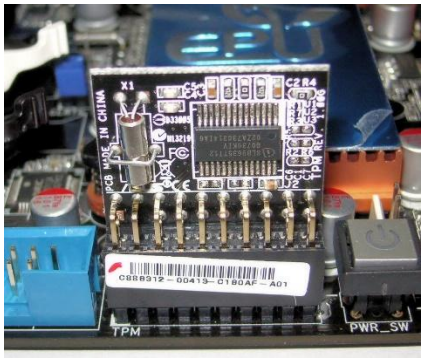
Trusted Platform Module (TPM)

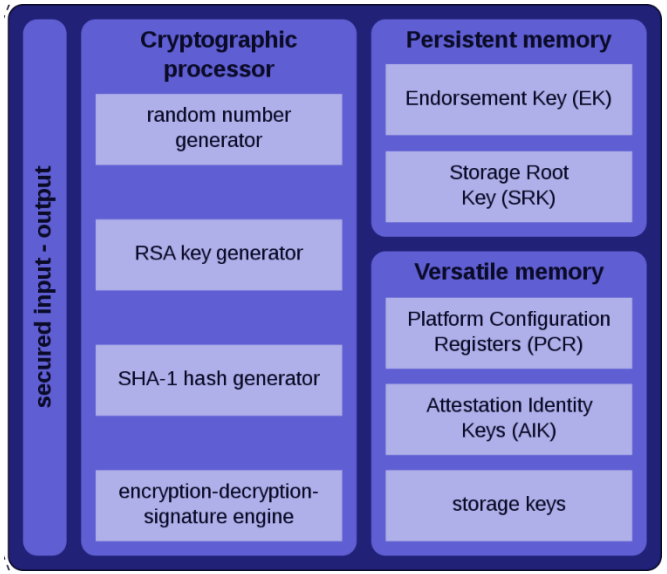
A chip integrated into the platform

- A separated co-processor
- Its state cannot be compromised by malicious host system software

Inside the chip

- Random number and key generators
- Crypto execution engine
- Different types of crypto keys.





Development and Implementation

Designed by Trusted Computing Group (TCG)

- First version: TPM 1.1b, released in 2003.
- An improved version: TPM 1.2, developed around 2005-2009
  - Equipped in PCs in 2006 and in servers in 2008
  - Standardized by ISO and IEC in 2009
- An upgraded version: TPM 2.0, released on 9 April 2014.

Application of TPM

- Intel Trusted Execution Technology (TXT)
- Microsoft Next-Generation Secure Computing Base (NGSCB)
- Windows 11 requires TPM 2.0 as a minimal system requirement
- Linux kernel starts to support TPM 2.0 since version 3.20
- Google includes TPMs in Chromebooks as part of their security model
- VMware, Xen, KVM all support virtualized TPM.

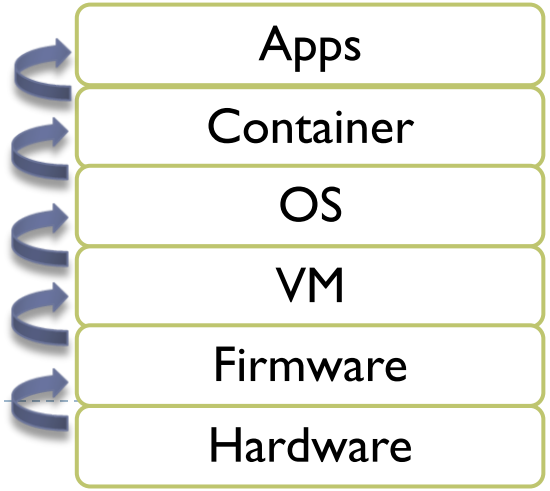
Building Chain of Trust with TPM

Chain of Trust: Establish verified systems from bottom to top

- From a hierarchic view, a computer system is a layered system.
  - Lower layers have higher privileges and can protect higher layers.
  - Each layer is vulnerable to attacks from below if the lower layer is not secured appropriately.
- TPM serves as the root of trust: establish a secure boot process from TPM, and continue until the OS has fully booted and apps are running.
  - The bottom layer validates the integrity of the top layer.
  - It is safe to launch the top layer only when the verification passes.

Potential applications

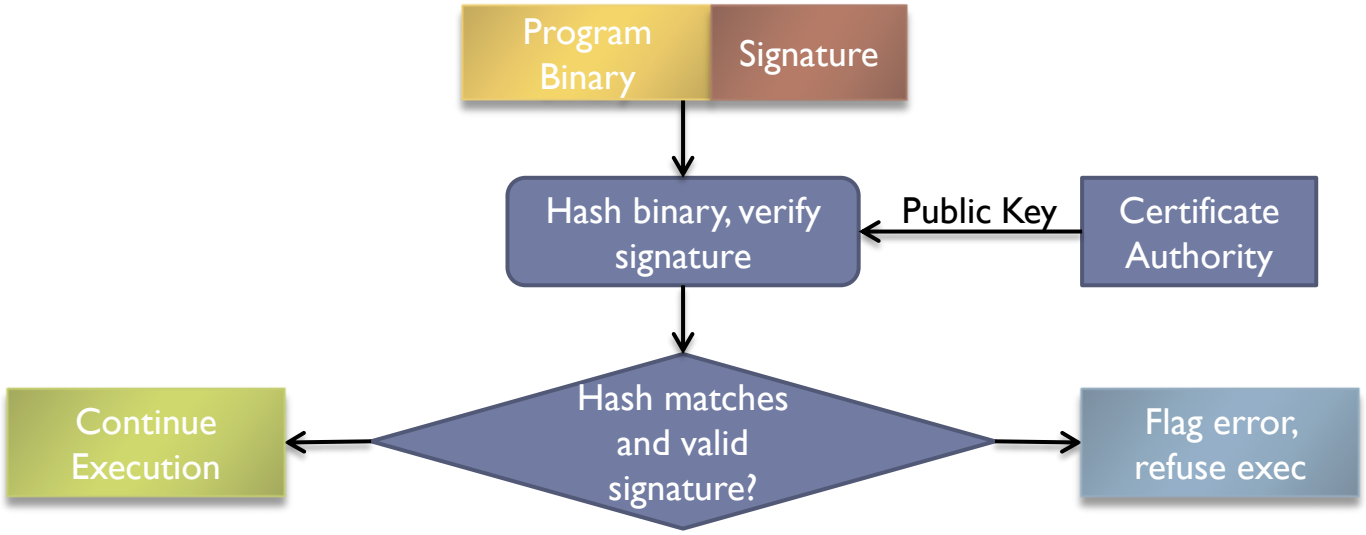
- Digital right management
- Enforcement of software license, e.g., Microsoft Office and Outlook
- Prevention of cheating in online games.



Integrity Verification

Only launch the layer that passes the integrity verification

- Load the code from the memory.
- Compute the hash value and verify the signature.
- Launch the code if the hash value matches and signature is valid.
- Otherwise, abort the boot process.



Data Encryption with TPM

Full disk encryption

- Encrypt the data with the key in TPM.
- It is difficult for any attacker to steal the key, which never leaves TPM.
- TPM can also provide platform authentication before data encryption

Application: Windows BitLocker

- Disk data are encrypted with the encryption key FVEK.
- FVEK is further encrypted with the Storage Root Key (SRK) in TPM.
- When decrypting the data, BitLocker first asks TPM to verify the platform integrity. Then it asks TPM to decrypt FVEK with SRK. After that, BitLocker can use FVEK to decrypt the data
- With this process, data can only be decrypted on the correct platform with the correct software launched.

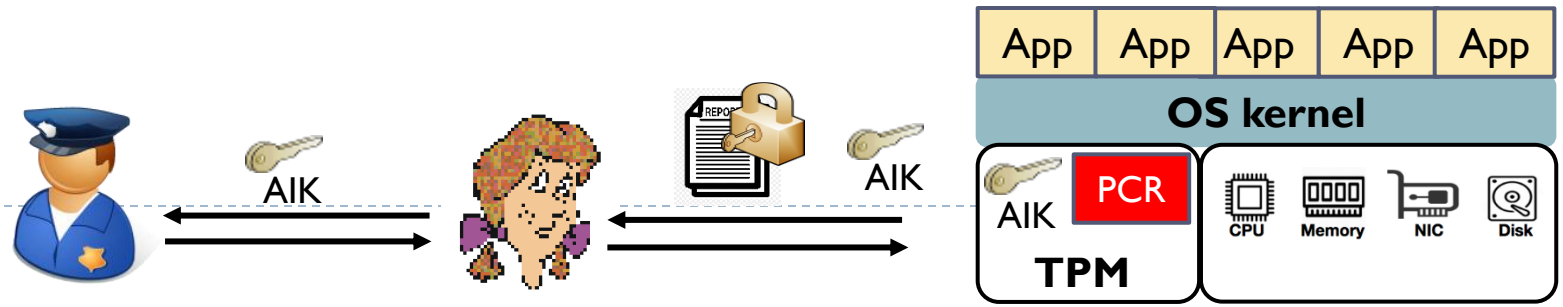
Remote Attestation with TPM

Integrity measurement architecture:

- TPM measures hash values of each loaded software, as integrity report.
- The hash values are stored in the Platform Configuration Registers (PCR) in TPM and could not be compromised by OS or any apps.

Remote attestation protocol

- TPM generates an Attestation Identity Key (AIK), to sign the hash values.
- The hash values together with AIK will be sent to client.
- A trusted third party, Privacy Certification Authority (PCA) is called to verify this AIK is indeed from the correct platform.
- Client uses this AIK to verify that received hash values are authentic.
- By checking the hash values, client knows if the loaded software is correct



Outline

- **Protection Strategies**
  - Confinement
  - Reference Monitor
- **Hardware-assisted Protection**
  - Basic Functionalities
  - Trusted Platform Module
  - Trusted Execution Environment