6. Secure Design Principles

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Content

- Secure Design Principles you should keep in mind when thinking about security during software development

- A brief exercise to apply the principles to an e-banking scenario

Goals

- You know and understand the secure design principles and can provide examples for each of the principles

- You can apply the principles to a given scenario and assess whether a principle is met or violated

Secure Design Principles

Secure Design Principles

- The technology we are using continuously advances
  - New platforms, programing languages, protocols, frameworks...
- Similarly, new threats arise, sometimes driven by new technology
  - This requires adapting secure development practices over time
    - Considering new attack vectors, employing new countermeasures, integrating new security technologies, and adapting security testing
- However, there are also some fundamental secure design principles that have established themselves over time
  - Fundamental in the sense that they are technology-independent and likely to be true also in the (far) future
- When developing secure systems, it's important to keep these principles in mind
  - Using them appropriately in your system should help you avoiding many security problems

Secure Design Principles Overview

- Secure the Weakest Link
- Defense in Depth
- Fail Securely
- Principle of Least Privilege
- Secure by Default
- Keep it Simple
- Hiding Secrets is Hard

Secure the Weakest Link (1)

- An information system usually consists of several different components
  - Browser, client computer, network, server, database…
  - But also users, administrators, support personnel, processes…
- The overall security is determined by the weakest component
  - Attackers try to identify the weakest component of a system as this is where they will most likely succeed
- Example: Assume the communication between client and server is secured with TLS that uses strong ciphers
  - Attackers will most likely not try to break the crypto, as the success probability is virtually zero
  - The attacker will focus their attacks on other "more promising" areas, e.g. the users or vulnerable client or server components
  - This does not mean breaking crypto has never succeeded (due to e.g. poor key generators or implementation flaws), but it's simply less likely

Secure the Weakest Link (2)

- Weak links are usually identified by performing risk analysis
  - Good risk management should always address the highest risks first and not the ones that are easy to mitigate
  - This guarantees that security investments are made at the right places

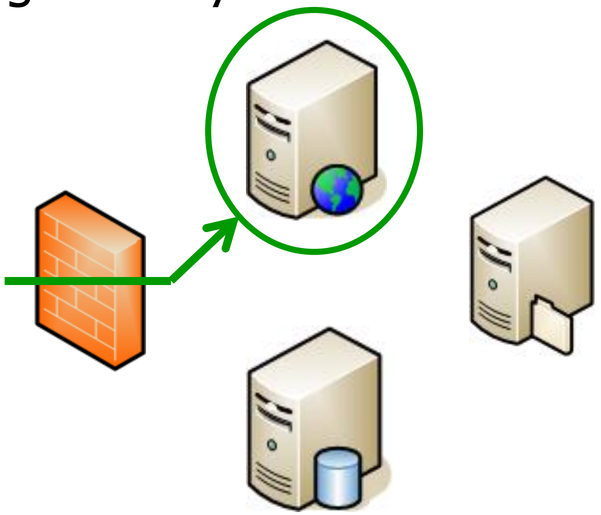
- Typical weak links:
  - Weak passwords, especially if users are not forced to fulfill minimum password strength requirements (length, character mix etc.)
  - Insecure support processes, e.g. related to password recovery (mother's maiden name…)
  - People, e.g. social engineering attacks on end users (phishing) or support personnel ("I'm the boss and need a new password NOW")
  - Implementation defects, e.g. web applications using easy-to-guess session IDs or failing to perform proper input validation

Defense in Depth (1)

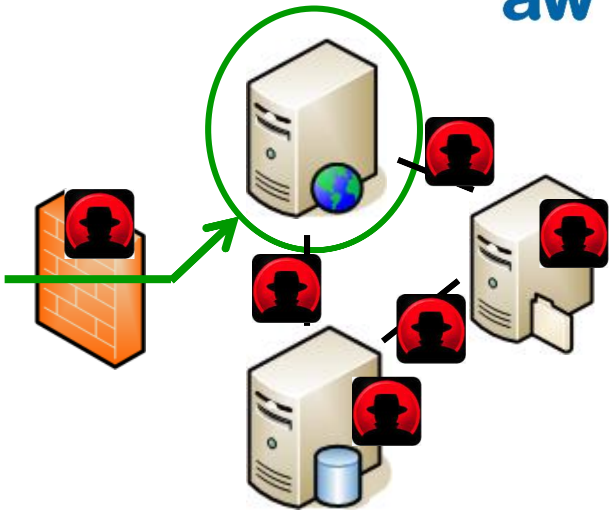
- Defense in Depth means that risks should be managed with multiple diverse defensive strategies
  - If one layer of defense fails, another layer may prevent a successful attack

Example: A web application consisting of multiple server components

- The development team decides that the following security measurements should be taken
  - Harden the component reachable from the outside (e.g. the web application server)
  - On the router, use a firewall so only the web application server can be accessed from the outside and only via HTTPS
  - This should "guarantee" that no other servers can be accessed from the outside and that the web application server cannot be compromised



Defense in Depth (2)



- Based on this assumption, they decide the following:
  - Internal communication between the server components can be done in the clear
  - Not directly exposed servers don't require much security attention
- But what if an attacker compromises the firewall?
  - He gets access to all non-encrypted traffic in the network (ARP spoofing)
  - He "sees" the other server components and may likely find vulnerabilities that can be exploited to compromise them
  - → The attacker has to overcome only one layer of defense to succeed
- In this case, a defense in depth approach would therefore include:
  - Encrypting the traffic also between the server components, which prevents the attacker from reading and manipulating it
  - Harden not only the exposed, but also the apparently "hidden" server components to avoid compromisation

Defense in Depth (3)

- Defense in Depth also means thinking beyond preventive measures
  - Consider the case when your preventive measures have failed and the attack takes or took place
- A powerful strategy should include mechanisms to prevent, detect, contain, and recover from attacks
- Example: how do banks defend against robbery?
  - Security guards outside the bank and cameras can prevent attacks
  - Detecting the attack is usually quite simple in the brick-and-mortar world
  - Having bank tellers stationed behind bulletproof glass may help containing the attack if violence breaks out (protecting the lifes of the tellers)
  - Another containment measure is that two people – who are rarely at the bank at the same time – must each provide a key to the vault with the really valuable stuff
  - Handing a specially prepared briefcase the emits dye when the robbers open it may help recovering from the attack
  - Appropriate insurance is also a method to recover from robbery

Defense in Depth (4)

Prevent / Detect / Contain / Recover in the cyberworld using a password guessing attack as example:

- Password-guessing attacks can be prevented by requiring users to pick passwords with certain requirements
- Password-guessing attempts can be detected by monitoring server logs for large number of failed login attempts from the same or a few IP addresses (an IDS can do this)
- Assuming an attacker manages to capture username/password pairs, one can contain the attack by denying all logins from suspicious IP addresses (assuming this can be detected) and changing the passwords
- Finally, to recover from the attack, one could do more detailed monitoring of the accounts and source IP addresses involved in the attack

Fail Securely (1)

- Fail securely means that a failure (which will happen in complex systems) must not compromise the security of the system
  - One reason why this principle is often violated is because in the case of failure, the focus is very often on "keep things running at all costs"
- Example: A company uses correctly configured firewalls to protect access to its various systems
  - The company also has a spare firewall in case one of the firewalls becomes inoperable
  - The firewall is configured as "let through everything" so it can easily replace a malfunctioning firewall with minimal service interruption
  - An attacker who knows this can try to disable a firewall (by exploiting a vulnerability), which causes the firewall to be replaced with the spare one
  - Until the new firewall is correctly configured, this gives the attacker a significant advantage

Fail Securely (2)

- Another possibility to violate the fail securely principle happens when a system supports also earlier insecure versions of a protocol
  - E.g. because older clients supporting only an older version are still used
  - But this means that if using the secure protocol version fails, the system gets less secure → this should be avoided
- Even worse, this may be exploited in a "version downgrading" attack
  - In this attack, the attacker forces both endpoints to use the earlier, insecure version although both would support the new one
  - To do so, the attacker acts as a man-in-the-middle and modifies some protocol messages to convince both client and server that the other side only supports an older protocol version
- Examples:
  - Downgrading of the NTLM protocol to its predecessor LM, which allows cracking even complex user passwords
  - Downgrading to SSLv2, which allows manipulating the cipher suites offered by the client

Fail Securely (3)

Another example: Credit card payment authorization

- To prevent credit card fraud, vendors use terminals to check a card before payment is authorized
  - The terminal contacts the credit card company to make sure the card is not reported stolen or that the credit limit has not yet been reached
  - In addition, the transaction is denied if any "suspicious spending pattern" is detected

- That's great, but what if the terminal or the phone line is down?
  - Vendors still sometimes use the old machines that make an imprint of the card, but none of the checks above takes place (and no PIN is required either)

- This means that if the system fails, it gets less secure
  - This can be exploited in a "physical version downgrading attack"
  - To execute the attack, try to "cut the phone line" before shopping

Principle of Least Privilege (1)

- A user or program should be given the least amount of privileges necessary to accomplish a task
  - So a malicious user and a compromised/malicious program can cause only limited damage
- One reason why this principle is often violated is laziness
  - It's usually simpler to write or install a program when it's run with full access rights as one does not have to think about access rights to low level system resources (e.g. files)
- Example of good practice: Postfix
  - Postfix is a popular *ix mail server
  - It is heavily modularized and each component (e.g. delivery to local mailboxes, sending of outbound messages) gets minimal access rights to do its job
  - There's just one (small) component running as root (the master daemon) as binding to port 25 is only possible by a process that runs as root

Principle of Least Privilege (2)

Examples of bad practice:

- Up to Windows XP, many programs required administrator privileges to function correctly and consequently most users worked with full administrator rights
- Many server programs still run with root privileges under *ix per default, which has repeatedly caused security problems in the past (e.g. sendmail)
- Web applications accessing a database often do this with a database user that has full access rights (sometimes including rights to modify the database schema)

Secure by Default

- Programs and operating systems should be delivered/installed with secure default configurations

- This includes, e.g., the following:
  - Turn off or don’t install features that are not required by most users
    - E.g. don’t enable file sharing by default as most users won’t need it
  - Personal firewall: block all incoming connections by default
  - Enable automated software updates by default (usually good for end-user computers, more questionable for servers)
  - The standard configuration of TLS should not use insecure cipher suites

- Example of a positive development:
  - Years ago, Windows operating systems were installed with many services enabled (e.g. IIS was turned on by default)
  - This has significantly changed during recent years and Windows operating systems are installed with reasonable default settings today

Keep it Simple (1)

- Complexity is the enemy of security
  - It’s much more difficult to develop and maintain a complex system in a secure way
  - Similarly, it’s much more difficult to analyze and test a complex system with respect to security – the likelihood you are going to miss something important is very high

- Simplicity also means that “it should be easy to use a system in a secure way”
  - Don’t expect users to read manuals – they won’t
  - Don’t expect your users to understand security and don’t expect them to configure it correctly (that’s why “Secure by Default” is important)
  - Don’t give the users the option to circumvent security as they likely will
    - Especially when security is perceived as a usability hindrance

Keep it Simple (2)

Some good practices to follow:

- Select a decent, as simple as possible (only as complex as necessary) software design
  - It's the basis also for sound security design
- Re-use proven software components or technologies when appropriate
  - This is especially important with security functions such as secure communication protocols and cryptographic algorithms
- Implement security-critical functions only once and place them in easily identifiable program components (e.g. in a separate package)
  - This will make it easier to use security-critical functions in your software
  - For instance, use a single checkPassword() or checkAccess() method in your software and take care to review that method for correctness

Keep it Simple (3)

- Don’t give the users security dialogues they can ignore
  - As they most likely will – because they want to “get things done”
  - A study in 2009 analyzed how users react to certificate warnings when browsing the web: approximately 50% ignore the warning

Keep it Simple (4)

- For the average user, the warning more looks like this:

Hiding Secrets is Hard

- Don’t build security on the assumption that the adversary does not know how your software works or that he cannot find secrets in your software
  - This is also known as “Security by Obscurity”
- There are powerful reverse engineering methods (e.g. decompiler) that can be applied to binaries
  - It’s very hard to hide the actual functionality of, e.g., a proprietary cryptographic algorithm
  - Hiding a secret such as a cryptographic key in a code binary is virtually impossible (e.g. search for randomness)
  - You can use code obfuscation to make the task for the adversary more difficult, but a determined adversary will most likely find out in detail how your software works
- Several examples undermine this
  - DeCSS for the cryptographic “protection” of DVD contents
  - The failure of many software copy protection mechanisms

Secure Design Principles – Exercise

Secure Design Principles – Exercise (1)

Assume a web-based e-banking application, which should provide “good” security. For the following statements, think about whether it’s a good or bad choice and to which secure design principle it is associated.

- To support as many users as possible, the server is configured to accept connections from browsers that only support SSLv2
- Users can disable the second authentication factor (login code received by SMS) in their profile settings
- A web application firewall (WAF) that can detect typical web application attacks (SQL injection, Cross-site scripting etc.) is used in front of the web application server

Secure Design Principles – Exercise (2)

- The web application server runs with root privileges, as this is required to write the logs

- To increase security, users get a hardened browser on a read-only USB stick, which must be used to access the e-banking site

- To further increase security, this browser uses a proprietary and secret encryption algorithm developed by the bank for TLS encryption

Summary

- There exist some fundamental secure design principles that have established themselves over time
  - Secure the Weakest Link
  - Defense in Depth
  - Fail Securely
  - Principle of Least Privilege
  - Secure by Default
  - Keep it Simple
  - Hiding Secrets is Hard
- They are technology-independent, which means they are likely to be true also in the future
- Keeping these principles in mind during software development should help you to avoid many security problems