Identity Authentication

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(with material from Bishop’s text “Introduction to Computer Science”)

Authentication

- Basics
- Passwords
- Challenge-Response
- Biometrics
- Location
- Multiple Methods

Basics

- Authentication: binding of identity to subject
  - Identity is that of external entity (my identity, Van, *etc*.)
  - Subject is computer entity (process, *etc*.)
- Note:
  - message authentication is a different topic and already mentioned in the applications of hash functions

Establishing Identity

- One or more of the following
  - What entity knows (*eg.* password)
  - What entity has (*eg.* Identity card, smart card)
  - What entity is (*eg.* fingerprints, retinal characteristics)
  - Where entity is (*eg*. In front of a particular terminal)

Authentication System

- We need a formal definition, rather abstract view, of an AS
- A 5-tuple (A, C, F, L, S)
  - *A – a set:* information that proves identity
  - *C – a set:* information stored on computer and used to validate authentication information
  - *F: a set of* complementation functions; $f : A \rightarrow C$
    - *To compute complement information from identity information*
  - *L:* authentication functions that prove identity
  - *S:* functions enabling entity to create, alter information in *A* or *C*

Example

- Password system, with passwords stored on line in clear text
  - *A* set of strings making up passwords
  - $C = A$
  - *F* singleton set of identity function $\{ I \}$
  - *L* single equality test function $\{ eq \}$
  - *S* function to set/change password

Passwords

- Sequence of characters
  - Examples: 10 digits, a string of letters, *etc*.
  - Generated randomly, by user, by computer with user input
- Sequence of words
  - Examples: pass-phrases
- Algorithms
  - Examples: challenge-response, one-time passwords

Storage

- Store as cleartext
  - If password file compromised, *all* passwords revealed
- Encipher file
  - Need to have decipherment, encipherment keys in memory
  - Reduces to previous problem ➔ need something else
- Solution: Instead store one-way hash of password
  - Got the file, attacker must still guess passwords or invert the hash values

Example: Unix

- By definition, a 5-tuple (*A*, *C*, *F*, *L*, *S*)
  - *A – a set:* information that proves identity
    -
  - *C – a set:* information stored on computer and used to validate authentication information
    -
  - *F: a set of* complementation functions; $f : A \to C$
    -
  - *L:* authentication functions that prove identity
    -
  - *S:* functions enabling entity to create, alter information in *A* or *C*
    -

Example: Unix

- By definition, a 5-tuple (*A*, *C*, *F*, *L*, *S*)
  - *A – a set:* information that proves identity
    - *A* = { strings of 8 chars or less }
  - *C – a set:* information stored on computer and used to validate authentication information
    - *C* = {hash values of password}
  - *F: a set of* complementation functions; $f : A \to C$
    - *F* = { versions of modified DES }
  - *L:* authentication functions that prove identity
    - *L* = { *login*, *su*, … }
  - *S:* functions enabling entity to create, alter information in *A* or *C*
    - *S* = { *passwd*, *nispasswd*, *passwd+*, … }

Attacking passwords

- Goal: find $a \in A$ such that:
  - For some $f \in F$, $f(a) = c \in C$
  - c is associated with entity
- Two ways to determine whether *a* meets these requirements:
  - By trying computing f(a) for a set of a values until succeed
  - By trying calling I(a) until succeed (I(a) returns true)

Preventing Attacks

- How to prevent this:
  - Hide one of *a*, *f*, or *c*
    - Prevents obvious attack from above
    - Example: UNIX/Linux shadow password files
      - Hides the *c*'s
  - Block access to all $l \in L$ or result of $l(a)$
    - Prevents attacker from knowing if guess succeeded
    - Example: preventing *any* logins to an account from a network
      - Prevents knowing results of *l* (or accessing *l*)

Dictionary Attacks

- Trial-and-error from a list of potential passwords
  - *Off-line*: know f and c's, and repeatedly try different guesses $g \in A$ until the list is done or passwords guessed
    - Examples: *crack*, *john-the-ripper*
  - *On-line*: have access to functions in L and try guesses g until some $l(g)$ succeeds
    - Examples: trying to log in by guessing a password

Success probability over a time period

Anderson's formula:

- *P* probability of guessing a password in specified period of time
- *G* number of guesses tested in 1 time unit
- *T* number of time units
- *N* number of possible passwords ($|A|$)
- Then $P \geq TG/N$

Example

- Goal
  - Passwords drawn from a 96-char alphabet
  - Can test 10^4 guesses per second
  - Probability of a success to be 0.5 over a 365 day period
  - What is minimum password length?
- Solution
  - $N \geq TG/P = (365\times24\times60\times60)\times10^4/0.5 = 6.31\times10^{11}$
  - Choose s such that $\Sigma^{s}_{j=0}\ 96^j \geq N$
  - So $s \geq 6$, meaning passwords must be at least 6 chars long

On password selection

- Random selection
  - Any password from *A* equally likely to be selected
- Pronounceable passwords
- User selection of passwords

Pronounceable Passwords

- Generate phonemes randomly
  - Phoneme is unit of sound, eg. *cv*, *vc*, *cvc*, *vcv*
  - Examples: helgoret, juttelon are; przbqxdfl, zxrptglfn are not
- Problem: too few
- Solution: key crunching
  - Run long key through hash function and convert to printable sequence
  - Use this sequence as password

User Selection

- Problem: people pick easy to guess passwords
  - Based on account names, user names, computer names, place names
  - Dictionary words (also reversed, odd capitalizations, control characters, “elite-speak”, conjugations or declensions, swear words, Torah/Bible/Koran/… words)
  - Too short, digits only, letters only
  - License plates, acronyms, social security numbers
  - Personal characteristics or foibles (pet names, nicknames, job characteristics, *etc*.

Picking Good Passwords

- "LIMm*2^Ap"
  - Names of members of 2 families
- "OoHeO/FSK"
  - Second letter of each word of length 4 or more in third line of third verse of Star-Spangled Banner, followed by "/", followed by author's initials
- What's good here may be bad there
  - "DMC/MHmh" bad at Dartmouth ("<u>D</u>artmouth <u>M</u>edical <u>C</u>enter/<u>M</u>ary <u>H</u>itchcock <u>m</u>emorial <u>h</u>ospital"), ok here
- Why are these now bad passwords? ☹

Proactive Password Checking

- Analyze proposed password for "goodness"
  - Always invoked
  - Can detect, reject bad passwords for an appropriate definition of "bad"
  - Discriminate on per-user, per-site basis
  - Needs to do pattern matching on words
  - Needs to execute subprograms and use results
    - Spell checker, for example
  - Easy to set up and integrate into password selection system

Salting

- Goal: slow dictionary attacks
- Method: perturb hash function so that:
  - Parameter controls *which* hash function is used
  - Parameter differs for each password
  - So given *n* password hashes, and therefore *n* salts, need to hash guess *n*

Examples

- Vanilla UNIX method
  - Use DES to encipher 0 message with password as key; iterate 25 times
  - Perturb E table in DES in one of 4096 ways
    - 12 bit salt flips entries 1–11 with entries 25–36
- Alternate methods
  - Use salt as first part of input to hash function

Unix actually is …

- UNIX system standard hash function
  - Hashes password into 11 char string using one of 4096 hash functions
- As authentication system:
  - *A* = { strings of 8 chars or less }
  - *C* = { 2 char hash id || 11 char hash }
  - *F* = { 4096 versions of modified DES }
  - *L* = { *login*, *su*, … }
  - *S* = { *passwd*, *nispasswd*, *passwd*+, … }

Guessing Through *L*

- Cannot prevent these
  - Otherwise, legitimate users cannot log in
- Make them slow
  - Backoff
  - Disconnection
  - Disabling
    - Be very careful with administrative accounts!
  - Jailing
    - Allow in, but restrict activities

Password Aging

- Force users to change passwords after some time has expired
  - How do you force users not to re-use passwords?
    - Record previous passwords
    - Block changes for a period of time
  - Give users time to think of good passwords
    - Don’t force them to change before they can log in
    - Warn them of expiration days in advance

Challenge-Response

- User, system share a secret function *f* (in practice, *f* is a known function with unknown parameters, such as a cryptographic key)

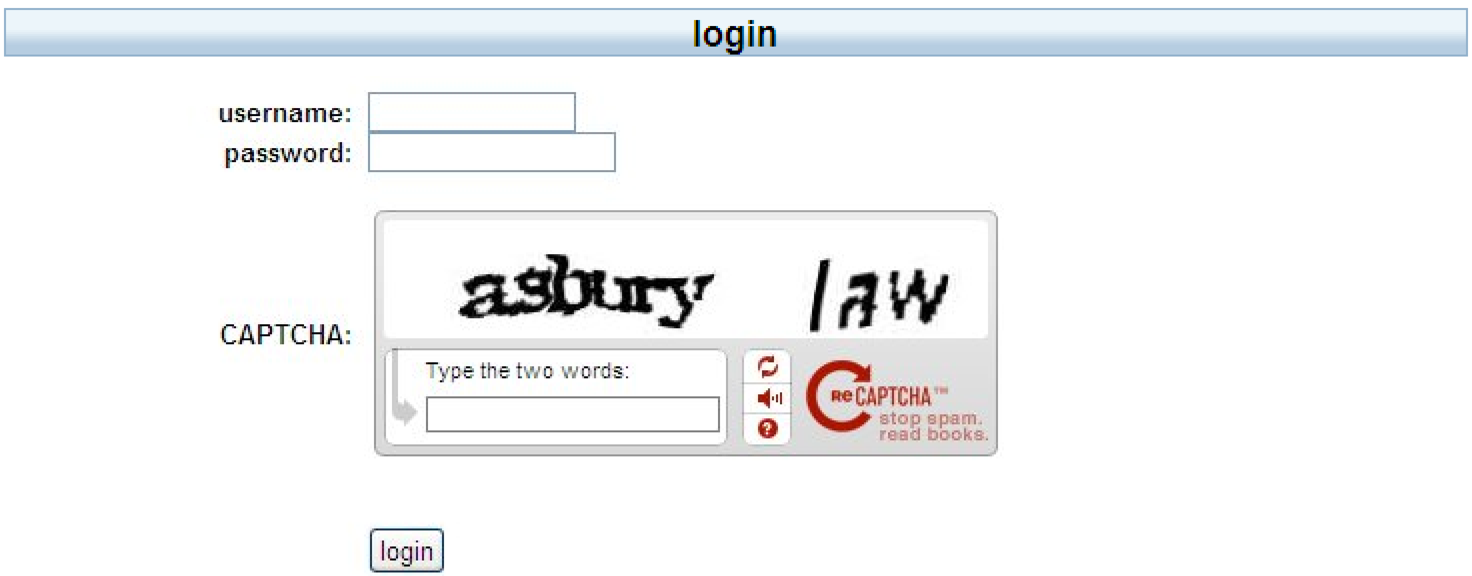
user —— *request to authenticate* ——→ *system*

user ←—— *random message r* *(the challenge)* —— *system*

user —— *f(r)* *(the response)* ——→ *system*

Pass Algorithms

- Challenge-response with the function *f* itself a secret
  - Challenge is a random string of characters
  - Response is some function of that string
  - Usually used in conjunction with fixed, reusable password



One-Time Passwords

- Password that can be used exactly *once*
  - After use, it is immediately invalidated
- Challenge-response mechanism
  - Challenge is number of authentications; response is password for that particular number
- Problems
  - Synchronization of user, system
  - Generation of good random passwords
  - Password distribution problem

S/Key

- One-time password scheme based on idea of Lamport
- h one-way hash function (MD5 or SHA-1, for example)
- User chooses initial seed k
- System calculates:

$$h(k) = k_1,\ h(k_1) = k_2,\ \ldots,\ h(k_{n-1}) = k_n$$

- Passwords are reverse order:

$$p_1 = k_n,\ p_2 = k_{n-1},\ \ldots,\ p_{n-1} = k_2,\ p_n = k_1$$

S/Key Protocol

System stores maximum number of authentications n, numbe of next authentication i, last correctly supplied password p_{i-1}.

$$\textit{user} \xrightarrow{\{\,\textit{name}\,\}} \textit{system}$$

$$\textit{user} \xleftarrow{\{\,i\,\}} \textit{system}$$

$$\textit{user} \xrightarrow{\{\,p_i\,\}} \textit{system}$$

System computes $h(p_i) = h(k_{n-i+1}) = k_{n-i} = p_{i-1}$. If match with what is stored, system replaces p_{i-1} with p_i and increments i.

Hardware Support

- Token-based
  - Used to compute response to challenge
    - May encipher or hash challenge
    - May require PIN from user
- Temporally-based
  - Every minute (or so) different number shown
    - Computer knows what number to expect when
  - User enters number and fixed password

C-R and Dictionary Attacks

- Same as for fixed passwords
  - Attacker knows challenge *r* and response *f*(*r*); if *f* encryption function, can try different keys
    - May only need to know *form* of response; attacker can tell if guess correct by looking to see if deciphered object is of right form
    - Example: Kerberos Version 4 used DES, but keys had 20 bits of randomness; Purdue attackers guessed keys quickly because deciphered tickets had a fixed set of bits in some locations

Encrypted Key Exchange

- Defeats off-line dictionary attacks
- Idea: random challenges enciphered, so attacker cannot verify correct decipherment of challenge
- Assume Alice, Bob share secret password *s*
- In what follows, Alice needs to generate a random public key *p* and a corresponding private key *q*
- Also, *k* is a randomly generated session key, and R_A and R_B are random challenges

EKE Protocol

$$\text{Alice} \xrightarrow{\text{Alice} \,||\, E_s(p)} \text{Bob}$$

$$\text{Alice} \xleftarrow{E_s(E_p(k))} \text{Bob}$$

Now Alice, Bob share a randomly generated secret session key *k*

$$\text{Alice} \xrightarrow{E_k(R_A)} \text{Bob}$$

$$\text{Alice} \xleftarrow{E_k(R_A R_B)} \text{Bob}$$

$$\text{Alice} \xrightarrow{E_k(R_B)} \text{Bob}$$

Biometrics

- Automated measurement of biological, behavioral features that identify a person
  - Fingerprints: optical or electrical techniques
    - Maps fingerprint into a graph, then compares with database
    - Measurements imprecise, so approximate matching algorithms used
  - Voices: speaker verification or recognition
    - Verification: uses statistical techniques to test hypothesis that speaker is who is claimed (speaker dependent)
    - Recognition: checks content of answers (speaker independent)

Other Characteristics

- Can use several other characteristics
  - Eyes: patterns in irises unique
    - Measure patterns, determine if differences are random; or correlate images using statistical tests
  - Faces: image, or specific characteristics like distance from nose to chin
    - Lighting, view of face, other noise can hinder this
  - Keystroke dynamics: believed to be unique
    - Keystroke intervals, pressure, duration of stroke, where key is struck
    - Statistical tests used

Cautions

- These can be fooled!
  - Assumes biometric device accurate *in the environment it is being used in!*
  - Transmission of data to validator is tamperproof, correct

Location

- If you know where user is, validate identity by seeing if person is where the user is
  - Requires special-purpose hardware to locate user
    - GPS (global positioning system) device gives location signature of entity
    - Host uses LSS (location signature sensor) to get signature for entity

Multiple Methods

- Example: “where you are” also requires entity to have LSS and GPS, so also “what you have”
- Can assign different methods to different tasks
  - As users perform more and more sensitive tasks, must authenticate in more and more ways (presumably, more stringently) File describes authentication required
    - Also includes controls on access (time of day, *etc*.), resources, and requests to change passwords

  - Pluggable Authentication Modules

PAM

- Idea: when program needs to authenticate, it checks central repository for methods to use
- Library call: *pam_authenticate*
  - Accesses file with name of program in */etc/pam_d*
- Modules do authentication checking
  - *sufficient*: succeed if module succeeds
  - *required*: fail if module fails, but all required modules executed before reporting failure
  - *requisite*: like *required*, but don't check all modules
  - *optional*: invoke only if all previous modules fail

Example PAM File

```
auth    sufficient    /usr/lib/pam_ftp.so
auth    required      /usr/lib/pam_unix_auth.so use_first_pass
auth    required      /usr/lib/pam_listfile.so onerr=succeed \
        item=user sense=deny file=/etc/ftpusers
```

For ftp:

1. If user "anonymous", return okay; if not, set PAM_AUTHTOK to password, PAM_RUSER to name, and fail
2. Now check that password in PAM_AUTHTOK belongs to that of user in PAM_RUSER; if not, fail
3. Now see if user in PAM_RUSER named in /etc/ftpusers; if so, fail; if error or not found, succeed

Key Points

- Authentication is not cryptography
  - You have to consider system components
- Passwords are here to stay
  - They provide a basis for most forms of authentication
- Protocols are important
  - They can make masquerading harder
- Authentication methods can be combined
  - Example: PAM

Kerberos

- A computer network authentication protocol
  - which allows nodes communicating over a non-secure network to prove their identity to one another in a secure manner.
- Details:
  - Self-study materials from Internet