Advanced Database Management Systems

Lecture 19

Security - Chapter 23

Database Security Issues

- Legal and ethical issues
  - Right of access
  - Privacy laws
- Policy issues
  - Government, institutional or corporate policies
- System-related issues
  - Where should security be handled: HW, OS or DBMS
- Multiple security levels
  - Categorization of data and users
  - Example: top secret, secret, confidential, unclassified

Threats to Databases

- Loss of **integrity**
  - Data should not be corrupted, through intentional or accidental acts
- Loss of **availability**
  - Data should remain accessible to those who have legitimate access rights
- Loss of **confidentiality**
  - Data should not be accessible to those who do not have legitimate access rights

Database Countermeasures

- **Access control**
  - User accounts and passwords identify database users
- **Inference control**
  - Statistical or summary data may allow users to infer or deduce information. Such inference must not allow inference of data that user is not authorized to access
- **Flow control**
  - Covert channels, which allow data to flow in manners violating security must be blocked
- **Encryption**
  - Encryption protects sensitive data during storage and transmission
  - Passwords, SSNs, credit card information …

Database Security Mechanisms

- **Discretionary** security mechanisms
  - Privilege grants allow specific users to perform specific operations on specific data
  - Initial grants start with DBA
  - Grants may be passed on between users

- **Mandatory** security mechanisms
  - Enforce multi-level security
  - Data and users are classified into security classes
  - Typically, user can only see data which has a lower (or same) classification as themselves
  - Role-based security is similar

Security and the DBA

- The **DBA** is the central authority for managing a database system …
  thus responsible for overall security
- Security responsibilities
  - granting privileges to users who need to use the system
  - classifying users and data in accordance with the policy of the organization
- ***System*** / ***root*** / ***superuser*** account allows:
  - Account creation – access control
  - Privilege granting – discretionary
  - Privilege revocation – discretionary
  - Security level assignment – mandatory

Access Protection and Audits

- Login Session: user logs in with account/password

- DBMS **tracks all operations** applied by a user throughout **each login session.**
  - Can be tracked in **system log**, which records all operations for recovery from a transaction failure or system crash.
  - A log used primarily for security purposes is an **audit trail**

- A **database audit** is performed when tampering is suspected
  - Logs are reviewed to try to identify what happened and who did it

Discretionary Access Control

Privileges

- The typical method of enforcing **discretionary access control** is based on the ***granting*** and ***revoking*** **privileges**

- **Account level privileges:**
  - DBA specifies the particular privileges that each account holds independently of the relations in the database
- **Relation level (table level)** privileges:
  - DBA controls privilege to access each individual relation or view in the database.

Account Level Privileges

- **CREATE SCHEMA** or **CREATE TABLE** privilege
- **CREATE VIEW** privilege
- **ALTER** privilege
- **DROP** privilege
- **MODIFY** privilege execute insert, delete, or update
- **SELECT** privilege

- Privilege names are based on corresponding SQL commands
- Account level privileges are not specified by SQL standard, left to DBMS to define

Relation Level Privileges

- These privileges are specified by SQL standard

- **SELECT** privilege on R
  - privilege to use the **SELECT** statement to retrieve tuples from R

- **UPDATE, DELETE** and **INSERT** privileges on R:
  - Capability to modify tuples of R
  - Both the **INSERT** and **UPDATE** privileges can specify that only certain attributes can be modified

- **REFERENCES** privilege on R:
  - Capability to **reference** relation R when specifying integrity constraints
  - Can also be restricted to specific attributes of R

Access Matrix Model

- The Access Matrix Model is a way of keeping track of discretionary privileges

- **Rows** represents **subjects**
  - (users, accounts, programs)

- **Columns** represent **objects**
  - (relations, records, columns, views, operations)

- Each position **M(i,j)** represents the types of privileges (read, write, update)
  that **subject i** holds on **object j**

Privilege Control

- Each relation R in a database is assigned an **owner account**
  - typically, the account used when the relation initially created
- Owner of a relation is given all privileges on that relation.
  - In SQL2, the DBA can assign an owner to a whole schema by creating the schema, using the **CREATE SCHEMA** command
- Account owner can **pass privileges** on to other users by **granting** privileges to their accounts

Specifying Privileges Using Views

- **Views** are often used for discretionary authorization
  - Example: owner A of a relation R wants to give account B read access to some fields of R

    A can create view V of R that includes only those attributes and then grant SELECT on V to B
  - Example: owner A of a relation R wants to give account B read access to some rows of R

    A can create view V’ by means of a query that selects only those tuples from R that A wants to allow B to access and then grant SELECT on V’ to B

  - Creating a view requires SELECT privilege on all relations involved in the view definition.

Revoking Privileges

- Revoking privileges takes them away
  - Sometime it is desirable to grant a privilege to a user temporarily, then revoke it
  - Example: The owner of a relation may want to grant the **SELECT** privilege to a user for a specific task and then revoke that privilege once the task is completed.

Propagation of Privileges

- When A grants a privilege to B, that privilege can be given with or without the **GRANT OPTION**.
- If the **GRANT OPTION** is given, B can also grant that privilege to other accounts.

- If B then grants the privilege to C, also with **GRANT OPTION,** privileges may **propagate** to other accounts without the knowledge of the original owner of the relation
- If A later revokes the privilege granted to B, all the privileges that propagated through B, based should be automatically revoked by the system.

Examples

- DBA creates four accounts: A1, A2, A3, A4
- A1 should be able to create base relations.

  DBA must issue the following GRANT command:

```
GRANT CREATETAB TO A1;
```

- Same effect can be accomplished by:

```
CREATE SCHEMA EXAMPLE AUTHORIZATION A1;
```

Examples

- A1 can now create tables under the schema called EXAMPLE
- A1 creates the two base relations: EMPLOYEE and DEPARTMENT
  - A1 is then **owner** of these two relations and has all relation privileges on each of them

- A1 grants A2 the privilege to insert and delete tuples in both of these relations, but A2 cannot propagate these privileges to others:

```
GRANT INSERT, DELETE ON
      EMPLOYEE, DEPARTMENT TO A2;
```

Examples

- A1 allows A3 to retrieve information from either table and also allows A3 to propagate the privilege to other accounts:

```
GRANT SELECT ON EMPLOYEE, DEPARTMENT
    TO A3 WITH GRANT OPTION;
```

- A3 can grant the SELECT privilege on the EMPLOYEE relation to A4:

```
GRANT SELECT ON EMPLOYEE TO A4;
```

A4 can't propagate the SELECT privilege since GRANT OPTION was not given to A4

Examples

- A1 decides to revoke the SELECT privilege on the EMPLOYEE relation from A3:

```
REVOKE SELECT ON EMPLOYEE FROM A3;
```

- DBMS must now automatically revoke the SELECT privilege on EMPLOYEE from A4

Examples

- A1 wants to give back to A3 a limited capability to SELECT from the EMPLOYEE relation with ability to propagate the privilege
  - limited to retrieve only the NAME, BDATE, and ADDRESS attributes and only for the tuples with DNO=5

```
CREATE VIEW A3EMPLOYEE AS
  SELECT NAME, BDATE, ADDRESS
  FROM EMPLOYEE
  WHERE DNO = 5;

GRANT SELECT ON A3EMPLOYEE TO A3
   WITH GRANT OPTION;
```

Examples

- A1 wants to allow A4 to update only the SALARY attribute of EMPLOYEE:

```
GRANT UPDATE ON EMPLOYEE (SALARY) TO A4;
```

  - **UPDATE** or **INSERT** privilege can specify particular attributes that may be updated or inserted in a relation.
  - Other privileges (**SELECT**, **DELETE**) are not attribute specific.

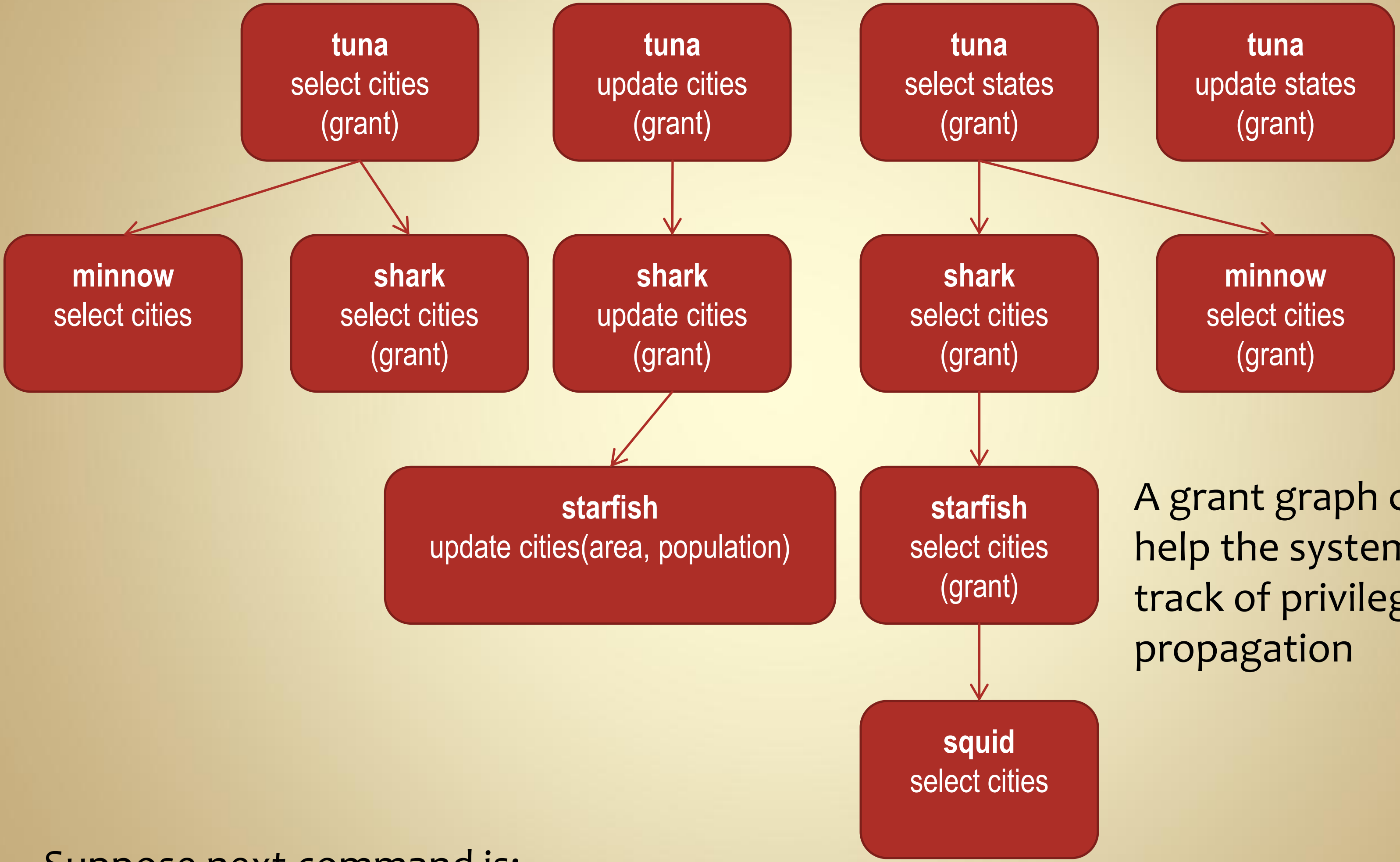
Example

tuna owns:

Cities(name, state, population)
States(name, abbreviation, capital, area, population)

```
tuna:     GRANT SELECT, UPDATE ON Cities
          TO shark WITH GRANT OPTION;

tuna:     GRANT SELECT ON Cities TO minnow;

tuna:     GRANT SELECT ON States
          TO shark, minnow WITH GRANT OPTION;

shark:    GRANT SELECT ON Cities
          TO starfish WITH GRANT OPTION;

shark:    GRANT UPDATE (area, population) ON Cities
          TO starfish;

shark:    GRANT UPDATE ON States TO starfish;
          (not allowed)

starfish: GRANT SELECT ON Cities TO squid;
```

Grant Graph



A grant graph can help the system keep track of privilege propagation

Suppose next command is:
shark: `REVOKE SELECT ON Cities FROM starfish`

Limits on Privilege Propagation

- Techniques to limit the propagation of privileges have been developed
  - not implemented in most DBMSs and not a part of SQL
  - Limiting **horizontal propagation** to an integer number i means that an account B given the GRANT OPTION can grant the privilege to at most i other accounts.
  - Limiting **vertical propagation** is more complicated
    it limits the depth of the granting of privileges

Mandatory Access Control

Mandatory Access Control

- Discretionary access control techniques (grant/revoke privileges) has been the main security mechanism for relational database systems
  - This is an all-or-nothing method:
  - a user either has or does not have a certain privilege

- Many applications require an **additional security policy** that classifies data and users based on security classes.
  - This approach of **mandatory access control,** would typically be **combined** with the discretionary access control mechanisms

Multilevel Security

- Typical **security classes:**
  top secret (TS), secret (S),
  confidential (C), unclassified (U)
  TS ≥ S ≥ C ≥ U

- Bell-LaPadula model classifies
  each **subject** (user, account, program) and
  object (relation, tuple, column, view, operation)
  into one of the security classifications, T, S, C, or U:
  - **class(S) → clearance** (classification) of a subject S
    class(O) → classification of an object O

Multilevel Security

- Two restrictions are enforced on data access based on the subject/object classifications:
  - **Simple security property:** A subject S is not allowed read access to an object O unless class(S) ≥ class(O)
  - Keeps subjects from accessing data above their clearance

  - **Star property:** A subject S is not allowed to write an object O unless class(S) ≤ class(O)
  - Keeps subjects from moving data from a high clearance to a lower clearance

Comparing DAC and MAC

- **Discretionary Access Control (DAC)** policies:
  - + high degree of flexibility
  - + suitable for a large variety of application domains
  - - vulnerable to malicious attacks, such as Trojan horses embedded in application programs.
- **Mandatory Access Control (MAC)** policies:
  - + ensure a high degree of protection
  - + prevent illegal flow of information
  - - too rigid - applicable in limited environments

- In many practical situations, DAC is preferred
  - better trade-off between security and applicability

Role Based Access Control

Role-Based Access Control

- **Role-based access control (RBAC)**
  - emerged rapidly in the 1990s
  - suitable for managing and enforcing security in large-scale enterprise-wide systems
- Permissions are associated with roles, and users are assigned to appropriate roles
  - avoid overhead of managing each individual's privileges
- Roles are created using **CREATE ROLE** and **DESTROY ROLE** commands
  - **GRANT** and **REVOKE** commands can then be used to assign and revoke privileges from roles

Role-Based Access Control

- **RBAC** ensures that only authorized users are given access to certain data or resources
- Many DBMSs support roles
- A role hierarchy is a natural way of organizing roles to reflect the organization's lines of authority and responsibility
- **RBAC** systems may allow temporal constraints on roles
  - time and duration of role activations
  - timed triggering of a role by an activation of another role

EXAMPLE

```
CREATE ROLE Bigfish;

GRANT SELECT ANY TABLE
TO Bigfish;

GRANT Bigfish
TO Tuna, Flounder;
```

Tuna and Flounder now have all privileges available to the BigFish role

E-Commerce Access Control

E-Commerce Access Control

- **E-Commerce environments** (and similar web environments) require elaborate policies
  - beyond traditional DBMS access control
  - e-commerce environment resources include not only data, but also knowledge and experience.
  - Access control mechanism should be flexible enough to support a wide spectrum of heterogeneous objects

E-Commerce Access Control

- Role-based models have promise for addressing the key security requirements of Web-based applications
- In contrast, **DAC** and **MAC** models **lack capabilities** needed to support security requirements of emerging enterprise and Web-based applications.

E-Commerce Access Control

- Heterogeneity of subjects requires access control policies based on user characteristics and qualifications.
  - A possible solution is the notion of credentials
  - A **credential** is a set of properties concerning a user that are relevant for security purposes
    - For example, age, position within an organization
  - XML may play a key role in access control for e-commerce applications

Statistical Database Security

Statistical Database Security

- **Statistical databases** are used mainly to produce statistics on various populations
- Database may contain **confidential data** on individuals, which should be protected from unauthorized access
- General users are only permitted to retrieve **statistical information** on the populations, such as **averages, sums, counts, maximums, minimums,** and **standard deviations**
- Statistical database security techniques must prohibit the retrieval of individual data

Statistical Database Security

- Allowed:
  - retrieve the *number* of individuals in a population
  - retrieve the *average income* of the population
- Not Allowed:
  - retrieve individual data, such as the income of a specific person

- This can be achieved by prohibiting queries that retrieve attribute values and allowing only queries using statistical aggregate functions

Statistical Database Security

- In some cases it is possible to **infer** the values of individual tuples from a sequence statistical queries
  - particularly true when the conditions result in a population consisting of a small number of objects
- Example:
  - Following are allowable queries:

    ```
    SELECT COUNT(*) FROM PERSON WHERE <condition>;
    SELECT AVG(INCOME) FROM PERSON WHERE <condition>;
    ```

  - Suppose condition on both queries is

    ```
    Last_degree=‘Ph.D.’ AND Sex=‘F’ AND
    City=‘Bellaire’ AND State=‘TX’
    ```

  - If first query returns 1, then we have an individual’s income.
  - If we can match the condition to that one actual person, we have gained prohibited information about that person

Flow Control

Flow Control

- **Flow control** regulates the distribution or flow of information among accessible objects
- A **flow** between object X and object Y occurs when a program reads values from X and writes values into Y
  - Flow controls check that information contained in some objects does not flow explicitly or implicitly into less protected objects
- A **flow policy** specifies the channels along which information is allowed to move
  - simplest flow policy specifies just two classes of information: confidential (C) and nonconfidential (N)
  - all flows allowed except those from class C to class N.

Covert Channels

- A **covert channel** allows a transfer of information that violates the security or the policy
  - **allows** information to pass from a higher classification level to a lower classification level through **improper means**
- Two broad categories:
  - **Storage channels** information is conveyed by accessing system information or information otherwise inaccessible to the user
  - **Timing channel** allow the information to be conveyed by the timing of events or processes
- One way to avoid covert channels:
  - programmers to not actually gain access to sensitive data that a program is supposed to process after the program has been put into operation

Encryption

Encryption

- **Encryption** is a means of maintaining secure data in an insecure environment.
- **Encryption** consists of applying an **encryption algorithm** to data using some pre-specified **encryption key.**
- The resulting data has to be **decrypted** using a **decryption key** to recover the original data.