

# Identity Authentication

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Van Nguyen – HUT

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(with material from Bishop's text "Introduction to Computer Security")

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

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# 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

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

# 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; *przbqxdf*, *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 (“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  $n$

# 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

$$h(x) = \text{DES}(x)$$

# Unix actually is ...

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



# Guessing Through $L$

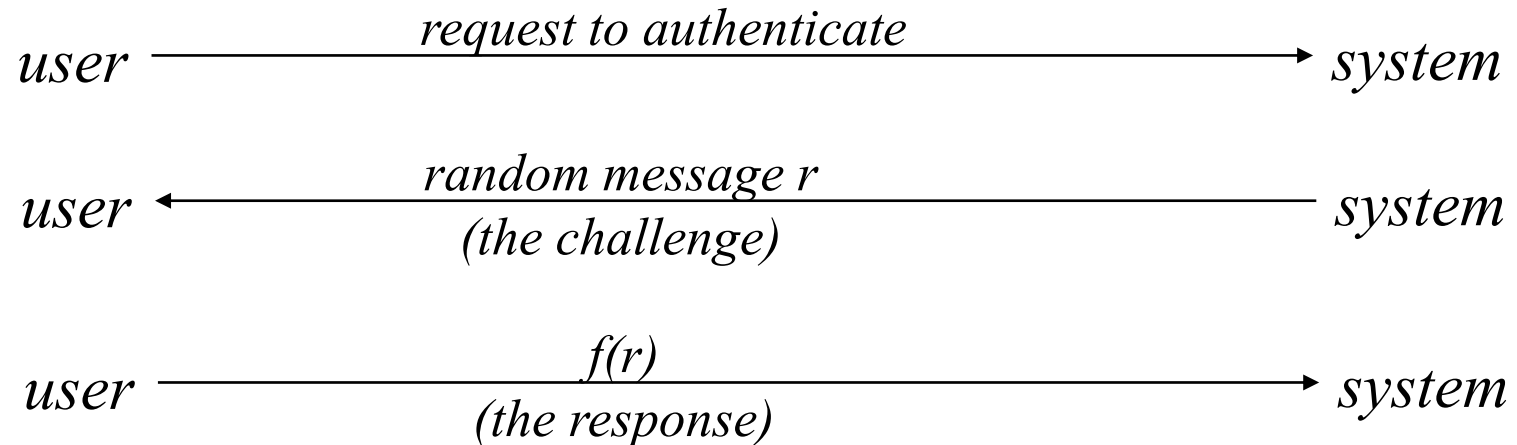
- Cannot prevent these
  - Otherwise, legitimate users cannot log in
- Make them slow
  - Backoff
  - Disconnection
  - Disabling
    - Be very careful with administrative accounts!
  - Jailing
    - Allow in, but restrict activities

# 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
  - Challenge is a random string of characters
  - Response is some function of that string
  - Usually used in conjunction with fixed, reusable password

login

username:

password:

CAPTCHA: 

login

# 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:

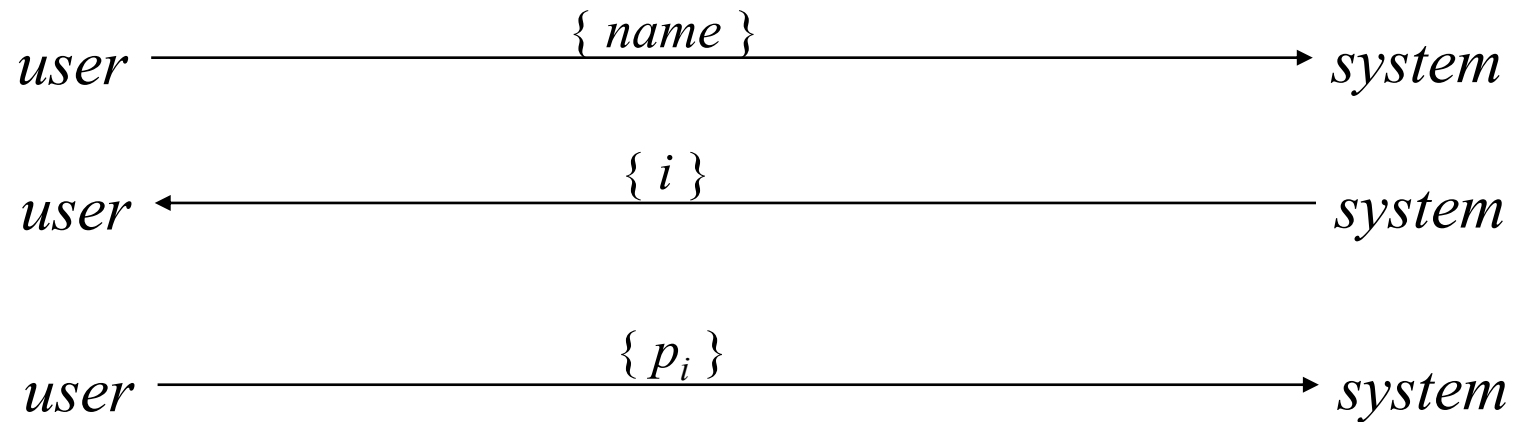
$$h(k) = k_1, h(k_1) = k_2, \dots, h(k_{n-1}) = k_n$$

- Passwords are reverse order:

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

# 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  $i$ .

# 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

*Alice*  $\xrightarrow{\text{Alice} \parallel E_s(p)}$  *Bob*

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

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

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

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

*Alice*  $\xrightarrow{E_k(R_B)}$  *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

