Chapter 5

Concurrency Control Techniques

Adapted from the slides of “Fundamentals of Database Systems” (Elmasri et al., 2006)

Chapter Outline

- Purpose of Concurrency Control
- Two-Phase Locking Techniques
- Concurrency Control Based on Timestamp Ordering
- Multi-version Concurrency Control Techniques
- Validation (Optimistic) Concurrency Control Techniques
- Granularity of Data Items And Multiple Granularity Locking

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 concurrency control decides if T1 or T2 should get the A and if the other transaction is rolled-back or waits.

2. Two-Phase Locking Techniques (1)

- 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.

Two-Phase Locking Techniques (2)

- 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.

Two-Phase Locking Techniques (3)

- Type of Locks:
  - Binary Locks
  - Shared/ Exclusive (or Read/ Write) Locks

Two-Phase Locking Techniques (4)

- Binary Locks
  - 2 values: locked and unlocked (1 and 0)
  - 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;
```

Two-Phase Locking Techniques (5)

- Binary Locks
  - The following code performs the unlock operation:

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

if any transactions are waiting then

  wake up one of the waiting the transactions;

Two-Phase Locking Techniques (6)

- Binary Locks
  - Rules:

1. A transaction *T* must issue the operation lock_item(*X*) before any read_item(*X*) or write_item(*X*) operations in *T.*

2. A transaction *T* must issue the operation unlock_item(*X*) after all read_item(*X*) and write_item(*X*) operations are completed in *T.*

3. A transaction *T* will not issue a lock_item(*X*) operation if it already holds the lock on item *X*.

4. A transaction *T* will not issue an unlock_item(*X*) operation unless it already holds the lock on item *X*.

Two-Phase Locking Techniques (7)

- Shared/ Exclusive (or Read/ Write) Locks
  - Two locks modes:
    - (a) shared (read)   (b) exclusive (write).
  - **Shared mode:** read 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.

Two-Phase Locking Techniques (8)

- Shared/ Exclusive (or Read/ Write) Locks
  - 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

Two-Phase Locking Techniques (9)

- Shared/ Exclusive (or Read/ Write) Locks
  - 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;
```

Two-Phase Locking Techniques (10)

- Shared/ Exclusive (or Read/ Write) Locks
  - The following code performs the **write lock** operation:

```
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;
```

Two-Phase Locking Techniques (11)

- Shared/ Exclusive (or Read/ Write) Locks
  - 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;
```

Two-Phase Locking Techniques (12)

- Shared/ Exclusive (or Read/ Write) Locks
  - Rules:

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

  2. A transaction *T* must issue the operation *write_lock(X)* before any *write_item(X)* operation is performed in *T*.

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

Two-Phase Locking Techniques (13)

- Shared/ Exclusive (or Read/ Write) Locks
  - Rules (cont.):

  4. A transaction *T* must 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* must 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* must not issue the operation *unlock(X)* unless it already holds a read (shared) lock or a write(exclusive) lock on item *X*.

Two-Phase Locking Techniques (14)

- Shared/ Exclusive (or Read/ Write) Locks
  - Lock conversion
    - **Lock upgrade**: existing read lock to write lock

if T_i has a read-lock (X) and T_j has no read-lock (X) ($i \neq j$) then

convert read-lock (X) to write-lock (X)

else

force Ti to wait until T_j unlocks X

- **Lock downgrade**: existing write lock to read lock

T_i has a write-lock (X) (*no transaction can have any lock on X*)

convert write-lock (X) to read-lock (X)

Two-Phase Locking Techniques (15)

- Two-Phase Locking
  - 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.

Two-Phase Locking Techniques (16)

- Two-Phase Locking

T_1	T_2
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);

Initial values: X=20, Y=30

Result serial schedule T_1 followed by T_2: X=50, Y=80

Result of serial schedule T_2 followed by T_1: X=70, Y=50

Two-Phase Locking Techniques (17)

- Two-Phase Locking

Time ↓

T_1	T_2
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 of schedule S:
X=50, Y=50
(nonserializable)

Two-Phase Locking Techniques (18)

- Two-Phase Locking

T_1'	T_2'
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);

T_1' and T_2' follow two-phase policy but they are subject to deadlock, which must be dealt with.

T'1	**T'2**
read_lock (Y);	
read_item (Y);	
write_lock (X);	
	read_lock (X);
	wait
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);

Guaranteed to be serializable

T’1	**T’2**
read_lock (Y);	
read_item (Y);	
	read_lock (X);
Deadlock	read_item (X);
write_lock (X);	
	write_lock (Y);
	~~unlock (X);~~
	~~read_item (Y);~~
	~~Y:=X+Y;~~
	~~write_item (Y);~~
	~~unlock (Y);~~
~~**unlock (Y);**~~	
~~read_item (X);~~	
~~X:=X+Y;~~	
~~write_item (X);~~	
~~unlock (X);~~	

Can produce a deadlock

Two-Phase Locking Techniques (19)

- Two-Phase Locking
  - Variations:
    - (a) **Basic**
    - (b) **Conservative**
    - (c) **Strict**
    - (d) **Rigorous**
  - **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.

Two-Phase Locking Techniques (20)

- Two-Phase Locking
  - **Strict**:
    - A transaction T does not release any of its *exclusive (write) locks* until *after* it commits or aborts.
    - The most commonly used two-phase locking algorithm.
  - **Rigorous:**
    - A Transaction T does not release any of its *locks (Exclusive or shared)* until after it commits or aborts.

Two-Phase Locking Techniques (21)

- Dealing with Deadlock and Starvation
  - **Deadlock**

$\underline{\mathbf{T'_1}}$	$\underline{\mathbf{T'_2}}$
read_lock (Y);	
read_item (Y);	
	read_lock (X);
	read_item (Y);
write_lock (X);	
(waits for X)	write_lock (Y);
	(waits for Y)

T'_1 and T'_2 did follow two-phase policy but they are deadlock

  - Deadlock (T'_1 and T'_2)

Two-Phase Locking Techniques (22)

- 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.

Two-Phase Locking Techniques (23)

- 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.

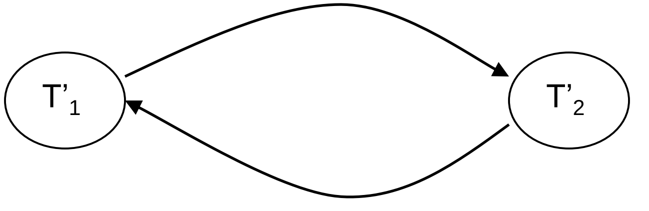
Two-Phase Locking Techniques (24)

- Dealing with Deadlock and Starvation
  - **Deadlock detection and resolution**
    - A **wait-for-graph:**
      - One node is for each transaction that is currently executing.
      - Whenever a transaction T_i is waiting to lock an item X that is currently locked by a transaction T_j, a directed edge ($T_i \rightarrow T_j$) is created.
      - When T_j releases the lock(s) on the items that T_i was waiting for, the directed edge is dropped.
      - We have a state of deadlock if and only if the wait-for graph has a cycle.
    - When the system should check for a deadlock?

Two-Phase Locking Techniques (25)

T'$_1$	**T'$_2$**
read_lock (Y); read_item (Y);	
	read_lock (X); read_item (X);
write_lock (X); (waits for X)	
	write_lock (Y); (waits for Y)

a) Partial schedule of T'$_1$ and T'$_2$



b) wait-for graph

Two-Phase Locking Techniques (26)

- 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.

Two-Phase Locking Techniques (27)

- Dealing with Deadlock and Starvation
  - **Deadlock avoidance**
    - Timestamp:
      - TS(T)
      - A unique identifier assigned to each transaction.
      - Typically based on the order in which transactions are started
      - If transaction T_1 starts before transaction T_2, then TS(T_1) < TS(T_2). Notice that the *older* transaction (which starts first) has the *smaller* timestamp value.

Two-Phase Locking Techniques (28)

- Dealing with Deadlock and Starvation
  - **Deadlock avoidance**
    - **Wait-die**:
      - If TS(T_i) < TS(T_j), then (T_i older than T_j) T_i is allowed to wait.
      - Otherwise (T_i younger than T_j) abort T_i (T_i *dies*) and restart it later ***with the same timestamp***.
    - **Wound-wait**:
      - If TS(T_i) < TS(T_j), then (T_i older than T_j) abort T_j (T_i *wounds* T_j) and restart it later ***with the same timestamp.***
      - Otherwise (T_i younger than T_j) T_i is allowed to wait.

Two-Phase Locking Techniques (29)

- 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.
  - Wound-Wait and wait-die scheme can avoid starvation.

3. Concurrency Control Based on Timestamp Ordering (1)

- **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.

Concurrency Control Based on Timestamp Ordering (2)

- **Timestamp**
  - The algorithm associates with each database item *X* with two timestamp (TS) values:
    - *Read_TS*(*X*): The **read timestamp** of item *X*; this is the largest timestamp among all the timestamps of transactions that have successfully read item *X*.
    - *Write_TS*(*X*):The **write timestamp** of item *X*; this is the largest timestamp among all the timestamps of transactions that have successfully written item *X*.

Concurrency Control Based on Timestamp Ordering (3)

- **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)
      - an younger transaction has already read the data item
      - abort and roll-back T ***with a new timestamp*** 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)
      - an younger transaction has already written to the data item
      - abort and roll-back T ***with a new timestamp*** 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))

Example:Three transactions executing under a timestamp-based scheduler

T1	T2	T3	A	B	C
200	150	175	RT =0 WT=0	RT = 0 WT=0	RT=0 WT=0
r1(B)				RT = 200	
	r2(A)		RT = 150		
		r3(C)			RT=175
w1(B)				WT=200	
w1(A)			WT=200		
	w2(C)				
	Abort				
		w3(A)			

Why T2 must be aborted (rolled-back)?

Concurrency Control Based on Timestamp Ordering (4)

- **Strict Timestamp Ordering**
  - 1. Transaction T issues a write_item(X) operation:
    - If TS(T) > write_TS(X), then delay T until the transaction T' that wrote 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 X has terminated (committed or aborted).
  - Ensures the schedules are both strict and conflict serializable

Concurrency Control Based on Timestamp Ordering (5)

- **Thomas's Write Rule**

  Modify the checks for the write_item(X) operation:

  - 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 because it is already outdated and obsolete.
  - 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).

4. Multiversion Concurrency Control Techniques (1)

- 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 Techniques (2)

- **Multiversion technique based on timestamp ordering**
  - Assume X_1, X_2, …, X_n are the version of a data item X created by a write operation of transactions. With each X_i a read_TS (read timestamp) and a write_TS (write timestamp) are associated.
  - **read_TS(X_i)**: The read timestamp of X_i is the largest of all the timestamps of transactions that have successfully read version X_i.
  - **write_TS(X_i)**: The write timestamp of Xi is the timestamps of the transaction hat wrote the value of version X_i.
  - A new version of X_i is created only by a write operation.

Multiversion Concurrency Control Techniques (3)

- **Multiversion technique based on timestamp ordering**

  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(X_i) > TS(T), then abort and roll-back T; otherwise create a new version Xi and read_TS(X) = write_TS(X_j) = TS(T).
  2. If transaction T issues read_item (X), find the version i of X that has the highest write_TS(X_i) of all versions of X that is also less than or equal to TS(T), then return the value of X_i to T, and set the value of read _TS(X_i) to the largest of TS(T) and the current read_TS(X_i).

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

Example: Execution of transactions using multiversion concurrency control

T1	T2	T3	T4	A_0	A_{150}	A_{200}
150	200	175	225			
r1(A)				read		
w1(A)					Create	
	r2(A)				Read	
	w2(A)					Create
		r3(A)			read	
			r4(A)			read

Note: T3 does not have to abort, because it can read an earlier version of A.

Multiversion Concurrency Control Techniques (4)

Multiversion Two-Phase Locking Using Certify Locks

- **Concept:**
  - Allow a transaction T' to read a data item X while it is write locked by a conflicting transaction T.
  - This is accomplished by **maintaining two versions of each data item X**
    - One version must always have been written by some committed transaction. This means a write operation always creates a new version of X.
    - The second version created when a transaction acquires a write lock an the item.

Multiversion Concurrency Control Techniques (5)

Multiversion Two-Phase Locking Using Certify Locks

- Steps:
  1. X is the committed version of a data item.
  2. T creates a second version X’ after obtaining a write lock on X.
  3. Other transactions continue to read X.
  4. T is ready to commit so it obtains a certify lock on X’.
  5. The committed version X becomes X’.
  6. T releases its certify lock on X’, which is X now.

Compatibility tables for

	Read	Write
Read	yes	no
Write	no	no

read/write locking scheme

	Read	Write	Certify
Read	yes	no	no
Write	no	no	no
Certify	no	no	no

read/write/certify locking scheme

Multiversion Concurrency Control Techniques (6)

Multiversion Two-Phase Locking Using Certify Locks

- Note:
  - In multiversion 2PL read and write operations from conflicting transactions can be processed concurrently.
  - This **improves concurrency** but it **may delay transaction commit** because of obtaining certify locks on all its writes. It avoids cascading abort but like strict two phase locking scheme conflicting transactions may get deadlocked.

5. Validation (Optimistic) Concurrency Control Techniques (1)

- In this technique only at the time of commit serializability is checked and transactions are aborted in case of non-serializable schedules.
- Three phases:
  1. **Read phase**
  2. **Validation phase**
  3. **Write phase**

1. **Read phase**:
   - A transaction can read values of committed data items. However, updates are applied only to **local copies** (versions) of the data items (in database cache).

Validation (Optimistic) Concurrency Control Techniques (2)

2. **Validation phase**: Serializability is checked before transactions write their updates to the database.

- This phase for T_i checks that, for each transaction T_j that is either committed or is in its validation phase, one of the following conditions holds:
  1. T_j completes its write phase before T_i starts its read phase.
  2. T_i starts its write phase after T_j completes its write phase, and the read_set of T_i has no items in common with the write_set of T_j
  3. Both the read_set and write_set of T_i have no items in common with the write_set of T_j, and T_j completes its read phase before T_i completes its read phase.
  - The first condition is checked first for each transaction T_j. If (1) is false then (2) is checked and if (2) is false then (3) is checked. If none of these conditions holds, → fails and Ti is aborted.

Validation (Optimistic) Concurrency Control Techniques (3)

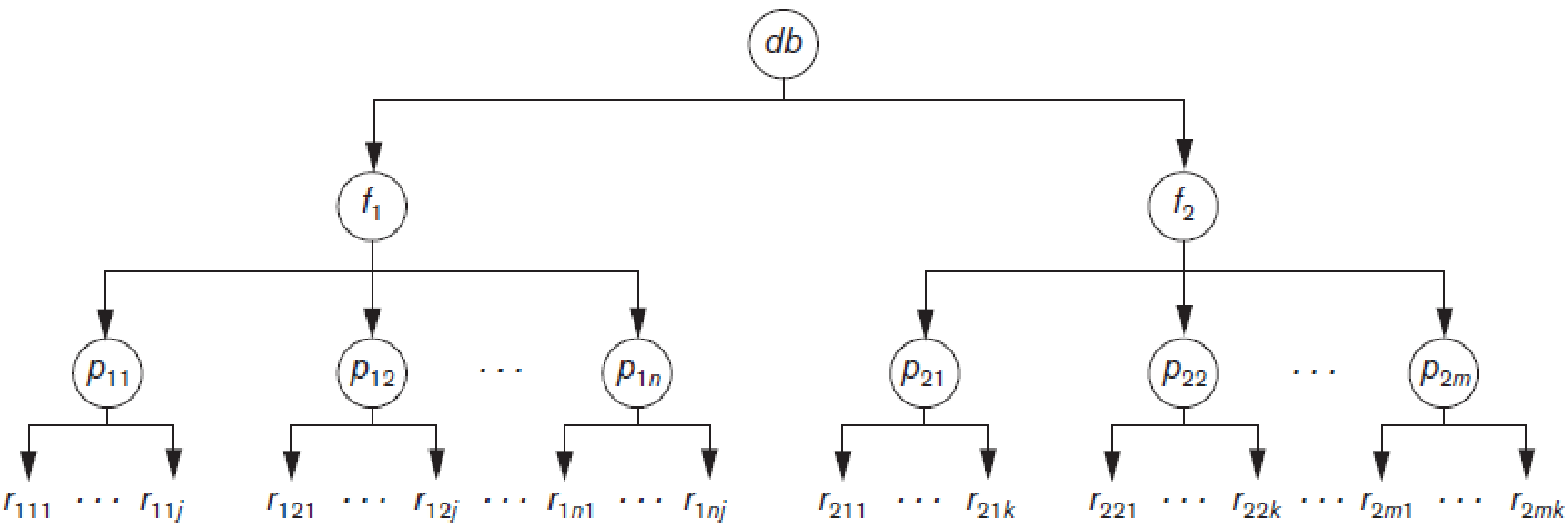
3. **Write phase**: On a successful validation transactions' updates are applied to the database; otherwise, transactions are restarted.

6. Granularity of Data Items And Multiple Granularity Locking (1)

- A lockable unit of data defines its granularity. Granularity can be coarse (entire database) or it can be fine (a tuple or an attribute of a relation).
- Data item granularity significantly **affects concurrency control performance**. Thus, the degree of concurrency is low for coarse granularity and high for fine granularity.
- Example of data item granularity:
  1. A field of a database record (an attribute of a tuple)
  2. A database record (a tuple or a relation)
  3. A disk block
  4. An entire file
  5. The entire database

Granularity of data items and Multiple Granularity Locking (2)

- The following diagram illustrates a hierarchy of granularity from coarse (database) to fine (record).



Granularity of data items and Multiple Granularity Locking (3)

- To manage such hierarchy, in addition to read and write, three additional locking modes, called intention lock modes are defined:
  - **Intention-shared (IS)**: indicates that a shared lock(s) will be requested on some descendent nodes(s).
  - **Intention-exclusive (IX)**: indicates that an exclusive lock(s) will be requested on some descendent node(s).
  - **Shared-intention-exclusive (SIX)**: indicates that the current node is locked in shared mode but an exclusive lock(s) will be requested on some descendent nodes(s).

Granularity of data items and Multiple Granularity Locking (4)

- These locks are applied using the following compatibility matrix:

	IS	IX	S	SIX	X
IS	Yes	Yes	Yes	Yes	No
IX	Yes	Yes	No	No	No
S	Yes	No	Yes	No	No
SIX	Yes	No	No	No	No
X	No	No	No	No	No

Intention-shared (IS
Intention-exclusive (IX)
Shared-intention-exclusive (SIX)

Granularity of data items and Multiple Granularity Locking (5)

- The set of rules which must be followed for producing serializable schedule:
  1. The lock compatibility must adhered to.
  2. The root of the tree must be locked first, in any mode.
  3. A node N can be locked by a transaction T in S or IX mode only if the parent node is already locked by T in either IS or IX mode.
  4. A node N can be locked by T in X, IX, or SIX mode only if the parent of N is already locked by T in either IX or SIX mode.
  5. T can lock a node only if it has not unlocked any node (to enforce 2PL policy).
  6. T can unlock a node, N, only if none of the children of N are currently locked by T.

Granularity of data items and Multiple Granularity Locking (6)

- An example of a serializable execution:

T_1	T_2	T_3
IX(db)		
IX(f_1)		
	IX(db)	
		IS(db)
		IS(f_1)
		IS(p_{11})
IX(p_{11})		
X(r_{111})		
	IX(f_1)	
	X(p_{12})	
		S(r_{11j})
IX(f_2)		
IX(p_{21})		
X(p_{211})		

T_1 wants to update r_{111}, r_{211}

T_2 wants to update all records on page p_{12}

T_3 wants to read r_{11j} and the entire file f_2

Granularity of data items and Multiple Granularity Locking (7)

- An example of a serializable execution (continued):

T_1	T_2	T_3
unlock(r_{211})		
unlock(p_{21})		
unlock(f_2)		
		S(f_2)
	unlock(p_{12})	
	unlock(f_1)	
	unlock(db)	
unlock(r_{111})		
unlock(p_{11})		
unlock(f_1)		
unlock(db)		
		unlock(r_{11j})
		unlock(p_{11})
		unlock(f_1)
		unlock(f_2)
		unlock(db)