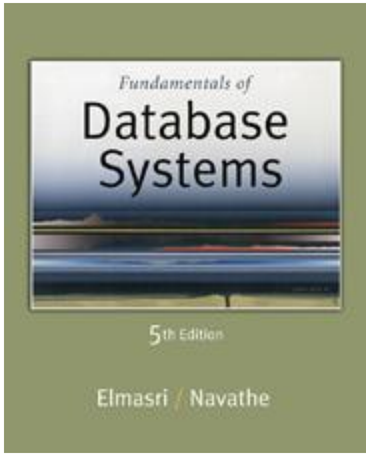
Chapter 18

Concurrency Control Techniques



Database Concurrency Control

- 1 Purpose of Concurrency Control
  - To enforce Isolation (through mutual exclusion) among conflicting transactions.
  - To preserve database consistency through consistency preserving execution of transactions.
  - To resolve read-write and write-write conflicts.

- Example:
  - In concurrent execution environment if T1 conflicts with T2 over a data item A, then the existing concurrency control decides if T1 or T2 should get the A and if the other transaction is rolled-back or waits.

Database Concurrency Control

Two-Phase Locking Techniques

- Locking is an operation which secures
  - (a) permission to Read
  - (b) permission to Write a data item for a transaction.
- Example:
  - Lock (X). Data item X is locked in behalf of the requesting transaction.
- Unlocking is an operation which removes these permissions from the data item.
- Example:
  - Unlock (X): Data item X is made available to all other transactions.
- Lock and Unlock are Atomic operations.

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Two-Phase Locking Techniques: Essential components

- Two locks modes:
  - (a) shared (read)   (b) exclusive (write).
- Shared mode: shared lock (X)
  - More than one transaction can apply share lock on X for reading its value but no write lock can be applied on X by any other transaction.
- Exclusive mode: Write lock (X)
  - Only one write lock on X can exist at any time and no shared lock can be applied by any other transaction on X.
- Conflict matrix

	Read	Write
Read	Y	N
Write	N	N

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Two-Phase Locking Techniques: Essential components

- Lock Manager:
  - Managing locks on data items.
- Lock table:
  - Lock manager uses it to store the identify of transaction locking a data item, the data item, lock mode and pointer to the next data item locked. One simple way to implement a lock table is through linked list.

Transaction ID	Data item id	lock mode	Ptr to next data item
T1	X1	Read	Next

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Two-Phase Locking Techniques: Essential components

- Database requires that all transactions should be well-formed. A transaction is well-formed if:
  - It must lock the data item before it reads or writes to it.
  - It must not lock an already locked data items and it must not try to unlock a free data item.

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Two-Phase Locking Techniques: (Binary Lock)

- The following code performs the lock operation:

```
B: if LOCK (X) = 0 (*item is unlocked*)
   then LOCK (X) ← 1 (*lock the item*)
   else begin
     wait (until lock (X) = 0 and
     the lock manager wakes up the transaction);
   goto B
   end;
```

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Two-Phase Locking Techniques: Essential components

- The following code performs the unlock operation:

LOCK (X) ← 0 (*unlock the item*)
if any transactions are waiting then
  wake up one of the waiting the transactions;

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Two-Phase Locking Techniques: (Multiple-mode locks: shared/exclusive or read/write locks)

- The following code performs the read_lock(X) operation:

```
B: if LOCK (X) = “unlocked” then
 begin LOCK (X) ← “read-locked”;
    no_of_reads (X) ← 1;
 end
 else if LOCK (X) ← “read-locked” then
         no_of_reads (X) ← no_of_reads (X) +1
      else begin wait (until LOCK (X) = “unlocked” and
         the lock manager wakes up the transaction);
         go to B
       end;
```

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Two-Phase Locking Techniques: Essential components

- The following code performs the write_lock(X) operation:

```
B: if LOCK (X) = "unlocked" then
 begin LOCK (X) ← "write-locked";
     else begin wait (until LOCK (X) = "unlocked" and
         the lock manager wakes up the transaction);
         go to B
       end;
```

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Two-Phase Locking Techniques: Essential components

- The following code performs the unlock(X) operation:

```
if LOCK (X) = “write-locked” then
 begin LOCK (X) ← “unlocked”;
     wakes up one of the waiting transactions, if any
 end
 else if LOCK (X) ← “read-locked” then
    begin
        no_of_reads (X) ← no_of_reads (X) -1
        if  no_of_reads (X) = 0 then
        begin
      LOCK (X) = “unlocked”;
     wake up one of the waiting transactions, if any
        end
    end;
```

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Two-Phase Locking Techniques: Essential components

- Lock conversion
  - Lock upgrade: existing read lock to write lock

    if Ti has a read-lock (X) and Tj has no read-lock (X) ($i \neq j$) then
    convert read-lock (X) to write-lock (X)
    else
    force Ti to wait until Tj unlocks X

  - Lock downgrade: existing write lock to read lock

    Ti has a write-lock (X) (*no transaction can have any lock on X*)
    convert write-lock (X) to read-lock (X)

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Two-Phase Locking Techniques: The algorithm

- Two Phases:
  - (a) Locking (Growing)
  - (b) Unlocking (Shrinking).
- **Locking (Growing) Phase:**
  - A transaction applies locks (read or write) on desired data items one at a time.
- **Unlocking (Shrinking) Phase:**
  - A transaction unlocks its locked data items one at a time.
- **Requirement:**
  - For a transaction these two phases must be mutually exclusively, that is, during locking phase unlocking phase must not start and during unlocking phase locking phase must not begin.

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Two-Phase Locking Techniques: The algorithm

T1	**T2**	**Result**
read_lock (Y);	read_lock (X);	Initial values: X=20; Y=30
read_item (Y);	read_item (X);	Result of serial execution
unlock (Y);	unlock (X);	T1 followed by T2
write_lock (X);	Write_lock (Y);	X=50, Y=80.
read_item (X);	read_item (Y);	Result of serial execution
X:=X+Y;	Y:=X+Y;	T2 followed by T1
write_item (X);	write_item (Y);	X=70, Y=50
unlock (X);	unlock (Y);	

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Two-Phase Locking Techniques: The algorithm

T1	T2
read_lock (Y); read_item (Y); **unlock (Y);**	
	read_lock (X); read_item (X); **unlock (X);** **write_lock (Y);** read_item (Y); Y:=X+Y; write_item (Y); unlock (Y);
write_lock (X); read_item (X); X:=X+Y; write_item (X); unlock (X);	

Time

Result

X=50; Y=50
Nonserializable because it.
violated two-phase policy.

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Two-Phase Locking Techniques: The algorithm

T'1	**T'2**	
read_lock (Y); read_item (Y); write_lock (X); unlock (Y); read_item (X); X:=X+Y; write_item (X); unlock (X);	read_lock (X); read_item (X); Write_lock (Y); unlock (X); read_item (Y); Y:=X+Y; write_item (Y); unlock (Y);	T1 and T2 follow two-phase policy but they are subject to deadlock, which must be dealt with.

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Two-Phase Locking Techniques: The algorithm

- Two-phase policy generates two locking algorithms
  - (a) **Basic**
  - (b) **Conservative**
- **Conservative**:
  - Prevents deadlock by locking all desired data items before transaction begins execution.
- **Basic**:
  - Transaction locks data items incrementally. This may cause deadlock which is dealt with.
- **Strict**:
  - A more stricter version of Basic algorithm where unlocking is performed after a transaction terminates (commits or aborts and rolled-back). This is the most commonly used two-phase locking algorithm.

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Dealing with Deadlock and Starvation

- **Deadlock**

T'1	**T'2**	
read_lock (Y); read_item (Y);		T1 and T2 did follow two-phase policy but they are deadlock
	read_lock (X); read_item (Y);	
write_lock (X); (waits for X)	write_lock (Y); (waits for Y)	

- Deadlock (T'1 and T'2)

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Dealing with Deadlock and Starvation

- **Deadlock prevention**
  - A transaction locks all data items it refers to before it begins execution.
  - This way of locking prevents deadlock since a transaction never waits for a data item.
  - The conservative two-phase locking uses this approach.

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Dealing with Deadlock and Starvation

- **Deadlock detection and resolution**
  - In this approach, deadlocks are allowed to happen. The scheduler maintains a wait-for-graph for detecting cycle. If a cycle exists, then one transaction involved in the cycle is selected (victim) and rolled-back.
  - A wait-for-graph is created using the lock table. As soon as a transaction is blocked, it is added to the graph. When a chain like: Ti waits for Tj waits for Tk waits for Ti or Tj occurs, then this creates a cycle. One of the transaction o

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Dealing with Deadlock and Starvation

- **Deadlock avoidance**
  - There are many variations of two-phase locking algorithm.
  - Some avoid deadlock by not letting the cycle to complete.
  - That is as soon as the algorithm discovers that blocking a transaction is likely to create a cycle, it rolls back the transaction.
  - Wound-Wait and Wait-Die algorithms use timestamps to avoid deadlocks by rolling-back victim.

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Dealing with Deadlock and Starvation

- **Starvation**
  - Starvation occurs when a particular transaction consistently waits or restarted and never gets a chance to proceed further.
  - In a deadlock resolution it is possible that the same transaction may consistently be selected as victim and rolled-back.
  - This limitation is inherent in all priority based scheduling mechanisms.
  - In Wound-Wait scheme a younger transaction may always be wounded (aborted) by a long running older transaction which may create starvation.

Database Concurrency Control

Timestamp based concurrency control algorithm

- **Timestamp**
  - A monotonically increasing variable (integer) indicating the age of an operation or a transaction. A larger timestamp value indicates a more recent event or operation.
  - Timestamp based algorithm uses timestamp to serialize the execution of concurrent transactions.

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Timestamp based concurrency control algorithm

- **Basic Timestamp Ordering**
  - 1. Transaction T issues a write_item(X) operation:
    - If read_TS(X) > TS(T) or if write_TS(X) > TS(T), then an younger transaction has already read the data item so abort and roll-back T and reject the operation.
    - If the condition in part (a) does not exist, then execute write_item(X) of T and set write_TS(X) to TS(T).
  - 2. Transaction T issues a read_item(X) operation:
    - If write_TS(X) > TS(T), then an younger transaction has already written to the data item so abort and roll-back T and reject the operation.
    - If write_TS(X) ≤ TS(T), then execute read_item(X) of T and set read_TS(X) to the larger of TS(T) and the current read_TS(X).

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Timestamp based concurrency control algorithm

- **Strict Timestamp Ordering**
  - 1. Transaction T issues a write_item(X) operation:
    - If TS(T) > read_TS(X), then delay T until the transaction T' that wrote or read X has terminated (committed or aborted).
  - 2. Transaction T issues a read_item(X) operation:
    - If TS(T) > write_TS(X), then delay T until the transaction T' that wrote or read X has terminated (committed or aborted).

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Timestamp based concurrency control algorithm

- **Thomas's Write Rule**
  - If read_TS(X) > TS(T) then abort and roll-back T and reject the operation.
  - If write_TS(X) > TS(T), then just ignore the write operation and continue execution. This is because the most recent writes counts in case of two consecutive writes.
  - If the conditions given in 1 and 2 above do not occur, then execute write_item(X) of T and set write_TS(X) to TS(T).