Security

Security Violations

Among the forms of malicious access are:

- Unauthorized reading of data (theft of information)
- Unauthorized modification of data
- Unauthorized destruction of data

Security Violations

To protect the database, we must take security measures at several levels

- Database system
- Operating system
- Network
- Physical
- Human

Authorization

Forms of authorization on parts of the database:

- **Read** - allows reading, but not modification of data.
- **Insert** - allows insertion of new data, but not modification of existing data.
- **Update** - allows modification, but not deletion of data.
- **Delete** - allows deletion of data.

Forms of authorization to modify the database schema

- **Index** - allows creation and deletion of indices.
- **Resources** - allows creation of new relations.
- **Alteration** - allows addition or deletion of attributes in a relation.
- **Drop** - allows deletion of relations.

Authorization Specification in SQL

- The **grant** statement is used to confer authorization

  grant <privilege list>

  on <relation name or view name> **to** <user list>
- <user list> is:
  - a user-id
  - **public**, which allows all valid users the privilege granted
  - A role (more on this later)
- Granting a privilege on a view does not imply granting any privileges on the underlying relations.
- The grantor of the privilege must already hold the privilege on the specified item (or be the database administrator).

Privileges in SQL

- **select:** allows read access to relation, or the ability to query using the view
  - Example: grant users U_1, U_2, and U_3 the **select** authorization on the *instructor* relation:

    grant select on *instructor* **to** U_1, U_2, U_3
- **insert**: the ability to insert tuples
- **update**: the ability to update using the SQL update statement
- **delete**: the ability to delete tuples.
- **all privileges**: used as a short form for all the allowable privileges

Revoking Authorization in SQL

- The **revoke** statement is used to revoke authorization.

  revoke <privilege list>
  on <relation name or view name> **from** <user list>

- Example:

  revoke select on *branch* **from** U_1, U_2, U_3

- <privilege-list> may be **all** to revoke all privileges the revokee may hold.
- If <revokee-list> includes **public,** all users lose the privilege except those granted it explicitly.
- If the same privilege was granted twice to the same user by different grantees, the user may retain the privilege after the revocation.
- All privileges that depend on the privilege being revoked are also revoked.

Roles

- **create role** *instructor*;
  - **grant** *instructor* **to** Amit;
- Privileges can be granted to roles:
  - **grant select on** *takes* **to** *instructor*;
- Roles can be granted to users, as well as to other roles
  - **create role** *teaching_assistant*;
  - **grant** *teaching_assistant* **to** *instructor*;
    - *instructor* inherits all privileges of *teaching_assistant*
- Chain of Roles
  - **create role** *dean*;
  - **grant** *instructor* **to** *dean*;
  - **grant** *dean* **to** Satoshi;

Authorization on Views

- **create view** *geo_instructor* **as**
  (**select** *
  from *instructor*
  where *dept_name* = 'Geology');
- **grant select on** *geo_instructor* **to** *gio_staff*
- Suppose that a *gio-staff* member issues
  - **select** *
    from *geo_instructor*;
- Clearly the gio-staff should be able to issue the query *?*
  - Need to deal with the case where gio-staff does not have authorization to instructor

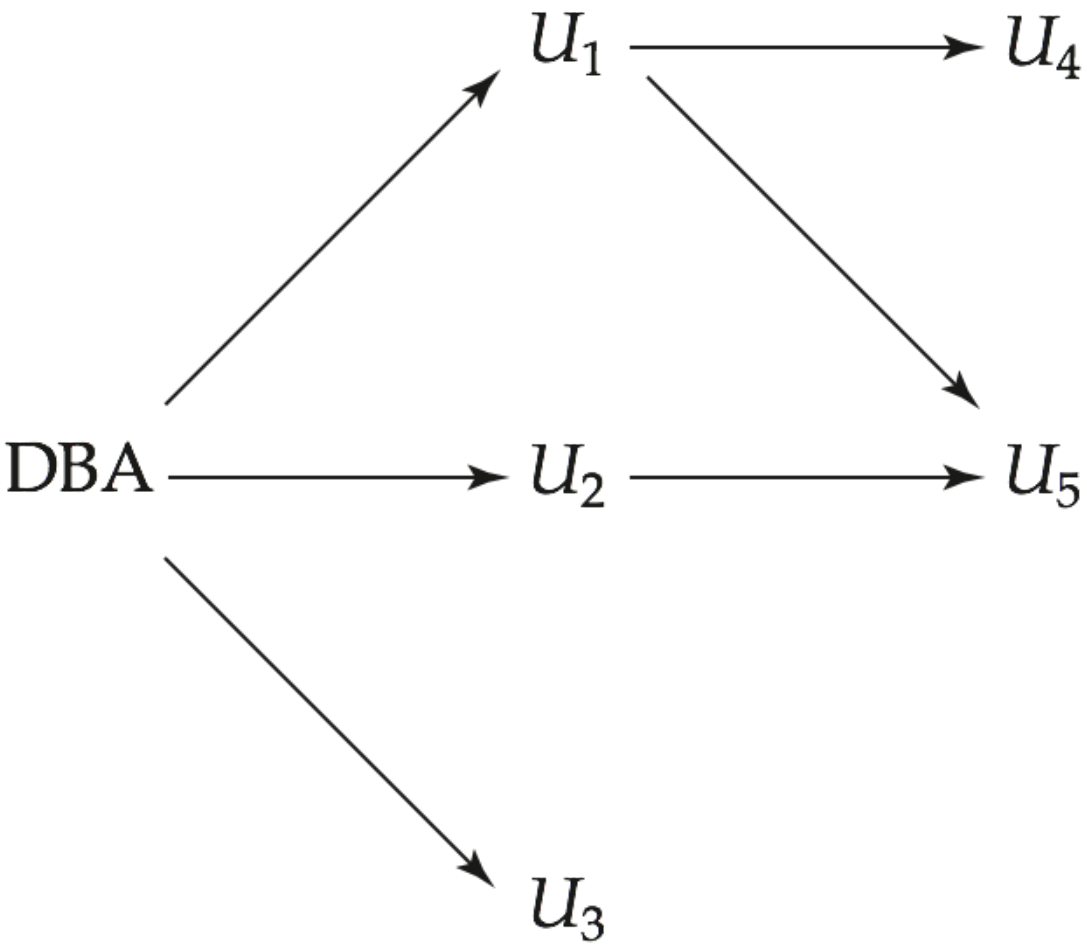
Authorizations on Schema

- **references** privilege to create foreign key
  - **grant reference** (*dept_name*) **on** *department* **to** Mariano;
  - why is this required?

Transfer of Privileges

- Transfer of privileges
  - **grant select on** *department* **to** Amit **with grant option**;
  - **revoke select on** *department* **from** Amit, Satoshi **cascade**;
  - **revoke select on** *department* **from** Amit, Satoshi **restrict**;
- Etc.

Authorization-grant graph



Encryption

- Data may be *encrypted* when database authorization provisions do not offer sufficient protection.
- Properties of good encryption technique:
  - Relatively simple for authorized users to encrypt and decrypt data.
  - Encryption scheme depends not on the secrecy of the algorithm but on the secrecy of a parameter of the algorithm called the encryption key.
  - Extremely difficult for an intruder to determine the encryption key.
- **Symmetric-key encryption**: same key used for encryption and for decryption
- **Public-key encryption** (a.k.a. **asymmentric-key encryption**): use different keys for encryption and decryption
  - encryption key can be public, decryption key secret

Encryption (Cont.)

- *Data Encryption Standard* (DES) substitutes characters and rearranges their order on the basis of an encryption key which is provided to authorized users via a secure mechanism. Scheme is no more secure than the key transmission mechanism since the key has to be shared.
- Advanced Encryption Standard (AES) is a new standard replacing DES, and is based on the Rijndael algorithm, but is also dependent on shared secret keys.
- *Public-key encryption* is based on each user having two keys:
  - *public key* – publicly published key used to encrypt data, but cannot be used to decrypt data
  - *private key* -- key known only to individual user, and used to decrypt data. Need not be transmitted to the site doing encryption.

  Encryption scheme is such that it is impossible or extremely hard to decrypt data given only the public key.
- The RSA public-key encryption scheme is based on the hardness of factoring a very large number (100's of digits) into its prime components

Encryption (Cont.)

- **Hybrid schemes** combining public key and private key encryption for efficient encryption of large amounts of data
- Encryption of small values such as identifiers or names vulnerable to **dictionary attacks**
  - especially if encryption key is publicly available
  - but even otherwise, statistical information such as frequency of occurrence can be used to reveal content of encrypted data
  - Can be deterred by adding extra random bits to the end of the value, before encryption, and removing them after decryption
    - same value will have different encrypted forms each time it is encrypted, preventing both above attacks
    - extra bits are called **salt bits**

Encryption in Databases

- Database widely support encryption
- Different levels of encryption:
  - **disk block**
    - every disk block encrypted using key available in database-system software.
    - Even if attacker gets access to database data, decryption cannot be done without access to the key.
  - **Entire relations, or specific attributes of relations**
    - non-sensitive relations, or non-sensitive attributes of relations need not be encrypted
    - however, attributes involved in primary/foreign key constraints cannot be encrypted.
- Storage of encryption or decryption keys
  - typically, single master key used to protect multiple encryption/decryption keys stored in database
- Alternative: encryption/decryption is done in application, before sending values to the database

Encryption and Authentication

- Password based authentication is widely used, but is susceptible to sniffing on a network.
- **Challenge-response** systems avoid transmission of passwords
  - DB sends a (randomly generated) challenge string to user.
  - User encrypts string and returns result.
  - DB verifies identity by decrypting result
  - Can use public-key encryption system by DB sending a message encrypted using user's public key, and user decrypting and sending the message back.
- **Digital signatures** are used to verify authenticity of data
  - E.g., use private key (in reverse) to encrypt data, and anyone can verify authenticity by using public key (in reverse) to decrypt data. Only holder of private key could have created the encrypted data.
  - Digital signatures also help ensure **nonrepudiation:** sender cannot later claim to have not created the data

SQL Injection

- Suppose query is constructed using
  - "select * from instructor where name = '" + name + "'"
- Suppose the user, instead of entering a name, enters:
  - X' or 'Y' = 'Y
- then the resulting statement becomes:
  - "select * from instructor where name = '" + "X' or 'Y' = 'Y" + "'"
  - which is:
    - select * from instructor where name = 'X' or 'Y' = 'Y'
  - User could have even used
    - X'; update instructor set salary = salary + 10000; --
- Prepared statement internally uses:
  "select * from instructor where name = 'X\' or \'Y\' = \'Y'
- **Always use prepared statements, with user inputs as parameters**
- Is the following prepared statemen secure?
  - conn.prepareStatement("select * from instructor where name = '" + name + "'")

Password Leakage

- Never store passwords, such as database passwords, in clear text in scripts that may be accessible to users
  - E.g. in files in a directory accessible to a web server
    - Normally, web server will execute, but not provide source of script files such as file.jsp or file.php, but source of editor backup files such as file.jsp~, or .file.jsp.swp may be served
- Restrict access to database server from IPs of machines running application servers
  - Most databases allow restriction of access by source IP address

Application-Level Authorization

- Current SQL standard does not allow fine-grained authorization such as “students can see their own grades, but not other’s grades”
  - Problem 1: Database has no idea who are application users
  - Problem 2: SQL authorization is at the level of tables, or columns of tables, but not to specific rows of a table
- One workaround: use views such as

  create view *studentTakes* **as**
  select *
  from *takes*
  where *takes.ID = syscontext.user_id*()

  - where syscontext.user_id() provides end user identity
    - end user identity must be provided to the database by the application
  - Having multiple such views is cumbersome

Application-Level Authorization (Cont.)

- Currently, authorization is done entirely in application
- Entire application code has access to entire database
  - large surface area, making protection harder
- Alternative: **fine-grained (row-level) authorization** schemes
  - extensions to SQL authorization proposed but not currently implemented
  - Oracle Virtual Private Database (VPD) allows predicates to be added transparently to all SQL queries, to enforce fine-grained authorization
    - e.g. add *ID= sys_context.user_id()* to all queries on student relation if user is a student

Audit Trails

- Applications must log actions to an audit trail, to detect who carried out an update, or accessed some sensitive data
- Audit trails used after-the-fact to
  - detect security breaches
  - repair damage caused by security breach
  - trace who carried out the breach
- Audit trails needed at
  - Database level, and at
  - Application level