On-board Credentials

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Outline

- On-board Credentials (ObCs): What and Why
- ObC Architecture
- Secure Provisioning of ObCs
- Instantiations of the Architecture
- Deployment Considerations
- ObCs in Action
- Status

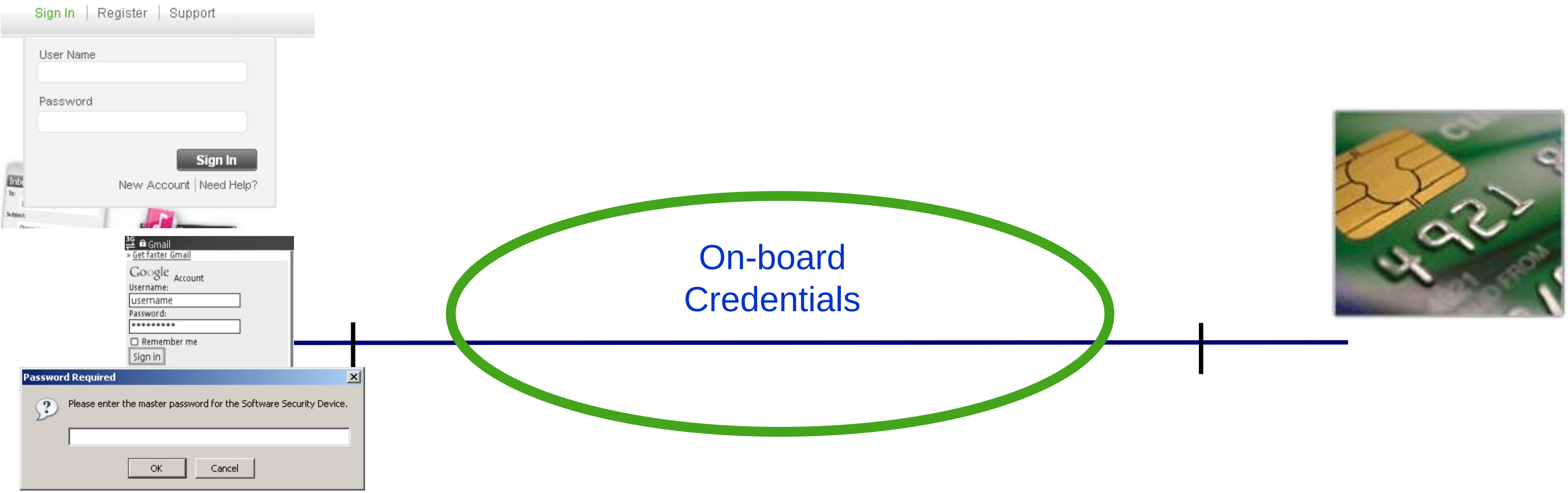
On-board Credentials: What and Why

On-board Credentials (ObCs)

An open credential platform that leverages on-board trusted execution environments

Secure yet inexpensive

ObCs: what and why



SW-only credentials

- Easy, cheap, flexible
- Insecure

Dedicated HW credentials

- Secure, intuitive
- Expensive, inflexible, single-purpose

Like multi-application smartcards, but without issuer control.

ObCs: design goals

- Credential programs can be executed securely
- Credential secrets can be stored securely
- Anyone can create and use new credential types

Credential = program + secret

  - Need a security model to strongly isolate credential programs from one another
- Anyone can provision credential secrets securely to a credential program
  - Need a mechanism to create a secure channel to the credential program
- Protection of asymmetric credentials is attestable to anyone
  - Anyone can verify that a private key is protected by the TEE

ObC Architecture

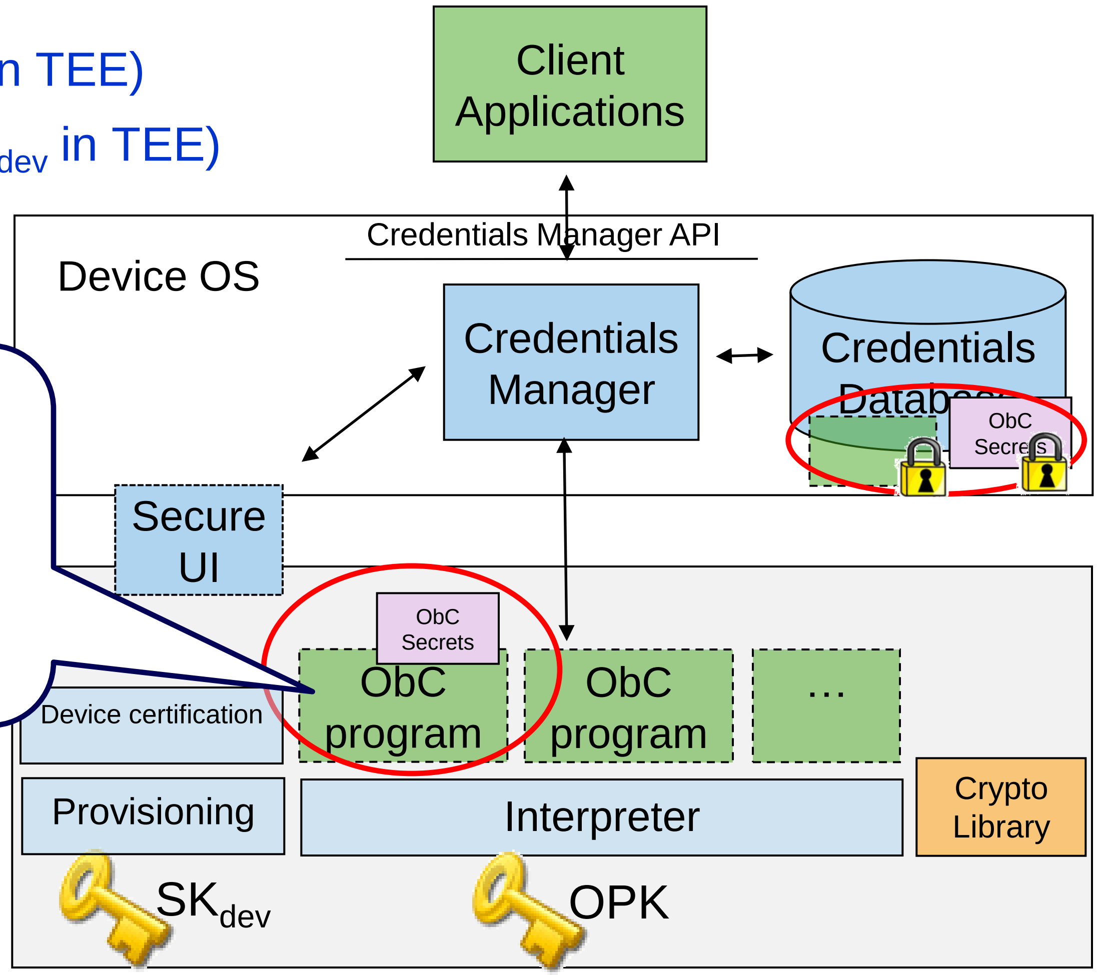
ObC Architecture

Credential = program + secret

On Trusted Execution Environments (TEEs) with

- Secure execution (within TEE)
- Secure storage (secret key OPK in TEE)
- Certified device keypair (PK_{dev}/SK_{dev} in TEE)
- Source of randomness

```
function main()
  read_array(IO_PLAIN_RW, 0, data)
  read_array(IO_SEALED_RW, 1, key)
  aesenc(cipher, data, key)
  write_array(IO_PLAIN_RW, 0, cipher)
  return 0
end
```



More in ACM ASIACCS '09 paper

Isolation of ObC Programs

Isolating the platform from programs

- Constraining the program counter, duration of execution, …

Isolating programs from one another

- Only one ObC program can execute at a time
- An ObC program can “seal” data for itself
    - Sealing key is different for every independent ObC program

      Sealing-key = KDF (OPK, program-hash)
    - A program can invoke functions like “seal(data)” (unsealing happens automatically on program loading)

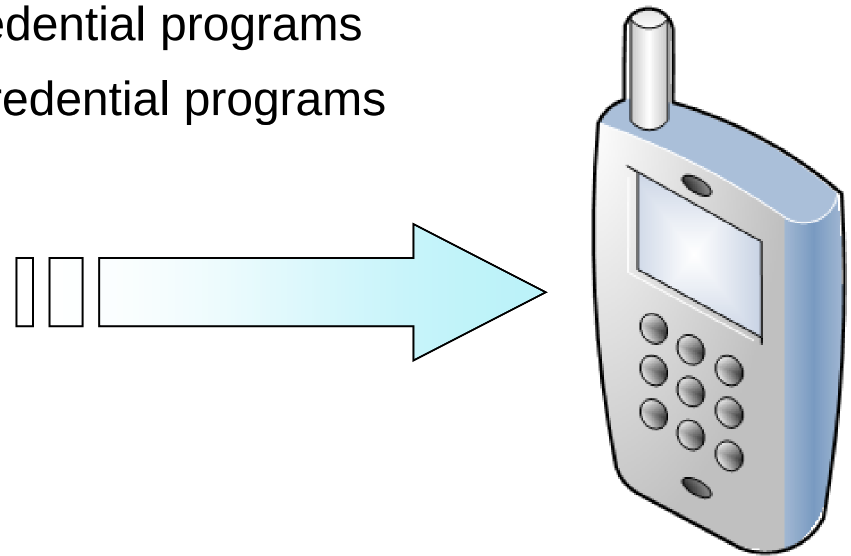
Programming language with single type

- No need for complicated type-safety verification

Secure Provisioning of ObCs

Requirements for Provisioning Credential Secrets

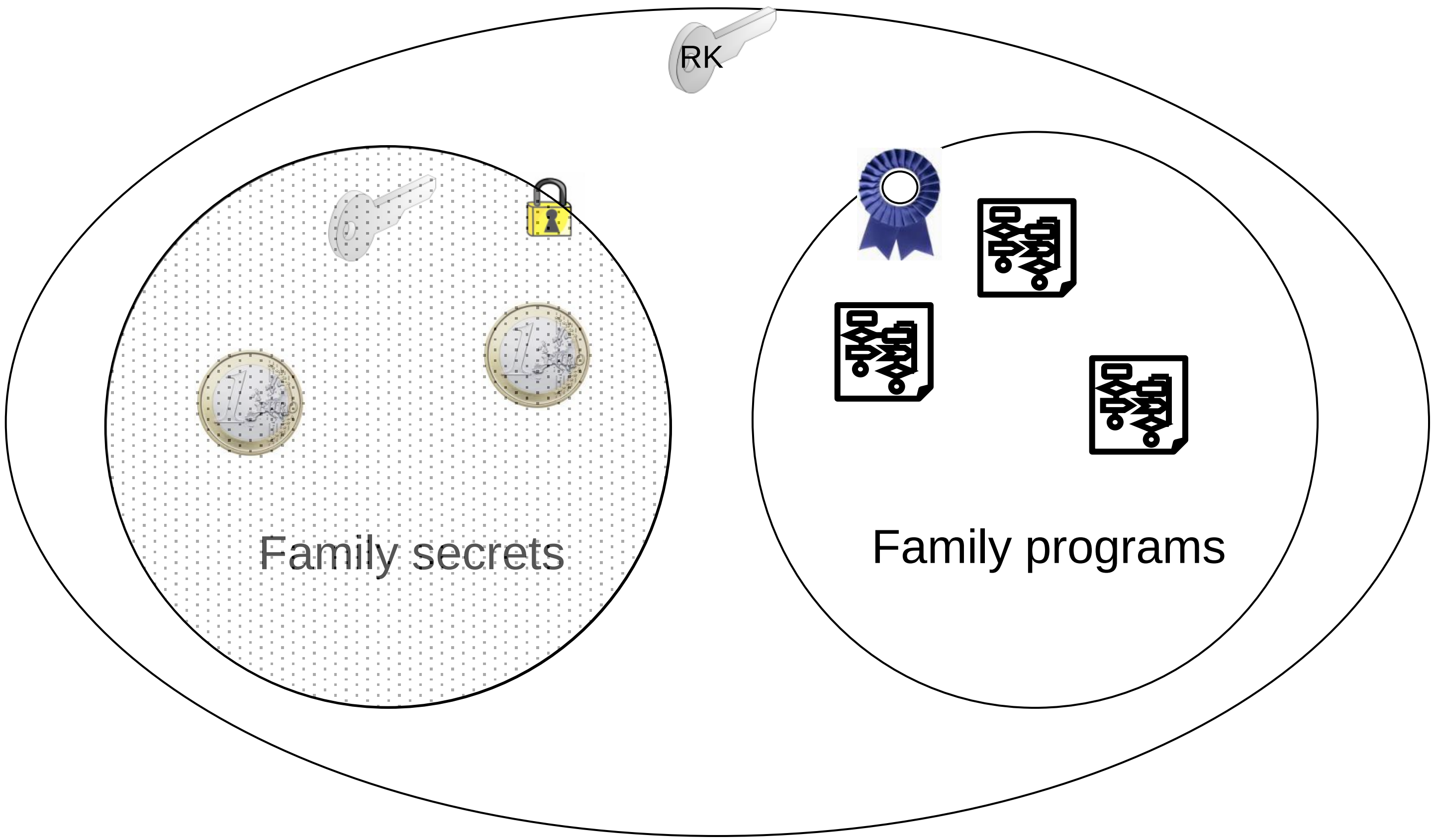
- Provisioning protocols typically focus on **user authentication** only
  - CT-KIP, Open Mobile Alliance Device Management (OMA DM), …
- Dynamic Symmetric Key Provisioning Protocol (DSKPP) (IETF RFC 6063)
  - Allows **device authentication** as well
- We need more…
  - provision a key so that it can be accessed by **specific credential programs**
- Subject to…
  - "Anyone can provision credential secrets securely to a credential program"
  - Support for multiple versions of credential programs
  - Support for several co-operating credential programs



Provisioning credential secrets (1/4)

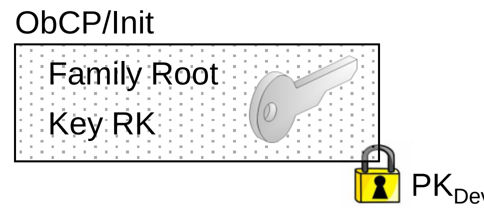
Idea: a **family** of credential secrets + credential programs endorsed to use them

"family" = dynamic trust domain; **same-origin** authorization policy

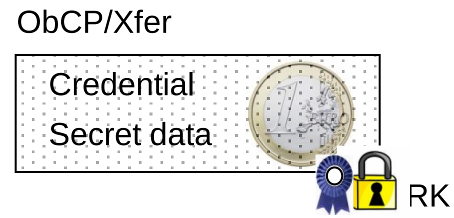


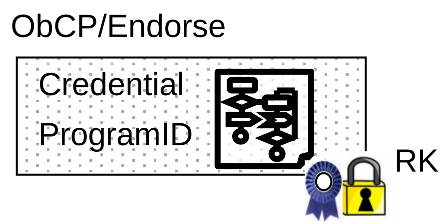
Provisioning credential secrets (2/4)

- Provision a family **root key** to the device
    - using ***authentic* device public key** PK_{Dev}



- Transfer encrypted credential secrets
    - using authenticated encryption (AES-EAX) with RK



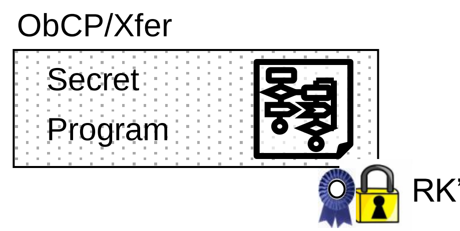


- Endorse credential programs for family membership
    - Program ID is a cryptographic hash of program text
    - using authenticated encryption (AES-EAX) with RK

Provisioning credential secrets (3/4)

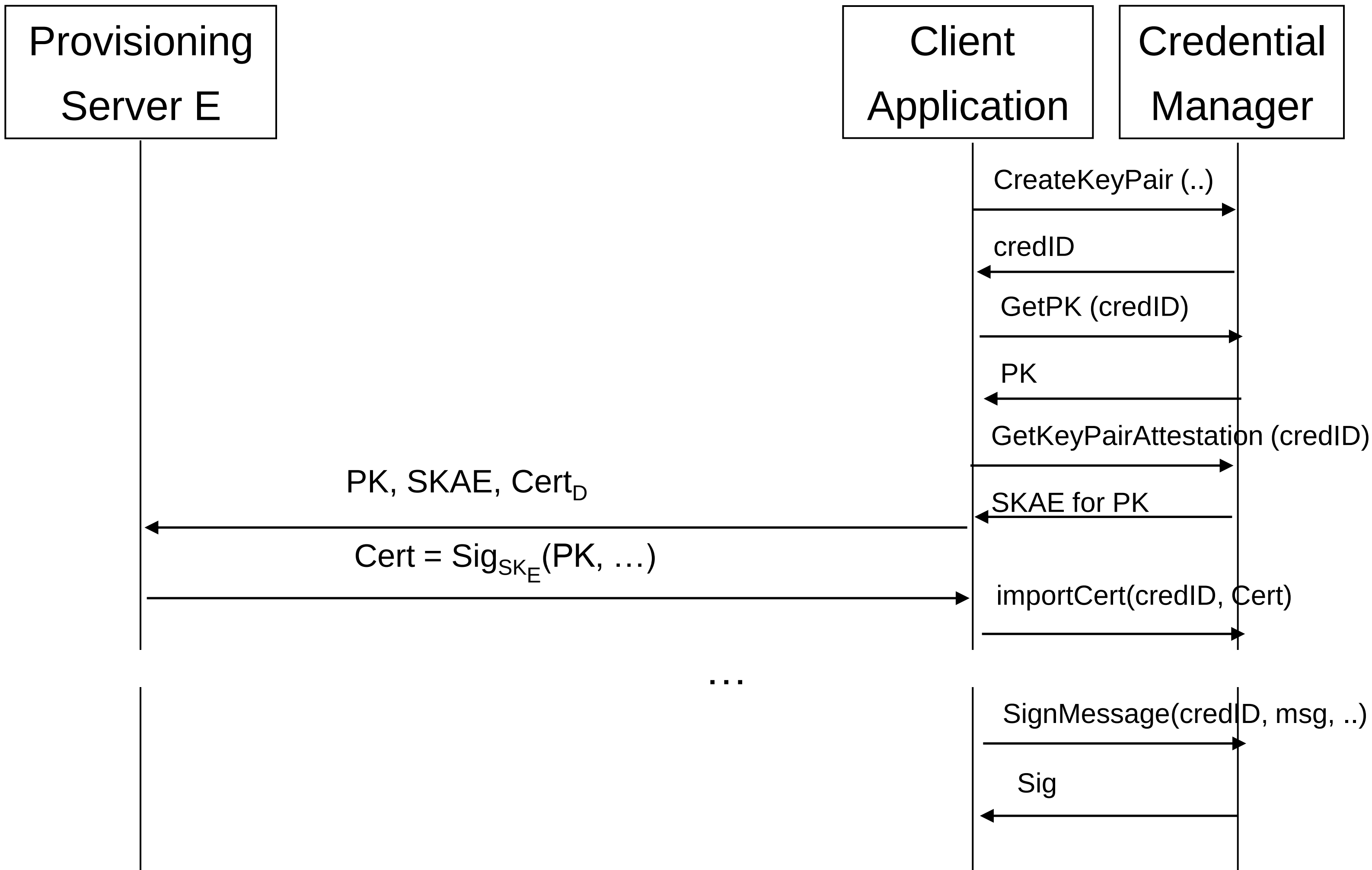
- Anyone can define a family by provisioning a root key (“Same Origin” policy)
- Multiple credential secrets and programs can be added to a family

- Credential Programs can be encrypted as well



Skip to asymmetric ObCs

Asymmetric ObCs



Cert$_D$ (Device certificate) Certificate for PK$_D$ issued by manufacturer

SKAE (Subject Key Attestation Evidence) for PK: Signature on PK issued by SK$_D$, attesting that SK is within the TEE

"Key Attestation from Trusted Execution Environments", Kostiainen et al, TRUST 2010

ObCs: design goals revisited

- Credential programs can be executed securely
  - Use a trusted execution environment (TEE)
- Credential secrets can be stored securely
  - Use a device-specific secret in TEE for secure storage

Credential = program + secret

- Anyone can create and use new credential types
  - Need a security model to strongly isolate credential programs from one another
  - Avoid the need for centralized certification of credential programs
- Anyone can provision credential secrets securely to a credential program
  - Need a mechanism to create a secure channel to the credential program
  - (certified) device keypair; unique identification for credential programs
- Protection of asymmetric credentials is attestable to anyone
  - Anyone can verify that a private key is protected by the TEE
  - Subject key attestation evidence

Instantiations of the Architecture

Skip to "ObCs in action"

M-Shield^{TM}: Example hardware TEE #1

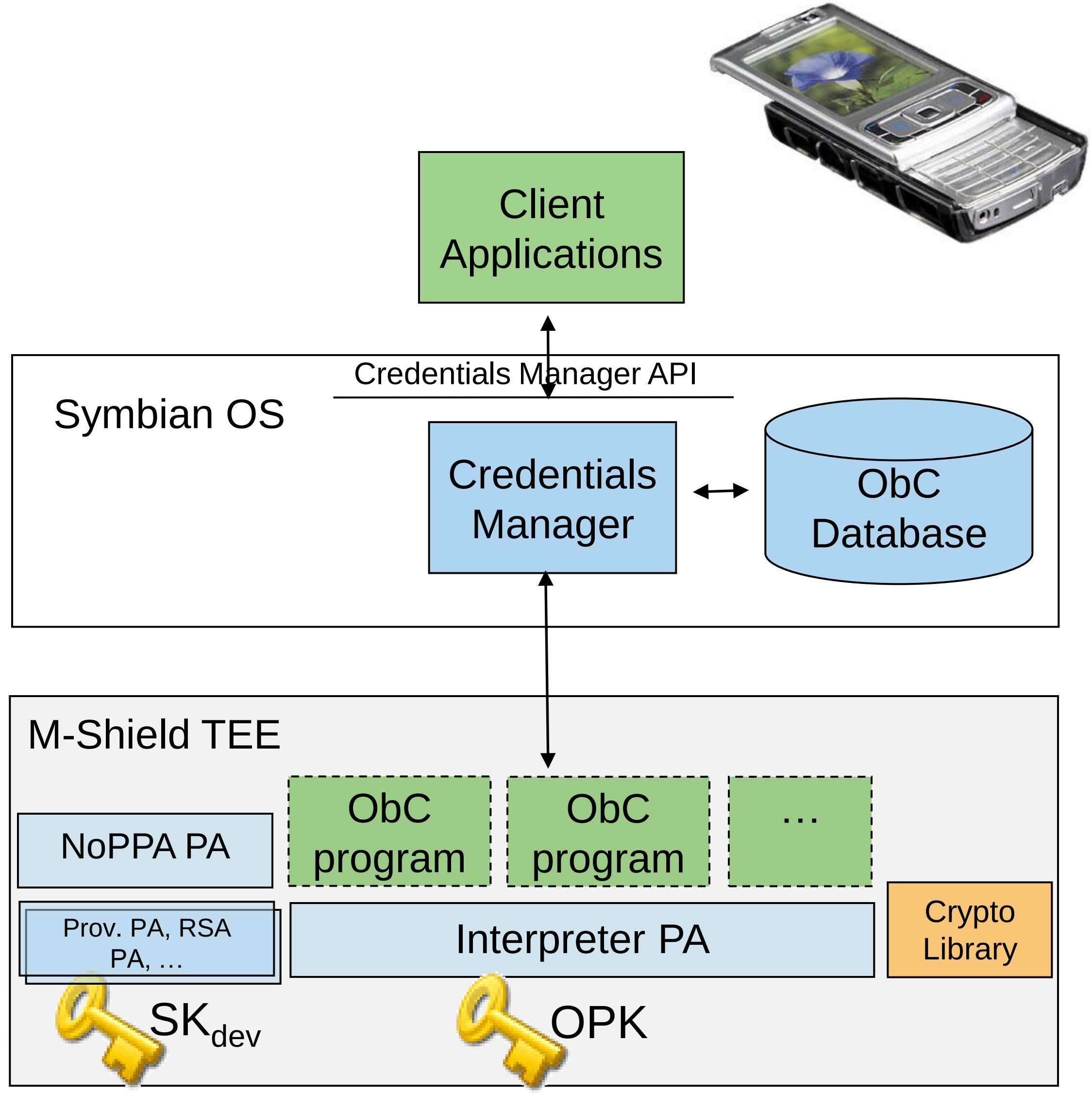
M-Shield provides

- Secure boot
- Chip-specific secret key (e-fuse)
- Secure execution of certified “Protected Applications” (PAs)
- On-chip RAM for PAs
- … (hardware RNG, crypto accelerators, …)

http://focus.ti.com/pdfs/wtbu/ti_mshield_whitepaper.pdf

ObC on Symbian/M-Shield secure h/w (2007-2009)

- M-Shield secure boot used for validation of OS
- Interpreter , Provisioning subsystem are PAs
  - Use on-chip RAM
- OPK from chip-specific secret
- Device key pair
  - generated by Prov. PA
  - protected by chip-specific secret key
  - [certified by manufacturer]



TPM: Example hardware TEE #2

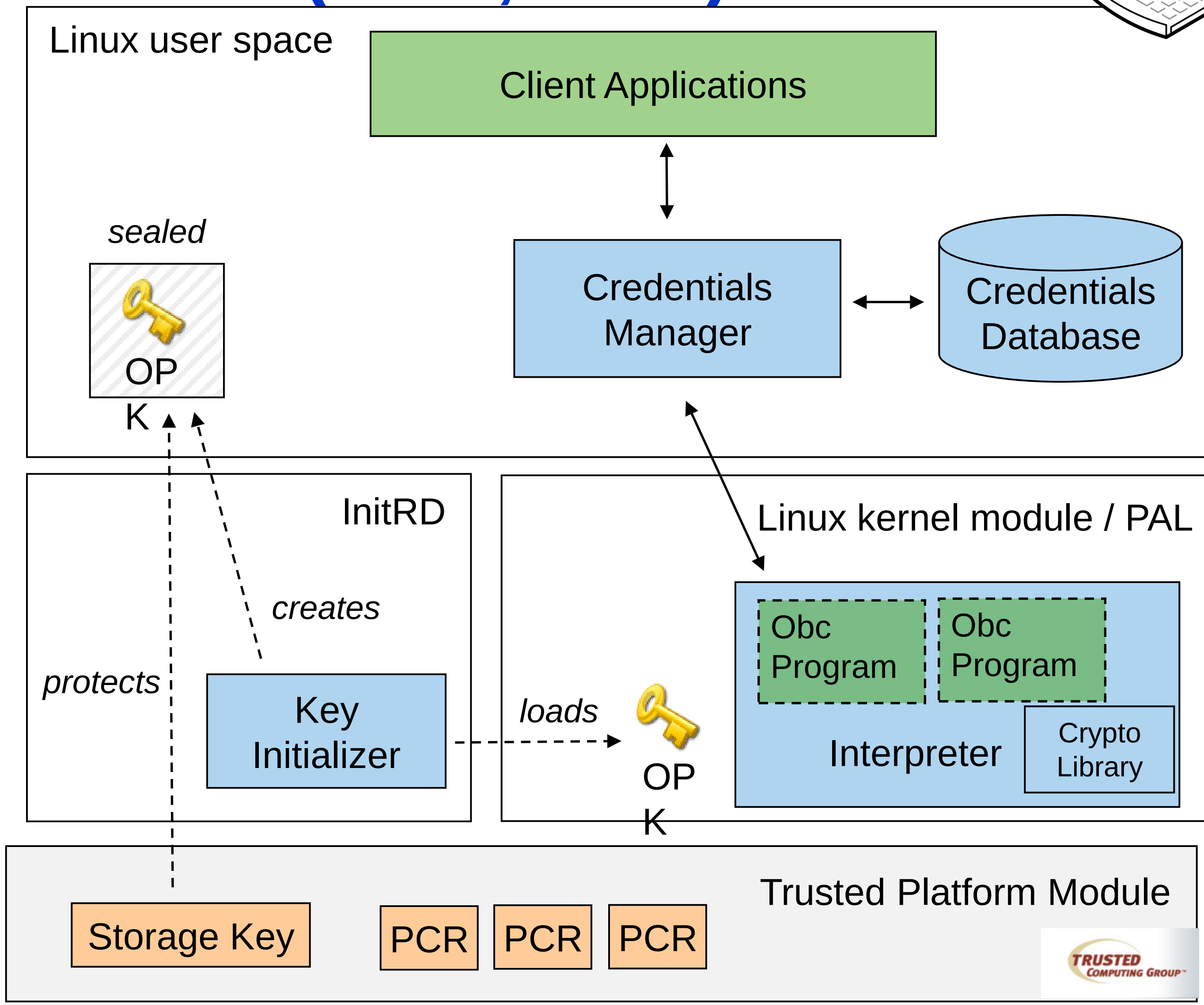
TPM provides

- Authenticated boot
  - Components during boot measured and recorded in Registers (PCRs) within TPM
  - A set of PCR values = a “configuration”
- Secure storage for keys bound to a specific configuration
- Ability to seal arbitrary data bound to a specific configuration
- Secure execution of selected cryptographic operations
- … (remote attestation, …)

TRUSTED COMPUTING GROUP™

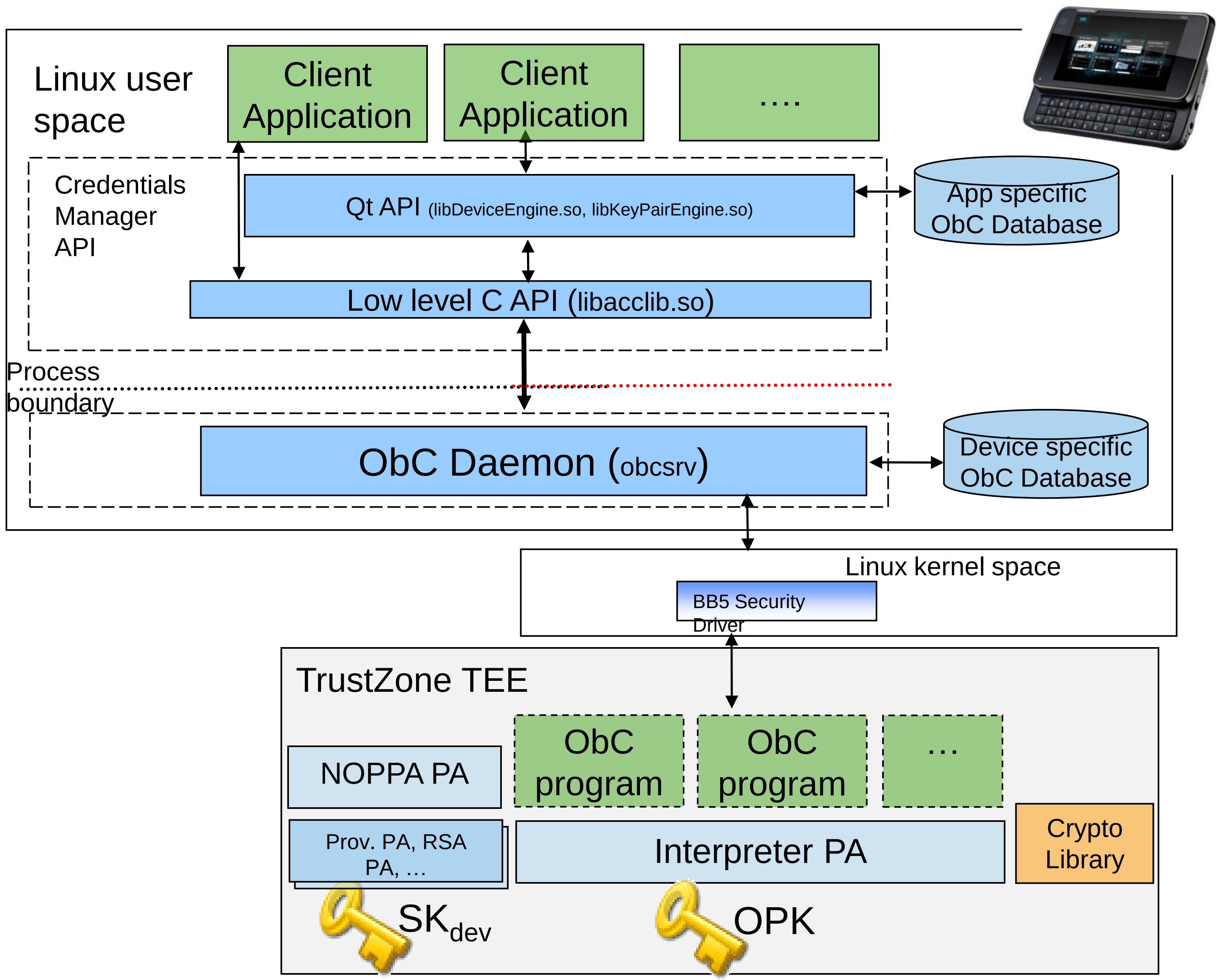
ObC using Linux/TPM (2006, 2009)

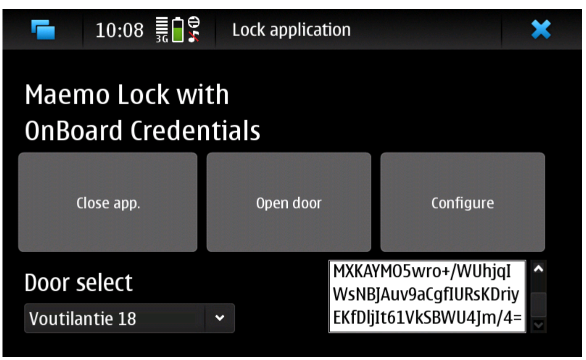
- Interpreter in kernel module on InitRD
- KeyInitializer in InitRD creates OPK on first use and seals for current configuration
- KeyInitializer unseals OPK on subsequent invocations.
- Security of execution improved using dynamic root of trust (2009): Flicker “PAL” instead of kernel module.



MSc thesis work:
http://asokan.org/asokan/research/Aish-Thesis-final.pdf

ObC on Maemo/TrustZone secure h/w (2009-2010)





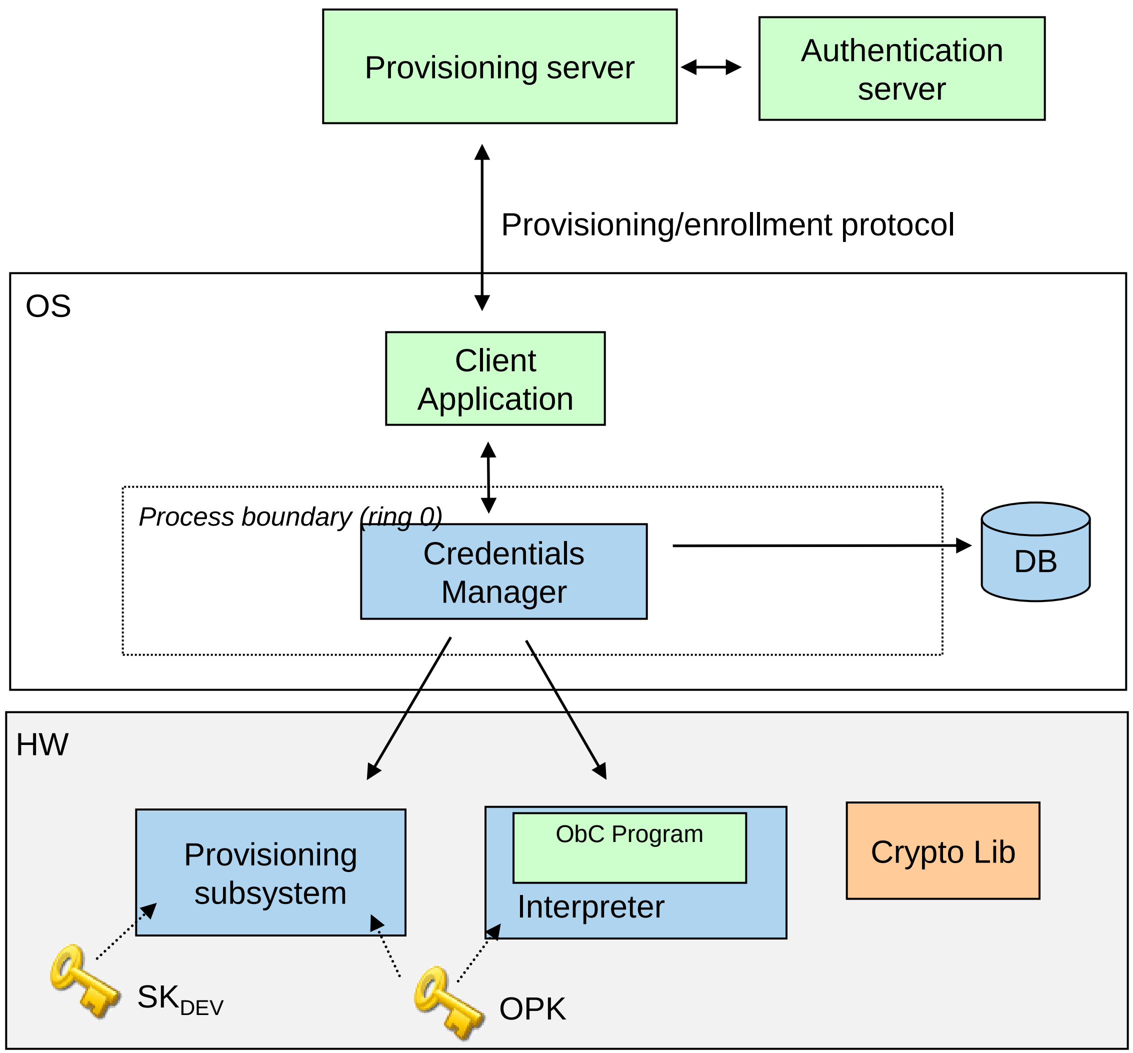
ObC for other platforms

- ObC for MeeGo Harmattan (N9) available in partially emulated mode (see later)
- Other ports yet to be announced publicly

Deployment considerations

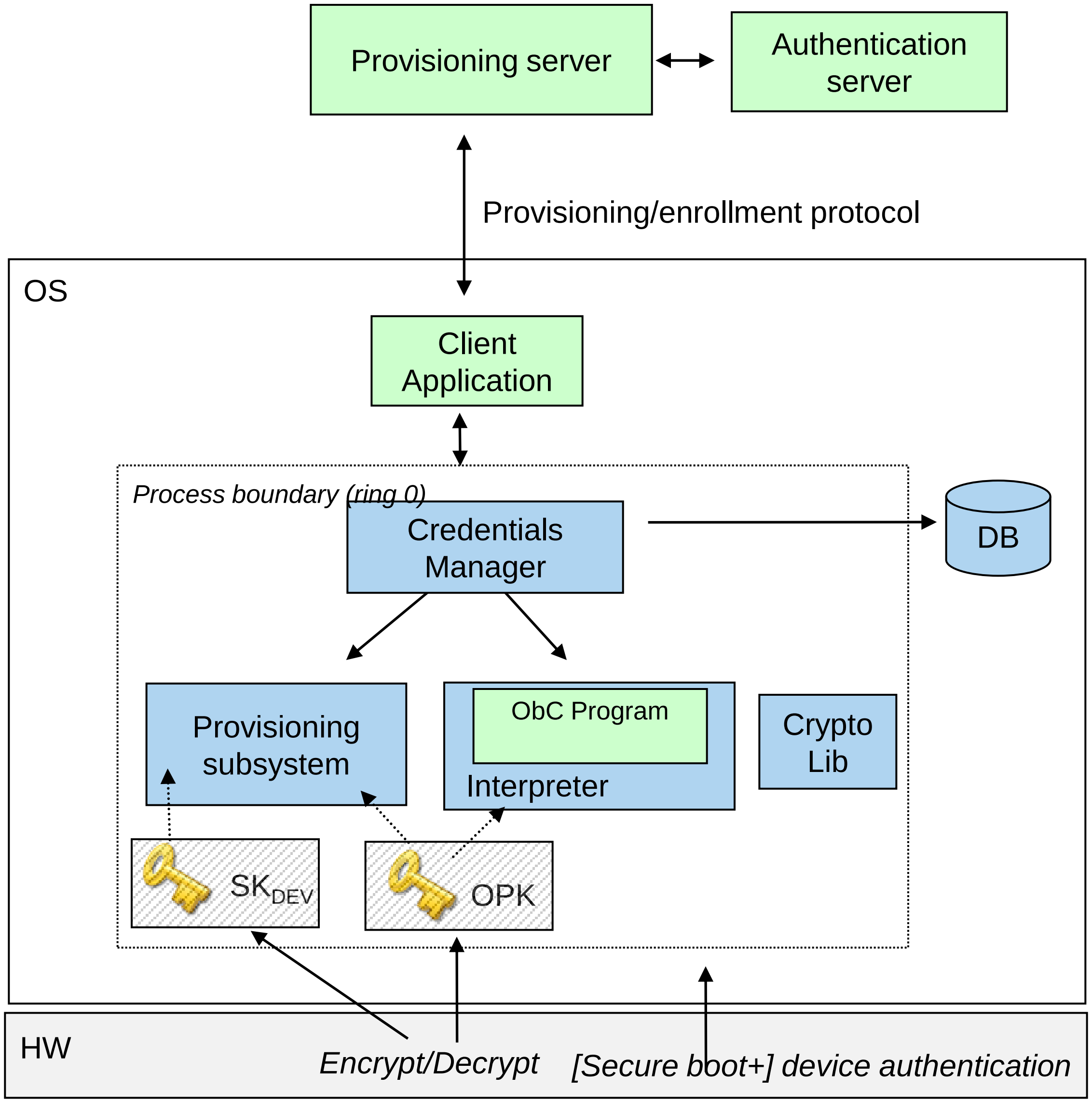
Skip to “ObCs in action”

1. ObC: Full use of secure hardware



- ObC secret and algorithm (ObC program) protected by hw TEE
  - PK_{Dev} to protect provisioning or attestation
  - Secrets not accessible to OS
  - Cannot be copied between devices
  - Hardware attack typically destructive and device-specific
- Encrypted secret stored in Credentials Manager database
  - Can be backed up
- Example: Symbian devices (N8 and newer, OS version Anna and later)

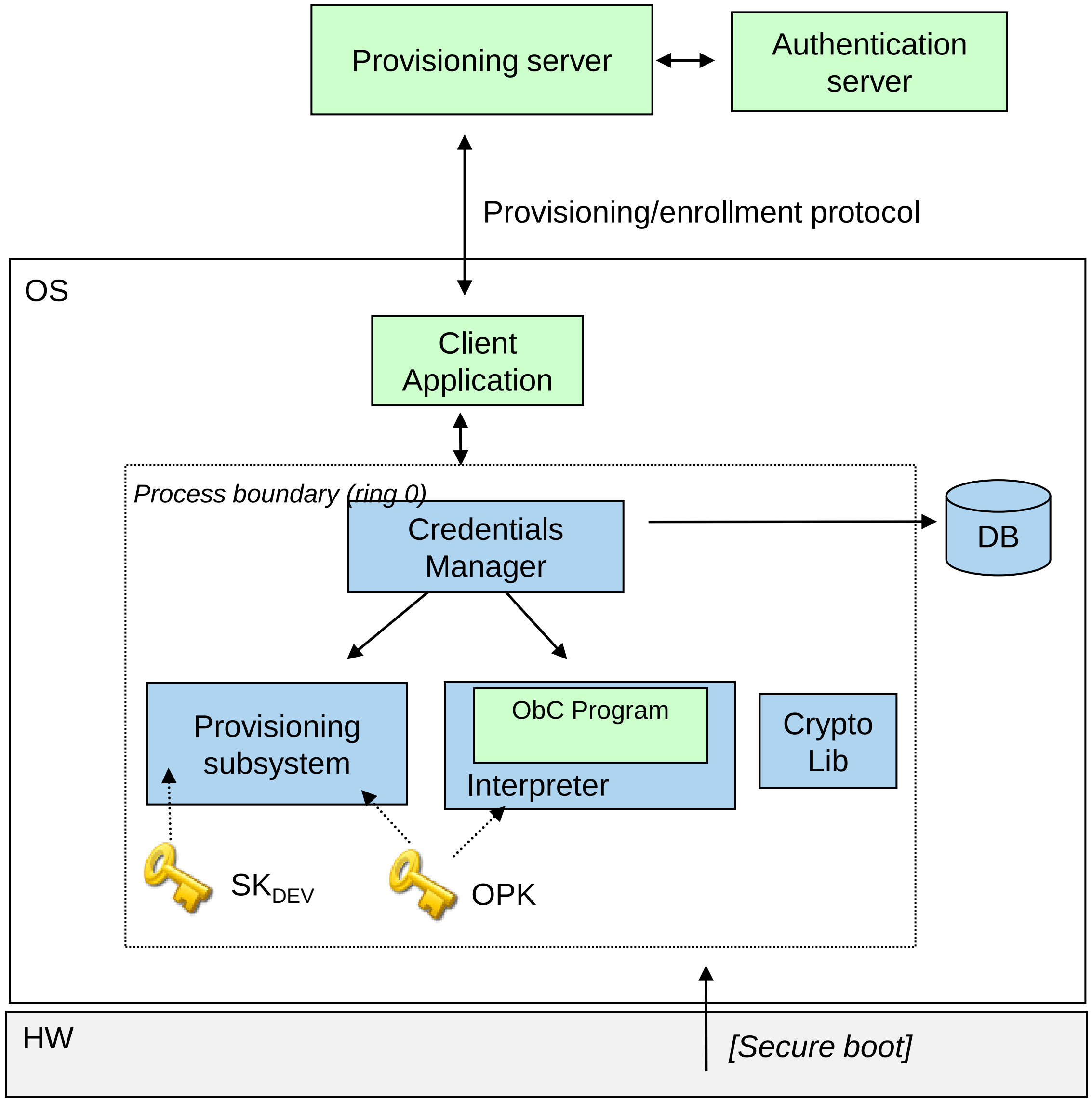
2. ObC: Partial use of secure hardware



- ObC PAs emulated in the Credential Manager (OS process)
- Secure HW used to enable secure storage and device authentication
- ObC program runtime execution protected by OS platform security

- Example: MeeGo Harmattan (N9)

3. ObC: Fully emulated

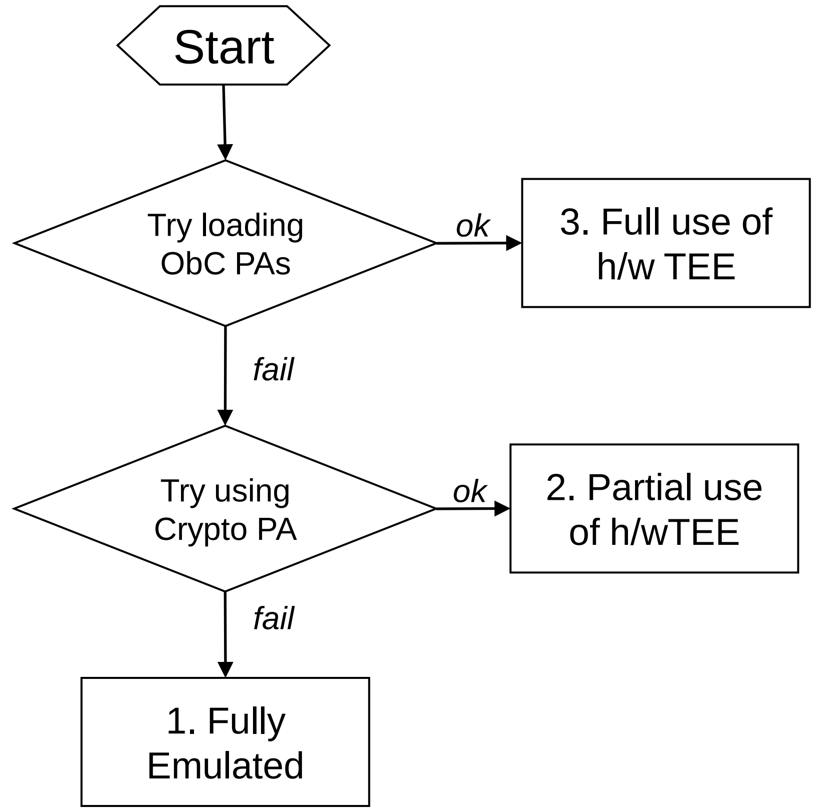


- ObC PAs emulated in the Credential Manager (OS process)
- Secure HW may be used for secure boot
- Storage ObC secrets and ObC program runtime execution protected by OS platform security
- No device authentication

- For debugging/development

ObC implementation supports all 3 variants

- Implementation contains code for emulating TEE PAs (interpreter+provisioning+crypto)
- Same software package can be installed in any device of the same type
  - automatically decides the variant to use
- (“PA” = “Protected Application” refers to code that runs in hardware TEE)



ObCs in action

Benefits of ObC

- Systematic means to expose useful TEE features (e.g., device authentication) to applications
- Portable programming platform over different chipset technologies for TEE code
- Means for 3rd-party development of credentials for TEE-equipped platforms

ObC Features

Secure user credentials

Custom Credentials

Secure key/code provisioning

Built-in Credentials

Key attestation or Secure key Provisioning

Device Certification

Validate device platform

Platform authentication

Device Authentication

Application Authentication

Content attestation

Target usage scenarios: Platform Authentication

Prove to a third party (e.g., external server)

- **Device authentication**: identity of device
  - E.g., CAPTCHA-avoidance, Comes-with-XYZ
- **Application authentication**: identity of application/process
  - E.g., Extended Web Service APIs for trusted apps
- **Content attestation**: type of content
  - E.g., Enforcing driver distraction rules in MirrorLink

Remote attestation problem

Attesting device

Verifier

What kind of software you are running?

Here is a certified statement of my current configuration (~ “measurements”)

Access control decision

Example: MirrorLink system

Attesting properties, rather than configuration, is more useful

Traditional property-based attestation

Attesting device

Trusted Authority

Verifier

Defines properties
Defines mappings from measurements to properties

list of properties →

← property certificates

Measure software configuration
Store **matching properties** into registers
Sign registers with certified key

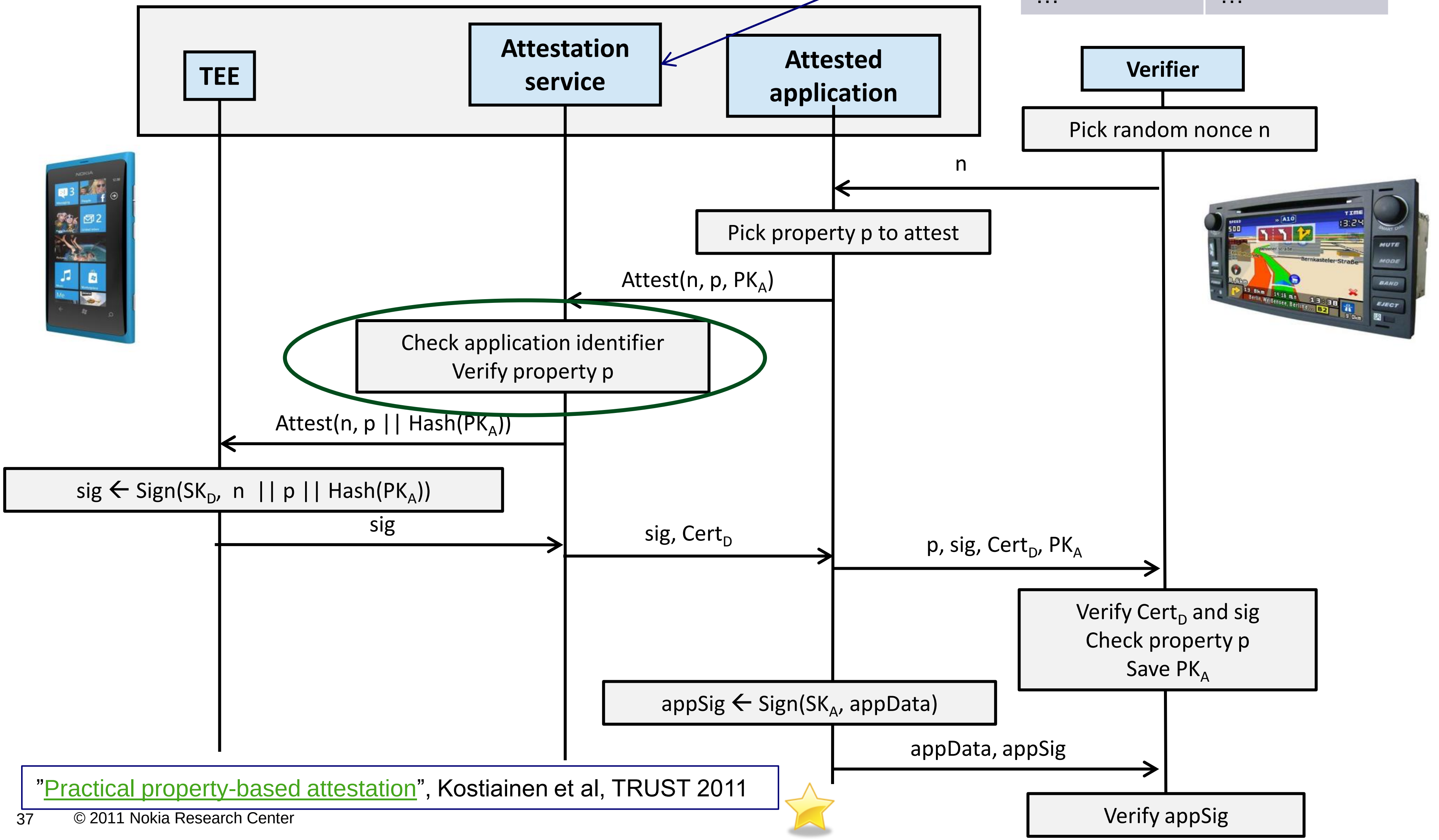
signed **properties**, device certificate →

Verify signature
Check properties

Sadeghi and Stüble, Property-based attestation for computing platforms: caring about properties, not mechanisms. Workshop on New Security Paradigms, 2004.

Attestation protocol

Application Identifier	Property
App1	P1, P2
App2	P3
…	…

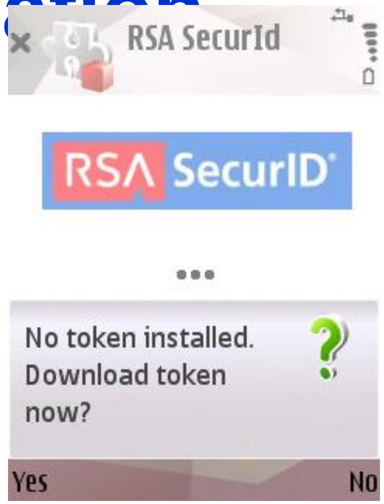


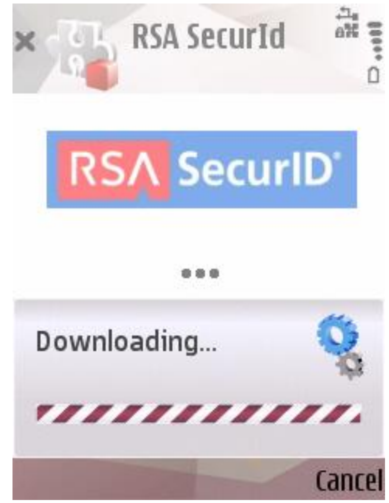
"Practical property-based attestation", Kostiainen et al, TRUST 2011

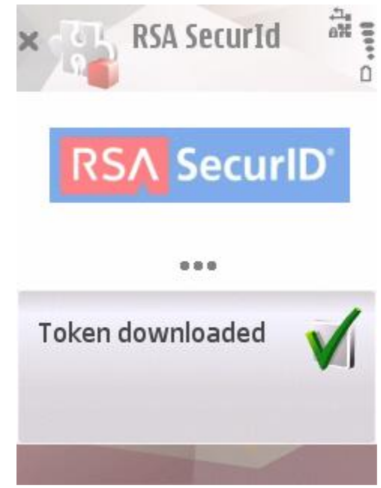
Target usage scenarios: User Credentials

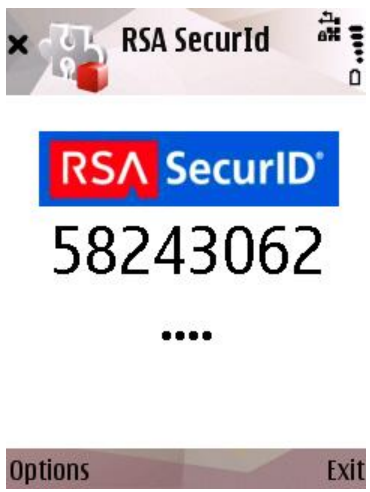
- Problem: provide the means to securely provision and store user credentials to user's personal device
- User benefits:
  - "no need to a bunch of different security tokens";
  - "digital credentials provisioned easily" (http, e-mail, …)
- **Transport ticketing**
- **"Soft" tokens:** embedded SIM, embedded SecurID
- **Phone-as-smartcard:** use device-resident credentials from legacy PC apps (e.g., browsers, Outlook, VPN clients)
- **Physical access control (opening doors)**
- …

An Example ObC: SecurID one-time password authentication









Joint research project with RSA security

Phone as smartcard (PASC)

- Applications use public key (PK) cryptography via standard frameworks
  - Crypto API (windows), Cryptoki (Linux, Mac), Unified Key/cert store (Symbian)
  - Agnostic to specific security tokens or how to communicate with them

→Any PK-enabled smartcard can be used seamlessly with PK-aware applications!

What if mobile phone can present itself as a PK-enabled smart card?

”Can hand-held computers *still* be better smartcards?”, Tamrakar et al, INTRUST 2010

ObC Status

ObC Status (1/2)

- Available on off-the-shelf Symbian devices
- Development environment for ObC programs (Windows, Linux)
  - Credential Manager and interfaces (native, *javascript*)
  - Available from Nokia under limited license agreement for research and testing
- Available as an installable software package for MeeGo (N9)
  - distributed as part of the same LLA
- Other platforms in the works

ObC Status (2/2)

- Related research
  - Support for piece-wise execution, sub-routines etc. (Ekberg et al, STC 2009 paper)
    - How to split up ObC programs into smaller pieces securely?
  - Considerations of implementing crypto primitives (Ekberg et al, TRUST 2012 paper)
    - Is authenticated encryption secure even in pipelined mode?
  - Credential Migration, backup/restore (Kostiainen et al, ACNS 2011 paper)
    - Balancing usability/security?
- Useful for several applications
  - Device authentication, financial services, secure messaging, …
  - Pragmatic means to solve otherwise hard privacy/security problems in distributed computing (e.g., secure multi-party computation)

Emerging standardization

- Global Platform Device Specifications define standard APIs for TEE applications
- Trusted applications and their data can be provisioned remotely
    - “credential provisioning”
- Modeled after smartcard application provisioning
    - Centralized provisioning
        - TEE supports a hierarchy of protection domains
        - Provisioned TAs must be authenticated using a cert chain
    - No “open provisioning”

Figure 3-1: TEE System Architecture

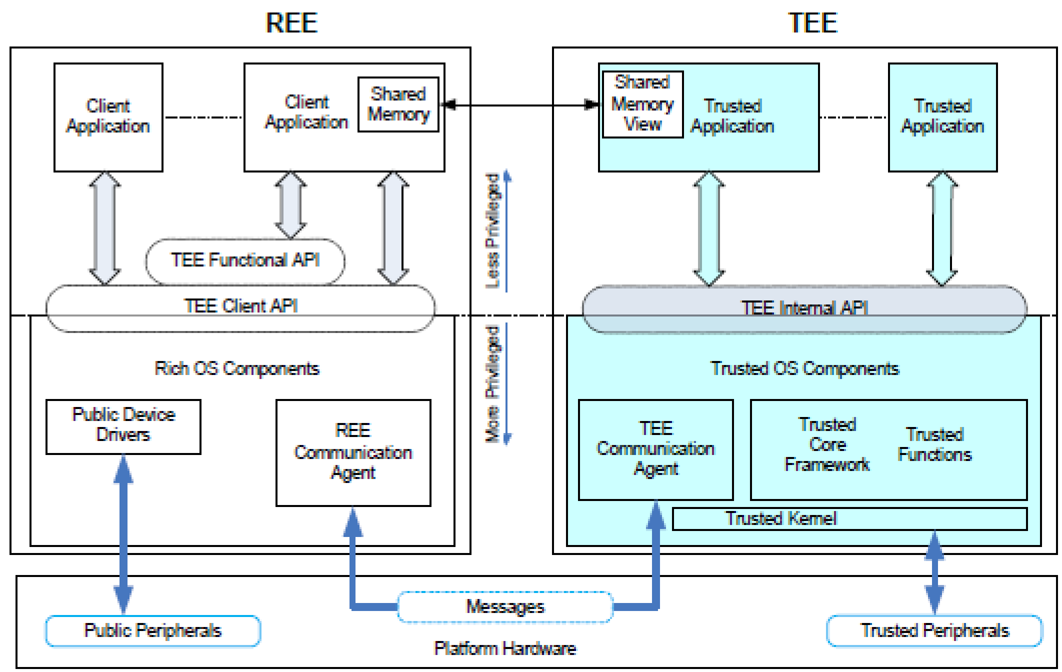


Figure taken from GlobalPlatform Device Technology TEE System Architecture Version 1.0, December 2011

Limitations

- Open provisioning model
  - Liability and risk management
  - User interaction issues: e.g., Credential migration
- Certification and tamper resistance
  - Not comparable to high-end smart cards
- Will open-provisioning emerge as an alternative to centralized provisioning?

Standing on the shoulders of giants

MTM

Late launch

2010

On-board Credentials

Mobile OS security architectures

Trusted Platform Module (TPM)

ARM TrustZone

2000

JavaCard platform

TI M-Shield

Java security architecture

Mobile hardware security architectures

1990

Hardware-assisted secure boot

1980

Simple smart cards

Reference monitor

Protection rings

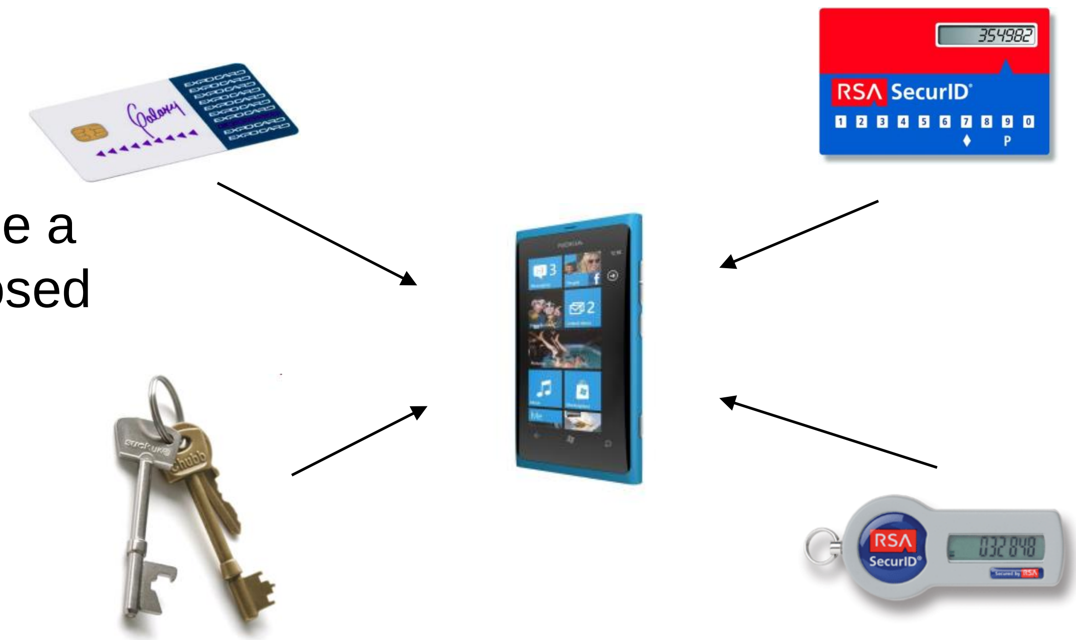
1970

Cambridge CAP
VAX/VMS

PC security
Mobile security
Smart card systems

Summary

- On-board Credentials platform
  - inexpensive
  - open
  - secure



- Open provisioning systems can be a viable alternative to traditional closed systems
- **Available for you to build on**
  - http://obc.nokiaresearch.com

- A step towards the vision of a **personal trusted device**

1. " On-board Credentials: An Open Credential Platform for Mobile Devices", Kari Kostiainen, Dr. Tech dissertation, Aalto University
2. Forthcoming Dr. Tech dissertation, Jan-Erik Ekberg, Aalto University

How to make it possible to build trustworthy information protection mechanisms that are simultaneously easy-to-use and inexpensive to deploy while still guaranteeing sufficient protection?