Identification and Authentication

- Password authentication
  - How passwords are compromised
  - How to protect and choose passwords
- Other types of authentication
  - Biometrics

Identification and Authentication

- Identification
  - Present an identifier to a security system
  - Example: username
- Authentication
  - Verify the claimed identity
  - Example: password
- An authenticated identity provides the basis for both access control and accountability
- Sometimes identification is included in the authentication step
  - Authentication is then divided into identification and verification

Username and Password

- Most common way to identify and authenticate users
- Identification ↔ username
- Authentication ↔ password
- Unauthorized access obtained by using someone else's password
- Badly chosen passwords will compromise security
  - Often the result of human ignorance or laziness

Common Passwords

- Stolen from Rockyou.com 2009 (SQL-injection)
- Stored in clear text (32 Million passwords)
- **Note:** People may or may not regard Rockyou.com as a place where you need complex passwords.

Password length	
5	4%
6	26%
7	19%
8	20%
9	12%
10	9%
11	4%
12	2%
13	1%

Characters used	
Numbers	16%
Letters	43%
Alphanumeric	37%
Other	4%

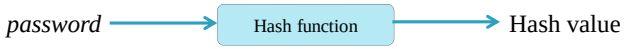
10 most common	
1.	123456
2.	12345
3.	123456789
4.	Password
5.	iloveyou
6.	princess
7.	Rockyou
8.	1234567
9.	12345678
10.	abc123

The Password File

- System needs to verify password
- Password needs to be stored somewhere
  - file, database,…
- Users should not be allowed to see other's password
  - → Password file must be protected

Protection:

- One-way (hash) function is used so passwords are not in clear
- Additional cryptography and/or access control is possible



We will improve this further soon!!!

Password File Protection

- We want to protect the hashed passwords
- Access control – Only priviliged users can access the file
  - In Unix (and Linux) hashed passwords are usually stored in a file only readable by root
  - Windows NT used a proprietary binary format of the file. (Security by obscurity)
  - In Windows 2000 and later, the SAM file is (optionally) encrypted with SysKey
  - The SAM file cannot be moved or copied when windows is running.
    - Still, there are tools to dump the content, see Laboratory 1

Obtaining Passwords

- Spoofing Attacks
- Obtaining file with hashed passwords
  - Brute force
  - Dictionary attack
  - Time-memory tradeoff
- Social engineering
- Guess password online
- Guess answer to secret question

Spoofing Attacks

- Username and password give *unilateral* authentication
  - System authenticates user but user does not authenticate system

Spoofing Attack:

- The attacker runs a program that presents a fake login screen.
- User enters username and password, and is then directed to the real login screen.

What to do?

- Prevention
  - Trusted path (CTRL+ALT+DEL in Windows)
  - Mutual authentication
  - One-time passwords
- Detection
  - Information about previous logon session
  - Display number of failed logins

Obtaining Hashed Passwords

- There are tools to dump the password database (SAM) in Windows
- Security vulnerablilites in other programs may allow you to read a password file in Unix or Linux
- Online forums, social networks, webmail providers, etc often have databases with hashed passwords. These can be obtained from security bugs
  - Some methods will be discussed in the course "Web Security" in HT1

Username	Password
Alice	g6F4fdsg8h...h5NHa
Bob	dsjk7H5dg0...d2a5V
Charlie	KJ7YtrcZa2...l9j7G
David	p09J7h6bD3...73Dnt

Brute Force

- Go through all possible passwords
  - Will take a long long time.
  - Can restrict to only test common characters (alphanumerical).
- 26+26 letters + 10 numbers
  - **Example:** Testing all alphanumerical passwords up to length 7 requires

$$\sum_{i=1}^{7} 62^i = 3579345993\ 194 \approx 2^{42}$$

  hash invocations
- Is this computationally possible?
  - Depends on which hash function is used, how many computers you have and how much time you have, but basically, yes.

Dictionary Attack

- Passwords are often based on words – try common words
- Consider *Oxford English Dictionary*
  - Contains about 200000 words
- **Complexity**
  - Trying 100 variations of each word require about 2^{24} hash invocations.
  - Doing the same thing for 50 languages require 2^{30} hash invocations
  - → Still about 4000 times faster than trying all alphanumerical passwords up to 7 characters
- "Easy" passwords can also be included in dictionaries
  - qwerty, q1w2e3r4t5, zaxscdvfbg, qwaszx, etc...
  - …and the 32,000,000 from Rockyou.com and similar

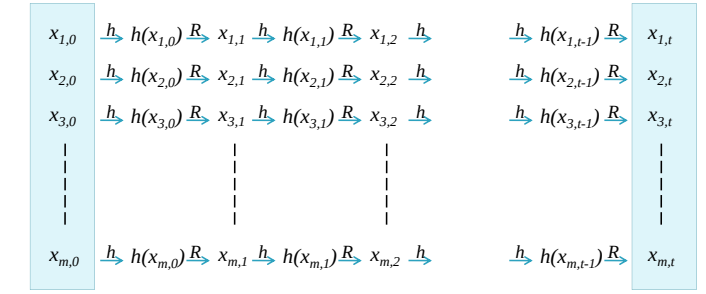
Time-Memory Tradeoff Attack

- In some sense a brute force attack
  - Done in a clever way and partly in advance
- Require lots of memory
- Attack introduced by Hellman in 1980
  - Explained for block cipher but works equally well for any one-way function
- Complexity divided into
  1. *preprocessing phase*
  2. *realtime (or online) phase*

Preprocessing Phase

- Let N be the search space
  - **Example:** alphanumerical passwords with length ≤ 7 gives $N = 2^{42}$
- Let h be the one-way function to invert
  - $y = h(x)$
- Let R be a reduction function mapping an output to a new password
  - $x_2 = R(h(x_1))$
- Idea:
  1. Pick random password $x_{1,0}$
  2. Compute $x_{1,1}=R(h(x_{1,0}))$, $x_{1,2}=R(h(x_{1,1}))$,...,$x_{1,t}=R(h(x_{1,t-1}))$
  3. Save $x_{1,0}$ as starting point and $x_{1,t}$ as ending point for this chain
  4. Pick new starting point $x_{2,0}$ and compute ending point $x_{2,t}$
  5. Do this for m starting points → we cover mt passwords

The Table



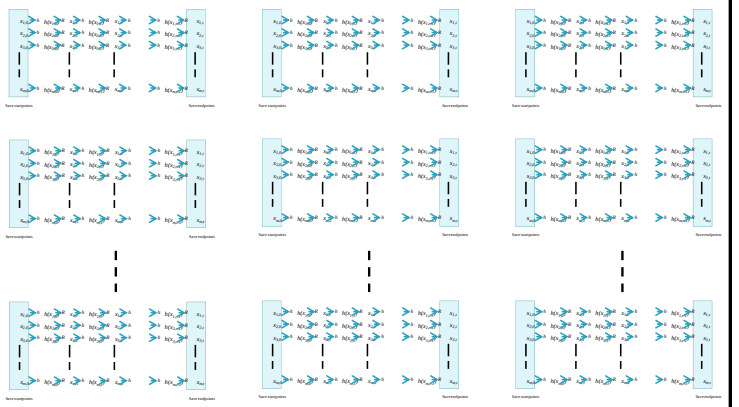
Save startpoints

Save endpoints

Table Coverage

- We cover mt points
- If $x_{i,j} = x_{u,v}$ the two chains will merge and we will not cover any new points
- Avoid merging: stop when $mt \cdot t = N$
  - Intuitive explanation: We have mt different points. If we add t points there are $mt \cdot t$ possibilities of collision
- We only cover a fraction mt/N = 1/t of the search space
  - We need t tables, each with different reduction function R
- Cost for preprocessing phase $P \approx N$ ← **NOTE!!!**
  - All points are processed
- Memory usage $M \approx mt$
  - m points saved for each table, and there are t tables

Actually 2m, but we do not care about small constants (and we did not specify unit anyway)



In total t tables, each with new reduction function

Realtime Phase

- Goal: find x when we know $h(x)$
- Do the following for each of the t tables
  1. Apply reduction function R
  2. If $R(h(x))$ is a saved endpoint, then go to 4.
  3. If $R(h(x))$ is not a saved endpoint, find $R(h(R(h(x))))$, etc... until endpoint is found. Then go to 4.
  4. When endpoint is found, take corresponding startpoint and iterate until $h(x)$ is found. Then x is the password!
- Cost for realtime phase $T \approx t^2$

Summary of Attack

- Realtime computations: $T = t^2$
- Preprocessing time: $P = N$
- Memory needed: $M = mt$
- Matrix stopping rule: $N = mt^2$

$\Rightarrow$ $N^2 = M^2 T$, $P = N$

- Example: $T = N^{2/3}$ and $M = N^{2/3}$
  - $N=2^{42}$ can be broken with table of size 2^{28} and 2^{28} computing steps
  - Thus after producing the table ONCE with cost 2^{42}, any password can be broken with cost 2^{28}. You just need to have the table.
  - Any parameters satisfying the tradeoff curve can be chosen
    - More memory → less time
    - Less memory → more time

Improvement: Rainbow Tables

- Oechslin 2003
- Practical improvement, but asymptotic complexities are the same as in Hellman's attack
- Idea: Use different reduction function for each computation of the hash function
- Collisions will merge chains with probability *1/t*
  - Only collisions in the same column will merge chains
- Only one large table needed
  - In practice, a few tables
- Realtime speedup factor approximately 2-10 (debated)
- See Laboratory 1 for more info

Downloadable Rainbow Tables

- Examples from *http://www.cryptohaze.com/*

Algorithm: MD5

Number of characters: 1-6

Characters:
!"#$%&'()*+,-./0123456789:;<=>?
@ABCDEFGHIJKLMNOPQRST
UVWXYZ[\]^_`abcdefghijklmno
pqrstuvwxyz{|}~

Size of table: 1.0 GB

Algorithm: MD5

Number of characters: 1-8

Characters:
!"#$%&'()*+,-./0123456789:;<=>?
@ABCDEFGHIJKLMNOPQRST
UVWXYZ[\]^_`abcdefghijklmno
pqrstuvwxyz{|}~

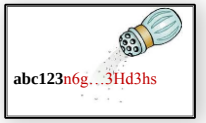
Size of table: 1.5 TB

- Does the choice of hash function matter to table size?

In the news, December 2009

Password Salting

- Add some extra info, **salt**, to the password before hashing.
  - Username
  - Randomly generated characters
- Salt stored with hashed password.



Username	Salt	Password
Alice	Gfgh5	g6F4fdsg8h...h5NHa
Bob	kd6sd	dsjk7H5dg0...d2a5V
Charlie	dsfjh	KJ7YtrcZa2...l9j7G
David	J7Fj2	p09J7h6bD3...73Dnt

- **Three advantages:**
  1. Slows down dictionary attacks when trying to break several passwords at once.
  2. One Rainbow table for each salt needed
  3. Two users with same password will have different hash

Guess Passwords Online

- Possible targets: webmail, forums, communities, web shops
- Enter username + password and see if it works
  - Takes a long time
- Better
  1. Write program that sends the correct HTTP requests (username + password) and analyses the response
  2. Wait...

- **Protection:**
  - Do not allow many automated login attemps in a short time
  - Force user to verify that he/she is human after some failed attempts

Example, Online Password Guessing

- ”Twitter” was compromised in the beginning of January 2009
  - Dictionary attack used to try passwords online for a specific account
  - Password was ”happiness”
  - Account turned out to belong to a staff member
- **Consequence:** Attacker had control over all accounts on ”Twitter”
  - Fake comments from e.g., Barack Obama, Britney Spears and Fox News were sent out.
- Article: http://blog.wired.com/27bstroke6/2009/01/professed-twitt.html

”Improved” Twitter

- Some time after the Jan 2009 attack Twitter decided to make improvements
  - The ”brute force” dictionary attack no longer worked
- In Sept 2012 another Twitter account was online brute forced
  - WTF??
- Turned out the login attempt limitations was per IP, not per account
- Article: http://www.buzzfeed.com/jwherrman/security-flaw-lets-hackers-steal-twitter-accounts
- Perhaps now ”improved Twitter” can be called improved Twitter?

On the positive side, but completely unrelated, Twitter uses bcrypt to hash passwords

Guess Answer to Security Questions

- Security question common to allow users that forgot their password to recover it
  - In some cases the right answer will give you immediate access
- But obviously:
  - Password difficulty is upper bounded by the problem of answering the question
- Makes no sense to pick ”Hd#6%5Sue!7s” as password and ”What is my mother’s name?” as question.
- Surely no one would do that.....or?

Example, Guessing Password Question

- Sarah Palin’s Yahoo account was compromised in Sept 2008
- **Required info:** Her birthday, her zip code and answer to security question
- **Security question:** ”where did you meet your spouse?”
  - **Answer:** Wasilla High (the high school where she studied)
- According to attacker:
  - It took about 45 minutes in total
  - He found nothing of interest

System Help Mechanisms

- Password checkers
  - Proactive checking
  - Reactive checking
- Automated password generation
- Password ageing
  - Require user to change after some given time
- Limit login attempts
  - Lockout user after a number of failed logins
- Show audit information
  - Inform user about number of failed logins after each login

Alternative Approaches

Several possible factors:

- Something you know (password, PIN,…)
- Something you hold (smartcards,…)
- Who you are (biometrics,...)
- What you do (writing speed,...)
- Where you are (restricted login,…)

} Most common

Something You Hold

- Examples
  - Smart card
  - Magnetic card
  - Physical key
- Usually combined with ”Something you know”, e.g., PIN

Example: RSA SecurID

Time | Token ID/seed → Hash algorithm → Authenticator → Submit: PIN + Authenticator

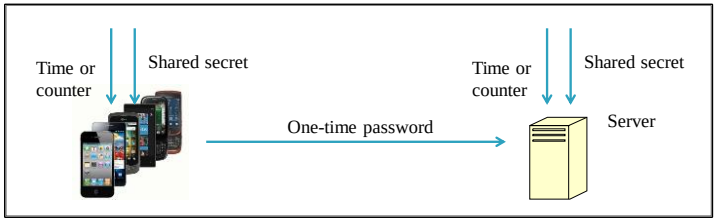
Server: Time | Token ID/seed → Hash algorithm → Authenticator → Verify: PIN and Authenticator

RSA SecurID

- Two factor authentication
  - Something you know – PIN
  - Something you have – Token
- Authenticator changes every 60 seconds
- One time password (OTP)
- Clock resynchronizes at authentication time

HOTP and TOTP

- Now we all have a device we can use – the smart phone



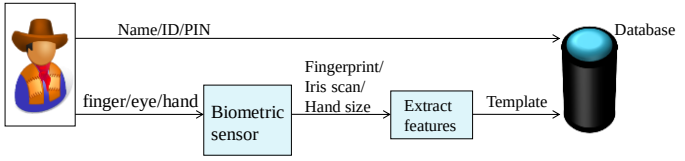
- See RFC 4226 for HOTP specification (HMAC-based one-time password algorithm)
  - Based on counter
- See RFC 6238 for TOTP specification (time-based one-time password algorithm)
  - Based on time
- See e.g., Google authenticator for implementation of TOTP

Who You Are

- Examples:
  - Fingerprint
  - Iris
  - Facial characteristics
  - Hand geometry
  - Retinal pattern
  - Voice
- **Requirements:** Uniqueness, Universality, Permanence, Measurability, User friendliness
- Can be used for both identification and verification

Biometric Systems

- Enrollment, create reference templates

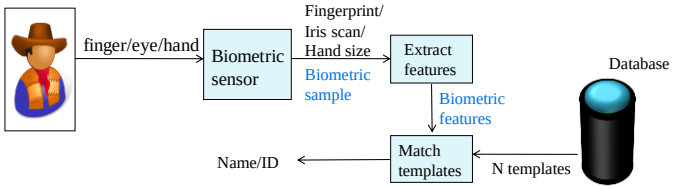


Several templates can be collected for one person

FER – Failure to Enroll Rate

Biometric Systems

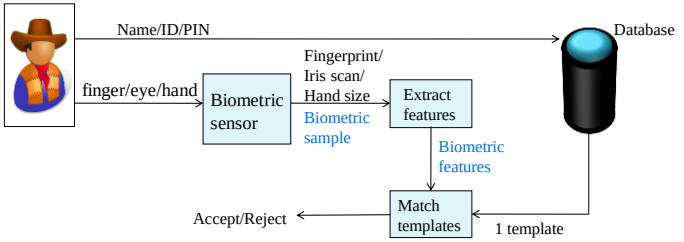
- Identification, *1:N* comparison



Identify a user from a database of *N* people

Biometric Systems

- Verification, 1:1 comparison



Errors

- Measurement will not exactly match reference template. (Different from passwords)
- Two kinds of errors
  - False positives (Accepting wrong user, security related)
  - False negatives (Rejecting legitimate user, comfort related)
- Matching algorithm used to compare with templates
- The matching is converted to a *score*. Better match gives higher score
- A threshold will determine what the minimum score must be to accept user as valid

FAR & FRR

FAR – False Acceptance Rate

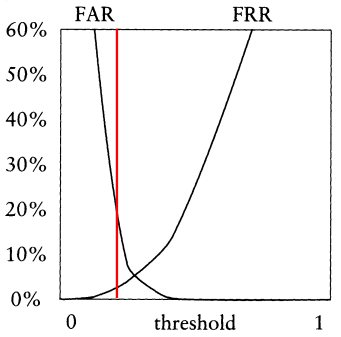
FRR – False Rejection Rate

Equal Error Rate (EER) when FAR=FRR

Course book also includes FTA – Failure To Aquire

We assume it is zero!

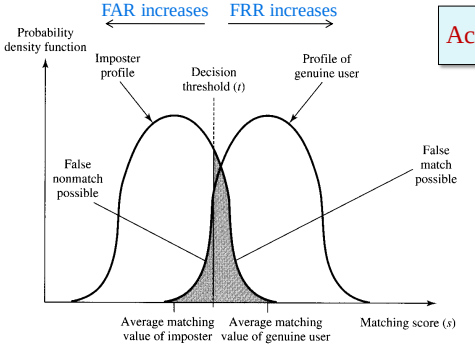
Graph for typical system



Normalized score on x-axis

Another View

Accept if s > t



Placement of threshold *t* provides a tradeoff

Picture taken from Stallings – Computer security (2008)

Two Additional Factors

- What you do
  - Signature
  - Typing speed

  } Sometimes included in "who you are"
- Where you are
  - Deny access from outside some perimeter
  - You can be logged on based on what computer you try to logon from
  - Some web stores only permit people from certain countries access