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Secure Element APIs and Practical Attacks on Secure Element-enabled Mobile Devices

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Outline

- Card Emulation + Secure Element + Mobile Phone
- APIs for Access to the Secure Element
- Mobile Phones as Target for Attacks
- New Attack Scenarios

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Card Emulation

- One of three operating modes of NFC devices
- Interaction with existing RFID reader/writer infrastructure
  - E.g. POS terminals, access control readers
- Implementation of card emulation mode
  - Dedicated smartcard chip (secure element)
    - Embedded secure element
    - UICC (“SIM card”)
    - (micro) SD card
  - Software card emulation
    - No secure element
    - Communication is handled by software on the application processor

Secure Element: Current View on Security

- Secure element is as secure as a regular (contactless) smartcard
  - Same security features (Secure storage, Secure execution environment, Hardware-based cryptography, Certified high security standard)
  - Same weaknesses
- Main weakness: Relay attack
  - Cannot be prevented by application-layer cryptographic protocols
  - Timing requirements by ISO 14443 are too loose to prevent relay over longer channels
  - Possible countermeasures:
    - Shielding of contactless interface
    - Secondary authentication (PIN codes …)
    - Distance bounding protocols (require additional fast communication channel; not implemented on current smartcards)
- **BUT: All known relay attacks require physical proximity (< 1 meter) between the attacker and the smartcard!**

Secure Element in a Mobile Phone

- Secure element adds security features to a mobile phone
- NOW: Mobile phone is **not** considered a security risk for the secure element
- **BUT: Mobile phone environment is a significant part of secure element security**
  - Potential host for malicious software
  - (Global) wireless connectivity (GSM, UMTS, WiFi, Bluetooth …)

APIs for Access to the Secure Element

- Security and Trust Services API (JSR 177) → Java ME
  - APDU-based connection to one specific smartcard applet
    - no application selection, no logical channel management
  - Access is only granted to applications with trusted signatures
    + user confirmation
  - Optional: fine-grained access control
    - Applications' signatures must chain back to root certificates provided by SE
    - Secure element provides access control lists (ACLs)
      - Per secure element and per applet policies
      - Access based on application's security domain and on APDU header

APIs for Access to the Secure Element

- BlackBerry 7 API[1]
  - Interface based on JSR 177
    - Additional API to handle multiple secure elements
  - Access is only granted to applications with trusted signatures
    - Special code-signing certificates need to be obtained from RIM (registration required)

[1] http://www.blackberry.com/developers/docs/7.0.0api/net/rim/device/api/io/nfc/se/package-summary.html

APIs for Access to the Secure Element

- Android
  - NFC-Extras API introduced in Android 2.3.4 (com.android.nfc_extras)
    - Not included in public SDK
  - Interfaces for APDU-based secure element access and for activation of card emulation
    - Connection to whole smart card and not limited to a single smartcard applet
  - Access control:
    - Android 2.3.4: NFC permission required
      - Any application with access to NFC has access to the SE
    - Android 2.3.5+: Applications require special permission
      - com.android.nfc.permission.NFCEE_ADMIN, only granted to applications signed with same key as NFC service (**effectively limited to manufacturer**)
    - Android 4.0+: Permissions defined in an XML file
      - XML file contains list of allowed application certificates (can only be modified with **OTA updates** or **root access**)

APIs for Access to the Secure Element

- SEEK for Android[1]
  - Project aims at bringing a standardized smartcard API to Android
  - Interface compliant to Open Mobile API
  - Fine-grained access control similar to JSR 177
    - Access based on application certificate, applet AID and APDU header information
    - Access policy is stored on secure element
    - Access control is enforced by the smartcard service on the application processor

[1] http://code.google.com/p/seek-for-android/

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Comparison of APIs

- Common to all APIs:
  - Some form of access control
  - Access control is always enforced by the operating system **on the application processor**

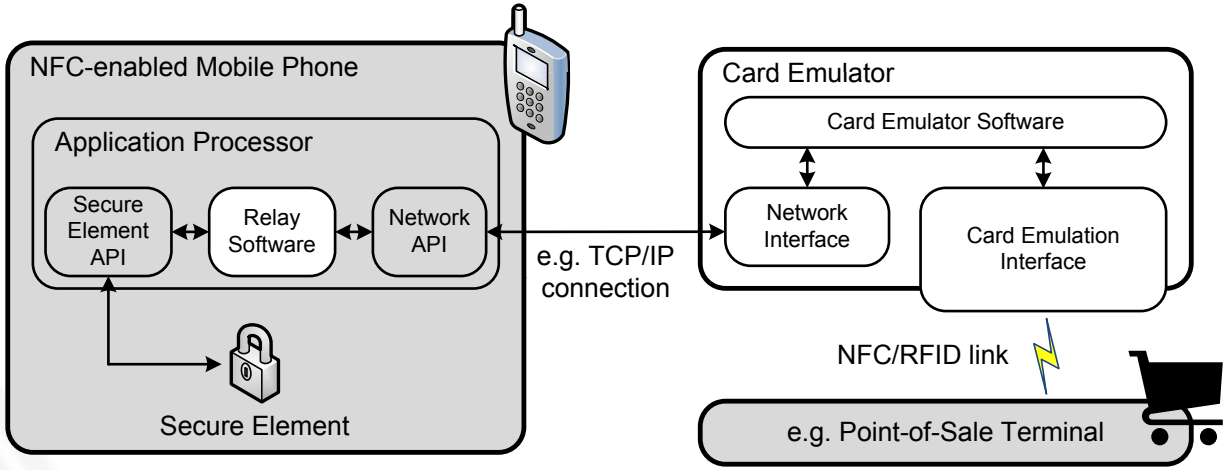
⇒ **APIs are designed to ultimately trust the operating system and the underlying mobile phone hardware**

⇒ **Secure Element trusts the operating system's access control decision**

Mobile Phone as Target for Attacks

- Threat: Malicious software/privilege escalation exploits
  - Android: Continuous history of privilege escalation exploits
    - mempodroid, Levitator, zergRush, GingerBreak, ZimperLich, KillingInTheName, RageAgainstTheCage, Exploid …
    - Vulnerabilities are fixed quite fast (months), but roll-out of patches takes significantly longer (many devices still don't run the latest firmware version)
- Threat: User
  - Jail breaking / Rooting
    - Security measures are intentionally circumvented by the user
    - Gain "improved" control over device or bypass DRM
    - **Not** limited to experienced users!
    - Elevated privileges may be used by malicious applications!
  - Carelessness
    - Apps are installed without review of requested permissions
    - Even dangerous combinations of privileges accepted by users

New Attack Scenario: Relay Attack



- Virtual pickpocketing without physical proximity to the mobile phone
  - Attack only requires an application on victim's mobile phone
  - Application accesses the secure element and relays APDU commands/responses over a network interface (GSM, UMTS, WiFi …)
  - Attackers can use the victims' secure elements as if they were in physical possession of them
  - Application may access additional resources (address book, key pad …)
- Timing constraints for the relay channel: none!
  - ISO 14443 has no timing requirements on the APDU layer
  - Payment protocols (defined by EMV) don't enforce any timing requirements either

New Attack Scenario: Denial of Service

- GlobalPlatform card management of many secure elements contains security feature:
  - After 10 successive authentication failures: card is put into TERMINATED state
    - Final (irreversible) state of GlobalPlatform card life cycle
    - Once in this state, installed applets continue to function, but card management (installation, removal … of applets) is no longer possible!

    ⇒ Secure Element is unusable for further card emulation applications
- What's necessary for a successful attack?
  - Access to the secure element
  - Three APDU commands have to be executed for one authentication attempt:
    - SELECT [Issuer Security Domain]
    - INITIALIZE UPDATE
    - EXTERNAL AUTHENTICATE
- Attack is possible on
  - Nokia 6131, Nokia 6212
  - Nexus S (with Android 2.3.4)
  - Nexus S/Galaxy Nexus (with Android 2.3.5+, if the application is able to gain root privileges)
  - …

Conclusion

- Attacks on contactless smartcards are well-known and can be prevented by physical measures (e.g. shielding)
- Adding a secure element to a mobile phone opens a new attack vector that has not been considered before
  - Attacks can be achieved **with pure software** on the victim's device
    - Denial of Service
    - Relay Attack
- Protection of secure element APIs varies widely
  - For all APIs: access control is managed by the operating system of the mobile phone
  - The secure element always trusts the operating system's access control decisions

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Thank You!

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