Advanced Database Systems Winter Semester

Week 3- Part One (Transaction Recovery, Nested Transactions, Deadlock)

Ahmad

Question 1

- Discuss why the isolation property of ACID properties will apply to both an Online shopping platform as well as an Online banking system despite that they are different applications dealing with different data.

Question 1- Solution

- Both types of systems may need to serve a large number of customers at any given time.
- For achieving consistency, both systems require that a transaction does not use the values that have been modified by another uncommitted transaction.
- A naïve approach to achieve this is handling one customer at a time. But the efficiency of the service would be extremely low with this approach.
- Therefore, the systems should allow different transactions to run concurrently. At the same time, the changes to the data are made as if the transactions run on a serial schedule, i.e., a transaction runs as if it is the only transaction in the system and does not become aware of other concurrent transactions which is the objective of isolation. Isolation helps with achieving a high level of efficiency while maintaining the consistency of the data that is manipulated.

Question 2

- A bank with millions of customers provides a bonus to each of its customer at the end of the year. The bonus is updated in the database as a flat transaction shown below. Discuss example and the associated issue(s) that can happen with such execution. Is it a good choice to use flat transaction here?

```
GiveEndofYearBonus()
    {
        exec sql BEGIN WORK
        for each customer in database
        {
                double bonus = calculate_bonus(customer);
                exec SQL UPDATE customer
            set account = account + :bonus
        }
        exec sql COMMIT WORK
    }
```

Question 2- Solution

- The customer table here is a large table with millions of customers. This means this transaction can potentially be doing a lot of work during its execution and take a long time. Any failure in this transaction's execution would mean a lot of work lost. So better not to have this transaction as a flat transaction.

Question 3

A flat transaction with save-points has the following statements as example. If condition1 is true once and the final commit is successful, what will be printed as the value of count?

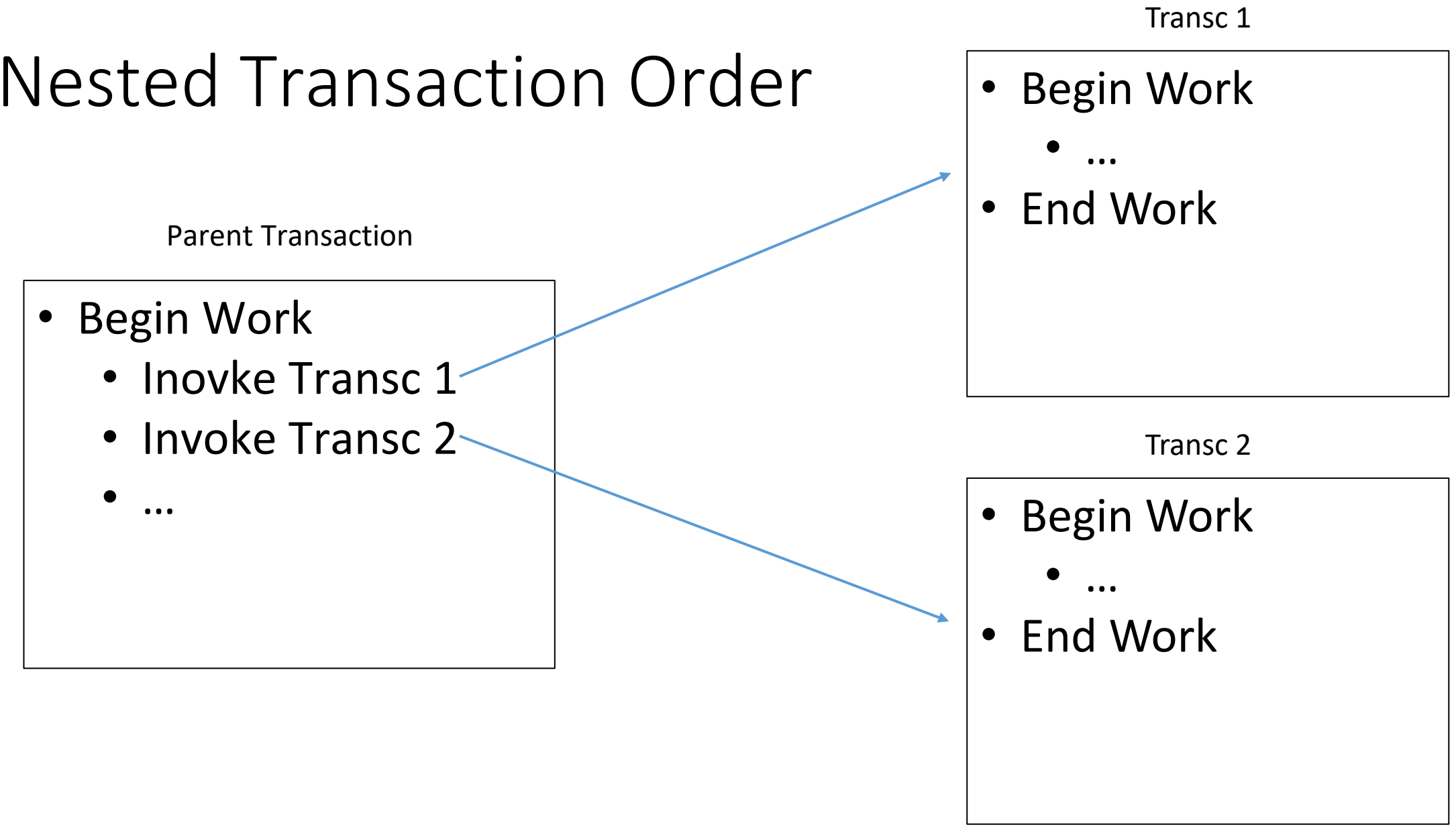
BEGIN WORK
count = 10
SAVE WORK 1
count = count+10
SAVE WORK 2
count = count+5
SAVE WORK3
count = count+5
If (condition1) ROLLBACK WORK(2)
count = count+1
print count
COMMIT WORK

Question 3- Solution

- If condition1 is true, then the transaction rolls back to the save point WORK2. The execution order then follow the order below, with the value of count shown in the sides. The final value of count is 21.

```
BEGIN WORK
count = 10
SAVE WORK 1
count = count+10  //count is 20 at this point
SAVE WORK 2
~~count = count+5~~
~~SAVE WORK3~~
~~count = count+5~~
~~If (condition1) ROLLBACK WORK(2)~~
count = count+1 // count is 21 at this point
      print count //21 will be printed as the value of count
COMMIT WORK
```

Nested Transaction Order



Nested Transaction

- Transactions can commit or roll-back.
  - A transaction commit will become durable only if all of its ancestors already Committed.
- A transaction rolls-back, all of its children will roll back.

Question 4- Breakout Rooms

- In a nested transaction, a transaction PARENT has three sub-transactions A, B and C. For each of the following scenarios, answer which of these four transactions' commits can be made durable, and which ones have to be forced to rollback.
  - Scenario 1: Commit by A, B, and C; but PARENT rolls back.
  - Scenario 2: Commit by A, B, C, and PARENT.
  - Scenario 3: Commit by A, B, and PARENT; but C rolls back.

Question 4- Solution

- In a nested transaction, a transaction PARENT has three sub-transactions A, B and C. For each of the following scenarios, answer which of these four transactions' commits can be made durable, and which ones have to be forced to rollback.
  - Scenario 1: Commit by A, B, and C; but PARENT rolls back.
  - Scenario 2: Commit by A, B, C, and PARENT.
  - Scenario 3: Commit by A, B, and PARENT; but C rolls back.

Solution:

- Scenario 1: Based on the rollback rule, all four transactions roll back, no durable commit by any transaction.
- Scenario 2: All four transactions make durable commits, no roll back.
- Scenario 3: Durable commits by A, B, and Parent; roll back by C only.

Advanced Database Systems Winter Semester

Week 3- Part Two (Dependency Relation, Dirty Read, Degree of Isolation)

Ahmad

Question 5

- What is the probability that a deadlock situation occurs?

Question 5- Solution

- What is the probability that a deadlock situation occurs?
  - It can also be found in Section 7.11.5 of the main reference book.
  - Lets assume,
    - Number of transactions = $n + 1 \sim= n$ (if n is large)
    - Each transaction access r number of locks exclusively
    - Total number of records in the database = R
    - On average, each transaction is holding $r/2$ locks approximately (minimum 0 and maximum r, hence average is $r/2$) – transaction that just commenced holds 0 locks, transaction that is just about to finish holds r locks.
    - Average number of locks taken by the other n transactions = $n * (r/2) =$

The probability that a particular transaction waits for a lock = Requesting an exclusive lock on one of the nr/2 locks held by the other n Transactions out of R possible locks = $\frac{nr}{2}$ out of potential R records = $\frac{nr}{2R}$

Question 3- Solution

The probability that a particular transaction waits for a lock = Requesting an exclusive lock on one of the nr/2 locks held by the other n Transactions out of R possible locks = $\frac{nr}{2}$ out of potential R records = $\frac{nr}{2R}$

- The probability that a particular transaction waits for a lock = $\frac{nr}{2R}$
- The probability that a particular transaction did not wait for a lock = $1 - \frac{nr}{2R}$
- The probability that a particular transaction did not wait (for any of the r locks), $P = \left(1 - \frac{nr}{2R}\right)^r \approx 1 - \left(\frac{nr^2}{2R}\right)$
  - [note that $(1 + \square)^r = 1 + r * \varepsilon$ when ε is small]
- The probability that a transaction waits in its life time $pw(T) = 1 - P = 1 - \left\{1 - \left(\frac{nr^2}{2R}\right)\right\} = \frac{nr^2}{2R}$
- Probability that a particular Transaction T waits for some transaction $T1$ and $T1$ waits for T is
- $= pw(T) * (pw(T1)/n) = nr^4/4R^2$ [since the probability $T1$ waits for T is $1/n$ times the probability $T1$ waits for someone]
- Probability of any two transactions causing deadlock is $= n * nr^4/4R^2 = n^2r^4/4R^2$
  - (This is a very small probability in practice)

Question 6-Breakout Rooms

- If we use the following comments to lock and unlock access to objects then: Which transactions below are in deadlock if they start around the same time?

T1	T2	T3	T4
Begin	Begin	Begin	Begin
LOCK(C)	LOCK(A)	LOCK(C)	LOCK(B)
Write C	Write A	Write C	Write B
UNLOCK(C)	LOCK(B)	UNLOCK(C)	LOCK(A)
End	Write(B)	End	Write A
	UNLOCK(A)		UNLOCK(A)
	UNLOCK(B)		UNLOCK(B)
	End		End

Question 6- Solution

T1	T2	T3	T4
Begin	Begin	Begin	Begin
LOCK(C)	LOCK(A)	LOCK(C)	LOCK(B)
Write C	Write A	Write C	Write B
UNLOCK(C)	LOCK(B)	UNLOCK(C)	LOCK(A)
End	Write(B)	End	Write A
	UNLOCK(A)		UNLOCK(A)
	UNLOCK(B)		UNLOCK(B)
	End		End

Solution:

T2 and T4 are in a deadlock as each of them will wait for the other to release a lock while holding a lock that the other needs to acquire to complete.

Question 7

- Isolation property in ACID properties states that each transaction should run without being aware or in interference with another transaction in the system. If that is the case, we can run transactions sequentially by locking the whole database itself and adhering to the Isolation property through a big lock per transaction. Review why this may not be an ideal solution.

Question 7- Solution

- This is in fact one type of, simplistic, concurrency control,
  - i.e., making sure that all transactions run in a sequence, i.e., in some order.
- But then we are not benefiting from the potential use of idle resources such as accessing disk while another transaction is using the CPU.
- So even under single CPU situations, concurrency can speed up things that we are not doing. In addition, if there is a long-running transaction in the system, holding up every other transaction till that long one finish is going to make the associated company's customers very unhappy. So in short, although we want our executions to be equal to the outcome of a serial execution of a given set of transactions, we do not really want to run them one after the other but rather in concurrency with each other.

Question 8

- Given two transactions, per operation of each transaction, we can use locks to make sure concurrent access is done properly to individual objects that are used in both transactions i.e., they are not accessed at the same time. This is after all what the operating systems do, e.g., lock a file while one program is accessing it so others cannot change it at the same time. Give two transactions showing that this is not enough to achieve the isolation property of transactions for RDBMSs.

Question 8- Solution

- This execution order above is not equal to T1 running first nor to T2 running first and does not obey the Isolation property, although, for each disk access, we first obtained a lock properly. Thus we need something more for proper concurrency control in DBMSs.

Answer (A is initially 0 on disk)	Transaction 1 at Process 1	Transaction 2 at Process 2
Operation 1	Lock(A)	
Operation 2	Read(A)	
Operation 3	Unlock(A)	
Operation 4	A = A +100	
Operation 5		Lock(A)
Operation 6		Read(A)
Operation 7		A = A + 50
Operation 8		Write(A)
Operation 9		Unlock(A)/Commit
Operation 10	Lock(A)	
Operation 11	Write(A)	
Operation 12	Unlock(A)/Commit	

Advanced Database Systems Winter Semester

Week 3- Part Three (Locking)

Ahmad

Question 9

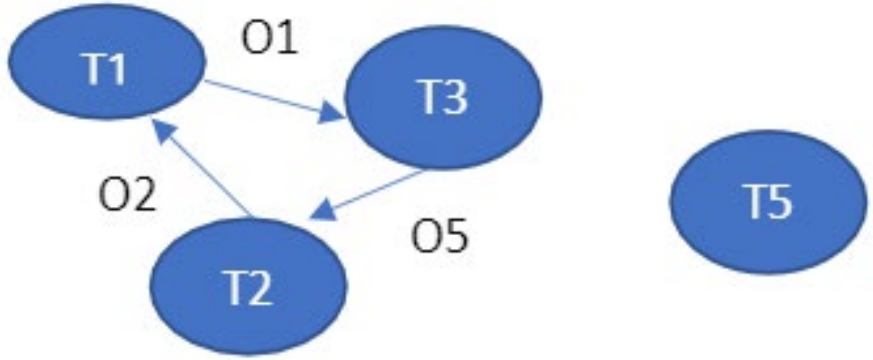
- What are the dependency relations in the following history? List as tuples in the form (Ti, Oi, Tj). Is it possible to do a serial execution of these transactions? If so, give an example serial execution order. If no, explain why not.
- $H = < (T1, R, O1), (T3, W, O5), (T3, W, O1),$
  $(T2, R, O5), (T2, W, O2), (T5, R, O4), (T1, R, O2), (T5, R, O3) >$

Question 9- Solution

- $H = < (T1, R, O1), (T3, W, O5), (T3, W, O1),$
  $(T2, R, O5), (T2, W, O2), (T5, R, O4), (T1, R, O2), (T5, R, O3) >$

Solution:

- $DEP(H) = \{< T1, O1, T3 >, < T3, O5, T2 >, < T2, O2, T1 >\}$
- We can also build the following dependency graph based on this like the following:



Question 10

- Given the solution above for question 5, can we say the history is equal to a serial history. If yes, show one such history. If not, show that there is a wormhole.

Question 10- Solution

- Given the solution above for question 3, can we say the history is equal to a serial history. If yes, show one such history. If not, show that there is a wormhole.

Solution:

There exists a cycle in the dependency graph, i.e., there are wormhole transactions (e.g., T 1 is before and after of T 3 at the same time). Therefore finding equivalent serial execution is not possible

Question 11- Breakout Rooms

- Assume the following two transactions start at nearly the same time and there is no other concurrent transaction. The 2nd operation of both transactions is Xlock(B).
  - Is there a potential problem if Transaction 1 performs the operation first?
  - What if Transaction 2 performs the operation first?

Transaction 1		Transaction 2	
1.1	Slock(A)	2.1	Slock(A)
1.2	Xlock(B)	2.2	Xlock(B)
1.3	Read(A)	2.3	Write(B)
1.4	Read(B)	2.4	Unlock(B)
1.5	Write(B)	2.5	Read(A)
1.6	Unlock(A)	2.6	Xlock(B)
1.7	Unlock(B)	2.7	Write(B)
		2.8	Unlock(A)
		2.9	Unlock(B)

Question 11- Solution

Transaction 1		Transaction 2	
1.1	Slock(A)	2.1	Slock(A)
1.2	Xlock(B)	2.2	Xlock(B)
1.3	Read(A)	2.3	Write(B)
1.4	Read(B)	2.4	Unlock(B)
1.5	Write(B)	2.5	Read(A)
1.6	Unlock(A)	2.6	Xlock(B)
1.7	Unlock(B)	2.7	Write(B)
		2.8	Unlock(A)
		2.9	Unlock(B)

- T1 and T2 start almost together.
- Second Op of both is Xlock(B)
  - Is there a potential problem if Transaction 1 performs the operation first?

    Solution:

    Nope, since T1 releases lock at the end.
  - What if Transaction 2 performs the operation first?

    Solution:

    Transaction1 may have a dirty read of B if it tries to run Step 1.2 immediately after Transaction 2 releases the Xlock on B.

    This is because when Transaction 2 releases the lock on B (Step 2.4), Transaction 1 will be granted the Xlock on B (Step 1.2). After that, Transaction 1 will read B (Step 1.4). After Transaction 1 completes, Transaction 2 will acquire another Xlock on B (Step 2.6) then modify the object. In other words, the reading of B by Transaction 1 happens between two writes of B by Transaction 2.

Review, Degrees of Isolation

Degrees of Isolation

Degree 3: A Three degree isolated Transaction has no lost updates, and has repeatable reads. This is "true" isolation.

Lock protocol is two phase and well formed.

It is sensitive to the following conflicts:

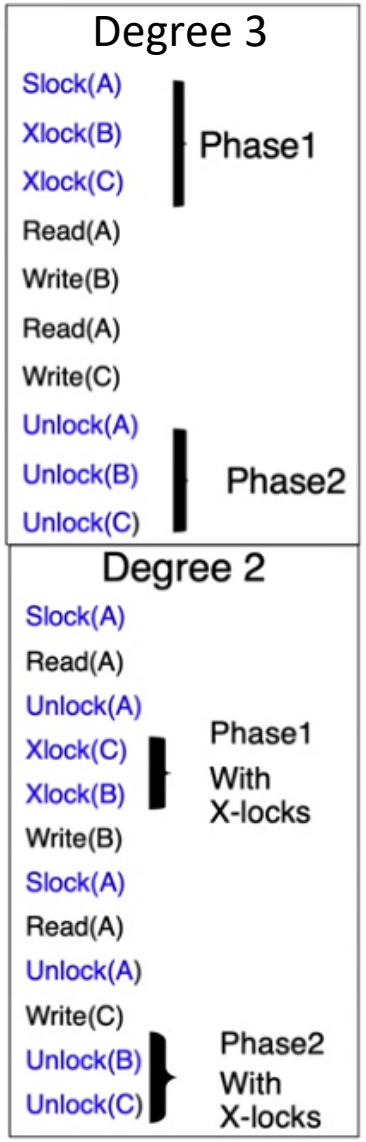
write->write; write ->read; read->write

Degree 2: A Two degree isolated transaction has no lost updates and no dirty reads.

Lock protocol is two phase with respect to exclusive locks and well formed with respect to Reads and writes. (May have Non repeatable reads.)

It is sensitive to the following conflicts:

write->write; write ->read;



Review, Degrees of Isolation

Degree 1: A One degree isolation has no lost updates.

Lock protocol is two phase with respect to exclusive locks and well formed with respect to writes.

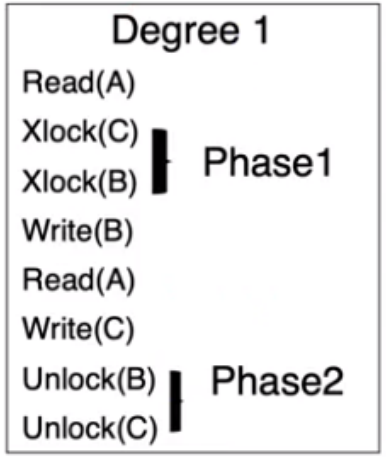
It is sensitive the following conflicts:

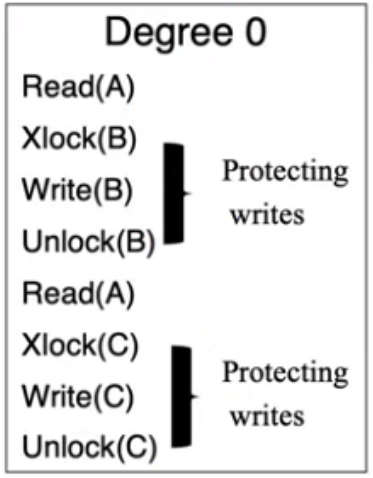
write->write;

Degree 0 : A Zero degree transaction does not overwrite another transactions dirty data if the other transaction is at least One degree.

Lock protocol is well-formed with respect to writes.

It ignores all conflicts.





Question 12

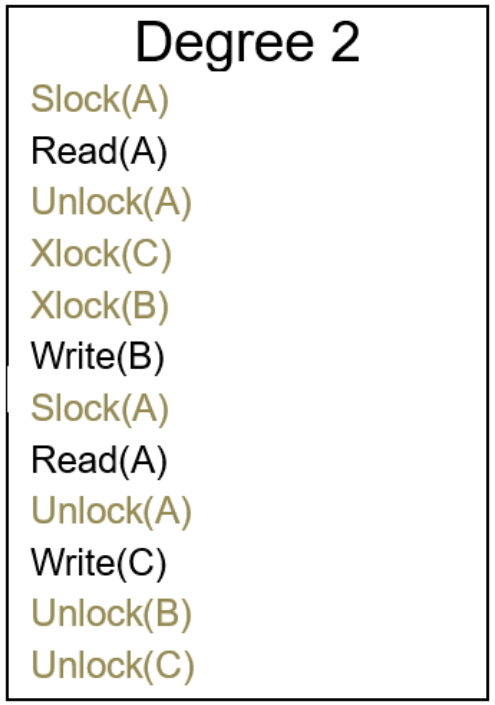
- What degree of Isolation does the following transaction provide?
  - Slock(A)
  - Xlock(B)
  - Read (A)
  - Write (B)
  - Read(C)
  - Unlock(A)
  - Unlock(B)

Question 12- Solution

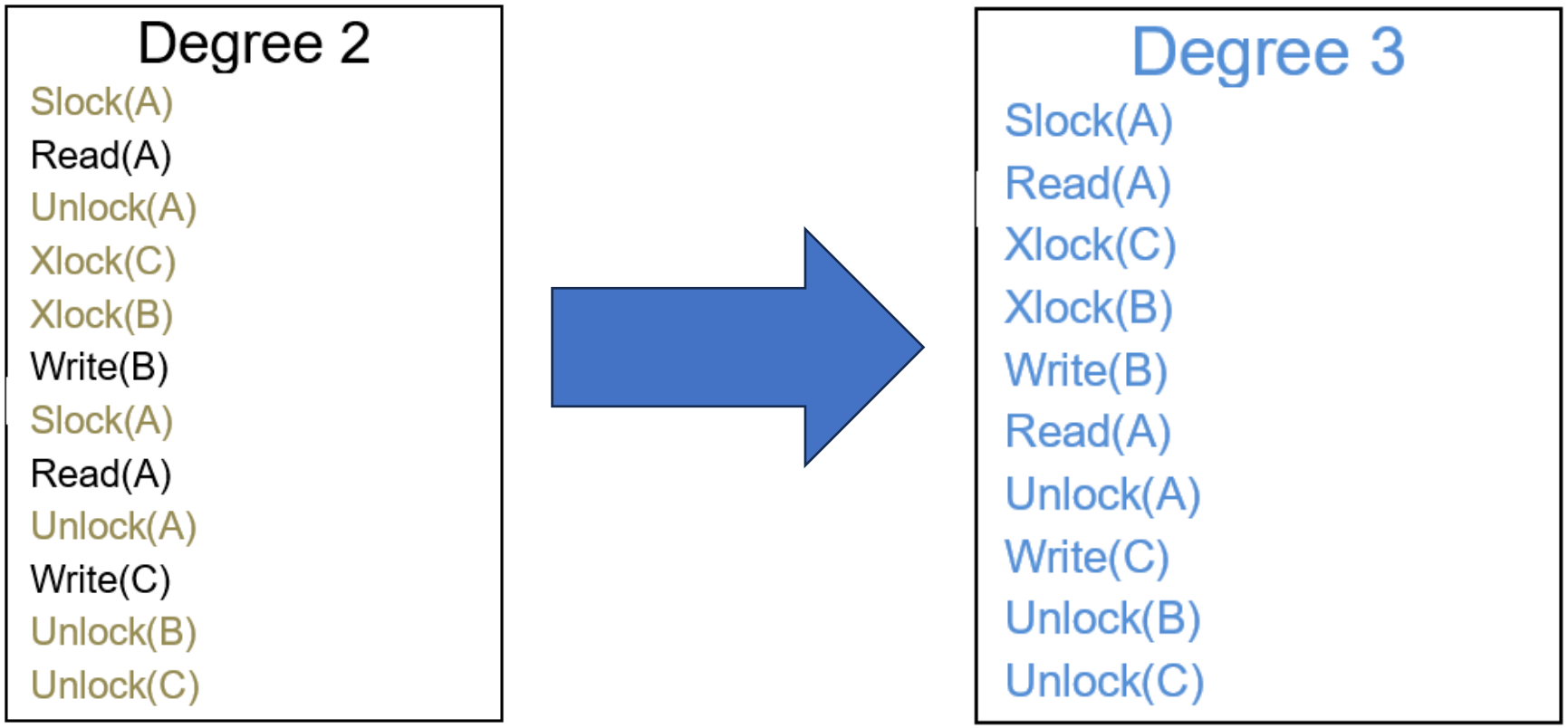
- Degree 1 as there is one read operation ‘Read(C)’ without taking any locks. All the write operations have an exclusive lock associated with them.

Question 13

- The following operations are given with Degree 2 isolation locking principles in place. Convert the locking sequence to Degree 3.



Question 13- Solution



Review, Compatibility of Locks

Compatibility Mode of Granular Locks							
Current	None	IS	IX	S	SIX	U	X
Request	+I- (Next mode) + granted / - delayed						
IS	+(IS)	+(IS)	+(IX)	+(S)	+(SIX)	-(U)	-(X)
IX	+(IX)	+(IX)	+(IX)	-(S)	-(SIX)	-(U)	-(X)
S	+(S)	+(S)	-(IX)	+(S)	-(SIX)	-(U)	-(X)
SIX	+(SIX)	+(SIX)	-(IX)	-(S)	-(SIX)	-(U)	-(X)
U	+(U)	+(U)	-(IX)	+(U)	-(SIX)	-(U)	-(X)
X	+(X)	-(IS)	-(IX)	-(S)	-(SIX)	-(U)	-(X)

Question 9

- Given the following Transactions:
  - Which of them can run in parallel if A = 3.
  - Which of them can run in parallel if A = 2.

	T2	T3
	Lock (U,A)	Lock (IX,A)
T1	Read A	Read A
Lock (S,A)	if(A ==3) {	if(A ==3){
Read A	Lock(X,A)	Lock(X,A)
Unlock A	Write A	Write A
	}	}
	Unlock A	Unlock A

Question 9- Solution

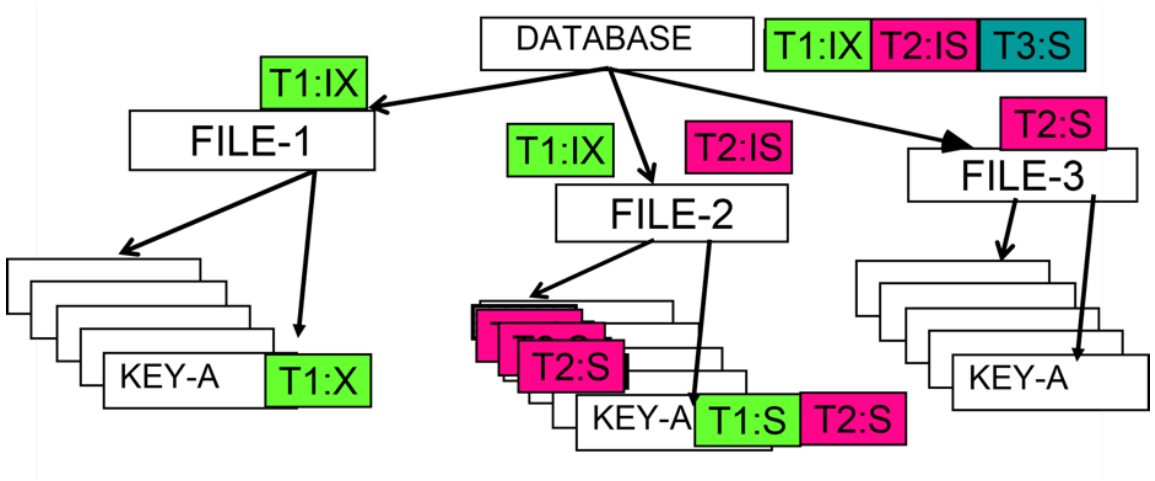
- Scenario 1: None of the them; only one can run at a time.
  - T1 and T2: For A==3, T2's X lock request will conflict with T1's shared lock.
  - T1 and T3: T3's IX lock conflicts with T1's shared lock.
  - T2 and T3: T2's update lock and T3's IX conflict with each other, and also the subsequent X locks for A==3 will conflict.

Question 9- Solution

- Scenario 2: T1 and T2 can run in parallel.
  - T1 and T2: T1 and T2 can run concurrently as T2's update lock can be granted with T1's shared lock (if T1 gets the lock first).
  - T1 and T3: T3's IX lock conflicts with T1's shared lock.
  - T2 and T3: T2's update lock and T3's IX conflict with each other.

Question 10

- Review the concepts of granular locks then answer the following question. Given the hierarchy of database objects and the corresponding granular locks in the following picture, which transactions can run if the transactions arrive in the order T1-T2-T3? What if the order is T3-T2-T1? Note that locks from the same transaction are in the same colour. We assume that the transactions need to take the locks when they start to run.



Question 10- Solution

Solution:

- If the order of the arrival of transactions is T1-T2-T3, then T1 and T2 can run in parallel while T3 waits. This is because
  - T1's IX lock at the root node is not compatible with T3's S lock at the same node.
- If the order is T3-T2-T1, then T3 and T2 can run while T1 waits. This is due to the similar reason as above. This example shows that the order of transactions can be a deciding factor of the set of parallel-running transactions. We should also note that granular locks can lead to the delay of transactions at any level in the hierarchy below the root node, e.g., a transaction may need to wait for a lock at the FILE-3 node or a KEY-A node due to lock compatibility issues.

Question 11

- With two-phase locking we have already seen a successful strategy that will solve concurrency problems for DBMSs. Then discuss why someone may want to invent something like Optimistic Concurrency control in addition to that locking mechanism.

Question 11- Solution

- Two-phase locking or in general locking assumes the worst, i.e. there are many updates in the system and most of them will lead to conflicts in access to objects. This means there is good rationale to pay the overhead of locking and stop problems from occurring in the first place. But what if the DBMS is one such that people tend to work on different parts of data, or most of the operations are read operations, and as such there aren't many conflicts at all. Then there is no need to pay the overhead of lock management but rather it may be better to allow transactions run freely and have a simple check when they finish whether there was any conflict with concurrent transactions. Most of the time there will not be so one will get increased concurrency with less overheads. Obviously, the reverse is also true, i.e., if there were really many conflicting writes then doing optimistic concurrency control means many problems would be observed only after running the transactions and a lot of work will need to be wasted to preserve consistency of the data. So there is no clear answer but depending on the situation a strategy may be good or bad.