Concurrency Control Techniques

Chapter 18

Chapter Objectives

- Discusses a number of concurrency control techniques that are used to insure the noninterference or isolation property (one of the **ACID** properties) of concurrently executing transactions.

	SID	Name	Major	YOB	GPA
A →	221234	Ali	ICS	1984	3.2
	221543	Ahmed	COE	1983	3.3
	221965	Emad	SE	1985	3.4
B →	222785	Fahd	SWE	1984	3.5
	223542	Lutfi	ICS	1984	3.6
	229851	Basam	COE	1985	3.7

- Chapter Outline

- Purpose of Concurrency Control
- Two-Phase Locking Based Concurrency Control
- Timestamp Based Concurrency Control
- Multiversion Concurrency Control Technique

- Purpose of Concurrency Control

- To enforce Isolation or noninterference 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.

... - Two-Phase Locking (2PL) ...

- A **lock** is a variable associated with a data item that describes the status of the item with respect to possible operations that can be applied to it.

- Locking is an operation which secures a permission to Read or a 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.

-- 2PL: Essential components ...

- Two locks modes:

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

Lock		
	Yes	No
	No	No

-- 2PL: Essential components ...

T_1 →

← T_3

T_2 →

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... -- 2PL: 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

... -- 2PL: 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 unlock the data item after it is done with it.
  - It must not lock an already locked data item.
  - It must not try to unlock a free data item.

... -- 2PL: Essential components ...

- The following code performs the **read-lock** 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;
```

... -- 2PL: Essential components ...

- The following code performs the **write-lock** 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;
```

... -- 2PL: Essential components ...

- The following code performs the **unlock** operation:

```
if LOCK (X) = "write-locked" then
      begin LOCK (X) ← "unlocked";
          wakes up one of the 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 transactions, if any
              end
         end;
```

... -- 2PL: 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 ≠ 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)

... -- 2PL: Essential components ...

- A transaction is said to follow 2PL protocol if all its locking operations precede its first unlock operation.
- 2PL algorithm
  - 2 Phases
    1. **Locking (Growing) Phase**: A transaction applies locks (read or write) on desired data items one at a time
    2. **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.

... -- 2PL: Essential components ...

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

T1 and T2 are **NOT** following 2PL protocol

... -- 2PL: Essential components ...

T3	T4
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);

T3 and T4 are following 2PL protocol

-- 2PL Algorithms

- Two-phase policy generates two locking algorithms:

1. **Conservative**: Prevents deadlock by locking all desired data items before transaction begins execution.

2. **Basic**: Transaction locks data items incrementally. This may cause deadlock which is dealt with

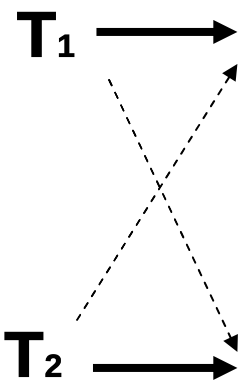
    - **Strict**: A more stricter version of Basic algorithm where unlocking is performed after a transaction terminates (commits or aborts and rolled-back). This is the most commonly used two-phase locking algorithm

-- Dealing with Deadlock and Starvation ...

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

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

... -- Dealing with Deadlock and Starvation ...



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→ : Holds ⇢ : Requests

... -- Dealing with Deadlock and Starvation ...

- Three techniques to solve deadlock problems
  - **Deadlock prevention**
    - A transaction locks all data items it refers to before it begins execution
  - **Deadlock detection and resolution**
    - 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
  - **Deadlock avoidance**
    - As soon as the algorithm discovers that blocking a transaction is likely to create a cycle, it rolls back the transaction

... -- 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.

- Timestamp based concurrency control algorithm ...

- A **timestamp** is a unique identifier created by a DBMS to identify a transaction.
- A timestamp is a monotonically increasing variable (integer) indicating the age a transaction. A larger timestamp value indicates a younger transaction.
- Timestamp based algorithm uses timestamp to serialize the execution of concurrent transactions.

…- Timestamp based concurrency control algorithm …

- In order to use timestamp values for serializable scheduling of transactions, the transaction manager of a DBMS associates with each database item X two timestamp (TS) values:
  - **Read_TS(X):** The timestamp (identifier) of the youngest transaction that has read X successfully.
  - **Write_TS(X):** The timestamp (identifier) of 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 an younger transaction has already read the data item so abort and roll-back T and reject the operation
   b) 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:
   a) 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.
   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).

… - Timestamp based concurrency control algorithm …

- Strict Timestamp Ordering (for ease of recoverability)

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).

- Multiversion concurrency control technique Concept ...

- This approach maintains a number of versions of a data item and allocates the right version to a read operation of a transaction. Thus unlike other mechanisms a read operation in this mechanism is never rejected.

- **Side effect**: Significantly more storage (RAM and disk) is required to maintain multiple versions. To check unlimited growth of versions, a garbage collection is run when some criteria is satisfied

- Multiversion concurrency control technique Concept ...

- Assume X1, X2, ..., Xn are the version of a data item X created by a write operation of transactions. With each Xi a read_TS (read timestamp) and a write_TS (write timestamp) are associated.
- **read_TS(Xi)**: The read timestamp of Xi is the largest of all the timestamps of transactions that have successfully read version Xi
- **write_TS(Xi)**: The write timestamp of Xi that wrote the value of version Xi.
- A new version of Xi is created only by a write operation.

- Multiversion concurrency control technique Concept ...

- To ensure serializability, the following two rules are used.

  1. If transaction T issues write_item (X) and version i of X has the highest write_TS(Xi) of all versions of X that is also less than or equal to TS(T), and read _TS(Xi) > TS(T), then abort and roll-back T; otherwise create a new version Xi and read_TS(X) = write_TS(Xj) = TS(T).

  2. If transaction T issues read_item (X), find the version i of X that has the highest write_TS(Xi) of all versions of X that is also less than or equal to TS(T), then return the value of Xi to T, and set the value of read _TS(Xi) to the largest of TS(T) and the current read_TS(Xi).

- Rule 2 guarantees that a read will never be rejected.

END