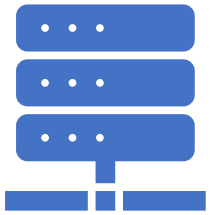
# CHAPTER 30

# Database Security

# Database Security Issues

- Database security a broad area
  - Legal, ethical, policy, and system-related issues
- Threats to databases
  - Loss of integrity
    - Improper modification of information
  - Loss of availability
    - Legitimate user cannot access data objects
  - Loss of confidentiality
    - Unauthorized disclosure of confidential information

# Database Security Issues (cont'd.)



**Database works as part of a network of services**

Applications, Web servers, firewalls, SSL terminators, and security monitoring systems

**Types of database control measures**

Access control

Inference control

Flow control

Encryption

# Database Security Issues (cont'd.)

## Discretionary security mechanisms

- Used to grant privileges to users

## Mandatory security mechanisms

- Classify data and users into various security classes
- Implement security policy

## Role-based security

# Database Security Issues (cont'd.)

- Control measures
  - Access control
    - Handled by creating user accounts and passwords
  - Inference control
    - Must ensure information about individuals cannot be accessed
  - Flow control
    - Prevents information from flowing to unauthorized users
  - Data encryption
    - Used to protect sensitive transmitted data

# Database Security and the DBA

## Database administrator (DBA)

- Central authority for administering database system
- Superuser or system account

## DBA-privileged commands

- Account creation
- Privilege granting
- Privilege revocation
- Security level assignment

# Access Control, User Accounts, and Database Audits

User must log in using assigned username and password

Login session

- Sequence of database operations by a certain user
- Recorded in system log

Database audit

- Reviewing log to examine all accesses and operations applied during a certain time period

# Sensitive Data and Types of Disclosures

- Sensitivity of data
  - Inherently sensitive
  - From a sensitive source
  - Declared sensitive
  - A sensitive attribute or sensitive record
  - Sensitivity in relation to previously disclosed data

# Sensitive Data and Types of Disclosures (cont'd.)

- Factors in deciding whether it is safe to reveal the data
  - Data availability
    - Not available when being updated
  - Access acceptability
    - Authorized users
  - Authenticity assurance
    - External characteristics of the user
    - Example: access only allowed during working hours

# Sensitive Data and Types of Disclosures (cont'd.)

**Typically a tradeoff between precision and security**

**Precision**

- Protect all sensitive data while making available as much nonsensitive data as possible

**Security**

- Ensuring data kept safe from corruption and access suitably controlled

# Relationship Between Information Security and Information Privacy

## Concept of privacy goes beyond security

- Ability of individuals to control the terms under which their personal information is acquired and used
- Security a required building block for privacy

## Preventing storage of personal information

## Ensuring appropriate use of personal information

## Trust relates to both security and privacy

# Discretionary Access Control Based on Granting and Revoking Privileges

- Two levels for assigning privileges to use a database system
  - Account level
    - Example: CREATE SCHEMA or CREATE TABLE privilege
    - Not defined for SQL2
  - Relation (or table) level
    - Defined for SQL2
    - Access matrix model

# Discretionary Access Control (cont'd.)

- Relation or table level (cont'd.)
  - Each relation R assigned an owner account
  - Owner of a relation given all privileges on that relation
  - Owner can grant privileges to other users on any owned relation
    - SELECT (retrieval or read) privilege on R
    - Modification privilege on R
    - References privilege on R

# Specifying Privileges Through the Use of Views

- Consider owner A of relation R and other party B
  - A can create view V of R that includes only attributes A wants B to access
    - Grant SELECT on V to B
- Can define the view with a query that selects only those tuples from R that A wants B to access

# Revocation and Propagation of Privileges

## Revoking of Privileges

- Useful for granting a privilege temporarily
- REVOKE command used to cancel a privilege

## Propagation of privileges using the GRANT OPTION

- If GRANT OPTION is given, B can grant privilege to other accounts
- DBMS must keep track of how privileges were granted if DBMS allows propagation

# Revocation and Propagation of Privileges (cont'd.)

- Horizontal and vertical propagation limits
  - Limiting horizontal propagation to an integer number *i*
    - Account *B* given the GRANT OPTION can grant the privilege to at most *i* other accounts
  - Vertical propagation limits the depth of the granting of privileges
  - Not available currently in SQL or other relational systems

# 30.3 Mandatory Access Control and Role-Based Access Control for Multilevel Security

- Mandatory access control
  - Additional security policy that classifies data and users based on security classes
  - Typical security classes
    - Top secret
    - Secret
    - Confidential
    - Unclassified
  - Bell-LaPadula model
    - Subject and object classifications

# Mandatory Access Control and Role-Based Access Control for Multilevel Security (cont'd.)

## Simple security property

- Subject S not allowed read access to object O unless class(S)≥class(O)

## Star property

- Subject not allowed to write an object unless class(S)≤class(O)
- Prevent information from flowing from higher to lower classifications

## Attribute values and tuples considered as data objects

A multilevel relation to illustrate multilevel security (a) The original EMPLOYEE tuples (b) Appearance of EMPLOYEE after filtering for classification C users (c) Appearance of

- EMPLOYEE after filtering
- for classification U users
- (d) Polyinstantiation of the
- Smith tuple

**EMPLOYEE**

| Name | Salary | JobPerformance | TC |
|---|---|---|---|
| Smith U | 40000 C | Fair S | S |
| Brown C | 80000 S | Good C | S |

**EMPLOYEE**

| Name | Salary | JobPerformance | TC |
|---|---|---|---|
| Smith U | 40000 C | NULL C | C |
| Brown C | NULL C | Good C | C |

**EMPLOYEE**

| Name | Salary | JobPerformance | TC |
|---|---|---|---|
| Smith U | NULL U | NULL U | U |

**EMPLOYEE**

| Name | Salary | JobPerformance | TC |
|---|---|---|---|
| Smith U | 40000 C | Fair S | S |
| Smith U | 40000 C | Excellent C | C |
| Brown C | 80000 S | Good C | S |

# Comparing Discretionary Access Control and Mandatory Access Control

- DAC policies have a high degree of flexibility
  - Do not impose control on how information is propagated
- Mandatory policies ensure high degree of protection
  - Rigid
  - Prevent illegal information flow

# Role-Based Access Control

- Permissions associated with organizational roles
  - Users are assigned to appropriate roles
- Can be used with traditional discretionary and mandatory access control
- Mutual exclusion of roles
  - Authorization time exclusion
  - Runtime exclusion
- Identity management

# Label-Based Security and Row-Level Access Control

- Sophisticated access control rules implemented by considering the data row by row
- Each row given a label
  - Used to prevent unauthorized users from viewing or altering certain data
- Provides finer granularity of data security
- Label security policy
  - Defined by an administrator

# XML Access Control

- Digital signatures for XML
  - XML Signature Syntax and Processing specification
    - Defines mechanisms for countersigning and transformations
- XML encryption
  - XML Encryption Syntax and Processing specification
    - Defines XML vocabulary and processing rules

# Access Control Policies for the Web and Mobile Applications

- E-commerce environments require elaborate access control policies
  - Go beyond traditional DBMSs
- Legal and financial consequences for unauthorized data breach
- Content-based access control
  - Takes protection object content into account
- Credentials

# SQL Injection

- SQL injection
  - Most common threat to database system
- Other common threats
  - Unauthorized privilege escalation
  - Privilege abuse
  - Denial of service
  - Weak authentication

# SQL Injection Methods

- Attacker injects a string input through the application
  - Changes or manipulates SQL statement to attacker's advantage
- Unauthorized data manipulation or execution of system-level commands
- SQL manipulation
  - Changes an SQL command in the application
  - Example: adding conditions to the WHERE clause

# SQL Injection Methods (cont'd.)

- SQL manipulation (cont'd.)
  - Typical manipulation attack occurs during database login
- Code injection
  - Add additional SQL statements or commands that are then processed
- Function call injection
  - Database or operating system function call inserted into vulnerable SQL statement to manipulate data or make a privileged system call

# Risks Associated with SQL Injection

- Database fingerprinting
- Denial of service
- Bypassing authentication
- Identifying injectable parameters
- Executing remote commands
- Performing privilege escalation

# Protection Techniques

- Blind variables (using parameterized statements)
  - Protects against injection attacks
  - Improves performance
- Filtering input (input validation)
  - Remove escape characters from input strings
  - Escape characters can be used to inject manipulation attacks
- Function security
  - Standard and custom functions should be restricted

# Introduction to Flow Control

- Flow control
  - Regulates the distribution or flow of information among accessible objects
  - Verifies information contained in some objects does not flow explicitly or implicitly into less protected objects
- Flow policy
  - Specifies channels along which information is allowed to move
    - Simple form: confidential and nonconfidential

# Introduction to Flow Control (cont'd.)

- Covert channels
  - Allows information to pass from a higher classification level to a lower classification level through improper means
  - Timing channel requires temporal synchronization
  - Storage channel does not require temporal synchronization

# Encryption and Public Key Infrastructures

- Encryption converts data into cyphertext
  - Performed by applying an encryption algorithm to data using a prespecified encryption key
  - Resulting data must be decrypted using a decryption key to recover original data
- Data Encryption Standard (DES)
  - Developed by the U.S. Government for use by the general public
- Advanced Encryption Standard (AES)
  - More difficult to crack

# Encryption and Public Key Infrastructures (cont'd.)

- Symmetric key algorithms
  - Also called secret key algorithms
  - Need for sharing the secret key
    - Can apply some function to a user-supplied password string at both sender and receiver
- Public (asymmetric) key encryption
  - Involves public key and private key
  - Private key is not transmitted
  - Two keys related mathematically
    - Very difficult to derive private key from public key

# Encryption and Public Key Infrastructures (cont'd.)

- Public (asymmetric) key encryption steps
  - Each user generates a pair of keys to be used for encryption and decryption of messages
  - Each user places public key in a public register or other accessible file
    - Keeps companion key private
  - Sender encrypts message using receiver's public key
  - Receiver decrypts message using receiver's private key
- RSA public key encryption algorithm

# Digital Signatures

- Consist of string of symbols
- Each is unique
  - Function of the message it is signing, along with a timestamp
  - Depends on secret number unique to the signer
- Public key techniques used to create digital signatures

# Digital Certificates

- Combines value of a public key with the identity of the person or service that holds the corresponding private key into a digitally signed statement
- Information included in the certificate
  - Owner information
  - Public key of the owner
  - Date of certificate issue and validity period
  - Issuer identification
  - Digital signature

# Privacy Issues and Preservation

- Growing challenge for database security
- Limit performing large-scale mining and analysis
- Central warehouses for vital information
  - Violating security could expose all data
- Distributed data mining algorithms
- Remove identity information in released data
- Inject noise into the data
  - Must be able to estimate errors introduced
- Mobile device privacy