

# Concurrency Control (Lock Based Protocol)

# Concurrency Control- Introduction

- Lock-Based Protocols
- Timestamp-Based Protocols
- Validation-Based Protocols
- Multiple Granularity
- Multiversion Schemes
- Deadlock Handling
- Insert and Delete Operations
- Concurrency in Index Structures

# Lock-Based Protocols

- A lock is a mechanism to control concurrent access to a data item
- Data items can be locked in two modes :
  1. *exclusive (X) mode*. Data item can be both read as well as written. X-lock is requested using **lock-X** instruction.
  2. *shared (S) mode*. Data item can only be read. S-lock is requested using **lock-S** instruction.
- Lock requests are made to concurrency-control manager. Transaction can proceed only after request is granted.

# Lock-Based Protocols (Cont.)

- Lock-compatibility matrix

	S	X
S	true	false
X	false	false

- A transaction may be granted a lock on an item if the requested lock is compatible with locks already held on the item by other transactions
- Any number of transactions can hold shared locks on an item, but if any transaction holds an exclusive on the item no other transaction may hold any lock on the item.
- If a lock cannot be granted, the requesting transaction is made to wait till all incompatible locks held by other transactions have been released. The lock is then granted.

# Lock-Based Protocols (Cont.)

- Example of a transaction performing locking:

```
 $T_2$ : lock-S(A);  
      read (A);  
      unlock(A);  
      lock-S(B);  
      read (B);  
      unlock(B);  
      display(A+B)
```

- Locking as above is not sufficient to guarantee serializability — if  $A$  and  $B$  get updated in-between the read of  $A$  and  $B$ , the displayed sum would be wrong.
- A **locking protocol** is a set of rules followed by all transactions while requesting and releasing locks. Locking protocols restrict the set of possible schedules.

# Pitfalls of Lock-Based Protocols

- Consider the partial schedule

$T_3$	$T_4$
lock-X( $B$ )	
read( $B$ )	
$B := B - 50$	
write( $B$ )	
	lock-S( $A$ )
	read( $A$ )
	lock-S( $B$ )
lock-X( $A$ )	

- Neither  $T_3$  nor  $T_4$  can make progress — executing **lock-S( $B$ )** causes  $T_4$  to wait for  $T_3$  to release its lock on  $B$ , while executing **lock-X( $A$ )** causes  $T_3$  to wait for  $T_4$  to release its lock on  $A$ .
- Such a situation is called a **deadlock**.
  - To handle a deadlock one of  $T_3$  or  $T_4$  must be rolled back and its locks released.

# Pitfalls of Lock-Based Protocols

## (Cont.)

- The potential for deadlock exists in most locking protocols. Deadlocks are a necessary evil.
- **Starvation** is also possible if concurrency control manager is badly designed. For example:
  - A transaction may be waiting for an X-lock on an item, while a sequence of other transactions request and are granted an S-lock on the same item.
  - The same transaction is repeatedly rolled back due to deadlocks.
- Concurrency control manager can be designed to prevent starvation.

# The Two-Phase Locking Protocol

- This is a protocol which ensures conflict-serializable schedules.
- Phase 1: Growing Phase
  - transaction may obtain locks
  - transaction may not release locks
- Phase 2: Shrinking Phase
  - transaction may release locks
  - transaction may not obtain locks
- The protocol assures serializability. It can be proved that the transactions can be serialized in the order of their **lock points** (i.e. the point where a transaction acquired its final lock).

# The Two-Phase Locking Protocol (Cont.)

- Two-phase locking *does not* ensure freedom from deadlocks
- Cascading roll-back is possible under two-phase locking. To avoid this, follow a modified protocol called **strict two-phase locking**. Here a transaction must hold all its exclusive locks till it commits/aborts.
- **Rigorous two-phase locking** is even stricter: here *all* locks are held till commit/abort. In this protocol transactions can be serialized in the order in which they commit.

# The Two-Phase Locking Protocol (Cont.)

- There can be conflict serializable schedules that cannot be obtained if two-phase locking is used.
- However, in the absence of extra information (e.g., ordering of access to data), two-phase locking is needed for conflict serializability in the following sense:

Given a transaction  $T_i$  that does not follow two-phase locking, we can find a transaction  $T_j$  that uses two-phase locking, and a schedule for  $T_i$  and  $T_j$  that is not conflict serializable.

# Lock Conversions

- Two-phase locking with lock conversions:

- First Phase:

- can acquire a **lock-S** on item
    - can acquire a **lock-X** on item
    - can convert a **lock-S** to a **lock-X** (**upgrade**)

- Second Phase:

- can release a **lock-S**
    - can release a **lock-X**
    - can convert a **lock-X** to a **lock-S** (**downgrade**)

- This protocol assures serializability. But still relies on the programmer to insert the various locking instructions.

# Automatic Acquisition of Locks

- A transaction  $T_i$  issues the standard read/write instruction, without explicit locking calls.

- The operation `read( $D$ )` is processed as:

```
    if  $T_i$  has a lock on  $D$ 
```

```
        then
```

```
            read( $D$ )
```

```
        else
```

```
            begin
```

```
                if necessary wait until no other  
                    transaction has a lock-X on  $D$ 
```

```
                grant  $T_i$  a lock-S on  $D$ ;
```

```
                read( $D$ )
```

```
            end
```

# Automatic Acquisition of Locks (Cont.)

- **write( $D$ )** is processed as:

- if  $T_i$  has a **lock-X** on  $D$

- then**

- write( $D$ )

- else

- begin**

- if necessary wait until no other trans. has any lock on  $D$ ,

- if  $T_i$  has a **lock-S** on  $D$

- then**

- upgrade** lock on  $D$  to **lock-X**

- else**

- grant  $T_i$  a **lock-X** on  $D$

- write( $D$ )

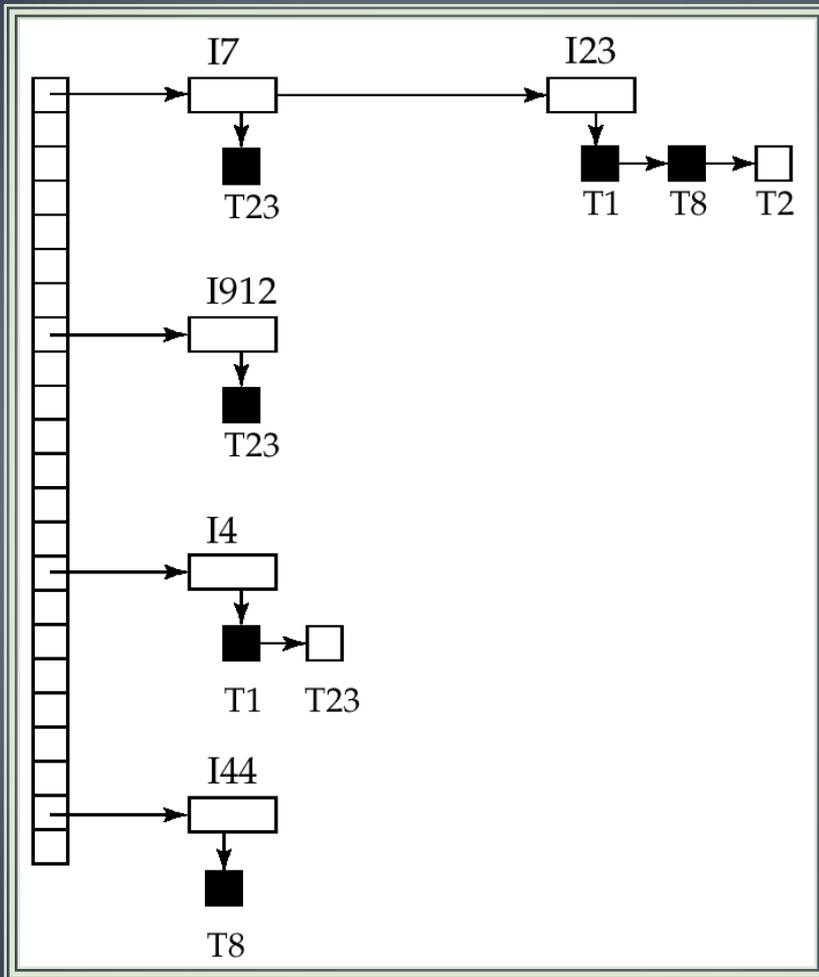
- end;**

- All locks are released after commit or abort

# Implementation of Locking

- A **Lock manager** can be implemented as a separate process to which transactions send lock and unlock requests
- The lock manager replies to a lock request by sending a lock grant messages (or a message asking the transaction to roll back, in case of a deadlock)
- The requesting transaction waits until its request is answered
- The lock manager maintains a datastructure called a **lock table** to record granted locks and pending requests
- The lock table is usually implemented as an in-memory hash table indexed on the name of the data item being locked

# Lock Table



- Black rectangles indicate granted locks, white ones indicate waiting requests
- Lock table also records the type of lock granted or requested
- New request is added to the end of the queue of requests for the data item, and granted if it is compatible with all earlier locks
- Unlock requests result in the request being deleted, and later requests are checked to see if they can now be granted
- If transaction aborts, all waiting or granted requests of the transaction are deleted
  - lock manager may keep a list of locks held by each transaction, to implement this efficiently