Android Security Symposium, Vienna, 9-11 September 2015

Secure Elements for You and Me: A Model for Programmable Secure Hardware in Mobile Ecosystems

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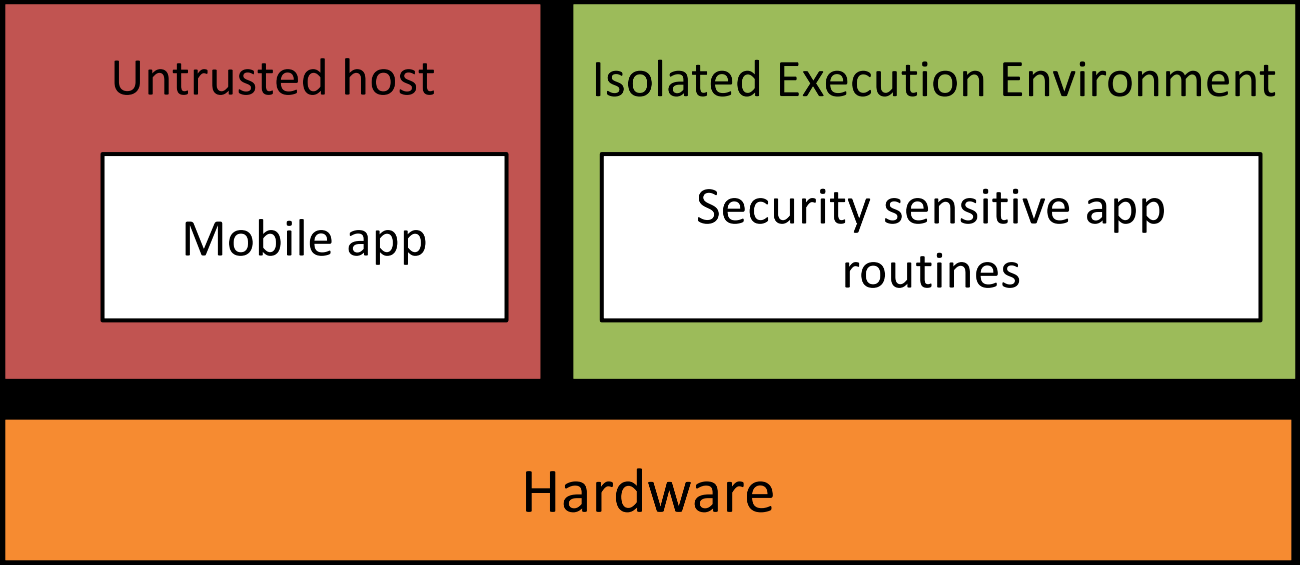
Motivation

- Secure hardware can drastically improve security of mobile apps
  - Provides isolated execution environment for security sensitive app routines


Untrusted host
Mobile app
Isolated Execution Environment
Security sensitive app routines
Hardware

Secure Hardware

Processor-based Trusted Execution Environments (TEEs)

- ARM TrustZone, TI M-Shield

Secure Element (SE) on UICC (or SIM) cards

Secure Hardware

Embedded SE (eSE)

- Standalone or NFC-based

Secure Element (SE) on an SD memory card

Mobile Payments Apps with Secure Hardware Support

- SE-supported apps from OS vendors
  - Google Wallet and Apple Play
- SIM-based apps from Mobile Network Operators (MNOs)
  - Vodafone payment app, MyWallet from Telekom, etc.
- But, “[…] there is a major shift towards cloud based software solutions away from hardware based technologies […]” (Advanced Payments Report 2014, Edgar Dunn & Company)
  - E.g., solutions of PayPal and Visa rely on cloud-based services

Other Security Sensitive Apps

- Online banking, mobile ticketing, access control applications, etc.
    - Typically rely on software-based security mechanisms
        - SmartCard emulated in software
        - OS-level isolation and access control

Why?

Secure hardware is not freely programmable

Problem Description and Challenges

- Widely deployed Secure Elements (SE) and Trusted Execution Environments (TEEs) are controlled by their stakeholders
- No effective business models exist to allow third party app developers to interact with SE/TEE stakeholders
- Access control to secure hardware APIs is controlled either by their stakeholders or by OS vendors, but not by app developers

Our Goal

A framework to allow third party developers to develop for secure hardware and to deploy their code

- Incentives for secure hardware stakeholders to allow such access
- Simplified interaction of third party developers and secure hardware stakeholders
- Access control to secure hardware APIs independent from OS vendors

Core Ideas

Market place code distribution ecosystem

- Bridges small and mid-size app developers and large hardware stakeholders

DRM for secure hardware code

- Hardware stakeholders grant installation rights (to users) by issuing installation tokens
- Financial incentives for hardware stakeholders

Developer-centric access control to secure hardware APIs

- Distribute access policy in installation tokens

Involved Parties

Developer D
- Develops mobile apps and applets, trustlets or trusted apps

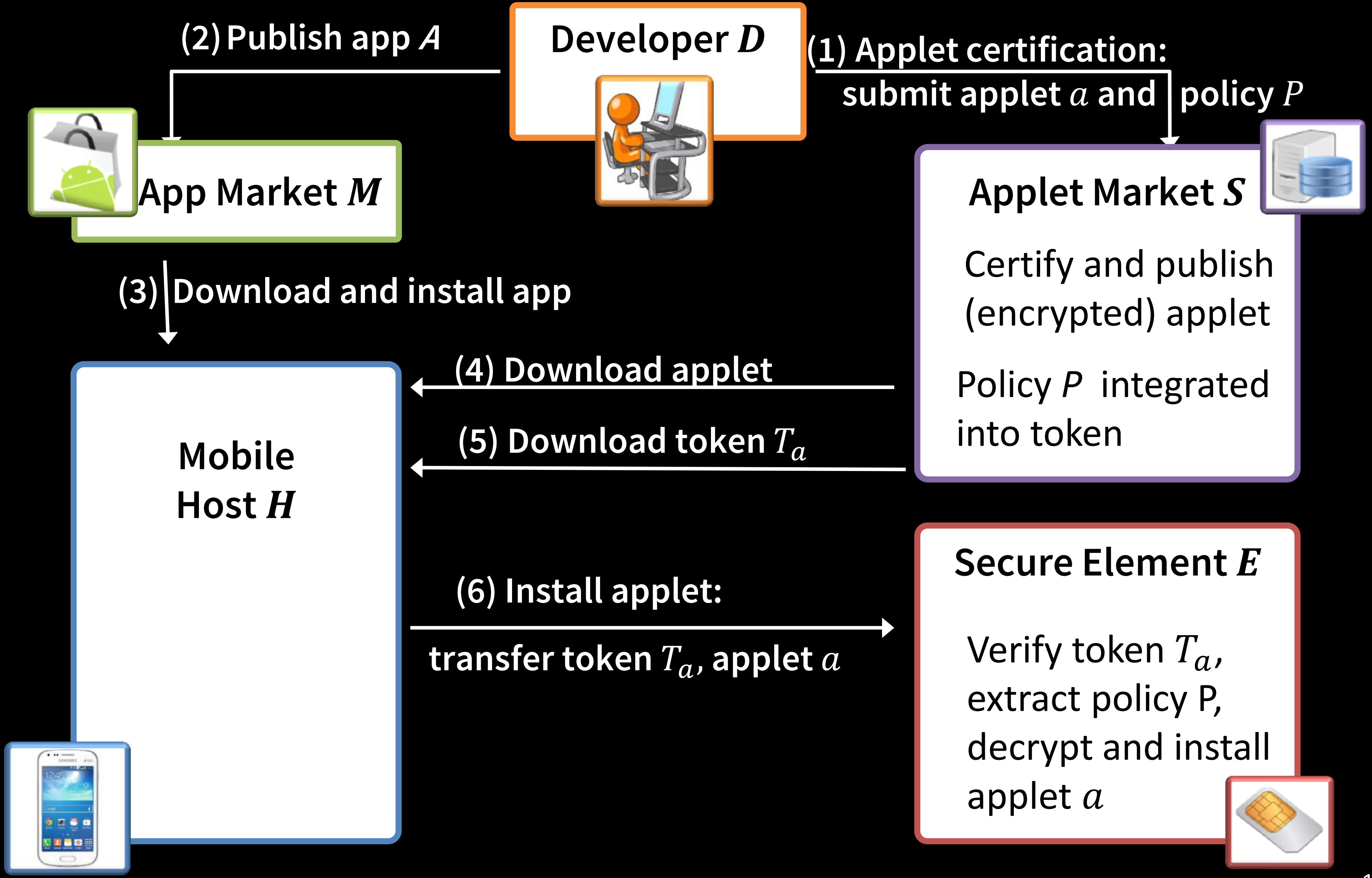
App Market M
- Usual app market where mobile apps are published

Applet Market S
- Maintained by the stakeholder of secure hardware

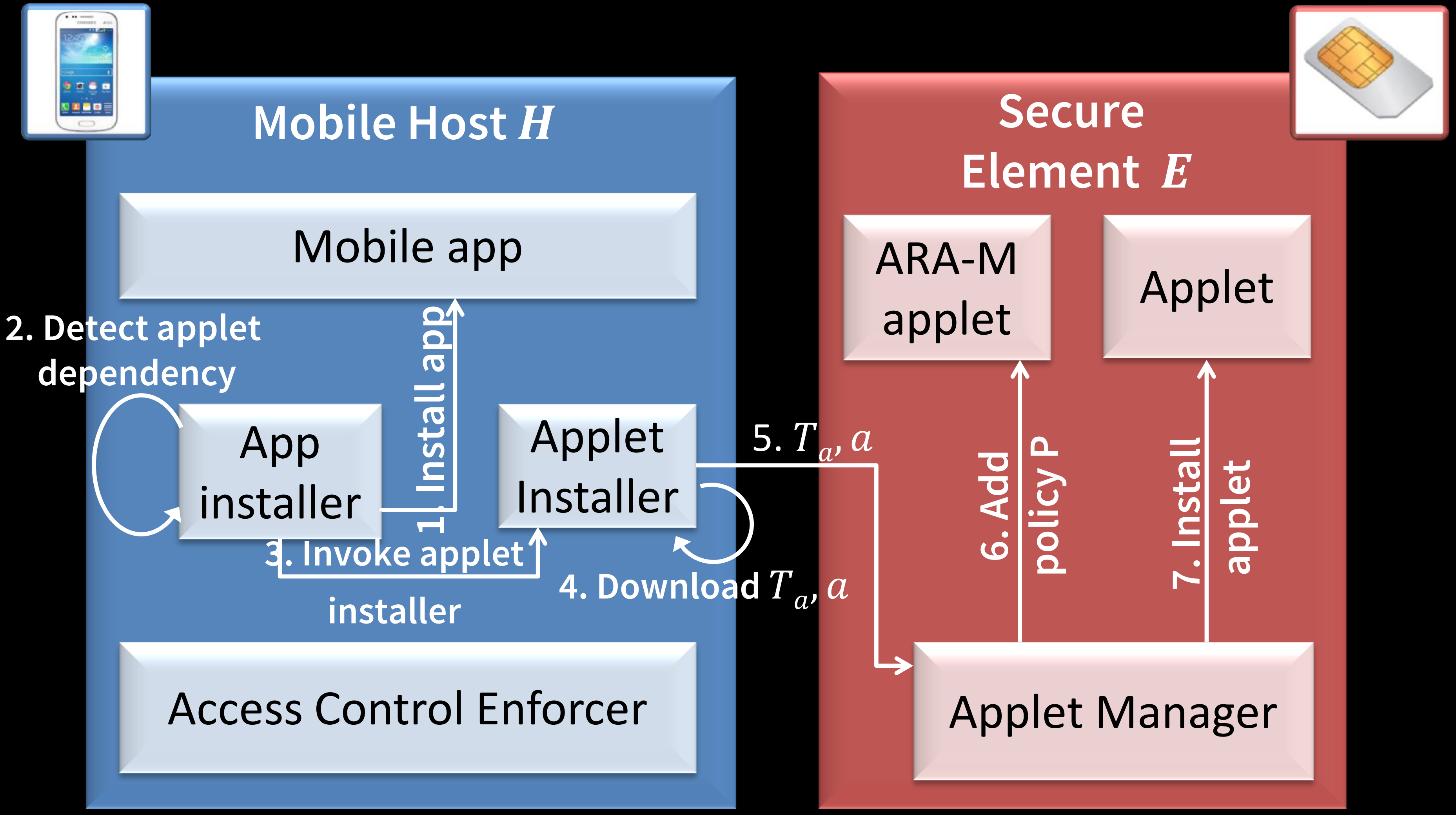
Secure Element SE
- Secure hardware which can run applets, trustlets, etc.

Mobile Host
- Mobile device, such as a smartphone or tablet

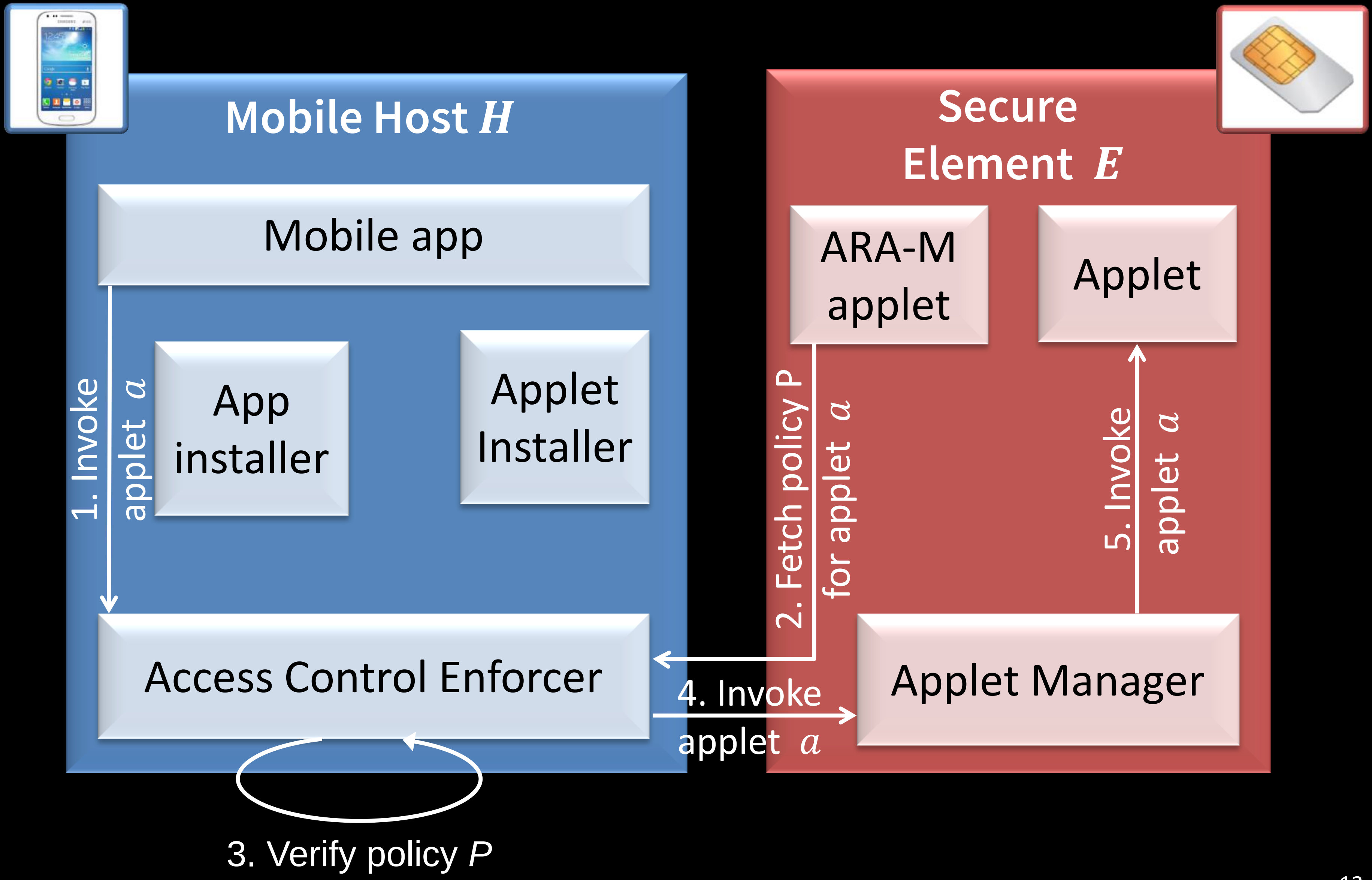
System Architecture


(2) Publish app A
Developer D
(1) Applet certification: submit applet a and policy P
App Market M
Applet Market S
Certify and publish (encrypted) applet
Policy P integrated into token
(3) Download and install app
(4) Download applet
(5) Download token T_a
Mobile Host H
(6) Install applet:
transfer token T_a, applet a
Secure Element E
Verify token T_a, extract policy P, decrypt and install applet a

Applet Installation



Applet Invocation



Associated Challenge

- Market-driven code provisioning scheme may stipulate rapid development of various SE applets
- Limited resources of hardware-based SEs limit number of installed applets
- Current resource quota mechanisms for SEs are not effective in case of market-driven code provisioning

Our solution: SE resource management

SE Resource Management

Applet Manager performs resource management by

- monitoring available SE resources
- maintaining statistics of applet usage
- de-installing of rarely used applets in case SE is out of resources
- installing applets on-demand in case previously de-installed applet is invoked

- On-demand applet installation
  - Transparent to mobile applications invoking the applet
  - May impact runtime performance

Implementation

Module	Size (LoC)	Language	Dependencies
Applet Manager	791	Java/Android	SpongyCastle Crypto API
jCardSim4Android*	4923	Java/Android	SmartCardIO
SmartCardIO**	728	Java/Android	
Applet Installer	1124	Java/Android	SpongyCastle Crypto API, Communication API
SE Stakeholder	1390	Java 6	BouncyCastle Crypto API, Communication API
Developer	656	Java 6	BouncyCastle Crypto API, Communication API
Communication API	545	Java 6, Java/Android	

*Port of open-source project jCardSim (http://jcardsim.org/) to Android
** Port of javax.smartcardio classes from Open-JDK v7 to Android

External SE Deployment

- Host on mobile device
- Emulated SE on a smartwatch (or any other wearable)

Performance Evaluation

	Applet installation*, ms	Applet de-installation*, ms	Applet execution**, ms
H and E on the same smartphone	46.27 ± 19.19	15.76 ± 7.83	38.43 ± 18.47
H on the smartphone, E on the smartwatch	415.27 ± 78.00	205.36 ± 72.54	150.34 ± 50.07
Hardware-based SE			24.47 ± 1.86

* Applet size 10953 Bytes

** Send 4 bytes to the applet and reply with 10 bytes

- Smartphone: Samsung Galaxy S3 (Android 4.4)
- Smartwatch: Samsung Galaxy Gear SM-V700 (Android 4.2)
- Hardware-based SE: Mobile Security Card SE 1.0 (G&D)

Summary and Further Work

Our model for programmable secure hardware

- Provides incentives for SE/TEE stakeholders
- Bridges small-size app developers and large stakeholders
- Developer-centric access control to secure hardware APIs compatible to Global Platform specifications

Further work:

- Support for Trusted Execution Environments
- Support for multiple types of secure hardware on a single platform

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