Software Architecture for Secure ECUs

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Agenda

“No safety without security and vice versa”

Established Safety Concepts

Safety Analysis Methods for Security Analysis

Secure Software Architecture Extensions

Summary
The Car of the Future: Increased comfort – Increased potential for damage

• **Autonomous Driving**
  – Highly safety-critical
  – Requires latest data from the “cloud”

• **Car-2-X Communication**
  – Communication with
    • other cars
    • infrastructure
    • mobile phone or other devices
  – ECUs have access to the on-board network

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Recent security breaches

**OpenSSL “Heartbleed” vulnerability**
- Sensitive data accessible via maintenance function
- Encryption and maintenance functions are technically unrelated
- Cause: implementation error

**Remote door unlock**
- Attacker could open cars with fake SMS
- Various vulnerabilities:
  - Partially unencrypted communication
  - Provision of sensitive data
  - Missing integrity checks
  - Weak or identical encryption keys
  - Replay attacks possible
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Summary
Memory Partitioning

Safety OS
- Data Protection
- Stack Protection
- Context Protection
- OS Protection
- Hardware Error management

Safety RTE
Protected communication between Memory Partitions

Safety E2E Protection
Safe communication to other ECUs

Safety Time Protection
- Alive supervision
- Deadline Monitoring
- Control flow monitoring
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Time and Execution Protection

- Alive Supervision
  - Control flow monitoring
  - Deadline Monitoring

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Communication Protection

E2E Protection:
- **Adds** CRC & message counter
- **Verifies** CRC & message counter

Sender Application

Receiver Application

Safety RTE

Communication Bus
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Static vs. Dynamic Threat Model

**Safety: static threat model**
- Threats are known at system design
- Threats are internal, e.g. random or systematic faults
- Iterations improve existing model with new knowledge

**Security: dynamic threat model**
- New threats can emerge during system operation
- Threats are external
- Intelligent opponent has to be considered

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Extending Safety Analysis to Security Analysis

• Safety and security rely on risk models

• It’s crucial to recognize and use synergies

• Extend hazard and risk analysis with malicious attacker
  – Attacker has access to all communication channels
  – Extend safety requirements with security requirements

Searching for security vulnerabilities brings new safety exposures to light and vice versa
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Summary
Using Partitioning to Protect Data

- **Memory Partitioning**
  - Read protection
  - Execution protection
  ⇒ Allow access to sensitive data only for authorized tasks

- **Stack Protection**
  - Stack protected via MPU
  ⇒ Prevention against stack-overflow attacks
Message Integrity

**Threats**

1. Unauthorized message access
   - Read, Modify, Delete
2. Impersonate other user
   - Initiate communication
3. Temporal attacks
   - Replay, Delay

**Countermeasures**

1. Encryption
   - Unauthorized read, modification, Impersonation of other user
2. Signatures
   - Modification, Impersonation of other user
3. Integrity Checksums
   - Modification
4. Message counters and timestamps
   - Replay, Delay

**MACs containing signatures and freshness values eliminate most threads**
Message Authentication

- MAC with key K is appended to message M
- Key is known to sender and receiver
- Alterations from Eve are detected by Bob
**Sender**
- Unsafe channel between application and SecOC module
  - Protect message with CRC from E2E in application
  - Safe transport between ECUs
- SecOC transforms CRC to MAC
  - Safe and secure transport between ECUs

**Receiver**
- SecOC transforms MAC to CRC
- Application checks CRC
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End-to-end protection with SecOC

Single SecOC approach

- Use MAC algorithm also for message integrity
- Place ASIL developed SecOC in highest AUTOSAR layer
- Omit overhead for additional end-to-end protection

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AUTOSAR safety and security architecture

- **Safety OS**
  - Memory write (safety), read and execution (security) protection

- **TimE Protection**
  - Control flow monitoring (safety)

- **E2E protection and SecOC**
  - Data integrity (safety, security)
  - Authentication (security)

- **Csm, CryShe**
  - Data encryption (security)
Csm, Cry, CryShe, Cal, Cpl,…

- AUTOSAR defines two sets of crypto routines
  - Crypto service manager (CSM/CRY)
  - Crypto abstraction library (CAL/CPL)
- Both AUTOSAR specifications subdivide crypto modules into two layers
  - Interface layer
    - SERVICES
  - Implementation layer
    - PRIMITIVES
  - CSM Interface layer
    - CSM
  - Implementation layer
    - CRY
  - CAL Interface layer
    - CAL
  - Implementation layer
    - CPL
- Only the interface layer is properly specified in AUTOSAR
  - This layer is completely standardized
- Contents of the implementation layer are left open for customer options
  - This layer implements customer specific solutions with a standardized interface to the interface layer
Use case examples – Secure Hardware Extension

- Attainable security level in software is limited.
- New automotive ECUs offer a ‘Secure Hardware Extension (SHE)’ module.
  - E.g. freescale Bolero 3M/Calypso, Infineon TC179x, Fujitsu Atlas-L family, Renesas RH850
- EB integrates the new hardware module with standard software.
- Development of drivers for SHE.
- Integration with AUTOSAR cryptographic module (Csm/CryShe).
- Tool driven configuration.
- We enable customers to easily switch between cryptographic routines in software and hardware.
Outlook: Hypervisor setup

- Core1: QM SWCs, SecOC
- Core2: ASIL SWC, CSM, CryHSM, E2E Lib
- Core3: Linux Application, Hardware Security Module (HSM), Inter OS communication
- Core4: Linux

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Summary
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• **Extend safety analyses with security aspects**
  – Safety and security complement each other
  – Employed methods are quite similar

• **Safe and secure software architectures**
  – Use partitioning mechanisms for protection mechanisms
  – Use secure authentication and integrity mechanisms for safe communication

• **Hypervisors combines two worlds**
  – Access to board net via AUTOSAR
  – Applications on e.g. Linux
  – Protected communication through Firewall
Thank you!

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