Computer Security 3e

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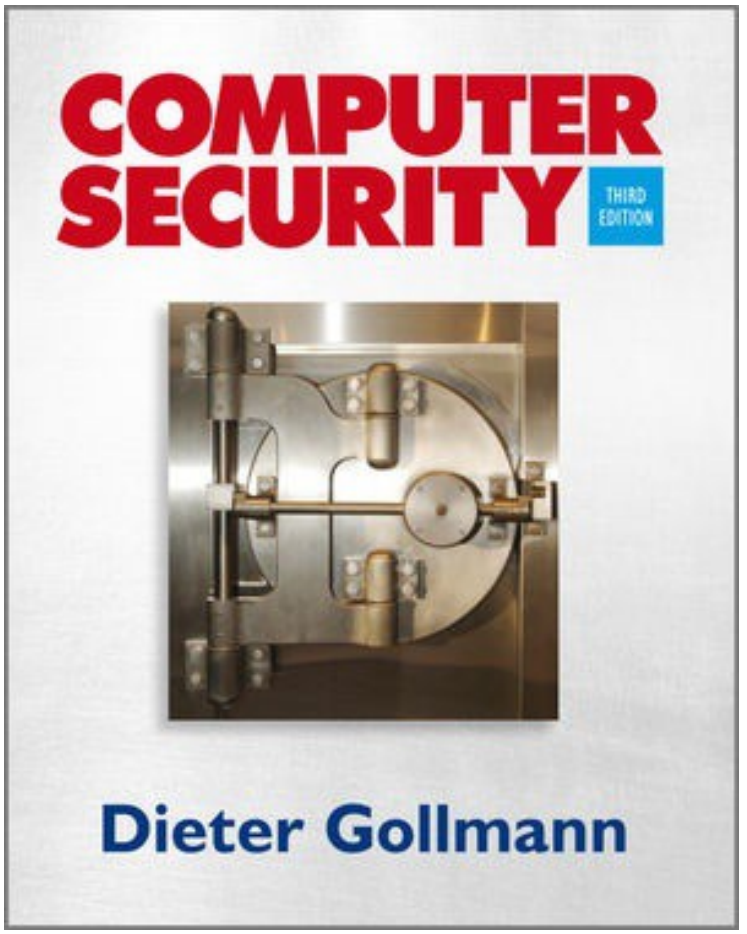


Chapter 4:
Identification & Authentication

Agenda

- User authentication
- Identification & authentication
- Passwords
  - how to get the password to the user
  - forgotten passwords
  - password guessing
  - password spoofing
  - compromise of the password file
- Biometrics
- TOCTTOU

Introduction

- A secure system might have to track the identities of the users requesting its services.
- Authentication: process of verifying a user's identity.
- Two reasons for authenticating a user:
  - The user identity is a parameter in access control decisions.
  - The user identity is recorded when logging security relevant events in an audit trail.
- It is not always necessary or desirable to base access control on user identities.
- Much stronger case for using identities in audit logs.

Identification & Authentication

- When logging on to a computer you enter
  - user name and
  - password
- The first step is called identification:
  - You announce who you are.
- The second step is called authentication;
  - You prove that you are who you claim to be.
- To distinguish this type of 'authentication' from other interpretations, we refer here to user authentication: the process of verifying a claimed user identity.
- Authentication by password is widely accepted and not too difficult to implement.

Bootstrapping Authentication

- Passwords should be secrets shared between the user and the system authenticating the user.
- How do you bootstrap a system so that the password ends up in the right places, but nowhere else?
- In an enterprise, users can collect their password personally.
- Otherwise, the password could be sent by mail, email, or phone, or entered by the user on a web page.
- You now have to consider who might intercept the message and who might actually pick it up.
  - E.g., a letter containing the password for an online bank account might be stolen or an impersonator may phone in asking for another user's password.

Authenticating a Remote User

- Do not give the password to the caller but call back an authorized phone number from your files, e.g. from an internal company address book.
- Call back someone else, e.g. the caller's manager or local security officer.
- Send passwords that are valid only for a single log-in request so that the user has to change immediately to a password not known by the sender.
- Send mail by courier with personal delivery.
- Request confirmation on a different channel to activate user account, e.g. enter the password on a web page and send confirmation by SMS (phone).

Resetting Passwords

- When setting up a new user account some delay in getting the password may be tolerated.
- If you have forgotten your password but are in the middle of an important task you need instant help.
- Procedures for resetting passwords are the same as listed previously, but now reaction should be instant.
  - Global organisations must staff a hot desk round the clock,
  - On a web site, auxiliary information may authenticate a user: mother's maiden name, phone number, name of pet, …
- Password support can become a major cost factor.
- Staff at hot desk needs proper security training.

Lesson

- Security mechanisms may fail to give access to legitimate users.
- Your security solution must be able to handle such situations efficiently.

Guessing Passwords

- Exhaustive search (brute force): try all possible combinations of valid symbols up to a certain length.
- Intelligent search: search through a restricted name space, e.g. passwords that are somehow associated with a user like name, names of friends and relatives, car brand, car registration number, phone number,…, or try passwords that are generally popular.
- Typical example for the second approach: dictionary attack trying all passwords from an on-line dictionary.
- You cannot prevent an attacker from accidentally guessing a valid password, but you can try to reduce the probability of a password compromise.

Defences

- Set a password: if there is no password for a user account, the attacker does not even have to guess it.
- Change default passwords: often passwords for system accounts have a default value like “manager”.
  - Default passwords help field engineers installing the system; if left unchanged, it is easy for an attacker to break in.
  - Would it then be better to do without default passwords?
- Avoid guessable passwords:
  - Prescribe a minimal password length.
  - Password format: mix upper and lower case, include numerical and other non-alphabetical symbols.
  - Today on-line dictionaries for almost every language exist.

Defences

- Password ageing: set an expiry dates for passwords to force users to change passwords regularly.
- Prevent users from reverting to old passwords, e.g. keep a list of the last ten passwords used.
- Limit login attempts: the system can monitor unsuccessful login attempts and react by locking the user account (completely or for a given time interval) to prevent or discourage further attempts.
- Inform user: after successful login, display time of last login and the number of failed login attempts since, to warn the user about recently attempted attacks.

Password Security

- Is security highest if users are forced to use long passwords, mixing upper and lower case characters and numerical symbols, generated for them by the system, and changed repeatedly?
  - Users may have difficulty memorizing complex passwords.
  - Users may have difficulty dealing with frequent password changes.
  - Users may find ways of re-using their favourite password.
- Passwords will be written on a piece of paper kept close to the computer.
  - Security experts routinely look out for passwords on notes posted on computer terminals.
  - Is it always a bad idea to write down your password?

Password Security

- People are best at memorizing passwords they use regularly.
- Passwords work reasonably well in situations where they are entered quite frequently, but not so with systems used only occasionally.
- Good advice:
  - When changing a password, type it immediately several times.
  - Do not change passwords before weekends or holidays.

Lesson

- Don’t look at security mechanisms in isolation.
- Putting too much emphasis on one security mechanism may actually weaken the system.
- Users will find ways of circumventing security to be able to do their job properly.
- There is a trade-off between the complexity of passwords and the faculties of human memory.

Phishing and Spoofing

- Identification and authentication through username and password provide unilateral authentication.
- Computer verifies the user's identity but the user has no guarantees about the identity of the party that has received the password.
- In phishing and spoofing attacks a party voluntarily sends the password over a channel, but is misled about the end point of the channel.

Spoofing Attacks

- Attacker starts a program that presents a fake login screen and leaves the computer.
- If the next user coming to this machine enters username and password on the fake login screen, these values are captured by the program.
  - Login is then typically aborted with a (fake) error message and the spoofing program terminates.
  - Control returned to operating system, which now prompts the user with a genuine login request.

Countermeasures

- Display number of failed logins: may indicate to the user that an attack has happened.
- Trusted path: guarantee that user communicates with the operating system and not with a spoofing program; e.g., Windows has a secure attention key CTRL+ALT+DEL for invoking the operating system logon screen.
- Mutual authentication: user authenticated to system, system authenticated to user.

Phishing

- Phishing: attacker impersonates the system to trick a user into releasing the password to the attacker.
  - E.g., a message could claim to come from a service you are using, tell you about an upgrade of the security procedures, and ask you to enter your username and password at the new security site that will offer stronger protection.
- Take care to enter your passwords only at the “right” site (but how do you know?)
- Social engineering: attacker impersonates the user to trick a system operator into releasing the password to the attacker.

Protecting the Password File

- Operating system maintains a file with user names and passwords
- Attacker could try to compromise the confidentiality or integrity of this password file.
- Options for protecting the password file:
  - cryptographic protection,
  - access control enforced by the operating system,
  - combination of cryptographic protection and access control, possibly with further measures to slow down dictionary attacks.

One-way Functions

- For cryptographic protection we can use one-way functions (cryptographic hash functions).
- Definition: A one-way function *f* is a function that is relatively easy to compute but hard to reverse.
  - Given an input *x* it is easy to compute *f*(*x*), but given an output *y* it is hard to find *x* so that *y* = *f*(*x*)
- Instead of the password *x*, the value *f*(*x*) is stored in the password file; when a user logs in entering a password *x'*, the system applies the one-way function *f* and compares *f*(*x'*) with the expected value *f*(*x*).

Password Salting

- Following common practice we refer to $f(x)$ as the encrypted password; to be precise, it is the hash of x. (More about encryption and hashing later.)
- To slow down dictionary attacks, a salt is appended to the password before encryption and stored with the encrypted password.
  - If two users have the same password, they will now have different entries in the file of encrypted passwords.
  - Example: Unix uses a 12 bit salt.

Access Control Settings

- Only privileged users must have write access to the password file.
  - Otherwise, an attacker could get access to the data of other users simply by changing their password, even if it is protected by cryptographic means.
- If read access is restricted to privileged users, then passwords in theory could be stored unencrypted.
- If password file contains data required by unprivileged users, passwords must be “encrypted”; such a file can still be used in dictionary attacks.
  - Typical example is **`/etc/passwd`** in Unix; many versions of Unix thus store encrypted passwords in a shadow password file that is not publicly accessible.

Lesson

- You have seen examples for two security design principles.
- Combining mechanisms can enhance protection.
  - Use of encryption and access control to guard password files.
- Separate security relevant data from data that should be openly available.
  - In Unix, **`/etc/passwd`** contains both types of data; shadow password files achieve the desired separation.

Caching Passwords

- Our description of login has been quite abstract: password travels directly from user to the password checking routine.
- In reality, it will be held temporarily in intermediate storage locations like buffers, caches, or a web page.
- The management of these storage locations is normally beyond the control of the user; a password may be kept longer than the user has bargained for.

Single Sign-on

- Having to remember many passwords for different services is a nuisance; with a single sign-on service, you have to enter your password only once.
- A simplistic single-sign on service could store your password and do the job for you whenever you have to authenticate yourself.
  - Such a service adds to your convenience but it also raises new security concerns.
- System designers have to balance convenience and security; ease-of-use is an important factor in making IT systems really useful, but many practices which are convenient also introduce new vulnerabilities.

More on Authentication

- If you are dissatisfied with the level of security provided by passwords, what else can you do?
- In general, the following options are open.
- You can be authenticated on the basis of
  - something you know,
  - something you hold,
  - who you are,
  - what you do,
  - where you are.

Something You Know

- The user has to know some secret to be authenticated.
- Examples: password, personal identification number (PIN), personal information like home address, date of birth, name of spouse (used e.g. by banks to authenticate customers on the phone).
- Anybody who obtains your secret “is you”.
- You leave no trace if you pass your secret to somebody else.
- There is a case of computer misuse where somebody has logged in using your username and password.
  - Can you prove your innocence?
  - Can you prove that you have not divulged your password?

Lesson

- A password does not authenticate a person.
- Successful authentication only implies that the user knew a particular secret.
- There is no way of telling the difference between the legitimate user and an intruder who has obtained that user's password.

Something You Hold

- User presents a physical token to be authenticated.
- Examples: keys, cards or identity tags (access to buildings), smart cards.
- Physical tokens can be lost or stolen.
- Anybody who is in possession of the token has the same rights as the legitimate owner.
- To increase security, physical tokens are often used in combination with something you know, e.g. bank cards come with a PIN or with a photo of the user.

Who You Are

- Biometric schemes use unique physical characteristics (traits, features) of a person such as face, finger prints, iris patterns, hand geometry (maybe even DNA at some time in the future).
- Biometrics may seem to offer the most secure solution for authenticating a person.
- We will use the example of fingerprints to sketch how biometric authentication works.
- Biometric schemes are still quite new; it has to be seen whether results from experiments conducted in controlled environments are a good indicator for practical performance.

Fingerprint

- Enrolment: reference sample of the user's fingerprint is acquired at a fingerprint reader.
- Features are derived from the sample.
  - Fingerprint minutiae: end points of ridges, bifurcation points, core, delta, loops, whorls, …
- For higher accuracy, record features for more than one finger.
- Feature vectors are stored in a secure database.
- When the user logs on, a new reading of the fingerprint is taken; features are compared against the reference features.

Identification & Verification

- Biometrics are used for two purposes:
  - Identification: 1:*n* comparison tries to identify the user from a database of *n* persons.
  - Verification: 1:1 comparison checks whether there is a match for a given user.
- Authentication by password: clear reject or accept at each authentication attempt.
- Biometrics: stored reference features will hardly ever match precisely features derived from the current measurements.

Failure Rates

- Measure similarity between reference features and current features.
- User is accepted if match is above a predefined threshold.
- New issue: false positives and false negatives
- Accept wrong user (false positive): security problem.
- Reject legitimate user (false negative): creates embarrassment and an inefficient work environment.

Technology Analysis

- Based on a (given) databases of biometric samples.
- Measures performance of the algorithms extracting and comparing biometric features.
- False match rate (FMR):

$$FMR \lceil \frac{\text{number of successful false matches}}{\text{number of attempted false matches}}$$

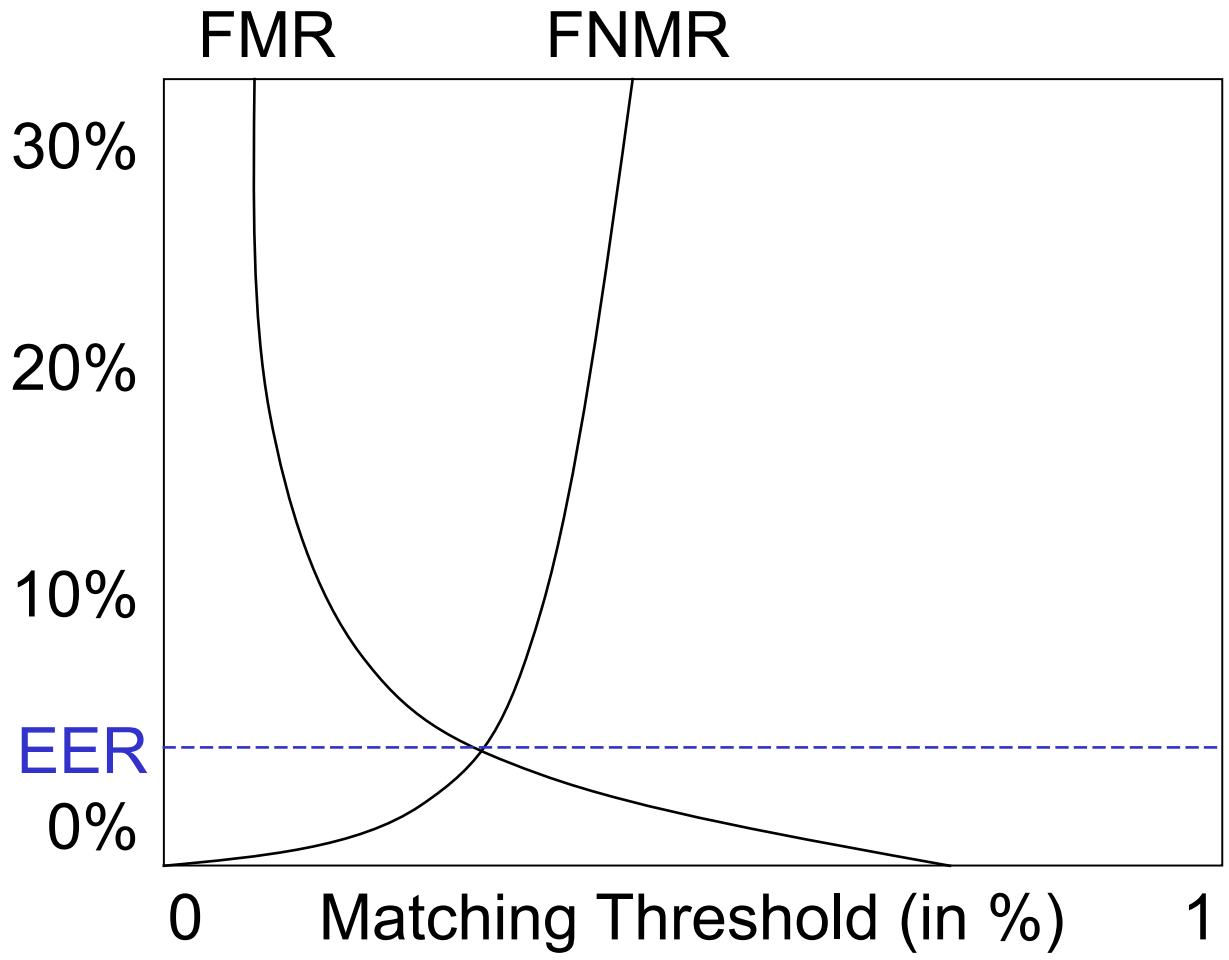
- False non-match rate (FNMR):

$$FNMR \lceil \frac{\text{number of rejected genuine matches}}{\text{number of attempted genuine matches}}$$

Equal-error Rate

- By setting the matching threshold, we can trade off a lower false match rate against a higher false non-match rate, and vice versa.
- Finding the right balance between those two errors depends on the application.
- Equal error rate (EER): given by the threshold value where FMR and FNMR are equal.
- Currently, the best state-of-the-art fingerprint recognition schemes have an EER of about 0.5 - 2%.
- Iris pattern recognition has a superior performance.
- State of the art: http://atvs.ii.uam.es/fvc2006.html.

FMR, FNMR, EER



Scenario Analysis

- Records error rates in actual field trials; measures performance of fingerprint reader (hardware and software) capturing templates at log-in time.
  - Failure-to-capture rate (FTC): frequency of failing to capture a sample.
  - Failure-to-extract rate (FTX): frequency of failing to extract a feature from a sample.
- Failure-to-acquire rate: frequency of failing to acquire a biometric feature: FTA = FTC + FTX⌈ (1 - FTC)
- False accept rate for the entire biometric scheme: FAR = FMR ⌈ (1 - FTA).
- False reject rate: FRR = FTA + FNMR ⌈ (1 - FTA).

Madrid Error (2004)

- False positive identification rate for a database with *n* persons:
  - FPIR = (1 - FTA) ⌈ (1 - (1 - FMR)^n).
- A fingerprint found in the Madrid train bombing was compared against a database of 530 million entries.
- A match was found and linked by four experts with 100% confidence to a US citizen (B. Mayfield).
- They were wrong: the guy did not even have a passport and had not left the country.
- Criteria for matching features had to be re-appraised.
  - http://www.henrytempleman.com/madrid_error, http://www.onin.com/fp/problemidents.html

Forged Fingers

- Fingerprints, and biometric traits in general, may be unique but they are no secrets.
- You are leaving your fingerprints in many places.
  - http://www.ccc.de/updates/2008/schaubles-finger
- Rubber fingers have defeated many a commercial fingerprint recognition systems in the past.
  - Minor issue if authentication takes place in the presence of security personnel.
  - When authenticating remote users additional precautions have to be taken to counteract this type of fraud.
- User acceptance: so far fingerprints have been used for tracing criminals.

What You Do

- People perform mechanical tasks in a way that is both repeatable and specific to the individual.
- Experts look at the dynamics of handwriting to detect forgeries.
- Users could sign on a special pad that measures attributes like writing speed and writing pressure.
- On a keyboard, typing speed and key strokes intervals can be used to authenticate individual users.

Where You Are

- Some operating systems grant access only if you log on from a certain terminal.
  - A system manager may only log on from an operator console but not from an arbitrary user terminal.
  - Users may be only allowed to log on from a workstation in their office.
- Decisions of this kind will be even more frequent in mobile and distributed computing.
- Global Positioning System (GPS) might be used to established the precise geographical location of a user during authentication.

Summary: Security Mechanisms Fail

- You may be worried about failures that wrongly permit an action.
- You should be equally worried about failures that wrongly deny access.
- Forgotten passwords, false biometric rejection: system not available to legitimate users.
- You have to implement measures that deal with such failures; this may be quite expensive.
- Even worse, you may believe that technology is perfect (or forget about this issue) and your system may fail in quite damaging ways.