Chapter 22

Transaction Management

Chapter 22 - Objectives

- Function and importance of transactions.
- Properties of transactions.
- Concurrency Control
  - Meaning of serializability.
  - How locking can ensure serializability.
  - Deadlock and how it can be resolved.

Transaction Support

Transaction

Action, or series of actions, carried out by user or application, which reads or updates contents of database.

- Logical unit of work on the database.
- Application program is series of transactions with non-database processing in between.
- Transforms database from one consistent state to another, although consistency may be violated during transaction.

Example Transaction

```
read(staffNo = x, salary)
salary = salary * 1.1
write(staffNo = x, new_salary)
```

(a)

```
delete(staffNo = x)
for all PropertyForRent records, pno
begin
    read(propertyNo = pno, staffNo)
    if (staffNo = x) then
    begin
        staffNo = newStaffNo
        write(propertyNo = pno, staffNo)
    end
end
```

(b)

Transaction Support

- Can have one of two outcomes:
  - Success - transaction *commits* and database reaches a new consistent state.
  - Failure - transaction *aborts*, and database must be restored to consistent state before it started.
  - Such a transaction is *rolled back* or *undone*.
- Committed transaction cannot be aborted.
- Aborted transaction that is rolled back can be restarted later.

Properties of Transactions

- Four basic *(ACID)* properties of a transaction are:

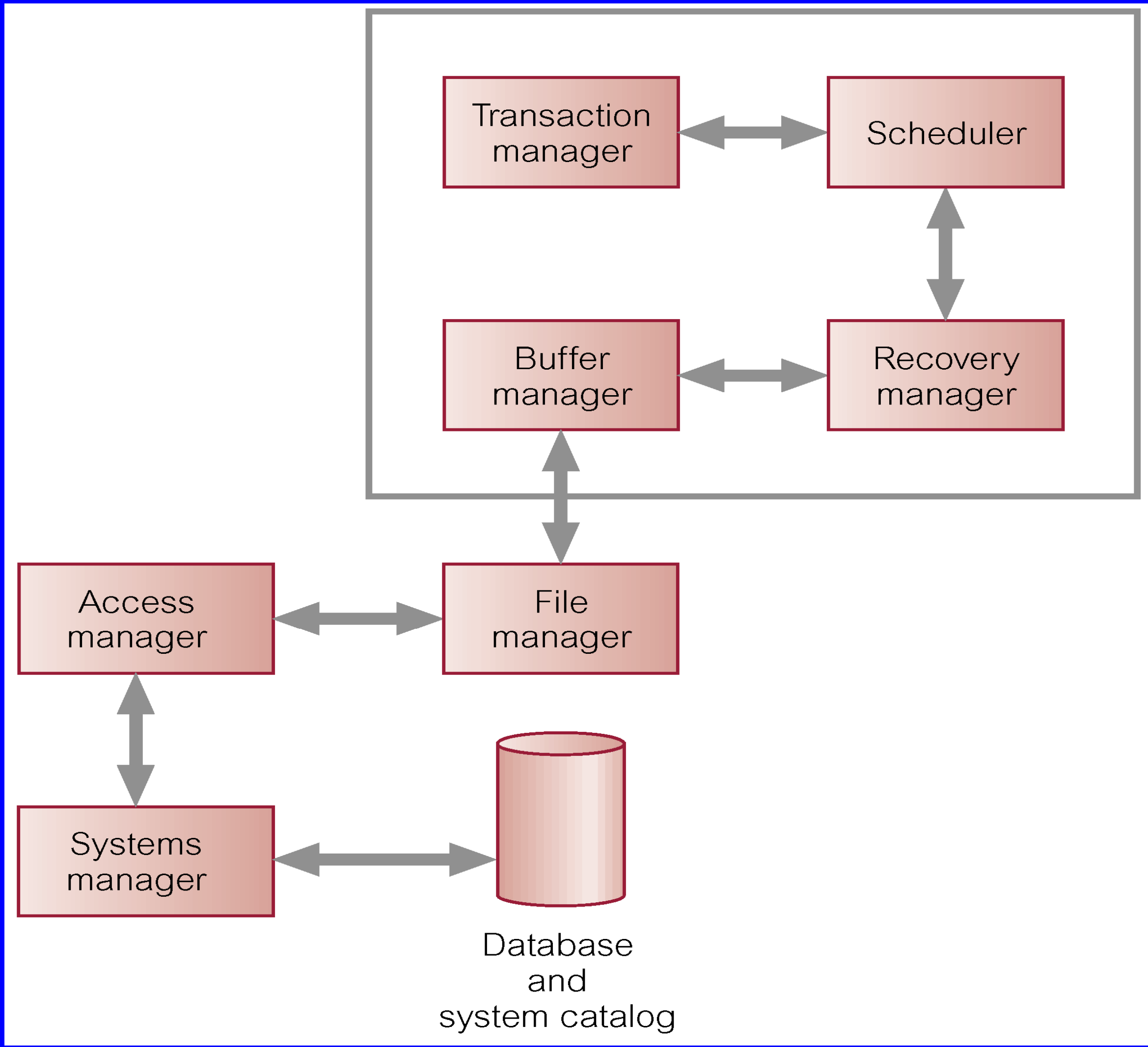
<u>Atomicity</u> 'All or nothing' property.

<u>Consistency</u> Must transform database from one consistent state to another.

<u>Isolation</u> Partial effects of incomplete transactions should not be visible to other transactions.

<u>Durability</u> Effects of a committed transaction are permanent and must not be lost because of later failure.

DBMS Transaction Subsystem



Concurrency Control

Process of managing simultaneous operations on the database without having them interfere with one another.

- Prevents interference when two or more users are accessing database simultaneously and at least one is updating data.
- Although two transactions may be correct in themselves, interleaving of operations may produce an incorrect result.

Need for Concurrency Control

- Three examples of potential problems caused by concurrency:
  - Lost update problem.
  - Uncommitted dependency problem.
  - Inconsistent analysis problem.

Lost Update Problem

- Successfully completed update is overridden by another user.
- T_1 withdrawing £10 from an account with bal_x, initially £100.
- T_2 depositing £100 into same account.
- Serially, final balance would be £190.

Lost Update Problem

Time	T_1	T_2	bal_x
t_1		begin_transaction	100
t_2	begin_transaction	read(bal_x)	100
t_3	read(bal_x)	$bal_x = bal_x + 100$	100
t_4	$bal_x = bal_x - 10$	write(bal_x)	200
t_5	write(bal_x)	commit	90
t_6	commit		90

- **Loss of T_2's update avoided by preventing T_1 from reading bal_x until after update.**

Uncommitted Dependency Problem

- Occurs when one transaction can see intermediate results of another transaction before it has committed.
- T_4 updates bal_x to £200 but it aborts, so bal_x should be back at original value of £100.
- T_3 has read new value of bal_x (£200) and uses value as basis of £10 reduction, giving a new balance of £190, instead of £90.

Uncommitted Dependency Problem

Time	T_3	T_4	bal_x
t_1		begin_transaction	100
t_2		read(bal_x)	100
t_3		$bal_x = bal_x + 100$	100
t_4	begin_transaction	write(bal_x)	200
t_5	read(bal_x)	⋮	200
t_6	$bal_x = bal_x - 10$	rollback	100
t_7	write(bal_x)		190
t_8	commit		190

- **Problem avoided by preventing T_3 from reading bal_x until after T_4 commits or aborts.**

Inconsistent Analysis Problem

- **Occurs when transaction reads several values but second transaction updates some of them during execution of first.**
- **Sometimes referred to as *dirty read* or *unrepeatable read*.**
- **T_6 is totaling balances of account x (£100), account y (£50), and account z (£25).**
- **Meantime, T_5 has transferred £10 from bal_x to bal_z, so T_6 now has wrong result (£10 too high).**

Inconsistent Analysis Problem

Time	T_5	T_6	bal_x	bal_y	bal_z	sum
t_1		begin_transaction	100	50	25	
t_2	begin_transaction	sum = 0	100	50	25	0
t_3	read(bal_x)	read(bal_x)	100	50	25	0
t_4	$bal_x = bal_x - 10$	$sum = sum + bal_x$	100	50	25	100
t_5	write(bal_x)	read(bal_y)	90	50	25	100
t_6	read(bal_z)	$sum = sum + bal_y$	90	50	25	150
t_7	$bal_z = bal_z + 10$		90	50	25	150
t_8	write(bal_z)		90	50	35	150
t_9	commit	read(bal_z)	90	50	35	150
t_{10}		$sum = sum + bal_z$	90	50	35	185
t_{11}		commit	90	50	35	185

- **Problem avoided by preventing T_6 from reading bal_x and bal_z until after T_5 completed updates.**

Serializability

- Objective of a concurrency control protocol is to schedule transactions in such a way as to avoid any interference.
- Could run transactions serially, but this limits degree of concurrency or parallelism in system.
- Serializability identifies those executions of transactions guaranteed to ensure consistency.

Serializability

Schedule

Sequence of reads/writes by set of concurrent transactions.

Serial Schedule

Schedule where operations of each transaction are executed consecutively without any interleaved operations from other transactions.

- No guarantee that results of all serial executions of a given set of transactions will be identical.

Nonserial Schedule

- **Schedule where operations from set of concurrent transactions are interleaved.**
- **Objective of serializability is to find nonserial schedules that allow transactions to execute concurrently without interfering with one another.**
- **In other words, want to find nonserial schedules that are equivalent to *some* serial schedule. Such a schedule is called *serializable*.**

Serializability

(THIS SLIDE MUST BE SKIPPED SEE MY CLASS NOTE)

- **In serializability, ordering of read/writes is important:**

(a) If two transactions only read a data item, they do not conflict and order is not important.

(b) If two transactions either read or write completely separate data items, they do not conflict and order is not important.

(c) If one transaction writes a data item and another reads or writes same data item, order of execution is important.

Example of Conflict Serializability

Time	T_7	T_8	T_7	T_8	T_7	T_8
t_1	begin_transaction		begin_transaction		begin_transaction	
t_2	read(bal_x)		read(bal_x)		read(bal_x)	
t_3	write(bal_x)		write(bal_x)		write(bal_x)	
t_4		begin_transaction		begin_transaction	read(bal_y)	
t_5		read(bal_x)		read(bal_x)	write(bal_y)	
t_6		write(bal_x)	read(bal_y)		commit	
t_7	read(bal_y)			write(bal_x)		begin_transaction
t_8	write(bal_y)		write(bal_y)			read(bal_x)
t_9	commit		commit			write(bal_x)
t_{10}		read(bal_y)		read(bal_y)		read(bal_y)
t_{11}		write(bal_y)		write(bal_y)		write(bal_y)
t_{12}		commit		commit		commit
	(a)		(b)		(c)	

Serializability (Ignore this slide, see my class note)

- **Conflict serializable schedule orders any conflicting operations in same way as some serial execution.**
- **Under *constrained write rule* (transaction updates data item based on its old value, which is first read), use *precedence graph* to test for serializability.**

Precedence Graph

- Create:
  - node for each transaction;
  - a directed edge $T_i \rightarrow T_j$, if T_j reads the value of an item written by T_I;
  - a directed edge $T_i \rightarrow T_j$, if T_j writes a value into an item after it has been read by T_i. (See below)
- If precedence graph contains cycle schedule is not conflict serializable.

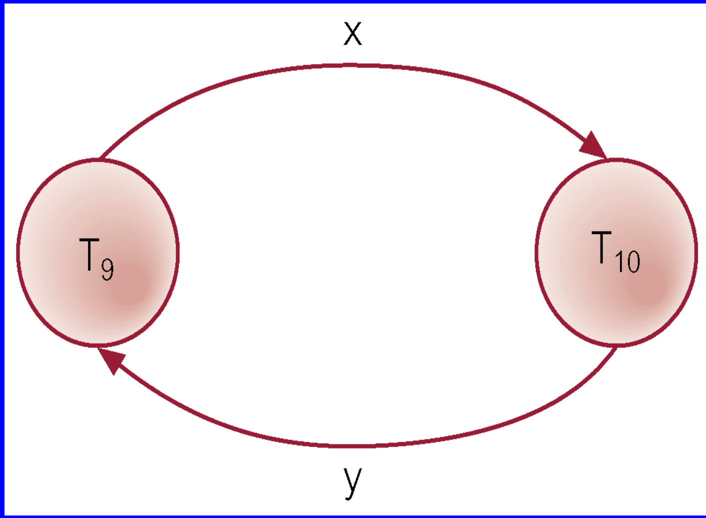
(Replace "read" by "read or written")

Example - Non-conflict serializable schedule

- T_9 is transferring £100 from one account with balance bal_x to another account with balance bal_y.
- T_{10} is increasing balance of these two accounts by 10%.
- Precedence graph has a cycle and so is not serializable.

Example - Non-conflict serializable schedule

Time	T_9	T_{10}
t_1	begin_transaction	
t_2	read(bal_x)	
t_3	$bal_x = bal_x + 100$	
t_4	write(bal_x)	begin_transaction
t_5		read(bal_x)
t_6		$bal_x = bal_x * 1.1$
t_7		write(bal_x)
t_8		read(bal_y)
t_9		$bal_y = bal_y * 1.1$
t_{10}		write(bal_y)
t_{11}	read(bal_y)	commit
t_{12}	$bal_y = bal_y - 100$	
t_{13}	write(bal_y)	
t_{14}	commit	



Locking

Transaction uses locks to deny access to other transactions and so prevent incorrect updates.

- **Most widely used approach to ensure serializability.**
- **Generally, a transaction must claim a *shared* (*read*) or *exclusive* (*write*) lock on a data item before read or write.**
- **Lock prevents another transaction from modifying item or even reading it, in the case of a write lock.**

Locking - Basic Rules

- If transaction has shared lock on item, can read but not update item.
- If transaction has exclusive lock on item, can both read and update item.
- Reads cannot conflict, so more than one transaction can hold shared locks simultaneously on same item.
- Exclusive lock gives transaction exclusive access to that item.

Locking - Basic Rules

- Some systems allow transaction to upgrade read lock to an exclusive lock, or downgrade exclusive lock to a shared lock.

Example - Incorrect Locking Schedule

- For two transactions above, a valid schedule using these rules is:

S = {write_lock(T_9, bal_x), read(T_9, bal_x), write(T_9, bal_x), unlock(T_9, bal_x), write_lock(T_{10}, bal_x), read(T_{10}, bal_x), write(T_{10}, bal_x), unlock(T_{10}, bal_x), write_lock(T_{10}, bal_y), read(T_{10}, bal_y), write(T_{10}, bal_y), unlock(T_{10}, bal_y), commit(T_{10}), write_lock(T_9, bal_y), read(T_9, bal_y), write(T_9, bal_y), unlock(T_9, bal_y), commit(T_9) }

Example - Incorrect Locking Schedule

- If at start, $bal_x = 100$, $bal_y = 400$, result should be:
  - $bal_x = 220$, $bal_y = 330$, if T_9 executes before T_{10}, or
  - $bal_x = 210$, $bal_y = 340$, if T_{10} executes before T_9.
- However, result gives $bal_x = 220$ and $bal_y = 340$.
- S is not a serializable schedule.

Example - Incorrect Locking Schedule

- Problem is that transactions release locks too soon, resulting in loss of total isolation and atomicity.
- To guarantee serializability, need an additional protocol concerning the positioning of lock and unlock operations in every transaction.

Two-Phase Locking (2PL)

Transaction follows 2PL protocol if all locking operations precede first unlock operation in the transaction.

- **Two phases for transaction:**
  - Growing phase - acquires all locks but cannot release any locks.
  - Shrinking phase - releases locks but cannot acquire any new locks.

Preventing Lost Update Problem using 2PL

Time	T_1	T_2	bal_x
t_1		begin_transaction	100
t_2	begin_transaction	write_lock(bal_x)	100
t_3	write_lock(bal_x)	read(bal_x)	100
t_4	WAIT	$bal_x = bal_x + 100$	100
t_5	WAIT	write(bal_x)	200
t_6	WAIT	commit/unlock(bal_x)	200
t_7	read(bal_x)		200
t_8	$bal_x = bal_x - 10$		200
t_9	write(bal_x)		190
t_{10}	commit/unlock(bal_x)		190

Preventing Uncommitted Dependency Problem using 2PL

Time	T_3	T_4	bal_x
t_1		begin_transaction	100
t_2		write_lock(bal_x)	100
t_3		read(bal_x)	100
t_4	begin_transaction	$bal_x = bal_x + 100$	100
t_5	write_lock(bal_x)	write(bal_x)	200
t_6	WAIT	rollback/unlock(bal_x)	100
t_7	read(bal_x)		100
t_8	$bal_x = bal_x - 10$		100
t_9	write(bal_x)		90
t_{10}	commit/unlock(bal_x)		90

Preventing Inconsistent Analysis Problem using 2PL

Time	T_5	T_6	bal_x	bal_y	bal_z	sum
t_1		begin_transaction	100	50	25	
t_2	begin_transaction	sum = 0	100	50	25	0
t_3	write_lock(bal_x)		100	50	25	0
t_4	read(bal_x)	read_lock(bal_x)	100	50	25	0
t_5	$bal_x = bal_x - 10$	WAIT	100	50	25	0
t_6	write(bal_x)	WAIT	90	50	25	0
t_7	write_lock(bal_z)	WAIT	90	50	25	0
t_8	read(bal_z)	WAIT	90	50	25	0
t_9	$bal_z = bal_z + 10$	WAIT	90	50	25	0
t_{10}	write(bal_z)	WAIT	90	50	35	0
t_{11}	commit/unlock(bal_x, bal_z)	WAIT	90	50	35	0
t_{12}		read(bal_x)	90	50	35	0
t_{13}		sum = sum + bal_x	90	50	35	90
t_{14}		read_lock(bal_y)	90	50	35	90
t_{15}		read(bal_y)	90	50	35	90
t_{16}		sum = sum + bal_y	90	50	35	140
t_{17}		read_lock(bal_z)	90	50	35	140
t_{18}		read(bal_z)	90	50	35	140
t_{19}		sum = sum + bal_z	90	50	35	175
t_{20}		commit/unlock(bal_x, bal_y, bal_z)	90	50	35	175

Cascading Rollback

- If *every* transaction in a schedule follows 2PL, schedule is serializable.
- However, problems can occur with interpretation of when locks can be released.

Cascading Rollback

Time	T_{14}	T_{15}	T_{16}
t_1	begin_transaction		
t_2	write_lock(**bal_x**)		
t_3	read(**bal_x**)		
t_4	read_lock(**bal_y**)		
t_5	read(**bal_y**)		
t_6	$bal_x = bal_y + bal_x$		
t_7	write(**bal_x**)		
t_8	unlock(**bal_x**)	begin_transaction	
t_9	⋮	write_lock(**bal_x**)	
t_{10}	⋮	read(**bal_x**)	
t_{11}	⋮	$bal_x = bal_x + 100$	
t_{12}	⋮	write(**bal_x**)	
t_{13}	⋮	unlock(**bal_x**)	
t_{14}	⋮	⋮	
t_{15}	rollback	⋮	
t_{16}		⋮	begin_transaction
t_{17}		⋮	read_lock(**bal_x**)
t_{18}		rollback	⋮
t_{19}			rollback

Cascading Rollback

- Transactions conform to 2PL.
- T_{14} aborts.
- Since T_{15} is dependent on T_{14}, T_{15} must also be rolled back. Since T_{16} is dependent on T_{15}, it too must be rolled back.
- This is called *cascading rollback*.
- To prevent this with 2PL, leave release of *all* locks until end of transaction.

Exercises from Chapter 22

- Exercise 22.1
- 22.3 (create your own detailed examples different from the text)
- For each example you created in Exercise 22.3, show in detail how two-phase locking solves the problem.
- 22.5
- 22.18 (only do serializable and cascading aborts)
- 22.19