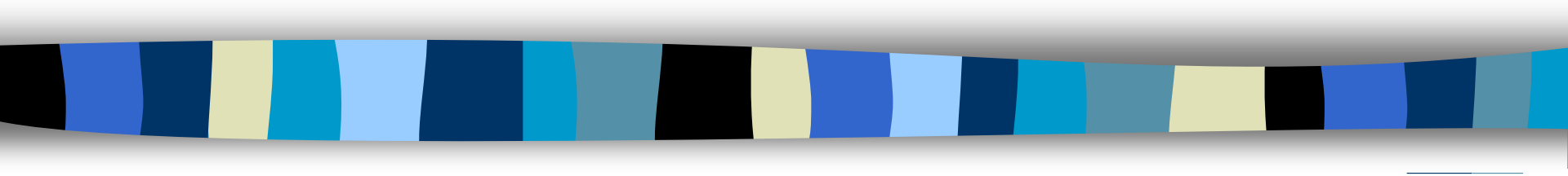
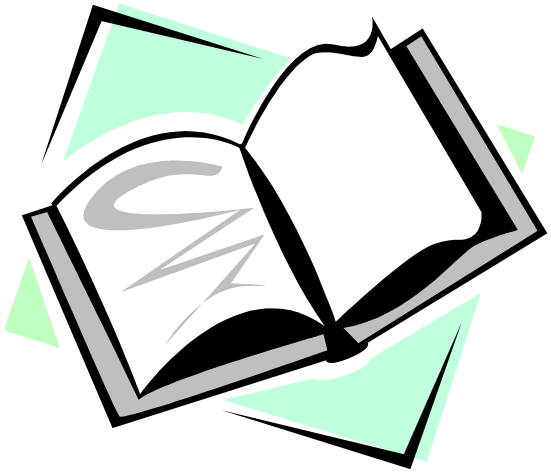
Information Security
CS 526



Topic 7: User Authentication

Readings for This Lecture

- Wikipedia
  - Password
  - Password strength
  - Salt_(cryptography)
  - Password cracking
  - Trusted path
  - One time password



Three A's of Information Security

- Security is about differentiating among authorized accesses and unauthorized accesses
  - Confidentiality, Integrity, Availability all require this
- Authentication
  - Figures out who is accessing
- Access control
  - Ensure only authorized access are allowed
- Auditing
  - Record what is happening, to identify attacks later and recover

Authentication & Access Control according to Wikipedia

- **Authentication** is the act of establishing or confirming something (or someone) as *authentic*, that is, that claims made by or about the subject are true. This might involve confirming the identity of a person, tracing the origins of an artifact, ensuring that a product is what its packaging and labeling claims to be, or assuring that a computer program is a trusted one.

- **Access control** is a system which enables an authority to control access to areas and resources in a given physical facility or computer-based information system.

User Authentication

- Using a method to validate users who attempt to access a computer system or resources, to ensure they are authorized
- Types of user authentication
  - Something you know
    - E.g., user account names and passwords
  - Something you have
    - Smart cards or other security tokens
  - Something you are
    - Biometrics

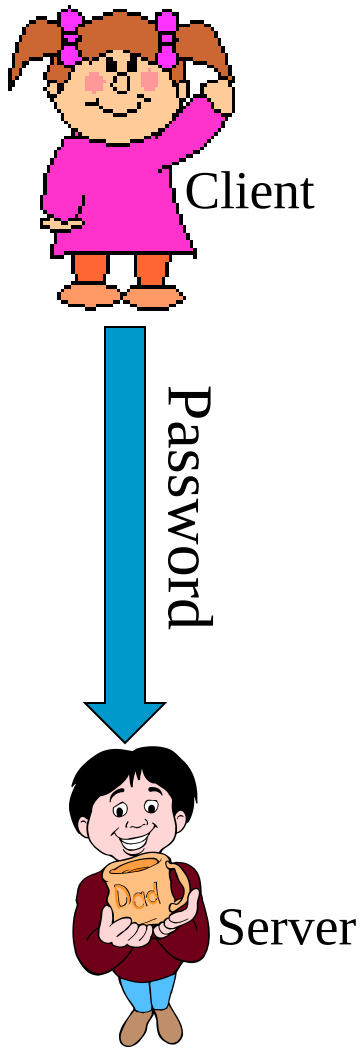
Variants of Passwords

- Password
- Passphrase
  - a sequence of words or other text used for similar purpose as password
- Passcode
- Personal identification number (PIN)

Scenarios Requiring User Authentication

- Scenarios
  - Logging into a local computer
  - Logging into a computer remotely
  - Logging into a network
  - Access web sites

- Vulnerabilities can exist at client side, server side, or communications channel.



Threats to Passwords

- Eavesdropping (insecure channel between client and server)
- Login spoofing (human errors), shoulder surfing, keyloggers
- Offline dictionary attacks
- Social engineering (human errors)
  - e.g., pretexting: creating and using an invented scenario (the pretext) to persuade a target to release information or perform an action and is usually done over the telephone
- Online guessing (weak passwords)

Guessing Attacks: Two Factors for Password Strength

- The average number of guesses the attacker must make to find the correct password
  - determined by how unpredictable the password is, including how long the password is, what set of symbols it is drawn from, and how it is created.

- The ease with which an attacker can check the validity of a guessed password
  - determined by how the password is stored, how the checking is done, and any limitation on trying passwords

Password Entropy

- The entropy bits of a password, i.e., the information entropy of a password, measured in bits, is
  - The base-2 logarithm of the number of guesses needed to find the password with certainty
  - A password with, say, 42 bits of strength calculated in this way would be as strong as a string of 42 bits chosen randomly.
  - Adding one bit of entropy to a password doubles the number of guesses required.

- Aka. Guess entropy

Estimating Password Entropy

- People are notoriously remiss at achieving sufficient entropy to produce satisfactory passwords.
- NIST suggests the following scheme to estimate the entropy of human-generated passwords:
  - the entropy of the first character is four bits;
  - the entropy of the next seven characters are two bits per character;
  - the ninth through the twentieth character has 1.5 bits of entropy per character;
  - characters 21 and above have one bit of entropy per character.
- This would imply that an eight-character human-selected password has about 18 bits of entropy.

Towards Better Measurement of Password Entropy

- NIST suggestion fails to consider usage of different category of characters:
  - Lower-case letters, digits, upper-case letters, special symbols
- Orders also matter:
  - “Password123!” should have different entropy from “ao3swPd!2s1r”
- State of art is to use variable-order markov chains to model probability of different strings as passwords
  - “A Study of Probabilistic Password Models” by Ma, Yang, Luo, Li in IEEE SSP 2014.
- Fundamental challenge: there are different attack strategies out there, which try passwords with different ordering

Example of Weak Passwords (from Wikipedia)

- Default passwords (as supplied by the system vendor and meant to be changed at installation time): *password*, *default*, *admin*, *guest*, etc.
- Dictionary words: *chameleon*, *RedSox*, *sandbags*, *bunnyhop!*, *IntenseCrabtree*, etc.
- Words with numbers appended: *password1*, *deer2000*, *john1234*, etc.,
- Words with simple obfuscation: *p@ssw0rd*, *l33th4x0r*, *g0ldf1sh*, etc.
- Doubled words: *crabcrab*, *stopstop*, *treetree*, *passpass*, etc., can be easily tested automatically.

Example of Weak Passwords (from Wikipedia)

- Common sequences from a keyboard row: *qwerty*, *12345*, *asdfgh*, *fred*, etc.
- Numeric sequences based on well known numbers such as 911, 314159, or 27182, etc.,
- Identifiers: *jsmith123*, *1/1/1970*, *555–1234*, "your username", etc.,
- Anything personally related to an individual: license plate number, Social Security number, current or past telephone number, student ID, address, birthday, sports team, relative's or pet's names/nicknames/birthdays, etc.,
  - can easily be tested automatically after a simple investigation of person's details.

Mechanisms to Avoid Weak Passwords

- Allow long passphrases, forbid short passwords
- Randomly generate passwords where appropriate
  - Though probably inappropriate for most scenarios
- Give user suggestions/guidelines in choosing passwords
  - e.g., think of a sentence and select letters from it, “It’s 12 noon and I am hungry” => “I’S12&IAH”
  - Using both letter, numbers, and special characters
- Check the quality of user-selected passwords
  - Use a number of rules of thumb; run dictionary attack tools
  - Evaluate strength of a password and explain the weaknesses
- This is an open research question
  - Any suggestion?

Balancing Password Entropy & Usability Concerns

- Forcing randomly generated passwords is often bad.
  - A user needs to remember passwords for tens, if not hundreds of accounts
  - High entropy passwords are difficult to remember
- The “Weakest Link” security principle applies here
  - Often times, guessing passwords is not the weakest link
  - One can use various ways to reduce adversary’s abilities to test password guesses
  - When a user cannot remember the password for an account, there must be a way to allow a user to retrieve it.
    - The recovering method either has low security, or costs lots of money
    - It creates a weaker link.

Another Relevant Security Principle

- Psychological acceptability:
  - It is essential that the human interface be designed for ease of use, so that users routinely and automatically apply the protection mechanisms correctly. Also, to the extent that the user's mental image of his protection goals matches the mechanisms he must use, mistakes will be minimized. If he must translate his image of his protection needs into a radically different specification language, he will make errors.
  - Taken from Saltzer & Schroeder: "**The Protection of Information in Computer Systems"**, which identifies 8 security principles, including the "open design" principle

Usability matters.

Storing Passwords (UNIX Case Study)

- Old UNIX
  - The file /etc/passwd stores H(password) together with each user's login name, user id, home directory, login shell, etc.
    - H is essentially a one-way hash function
  - The file /etc/passwd must be world readable
  - Brute force attacks possible even if H is one-way
    - how to most effectively brute-force when trying to obtain password of any account on a system with many accounts?

Password Salts

- More modern UNIX
  - Divide /etc/password into two files: /etc/password; and /etc/shadow (readable only by root)
- Store [r, H(password,r)] rather than H(password) in /etc/shadow
  - r is randomly chosen for each password
  - r is public, similar to Initial Vector in CBC & CTR modes
- Benefits
  - dictionary attacks much more difficult
    - cost of attacking a single account remains the same
  - if two users happen to choose the same password, it doesn't immediately show

Mechanisms to Defend Against Dictionary and Guessing Attacks

- Protect stored passwords (use both cryptography & access control)
  - An instance of the “Defense in Depth” principle:
    - Use multiple independent method of defense, so that even if one layer fails, security is still not compromised
    - Consider, e.g., password dataset compromises
- Disable accounts with multiple failed attempts
- Require extra authentication mechanism (e.g., phone, other email account, etc.)

Mechanisms to Defend Against Login Spoofing: Trusted Path

- Login Spoofing Attacks:
  - write a program showing a login window on screen and record the passwords
  - put su in current directory
- Defense: Trusted Path
  - Mechanism that provides confidence that the user is communicating with the real intended server
    - attackers can't intercept or modify whatever information is being communicated.
    - defends attacks such as fake login programs
  - Example: Ctrl+Alt+Del for log in on Windows
    - Causes a non-maskable interrupt that can only be intercepted by the operating system, guaranteeing that the login window cannot be spoofed

Spoofing & Defenses on the Web

- Phishing attacks
  - attempting to acquire sensitive information such as usernames, passwords and credit card details by masquerading as a trustworthy entity in electronic communication.
- Website forgery
  - Set up fake websites that look like e-commerce sites and trick users into visiting the sites and entering sensitive info
- Defense methods
  - Browser filtering of known phishing sites
  - Cryptographic authentication of servers (will talk about in future)
  - User-configured authentication of servers
    - To ensure that the site is the one the human user has in mind
    - E.g., site key, pre-selected picture/phrases

KeyLogging

- Threats from insecure client side
- Keystroke logging (keylogging) is the action of tracking (or logging) the keys struck on a keyboard, typically in a covert manner so that the person using the keyboard is unaware that their actions are being monitored.
- Software -based
  - key-stroke events, grab web forms, analyze HTTP packets
- Hardware-based
  - Connector, wireless sniffers, acoustic based
- Defenses:
  - Anti-spyware, network monitors, on-screen soft keyboard, automatic form filler, etc.
- In general difficult to deal with once on the system

Using Passwords Over Insecure Channels

- One-time passwords
  - Each password is used only once
  - Defend against passive adversaries who eavesdrop and later attempt to impersonate
- Challenge response
  - Send a response related to both the password and a challenge
- Zero knowledge proof of knowledge
  - Prove knowledge of a secret value, without leaking any info about the secret

How to do One-Time Password

- Shared lists of one-time passwords

- Time-synchronized OTP
  - E.g., use $MAC_K(t)$, where K is shared secret, and t is current time

- Using a hash chain (Lamport)
  - h(s), h(h(s), h(h(h(s))), …, $h^{1000}(s)$
  - use these values as passwords in reverse order

Lamport's One-Time Password: Using a Hash Chain

- One-time setup:
  - A selects a value w, a hash function H(), and an integer t, computes $w_0 = H^t(w)$ and sends w_0 to B
  - B stores w_0
- Protocol: to identify to B for the i^{th} time, $1 \leq i \leq t$
  - A sends to B: A, i, $w_i = H^{t-i}(w)$
  - B checks $i = i_A$, $H(w_i) = w_{i-1}$
  - if both holds, $i_A = i_A + 1$

Challenge-Response Protocols

- Goal: one entity authenticates to other entity proving the knowledge of a secret, ‘challenge’
- How to design this using the crypto tool we have learned?
- Approach: Use time-variant parameters to prevent replay, interleaving attacks, provide uniqueness and timeliness
  - e.g., nounce (used only once), timestamps

Challenge-response based on symmetric-key crypto

- Unilateral authentication, timestamp-based
  - A to B: $MAC_K(t_A, B)$
- Unilateral authentication, nounce-based
  - B to A: r_B
  - A to B: $MAC_K(r_B, B)$
- Mutual authentication, nounce-based
  - B to A: r_B
  - A to B: r_A, $MAC_K(r_A, r_B, B)$
  - B to A: $MAC_K(r_B, r_A)$

Other Defenses

- Alternatives to passwords
  - graphical passwords
- Go beyond passwords
  - security tokens
  - biometrics
  - 2-factor authentication
    - Uses two independent authentication methods
    - US Banks are required to use 2-factor authentication by end of 2006 for online banking
  - Out of band authentication: uses a channel other than the internet
    - E.g., phone

Open Problems

- Alternatives to passwords?
  - The secret should be easy to remember, difficult to guess, and easy to enter into the system.
- Better measure of password quality.
- Better ways to make user choose stronger passwords.
- Better ways to use other devices for authentication
- Effective 2-factored and/or out of band authentication for the Web
- Phishing defense

Coming Attractions …

- Basics of OS Security and Access Control