Security

CSE 454

The Two "Auth-" Operations

- **Authentication**
  - "Process of accepting *credentials* from a user and *validating* those credentials against some *authority*"
  - The result is an authenticated identity
- **Authorization**
  - "Process of *determining* whether the authenticated *identity* has *access* to a given resource"
- **Both steps follow this order and both are essential!**

What Can Go Wrong?

- **Authentication breaks if:**
  - Credentials are forged
  - Authority is subverted
  - Validating function is replaced
- **Authorization breaks if:**
  - Authentication identity is forged
  - Access matrix is tampered with
  - Matrix lookup function is replaced
- Lesson: **Security needs to be provisioned on each step!**

Types of Authentication

- **Server authentication**
  - Necessary in e-commerce
  - Achieved via:
    - X.509 certificates, signed by known certificate authorities (CA)
    - Digital signatures using public/private key encryption
- **Client authentication**
  - Necessary in e-commerce
  - Majority of clients typically do not use X.509 certificates, or public/private key pairs
    - How many of you use one of these methods for authentication?

How to Evaluate Proposed Approaches?

Ask:

1. What problem is the approach trying to solve?

2. What are the ways in which the approach can fail (including, be deliberately made to fail)?

3. Given the ways the approach can fail, does it really solve the problem at hand?

4. What are the costs (financial and otherwise) of deploying a real implementation of the approach?

5. Given the failure conditions and costs, is it worthwhile?

Client Authentication Methods

- **Client certificates**
  - No incentive for clients to have one ⇒ not widely deployed
- **Digital signatures**
  - No PKI yet ⇒ hard to safely distribute public keys
- **Passwords**
  - Most primitive, pervasive method
  - Easy to use, easy to crack: passwords are guessable (or users forget)
    - **Copy-and-store-in-wallet** - works well in practice with random passwords
    - **Visual passwords** - random art; a drawing in lieu of a word
    - **S/Key protocol** - changing passwords on every communication
    - **Smart cards** - store random password safely; PIN for theft protection; activated only by a special card reader; European invention

Client Authentication Methods

- **Biometrics**
  - Unique, inherently tied to the individual
  - But:
    - **Fingerprinting** - non-permanent, could be tampered with
    - **Retina scans** - non-permanent, invasive, even dangerous
    - **Face recognition** - high false positives rate, could be easily fooled
    - **Voice recognition** - high false positive and false negative rate, recordable
    - **DNA analysis** - slow, extremely invasive, may be non-permanent
    - (**Normal) Signature** - varies widely (high false negative rate), more appropriate for non-repudiation that authentication
    - **Typing Timing** - Local startup. Test timing & rhythm when typing password

Client Authentication on the Web

- **What assumptions / constraints does the Web environment imply?**
- **Which of the above methods are unsuitable for authentication on the Web?**
- **What remains?**

Motivation

- **Growing need for *personalized, access-controlled* Web-based services**
  - E.g.: nytimes.com, myuw.washington.edu, hotmail.com
- **Some popular authentication mechanisms not suitable for the Web environment**
  - Designed for long-running connections
  - Involve expensive computations - public/private key crypto
  - Authentication identities can be replayed - biometrics
- **Developers lack proper background in security**
- Result: **Proliferation of home-grown weak authentication schemes**

Limitations on Web Authentication Schemes

- **Must use only *widely deployed*, *portable* and *lightweight* technologies**
  - No smart cards or client certificates; JavaScript may be ok
- **Must require minimum user involvement**
  - No password re-typing or perpetual dialog boxes
- **Must not unduly overload servers with expensive computations**
  - No public-key crypto; cryptographic hashes are fine
- **Must store client state in a very limited space**
  - E.g.: cookies on the client, (maybe) a database on server

Not All Web Authentication Schemes Are Created Equal

Designs differ depending on:

- **Type of service**
  - General subscription
    - Online newspapers and libraries
  - User customization
    - Online identities, per-user content filtering
- **Security needs**
  - Sensitivity of the client data
    - Store data on server and put an index to it in a client cookie
  - Load tolerance on the server
    - Delicate tradeoff with clients' need for strong protection

Threat Model: What *Attacks* Do We Fear?

- **Forging* an authentication token for**
  - A *random* user (a.k.a. existential forgery)
    - Useful for free access to subscription services
  - A *chosen* user (a.k.a. selective forgery)
    - Allows access to data for any selected user
  - *All* users (a.k.a. total break)
    - Allows forging tokens for all users at any time

*** forging ≠ replay attack**

Threat Model:
What *Adversaries* Do We Fear?

Active Adversary

- **Eavesdropping Adversary**
  - **Interrogative Adversary**
    - Queries the server (adaptively, based on previously seen data)
    - Creates new accounts (assuming no out-of-bound throttling)
    - Uses publicly known information
  - Records traffic between users and the server
  - Replays selected captured messages
- Modifies / injects traffic between users and the server
- Mounts man-in-the-middle attack

- Resolution: **Viable schemes must *at least* protect against interrogative adversaries!**

Hints for Designing Client Authentication Schemes

Disclaimer:

Hints are useful, but following them is neither necessary, nor sufficient for security

Hints: Use Cryptography Appropriately

- **Using crypto is inescapable if you want to protect from adversaries!**
- **Hint #1: Assess your needs for protection**
  - Tradeoffs between usability and complexity
- **Hint #2: Choose a "tried and true" existing scheme**
  - Home-grown schemes are almost always trivial to break

Hints: Use Cryptography Appropriately

If you *absolutely must* design your own scheme:

- **Hint #3: Think twice! Ask those who know better!**
- **Hint #4: Have it reviewed by security experts**
  - Announcing it loudly is good but not sufficient
- **Hint #5: Keep the scheme simple**
  - Makes it easier to analyze for security
- **Hint #6a: Do not rely on the secrecy of the protocol**
  - Gives you false sense of security until someone figures it out
- **Hint #6b: Instead, rely on the secrecy of *keys***

Hints: Use Cryptography Appropriately

- **Hint #7: Understand the properties and details of crypto primitives you use**
  - Many provide some assurances, but not other (e.g., SSL)
  - Many make fine-print assumptions
    - UNIX crypt() hash function truncates input beyond 8 characters
- **Hint #8: Avoid composing security schemes**
  - May weaken the composite, even if secure in isolation
    - E.g., using the same secret key for multiple purposes

Status on Using Passwords

- **Users don't want passwords**
  - Tradeoff between usability and security
  - Users tend to pick poor (easy) passwords
    - Do not suggest ideas - they will blindly follow it
- **Users tend to reuse passwords across many sites**
  - How many different passwords do you use?
  - How many of them do you commit to memory?
  - How many of them do you have written somewhere (as a backup)?
- **Compromising a password leads to impersonation**

Hints: Protect Passwords

- **Hint #9: Prohibit easy-to-guess passwords**
  - Otherwise: an easy prey for dictionary attacks
  - Change periodically, enforce non-similarity, minimum password length, special characters
  - Giving out (random) passwords may turn off users
- **Hint #10: Never reveal a user's password**
  - User knows it, everyone else has no reason to ask for it
  - Keep passwords always encrypted in transfer
    - Login over SSL for confidentiality of password exchange
  - Avoid unnecessary password transfers
    - Give out and use (temporary) client authentication tokens instead

Hints: Protect Passwords

- **Hint #11: Redo authentication before security-sensitive operations**
  - E.g.: changing passwords
  - Avoids attacks through replayed authentication tokens

Hints: Handle Authentication Tokens Wisely

- **Hint #12: Avoid predictable authentication tokens**
  - E.g.: publicly available info, sequential ID numbers, etc.
- **Hint #13: Protect tokens from tampering**
  - Tokens may contain sensitive user info
  - Use only strong cryptographic hash functions (e.g., no CRC)
  - Use a keyed message digest (e.g., MAC, no MD5)
- **Hint #14: If combining multiple data into a token, separate components unambiguously**
  - Avoids a splicing attack:
    - "Alice" • "213" • "Bob" == "Alice2" • "13" • "Bob"

Hints: Handle Authentication Tokens Wisely

- **Hint #15: Encrypt tokens**
  - For tokens stored in cookies and sent over SSL, set Secure flag
  - Prevents eavesdroppers from capturing and replaying tokens
- **Hint #16: Do not include a token as part of a URL**
  - Otherwise, token may leak through plaintext channels
    - E.g.: cross-site scripting attack using the HTTP Referer field
- **Hint #17: Avoid using persistent cookies**
  - If cookie (file) is leaked, attacker can impersonate user
  - Can users defend against this threat (the authentication scheme designer may have been negligent)?

Hints: Handle Authentication Tokens Wisely

- **Hint #18: Make authentication tokens expire:**
  - Store a tamper-resistant timestamp in cookie, or keep token expiration time on the server
    - Limits the potential damage in case a token leaks out
- **Hint #19: Do not trust the client…**
  - … to enforce token expiration (manipulating a cookie is easy)
  - … (in general) for anything that the client can possibly forge
- **Hint #20: To prevent replays of leaked tokens:**
  - Keep tokens confidential and mint new ones after each use
  - Bind tokens to network addresses
    - But DHCP users' tokens may expire prematurely

Sample Authentication Scheme

- **Goals**
  - Statelessly verify authenticity of request and its contents
  - Explicitly control lifetime of token
  - Portability
- **Design choice**
  - Authentication cookies
    - Anyone with a valid cookie has access to protected server content
- **Claim**
  - Secure against an interrogative adversary
  - If layered over SSL with server authentication, secure against an active adversary

Cookie Basics

- **HTTP is a stateless protocol**
- **Client IDs generated by server, stored on client**
- **Sent back to server with subsequent requests**
- **Cookie attributes:**
  - Data - used to uniquely identify client
  - Domain - cookie only applies to this server domain
  - Path - server path
  - Secure flag - should cookie data be encrypted?
  - Expiration - current session or physical time

Suggested Cookie Structure

exp=t&data=s&digest=MAC_k(exp=t&data=s)

t → expiration time (seconds past 1970 GMT)
s → data, associated with the client
k → server secret key
MAC → strong cryptographic hash function

$$HMAC_k(M) ::= H(k \oplus 0x5c \bullet H(k \oplus 0x36 \bullet M))$$

where $H \in$ {SHA1, MD5}, M is the message

Disecting the Scheme

- **Expiration time:**
  - Avoids keeping server state
  - Tradeoff between potential damage and frequent reauthentication (security vs. usability)
  - Should users be allowed to control it?
- **Data:**
  - Sensitive data should not be stored here
    - If needed, store cryptographically random session ID, while keeping important data on server
  - Balance between respecting users' privacy and saving server resources
    - Likely to be biased in favor of the latter

Disecting the Scheme

- **Key:**
  - Recommended length is twice that of block encryption ciphers (~160 bits or more)
    - Fends off birthday attacks

Disecting the Scheme

Strengths:

- **Simplicity**
- **Authenticating clients:**
  - Requires O(1) server state (for the key)
  - Takes O(1) time
  - Would depend on number of clients if server state were kept
- **Easier to deploy multiserver systems**
  - No need for dynamically shared data between servers

Disecting the Scheme

Weaknesses:

- **Server is vulnerable against colluding clients**
  - Clients more likely to share temporary tokens than passwords
  - How many other people's passwords do you know?
- **No mechanism for selective secure token revocation**
  - Unnecessary for short sessions
    - Separation of policy and mechanism?
  - If needed, keep session status on server
    - Yahoo does it
  - But, allows simultaneous revocation of all tokens
    - By changing the secret server key

Security Analysis

Strength of authentication scheme depends on:

- **Strength of MAC function**
- **Secrecy of server key**
- **Strength of server key and frequency of changing it**
  - Longer keys adversely affect performance of hash functions
- **Strength of client passwords against guessing and dictionary attacks**

Performance Factors

- **HMAC-SHA1**
  - 1.2 ms / request
  - Runs on small chunks of data
- **SSL**
  - 90 ms / request
  - Runs on the entire HTTP stream
  - New connections are costly to setup, session resumption helps

Other Authentication Schemes

- **HTTP Basic Authentication**
  - Sends username and password repeatedly in cleartext
  - Falls prey to eavesdropping adversaries
    - `dsniff` - automated tool for sniffing authentication exchanges
- **HTTP Digest Authentication**
  - Encrypts username and password before transmitting
  - Little client support yet
- **SSL**
  - Requires public-key crypto in X.509 certificates
  - No global PKI → no wide support for client certificates
  - Involves heavyweight operations

Conclusions

- **No single authentication scheme can effectively and efficiently meet the requirements of all Web sites and Web clients**
- **There are clear guidelines (but no standards yet) for designing secure authentication schemes**

Open Issues

- **What can end users do to protect themselves?**
  - Those who can provide a solution (i.e., vendors) have no incentive to do so.
  - Those who really care about finding a solution (i.e., clients) cannot create one.
- **Should there be a standard for authentication protocols? What factors play against establishing such a standard?**
- **Would you trust a centralized authentication service (such as Microsoft Passport) with your data? A step in which direction is this - forward or backward?**

SPAM

- **Problem**
  - Zero marginal cost of sending an email
- **Solutions**
  - Machine learning client to detect spam
  - Brightmail
    - Dummy accounts
    - Correlate SPAM messages
    - Supply fingerprint to enterprise customers
  - Client refuses messages from unknown senders, until
    - They respond to a Turing test query
    - They execute a computationally expensive applet
    - Micropayment

Link Spam

- Keyword / Meta tag stuffing
  - Linguistic spoofing
- Multiple titles
- Tiny fonts
- Invisible text
  - <body bgcolor="FFFFFF">
  - Your text here
  - Problem: takes up space. Size=1? Bottom?
- Doorway / jump pages
  - Fast meta refresh
- Cloaking ~ Code swapping
- Pagerank spoofing (Link newtworks)

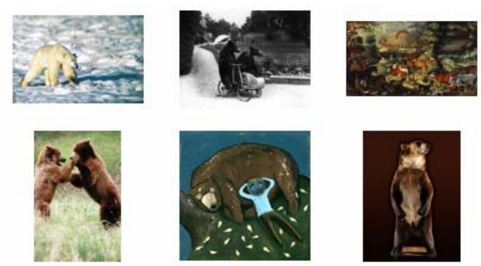
Robots

- Threat: automatic creation of accounts
  - Paypal
  - Storage associated: Hotmail, Yahoo communities…
  - Adbots in chat rooms
  - Online polls
- Solutions
  - Turing tests
    - Distorted speech recognition
    - Overlayed distorted text recognition
    - CAPTCHA
      - Automated public Turing test to tell computers and humans apart
      - http://www.captcha.net/

Gimpy: Type 3 words

Mori & Malik (UCB) program solving ez-gimpy with accuracy 83%

Semantic Tests



ESP Game

http://www.espgame.org/

Viruses

- Defn
  - Requires human action to spread
  - Infects most files on local computer
  - Doesn't automatically spread across network
  - Carries payload (destructive or annoying messages)
- Common Modus Operandi
  - Macro attached to office document
- Solutions
  - Fingerprint based (to detect viruses)
  - Application checksums (to detect tampering)

Worms

- **Defn**
  - Automatically spreads to other systems
- **Modus Operandi**
  - Protocol worms
  - Hybrid virus / worms
- **Solutions**