Authentication

By: Hamid Reza Shahriari

References

- Chapter 12 of the book:
  - Computers Security: The Art and Science
  - Some other papers (available in the course page)

- Main parts of slides are taken from http://nob.cs.ucdavis.edu/book/

Chapter 12: Authentication

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

Overview

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

Basics

- Authentication: binding of identity to subject

- نسبت دادن هویت به یک عامل/مولفه
  - هویت مربوط به نهاد خارجی است (مثلا فرد)
  - عامل/مولفه نهاد کامپیوتری است (پردازه، برنامه و ...).

Establishing Identity

- One or more of the following
  - What entity knows (*eg.* password)
  - What entity has (*eg.* 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; $f: A \rightarrow C$
  - L functions that prove identity; $I \in L, I: A \times C \rightarrow \{\textit{true, false}\}$
  - 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 clear text
  - 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

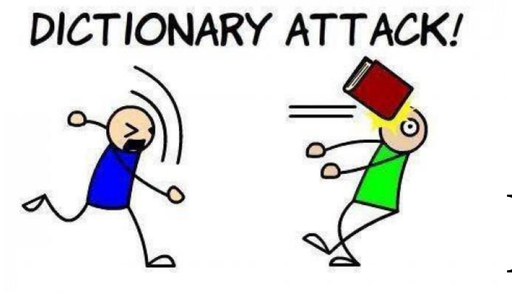
- UNIX system standard hash function
  - Hashes password into 11 char string using one of 4096 hash functions
- As authentication system:
  - A = { strings of 8 chars or less }
  - C = { 2 char hash id || 11 char hash }
  - F = { 4096 versions of modified DES }
  - L = { *login*, *su*, … }
  - S = {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

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 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
  - $N \geq TG/P = (365\times24\times60\times60)\times10^4/0.5 = 6.31\times10^{11}$
  - 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

Approaches: 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

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

- "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 ("<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

Example: OPUS

- Goal: check passwords against large dictionaries quickly
  - Run each word of dictionary through k different hash functions h_1, …, h_k producing values less than n
  - Set bits h_1, …, 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)

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

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)

$$\begin{tikzcd}
\textit{user} \arrow[r, "\textit{request to authenticate}"] & \textit{system} \\
\textit{user} & \textit{system} \arrow[l, "\textit{random message } r"', "\textit{(the challenge)}"] \\
\textit{user} \arrow[r, "f(r)", "\textit{(the response)}"'] & \textit{system}
\end{tikzcd}$$

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}.

$$\begin{tikzcd}
user \arrow[r, "\{\ name\ \}"] & system \\
user & system \arrow[l, "\{\ i\ \}"'] \\
user \arrow[r, "\{\ p_i\ \}"] & system
\end{tikzcd}$$

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

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

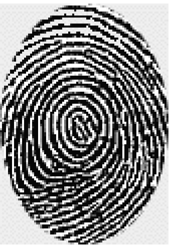
$$\mathit{Alice} \xleftarrow{E_s(E_p(k))} \mathit{Bob}$$

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

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

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

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



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

Biometrics

- Advantages
  - Cannot be disclosed, lost, forgotten
- Disadvantages
  - Cost, installation, maintenance
  - Reliability of comparison algorithms
    - False positive: Allow access to unauthorized person
    - False negative: Disallow access to authorized person
  - Privacy?
  - If forged, how do you revoke?

Biometrics

- Common uses
  - Specialized situations, physical security
  - Combine
    - Multiple biometrics
    - Biometric and PIN
    - Biometric and token

Token-based Authentication
Smart Card

- With embedded CPU and memory
  - Carries conversation w/ a small card reader
- Various forms
  - PIN protected memory card
    - Enter PIN to get the password
  - Cryptographic challenge/response cards
    - Computer create a random challenge
    - Enter PIN to encrypt/decrypt the challenge w/ the card

257324
VASCO

BlackBerry
CRYPTOMATHIC
Your Secure Code
694172
htc
10:06 AM
CRM OTP
Registration
CRYPTOMATHIC
The application is connecting to our secure server to register your device.
This might take a few seconds, please wait.
Orange
14:00
CRYPTOMATHIC
bank_user
005043
Generate Next OTP
Registration + Settings

PASSWORD
8569734
SecureCard 2000
确认
删除

ENTER PIN
menu
ON
HID

SafeID
77495012
Deepnet Security
OK

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

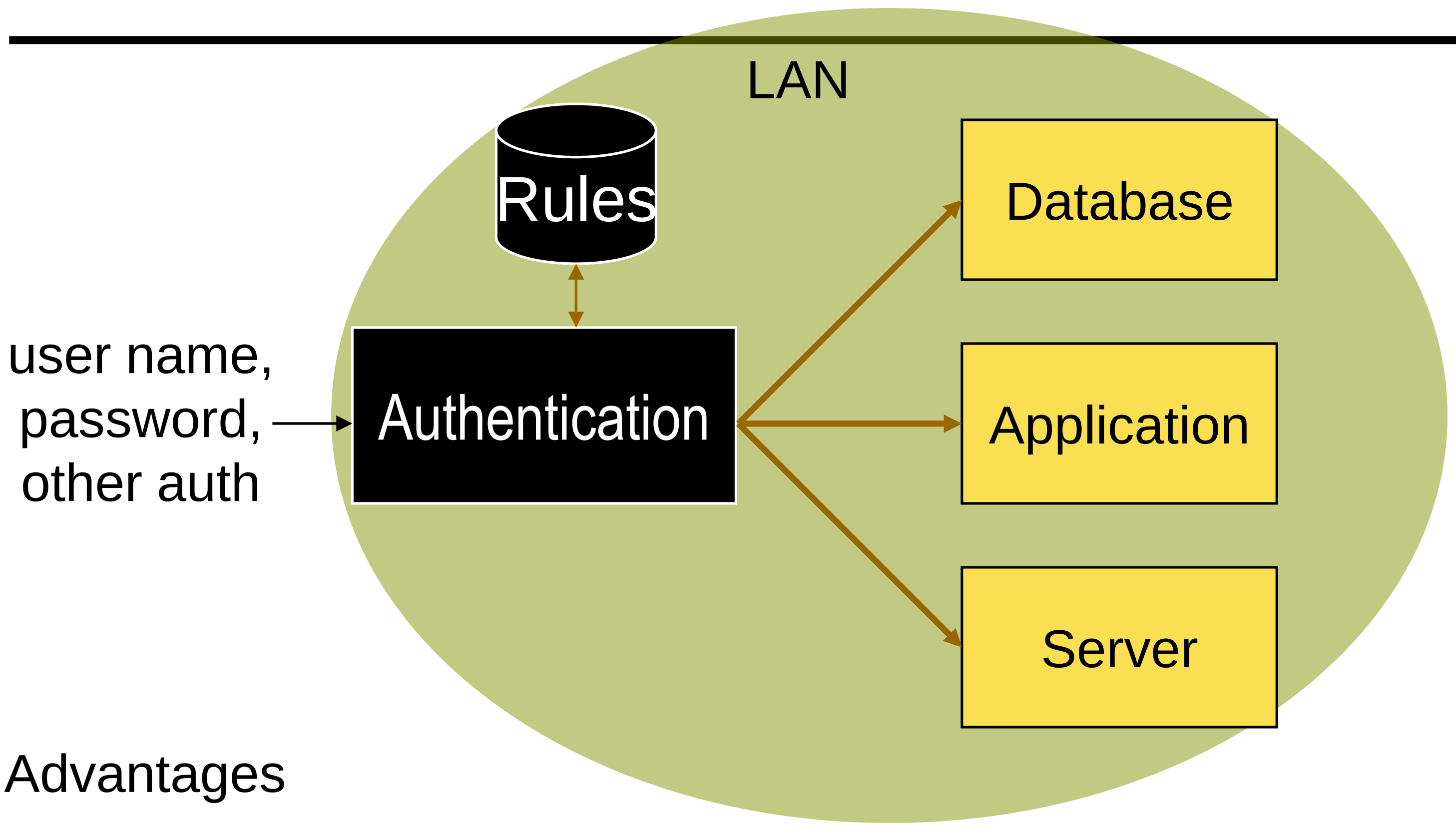
```
auth sufficient /usr/lib/pam_ftp.so
auth required   /usr/lib/pam_unix_auth.so use_first_pass
auth required   /usr/lib/pam_listfile.so onerr=succeed \
                      item=user sense=deny file=/etc/ftpusers
```

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

Single sign-on systems

e.g. Securant, Netegrity,

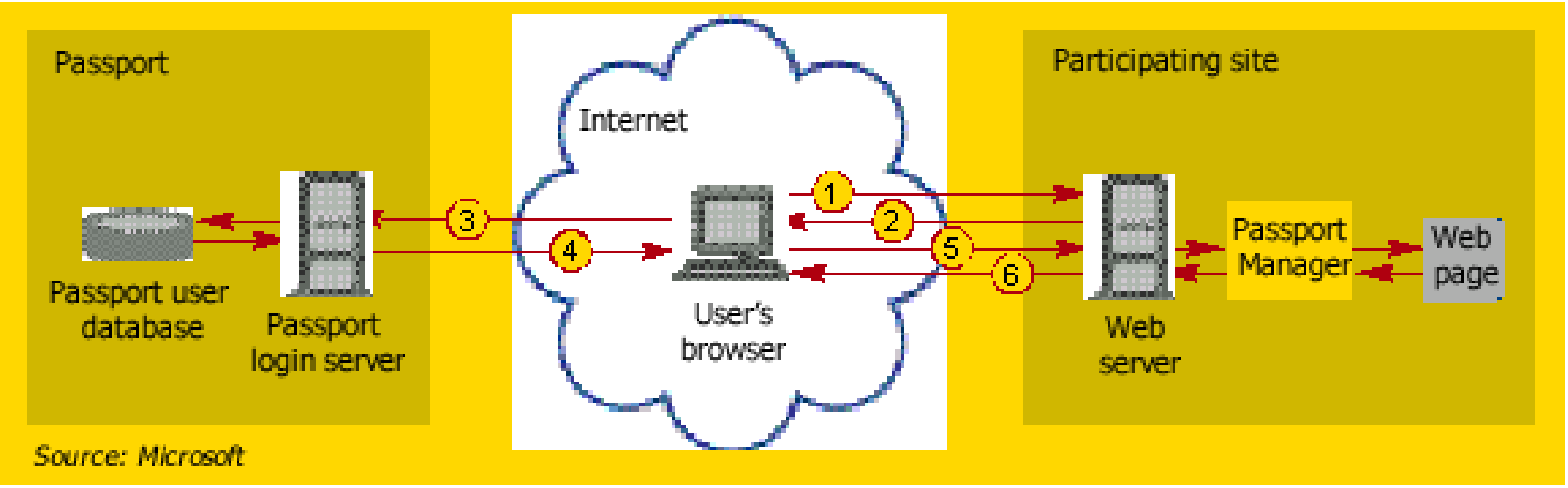


- Advantages
  - User signs on once
  - No need for authentication at multiple sites, applications
  - Can set central authorization policy for the enterprise

Microsoft Passport

- Launched 1999
  - Claim > 200 million accounts in 2002
  - Over 3.5 billion authentications each month
- Log in to many websites using one account
  - Used by MS services Hotmail, MSN Messenger or MSN subscriptions; also Radio Shack, etc.
  - Hotmail or MSN users automatically have Microsoft Passport accounts set up

Passport log-in



Sign-In of the Times. 1) The Passport authentication process begins when a user signs in from a participating Web site. 2) The user's browser is redirected to a Passport login server. 3) The Passport server prompts the user for an e-mail address and password and checks it against its database. 4) The Passport server places three encrypted cookies to the user's browser, which is redirected to the participating Web site. 5) The participating site decrypts the authentication cookie via the Passport Manager object. 6) The site serves up the requested Web page.

Trusted Intermediaries

Symmetric key problem:

- How do two entities establish shared secret key over network?

Solution:

- trusted key distribution center (KDC) acting as intermediary between entities

Public key problem:

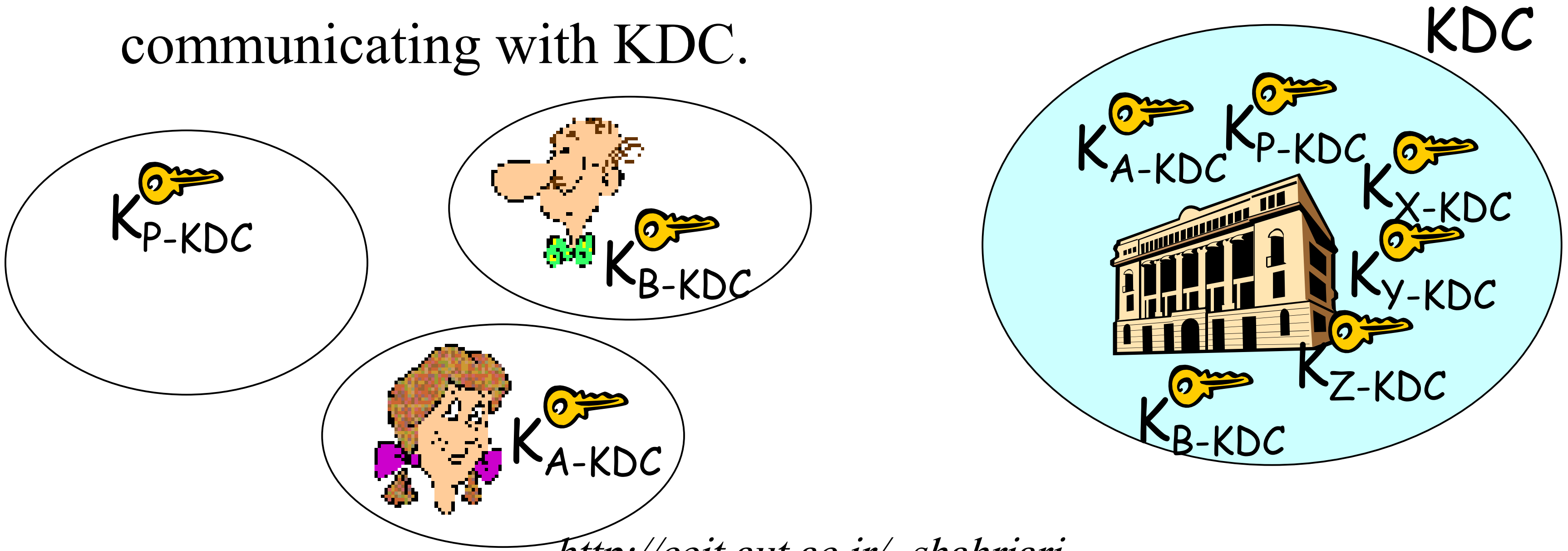
- When Alice obtains Bob's public key (from web site, e-mail, diskette), how does she know it is Bob's public key, not Trudy's?

Solution:

- trusted certification authority (CA)

Key Distribution Center (KDC)

- Alice, Bob need shared symmetric key.
- KDC: server shares different secret key with *each* registered user (many users)
- Alice, Bob know own symmetric keys, $K_{A\text{-}KDC}$ $K_{B\text{-}KDC}$, for communicating with KDC.



Key Distribution Center (KDC)

Q: How does KDC allow Bob, Alice to determine shared symmetric secret key to communicate with each other?

Alice and Bob communicate: using R1 as *session key* for shared symmetric encryption

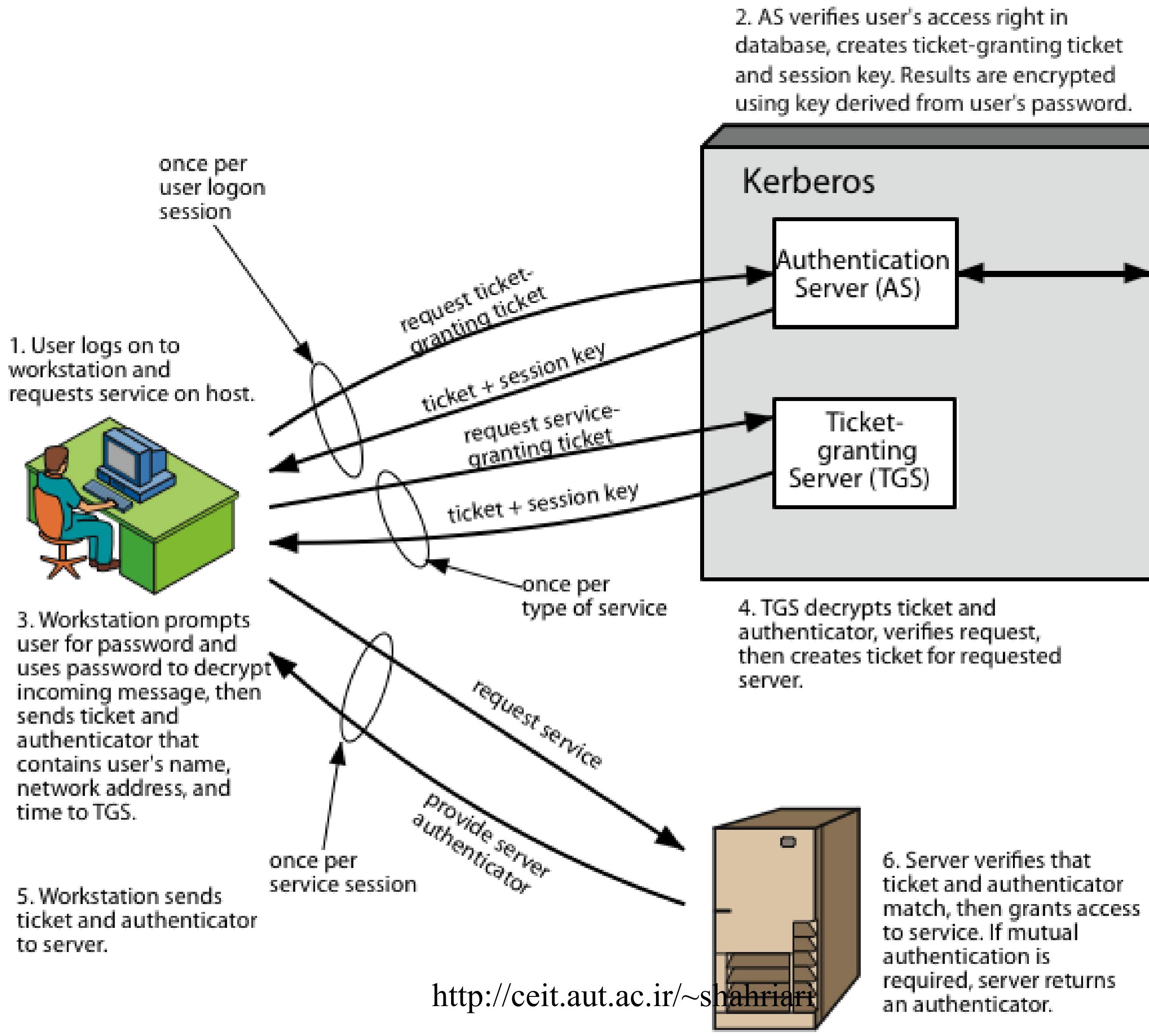
Ticket and Standard Using KDC

- Ticket
  - In $K_{A\text{-}KDC}$(R1, $K_{B\text{-}KDC}$(A,R1)), the $K_{B\text{-}KDC}$(A,R1) is also known as a ticket
  - Comes with expiration time
- KDC used in Kerberos: standard for shared key based authentication
  - Users register passwords
  - Shared key derived from the password

Kerberos

- Trusted key server system from MIT
  - one of the best known and most widely implemented **trusted thi** **party** key distribution systems.
- Provides centralised private-key third-party authentication in a distributed network
  - allows users access to services distributed through network
  - without needing to trust all workstations
  - rather all trust a central authentication server
- Two versions in use: 4 & 5
- Widely used
  - Red Hat 7.2 and Windows Server 2003 or higher

Kerberos 4 Overview


2. AS verifies user's access right in database, creates ticket-granting ticket and session key. Results are encrypted using key derived from user's password.
once per user logon session
Kerberos
Authentication Server (AS)
request ticket-granting ticket
ticket + session key
1. User logs on to workstation and requests service on host.
request service-granting ticket
Ticket-granting Server (TGS)
ticket + session key
once per type of service
3. Workstation prompts user for password and uses password to decrypt incoming message, then sends ticket and authenticator that contains user's name, network address, and time to TGS.
4. TGS decrypts ticket and authenticator, verifies request, then creates ticket for requested server.
request service
provide server authenticator
once per service session
5. Workstation sends ticket and authenticator to server.
6. Server verifies that ticket and authenticator match, then grants access to service. If mutual authentication is required, server returns an authenticator.

Kerberos Realms

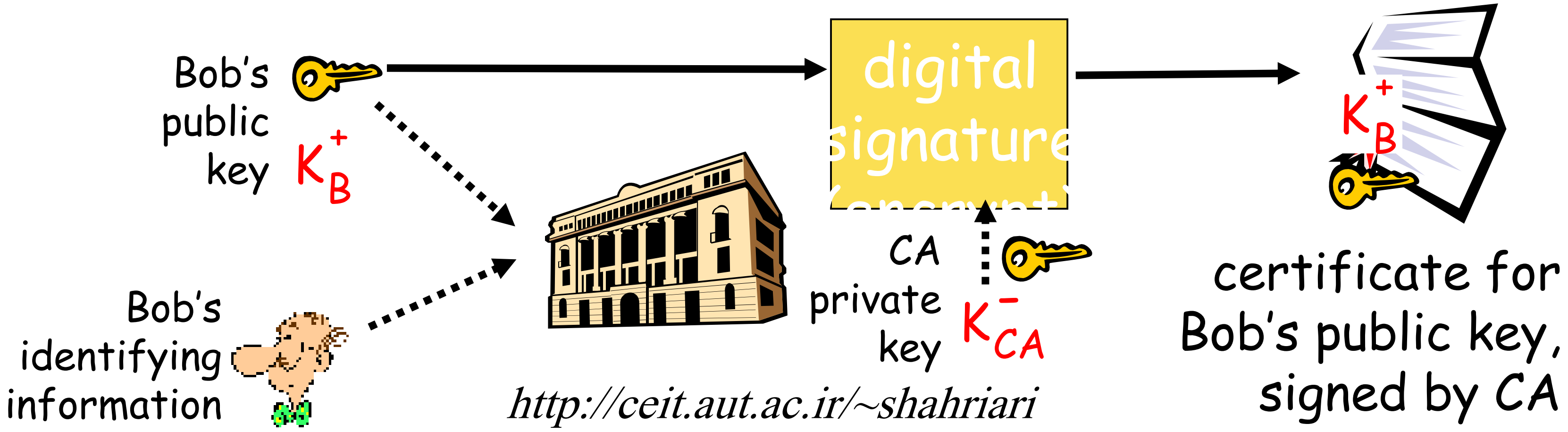
- A Kerberos environment consists of:
  - a Kerberos server
  - a number of clients, all registered with server
  - application servers, sharing keys with server
- This is termed a realm
  - typically a single administrative domain
- If have multiple realms, their Kerberos servers must share keys and trust

When NOT Use Kerberos

- No quick solution exists for migrating user passwords from a standard UNIX password database to a Kerberos password database
  - such as /etc/passwd or /etc/shadow
- For an application to use Kerberos, its source must be modified to make the appropriate calls into the Kerberos libraries
- Kerberos assumes that you are using trusted hosts on an untrusted network
- All-or-nothing proposition
  - If *any* services that transmit plaintext passwords remain in use, passwords can still be compromised

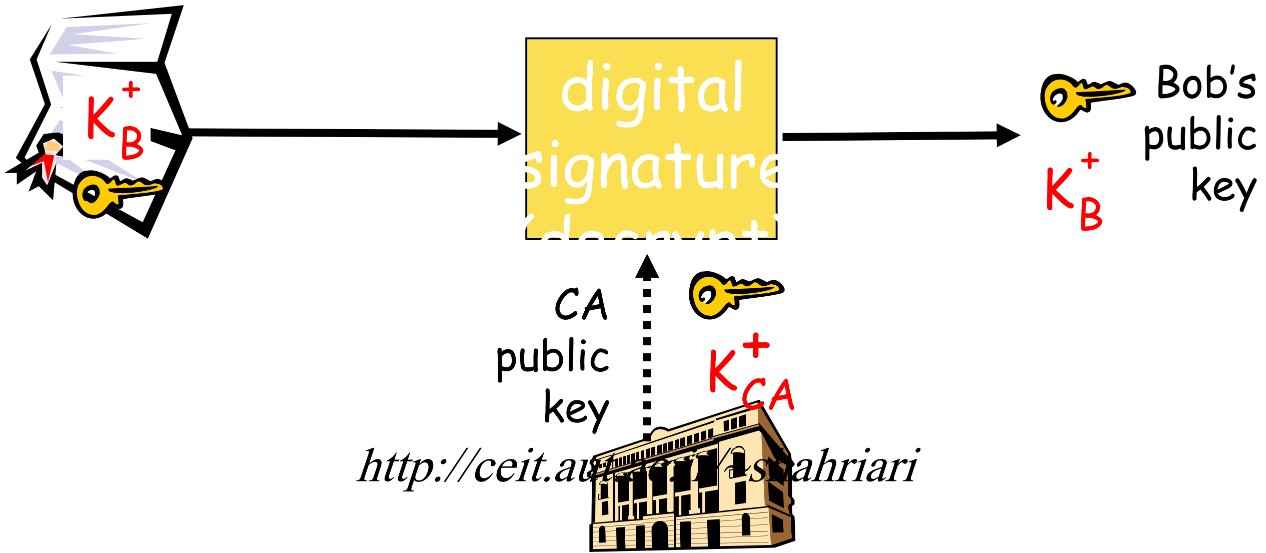
Certification Authorities

- Certification authority (CA): binds public key to particular entity, E.
- E (person, router) registers its public key with CA.
  - E provides "proof of identity" to CA.
  - CA creates certificate binding E to its public key.
  - Certificate containing E's public key digitally signed by CA – CA says "this is E's public key"


Bob's public key
K_B^+
digital signature (encrypt)
CA private key
K_{CA}^-
K_B^+
certificate for Bob's public key, signed by CA
Bob's identifying information

Certification Authorities

- When Alice wants Bob's public key:
  - gets Bob's certificate (Bob or elsewhere).
  - apply CA's public key to Bob's certificate, get Bob's public key
- CA is heart of the X.509 standard used extensively in
  - SSL (Secure Socket Layer), S/MIME (Secure/Multiple Purpose Internet Mail Extension), and IP Sec, etc.



Single KDC/CA

- Problems
  - Single administration trusted by all principals
  - Single point of failure
  - Scalability
- Solutions: break into multiple domains
  - Each domain has a trusted administration

Multiple KDC/CA Domains

Secret keys:

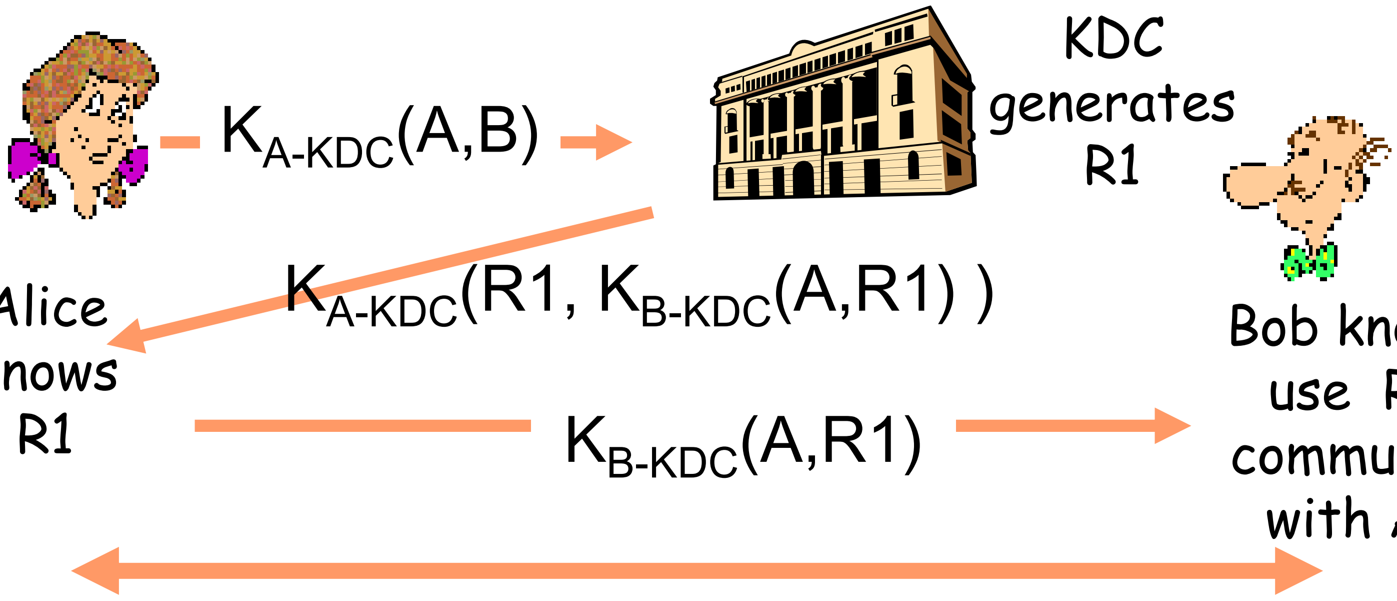
- KDCs share pairwise key
- topology of KDC: tree with shortcuts

Public keys:

- cross-certification of CAs
- example: Alice with CA_A, Boris with CA_B
  - Alice gets CA_B's certificate (public key p_1), signed by CA_A
  - Alice gets Boris' certificate (its public key p_2), signed by CA_B (p_1)

Key Distribution Center (KDC)

Q: How does KDC allow Bob, Alice to determine shared symmetric secret key to communicate with each other?



$K_{A\text{-}KDC}(A,B)$
KDC generates R1
$K_{A\text{-}KDC}(R1, K_{B\text{-}KDC}(A,R1))$
Alice knows R1
$K_{B\text{-}KDC}(A,R1)$
Bob knows to use R1 to communicate with Alice

Alice and Bob communicate: using R1 as *session key* for shared symmetric encryption

Consider the KDC and CA servers. Suppose a KDC goes down. What is the impact on the ability of parties to communicate securely; that is, who can and cannot communicate? Justify your answer. Suppose now a CA goes down. What is the impact of this failure?

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
- Single Sign On (SSO)