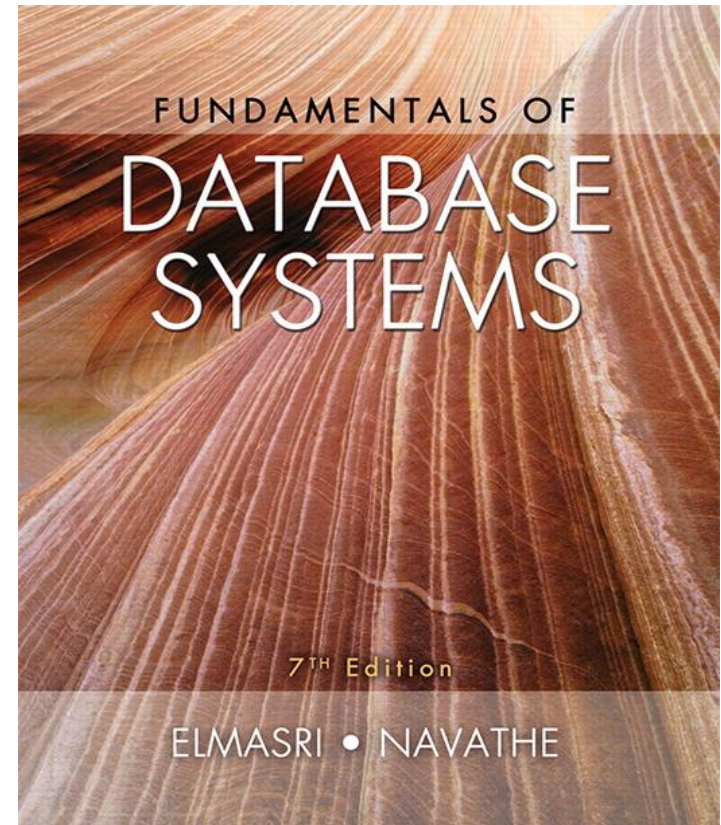


Comp-4150: Advanced and Practical Database Systems

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CHAPTER 30

Database Security



Chapter 30: Database Security

Outline

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- 2. Discretionary Access Control Based on Granting and Revoking Privileges
- 3. Mandatory Access Control and Role-Based Access Control for Multilevel Security
- 4. SQL Injection
- 5. Introduction to Statistical Database Security
- 6. Introduction to Flow Control
- 7. Encryption and Public Key Infrastructures
- 8. Privacy Issues and Preservation
- 9. Challenges to Maintaining Database Security

30.1 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

Introduction to 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

30.2 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 $\text{class}(S) \geq \text{class}(O)$
- Star property
 - Subject not allowed to write an object unless $\text{class}(S) \leq \text{class}(O)$
 - Prevent information from flowing from higher to lower classifications
- Attribute values and tuples considered as data objects

(a) EMPLOYEE

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

(b) EMPLOYEE

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

(c) EMPLOYEE

Name	Salary	JobPerformance	TC
Smith U	NULL U	NULL U	U

(d) 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

Figure 30.2 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

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

30.4 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

30.5 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	<u>Ssn</u>	Income	Address	City	State	Zip	Sex	Last_degree
------	------------	--------	---------	------	-------	-----	-----	-------------

Figure 30.3 The PERSON relation schema for illustrating statistical database security

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

30.6 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

30.7 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

30.8 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

30.9 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
 - Damage assessment
 - Reconfiguration
 - Repair
 - Fault treatment

30.10 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

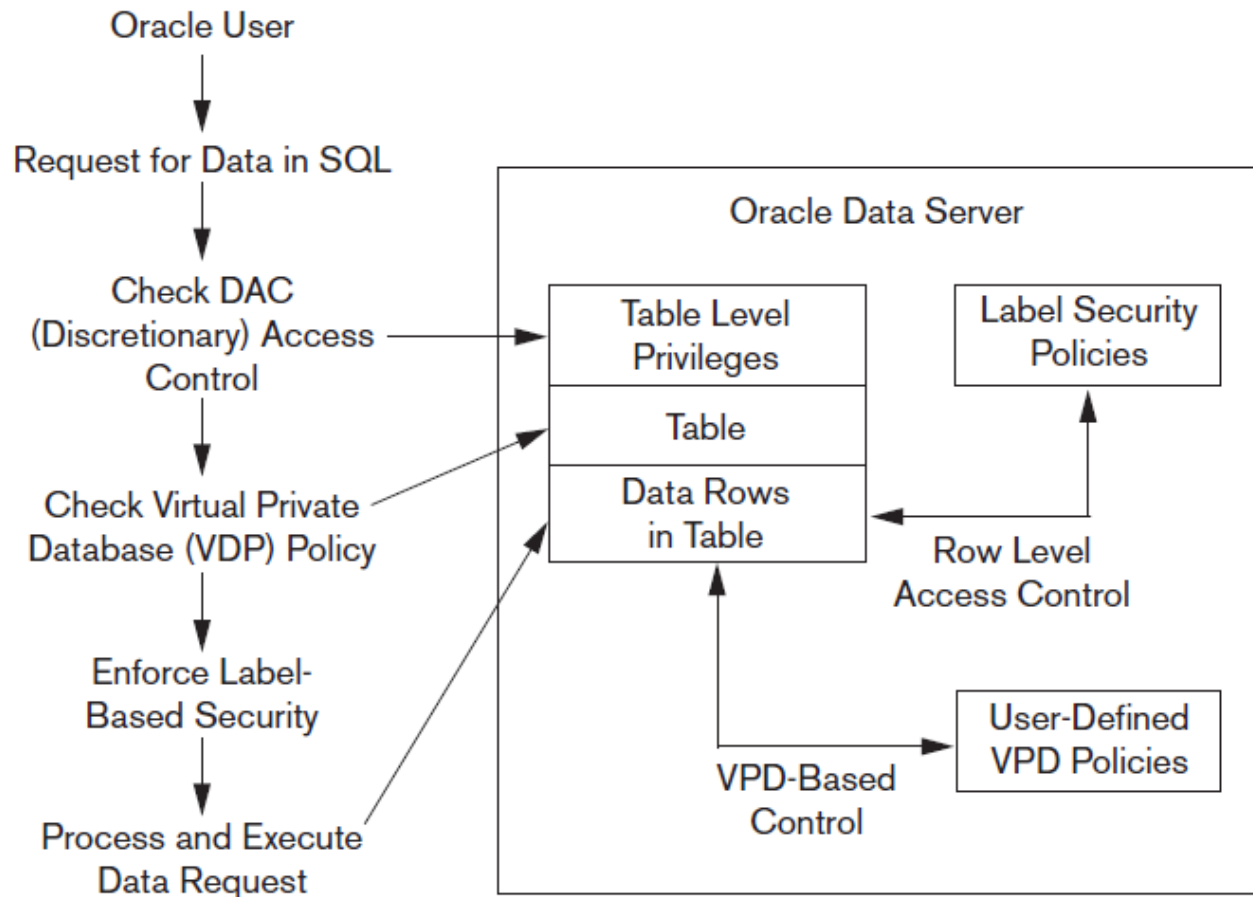


Figure 30.4 Oracle label security architecture. Data from: Oracle (2007)

How Data Labels and User Labels Work Together

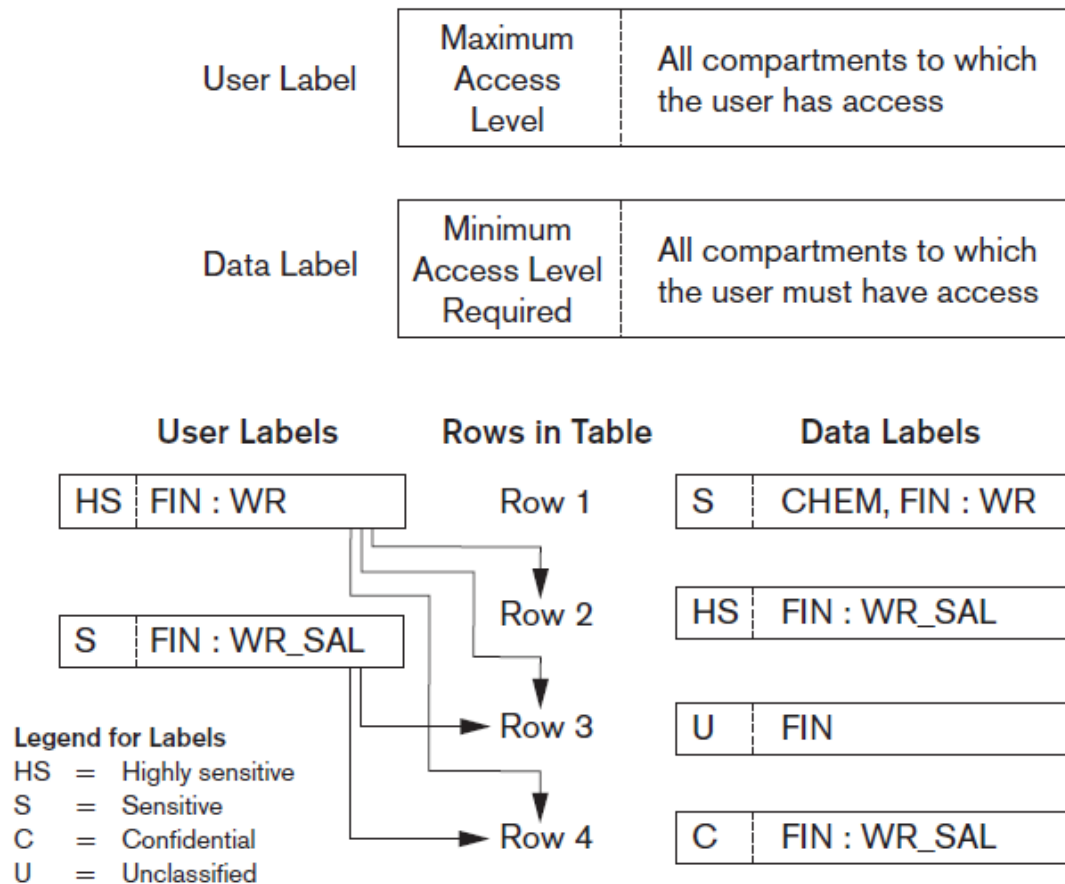


Figure 30.5 Data labels and user labels in Oracle. Data from: Oracle (2007)

30.11 Summary

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