Authentication

CS461/ECE422

Fall 2009

Reading

- Chapter 12 from *Computer Security*
- Chapter 10 from *Handbook of Applied Cryptography* *http://www.cacr.math.uwaterloo.ca/hac/abo*

Overview

- Basics of an authentication system
- Passwords
  - Storage
  - Selection
  - Breaking them
  - One time
- Challenge Response
- Biometrics

Ivanhoe, Sir Walter Scott

- Paraphrased:

  (Wamba gains entry to the castle dressed as a friar)

  Wamba: Take my disguise and escape, I will stay and die in your place.

  Cedric: I can't possibly impersonate a friar, I only speak English.

  Wamba: If anyone says anything to you, just say "*Pax vobiscum*."

  Cedric: What does that mean?

  Wamba: I don't know, but it works like a charm!

Basics

- Authentication: binding of identity to subject
  - Identity is that of external entity (my identity, the Illini Union Bookstore, *etc*.)
  - Subject is computer entity (process, network connection, *etc*.)

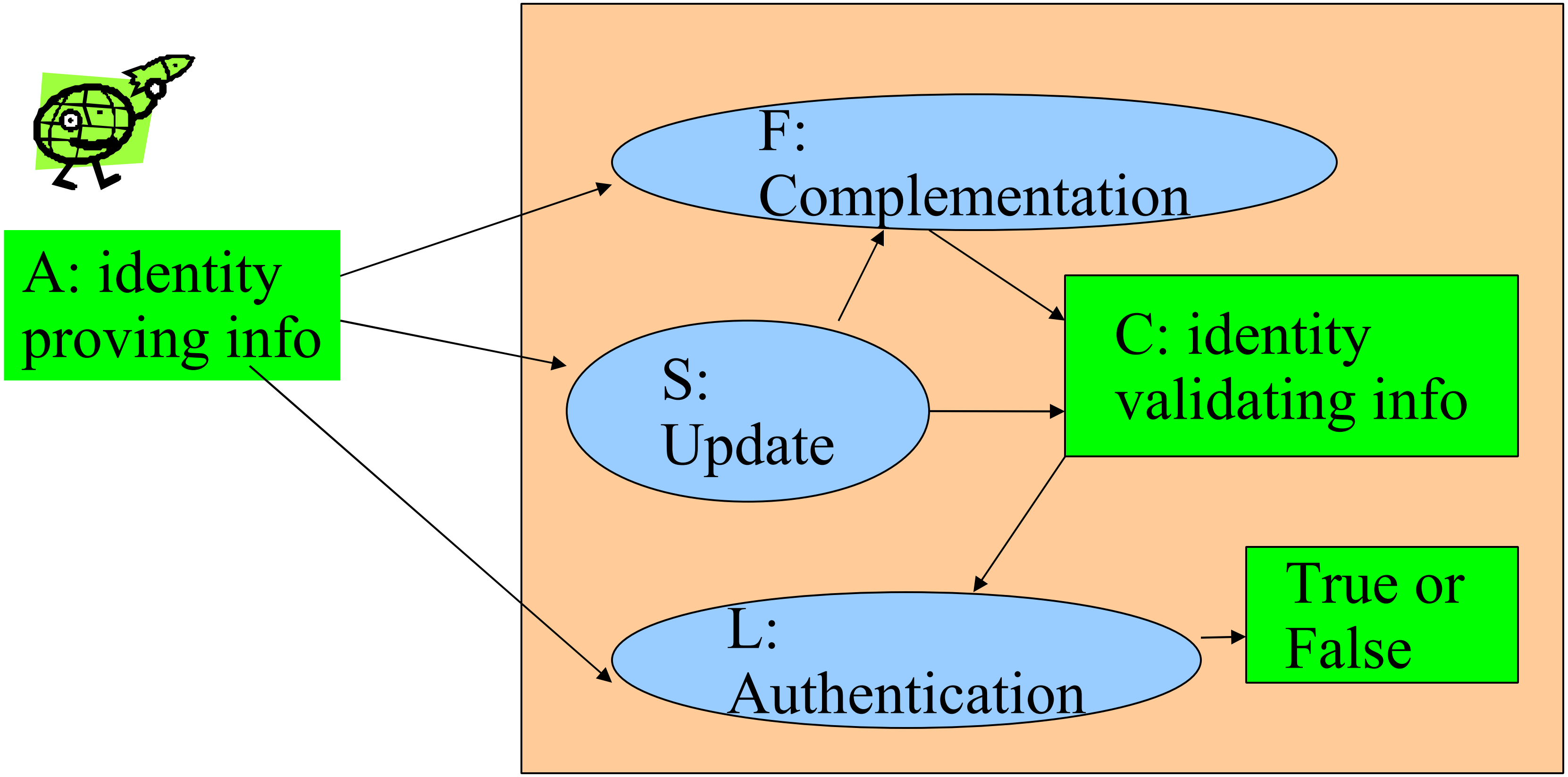
Establishing Identity

- One or more of the following
  - What entity knows (*e.g*. password, private key)
  - What entity has (*e.g*. badge, smart card)
  - What entity is (*e.g*. fingerprints, retinal characteristics)
  - Where entity is (*e.g*. In front of a particular terminal)
- Example: scene from *Ivanhoe*
- Example: Credit card transaction

Authentication System

- (A, C, F, L, S)
  - A: information that proves identity
  - C: information stored on computer and used to validate authentication information
  - F: set of complementation functions that generates C; $f : A \rightarrow C$
  - L: set of authentication functions that verify identity; $l : A \times C \rightarrow \{$ **true**, **false** $\}$
  - S: functions enabling entity to create, alter information in A or C

Authentication System



Example

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

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

- Original UNIX system standard hash function
  - Hashes password into 13 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+*, … }

Dictionary Attacks

- Trial-and-error from a list of potential passwords
  - *Off-line (type 1)*: 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 (type 2)*: have access to functions in L and try guesses g until some $l(g,c)$ succeeds
    - Examples: trying to log in by guessing a password

Preventing Attacks

- How to prevent this:
  - Hide information so that either *a*, *f*, or *c* cannot be found
    - Prevents obvious attack from above
    - Example: UNIX/Linux shadow password files
      - Hides *c*'s
  - Block access to all $l \in L$ or result of $l(a,c)$
    - 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*)

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 $P \geq \frac{TG}{N}$

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 $\sum_{j=0}^{s} 96^j \geq N$
  - So $s \geq 6$, meaning passwords must be at least 6 chars long
  - What exactly does that equation mean?

Salting

- Have a set of n complementation functions
  - Randomly select one function when registering new authentication info (function S)
  - Store ID of complementation function with complementation info
- Attacker must try all n complementation functions to see if his guess matches any password
- When does this help? When does it not?

Approaches: Password Selection

- Random selection
  - Any password from *A* equally likely to be selected
  - See previous example
  - Make sure it's random! (e.g. period of 2^{32} is not enough for $(26+10)^8$ passwords)
- Key crunching (*e.g.* hashing) a long key to a sequence of shorter keys
- Pronounceable passwords
- User selection of passwords

Pronounceable Passwords

- Generate phonemes randomly
  - Phoneme is unit of sound, *e.g. cv*, *vc*, *cvc*, *vcv*
  - Examples: helgoret, juttelon are; przbqxdfl, zxrptglfn are not
- ~ 440 possible phonemes
- 440^6 possible keys with 6 phonemes (12-18 characters long), about the same as 96^8
- Used by GNU Mailman mailing list software (?)

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, "l33t-speak", conjugations or declensions, Torah/Bible/Koran/… words)
  - Too short, digits only, letters only
  - License plates, acronyms, social security numbers
  - Personal characteristics or foibles (pet names, nicknames, *etc*.)

Picking Good Passwords

- Examples from textbook
  - "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 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*
- Doesn't help against attacking a single user
  - Does help in bulk attack

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 0–11 with entries 24–35
    - E Table is per round expansion table
- 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
  - Backoff
  - Disconnection
  - Disabling
    - Be very careful with administrative accounts!
  - Jailing
    - Allow in, but restrict activities

Leaking Information

- User friendly system gives cause of login failure
  - Bad user vs bad password
- Speed of response may give clue

Detecting Trojan Login

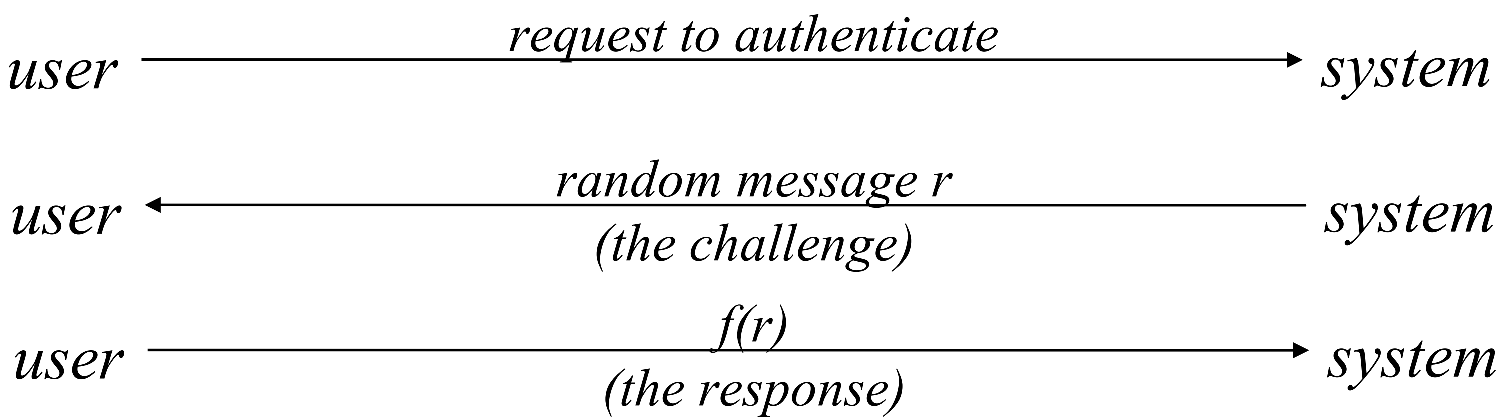
- Trusted path
  - More in next couple lectures
- Recognize last login time stamp
- Recognize previously selected picture
- Certificate

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)



One-Time Passwords

- Password that can be used exactly *once*
  - After use, it is immediately invalidated
- Challenge-response mechanism
  - Challenge is one of a 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:

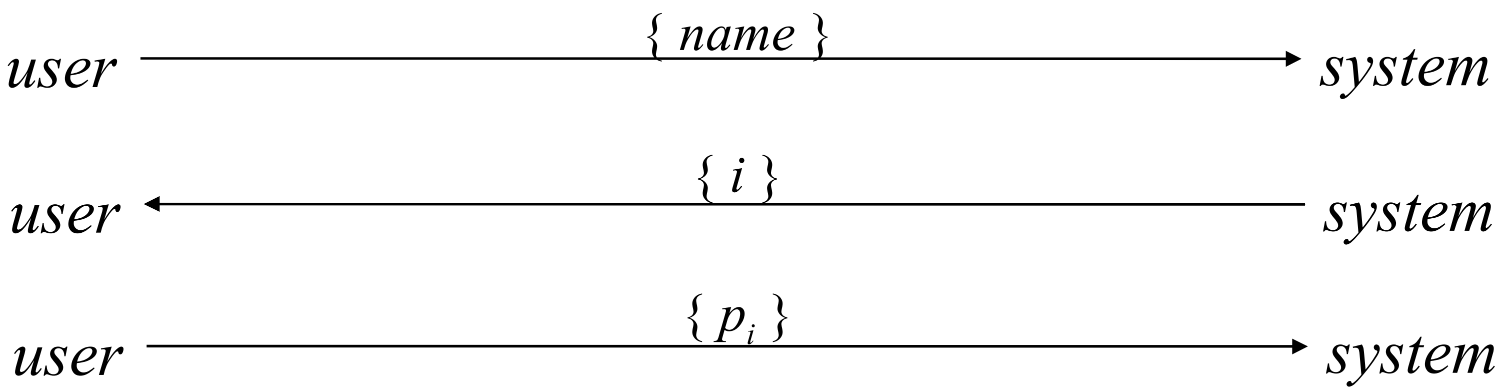
$$h(k) = k_1,\ h(k_1) = k_2,\ \ldots,\ h(k_{n-1}) = k_n$$

- 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 $h(p_i) = h(k_{n-i+1}) = k_{n-i+2} = p_{i-1}$. If match with what is stored, system replaces p_{i-1} with p_i and increments i.
(Note error in the *CSA&S* textbook.)

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

Biometrics

- Automated measurement of biological, behavioural 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

Biometric

- Physical characteristics encoded in a template
  - The C or complement information
- User registers physical information (S)
  - Generally with multiple measurements
- The L function takes a measurement and tries to line up with template

Authentication vs Identification

- Used for surveillance
  - Subject is motivated to avoid detection
- Used for authentication
  - Subject is motivated to positively identify
  - Perhaps pick up other's characteristics
- False positives vs false negatives

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 (remember *pax vobiscum*)
- Physical characteristics change over time
- Some people may not be able to identify via specific characteristics
  - Albinos and iris scans

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

Key Points

- Authentication ≠ cryptography
  - You have to consider system components
- Passwords are here to stay
  - They provide a basis for most forms of authentication
- Biometrics can help but not magic bullet