TPM and Intel ® PTT Overview

TCE 4th summer school on computer security and big data

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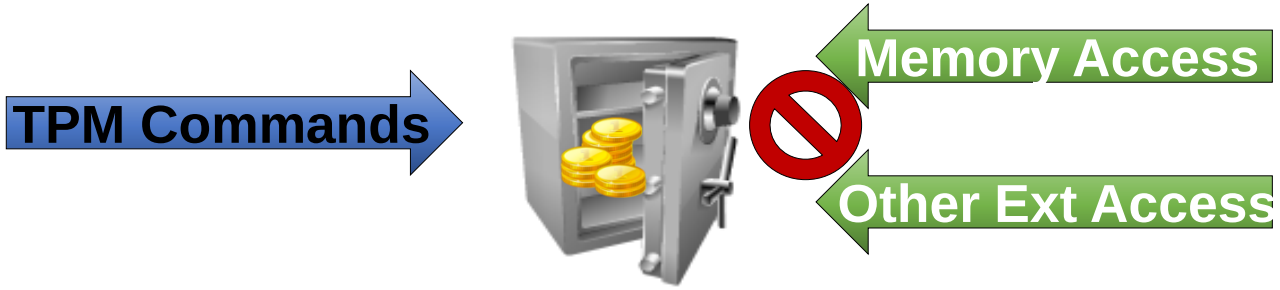
Agenda

- TPM overview
    - What is TPM?
    - Chain of trust measurements
  - TPM usage examples
    - Sealing data
    - Attestation
    - Virtual Smart Cards
    - Storage keys and hierarchies
  - Intel® PTT
    - How TPM is implemented in Intel platforms

What is a TPM?

- TPM = Trusted Platform Module
  - TPM is a HW device which provides trust capabilities to the platform
- Standard developed by TCG = Trusted Computing Group
- Why a TPM, why not software?
  - Asset protected from “Host” software. E.g., OS, VMM
  - Host has no access to assets (secrets) except thru TPM 2 defined interfaces
    - No direct memory access

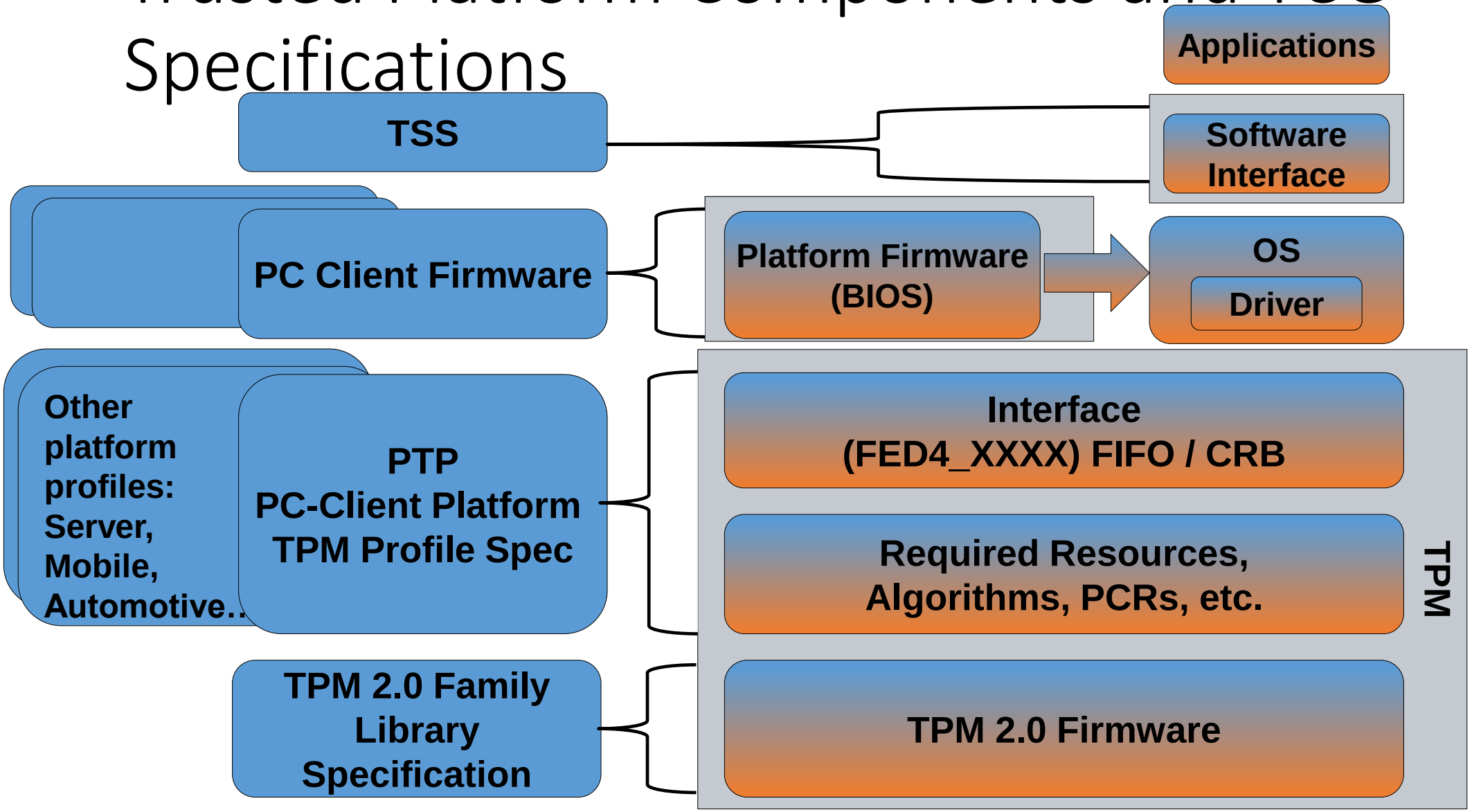


- Binding to RTM (root of trust for measurement)
  - More than ever 1:1 relationship people:device

Usages – Just a few!

- Digitally signed transactions
- Local encryption (e.g., disk encryption, BitLocker)
  - Lower value w/o TPM
- Enables low entropy passwords (easy to remember)
  - Dictionary attacks ineffective
- Protect assets against unauthorized software (e.g., Rooted OS)
    - Measure the boot chain – can use TXT / BootGuard
- Network admission
  - Local network
  - VPN

Trusted Platform Components and TCG Specifications



PCR: Collecting platform measurements

Roots of trust

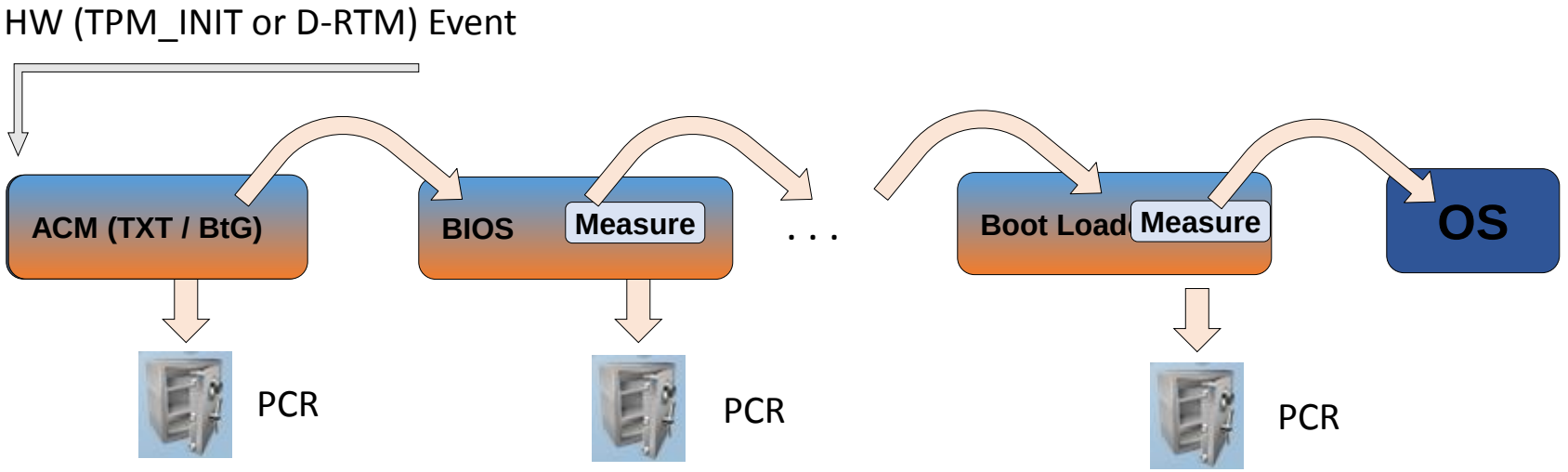
- To trust a platform, we need to know
    1. The HW identity is what we expect
    2. SW stack can be trusted
- TCG defines three “roots of trust” in a trusted platform
- Root of Trust for Measurement (RTM)
    - The first set of instructions executed when a new chain of trust is established.

The RTM stores the measurements in RTS

- Root of Trust for Storage (RTS)
    - A shielded location that cannot be accessed by CPU by any mean other than TPM command
- Root of Trust for Reporting (RTR)
    - Attests the HW identity of the platform

The RTR reports the contents of the RTS

Chain of Trust



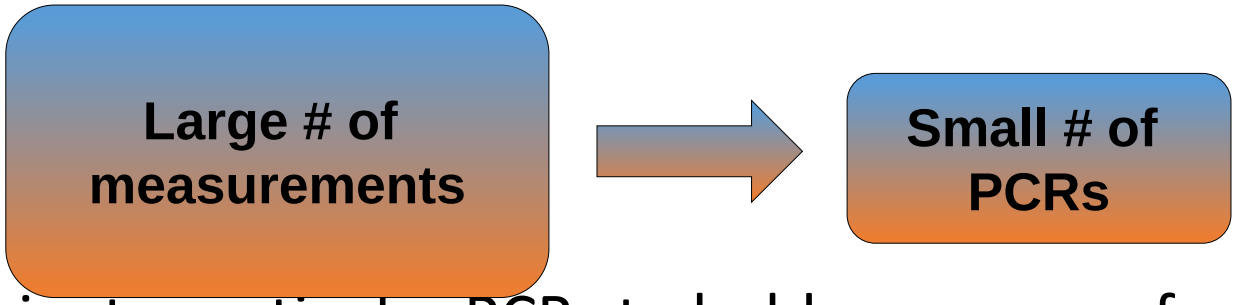
- **CRTM – Core Root of Trust for Measurement**
  - The first component executed after TPM_INIT or D-RTM Event
  - Immutable
  - Inherently trusted
- **Chain of Trust – a series of recordings resulting in a log, allowing audit of execution sequence.**

PCR= Platform Configuration Register

- A PCR can only be extended, not written:

  TPM_PCRExtend(n, digest) :=
  pcr[n] ← hash(pcr[n] | digest)

"Extending" allows to store more than one measurement in a limited space



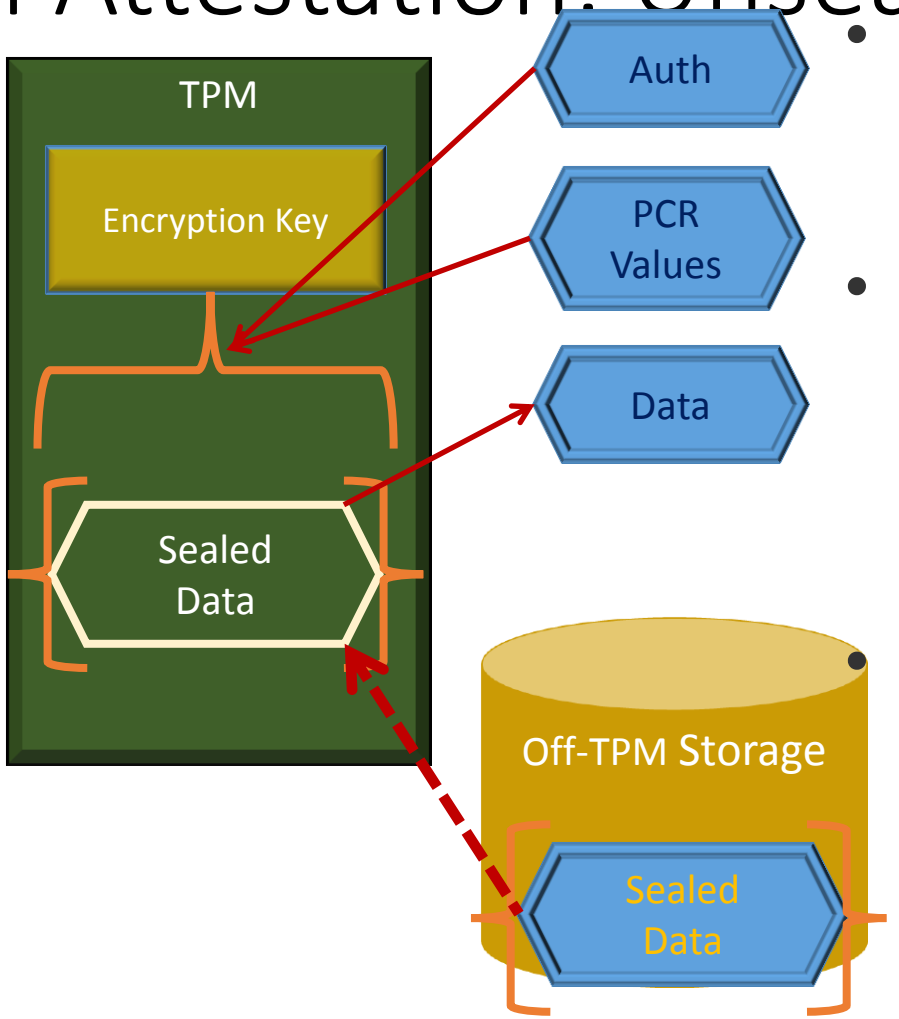
- nominate particular PCRs to hold sequence of measurements at a particular phase in the boot
  - E.g. PCR0 used for ACM and BIOS measurements
- PCRs may be read by anyone – not a secret
- Access to objects may be tied to particular PCR values

TPM usage: Keys and Hierarchies

TPM objects – keys and data

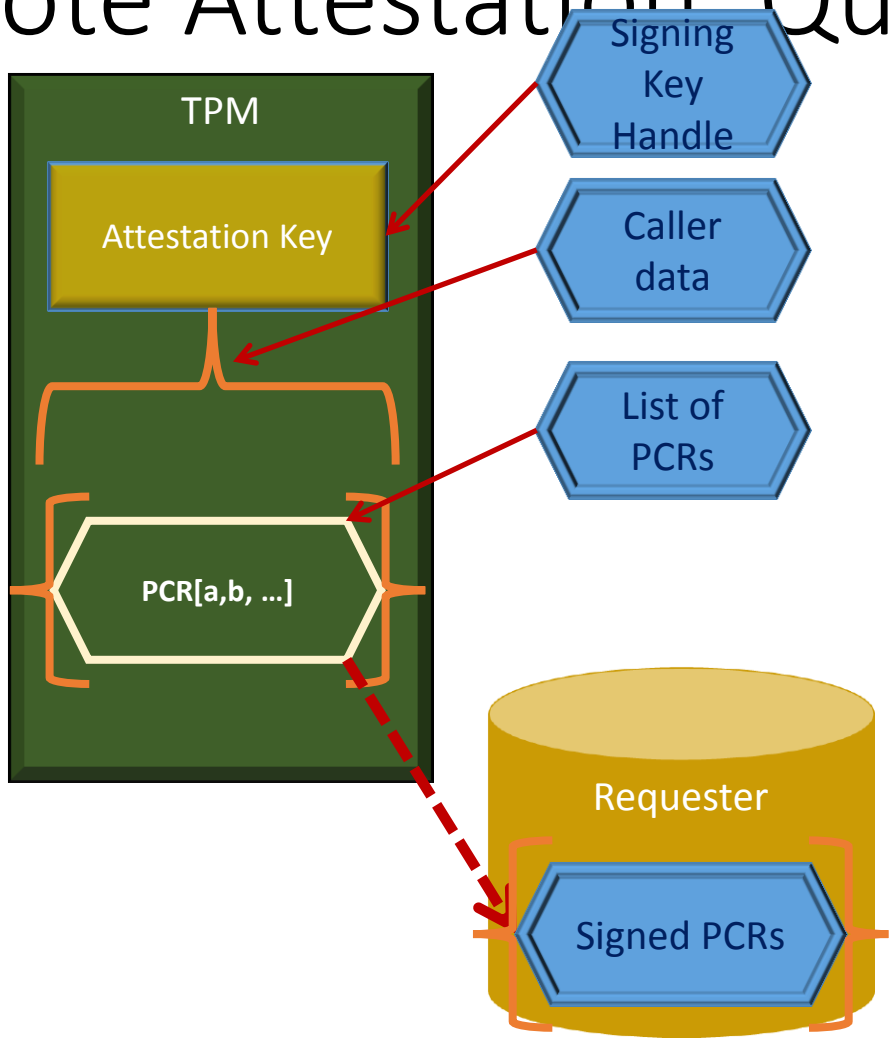
- TPM can create, use and protect objects (which can be either data objects or keys for signing or encryption)
- Signing keys usages:
  - Remote Attestation
  - General purpose signing
- Encryption keys usages:
  - Data “sealing” (or local attestation)
  - General purpose encryption
  - Protecting other keys
    - A hierarchy of keys can be generated this way

Local Attestation: Unseal Data



- **Send to TPM**
  - Sealed Data + auth value
  - Define policy for unsealing - tie to specific PCR values
- **TPM decrypts data**
  - Using an Encryption key
  - If and only if Hash[PCR] from Sealed data == current PCR values
    - i.e. Platform is in the Trusted State
  - Auth value must match
- **Unsealed data returned to Trusted Environment**

Remote Attestation: Quote



Basic feature of trusted computing is an ability of platform to report its current execution snapshot encoded in PCR values to remote site.

Example: TPM Quote

- TPM Quote is signed data blob containing PCR values

Requester sends qualifying data, list of PCRs

TPM creates response using qualifying data (added to hash) and list of PCRs

TPM signs response using Attestation Key

Sends signed response to Requester

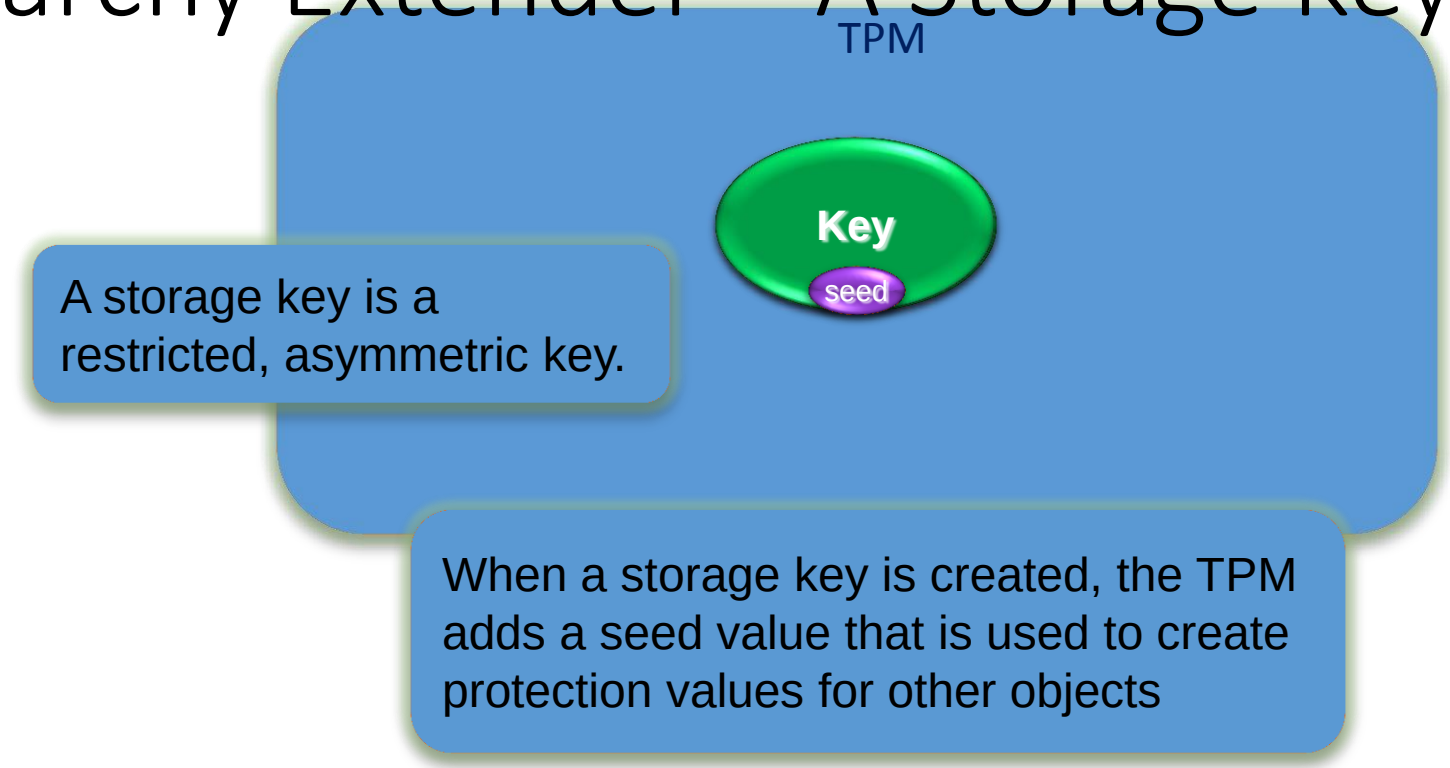
Virtual smart cards

- Virtual smart cards are SW devices that act as a physical smart card, using the TPM's cryptographic abilities.
- The key associated with the VSC is created by the TPM as part of the storage hierarchy, and can be stored off-chip, e.g. the computer's hard drive.
- The VSC meets the main criteria a traditional smart card meets:
- Non-Exportability: Using the key is only possible on the TPM associated with the computer itself
- Isolated cryptography: the cryptographic operations occur on the TPM itself which is isolated from the main processor
- Anti-hammering: The TPM has a built-in dictionary attack mechanism to prevent hammering on the user's PIN.

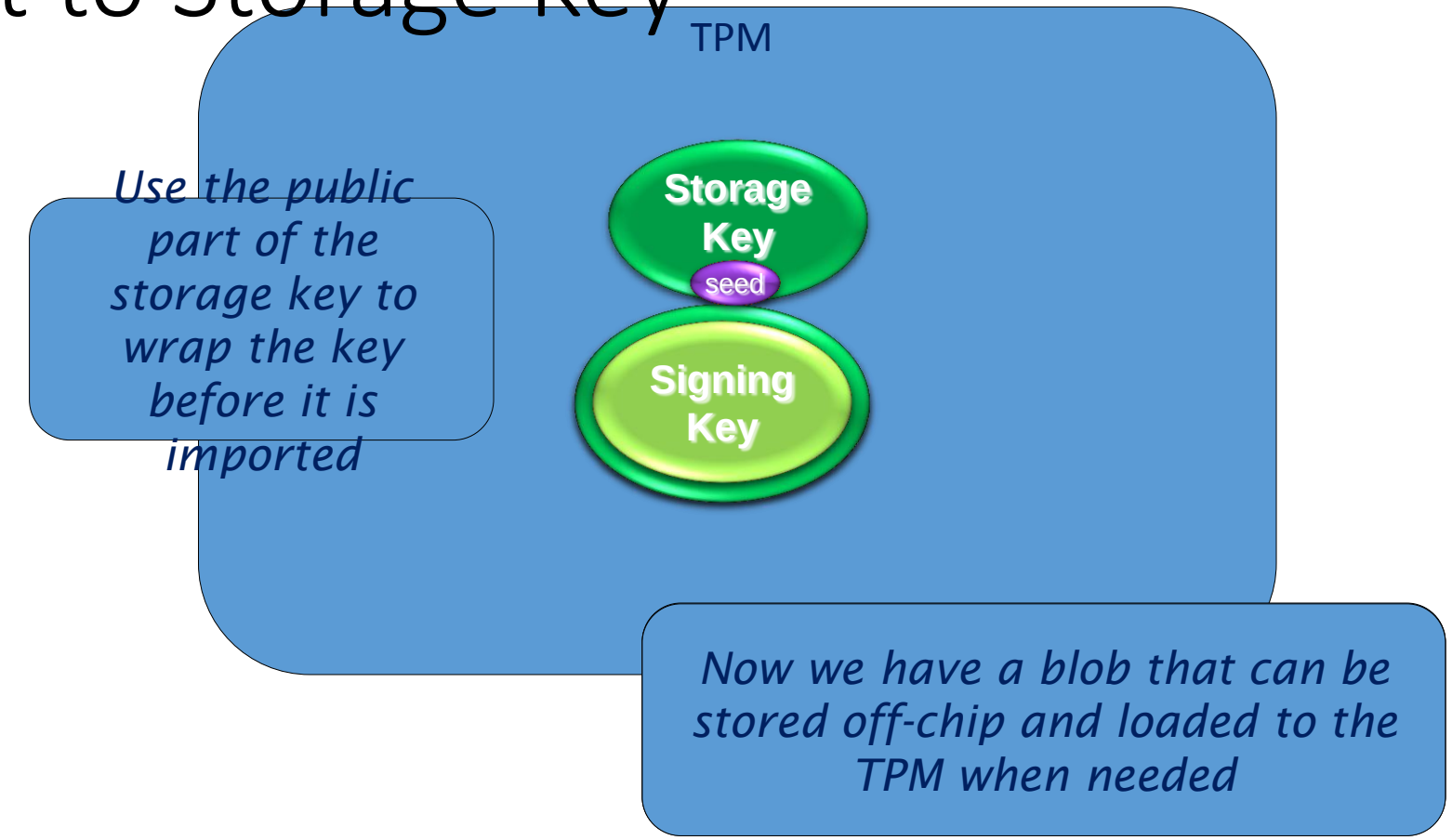
Storage Keys

- A key used to protect other TPM keys is a *Storage Key*.
- The purpose of a storage key is to have a place to attach keys generated somewhere else
    - IT creates a key and wants to put on your system but only wants the TPM to be able to use the key
    - Give the IT department the public key of a Storage Key on your TPM
    - IT encrypts their key to the TPM key on your computer
    - Sends the encrypted bundle to you
    - Your TPM imports the key
  - Keys can also be created internally and attached to a storage key
    - E.g. Attestation keys

Hierarchy Extender – A Storage Key



Import to Storage Key



TPM hierarchies

- TPM2.0 can support up to 3 storage hierarchies
- Storage hierarchy: for usage by OS user – allows protecting keys and data
- Endorsement hierarchy: for keeping “Attestation Keys”. Root of the hierarchy is the Endorsement Key (EK)
    - EK is unique per platform
    - An EK certificate can be provided by the TPM vendor
    - A certified EK can be used to generate additional certified attestation keys
- Platform hierarchy: for usage by BIOS – allows orthogonal use of TPM by BIOS and OS

•Each hierarchy also represents a control surface to the TPM – for example, commands can be authorized by the platform auth value to make sure they are executed in a controlled environment.

TPM1.2 vs TPM2.0

TPM1.2	TPM2.0
Fixed crypto algorithm set: RSA, SHA-1, AES	Flexible algorithm set
Command authorization using auth value	Add enhanced authorization: operations can be tied to varied and multiple factors
Single storage hierarchy and ownership	3 hierarchies, allowing orthogonal use by BIOS and OS
Cumbersome provisioning required to start using the TPM	Simplified provisioning – TPM can be used out of the box
Assets protected internally using asymmetric algorithm	Assets protected internally using symmetric algorithm

Intel® PTT

Intel® PTT (Platform Trust Technology) implementation

- PTT is a TPM2.0 implementation implemented as a FW application in ME
    - An OEM can use either a discrete TPM part, or use the Intel® PTT embedded in FW
- HW interface implemented in ME HW
- RAM is isolated from host access and other applications access by ME task isolation mechanisms
- NVRAM data is protected using blob mechanism
    - Integrity
    - Confidentiality
    - Anti-Replay
- A subset of TPM commands is available during the FW bring-up to allow early access to PTT by the host

References

- TCG website:
- http://www.trustedcomputinggroup.org
- “A Practical Guide to TPM2.0: Using the Trusted Platform Module in the New Age of Security” by Will Arthur and David Challener

Backup

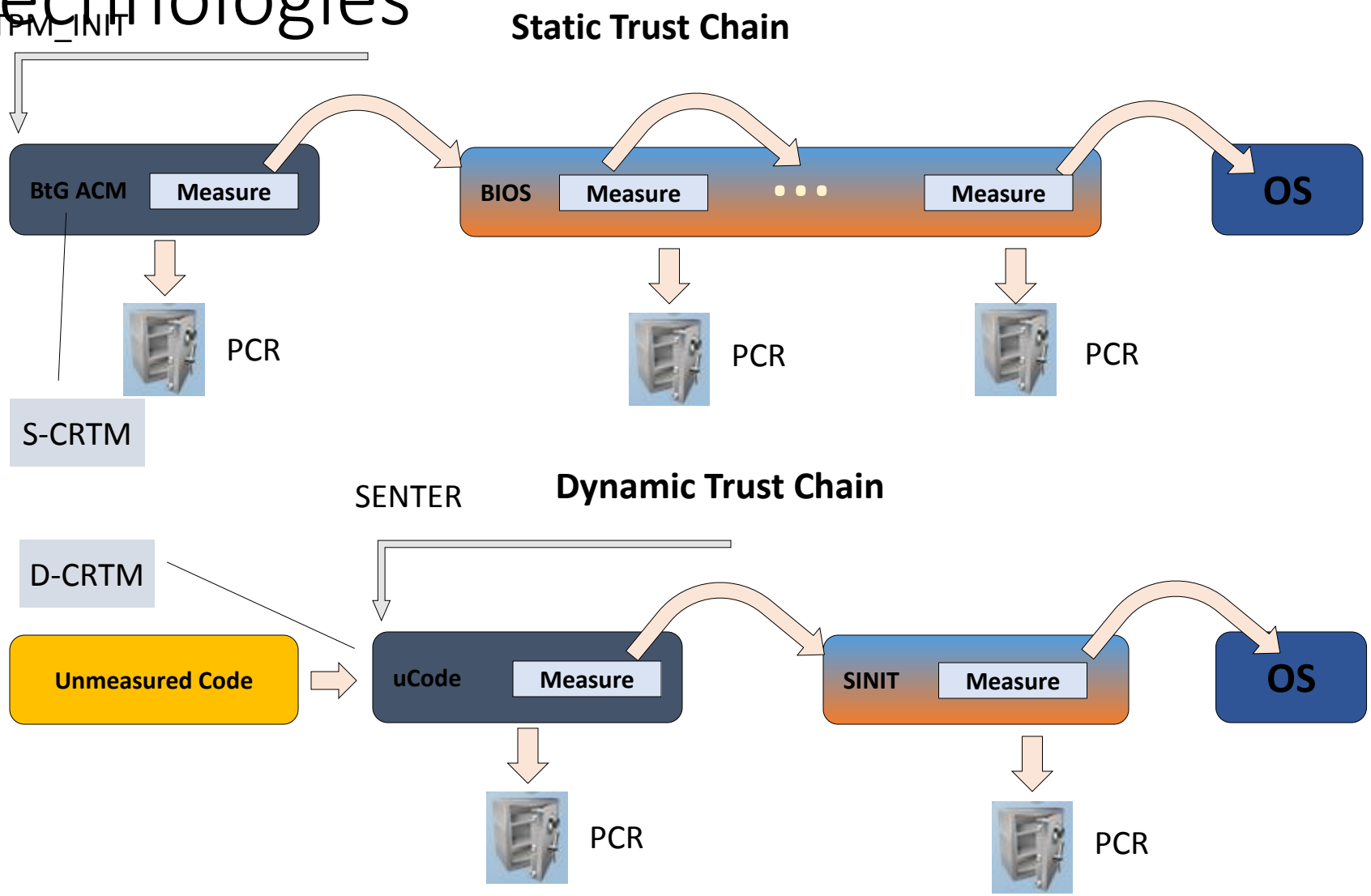
PCR operations

- A PCR cannot be written, only “extended”
  - *TPM_PCRExtend(n, digest) :=*
    pcr[n] ← hash(pcr[n] | digest)
  - *TPM_PCREvent(n, data):=*
    pcr[n] ← hash(pcr[n] | hash[data])
- PCRs can be read by anyone – not a secret
  - *TPM_PCRRead(n) :=* **output** *PCR[n]*
- Access to TPM objects may be tied to a specific PCR value
- PCR *‘quote’* operation, for nonce *i:*
  - *TPM Quote($\{n_1, \ldots n_m\}$, i, auth, k) :=*
    - *output ($\{PCR[n_1], \ldots PCR[n_m], i\}_{key(k)}$)*

History of TCG

- TCPA (Trusted Computing Platform Alliance)
  - “Letter-based” organization
  - Compaq, IBM, Intel, Hewlett-Packard, Microsoft
  - No formal governance
  - Defined TPM 1.1b, 1.2
- TCG (Trusted computing Group)
  - Incorporated “non-profit” organization
  - Multiple membership Levels
    - Promoter; Contributor; Adopter
    - + Liaison & other new Levels
  - TCG took over TPM 1.2 Spec

Chains of Trust: Intel Secure boot technologies



Locality

- **Access Control to TPM Resources**

Locality provides identity (source authentication) of component accessing TPM