Authentication

ECS 153 Spring Quarter 2021

Module 7

Basics

- Authentication: binding of identity to subject
  - Identity is that of external entity (my identity, Matt, *etc*.)
  - Subject is computer entity (process, *etc*.)

Establishing Identity

- One or more of the following
  - What entity knows (*eg.* password)
  - What entity has (*eg.* badge, smart card)
  - What entity is (*eg.* fingerprints, retinal characteristics)
  - Where entity is (*eg*. In front of a 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; for $f \in F$, $f : A \to C$
  - L functions that prove identity; for $l \in L$, $l : A \times C \to \{ \text{true}, \text{false} \}$
    - l is lowercase "L"
  - 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
- Store one-way hash of password
  - If file read, attacker must still guess passwords or invert the hash

Example

- UNIX system original 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+*, … }

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)

Approaches: Password Selection

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

Random Passwords

- Choose characters randomly from a set of possible characters; may also choose length randomly from a set of possible lengths
- Expected time to guess password maximized when selection of characters in the set, lengths in the set, are equiprobable
- In practice, several factors to be considered:
  - If password too short, likely to be guessed
  - Some other classes of passwords need to be eliminated, such as repeated patterns ("aaaaa"), known patterns ("qwerty")
  - But if too much is excluded, space of possible passwords becomes small enough to search exhaustively

Generating Random Passwords

- Random (pseudorandom) number generator period critical!
- Example: PDP-11 randomly generated passwords of length 8, and composed of capital letters and digits
  - Number of possible passwords = $(26 + 10)^8 = 36^8 = 2.8 \times 10^{12}$
  - Took 0.00156 to test a password, so would take about 140 years to try all
- Attacker noticed the pseudorandom number generator on PDP-11, with word size of 16 bits, had period of $2^{16} - 1$
  - Number of possible passwords = $2^{16} - 1 = 65{,}535 = 6.5 \times 10^4$
  - Took 0.00156 to test a password, so would take about 102 seconds to try all
- When launched, found all passwords in under 41 seconds

Remembering Random Passwords

- Humans can repeat with perfect accuracy 8 meaningful items
  - Like digits, letters, words
- Write them down
  - Put them in a place where others are unlikely to get to them
  - Purse or wallet is good; keyboard or monitor is not
- Write obscured versions of passwords
  - Let $p \in P$ be password; choose invertible transformation algorithm t: $P \rightarrow A$
  - Write down $t^{-1}(p)$ but not t
  - Now user must memorize t, not each individual password
- Use a password manager (password wallet)
  - Now must remember password to unlock the other 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
- Bigger problem: distribution of passwords
  - Probabilities of selection of particular phonemes, hence passwords, not equiprobable
  - Generated passwords tend to cluster; if an attacker finds a cluster with passwords user is likely to select, this reduces search space greatly

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

- "WtBvStHbChCsLm?TbWtF.+FSK"
  - Intermingling of letters from Star Spangled Banner , some punctuation, and author's initials
- What's good somewhere may be bad somewhere else
  - "DCHNH,DMC/MHmh" bad at Dartmouth ("Dartmouth College Hanover NH, Dartmouth Medical Center/Mary Hitchcock memorial hospital"), ok elsewhere (probably)
- 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

Example: OPUS

- Goal: check passwords against large dictionaries quickly
  - 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 to 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)

Passphrases

- A password composed of multiple words and, possibly, other characters
- Examples:
  - “home country terror flight gloom grave”
    - From Star Spangled Banner, third verse, third and sixth line
  - “correct horse battery staple”
    - From xkcd
- Caution: the above are no longer good passphrases

Remembering Passphrases

- Memorability is good example of how environment affects security
  - Study of web browsing shows average user has 6-7 passwords, sharing each among about 4 sites (from people who opted into a study of web passwords)
    - Researchers used an add-on to a browser that recorded information about the web passwords but *not* the password itself
- Users tend not to change password until they know it has been compromised
  - And when they do, the new passwords tend to be as short as allowed
- Passphrases seem as easy to remember as passwords
  - More susceptible to typographical errors
  - If passphrases are text as found in normal documents, error rate drops

Password Manager (Wallet)

- A mechanism that encrypts a set of user’s passwords
- User need only remember the encryption key
  - Sometimes called “master password”
  - Enter it, and then you can access all other passwords
- Many password managers integrated with browsers, cell phone apps
  - So you enter the master password, and password manager displays the appropriate password entry
  - When it does so, it shows what the password logs you into, such as the institution with the server, and hides the password; you can then have it enter the password for you

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

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

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
  - $N \geq TG/P = (365 \times 24 \times 60 \times 60) \times 10^4 / 0.5 = 6.31 \times 10^{11}$
  - 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

Guessing Through *L*

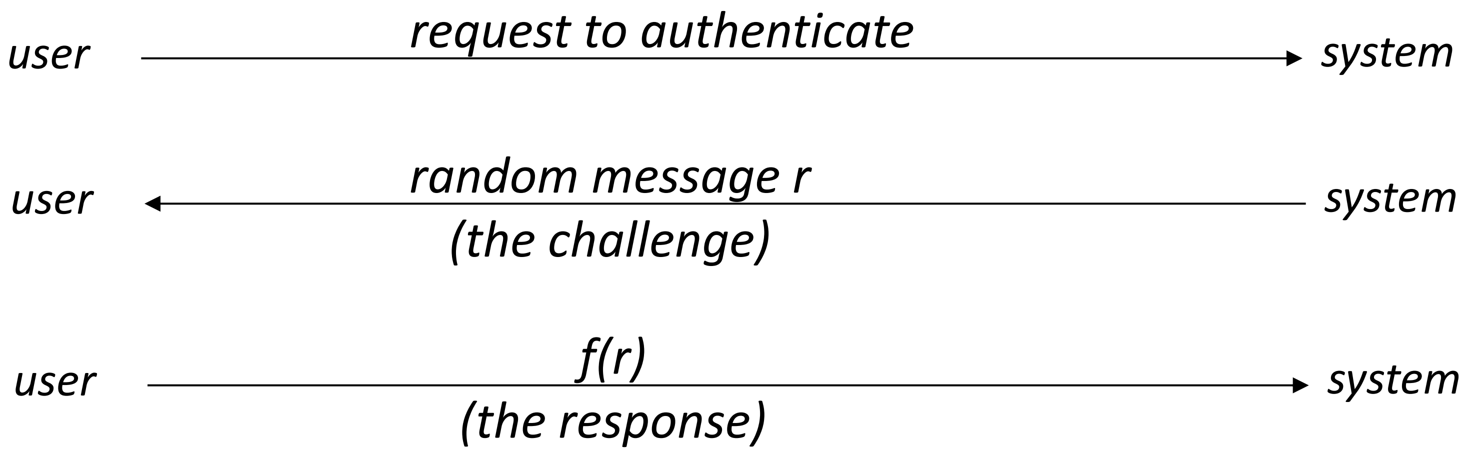
- Cannot prevent these
  - Otherwise, legitimate users cannot log in
- Make them slow
  - Backoff
  - Disconnection
  - Disabling
    - Be very careful with administrative accounts!
  - Jailing
    - Allow in, but restrict activities

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)



Pass Algorithms

- Challenge-response with the function *f* itself a secret
  - Example:
    - Challenge is a random string of characters 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"
  - 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:

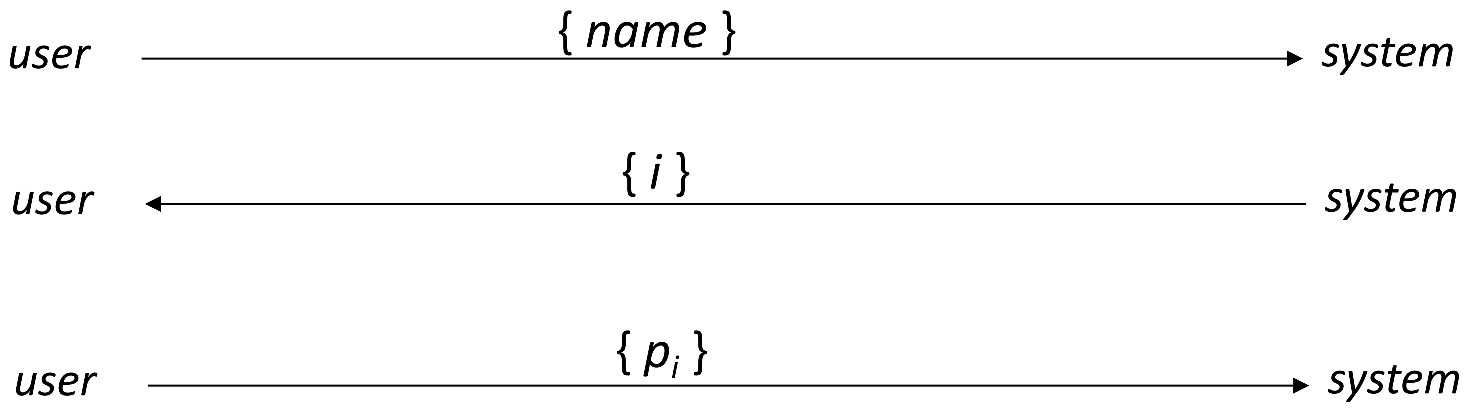
$$h(k) = k_1, h(k_1) = k_2, \ldots, h(k_{n-1}) = k_n$$

- 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, 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

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

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