Chapter 11
Database Recovery

Failures in DBMS

- Two common kinds of failures
- System failure (e.g. power outage)
  - affects all transactions currently in progress but does not physically damage the data (soft crash)
- Media failures (e.g. Head crash on the disk)
  - damage to the database (hard crash)
  - need backup data
- Recovery scheme responsible for handling failures and restoring database to consistent state

Recovery

- Recovering the database itself
- Recovery algorithm has two parts
  - Actions taken during normal operation to ensure system can recover from failure (e.g., backup, log file)
  - Actions taken after a failure to restore database to consistent state
- We will discuss (briefly)
  - Transactions/Transaction recovery
  - System Recovery

Transactions

- A database is updated by processing *transactions* that result in changes to one or more records.
- A user's program may carry out many operations on the data retrieved from the database, but the DBMS is only concerned with data read/written from/to the database.
- The DBMS's abstract view of a user program is a sequence of transactions (reads and writes).
- To understand database recovery, we must first understand the concept of *transaction integrity*.

Transactions

- A transaction is considered a logical unit of work
  - START Statement: BEGIN TRANSACTION
  - END Statement: COMMIT
  - Execution errors: ROLLBACK
- Assume we want to transfer $100 from one bank (A) account to another (B):

  UPDATE Account_A SET Balance= Balance -100;
  UPDATE Account_B SET Balance= Balance +100;

- We want these two operations to appear as a **single atomic action**

Transactions

- We want these two operations to appear as a **single atomic action**
  - To avoid **inconsistent states** of the database **in-between** the two updates
  - And obviously we cannot allow the first UPDATE to be executed and the second not or vice versa.
- Transactions guarantee that, if a failure occurs before the transaction reaches its planned termination, then those previous transaction updates will be **undone**.

Pseudocode Transaction

```
   BEGIN TRANSACTION
          UPDATE ACCOUNT_A {BALANCE = BALANCE -100}
          IF any error occurred then GO TO UNDO; END IF;
          UPDATE ACCOUNT_B {BALANCE = BALANCE +100}
          IF any error occurred then GO TO UNDO; END IF;
   COMMIT;
          GO TO FINISH;
UNDO:
   ROLLBACK;
FINISH:
   RETURN;
```


Transaction Recovery

- COMMIT establishes a Commit Point or Synch Point
  - A point at which we assume the database in a correct state
- ROLLBACK has to roll back the database to the state it had before the Transaction started.

Transaction **ACID** Properties

- **A**tomicity
  - Transactions are atomic (all or nothing)
- **C**onsistency
  - Transaction transform the DB from one correct state to another correct state
- **I**solation
  - Transactions are isolated from each other
- **D**urability
  - Once a transaction commits, changes are permanent: no subsequent failure can reverse the effect of the transaction.

Atomicity

```
UPDATE Account_A SET Balance= Balance -100;
1.    Read(A)
2.    A = A – 100
3.    Write(A)
UPDATE Account_B SET Balance= Balance +100;
4.    Read(B)
5.    B = B + 100
6.    write(B)
```

- Transaction may fail after step 3 and before step 6 (failure could be due to software or hardware)
- The system should ensure that updates of a partially executed transaction are not reflected in the database

Consistency

```
UPDATE Account_A SET Balance= Balance -100;
1.    Read(A)
2.    A = A – 100
3.    Write(A)
UPDATE Account_A SET Balance= Balance +100;
4.    Read(B)
5.    B = B + 100
6.    write(B)
```

- In this example, the sum of A and B is unchanged by the execution of the transaction

Isolation

```
      Transaction T1                      Transaction T2
1.    Read(A)
2.    A = A – 100
3.    Write(A)
                                 Read(A), Read(B), Write(A+B)
4.    Read(B)
5.    B = B + 100
6.    write(B)
```

- What will T2 "see"? Database changes not revealed to users until after transaction has completed
- Isolation can be ensured trivially by running transactions **serially**
- However, executing multiple transactions concurrently has significant benefits
  - Keep CPU humming when disk I/O takes place.

Durability

```
UPDATE Account_A SET Balance= Balance -100;
1.     Read(A)
2.     A = A – 100
3.     Write(A)
UPDATE Account_A SET Balance= Balance +100;
4.     Read(B)
5.     B = B + 100
6.     write(B)
```

- Database changes are permanent (once the transaction was committed).

Passing the ACID Test

- Logging and Recovery
  - Guarantees Atomicity and Durability
  - Log file based recovery techniques
- Concurrency Control
  - Guarantees Consistency and Isolation, given Atomicity
- We'll do Recovery Methods first
  - Assume no concurrency and study recovery methods – Log based recovery
  - Concurrency control methods will then generate schedules that are "recoverable"

Concept: Log-based Recovery

- Write to a log file before writing to database
  - Enter log records
- Transaction states:
  - Start, Abort, Commit

Example log file

```
            DB(A = 1000,B = 2000)

Transaction     Log File

T1 start        <T1,Start>
Read(A)
A = A-100
Write(A)        <T1,A,1000,900>
T1 end          <T1, Commit>
T2 start        <T2, Start>
Read(B)
B=B+100
Write(B)        <T2, B, 2000, 2100>
T2 end          <T2, Commit>
```

Recovery using Log File

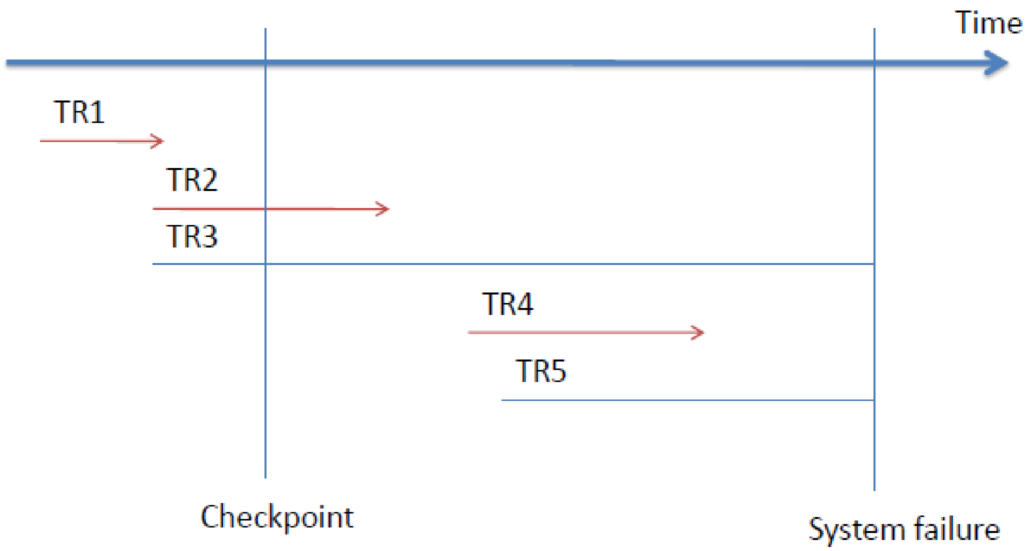
- When has a transaction committed?
  - When <Ti, start> and <Ti, Commit> is in the log file
- When has a transaction failed/aborted?
  - When <Ti, Start> is in the log file but no <Ti,Commit>

- Backward Recovery:
  - Undo transaction (restore old values) if no Commit
- Forward Recovery:
  - Start with an earlier copy of the database
  - Redo transaction (write new values) if Commit

Checkpoints

- Recovery system consults log file when failure occurs
  - Search entries in log file
  - Time depends on number of entries
- Why redo transactions already written to disk?
  - Introduce ***checkpoint*** records into log file
- Only transactions committed *after* last checkpoint need to be redone after a failure

Example Checkpoint



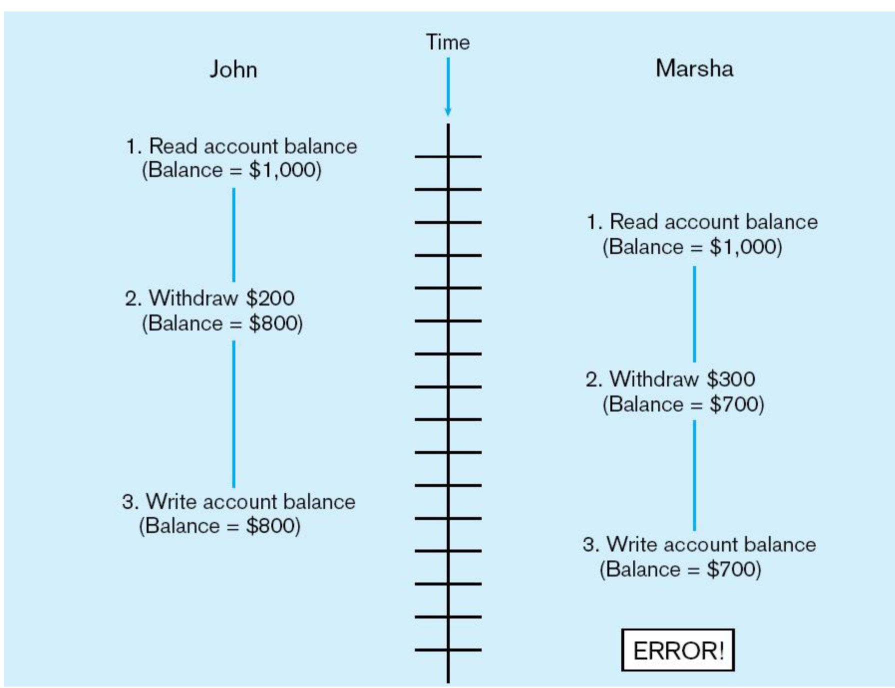
At restart, transactions 2 and 4 must be redone.

Concurrency in Transaction Processing

Concurrency Control

- Typically a DBMS allows many different transactions to access the database at the same time
- This may result in data inconsistency
- ***Solution*–Concurrency Control**
  - The process of managing simultaneous operations against a database so that ACID properties are maintained

Figure 11-10 Lost update (no concurrency control in effect)

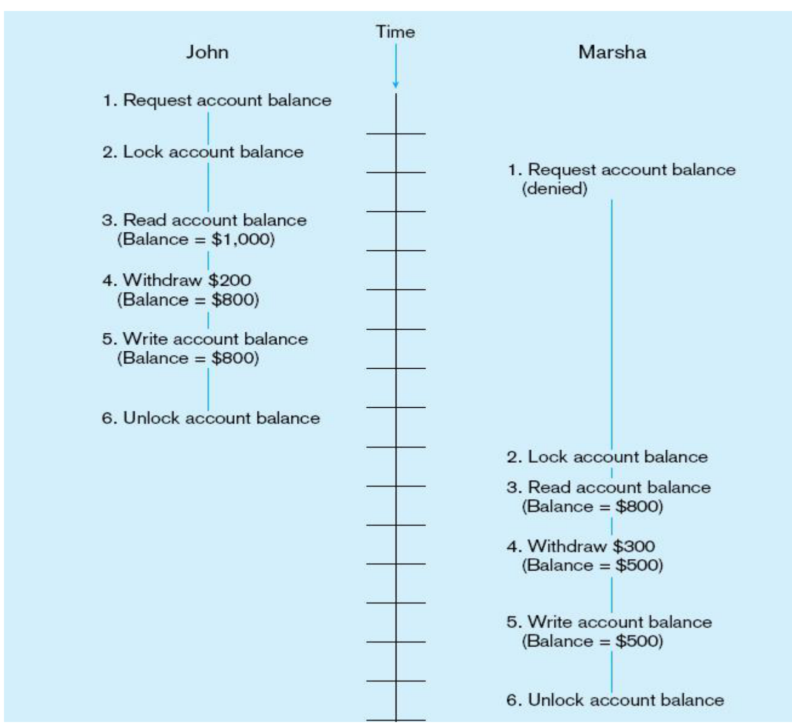


Simultaneous access causes updates to cancel each other.

Concurrency Control Techniques

- Serializability
  - Finish one transaction before starting another
- Locking Mechanisms (Pessimistic Approach)
  - The most common way of achieving serialization
  - Data that is retrieved for the purpose of updating is locked for the updater
  - No other user can perform update until unlocked
- Versioning (Optimistic Approach)
  - Newer approach to concurrency control

Figure 11-11: Updates with locking (concurrency control)



This prevents the lost update problem

Locking Mechanisms

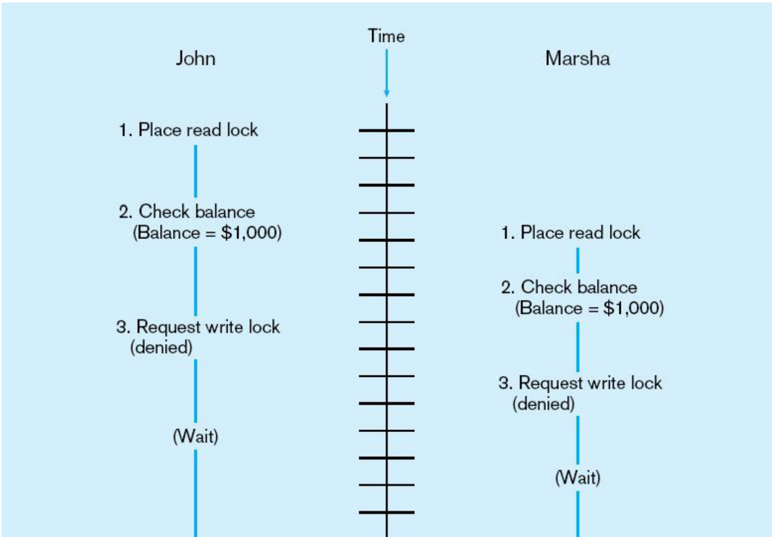
- Locking level:
  - Database–used during database updates
  - Table–used for bulk updates
  - Block or page–very commonly used
  - Record–only requested row; fairly commonly used
  - Field–requires significant overhead; impractical

- Types of locks:
  - Shared lock–Read ,but no update, permitted. Used when just reading to prevent another user from placing an exclusive lock on the record
  - Exclusive lock–No access permitted. Used when preparing to update.

Deadlock

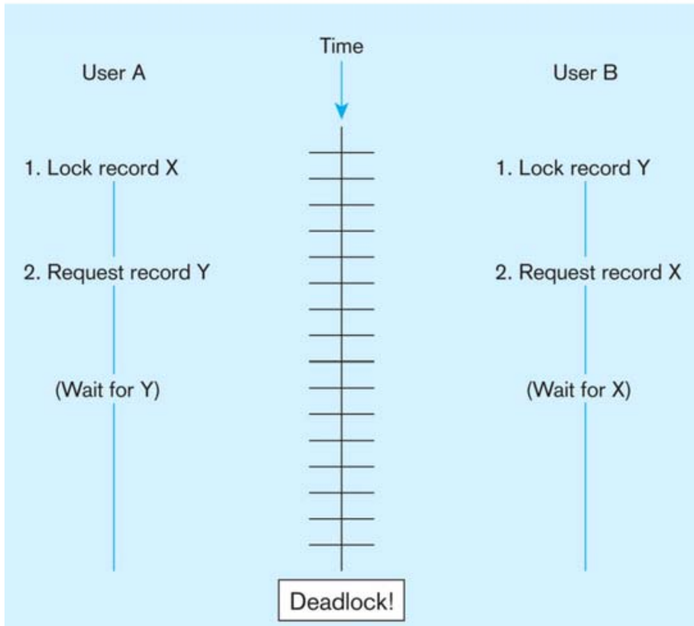
- An impasse that results when two or more transactions have locked common resources, and each waits for the other to unlock their resources.

John and Marsha will wait forever for each other to release their locked resources!



Another Deadlock Example

- Unless DBMS intervenes, both users will wait indefinitely!



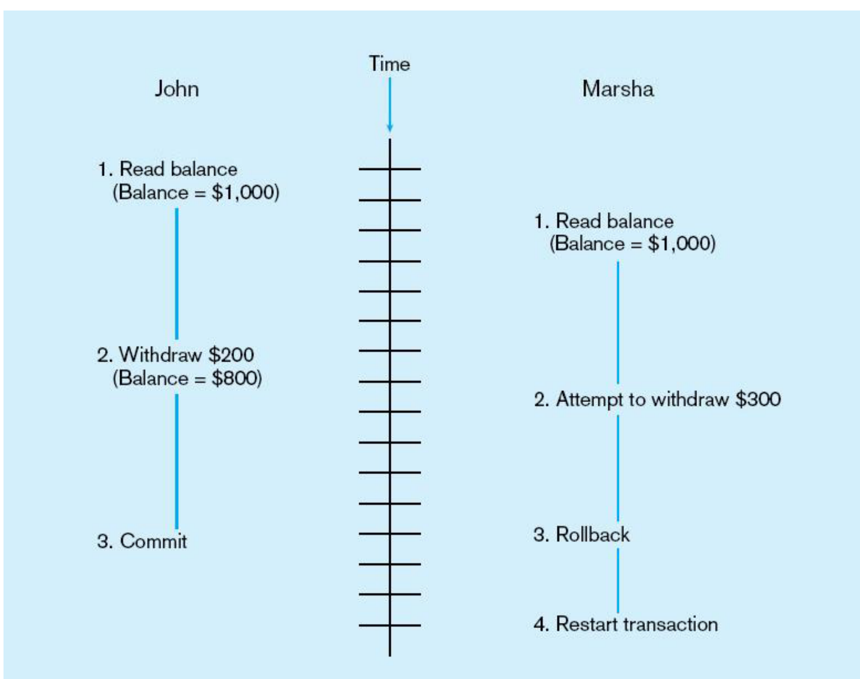
Managing Deadlock

- Deadlock Prevention:
  - Lock all records required at the beginning of a transaction
  - Two-phase locking protocol
    - Growing phase: all necessary locks acquired
    - Shrinking phase: all locks released
  - May be difficult to determine all needed resources in advance
- Deadlock Resolution:
  - Allow deadlocks to occur
  - Mechanisms for detecting and breaking them
  - Simple hack: *timeouts*. T1 made no progress for a while? Shoot it!

Versioning

- Optimistic approach to concurrency control
- Replaces locking
- Assumption is that simultaneous updates will be infrequent
- Each transaction can attempt an update as it wishes
- The system will reject an update when it senses a conflict
- Use of rollback and commit for this

Figure 11-14 The use of versioning



Better performance than locking

End of Lecture

Three things in life that are certain:

Death

Taxes

And

Lost Data

As computer scientists, at least we may try to do something against the latter.