EECS565 Intro to Computer and Information Security

Intro to Database Security

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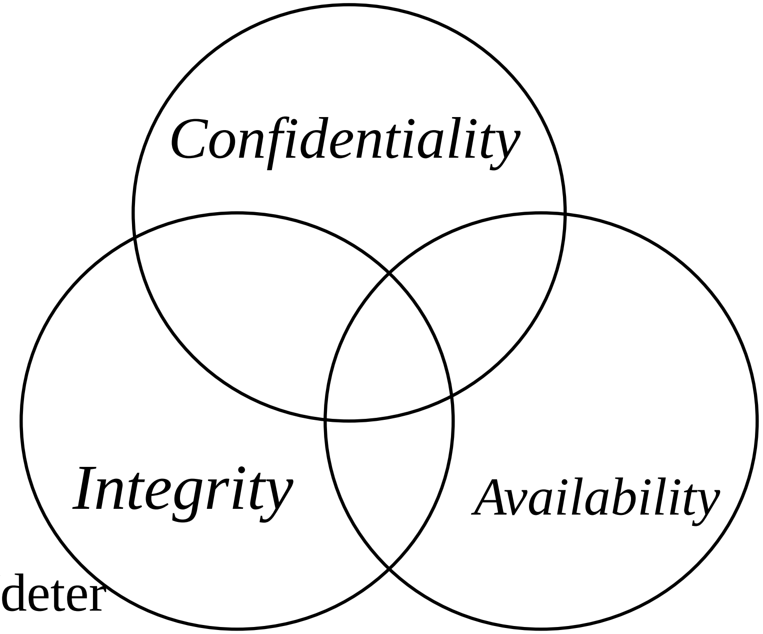
Database Security

Prevent/detect/deter improper
Disclosure of information



Prevent/detect/deter
Improper **modification**
of information

Prevent/detect/deter improper
Denial of access to services

DBMS

- Collection of
  - interrelated data and
  - set of programs to access the data
- Convenient and efficient processing of data
- Database Application Software

Database Security

- Protect Sensitive Data from
  - Unauthorized disclosure
  - Unauthorized modification
  - Denial of service attacks
- Security Controls
  - Security Policy
  - Access control models
  - Integrity protection
  - Privacy problems
  - Fault tolerance and recovery
  - Auditing and intrusion detection

Data Confidentiality

- Access control
  - which data users can access
- Information flow control
  - what users can do with the accessed data
- Inference Attacks
- Data Mining

Access Control

- Ensures that all direct accesses to object are authorized
- Protects against accidental and malicious threats by regulating the read, write and execution of data and programs
- Requires:
  - Proper user identification
  - Information specifying the access rights is protected form modification

Access Control

- Access control components:
  - Access control policy
    - specifies the authorized accesses of a system
  - Access control mechanism
    - implements and enforces the policy

Access Control Models

- How to describe the policies?
  - “Who can access what?”
  - Subject: active entity that requests access to an object
    - - e.g., user or program
  - Object: passive entity accessed by a subject
    - - e.g., record, relation, file
  - Access right (privileges): how a subject is allowed to access an object
    - - e.g., subject s can read object o

Access Control Models

- Mandatory Access Control (MAC)
- Discretionary Access Control (DAC)
- Role-Based Access Control (RBAC)

Mandatory Access Control- MAC

- Motivated by government in late 1980’s/early 1990’s
- Utilize security classifications
  - TS: Top Secret, S: Secret, C: Classified, U: Unclassified
  - TS > S > C > U
- Each subject and object are classified into one of the security classifications (TS, S, etc.)
- Bell-LaPadulla properties (restrictions on data access)
  - simple property: No READ UP
  - star (*) property: No WRITE DOWN (write at own level)

MLS

- Multilevel relational (MLS) schema
  - classification attribute C
  - tuple classification TC
  - R(A_1, C_1, A_2, C_2, ...A_n, C_n, TC) *Jajodia-Sandhu*

MLS Relation Example

Vessel	Objective	Destination
Micra	Shipping	Moon
Vision	Spying	Saturn
Avenger	Spying	Mars
Logos	Shipping	Venus

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Vessel	C-V	Objective	C-O	Destination	C-D	TC
Micra	U	Shipping	U	Moon	U	U
Vision	U	Spying	U	Saturn	U	U
Avenger	C	Spying	C	Mars	C	C
Logos	S	Shipping	S	Venus	S	S

MLS

- Read from MLS tables
  - Access to each record is determined by TC
  - Level U sees first 2 tuples
  - Level C sees first 3 tuples
  - Level S sees all tuples

Vessel	C-V	Objective	C-O	Destination	C-D	TC
Micra	U	Shipping	U	Moon	U	U
Vision	U	Spying	U	Saturn	U	U
Avenger	C	Spying	C	Mars	C	C
Logos	S	Shipping	S	Venus	S	S

MLS Insert

- What if a U user wants to insert a tuple with vessel = Avenger?
- If reject the insert – what will happen?
  - Covert channel
- If insert another Avenger, what about the primary key? Will have 2 Avengers
  - PK + Classification

Vessel	C-V	Objective	C-O	Destination	C-D	TC
Micra	U	Shipping	U	Moon	U	U
Vision	U	Spying	U	Saturn	U	U
Avenger	C	Spying	C	Mars	C	C
Logos	S	Shipping	S	Venus	S	S

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Logos	S	Shipping	S	Venus	S	S

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Logos	S	Shipping	S	Venus	S	S
Avenger	U	Shipping	U	Mars	U	U

MLS Update

- What if the S level wants to update one of the tuples at the U level?
  - U cannot see the update
  - Replicate the tuple

Vessel	C-V	Objective	C-O	Destination	C-D	TC
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Logos	S	Shipping	S	Venus	S	S
Avenger	U	Shipping	U	Mars	U	U

MLS Update

- What if the S level wants to update one of the tuples at the U level?
  - U cannot see the update
  - Replicate the tuple
    - Replicate (Vision, ………., U)
    - Update it to (Vision, ……….., S)

Vessel	C-V	Objective	C-O	Destination	C-D	TC
Micra	U	Shipping	U	Moon	U	U
Vision	U	Spying	U	Saturn	U	U
Avenger	C	Spying	C	Mars	C	C
Logos	S	Shipping	S	Venus	S	S
Avenger	U	Shipping	U	Mars	U	U
Vision	U	Spying	U	Venus	S	S

MLS

- Wrap up
  - Simple
  - Easy to manage: just assign a security classification to each user
  - The security classifications are used in government and military
  - MLS is widely adopted in government and military.

Discretionary Access Control (DAC)

- All commercial DB systems adopt DAC
- Current discretionary authorization models for relational DBMS are based on the System R authorization model
    - P. P. Griffiths and B. W. Wade, "An Authorization Mechanism for a Relational Database System," *ACM Transactions on Database Systems (TODS)* Volume 1 Issue 3, Sept. 1976.
- It is based on ownership administration with administration delegation

Discretionary Access Control (DAC)

- For each subject access right to the objects are defined
  - (subject, object, +/- access mode)
  - E.g. (Black, Employee-relation, read)
- Based on granting and revoking privileges
- Assign privileges
  - to account level (subject)
    - independent of the relations
    - create schema, create table, create view
  - on relation level (object)
    - on a particular base relation or view

Authorization ID's

- A user is referred to by *authorization ID*, typically their login name.
- There is an authorization ID PUBLIC.
  - Granting a privilege to PUBLIC makes it available to any authorization ID.

- The objects on which privileges exist include stored tables and views.
- Other privileges are the right to create objects of a type, e.g., triggers.

Privileges

- A file system identifies certain privileges on the objects (files) it manages.
  - Typically read, write, execute.
- SQL identifies a more detailed set of privileges on objects (relations) than the typical file system.
- Nine privileges in all, some of which can be restricted to one column of one relation.

Privileges

- Some important privileges on a relation:
  1. SELECT = right to query the relation.
     - May apply to only one attribute.
  2. INSERT = right to insert tuples.
  3. DELETE = right to delete tuples.
  4. UPDATE = right to update tuples.
     - May apply to only one attribute.

Granting Privileges

- You have all possible privileges on the objects, such as relations, that you create.
- You may grant privileges to other users (authorization ID’s), including PUBLIC.
- You may also grant privileges WITH GRANT OPTION, which lets the grantee also grant this privilege.

The GRANT Statement

- To grant privileges, say:

  GRANT <list of privileges>

  ON <relation or other object>

  TO <list of authorization ID’s>;

- If you want the recipient(s) to be able to pass the privilege(s) to others add:

  WITH GRANT OPTION

Example: GRANT

- Suppose you are the owner of Sells. You may say:

```
GRANT SELECT, UPDATE(price)
ON Sells
TO sally;
```

- Now Sally has the right to issue any query on Sells and can update the price component only.

Example: Grant Option

- Suppose we also grant:

```
GRANT UPDATE ON Sells TO sally
WITH GRANT OPTION;
```

- Now, Sally not only can update any attribute of Sells, but can grant to others the privilege UPDATE ON Sells.
  - Also, she can grant more specific privileges like `UPDATE(price)ON Sells`.

Revoking Privileges

```
REVOKE <list of privileges>
ON <relation or other object>
FROM <list of authorization ID’s>;
```

- Your grant of these privileges can no longer be used by these users to justify their use of the privilege.
  - But they may still have the privilege because they obtained it independently from elsewhere.

REVOKE Options

- We must append to the REVOKE statement either:
  1. CASCADE. Now, any grants made by a revokee are also not in force, no matter how far the privilege was passed.
  2. RESTRICT. If the privilege has been passed to others, the REVOKE fails as a warning that something else must be done to “chase the privilege down.”

RBAC

- Role-based access control (RBAC)
- Sandhu, R., Coyne, Feinstein, Youman: “Role-Based Access Control Models,” *IEEE Computer*, 29 (2): 38–47.
  - Semantic construct
  - System administrator creates roles according to job functions

RBAC

- Role
  - Specific task competency
  - duty assignments
  - Embody authority and responsibility
- Grant permissions to users in these roles
  - Roles & permissions
  - Users & roles

Motivation

- Roles define individuals and extent of resource access
- Combination of users and permissions can change
  - E.g. user membership in roles
- Permissions associated with roles stable
- Administration of roles rather than permissions
- Role permission predefined
  - Easier to add/remove users membership than create new roles/permissions
- Roles part of SQL3
- Supported by many software products
  - Roles used in Windows NT, XP (system admin)

RBAC basics

- Access control in RBAC exists in:
  - Role-permission (stable)
  - User-role (dynamic)
  - Role-role relationships (stable)
- RBAC supports principles:
  - Least privilege
  - Separation of duties- mutually exclusive roles
  - Data abstraction- abstract permissions (not just R/W)
- Limitations
  - RBAC cannot enforce way principles applied – system admin could configure to violate

Constraints

- Mutually exclusive roles
  - User at most 1 role in ME set
  - Combinations of roles and permissions can be prohibited
- Cardinality
  - Maximum number of members in a role
  - Minimum cardinality difficult to implement
- Prerequisite role
  - User assigned to role B, only if assigned to A
  - Permission p assigned to role only if role has permission q

DAC, MAC vs. RBAC

- DAC vs. MAC emerged from defense security research
- RBAC independent of access control
- RBAC can be used to implement DAC, MAC

Database Encryption

- Application level encryption
- Database encryption

- Protect keys

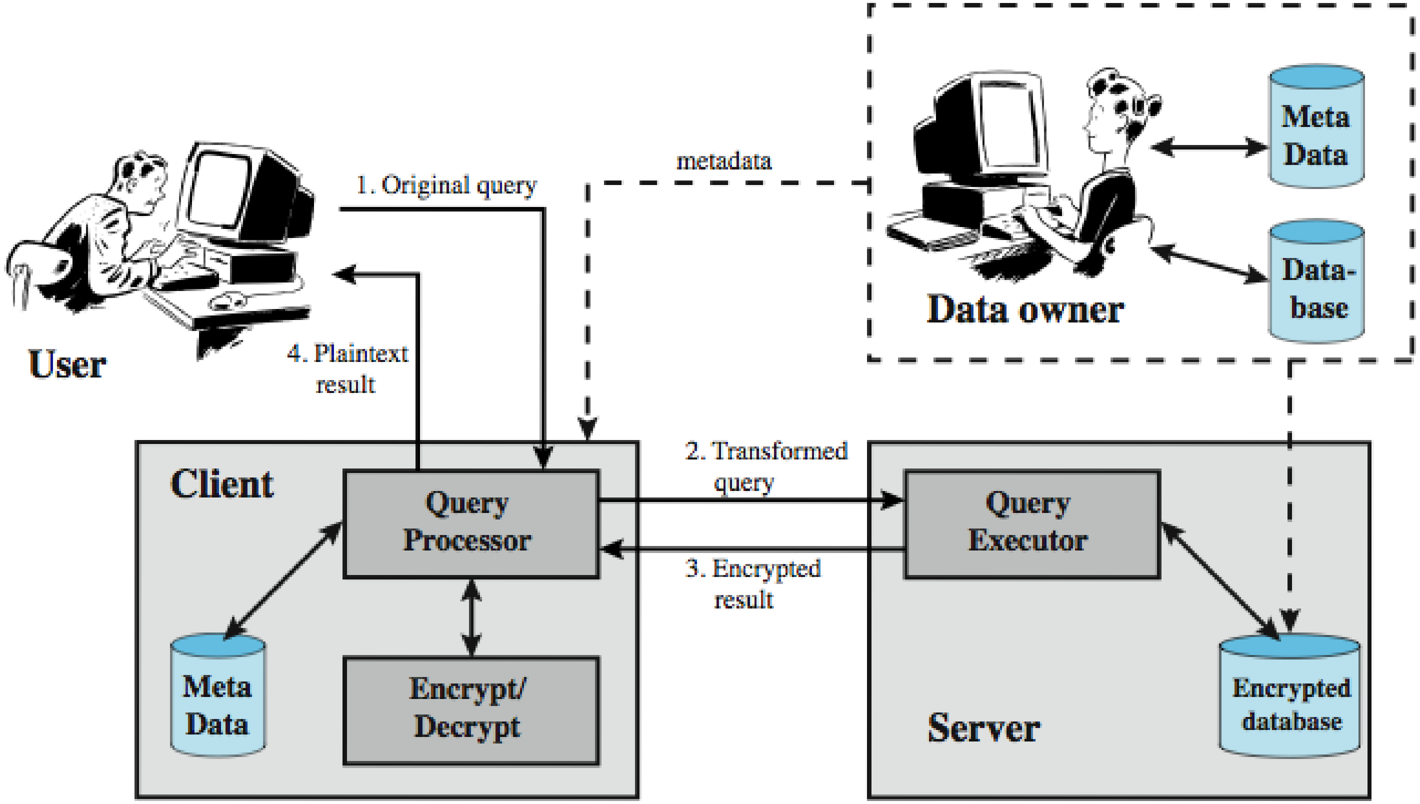
Application Level Encryption

- Data protected in database & storage
- Data protected in use and transit
- Programming needed in the applications
- Power of database limited -indexing, searching, stored procedures
- All access must go through application
- Key management

Database Encryption

- Protects data as it is written to and read from a database
- Secures data in the file-system used by database
- Enables field level encryption
- Transparent to applications
- Watch data in transit

Database Encryption



Limit the amount of encrypt/decrypts

- Three Important Techniques
  - Column level encryption
  - Search without decrypting data
  - Conduct data operations without decrypting data

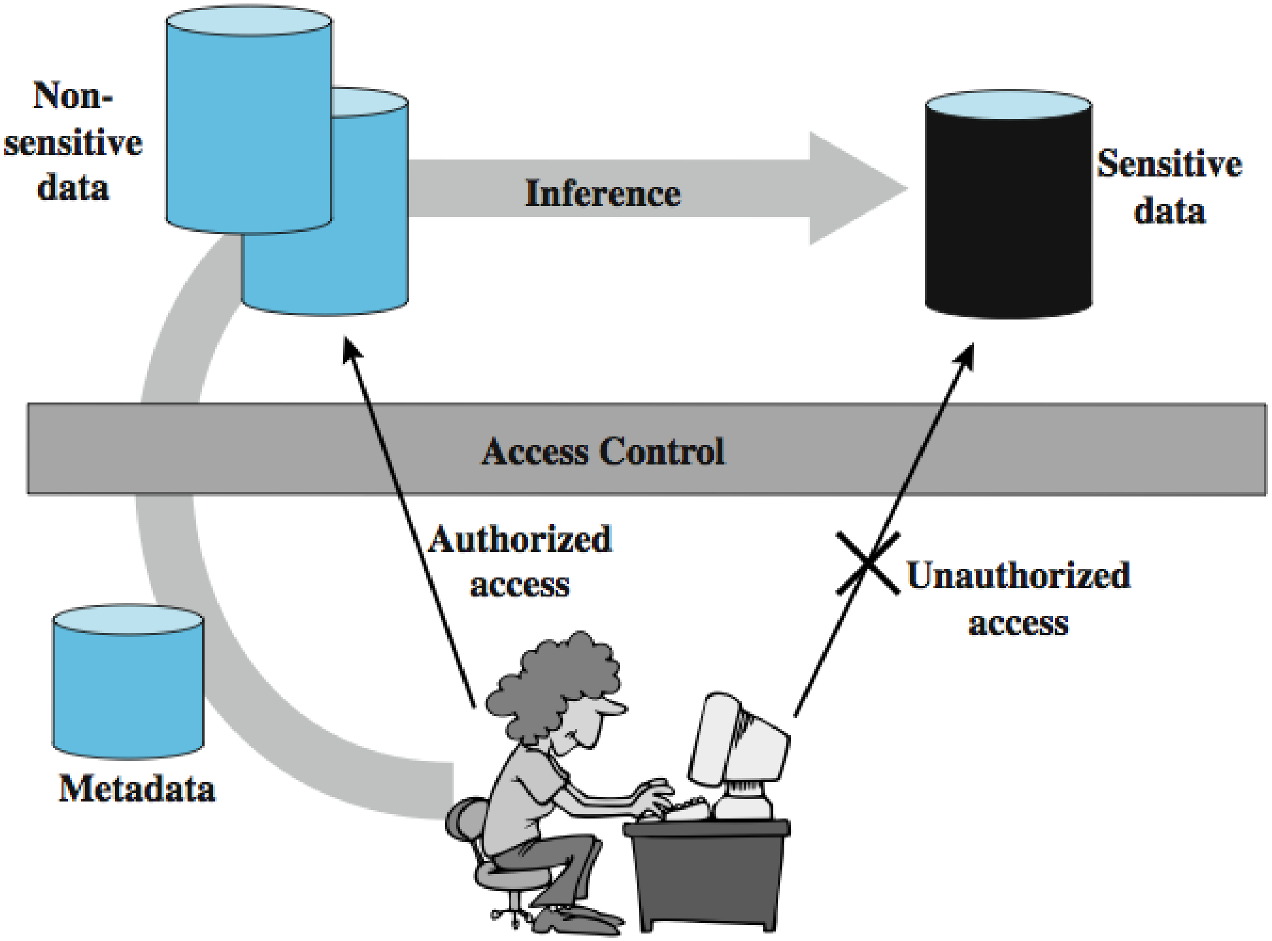
Sharing Non-Sensitive Data

- A database may contain both sensitive (e.g. salary) and non-sensitive (e.g. name) data.
- Security Goal: To disclose only non-sensitive data.
  - In some cases: aggregated sensitive data (e.g. average salary)
- Precision Goal: To protect all sensitive data while disclosing as much non-sensitive data as possible.
- Ideal combination is to maintain perfect security with maximum precision.

Sensitive Data Disclosure

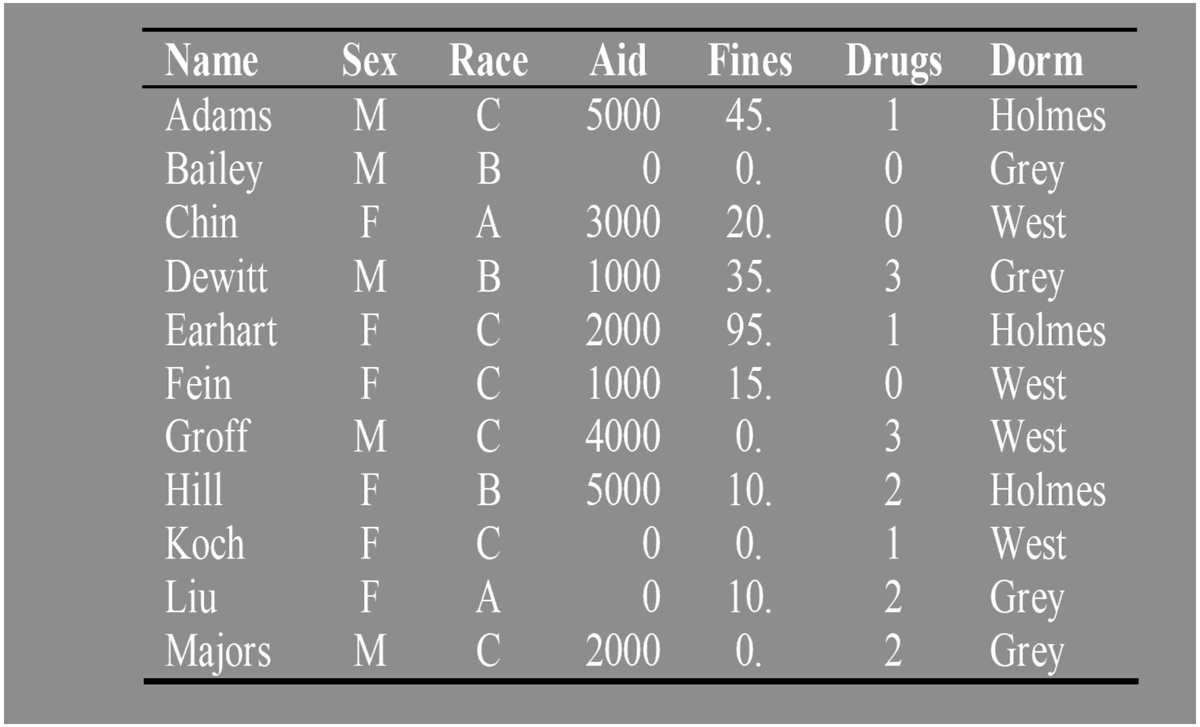
- Exact data: exact value of a sensitive data item
- Bounds: knowing the lower and upper bounds values of a sensitive data item
- Negative Result: queries may be made to determine a negative result from which sensitive data may be disclosed (e.g. Alice’s salary is not lower than 150K/year).
- Existence: the existence of data is itself a sensitive piece of data
- Probable value: it may be possible to determine the probability that a certain element has a certain value.

The Inference Problem



The Inference Problem

- Inference problem is to infer or derive sensitive data from non-sensitive data.
- Sample table with 3 sensitive fields: Aid, Fines and Drugs when disclosed for a given individual



Name	Sex	Race	Aid	Fines	Drugs	Dorm
Adams	M	C	5000	45.	1	Holmes
Bailey	M	B	0	0.	0	Grey
Chin	F	A	3000	20.	0	West
Dewitt	M	B	1000	35.	3	Grey
Earhart	F	C	2000	95.	1	Holmes
Fein	F	C	1000	15.	0	West
Groff	M	C	4000	0.	3	West
Hill	F	B	5000	10.	2	Holmes
Koch	F	C	0	0.	1	West
Liu	F	A	0	10.	2	Grey
Majors	M	C	2000	0.	2	Grey

Direct Attack

```
SELECT Name
FROM Sample
WHERE Sex=‘M’ AND Drugs=1;

SELECT Name
FROM Sample
WHERE (Sex=‘M’ AND Drugs=1)
    OR (Sex<>’M’ AND Sex<>’F’)
    OR Dorm=‘Ayres’;
```

To confuse the DB

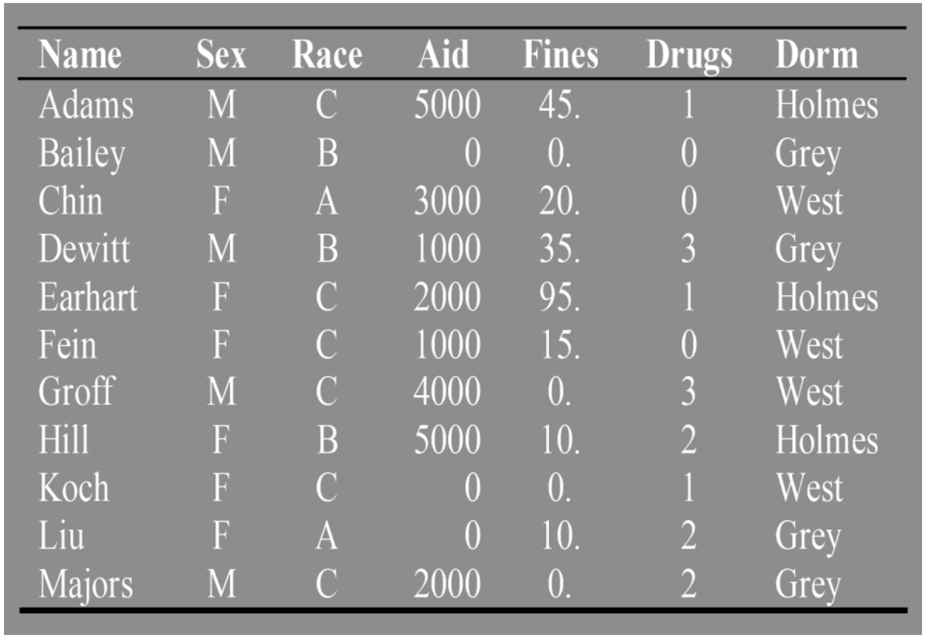
Indirect Attack

- Statistical databases (queries)
- provides data of a statistical nature
  - e.g. counts, averages
- two types:
  - pure statistical database
  - ordinary database with statistical access
    - some users have normal access, others statistical
- access control objective to allow statistical use without revealing individual entries
- security problem is one of inference
- **Indirect attack - infer a result based on one or more statistical results.**

Indirect Attack

- **Sum**: a reported sum may be used to infer a value.

SELECT Dorm, Sex, SUM(Aid) As Sum_Aid
FROM Sample
Group BY Dorm, Sex;



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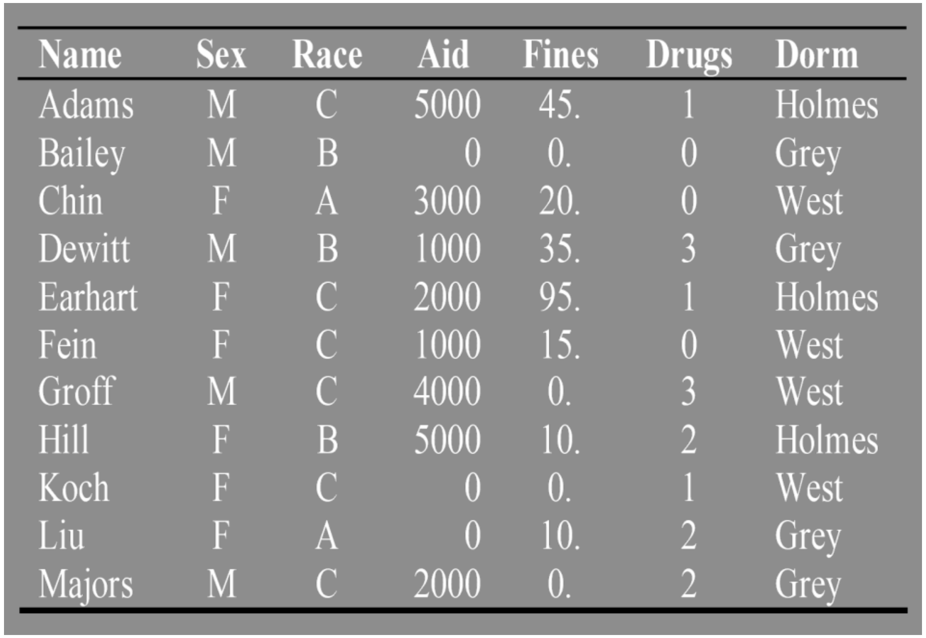
Liu	F	A	0	10.	2	Grey
Majors	M	C	2000	0.	2	Grey

Dorm	Sex	Sum_Aid
Holmes	M	5000
Holmes	F	7000
Grey	M	3000
Grey	F	0
West	M	4000
West	F	4000

Indirect Attack

- **Sum**: a reported sum may be used to infer a value.

```
SELECT  Dorm, Sex, COUNT(*) As    Tot_Students
FROM  Sample
Group BY Dorm, Sex;
```



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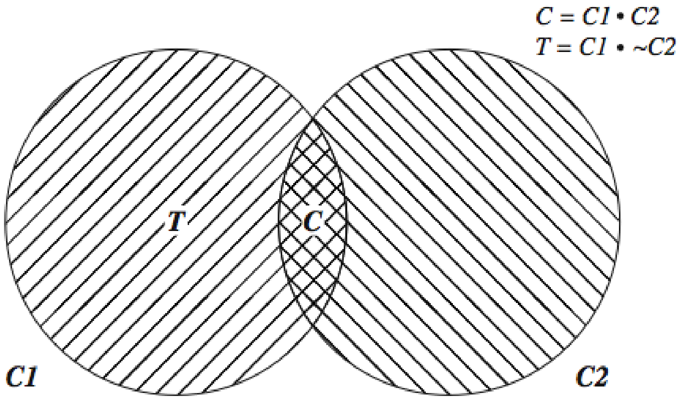
Majors	M	C	2000	0.	2	Grey

Dorm	Sex	Tot_Students
Holmes	M	1
Holmes	F	2
Grey	M	3
Grey	F	1
West	M	1
West	F	3

Tracker Attacks

- divide queries into parts
  - C = C1 AND C2
  - count(C) = count(C1) - count (C1 AND ~*C2)*
- combination is called a tracker
- each part acceptable query size
- overlap is desired result



Tracker Attacks

- Tracker attacks: Generate the desired data by using additional queries that generate small results.

  SELECT COUNT(*)
  FROM Sample
  WHERE Sex = ‘F’ AND Race = ‘C’ AND Dorm = ‘Holmes’;

- Use rules of logic and algebra to rewrite query:

  count (a AND b AND c)
  = count(a) - count(a AND NOT (b AND c))
  = count(a) - count(a AND (NOT b OR NOT c))

Tracker Attacks

```
SELECT COUNT(*)
FROM Sample
WHERE Sex = ‘F’;

SELECT COUNT(*)
FROM Sample
WHERE Sex = ‘F’ AND ((Race  <>‘C’) OR
   (Dorm <> ‘Holmes’));
```

Controls for Inference Attacks

- Query controls
  - Limit overlap between new and previous queries
- Partitioning
  - Cluster records into exclusive groups and only allow queries on entire groups
- Item controls
  - Suppression: query is rejected without sensitive data provided.
  - Concealing: the answer provided is close to but not exactly the actual answer.

Controls for Inference Attacks

- No perfect solution
- Three paths to follow:
  - Suppress obvious sensitive information (easily).
  - Track what the user knows (costly).
    - They are used to limit queries accepted and data provided.
  - Disguise the data (problem with precision).
    - It’s applied only to the released data.