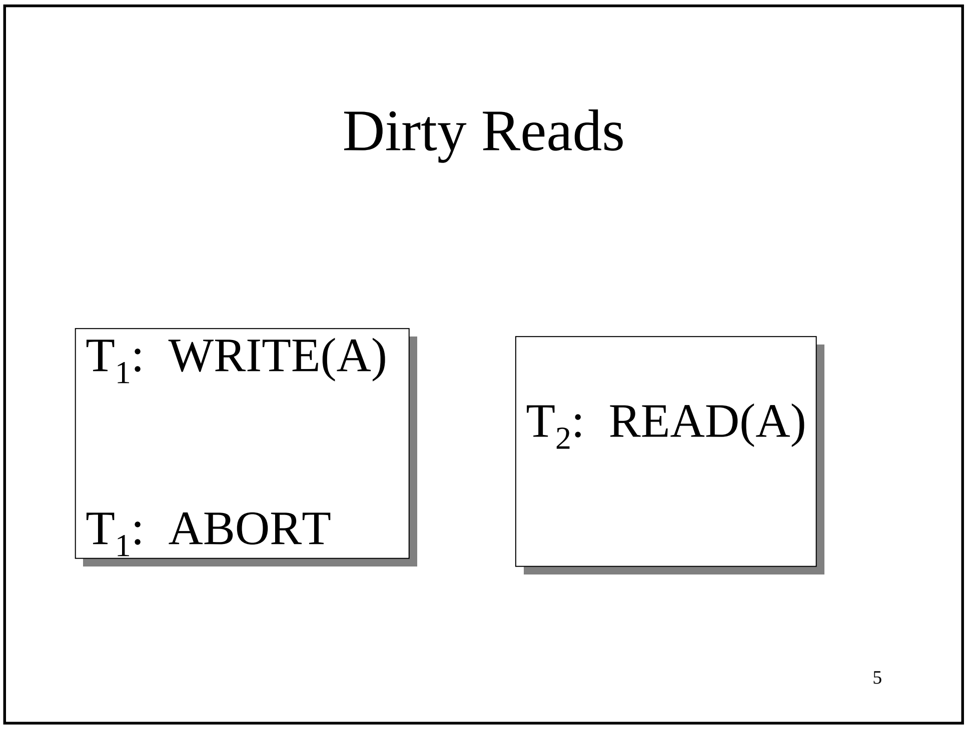
The SCHEDULER is responsible for that

Three Famous Anomalies

What can go wrong if we didn't have concurrency control:

- Dirty reads
- Lost updates
- Inconsistent reads

Many other things may go wrong, but have no names

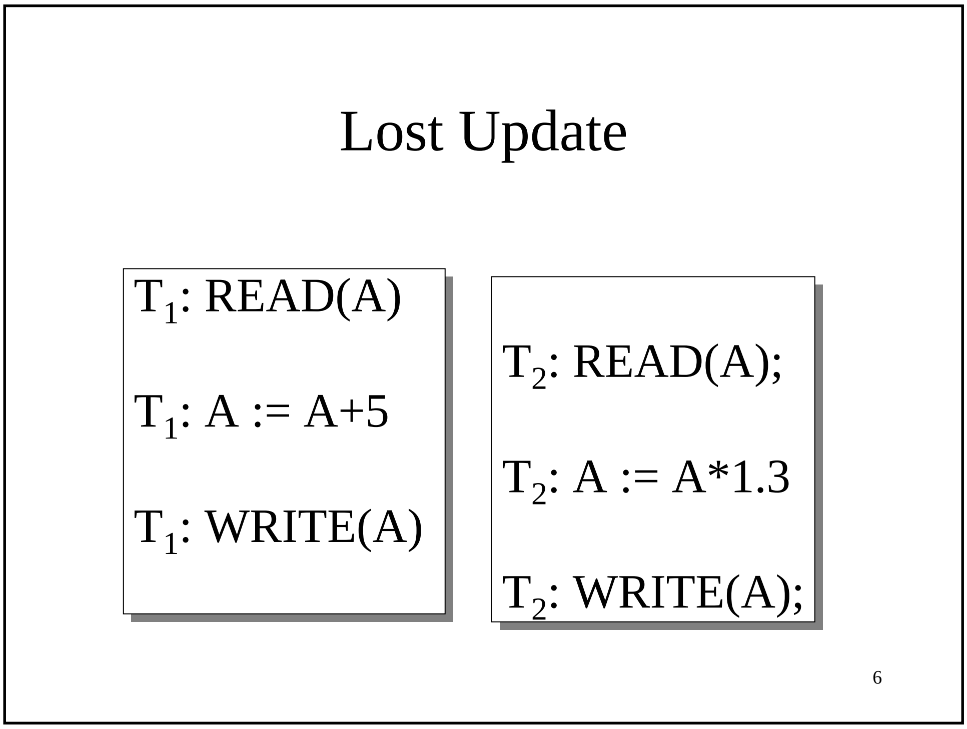


Dirty Reads

T_1: WRITE(A)

T_2: READ(A)

T_1: ABORT



Lost Update

T_1: READ(A)

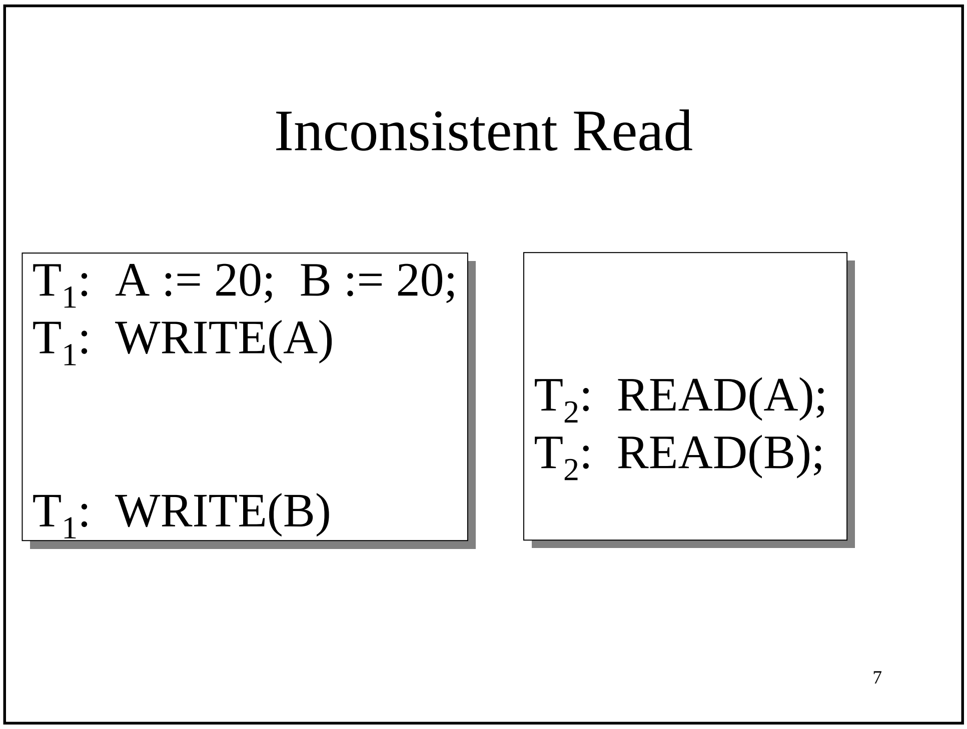
T_2: READ(A);

T_1: A := A+5

T_2: A := A*1.3

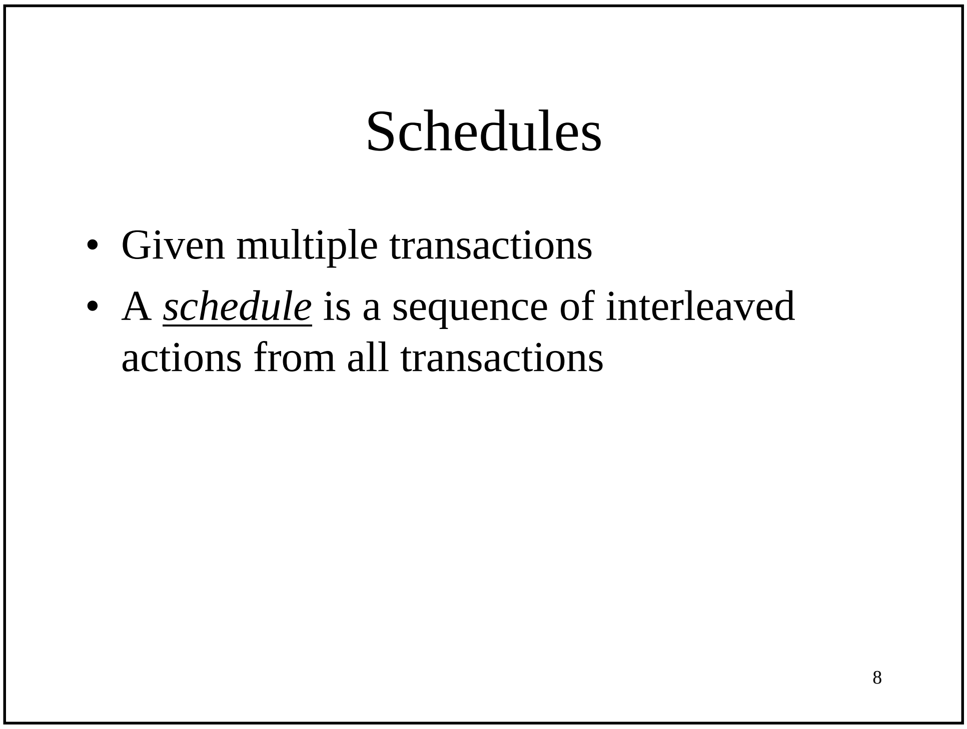
T_1: WRITE(A)

T_2: WRITE(A);



Inconsistent Read

T_1: A := 20; B := 20;	
T_1: WRITE(A)	
	T_2: READ(A);
	T_2: READ(B);
T_1: WRITE(B)	



Schedules

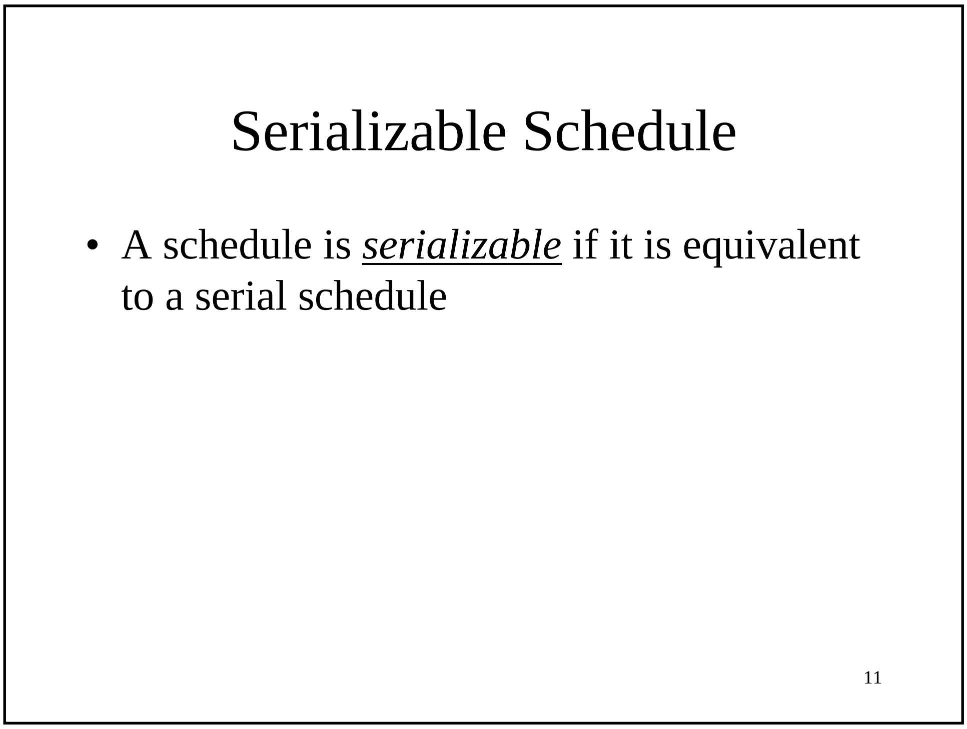
- Given multiple transactions
- A *schedule* is a sequence of interleaved actions from all transactions

Example

T1	T2
READ(A, t)	READ(A, s)
t := t+100	s := s*2
WRITE(A, t)	WRITE(A,s)
READ(B, t)	READ(B,s)
t := t+100	s := s*2
WRITE(B,t)	WRITE(B,s)

A Serial Schedule

T1	T2
READ(A, t)	
t := t+100	
WRITE(A, t)	
READ(B, t)	
t := t+100	
WRITE(B,t)	
	READ(A,s)
	s := s*2
	WRITE(A,s)
	READ(B,s)
	s := s*2
	WRITE(B,s)



Serializable Schedule

- A schedule is ***serializable*** if it is equivalent to a serial schedule

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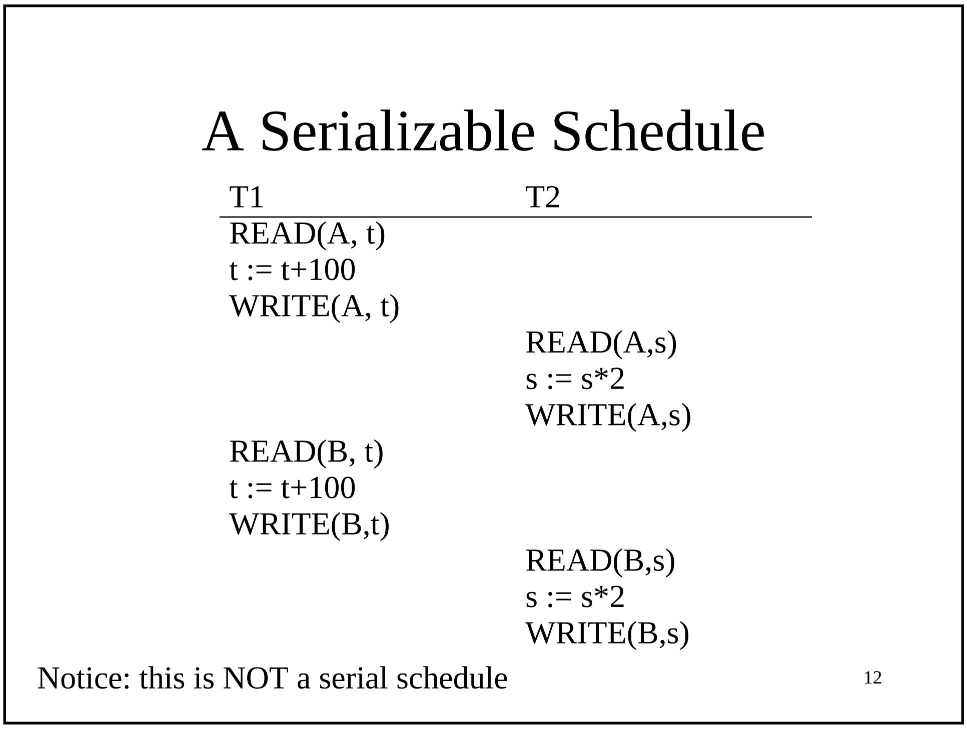

A Serializable Schedule

T1	T2
READ(A, t)	
t := t+100	
WRITE(A, t)	
	READ(A,s)
	s := s*2
	WRITE(A,s)
READ(B, t)	
t := t+100	
WRITE(B,t)	
	READ(B,s)
	s := s*2
	WRITE(B,s)

Notice: this is NOT a serial schedule

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A Non-Serializable Schedule

T1	T2
READ(A, t)	
t := t+100	
WRITE(A, t)	
	READ(A,s)
	s := s*2
	WRITE(A,s)
	READ(B,s)
	s := s*2
	WRITE(B,s)
READ(B, t)	
t := t+100	
WRITE(B,t)	

Ignoring Details

- Sometimes transactions’ actions may commute accidentally because of specific updates
  - Serializability is undecidable !
- The scheduler shouldn’t look at the transactions’ details
- Assume worst case updates, only care about reads r(A) and writes w(A)

Notation

T_1: $r_1(A)$; $w_1(A)$; $r_1(B)$; $w_1(B)$
T_2: $r_2(A)$; $w_2(A)$; $r_2(B)$; $w_2(B)$

Conflict Serializability

Conflicts:

Two actions by same transaction T_i: $r_i(X)$; $w_i(Y)$

Two writes by T_i, T_j to same element $w_i(X)$; $w_j(X)$

Read/write by T_i, T_j to same element $w_i(X)$; $r_j(X)$

$r_i(X)$; $w_j(X)$

Conflict Serializability

- A schedule is <u>*conflict serializable*</u> if it can be transformed into a serial schedule by a series of swappings of adjacent non-conflicting actions

Example:

$r_1(A); w_1(A); r_2(A); w_2(A); r_1(B); w_1(B); r_2(B); w_2(B)$

⇓

$r_1(A); w_1(A); r_1(B); w_1(B); r_2(A); w_2(A); r_2(B); w_2(B)$

Conflict Serializability

- Any conflict serializable schedule is also a serializable schedule (why ?)

- The converse is not true, even under the "worst case update" assumption

Lost write

$w_1(Y); w_2(Y); w_2(X); w_1(X); w_3(X);$

⇓

Equivalent, but can't swap

$w_1(Y); w_1(X); w_2(Y); w_2(X); w_3(X);$

The Precedence Graph Test

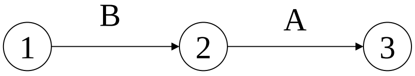
Is a schedule conflict-serializable ?

Simple test:

- Build a graph of all transactions T_i
- Edge from T_i to T_j if T_i makes an action that conflicts with one of T_j and comes first
- The test: if the graph has no cycles, then it is conflict serializable !

Example 1

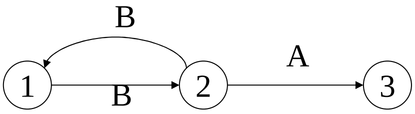
$r_2(A); r_1(B); w_2(A); r_3(A); w_1(B); w_3(A); r_2(B); w_2(B)$



This schedule is conflict-serializable

Example 2

$r_2(A); r_1(B); w_2(A); r_2(B); r_3(A); w_1(B); w_3(A); w_2(B)$



This schedule is NOT conflict-serializable

Scheduler

- The scheduler is the module that schedules the transaction’s actions, ensuring serializability
- How ? Three techniques:
  - Locks
  - Time stamps
  - Validation

Locking Scheduler

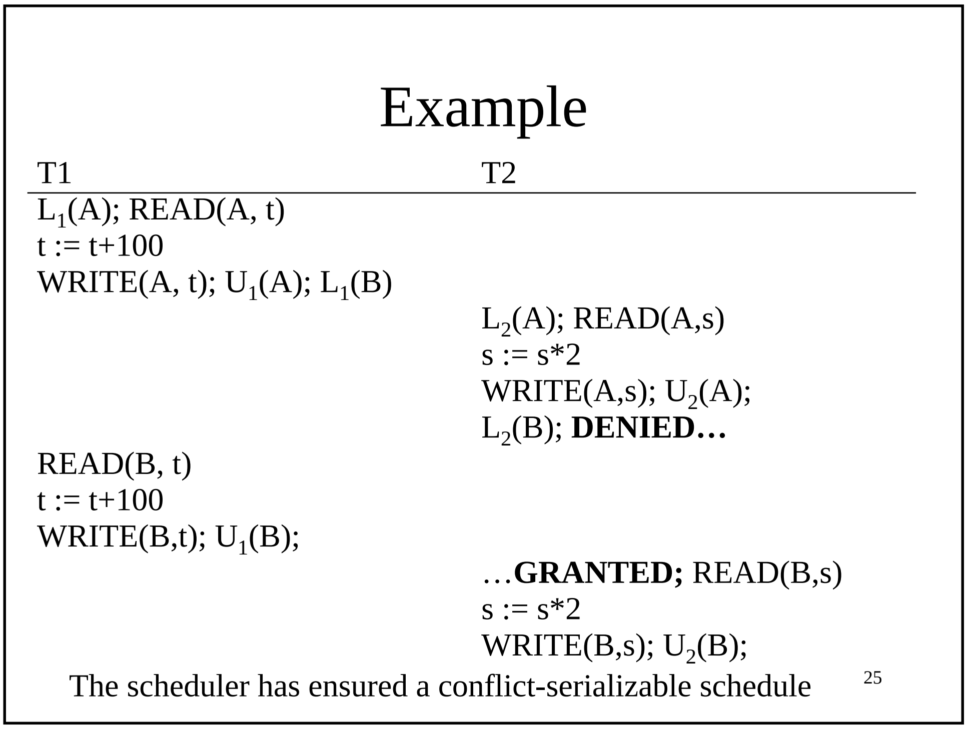
Simple idea:

- Each element has a unique lock
- Each transaction must first acquire the lock before reading/writing that element
- If the lock is taken by another transaction, then wait
- The transaction must release the lock(s)

Notation

$l_i(A)$ = transaction T_i acquires lock for element A

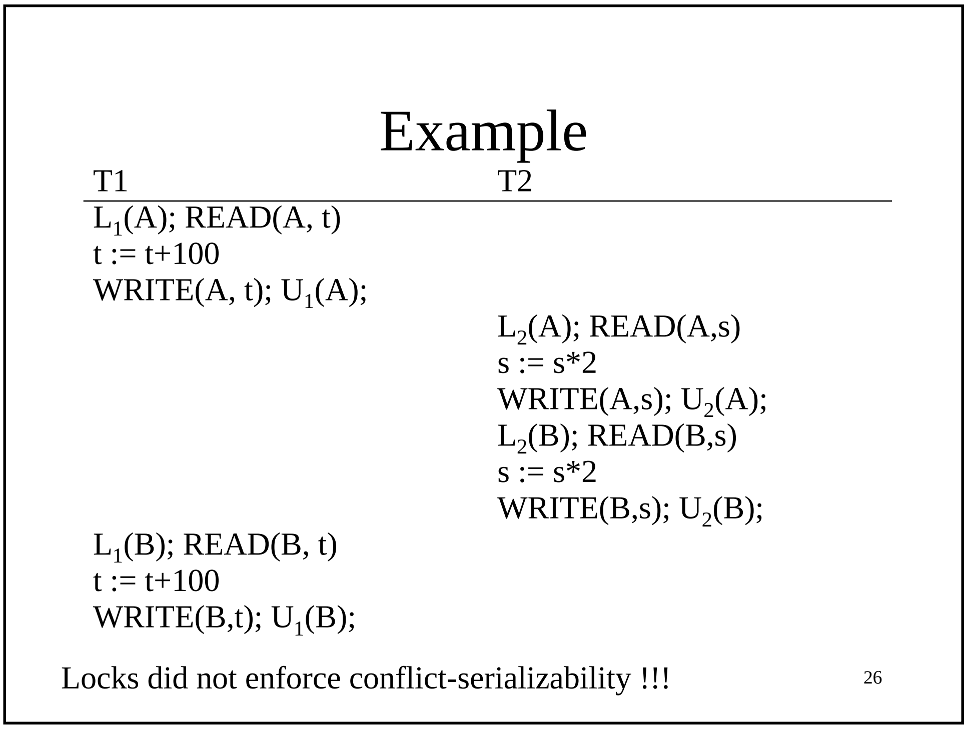
$u_i(A)$ = transaction T_i releases lock for element A



Example

T1	T2
L_1(A); READ(A, t)	
t := t+100	
WRITE(A, t); U_1(A); L_1(B)	
	L_2(A); READ(A,s)
	s := s*2
	WRITE(A,s); U_2(A);
	L_2(B); **DENIED…**
READ(B, t)	
t := t+100	
WRITE(B,t); U_1(B);	
	…**GRANTED;** READ(B,s)
	s := s*2
	WRITE(B,s); U_2(B);

The scheduler has ensured a conflict-serializable schedule



Example

T1	T2
L_1(A); READ(A, t)	
t := t+100	
WRITE(A, t); U_1(A);	
	L_2(A); READ(A,s)
	s := s*2
	WRITE(A,s); U_2(A);
	L_2(B); READ(B,s)
	s := s*2
	WRITE(B,s); U_2(B);
L_1(B); READ(B, t)	
t := t+100	
WRITE(B,t); U_1(B);	

Locks did not enforce conflict-serializability !!!

Two Phase Locking (2PL)

The 2PL rule:

- In every transaction, all lock requests must preceed all unlock requests
- This ensures conflict serializability ! (why?)

Example: 2PL transactcions

T1	T2
L_1(A); L_1(B); READ(A, t)	
t := t+100	
WRITE(A, t); U_1(A)	
	L_2(A); READ(A,s)
	s := s*2
	WRITE(A,s);
	L_2(B); **DENIED…**
READ(B, t)	
t := t+100	
WRITE(B,t); U_1(B);	
	…**GRANTED;** READ(B,s)
	s := s*2
	WRITE(B,s); U_2(A); U_2(B);

Now it is conflict-serializable

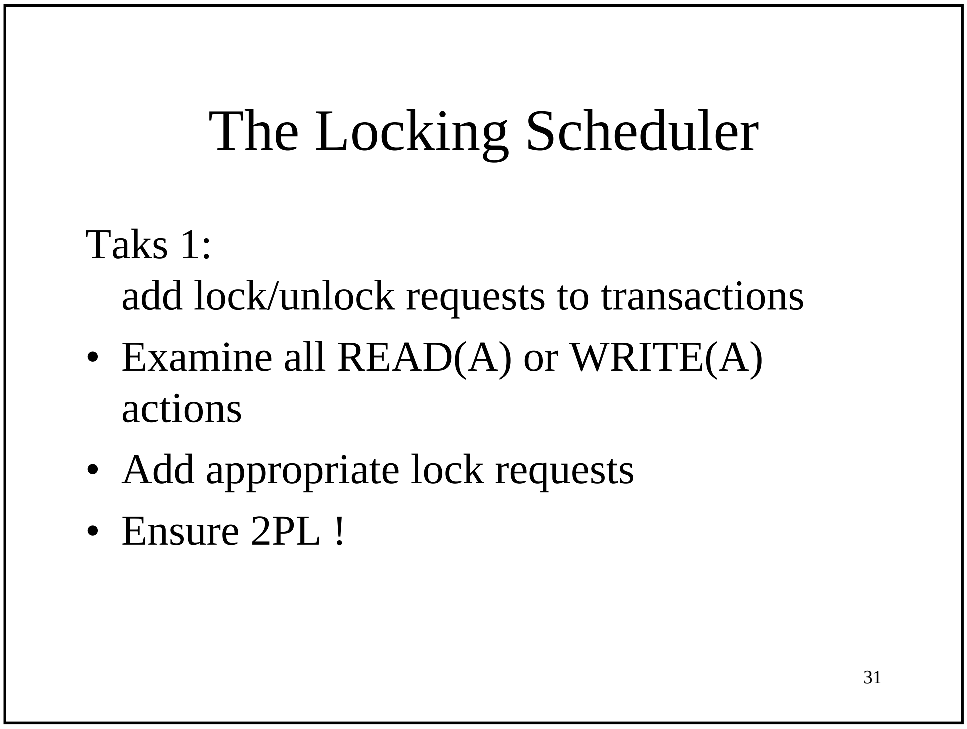
Deadlock

- Trasaction T_1 waits for a lock held by T_2;
- But T_2 waits for a lock held by T_3;
- While T_3 waits for . . . .
- . . .
- . . .and T_{73} waits for a lock held by T_1 !!

Could be avoided, by ordering all elements (see book); or deadlock detection plus rollback

Lock Modes

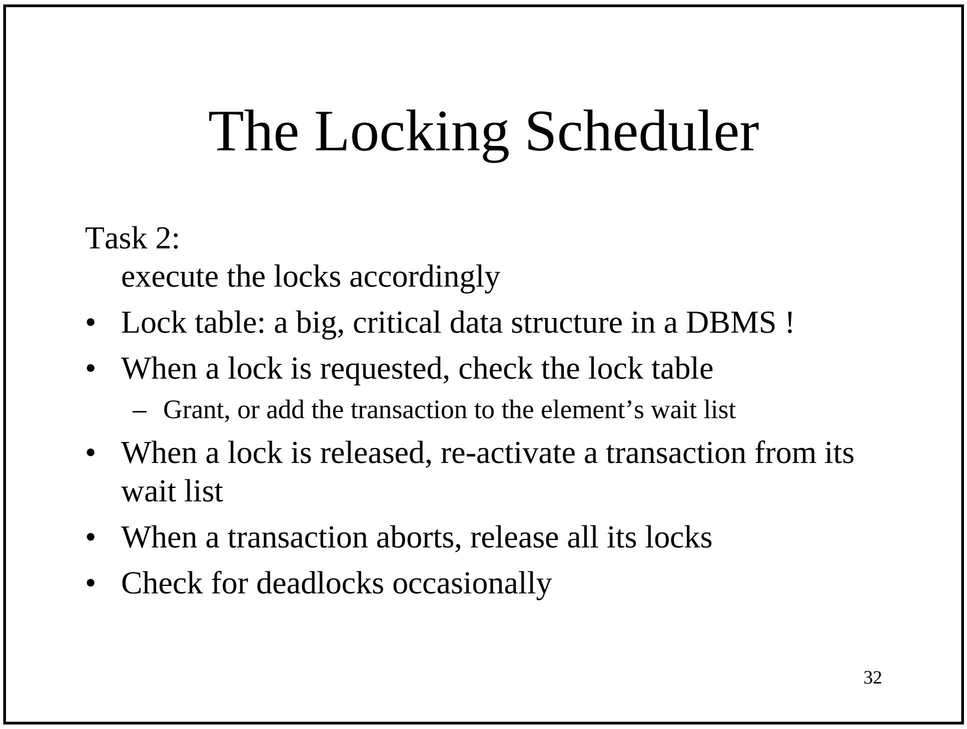
- S = Shared lock (for READ)
- X = exclusive lock (for WRITE)
- U = update lock
  - Initially like S
  - Later may be upgraded to X
- I = increment lock (for A := A + something)
  - Increment operations commute
- READ CHAPTER 18.4 !



The Locking Scheduler

Taks 1:
add lock/unlock requests to transactions

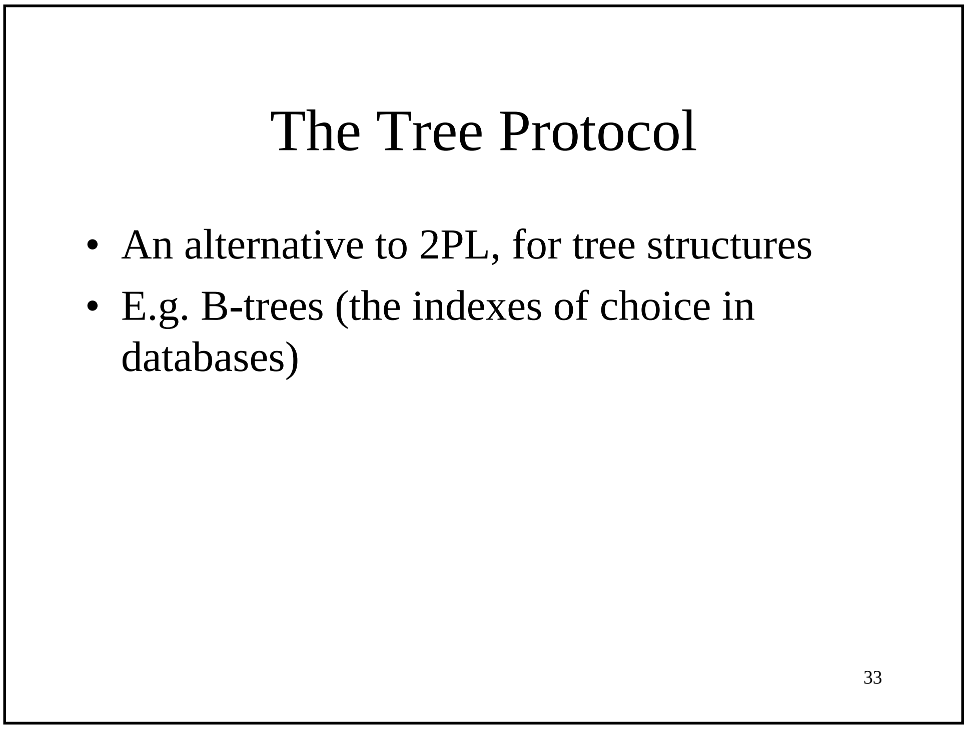
- Examine all READ(A) or WRITE(A) actions
- Add appropriate lock requests
- Ensure 2PL !



The Locking Scheduler

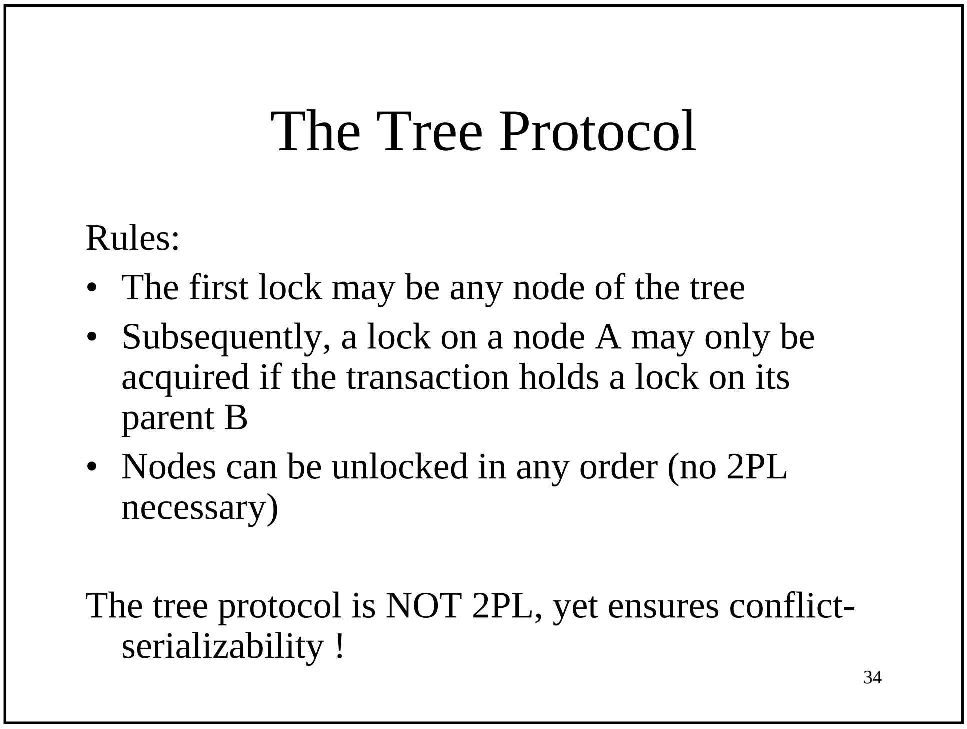
Task 2:
execute the locks accordingly

- Lock table: a big, critical data structure in a DBMS !
- When a lock is requested, check the lock table
  - Grant, or add the transaction to the element’s wait list
- When a lock is released, re-activate a transaction from its wait list
- When a transaction aborts, release all its locks
- Check for deadlocks occasionally



The Tree Protocol

- An alternative to 2PL, for tree structures
- E.g. B-trees (the indexes of choice in databases)



The Tree Protocol

Rules:

- The first lock may be any node of the tree
- Subsequently, a lock on a node A may only be acquired if the transaction holds a lock on its parent B
- Nodes can be unlocked in any order (no 2PL necessary)

The tree protocol is NOT 2PL, yet ensures conflict-serializability !