Module 7
Database Security

Introduction to 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

Introduction to 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

Introduction to 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

Control Measures

- Control measures
  - Access control
    - Handled by creating user accounts and passwords
  - Inference control (for statistical DBs)
    - 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: a measure of the importance assigned to the data
  - Inherently sensitive (e.g., health info, grades)
  - From a sensitive source (e.g., an informer)
  - Declared sensitive
  - A sensitive attribute or sensitive record (e.g., grade)
  - 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 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 unauthorized access suitably controlled

Relationship Between Information Security and Information Privacy

- Security: technology to ensure info protection
- Concept of privacy goes beyond security
  - Ability of individuals to control the terms under which their personal information is acquired and used
  - Preventing storage of personal information
  - Ensuring appropriate use of personal information
- Security a required building block for privacy

Discretionary Access Control Based on Granting and Revoking Privileges

- DAC: Two levels for assigning privileges to use a database system
  - Account level
    - Example: CREATE, DROP, ALTER, MODIFY, SELECT privileges
    - Not defined for SQL2 (DBMS vendors decide)
  - 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

Simple GRANT Syntax

- GRANT priv_type [, priv_type] ...

  ON object_type

  TO user [user] ...

  [WITH GRANT OPTION]

Example: Granting/Revoking Privileges

- DBA to A1
  - GRANT CREATETAB TO A1;
  - CREATE SCHEMA Example AUTHORIZATION A1
  - A1 can create new tables
- A1 creates relations Emp and Dept
- A1 to A2
  - GRANT INSERT DELETE on Emp, Dept TO A2;
  - A2 was not given the WITH GRANT OPTION
  - A2 cannot give privilege to other users

Example: Granting/Revoking Privileges

- A1 to A3
  - GRANT SELECT On Emp, Dept TO A3 WITH GRANT OPTION;
  - A3 given the WITH GRANT OPTION
  - A3 can give privilege to other users
- A3 to A4
  - GRANT SELECT On Emp TO A4;
  - A4 cannot propagate the SELECT privilege

Example: Granting/Revoking Privileges

- Suppose A1 decides to revoke the SELECT privilege from A3
  - REVOKE SELECT ON Emp FROM A3;
  - DBMS revokes SELECT privilege on Emp from A3 but also A4
  - Why? Because A3 no longer has that privilege

Example: Granting/Revoking Privileges

- Suppose A1 wants to give back to A3 a limited capability on to SELECT on Emp

```
CREATE VIEW A3Emp AS
SELECT Name, Bdate, Address
FROM Emp
WHERE Dno = 5;

GRANT SELECT ON A3Emp TO A3 WITH
GRANT OPTION
```

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

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
  - Both roles cannot be used simultaneously
- 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
- On top of DAC (the use must satisfy DAC and then the label security requirements)

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

Simple SQL injection

- SELECT email

  FROM Email-Addresses

  WHERE email = ‘saiedian@ku.edu’

- SELECT email-address

  FROM Email-Addresses

  WHERE email = 'anything' OR 'x'='x';

Simple SQL Injection

```
$name = $ REQUEST['name'];
$query = "SELECT * FROM suppliers WHERE name = '" . $name . "';"
$result = mysql_query($query);
```

Bob'; drop table customers;

Risks Associated with SQL Injection

- Database fingerprinting (the type of database)
- Denial of service (flood the server)
- Bypassing authentication
- Identifying injectable parameters
- Executing remote commands
- Performing privilege escalation

Protection Techniques

- Bind 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 Statistical Database Security

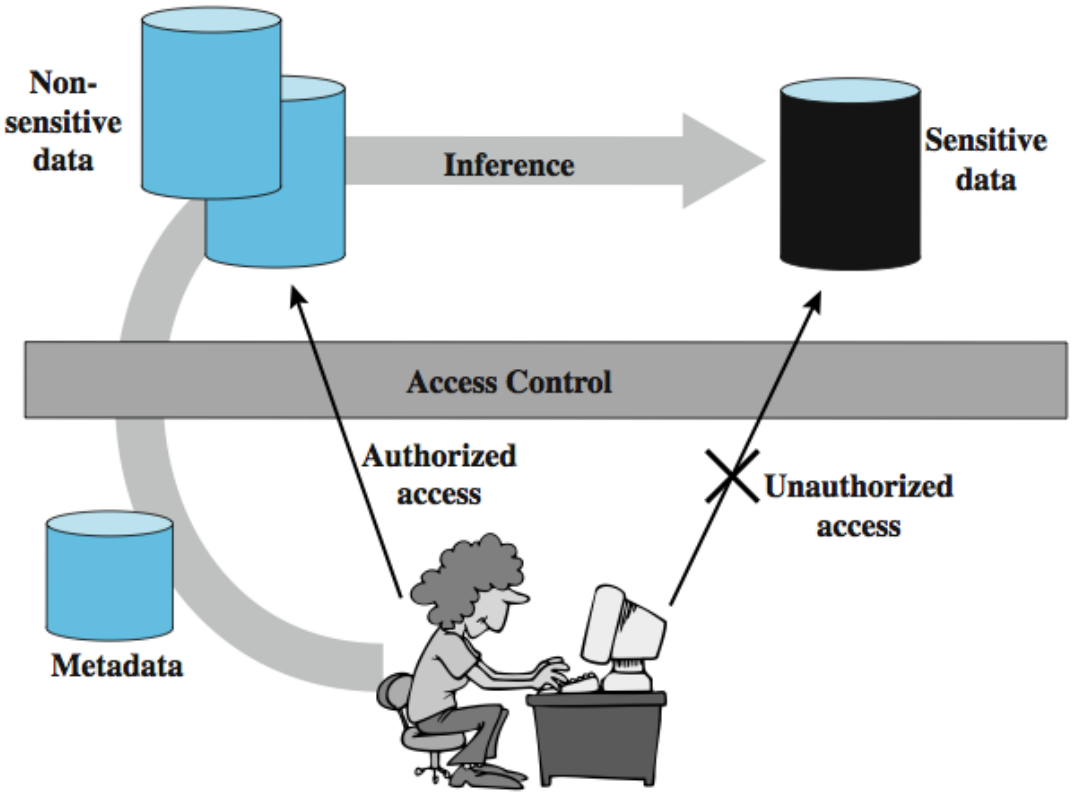
- Statistical databases used to provide statistics about various populations
  - Users permitted to retrieve statistical information
  - Must prohibit retrieval of individual data
- Population: set of tuples of a relation (table) that satisfy some selection condition

PERSON

Name	Ssn	Income	Address	City	State	Zip	Sex	Last_degree

Figure 30.3 The PERSON relation schema for illustrating statistical database security

Inference Problem



Inference Example

Name	Position	Salary ($)	Department	Dept. Manager
Andy	senior	43,000	strip	Cathy
Calvin	junior	35,000	strip	Cathy
Cathy	senior	48,000	strip	Cathy
Dennis	junior	38,000	panel	Herman
Herman	senior	55,000	panel	Herman
Ziggy	senior	67,000	panel	Herman

(a) Employee table

Position	Salary ($)
senior	43,000
junior	35,000
senior	48,000

Name	Department
Andy	strip
Calvin	strip
Cathy	strip

(b) Two views

Name	Position	Salary ($)	Department
Andy	senior	43,000	strip
Calvin	junior	35,000	strip
Cathy	senior	48,000	strip

(c) Table derived from combining query answers

Introduction to Statistical Database Security (cont'd.)

- Only statistical queries are allowed

```
Q1: SELECT COUNT (*)FROM PERSON
    WHERE <condition>;
Q2: SELECT AVG (Income) FROM PERSON
    WHERE <condition>;
```

- Preventing the inference of individual information
  - Provide minimum threshold on number of tuples
  - Prohibit sequences of queries that refer to the same population of tuples
  - Introduce slight noise or inaccuracy
  - Partition the database
    - Store records in groups of minimum size

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

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

Challenges to Maintaining Database Security

- Data quality
  - Quality stamps
  - Application-level recovery techniques to automatically repair incorrect data
- Intellectual property rights
  - Digital watermarking techniques

Challenges to Maintaining Database Security (cont'd.)

- Database survivability
  - Confinement: take immediate action to eliminate/reduce attacker's access
  - Damage assessment
  - Reconfiguration
  - Repair: recover corrupted or lost data and reinstall failed system functions
  - Fault treatment: identify the weaknesses and holes

Oracle Label-Based Security

- Oracle label security
  - Enables row-level access control
  - Every table or view has an associated security policy
- Virtual private database (VPD) technology
  - Feature that adds predicates to user statements to limit their access in a transparent manner to the user and the application
  - Based on policies

Label Security Architecture

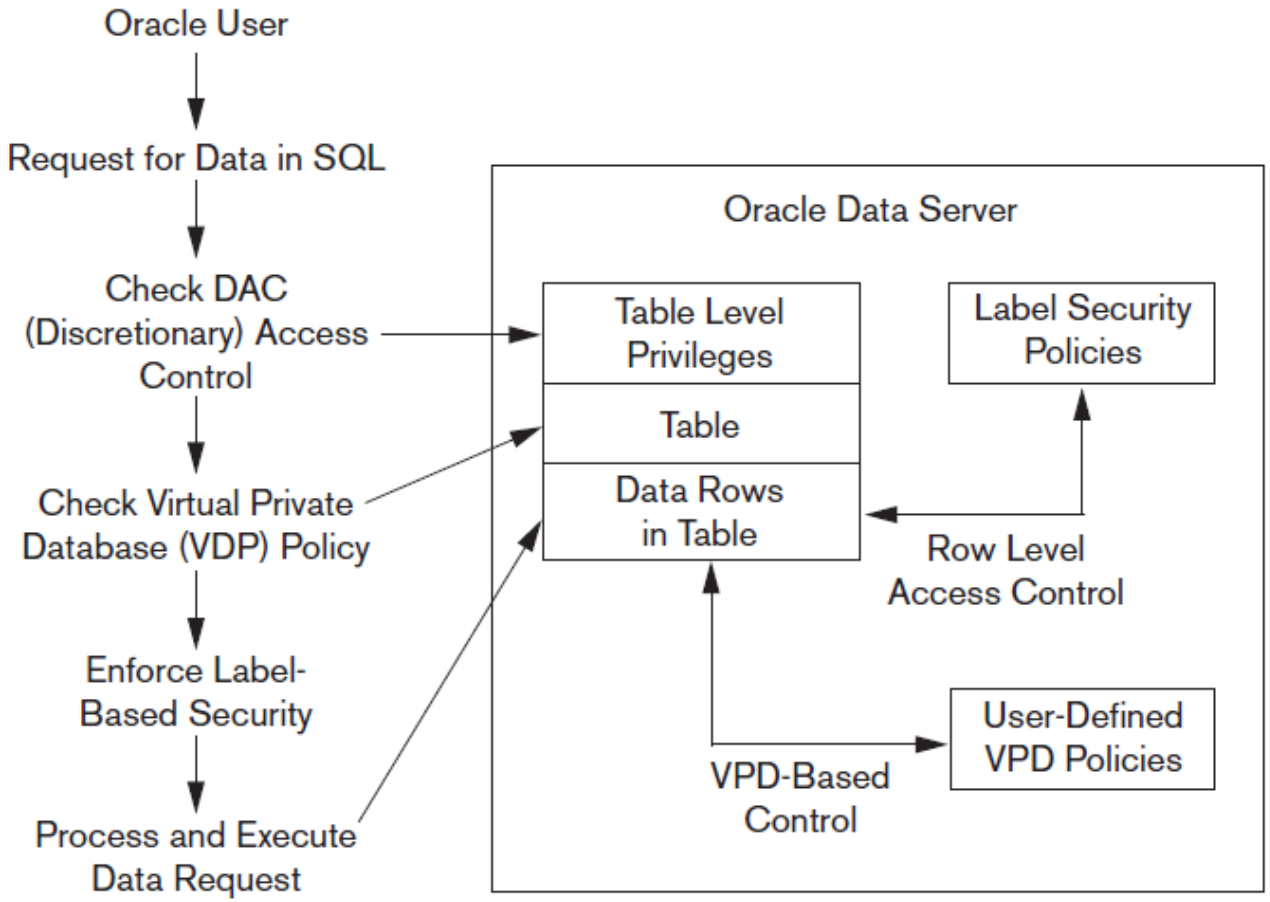


Figure: Oracle label security architecture. Data from: Oracle (2007)

How Data Labels and User Labels Work Together

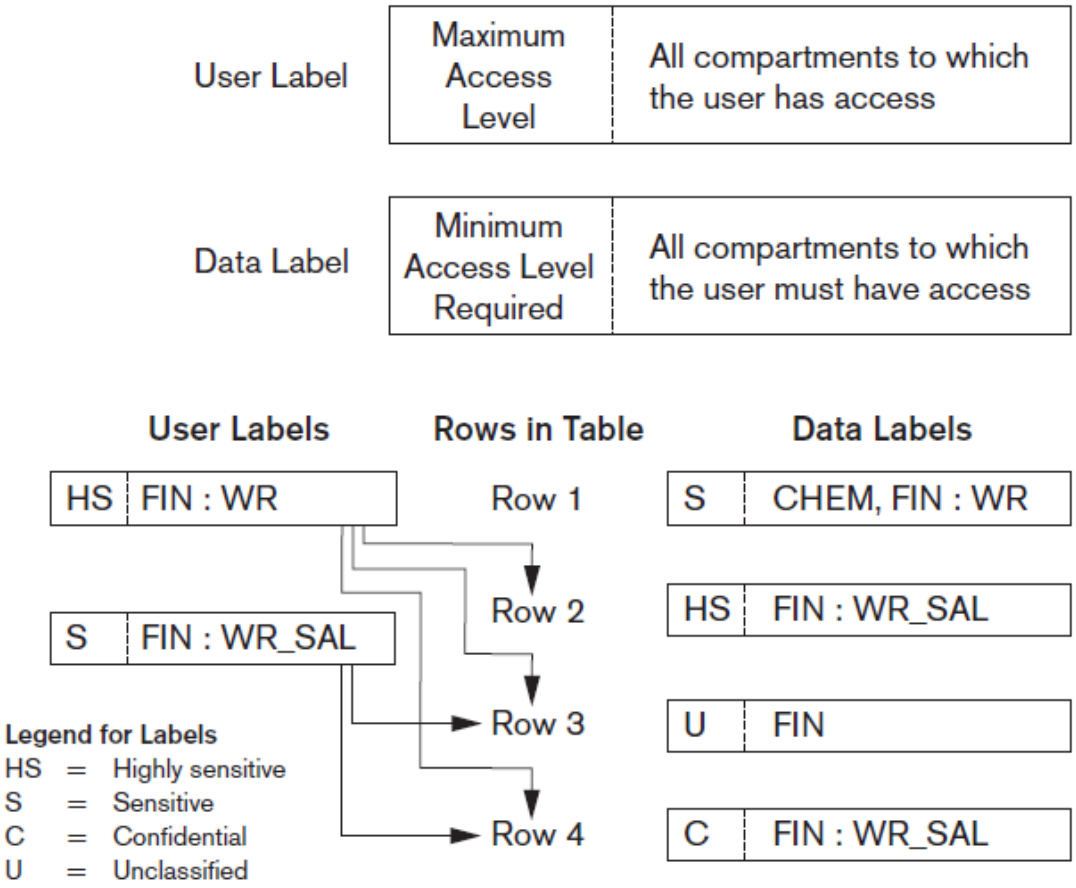


Figure: Data labels and user labels in Oracle. Data from: Oracle (2007)

Summary

- Threats to databases
- Types of control measures
  - Access control
  - Inference control
  - Flow control
  - Encryption
- Mandatory access control
- SQL injection
- Key-based infrastructures