Advanced Security for Systems Engineering – Lecture 02: Secure Architectures

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Agenda

Introduction/Definition
Secure Architectures
Designing Secure Systems
Secure Design Principles
Trade-off between IT Security Goals
References
Introduction

- Software/system architecture: mapping of the problem to software and hardware components
- Main components with connections of them
- Basic, abstract, high level design
- Security architecture
  - Definition of the basic security components
  - Security principles for building the system
Secure Architecture?

(See CERT Secure Coding Standards)
Another Secure Architecture?

(See Bodiam Castle, Chuck Andolino, CC BY-SA 2.0)
Complexity in Real-World IT

(See Curphey M, Arawo R. Web application security assessment tools)
Basis for Designing Secure Systems

- Defining the appropriate security requirements
- in a suited threat model and
- ensuring well-implemented security-mechanisms.

- Project as a whole needs to be considered
  - Software
  - Network
  - Hardware
  - Physical Security
Broad Goals for a Security Architecture

- Detect attacks
- Resist attacks
- React to attacks
- Recover from attacks

(See Bass, Clements and Kazman, 2012)
Influences for a Secure Architecture
Examples of Influences for a Secure Architecture

- Stake Holder Requirements
- Technical Requirements
- Business Requirements
- Know-How
- Legal Requirements (e.g., GDPR)
- Operation
- Sphere of Influence
- Maintenance/Maintainability
- Best Practice
- Threat Model
- Policies
- Security Requirements

Secure Architecture
Some Details of Influences

- Which security properties shall the system (or specific parts of the system) guarantee? E.g., confidentiality/anonymity,…
- Multiple requirements from different sources/stakeholders
- Are specific standards/regulations necessary?
- Is a certification necessary? Which one? (e.g., Common Criteria, PCI)
- Which requirements conflict? What to do about it?
- What to do if requirements change? Is there a process to recognize that?

→ IT Security in Large IT Infrastructures SS2023
Principles for Secure Architectures

- Security requirements analysis
- Protection requirements analysis
- Create barricades around to be protected artifacts using different mechanisms
- The more important a resource is, the more security measures
- Security architecture
Threat Model

- What are the assumed capabilities of the attacker? E.g.,
  - Active vs. passive attacker
  - Physical access vs. remote access only

- Which components of the system are
  - trusted,
  - partly trusted (e.g., distributed trust, honest-but-curious),
  - untrusted?
Hardware Security Architecture

- Devices
  - PCB design and layout
  - Secure CPU, MCU:
    - RAM encryption
    - Tamper detection
    - Secure keystore
    - Secure boot
    - ...

- Data center
  - HSM (Hardware Security Modules)
  - KMS (Key Management System)
Secure Design Principles

- Least Privilege
- Separation of Duties
- Fail Secure
- Economy of Mechanisms
- Complete Mediation
- Least Common Mechanisms
- Psychological Acceptability
- Leveraging Existing Components

(See Jerome H. Saltzer und Michael D. Schroeder, 1975)
Least Privilege – Design Techniques

- Modular Architecture:
  - Split entire system into smaller subunits
  - Each subunit is discrete with unitary functionality (cohesive)
  - Each subunit is designed to perform a set of logical operations
  - Each subunit is rather independent to others (coupling)

- Use virtualization

- Divide system into different network zones with defined interfaces between the zones, e.g., DMZ

- Best practice suggests: Designed software modules are highly cohesive and loosely coupled
Separation of Duties – Design Techniques

- When designed and implemented correctly, damage by a person or resource is reduced
- Separation of duties should be found in application features (i.e., role-based access control) and software development life-cycle (i.e., deny access for developers on production systems)
- Example when dealing with cryptographic keys:
  - Splitting of cryptographic keys, e.g., key ceremony for exchange of cryptographic keys
- Best practice suggests to implement separation of duties with auditing
Fail Secure – Design Techniques

- Define secure state to get into after errors
- Do not allow exceptions to go unhandled
- Do not allow any exceptions to reach the GUI
- Check, if error handlers are called frequently (i.e. there might be a security vulnerability)
Economy of Mechanisms – Design Techniques

- Avoid unnecessary functionality and unnecessary security mechanisms
- Strive for simplicity
  - Keep security mechanisms simple
  - Implementation should not be partial → otherwise security issues
  - Model the data in a simple way (results in simpler validation routines)
- Strive for operational ease of use (e.g., SSO)
Complete Mediation – Design Techniques

- Identify code paths that access privileged and sensitive resources and secure them
- Avoid duplicate code for input validation
- Be aware of social engineering attacks and security unaware users
- Keep in mind users that don’t know how to use the software
Least Common Mechanisms – Design Techniques

- Design should isolate code (functions) by user roles → limits exposure of sensitive data

- Example:
  - Instead of sharing a function between superusers and nonsuperusers consisting of different code paths for each party, implement two separate functions to serve the different roles
Psychological Acceptability – Design Techniques

- Applications and especially security protection mechanisms should
  - be easy to use
  - not affect accessibility
  - be transparent to the user

- Users should not be burdened by security mechanisms

- Example:
  - Password policy that requires min. 16 characters for passwords may enforce users to write down their passwords and decrease overall security
Leveraging Existing Components – Design Techniques

- Promotes the reusability of existing components
- Tier architecture is advisable
  - Software functionality can be separated into presentation, business and data access tiers
  - Different presentation layers can be implemented
- Reuse tested and well known concepts and patterns for the architecture
- Reuse components if you know them! However, be careful about the security of existing components you don’t know
Open Design – Design Techniques

- Avoid security by obscurity
  - No hard coding of sensitive information in source code or binaries (e.g., cryptographic keys, passwords, connection strings)
  - Use hidden form fields in web application carefully, i.e., modified client
  - Hidden URLs for secret documents without authentication, i.e., google hacking
- Use open and proven crypto systems
Defense in Depth – Overview

- Defense in Depth (layered defense) results from layering
  - Security controls = countermeasure to avoid / minimize security risk and
  - Risk mitigation safeguards into software design

- Should give an organization time to detect and respond to an attack

- Goal is that software doesn’t get totally compromised, because of single security breach

- Example: it’s not good to rely on a firewall only for an internal-use-only application

- More important assets should have more security layers

- Can be reactive (e.g., detect malicious activities and block them) or preventive (e.g., awareness training, security patches)
Defense in Depth – Shortcomings

- Can add complexity to the software system
- Contradicts to the principle of simple design
- Therefore, might introduce new risks
Trade-off between IT Security Goals

- IT Security Goals
  - Confidentiality
  - Integrity
  - Availability
  - Authenticity

- Security Goals may conflict with each other, when designing software architecture, e.g.,
Trade-off between IT Security Goals

- IT Security Goals
  - Confidentiality
  - Integrity
  - Availability
  - Authenticity

- Security Goals may conflict with each other, when designing software architecture, e.g.,
  - Confidentiality vs. availability
    (e.g., Encrypted data not recoverable, if key lost)
  - Availability vs. authenticity
    (e.g., Slow hashing algorithms within authentication process)
Cryptography

- Where?
- When?
- Recovery of encrypted data when private key is lost?
- Availability/processing speed

→ A Catalog of Security Architecture Weaknesses (Santos, Tarrit and Mirakhorli)
Network Security Architecture

- Connection of external sites/remote work
- Firewalls, VPN, Honeypots, DMZ, TLS, ...
- Adversarial Model in a Networking Setting
  - Protection against tampering: integrity protection
  - Protection against Replay and Re-order attacks: protocol must use, e.g., a message counter in the authenticated data, or an authenticated nonce value with the message that must be different for each new message
  - Protocol Downgrade Attack
    - TLS versions supported by server
    - HSTS
Example of Failed Security Architecture

(See The Washington Post)
Example of Large Security Architecture

(See Gesamtarchitektur Release Version 1.5.0, gematik)
Outlook: Guest Lecture about Zero Trust Architectures

- Guest lecture on November 25 finalized
- CSO of gematik
- Implementation of Zero Trust in Complex IT Infrastructures (Current Status of Implementation within the German Health Telematics Infrastructure)


Open Security Architecture


Gilberto Pedraza-Garcia, Hernan Astudillo, and Dario Correal. A methodological approach to apply security tactics in software architecture design. In *2014 IEEE Colombian Conference on Communications and Computing (COLCOM)*, pages 1–8, June 2014. doi: 10.1109/ColComCon.2014.6860432
Summary

- Solid architecture is the basis of secure systems
- IT security goals may conflict with another
- Due to business needs decide what design principles to use
- Balancing of different design principles is recommended
- “Complexity is the worst enemy of security” (Schneier)
Thank you!

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