Trusted Platform Modules and Hardware-based Security

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TPM Introduction

- Microcontroller affixed to the motherboard.

- Cryptographic functions like key storage and RSA encryption.

- Basic idea is to make computing platforms more secure. Has received bad publicity for ”depriving” the user of platform control.

Use cases

- Secure storage – Hardware based storage of sensitive information like keys.
- Secure communication – Network of trusted entities.
- Digital Rights Management (DRM) - Copy control of media files only under certain conditions.
- Software vendors can block application instances known to be copies.

Trusted Computing (TC)

- Set of hardware and software components ensuring a platform’s behaviour.
- TPM core hardware component.
- No ”real” current customer demand for TPMs → cheap
- The TPM is platform agnostic

Trusted Computing Group (TCG)

- TCG - Industry Consortium founded in April 2003. Predecessor TCPA, first spec 2000.

- Founding members include HP, IBM, Intel and Microsoft, today 100+

- Driving force possibly DRM.

- The goal is to specify TC standards.

Public Key Cryptography

- Symmetric encryption and key distribution
- Assymetric encryption - private and public keys.
- RSA:
  - public key (n,e), private key d
  - message m, ciphertext c

$$c = m^{e} \bmod n$$
$$e = c^{d} \bmod n$$

Public Key Cryptography

- RSA not used for bulk encryption.
- Wrap symmetric key with RSA key.
- RSA-wrapping of other RSA-keys gives key storage structures.
- Digital Signatures

Hash functions

- Representation of a message with a *hash-value* of predefined length called a *digest*.

- Design requirements, collision free one-way functions.

- SHA-1 most widely used, developed by NSA.

- Hash functions are often used to ”convert” passwords to predefined length.

HMAC

- Stands for keyed **H**ash **M**essage **A**uthentication **C**ode.

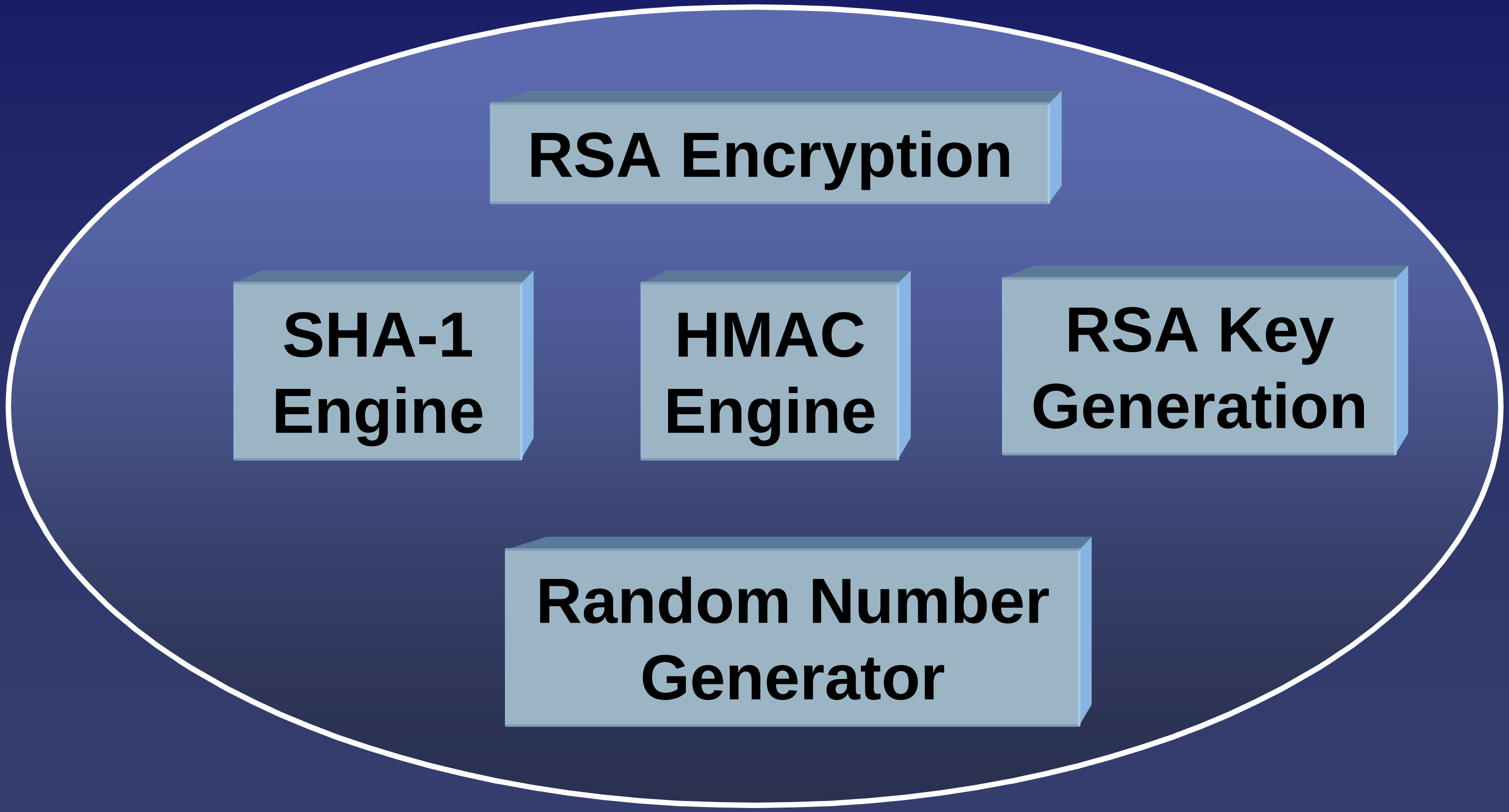
- Compute a digest of a message using a secret key.

$$\boxed{HMAC_K(m) = h(K \otimes opad \,||\, h(K \otimes ipad \,||\, m))}$$

with key K, message m and hash function h. Opad and ipad are just padding parameters.

TPM Components

Cryptographic Functionality



RSA Encryption

SHA-1 Engine

HMAC Engine

RSA Key Generation

Random Number Generator

Cryptographic Functionality

- **RSA encryption** – Hardware implementation of encrypt/decrypt. Central function.

- **SHA1 Engine** – Used primarily by the TPM internally. The TPM is not a cryptographic accelerator (no through-put requirements).

- **HMAC Engine** – SHA1 underlying hash function. Same usage principle as SHA1, only resource limited entities should use the TPM implementation directly.

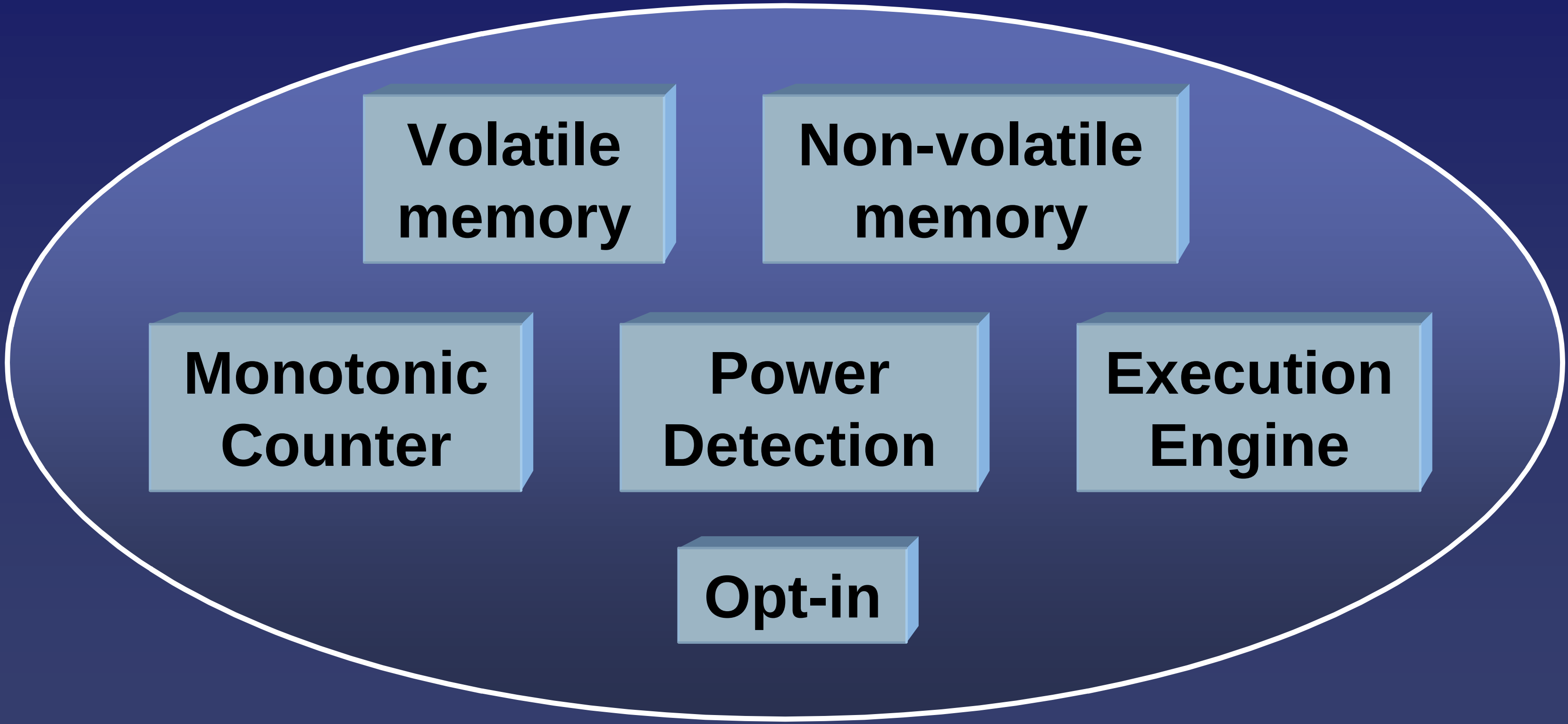
Cryptographic Functionality

- **Random Number Generator (RNG)** – Hardware based random numbers for nonces, and symmetric and assymetric key generation.

- **RSA key generation** – Generation of RSA keys using the RNG.

TPM Components

Other Components



The Life of a TPM

1

Manufacturing – Creation of unique Endorsement Key Pair (EK).

2

Platform user takes ownership.
Identification through shared secret.
Storage Root Key (SRK) is created.

3

The TPM is used by the platform user, creating for instance so called AIKs.

4

The platform user forgets the owner password, has to retake ownership and loses all stored data.

Programming Interfaces

Windows Support:

- MS-CAPI through TPM CSP.
- PKCS#11, platform independent
- TCG Software Stack (TSS). The only interface compulsory to ship according to the TCG specifications.

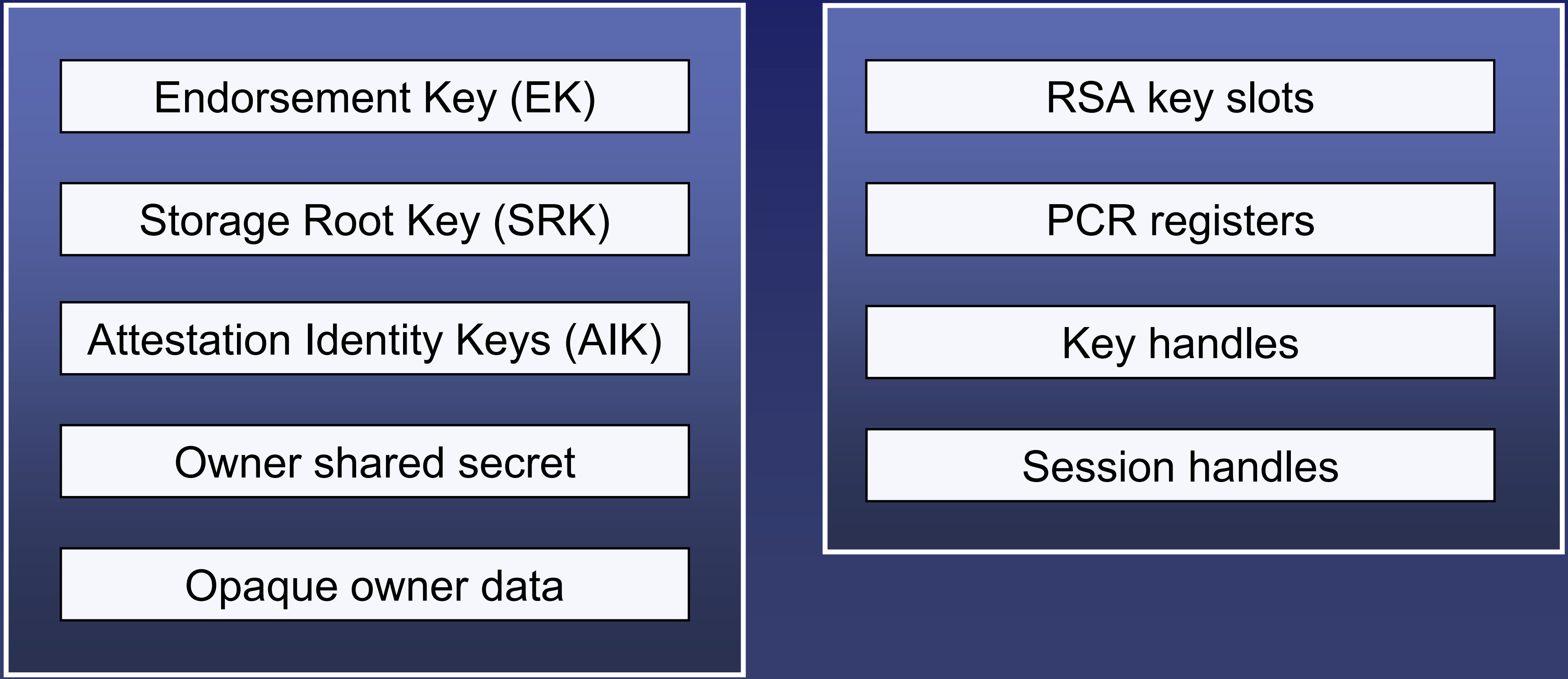
Programming Interfaces

- TSS parts in decreasing abstraction level:
  - TSS Service Provider (TSP), dll in Windows. Access point for normal applications.
  - TSS Core Service (TCS), Windows NT Service
  - TCG Device Driver Library (TDDL)

Pre-boot Support:

- BIOS INT 1Ah interrupt interface

Memory Structure



Non-Volatile (persistant)
Memory

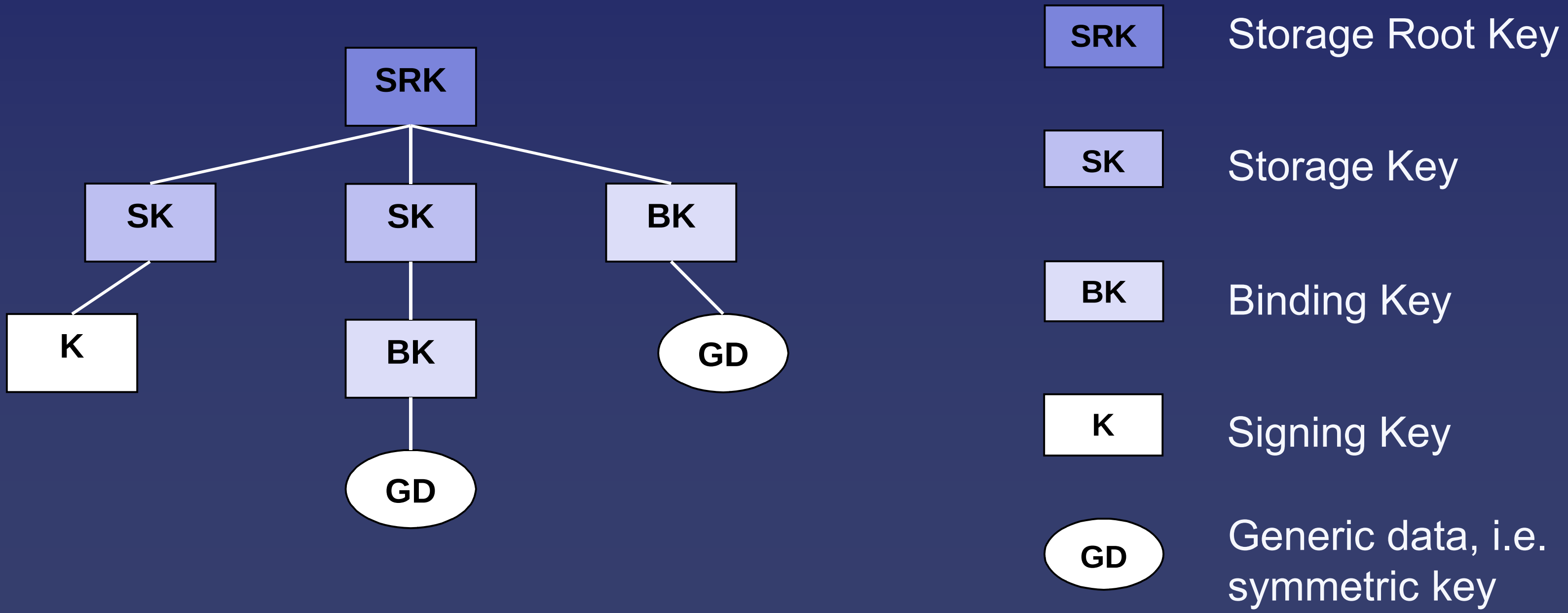
- Endorsement Key (EK)
- Storage Root Key (SRK)
- Attestation Identity Keys (AIK)
- Owner shared secret
- Opaque owner data

Volatile
Memory

- RSA key slots
- PCR registers
- Key handles
- Session handles

Protected Storage

- Very limited on-chip storage.
- RSA-wrapping with SRK as root key.
- Storage hierarchy tree:



Access Control

- Shared secrets controls access to entities and certain operations

  - 20 bytes long

  - called *AuthData* in TCG specifications

  - Typically hash from password

- Owner authorization required to

  - Temporary disable or deactivate the TPM.

  - Read/Write in the NV Memory Area.

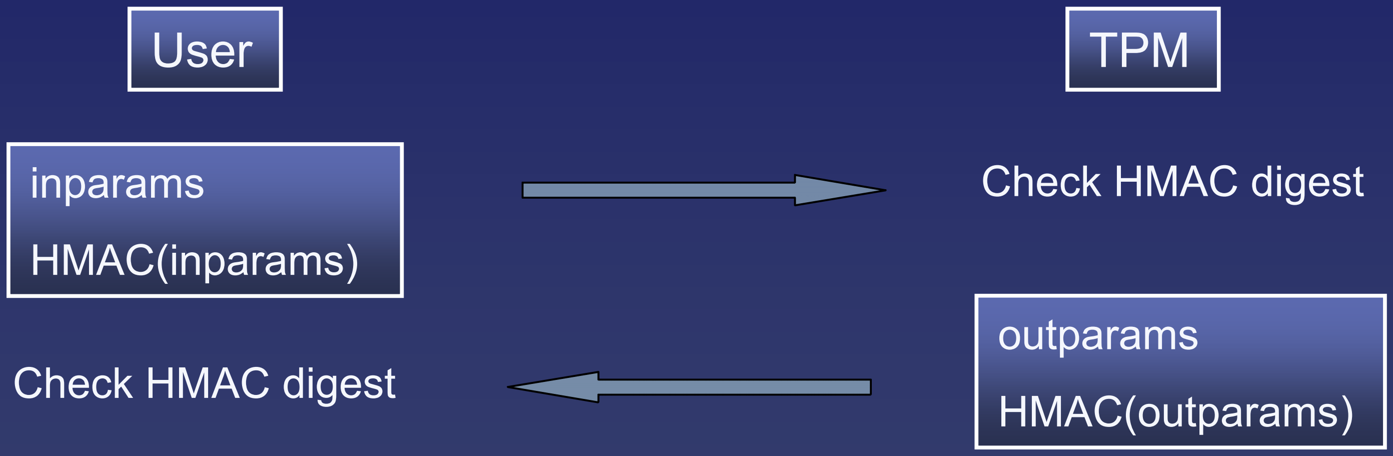
  - Change the shared secret for the SRK.

Access Control

- Authorization sessions

  - Rolling nonce (**N**umber used **ONCE**) procedure

  - HMAC(params) digest = $\text{HMAC}_{\textit{AuthData}}(\text{params} \mid\mid \text{nonce})$



User

TPM

inparams

HMAC(inparams)

Check HMAC digest

outparams

HMAC(outparams)

Check HMAC digest

- Transport encryption – Wrapping of commands containing sensitive information.

Security Problems?

Software attacks:

- SHA1 collision vulnerability
- Dictionary attacks, some form of mitigation required.

Hardware attacks:

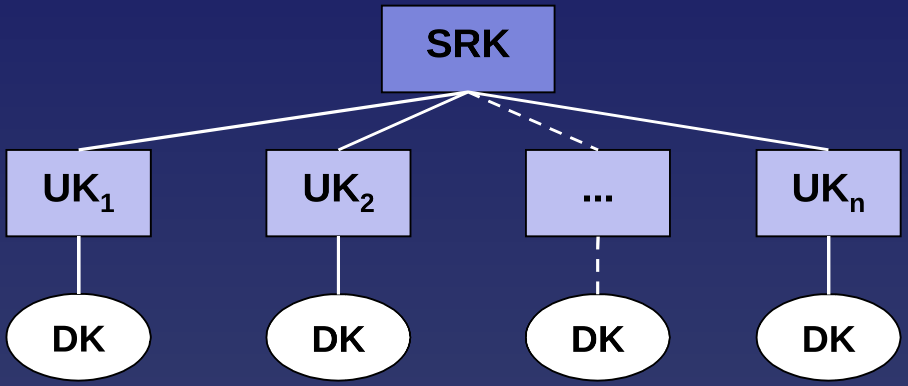
- Vulnerable to sophisticated physical attacks due to cost reasons.

Use case – Disc encryption

- User key storage structure

UK$_i$ User Key i

DK Disc encryption Key



Use case – Disc encryption

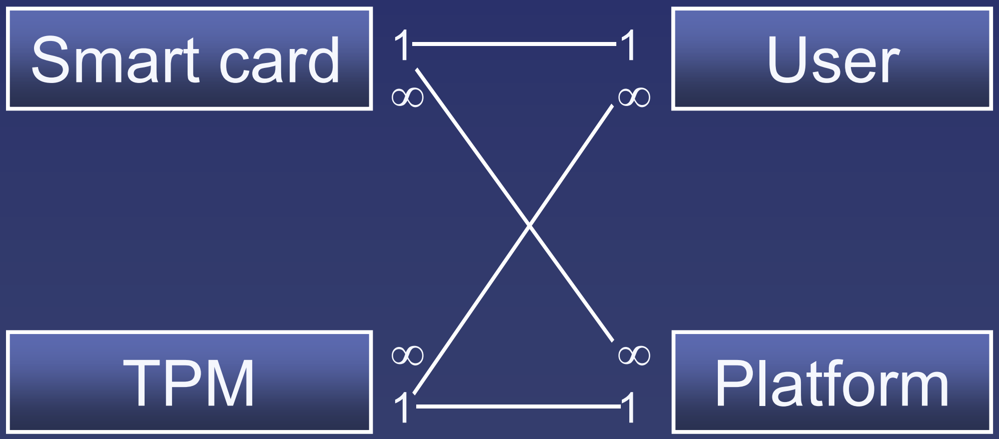
- SRK authorization problem, possible cause DRM background

- Windows Vista Solution: Suppose SRK shared secret is a predefined dummy-value i.e. $AuthData_{SRK} \equiv 0x0$

- User keys protected with their own *AuthData*

Smartcard Comparison

- Creditcard-shaped plastic card used to store authentication data.
- TPM affixed to motherboard, Smartcards removable tokens → different user mapping.



Smart card 1 ∞

1 ∞ User

TPM ∞ 1

∞ 1 Platform

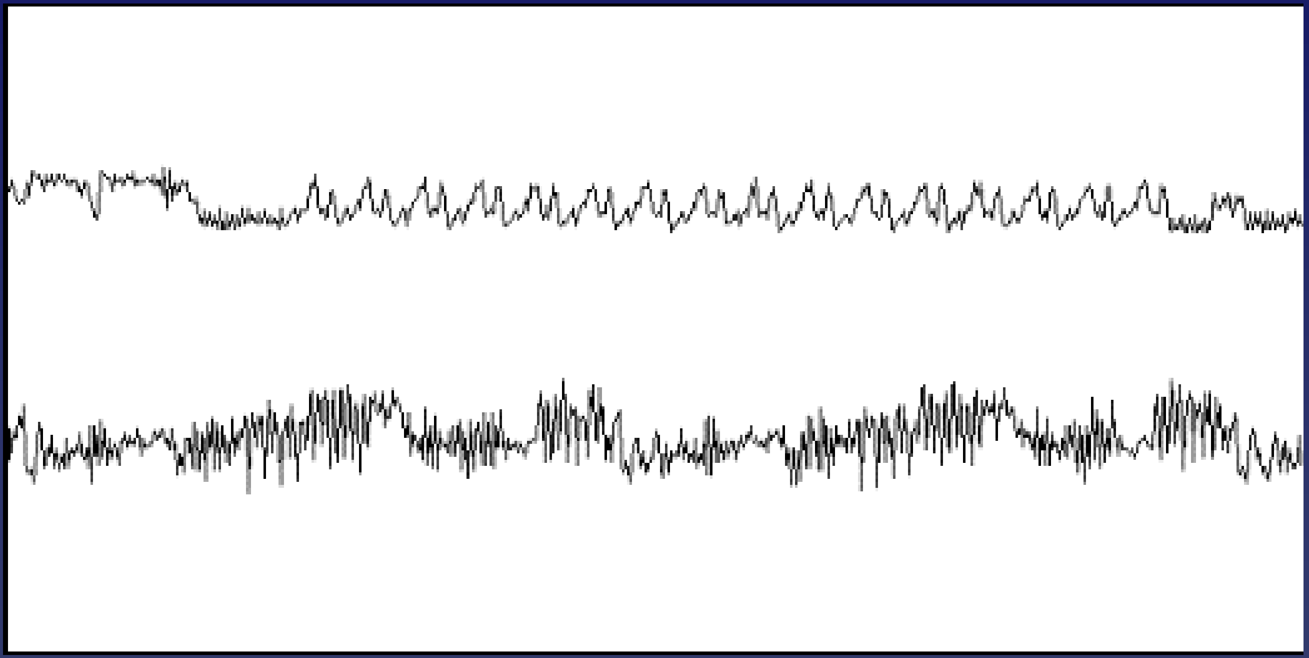
Smartcard Comparison

- Mobility of the smartcard is an extra security measure. Though easy to lose a portable card.
- Smartcards store all RSA keys on the card. The protected storage structure of the TPM does not.
- TPM has machine binding of i.e. keys using the PCR registers.

Tamper Protection

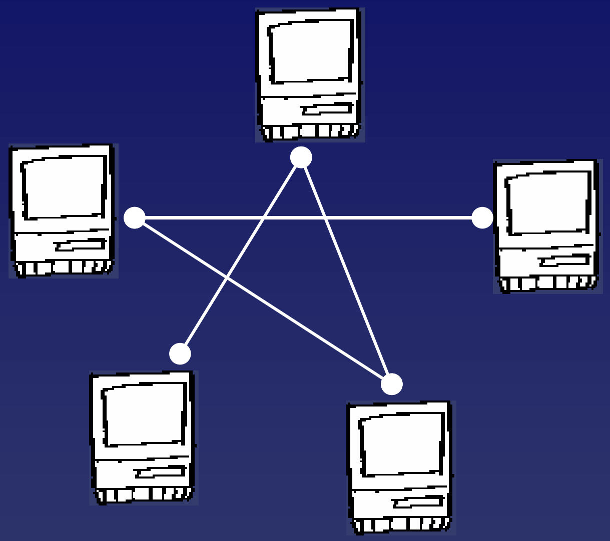
- Smartcards and TPMs are both vulnerable to so called non-invasive attacks (i.e. power analysis and timing attacks).
- Smartcards and probably also TPMs are vulnerable to invasive attacks like micro probing.
- Smartcard danger: Physical attacks using ”fake” smartcard reader giving no tamper evidence.

Power Analysis of DES



Integrity Protection

- Trusted networks based on TPM:



- Platform integrity through TPM self-authentication together with Root of Trust.
- Unique identity (EK) needed to avoid BORE-attacks.

Integrity Protection

- Attestation Identity Keys (AIK)
  - RSA key pair
  - Aliases for the Endorsement Key (EK)
  - Mapping kept at ”trusted third party”, normallly a Certificate Authority (CA)
  - Trusting the trusted third party?

Integrity Protection

Direct Anonymous Attestation (DAA)

- TPM 1.2 feature after AIK integrity issue.
- Verify a signature without revealing the signer.
- Identify groups of TPMs together. Track individual TPM if a DAA key is repeatedly.
- Based on zero-proof techniques

Tech Outlook

- Current version is 1.2. TPM 1.1 was criticised for lack of security measures and integrity protection.
- Around 5 different vendors manufacture TPM 1.2 microcontrollers.
- Future inclusion of the TPM into the CPU to avoid unnecessary communication over insecure busses.

Usage Outlook

- No current use in major PC applications.

  Apple uses the TPM to prevent OS X from running on PCs. Cracked in a week.

- Windows Vista, scheduled for the fall 2006 demands a TPM 1.2 installed.

- TPM Linux Driver and TSS implementation exists.

Usage Outlook

- DRM money will probably drive the usage forward forcing customers to accept the technology.
- TPM more likely to be used in enterprise environments than by private customers.
- The next platform is mobile devices. Ericsson has an optional DRM package right now which is not based on the TPM.

Popular Myths

- The TPM will not allow open source software to run.
- TPM Data protection is perfect.
- TC is required to combat computer threats.
- The TPM enhances user authentication.

Questions

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Discussion