UNIT 6

Concurrency Control

Content

- Types of locks and system lock tables
- Serializablility by Two-Phase Locking
- Dealing with Deadlock and Starvation
- Timestamp ordering
- Validation concurrency control

Needs of Lock

Locking technique is used to **control concurrent execution** of transactions.

Enforce **Isolation execution.**

Locks are used as a means of synchronizing the access by concurrent transactions.

Lock:

Lock is a variable associated with a data item that describes the **possible operations that are allowed on data item**.

Types of Lock

- Binary Lock :
- Shared/Exclusive (Read/Write) Lock

Binary Lock

- A Binary Lock can have two state or values:
  - Lock
  - Unlock
- 1 -> indicates locked
- 0 -> indicates unlocked.

Locking

Locking is an operation which secures

- Permission to Read a data item for a transaction.

  OR

- Permission to Write a data item for a transaction.

A distinct lock is associated with each database item x.

Example: Lock (X)

Data item X is locked in behalf of the requesting transaction.

Unlocking

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.

Exclusive/Shared Lock

Shared Mode: Read lock (X).

More than one transaction can apply share lock on X for reading.

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.

If a transaction have exclusive lock then no transaction have exclusive lock on same item.

Lock table and Lock manager

- **Lock table :**
  - In the Lock table, system maintain only the items that are concurrently.
  - Lock table is organize as a hash file.
  - Item not in lock table are consider to be unlocked.

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

- **Lock Manager :**
  - Managing locks on data items.

Well-formed Transaction

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

Lock Operation of Binary Lock

Lock_item(X) :

B:

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

Unlock Operation of Binary Lock

Unlock_item(X) :

LOCK (X) $\leftarrow$ 0 (*unlock the item*)

if (any transactions are waiting) then

wake up one of the waiting the transactions;

Rules for transaction in binary locking scheme

1. A transaction T must issue the operation lock_item(X) before any read_item(X) or write_item(X) operation performed in T.
2. A transaction T must issue the operation unlock_item(X) after all read_item(X) and write_item(X) operation completed in T.
3. A transaction T will not issue a lock_item(X) operation if it already hold lock on item X.
4. A transaction T will not issue a unlock_item(X) operation unless it already hold lock on item X.

Lock Operation of Shared Lock

read_item(X) :

```
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;
```

Lock Operation of exclusive Lock

write_item(X) :

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

Unlock Operation for two-mode

Unlock(x) :

```
if LOCK (X) = "write-locked" then
      begin
         LOCK (X) ← "unlocked";
         wake up on of the waiting transaction, if any
      end
  else if LOCK (X) = "read-locked" then
      begin
         no_of_read(X) ← no_of_read(X)-1 ;
         if no_of_read(X) =0 then
               begin
                  LOCK (X) ← "unlocked";
                  wake up on of the waiting transaction, if any
               end
      end;
```

Rules for transaction in shared/exclusive locking scheme

1. A transaction T must issue the operation read_lock(X) or write_lock(X) before any read_item(X) operation performed in T.

2. A transaction T must issue the operation write_lock(X) before write_item(X) operation perforemed in T.

3. A transaction T must issue the operation unlock(X) after all write_item(X) operation are completed in T.

Rules for transaction in shared/exclusive locking scheme

4. A transaction T will not issue a read_lock(X) operation if it already holds a read(shared) lock or a write(exclusive) lock on item X.

5. A transaction T will not issue a write_lock(X) operation if it already holds a read(shared) lock or a write(exclusive) lock on item X.

6. A transaction T will not issue an unlock(x) operation unless it already holds a read(shared) lock or a write(exclusive) lock on item X.

Serializablility by Two Phase Locking

- A transaction is said to follow the **two-phase locking protocol** if all locking operations (read_lock, write_lock) precede the first unlock operation in the transaction.
- Such transaction can be divided in to 2 phase
  - Expanding or Growing (first) Phase
  - Shrinking (Second) Phase

Serializablility by Two Phase Locking

- **Locking (Growing) Phase:** In this phase new locks on the items can be acquired but none can be released.
  - A transaction applies locks (read or write) on desired data items one at a time.(Gain Lock)
- **Unlocking (Shrinking) Phase:** In this phase existing lock can be released but no new lock can be acquired.
  - A transaction unlocks its locked data items one at a time.(Release Lock)
- **Requirement:** For a transaction these two phases must be mutually exclusively, that is,
  - During locking phase unlocking phase must not start
  - During unlocking phase locking phase must not begin.

Serial Schedule of T1 and T2

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);	

Problem to violated to phase locking Protocol

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)	

Result :

X=50; Y=50

Non-Serializable because it violated two phase policy.

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

- Follows Two phase locking protocols

Two phase locking protocols

- **Advantage:**
  - It produce Serializable schedule.
- **Problem With two phase locking protocols**
  - Two phase locking protocols can produce deadlock.

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)

Variation of two phase locking

- Two-phase policy generates two locking algorithms
  - Basic
  - Conservative.
- **Conservative:**
  - Prevents deadlock by locking all desired data items before transaction begins execution by pre-declaring its read-set and write-set.
  - Deadlock free protocol
  - If any of pre-declared items can not be locked, then the transaction does not lock any of its items, and it wait until all the item available for locking.

Terms in two-phase locking protocols

- **Strict 2PL** :
  - A transaction must released all it's exclusive lock only when it is committed or abort.
  - Transaction T does not released any of its exclusive lock until after commit or aborts.
- **Rigorous 2PL :**
  - A transaction must released all it's lock only when it's commit or abort.
  - Transaction T does not released any of its lock(exclusive or Shared) until after commit or aborts.
  - It is easier to implement than strict 2PL.

Difference between Conservative and Rigorous 2PL

- Conservative: Growing phase
- Rigorous : Expanding Phase

Deadlock

- **Deadlock** occurs when each transaction T in a set of two or more transaction is waiting for some item that is locked by some other transaction T' in the set.
- Hence each transaction in the set is on a waiting queue, waiting for one of the other transaction in the set to release the lock on an item.

Deadlock

T1	T2
read_lock (Y) read_item(Y)	
	read_lock (X) read_item(X)
write_lock (X) (waits for X)	
	write_lock (Y); (waits for Y)

T1 and T2 did follow two-phase policy but they are deadlock

3. Dealing with Deadlock

- There are several ways to dealing with deadlock
  - Deadlock prevention
  - Deadlock detection
  - Prevent Starvation

Deadlock prevention

- ***Deadlock prevention*** protocols ensure that the system will *never* enter into a deadlock state.
- Some prevention strategies :
  1. Require that each transaction locks all its data items before it begins execution (pre-declaration).
     - The conservative two-phase locking uses this approach
  2. On the basis of transaction timestamp TS(T)

Transaction Timestamp TP(S)

- Transaction timestamp is a unique identifier assigned to each transaction.
- It is based on the order in which transaction are started.
- If transaction T_1 starts before transaction T_2 then

  $TS(T_1) < TS(T_2)$
- Older transaction has smaller timestamp value.
- Two scheme that prevent deadlock
  1. Wait-Die
  2. Wound-Wait

- **wait-die scheme** — non-preemptive

  If TS(i)< TS(j), then (Ti older than Tj)

  Ti allowed to wait;

  otherwise (Ti younger than Tj)

  abort Ti(Ti dies) and

  restart it later with the same timestamp.

  - Older transaction may wait for younger one to release data item. Younger transactions never wait for older ones; they are rolled back instead.
  - A transaction may die several times before acquiring needed data item

- **wound-wait scheme** — preemptive

  If TS(i)< TS(j), then (Ti older than Tj)

  abort Tj (Ti wounds Tj)

  restart it later with the same timestamp.

  otherwise (Ti younger than Tj)

  Ti allowed to wait

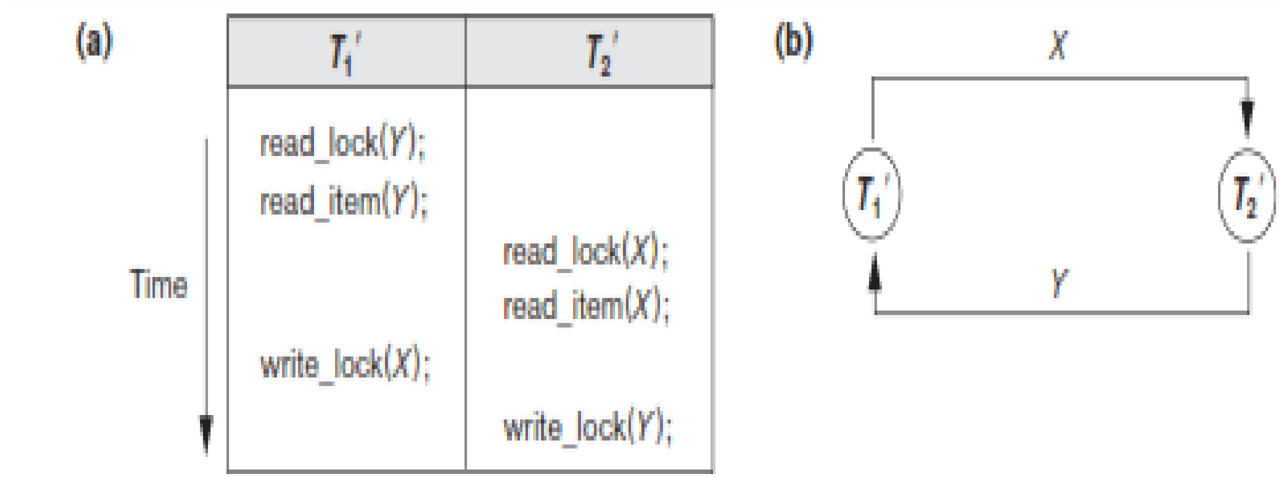
  - older transaction *wounds* (forces rollback) of younger transaction instead of waiting for it. Younger transactions may wait for older ones.
  - may be fewer rollbacks than *wait-die* scheme.

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 of the cycle is selected and rolled back.

wait-for graph

- One node is created in the wait-for graph for each transaction that is currently executing.
- Whenever transaction Ti waiting to lock an item X, that is currently lock by transaction Tj.
  - Direct edge is created from (Ti $\longrightarrow$ Tj)
- We have a state of deadlock if and only if the wait-for graph has a cycle.



Check whether the following schedule produce deadlock or not?

T1	T2
lock (A) ;	
read (A) ;	
write(A);	lock(B);
	write(B);
	read(B);
lock(B);	
	lock(A);

Apply two phase locking and then check whether schedule is deadlocked or not?	
T1	T2
read (A) ;	
	read(B);
	Read(A)
read(B);	
If A=1	
then B:=B+1	
	If B=1 then
	A:=A+1
	Write(A)
Write(b)	

Starvation

- Starvation :it occurs when a transaction cannot proceed for an indefinite period of time while other transaction in the system continue normally.
- This may occur if the waiting scheme for locked items is unfair.
- Solution of Starvation :
    - First come first served
    - Based on priority
        - But increased the priority of the transaction the longer it waits. until it get highest priority.

Concurrency control based on timestamp ordering

Timestamp

- Transaction timestamp is a unique identifier assigned to each transaction.
- It is based on the order in which transaction are started.
  - A larger timestamp value indicates a more recent event or operation.
  - Timestamp based algorithm uses timestamp to serialize the execution of concurrent transactions.

Timestamp ordering algorithm

- **Timestamp Ordering** : A schedule in which the transaction participate is then Serializable, and equivalent serial schedule has the transaction in order of their timestamp value this is called timestamp ordering.
- order of accessed item that does not violate serializablility order, for that algorithm associated with each database item X is used.

- **read_TS(X)**
  - The read timestamp of item X; this is largest timestamp among all the timestamp of transaction that have successfully read item X.
  - read_TS(X)=TS(T)
    - Where T is the youngest transaction that has read X successfully.
- **write_TS(X)**
  - The write timestamp of item X; this is largest timestamp among all the timestamp of transaction that have successfully written item X.
  - write_TS(X)=TS(T)
    - Where T is the youngest transaction that has written X successfully.

Timestamp based concurrency control algorithm

Basic Timestamp Ordering

1. Transaction T issues a write_item(X) operation:

   a. If read_TS(X) > TS(T) or if write_TS(X) > TS(T), then

      abort and roll-back T and reject the operation.

      (younger transaction has already read the data item)

   b. If the condition in part (a) does not exist, then

      execute write_item(X) of T and set write_TS(X)=TS(T).

Timestamp based concurrency control algorithm

Basic Timestamp Ordering

2. Transaction T issues a read_item(X) operation:

   a. If write_TS(X) > TS(T), then

      abort and roll-back T and reject the operation.

      (younger transaction has already written to the data item)

   b. 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).

- **Advantage :**
  - Basic TO always produce conflict Serializable schedule.
  - Deadlock does not occur.
- **Problem with Basic TO**
  - Cyclic restart may occur if a transaction is continually aborted and restarted.
- A Modification of Basic TO algorithm is known as **Thomas's write rule.**
  - It does not enforce conflict serializability
  - But it reject fewer write operation by modifying the checks for the write_item(X) operation.

Timestamp based concurrency control algorithm

Thomas's Write Rule

1. If read_TS(X) > TS(T) then abort and roll-back T and reject the operation.
2. 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.
3. 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).

Validation concurrency control techniques

- optimistic concurrency control technique (validation or certification technique)
  - No checking is done while the transaction is executing.
  - It follows some scheme.
    - In this scheme , updation in the transaction are not applied directly to the database item until the transaction reaches it end.
    - All updation applied to local copies of data item that are kept for transaction.
    - At the end of transaction, concurrency control phases checks whether any of transaction’s updates violates serializability or not.

Three phases of concurrency control protocol

- **Read Phase:**
  - A transaction can read values of committed data items from the database.
  - However , updation are applied only to local copies of data items.
- **Validation Phase :**
  - Checking is performed to ensure that serializability will not be violated if transaction updates are applied to the database.
- **Write Phase**
  - If validation phase is successful, the transaction updates are applied to the database;
  - Otherwise , the updates are discarded and the transaction is restarted .

Validation Phase

- This phase for Ti checks that, for each transaction Tj that is either committed or is in its validation phase, one of the following conditions holds:

  1. Tj completes its write phase before Ti starts its read phase.
  2. Ti starts its write phase after Tj completes its write phase, and the read_set of Ti has no items in common with the write_set of Tj
  3. Both the read_set and write_set of Ti have no items in common with the write_set of Tj, and Tj completes its end phase.