CSE509: (Intro to) Systems Security

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Passwords

Authentication

- Basics
- Passwords
  - Storage
  - Selection
  - Breaking them
- Other methods
- Multiple methods

Authentication Basics

- Binding of identity to subject
  - Identity: external entity (e.g., Matt)
  - Subject: computer entity (process, *etc*.)

Establishing Identity

- One or more of the following
  - **What** entity **knows** (*e.g.* password)
  - **What** entity **has** (*e.g.* badge, smart card)
  - **What** entity **is** (*e.g.* fingerprints)
  - **Where** entity **is** (*e.g.* at particular terminal)

Authentication System

- (A, C, F, L, S)
  - A information that proves identity
  - C information stored on computer and used to validate authentication information
  - F complementation function; $f : A \rightarrow C$
  - L 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, computer with user input
- Sequence of words
  - Examples: pass-phrases
- Algorithms
  - Examples: challenge-response, one-time passwords

Storage

- Store as clear-text
  - If password file compromised, *all* passwords revealed
- Encipher file
  - Need to have decipherment, en-cipherment keys in memory
  - Reduces to previous problem
- Store one-way hash of password
  - If read, attacker must guess password or invert the hash

Example

- UNIX system standard hash function
  - Hashes password into 11 char string using one of 4096 (*we find out why this number later*) 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+*, … }

Anatomy of Attacking

- 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:
  - Direct approach: as above
  - Indirect approach: as $l(a)$ succeeds iff $f(a) = c \in C$ for some c associated with an entity, compute $l(a)$

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 *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: 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

Using Time

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 $\Sigma^{s}_{j=0} 96^j \geq N$
  - $s \geq 6$: passwords must be at least 6 chars long

Approaches: Password Selection

- Random selection (not realistic)
  - any password from *A* selected equally likely
- 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
  - 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, places
  - 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

- "LlMm*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 ("Dartmouth Medical Center/Mary Hitchcock memorial hospital"), 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 setup/integrate into password selection system

Example: OPUS

- Goal: check passwords against large dictionaries quickly
  - "Bloom Filters": allow to test set membership in less space (!)
    - Run each word of dictionary through k different hash functions $h_1, \ldots, h_k$ producing values less than n
    - Set bits $h_1, \ldots, h_k$ in OPUS dictionary
    - To check new proposed word, generate bit vector and see if *all* corresponding bits set
      - If so, word is in one of the dictionaries to some degree of probability
      - If not, it is not in the dictionaries

Example: *passwd+*

- Provides “little language” (describe proactive checking)
  - test length(“$p”) < 6
    - If password under 6 characters, reject it
  - test infile(“/usr/dict/words”, “$p”)
    - If password in file /usr/dict/words, reject it
  - test !inprog(“spell”, “$p”, “$p”)
    - If password not in the output from program spell, given the password as input, reject it (because it’s a properly spelled word)

Salting

- Main goal: slow down 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* times

Examples

- Vanilla UNIX method
  - Use DES to encipher message with password as key; iterate 25 times
  - Perturb DES in one of 4096 ways according to 12 bit salt
- Alternate methods
  - Use salt as first part of input to hash function

Guessing Through *L*

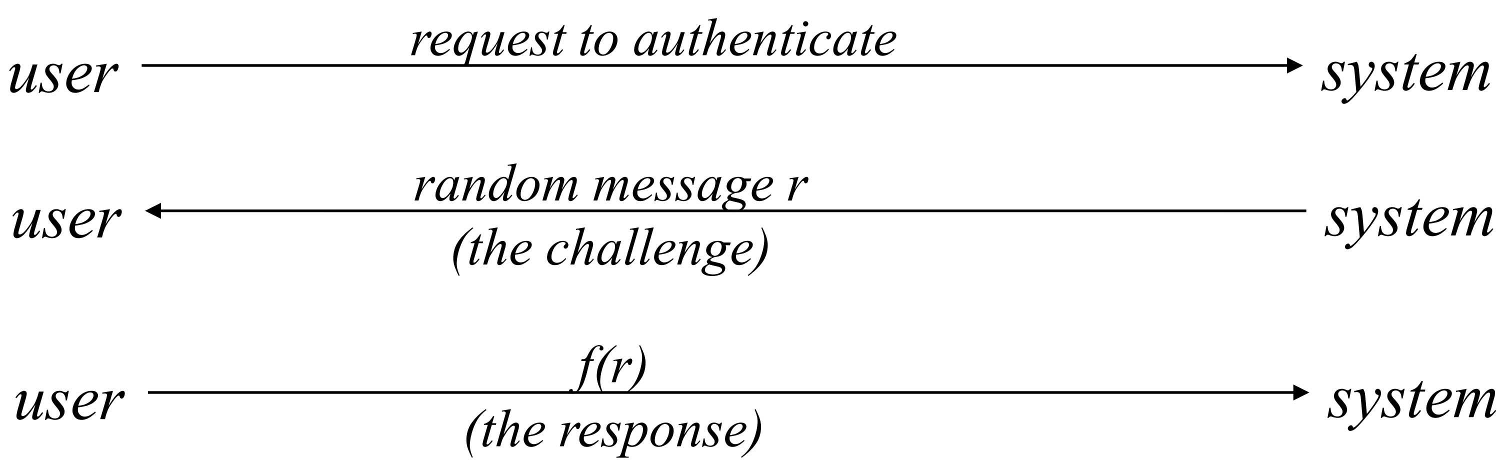
- Cannot prevent these
  - Otherwise, legitimate users cannot log in
- Make them slow
  - Back-off
  - Disconnection
  - Disabling
    - Be very careful with administrative accounts!
  - Jailing
    - Allow in, but restrict activities
    - “Honey-pots”

Password Aging

- Force users to change passwords after some time has expired
  - How do you force users not to re-use passwords?
    - Record previous (n) 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 (CR) Protocols

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



Pass Algorithms

- Challenge-response where *f* itself is a secret
  - Example:
    - Challenge: random string such as “abcdefg”, “ageksido”
    - Response is some function of that string such as “bdf”, “gkip”
  - Can alter algorithm based on ancillary information
    - Network connection is as above
    - Dial-up might require “aceg”, “aesd”
  - 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 (Lamport)
- h one-way hash function (e.g., SHA256)
- User chooses initial seed k
- System calculates:

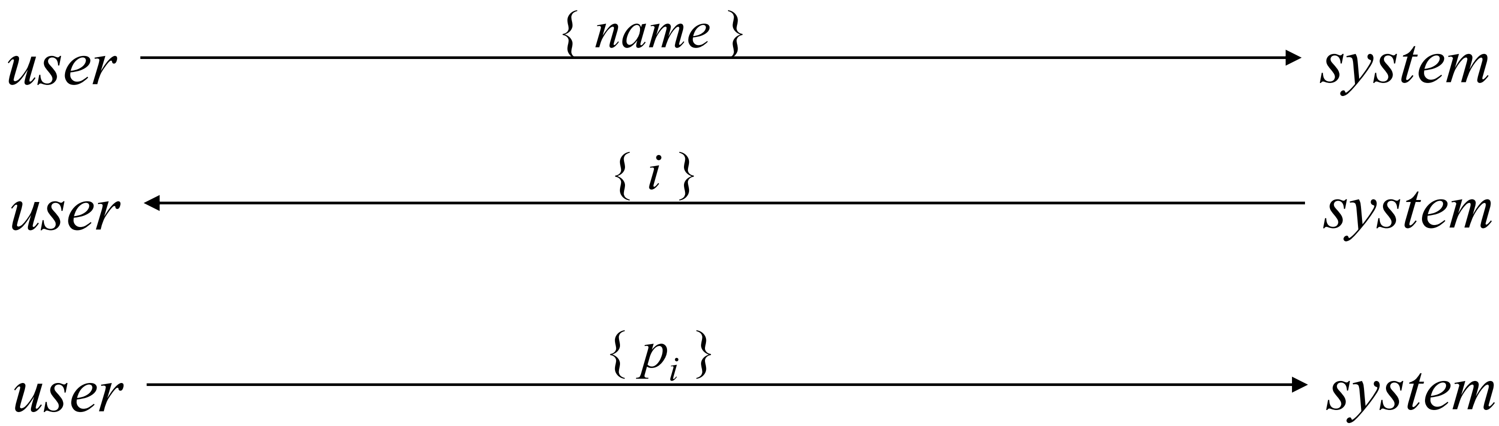
$$h(k) = k_1,\ h(k_1) = k_2,\ \ldots,\ h(k_{n-1}) = k_n$$

- Passwords are chosen in 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, number of next authentication i, last correctly supplied password p_{i-1}.



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

Dictionary Attacks in CR

- 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 only 20 bits of randomness; Purdue attackers guessed keys quickly because deciphered tickets had a fixed set of bits in some locations ☺

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
    - Imprecise: approximate matching algorithms used
  - Voice: 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
    - E.g. distance from nose to chin
    - Lighting, view of face, other noise can hinder this
  - Keystroke dynamics: believed to be unique
    - 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 alike (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 (PAMs)

PAM: Pluggable Authentication Module

- 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