SECURITY IN COMPUTING, FIFTH EDITION

Databases

Objectives for Chapter 7

- Basic database terminology and concepts
- Security requirements for databases
- Implementing access controls in databases
- Protecting sensitive data
- Data mining and big data

Database Terms

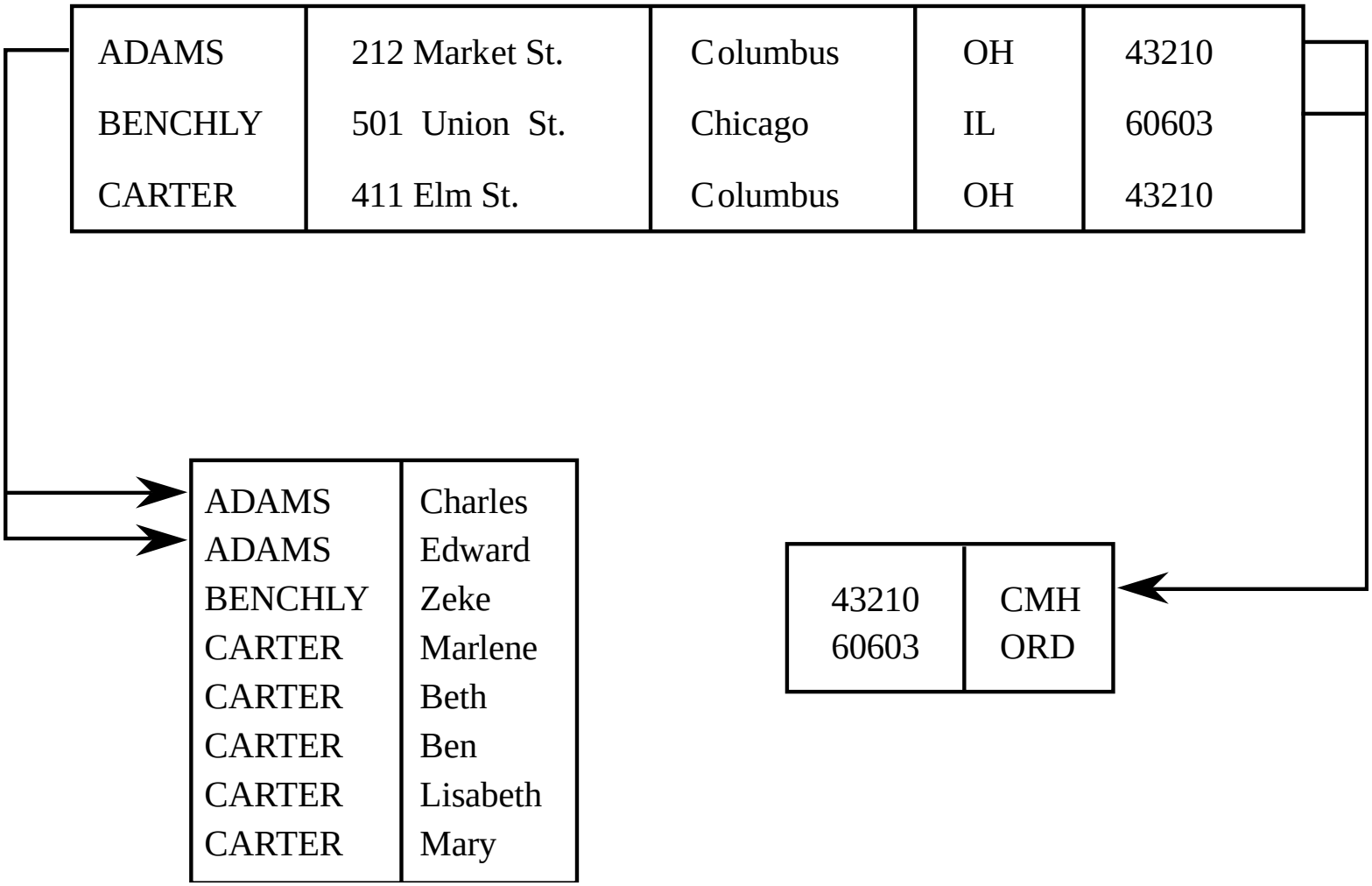
- Database administrator
- Database management system (DBMS)
- Record
- Field/element
- Schema
- Subschema
- Attribute
- Relation

Database Terms

- What is a database?
  - A collection of data and a set of rules that organize the data by specifying certain relationships among the data
- Database administrator
  - Person who defines the rules that organize the data and controls who should have access to what parts of the data
- Database management system (DBMS)
  - The system through which users interact with the database
- Record
  - One related group of data

- Field/element
  - Elementary data items that make up a record (e.g., name, address, city)
- Schema
  - Logical structure of a database
- Subschema
  - The portion of a database a given user has access to
- Attribute
  - A column in a database

Database Example



Schema Example

Name	First	Address	City	State	Zip	Airport
ADAMS	Charles	212 Market St.	Columbus	OH	43210	CMH
ADAMS	Edward	212 Market St.	Columbus	OH	43210	CMH
BENCHLY	Zeke	501 Union St.	Chicago	IL	60603	ORD
CARTER	Marlene	411 Elm St.	Columbus	OH	43210	CMH
CARTER	Beth	411 Elm St.	Columbus	OH	43210	CMH
CARTER	Ben	411 Elm St.	Columbus	OH	43210	CMH
CARTER	Lisabeth	411 Elm St.	Columbus	OH	43210	CMH
CARTER	Mary	411 Elm St.	Columbus	OH	43210	CMH

Queries

- A query is a command that tells the database to retrieve, modify, add, or delete a field or record
- The most common database query language is SQL
- The result of executing a query is a subschema

Example SQL Query

- `SELECT ZIP='43210'`

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CARTER	Mary	411 Elm St.	Columbus	OH	43210	CMH

Advantages of Databases

- A database is a single collection of data, stored and maintained at one central location
- People and application have access to it as needed
- Implementation may involve some other physical storage
  - At a local or remote location
- The users are unaware of the physical arrangements
  - Only see a unified logical arrangement

Advantages of Databases

- Shared access
  - many users can use one common, centralized set of data
- Controlled access
  - Only authorized users are allowed to view or to modify data values
- Minimal redundancy
  - Individual users do not have to collect and maintain their own sets of data
- Data consistency
  - A change to a data value affects all users of the data value
- Data integrity
  - Data values are protected against accidental or malicious undesirable changes

Database Security

- Why is security required?
- Databases used by many entities, such as:
  - banks, large retailers, and law enforcement
- Therefore, data needs to be protected
  - It's confidentiality, integrity and availability to its users

Database Security Requirements

- Physical integrity
- Logical integrity
- Element integrity
- Auditability
- Access control
- User authentication
- Availability

Reliability and Integrity

- Reliability: in the context of databases, reliability is the ability to run for long periods without failing
- Database integrity: concern that the database as a whole is protected against damage
- Element integrity: concern that the value of a specific data element is written or changed only by authorized users
- Element accuracy: concern that only correct values are written into the elements of a database

Database Update

- Concern: What if the database system fails in the middle of an update?
  - Leaving the database in a partially updated and inconsistent state
- Solution: two-phase update

Two-Phase Update

- Phase 1: Intent
  - DBMS does everything it can, other than making changes to the database, to prepare for the update
    - Collects records, opens files, locks out users, makes calculations
  - DBMS commits by writing a commit flag to the database
- Phase 2: Write
  - DBMS completes all write operations
  - DBMS removes the commit flag
- If the DBMS fails during either phase 1 or phase 2, it can be restarted and repeat that phase without causing harm

Other Database Security Concerns

- Error detection and correction codes to protect data integrity
- For recovery purposes, a database can maintain a change log, allowing it to repeat changes as necessary when recovering from failure
- Databases use locks and atomic operations to maintain consistency
  - Writes are treated as atomic operations
  - Records are locked during write so they cannot be read in a partially updated state

Sensitive Data

- Inherently sensitive
  - Passwords, locations of weapons
- From a sensitive source
  - Confidential informant
- Declared sensitive
  - Classified document, name of an anonymous donor
- Part of a sensitive attribute or record
  - Salary attribute in an employment database
- Sensitive in relation to previously disclosed information
  - An encrypted file combined with the password to open it

Preventing Disclosure

- Keeping records from being dumped out of the database is not sufficient to actually prevent disclosure.
- There are many ways to deduce the content of a database listed on this slide
  - all of them must be considered when protecting sensitive database information.
- To apply the appropriate protection mechanisms, it is important to understand:
  - the range of possible contents of each attribute
  - the data available to potential attackers

Types of Disclosures

- Exact data
- Bounds
- Negative result
- Existence
- Probable value
- Direct inference
- Inference by arithmetic
- Aggregation
- Hidden data attributes
  - File tags
  - Geotags

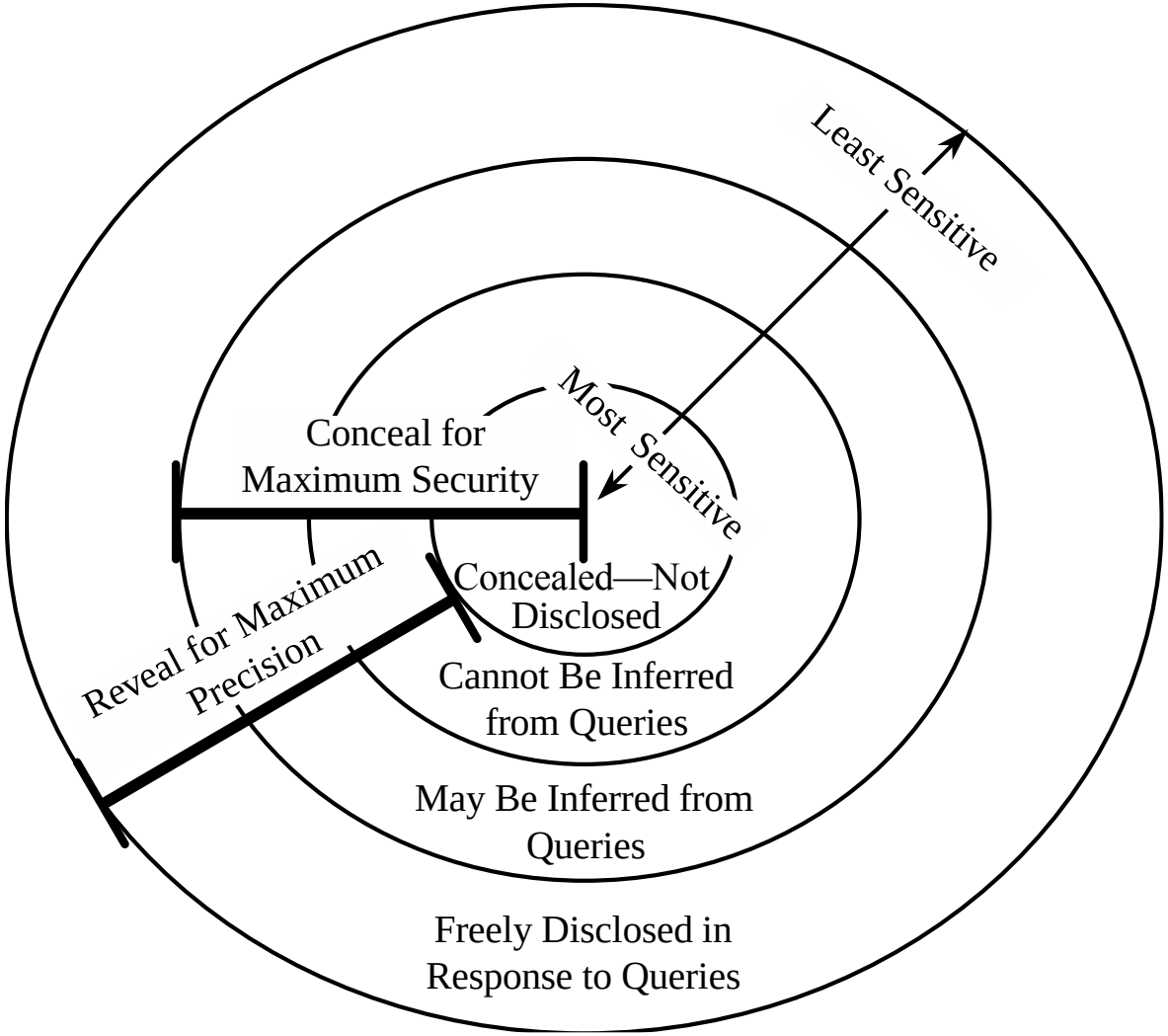
Preventing Disclosure

- Suppress obviously sensitive information
- Keep track of what each user knows based on past queries
- Disguise the data

Security vs. Precision

- Precise, complete, and consistent responses to queries against sensitive information make it more likely that the sensitive information will be disclosed

Security vs. Precision



Suppression Techniques

- Limited response suppression
  - Eliminates certain low-frequency elements from being displayed
- Combined results
  - Ranges, rounding, sums, averages
- Random sample
- Blocking small sample sizes
- Random data perturbation
  - Randomly add or subtract a small error value to/from actual values
- Swapping
  - Randomly swapping values for individual records while keeping statistical results the same

Data Suppression

- Less complex data makes for simpler inference and therefore is more likely to require suppression.
- The disclosure prevention must be balanced against the database requirements
  - as the loss of precision and completeness may make the database unusable

Data Mining

- Data mining uses statistics, machine learning, mathematical models, pattern recognition, and other techniques to discover patterns and relations on large datasets
- The size and value of the datasets present an important security and privacy challenge, as the consequences of disclosure are naturally high

Data Mining Challenges

- Correcting mistakes in data
  - What happens when data is moved to more databases before the original database can be corrected?
    - Need for correction may not be disclosed
    - Open challenge
- Preserving privacy
- Granular access control
  - Access control is often performed in a coarse way
- Secure data storage
  - Data may be collected globally and through cloud providers
    - Where security details are largely unknown to users

Data Mining Challenges

- Transaction logs
- Real-time security monitoring

Data Mining Challenges

- Many challenges remain open, partially solved or solved in certain data mining packages.
- As data mining platforms evolve, these features will mature

Summary

- Database security requirements include:
  - Physical integrity
  - Logical integrity
  - Element integrity
  - Auditability
  - Access control
  - User authentication
  - Availability

Summary

- There are many subtle ways for sensitive data to be inadvertently disclosed
- There is no single answer for prevention
- Data mining and big data have numerous open security and privacy challenges

- Questions?