Last time

- Internet Application Security and Privacy
  - Application-layer security and privacy: remailers, PGP/gpg, OTR

This time

- Finish OTR
- Database Security
  - Introduction to Databases
  - Security Requirements
  - Integrity
  - Auditability, Access Control, and Availability

Deniable Authentication

- Do **not** want digital signatures
  - Non-repudiation is great for signing contracts, but undesirable for private conversations
- But we **do** want authentication
  - We can't maintain privacy if attackers can impersonate our friends

- Use Message Authentication Codes
  - We talked about these earlier

No Third-Party Proofs

- Shared-key authentication
  - Alice and Bob have the same MK
  - MK is required to compute the MAC
  - How is Bob assured that Alice sent the message?
- Bob cannot prove that Alice generated the MAC
  - He could have done it, too
  - Anyone who can verify can also forge
- This gives Alice a measure of deniability

Using these techniques

- Using these techniques, we can make our online conversations more like face-to-face “off-the-record” conversations

- But there's a wrinkle:
  - These techniques require the parties to communicate *interactively*
  - This makes them unsuitable for email
  - But they're still great for instant messaging!

Off-the-Record Messaging

- Off-the-Record Messaging (OTR) is software that allows you to have private conversations over instant messaging, providing:
- Encryption
  - Only Bob can read the messages Alice sends him
- Authentication
  - Bob is assured the messages came from Alice

Off-the-Record Messaging

- Perfect Forward Secrecy
  - Shortly after Bob receives the message, it becomes unreadable to anyone, anywhere
- Deniability
  - Although Bob is assured that the message came from Alice, he can't convince Charlie of that fact
  - Also, Charlie can create *forged transcripts* of conversations that are every bit as accurate as the real thing

Off-the-Record Messaging

- Availability of OTR:
  - It's built in to Adium X (a popular IM client for OSX)
  - It's a plugin for pidgin (a popular IM client for Windows, Linux, and others)
    - With these two methods, OTR works over almost any IM network (AIM, ICQ, Yahoo, MSN, etc.)
  - It's a proxy for other Windows or OSX AIM clients
    - Trillian, iChat, etc.
  - Third parties have written plugins for other clients
    - Miranda, Trillian, Kopete

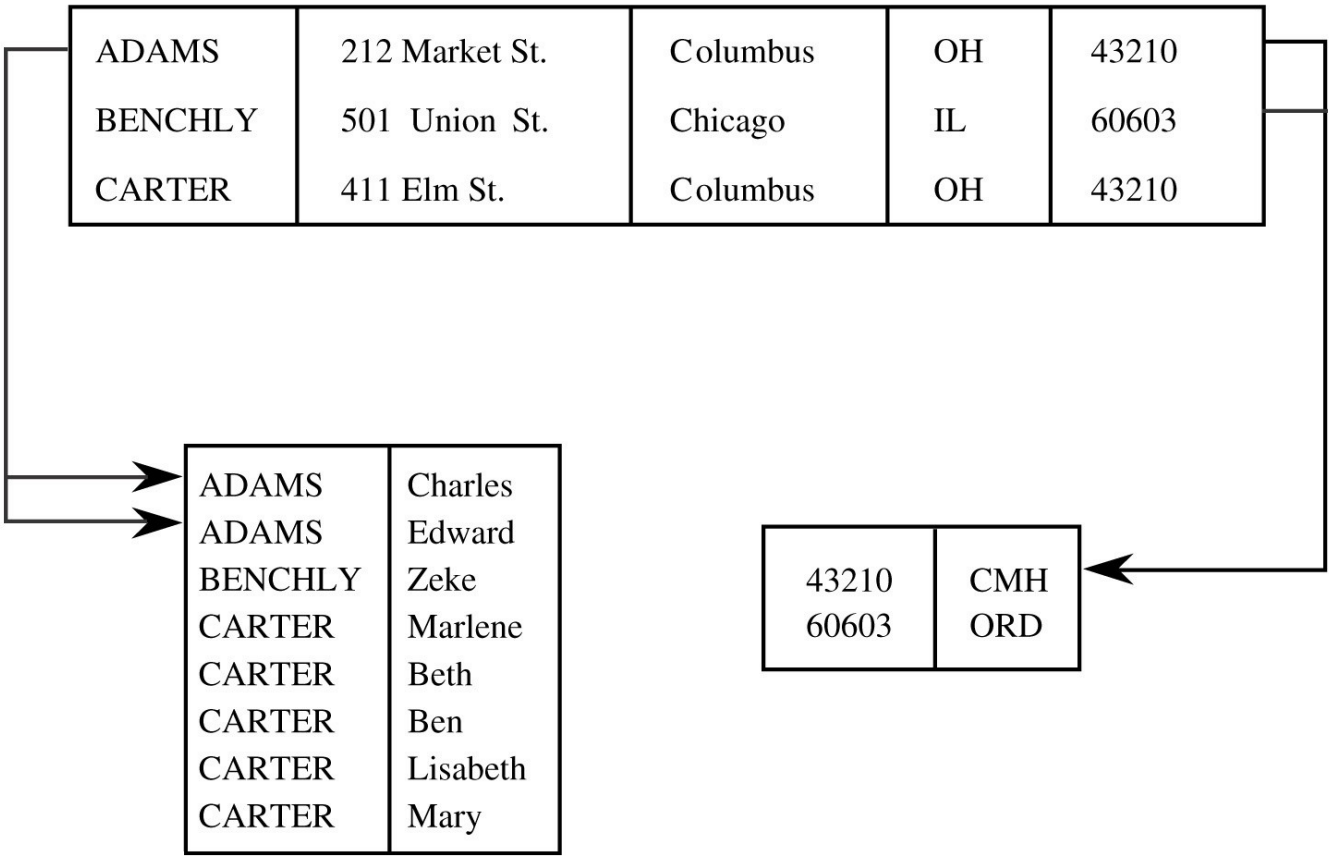
(Relational) Databases

- Structured, queryable collection of data (records)
- Each record consists of fields (elements)
- Structure (schema) set by database administrator
- Database management system (DBMS) provides support for queries and management
- Most popular DBMS is based on relational model
- Stores records in one or multiple tables (relations)
  - Table has named columns (attributes) and rows (tuples)
  - Individual tables can have relationships between them

Schema

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

Relations


ADAMS
212 Market St.
Columbus
OH
43210
BENCHLY
501 Union St.
Chicago
IL
60603
CARTER
411 Elm St.
Columbus
OH
43210
ADAMS
Charles
ADAMS
Edward
BENCHLY
Zeke
CARTER
Marlene
CARTER
Beth
CARTER
Ben
CARTER
Lisabeth
CARTER
Mary
43210
CMH
60603
ORD

Database Queries

- Most popular query language is SQL
  - `SELECT First FROM NAME-ZIP WHERE (Zip = '43210') AND (Name = 'ADAMS')`
    - Prints first names of people in relation NAME-ZIP whose zip code is 43210 and whose last name is Adams
  - `SELECT Name, Airport FROM NAME-ZIP, ZIP-AIRPORT WHERE NAME-ZIP.Zip = ZIP-AIRPORT.Zip`
    - Prints each person's last name and his/her airport by joining relations NAME-ZIP and ZIP-AIRPORT
  - `SELECT COUNT(Name) FROM NAME-ZIP WHERE City = 'Chicago'`
    - Prints number of families in Chicago
    - Can also do other computations, like `SUM`, `MIN`, or `AVG`
- Result of a query is a subschema

Security Requirements

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

Database Integrity

- Protects against database corruption
- Allow only authorized individuals to perform updates
- Recover from physical problems
  - Power failures, disk crashes,….
- Perform periodic backups
- Keep log of transactions to replay transactions since last backup

Element Integrity

- Ensures correctness/accuracy of database elements
- Access control to limit who can update element
- Element checks to validate correctness
  - Element must be numeric, within a particular range,…
  - Not more than one employee can be president
  - Helps against mistakes by authorized users
  - Typically enforced by triggers (procedures that are automatically executed after an `INSERT`, `DELETE`,…)

Element Integrity (cont.)

- Change log or shadow fields to undo erroneous changes
  - In case the above fail, require additional space
- Error detection codes to protect against OS or hard disk problems

Integrity: Two-Phase Update

- For a set of operations, either all of them or none of them should be performed
  - Integrity violation if only some are performed
- First phase: gather information required for changes, but don't perform any updates, repeat if problem arises
- Second phase: make changes permanent, repeat if problem arises
- See text for example

Integrity: Concurrency Control

- Concurrent modifications can lead to integrity violation
  - Two operations A and B read variable X
  - A then writes new value of X
  - B then writes new value of X
  - A's update gets lost
- Need to perform A and B as atomic operations
- Take CS 454 for more about this

Referential Integrity

- Each table has a primary key
- Minimal set of attributes that uniquely identifies each tuple
  - User ID or social insurance number
  - First name and last name (maybe not)
- A table might also have a or multiple foreign keys, which are primary keys in some other table
  - Zip is (likely) a primary key in ZIP-AIRPORT
  - Zip is a foreign key in NAME-ZIP
- Referential integrity ensures that there are no dangling foreign keys
  - For each zip in NAME-ZIP, there is an entry in ZIP-AIRPORT

Auditability

- Keep an audit log of all database accesses
  - Both read and write
- Access control can be difficult (see later), audit log allows to retroactively identify users who accessed forbidden data
  - Police officer looking at somebody's criminal record as a favor to a friend, unauthorized medical personnel looking at George's Clooney's medical record
- Maybe combination of accesses resulted in disclosure, not a single one (see later)
- Must decide about granularity of logging
  - Should results of a query be logged?

Access Control

- More difficult than OS access control
- Might have to control access at the relation, record or even element level
- Many types of operations, not just read/write
  - `SELECT, INSERT, UPDATE, CREATE, DROP,…`
- Relationships between database objects make it possible to learn sensitive information without directly accessing it
  - Inference problem (see later)
- Efficiency problem in presence of thousands of records, each consisting of dozens of elements

Access Control (cont.)

- Access control might consider past queries
  - Current query, together with past ones, could reveal sensitive information
    - Iteratively querying whether element is in set ultimately leaks set
- Or type of query
  - `SELECT lastname, salary FROM staff WHERE salary > 50000`

    might be forbidden, but not
  - `SELECT lastname FROM staff WHERE salary > 50000`

User Authentication / Availability

- Database might do its own authentication
- Additional checks possible
  - E.g., time of day

- Databases facilitate sharing, but availability can suffer if multiple users want to access the same record
  - Block access until other user finishes updating record

Types of Data Disclosure

- Exact data
- Bounds
  - Sensitive value is smaller than H, but bigger than L
  - Might iteratively decrease range (binary search)
- Negative result
  - Knowing that a person does not have zero felony convictions is sensitive, even if actual number is hidden
- Existence
  - Knowing of existence of some data can be sensitive
- Probable value
  - Sensitive data has value x with probability y

Recap

- Finish OTR
- Database Security
  - Introduction to Databases
  - Security Requirements
  - Integrity
  - Auditability, Access Control, and Availability

Next time

- Database Security
  - Data Inference
  - Statistical Inference
  - Controls against Inference
- Multilevel Security Databases
  - Separation
  - Integrity Locks
  - Designs of MLS Databases
- Data Mining
  - Integrity and Availability
  - Privacy and Data Mining
  - Privacy-Preserving Data Mining