CSci 4271W
Development of Secure Software Systems
Day 25: Authentication

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Outline

Authentication factors

- Something you know (password, PIN)
- Something you have (e.g., smart card)
- Something you are (biometrics)
- CAPTCHAs, time and location, . . .
- Multi-factor authentication

Passwords: love to hate

- Many problems for users, sysadmins, researchers
- But familiar and near-zero cost of entry
- User-chosen passwords proliferate for low-stakes web site authentication

Password entropy

- Model password choice as probabilistic process
- If uniform, $\log_2 |S|$
- Controls difficulty of guessing attacks
- Hard to estimate for user-chosen passwords
  - Length is an imperfect proxy

Password hashing

- Idea: don't store password or equivalent information
- Password 'encryption' is a long-standing misnomer
  - E.g., Unix `crypt(3)`
- Presumably hard-to-invert function h
- Store only $h(p)$

Dictionary attacks

- Online: send guesses to server
- Offline: attacker can check guesses internally
- Specialized password lists more effective than literal dictionaries
  - Also generation algorithms (s $\rightarrow$ \$, etc.)
- $\sim$25% of passwords consistently vulnerable

Better password hashing

- Generate random salt s, store $(s, h(s, p))$
  - Block pre-computed tables and equality inferences
  - Salt must also have enough entropy
- Deliberately expensive hash function
  - AKA password-based key derivation function (PBKDF)
  - Requirement for time and/or space

Password usability

- User compliance can be a major challenge
  - Often caused by unrealistic demands
- Distributed random passwords usually unrealistic
- Password aging: not too frequently
- Never have a fixed default password in a product

Backup authentication

- Desire: unassisted recovery from forgotten password
- Fall back to other presumed-authentic channel
  - Email, cell phone
- Harder to forget (but less secret) shared information
  - Mother's maiden name, first pet's name
- Brittle: ask Sarah Palin or Mat Honan

Backup auth suggestion: use time

- Need for backup often comes for infrequently-used accounts
- May be acceptable to slow down recovery if it reduces attack risk
  - Account recovery is a hassle anyway
- Time can allow legitimate owner to notice malicious request

Centralized authentication

- Enterprise-wide (e.g., UMN ID)
- Anderson: Microsoft Passport
- Today: Facebook Connect, Google ID
- May or may not be single-sign-on (SSO)

Biometric authentication

- Authenticate by a physical body attribute

+ Hard to lose
— Hard to reset
— Inherently statistical
— Variation among people

Example biometrics

- (Handwritten) signatures
- Fingerprints, hand geometry
- Face and voice recognition
- Iris codes

Outline

User authentication

Announcements intermission

Error rate trade-offs

Web authentication

Names and identities

Note to early readers

- This is the section of the slides most likely to change in the final version
- If class has already happened, make sure you have the latest slides for announcements

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Imperfect detection

- Many security mechanisms involve imperfect detection/classification of relevant events
- Biometric authentication
- Network intrusion detection
- Anti-virus (malware detection)
- Anything based on machine learning

Detection results

- True positive: detector says yes, reality is yes
- True negative: detector says no, reality is no
- False positive: detector says yes, reality is no
- False negative: detector says no, reality is yes
- Note: terminology may flip based on detecting good or bad

Why a trade-off?

- Imperfect methods have a trade-off between avoiding FPs and avoiding FNs
- Sometimes a continuous trade-off (curve), e.g. based on a threshold
  - E.g., spam detector "score"
- May need to choose both a basic mechanism and a threshold

Two ratios to capture the trade-off

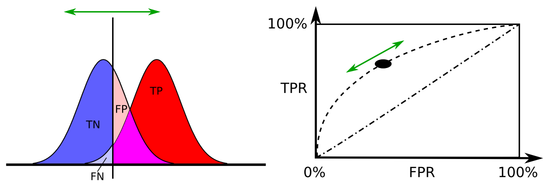
- True positive rate:

$$\mathrm{TPR} = \frac{\mathrm{TP}}{\mathrm{P}} = \frac{\mathrm{TP}}{\mathrm{TP} + \mathrm{FN}} = 1 - \mathrm{FNR}$$

- False positive rate:

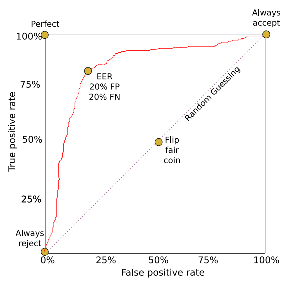
$$\mathrm{FPR} = \frac{\mathrm{FP}}{\mathrm{N}} = \frac{\mathrm{FP}}{\mathrm{FP} + \mathrm{TN}} = 1 - \mathrm{TNR}$$

ROC curve intro



Source: https://commons.wikimedia.org/wiki/File:ROC_curves.svg CC-BY-SA 3.0 "Sharpr"

Error rates: ROC curve



Extreme biometrics examples

- `exact_iris_code_match`: very low false positive (false authentication)
- `similar_voice_pitch`: very low false negative (false reject)

Where are these in ROC space?

A `if (iris()) return REJECT; else return ACCEPT;`

B `return REJECT;`

C `if (iris()) return ACCEPT; else return REJECT;`

D `if (iris() && pitch()) return ACCEPT; else return REJECT;`

E `return ACCEPT;`

F `if (rand() & 1) return ACCEPT; else return REJECT;`

G `if (pitch()) return ACCEPT; else return REJECT;`

H `if (iris() || pitch()) return ACCEPT; else return REJECT;`

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Per-website authentication

- Many web sites implement their own login systems
  - + If users pick unique passwords, little systemic risk
  - – Inconvenient, many will reuse passwords
  - – Lots of functionality each site must implement correctly
  - – Without enough framework support, many possible pitfalls

Building a session

- HTTP was originally stateless, but many sites want stateful login sessions
- Built by tying requests together with a shared session ID
- Must protect confidentiality and integrity

Session ID: what

- Must not be predictable
  - Not a sequential counter
- Should ensure freshness
  - E.g., limited validity window
- If encoding data in ID, must be unforgeable
  - E.g., data with properly used MAC
  - Negative example: crypt(username || server secret)

Session ID: where

- Session IDs in URLs are prone to leaking
  - Including via user cut-and-paste
- Usual choice: non-persistent cookie
  - Against network attacker, must send only under HTTPS
- Because of CSRF, should also have a non-cookie unique ID

Session management

- Create new session ID on each login
- Invalidate session on logout
- Invalidate after timeout
  - Usability / security tradeoff
  - Needed to protect users who fail to log out from public browsers

Account management

- Limitations on account creation
  - CAPTCHA? Outside email address?
- See previous discussion on hashed password storage
- Automated password recovery
  - Usually a weak spot
  - But, practically required for large system

Client and server checks

- For usability, interface should show what's possible
- But must not rely on client to perform checks
- Attackers can read/modify anything on the client side
- Easy example: item price in hidden field

Direct object references

- Seems convenient: query parameter names resource directly
  - E.g., database key, filename (path traversal)
- Easy to forget to validate on each use
- Alternative: indirect reference like per-session table
  - Not fundamentally more secure, but harder to forget check

Function-level access control

- E.g. pages accessed by URLs or interface buttons
- Must check each time that user is authorized
  - Attack: find URL when authorized, reuse when logged off
- Helped by consistent structure in code

Outline

Accounts versus identities

- "Identity" is a broad term that can refer to a personal conception or an automated sytem
- "Name" is also ambiguous in this way
- "Account" and "authentication" refer unambiguously to institutional/computer abstractions
- Any account system is only an approximation of the real world

Real human names are messy

- Most assumptions your code might make will fail for someone
  - ASCII, length limit, uniqueness, unchanging, etc.
- So, don't design in assumptions about real names
- Use something more computer-friendly as the core identifier
  - Make "real" names or nicknames a presentation aspect

Zooko's triangle

- Claims (2001) it is hard/impossible for a naming scheme to be simultaneously:
  - Human-meaningful
  - Secure
  - Decentralized
- Too imprecise to be definitively proven/refuted
  - Blockchain-based name systems are highest-profile claimed counterexamples
- A useful heuristic for seeing design tensions

Identity documents: mostly unhelpful

- "Send us a scan of your driver's license"
  - Sometimes called for by specific regulations
  - Unnecessary storage is a disclosure risk
  - Fake IDs are very common

Identity numbers: mostly unhelpful

- Common US example: social security number
- Variously used as an identifier or an authenticator
  - Dual use is itself a cause for concern
- Known by many third parties (e.g., banks)
- No checksum, guessing risks
- Published soon after a person dies

“Identity theft”

- The first-order crime is impersonation fraud between two other parties
  - E.g., criminal trying to get money from a bank under false pretenses
- The impersonated “victim” is effectively victimized by follow-on false statements
  - E.g., by credit reporting agencies
  - These costs are arguably the result of poor regulatory choices
- Be careful w/ negative info from 3rd parties