Database Security

Introduction: Security in a DBMS (Database Management System) is a critical aspect of database management that ensures the protection of data from unauthorized access, malicious cyber-attacks, misuse, or corruption. It includes various mechanisms such as authentication, access control, encryption, and auditing to safeguard sensitive information.

Security is an important issue in database management because information stored in a database is very valuable and many time, very sensitive. So the data in a database management system need to be protected from misuse and should be protected from unauthorized access and updates. It is popular belief that hackers cause most security breaches (A security breach refers to unauthorized access, disclosure, or manipulation of sensitive data, computer systems, applications, networks, or devices.), but in reality 80% of data loss is due to insiders.

Importance of Database Security

Database security is crucial for protecting sensitive information stored in a DBMS from unauthorized access, breaches, and corruption. Below are key reasons why database security is essential, along with detailed explanations for each point.

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1. Protects Sensitive Data

Databases store confidential information such as financial records, personal details, healthcare data, and business transactions. If

security measures are weak, this data can be accessed by unauthorized individuals, leading to identity theft or financial fraud.

Example:

- **A hospital database** restricts patient information to doctors and medical staff.
- **A banking system** prevents unauthorized employees from viewing customer account details.

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2. Prevents Unauthorized Access

Unauthorized users, including hackers and even employees, may attempt to access or modify database records. Implementing **authentication (user verification)** and **access control (user permissions)** ensures that only authorized individuals can access sensitive data.

Example:

- In a hospital management system, only doctors should access patient medical records, while receptionists should only manage appointments.

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3. Ensures Data Integrity (Prevents Tampering)

Data integrity ensures that the information stored in a database remains accurate, complete, and unaltered unless modified by authorized users. Security measures prevent accidental changes, malicious modifications, and corruption of data.

Example: A hacker changing employee salaries in a company database can lead to financial losses. Security features like **encryption** help maintain integrity.

4. Prevents Data Loss and Corruption

Cyberattacks, malware, and system failures can corrupt or delete critical database files. **Regular backups, firewalls** help prevent and recover from such incidents.

Example:

- A power outage in a data center could corrupt transaction records. **Automated backups and disaster recovery plans** ensure data restoration.

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5. Protects Against Cyber Threats (Hacking, SQL Injection, Malware)

Databases are prime targets for cybercriminals using **SQL injection and malware** to steal or corrupt data. Security measures like **firewalls, encryption, and input validation** prevent these attacks.

Example:

- **SQL Injection Attack:** If an attacker inputs malicious SQL code into a login form, they could gain access to the entire database.

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6. Ensures Business Continuity

If a database is compromised ("Compromised data" means sensitive or confidential information has been accessed, stolen, or tampered

by unauthorized individuals), a business may suffer downtime, leading to financial losses and reputational damage. Strong security measures ensure that data remains available and that operations continue without interruption.

Example:

- A retailer's database going offline due to a cyberattack could halt(stop) all online transactions, causing revenue loss.

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7. Data Tampering

Privacy of communications is essential to ensure that data cannot be modified or viewed in transit. The chances of data tampering are high in case of distributed environments as data moves between sites. In a data modification attack, an unauthorized party on the network stop data in transit and changes that data before retransmitting it.

Example:

Changing the amount of a banking transaction from Rs. 1000 to Rs. 10000.

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8. Builds Customer and Stakeholder Trust

Explanation:

Customers and stakeholders expect businesses to protect their data. A security breach can damage trust, harm brand reputation, and lead to customer loss.

Example:

- If an e-commerce website suffers a data breach exposing customer credit card details, customers may stop using its services.

9. Insider Threats

Employees with database access might misuse their privileges to steal or manipulate data.

Example:

- A disgruntled employee trying to delete financial records can be prevented with **restricted access.**

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10. Supports Secure Data Sharing and Collaboration

Businesses often share data between departments, partners, or clients. **Encryption, role-based access** ensure that data is shared securely without leaks or unauthorized modifications.

Example:

- A company sharing **data** with vendors must ensure that only authorized partners can access relevant details.

Security Threats

A Database Management System (DBMS) is vulnerable to various security threats that can lead to data breaches, loss, corruption, or

unauthorized modifications. Below are the most critical threats in DBMS security, along with detailed explanations for each.

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1. Unauthorized Access

Explanation:

Unauthorized users may try to gain access to the database using stolen credentials, weak authentication, or system loopholes. Without proper **access control and authentication**, attackers can view, modify, or delete sensitive data.

Example:

- A hacker using a stolen password to access a bank's customer database and transfer funds fraudulently.

Prevention:

- Implement **Multi-Factor Authentication (MFA)**.
- Enforce **strong password policies**.
- Use **role-based access control (RBAC- Permissions are assigned based on user roles (e.g., Admin, Manager, Employee)** to limit user privileges.

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2. SQL Injection Attacks

Explanation:

SQL injection is a hacking technique where attackers insert **malicious SQL queries** into input fields to manipulate the database.

This can allow them to **bypass authentication, extract data, or even delete entire tables**.

Example:

- **Malicious Input:**

SELECT * FROM users WHERE username = 'admin' --' AND password = 'password';

    - The -- comment ignores password verification, granting access without authentication.

Prevention:

- Perform **input validation** to block suspicious characters.
- Implement **firewalls** to filter SQL injection attempts.

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3. Privilege Abuse (Insider Threats)

Explanation:

Employees or administrators with high-level database access might misuse their privileges to steal, modify, or leak sensitive data.

Example:

- A disgruntled employee **deleting critical business records** or **selling customer data** to competitors.

Prevention:

- Implement **Role-Based Access Control (RBAC)** to restrict permissions.

- Monitor and log all **user activities** in the database.
- Use **audit trails** to detect and track suspicious behavior.

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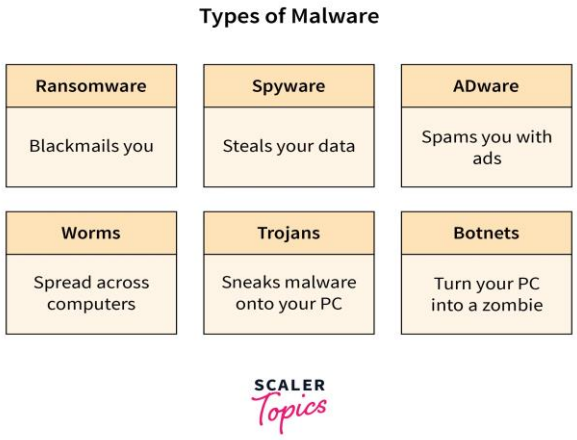
4. Malware and Ransomware Attacks

Explanation:

Attackers may use malware or ransomware to **encrypt** database files, making them inaccessible unless a ransom is paid.



Example:

- In 2021, the **Colonial Pipeline ransomware attack** disrupted fuel supply by locking access to the company's database.

Prevention:

- Regularly **update database security patches**.
- Use **antivirus and anti-malware tools**.
- Maintain **offline and cloud backups** to recover from ransomware attacks.

5. Denial of Service (DoS) Attacks

Explanation:

A DoS attack floods the database server with excessive requests, overwhelming it and causing slowdowns or crashes.

Example:

- Attackers sending millions of fake queries to an e-commerce database, preventing customers from placing orders.

Prevention:

- Set **query execution limits** to prevent excessive requests.
- Use **firewalls and Intrusion Detection Systems (IDS)** to filter malicious traffic.

6. Data Leakage and Unsecured Data Transmission

Explanation:

If data is not **properly encrypted**, attackers can intercept it while being transferred over the network.

Example:

- A hacker **eavesdropping (To listen secretly to a private conversation) on an unencrypted Wi-Fi network** can steal credit card details from an online transaction.

Prevention:

- Use **TLS (Transport Layer Security)** to encrypt data in transit.
- Implement **database encryption** to protect stored data.

- Restrict access to **database ports and communication channels**.

7. Phishing and Social Engineering Attacks

Explanation:

Hackers trick database administrators or employees into revealing login credentials through fake emails, messages, or phone calls.

Example:

- A phishing email posing as a security update asks an employee to enter their database login credentials, which are then stolen.

Prevention:

- Train employees to recognize **phishing attempts**.
- Implement **Multi-Factor Authentication (MFA)** to prevent unauthorized logins.
- Use **email filters** to block phishing emails.

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8. Weak Authentication and Poor Password Policies

Explanation:

Using weak passwords or default credentials makes it easier for hackers to guess login details.

Example:

- A hacker using a dictionary attack to guess weak passwords like 123456 or password.

Prevention:

- Enforce **strong password policies** (at least **12 characters, uppercase, lowercase, numbers, and symbols**).
- Implement **account lockout policies** after multiple failed login attempts.

9. Backup Data Theft

Explanation:

Hackers may target **backup files** stored on external drives or cloud storage if they are not properly secured.

Example:

- A company storing **unencrypted customer backups** in the cloud risks exposure if the cloud account is hacked.

Prevention:

- Encrypt all **backup files** before storage.
- Store backups in **multiple secure locations**.
- Limit access to backup files using **strict permissions**.

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10. Insider Sabotage

Explanation:

Disgruntled(disappointed/annoyed) employees or unethical administrators may **delete or alter** database records to harm the organization.

Example:

- A former employee, before leaving the company, deletes all financial records from the database.

Prevention:

- Implement **role-based access controls (RBAC)**.
- Immediately **revoke access for departing employees**.

Security Mechanisms/Methods in DBMS

A **Database Management System (DBMS)** must implement **various security mechanisms** to protect against threats like unauthorized access, data breaches, and cyberattacks. Below are the key security mechanisms in a DBMS, explained in detail.

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1. Authentication Mechanism

Explanation:

Authentication verifies the identity of users before granting them access to the database. It ensures that only authorized users can log in.

Example:

- A user must enter a **username and password** to access an online banking system.

Types of Authentication:

- **Single-Factor Authentication (SFA)** – Only a password is required.
- **Multi-Factor Authentication (MFA)** – Requires an additional factor, like an **OTP (One-Time Password)** or biometric verification.
- **Biometric Authentication** – Uses fingerprint or facial recognition.

Prevention:

- Enforce **strong password policies**.
- Implement **MFA for critical database accounts**.
- Use **biometric authentication** where possible.

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2. Authorization and Access Control

Explanation:

Authorization defines **who can access what** in the database by assigning different privileges to different users.

Example:

- In a **hospital database**, doctors can access patient medical records, but receptionists can only access appointment details.

Types of Access Control:

- **Role-Based Access Control (RBAC)** – Assigns permissions based on user roles (e.g., Admin, Manager, Employee).

- **Discretionary Access Control (DAC)** – Data owners decide who gets access.
- **Mandatory Access Control (MAC)** – Access is controlled by predefined security policies (used in military and government databases).

Prevention:

- Follow the **Principle of Least Privilege (PoLP)** – Users get only the minimum permissions needed.
- Regularly **review and update user roles**.
- Use **fine-grained access control** to restrict access to sensitive data.

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3. Encryption Mechanism

Explanation:

Encryption converts **plaintext data** into an **unreadable format** (ciphertext) to protect it from unauthorized access.

Example:

- **Encrypted Credit Card Information** stored in an e-commerce database prevents hackers from reading the data even if they gain access.

Types of Encryption:

- **Data-at-Rest Encryption** – Protects stored data.

- **Data-in-Transit Encryption** – Protects data during transmission.
- **End-to-End Encryption (E2EE)** – Data remains encrypted throughout communication channels.

Prevention:

- Use **AES (Advanced Encryption Standard)** for encrypting stored data.
- Implement **SSL(Secure Socket Layer)for securing data transmission**.
- Encrypt **backup files** to prevent unauthorized access.

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4. Backup and Recovery Mechanism

Explanation:

Regular backups ensure that data can be restored in case of data loss due to cyberattacks, system failures, or human errors.

Example:

- A company suffering a **ransomware attack** can restore its database using recent backups instead of paying the ransom.

Types of Backups:

- **Full Backup** – A complete copy of the database.
- **Incremental Backup** – Stores only changes made since the last backup.

- **Differential Backup** – Stores all changes since the last full backup.

Prevention:

- Automate **daily and weekly backups**.
- Store **backups in multiple locations (cloud, offline storage)**.
- Test **disaster recovery plans regularly**.

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5. Firewalls and Network Security Mechanisms

Explanation:

Firewalls protect the database from external threats by blocking unauthorized network traffic.

Example:

- A firewall blocks an **IP address trying to make multiple failed login attempts** on a database server.

Types of Firewalls:

- **Network Firewalls** – Protects the entire network where the database is hosted.
- **Database Firewalls** – Monitors and filters SQL queries for suspicious patterns.

Prevention:

- Restrict **database access to specific IP addresses**.
- Block **unauthorized remote connections**.

6. Time-Based and Location-Based Access Control

Explanation:

Restricts database access based on **time of day** or **geographic location**.

Example:

- A company may allow employees to access the database only **during working hours** from a specific office location.

Prevention:

- Implement **geofencing** to block logins from unauthorized countries.
- Set **session time limits** for database access.