Introduction to the Trusted Platform Module
Design Goals and Capabilities

CSC 495/680 Lecture
September 13-?, 2010

References:
- *A Practical Guide to Trusted Computing*, Chapters 2-3
- Trusted Computing Group documentation

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TPM Design Goals

- Book lists:
  - Secure report the environment that booted
  - Securely store data
  - Securely identify the user and system
  - Support standard security systems and protocols
  - Support multiple users on the same system while preserving security among them
  - Be produced inexpensively
- Book states will be FIPS 140-2 and CC EAL3 (or EAL4+)
  - What does this mean?

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What is "Assurance"?

- "Assurance" refers to "ways of convincing others that a model, design, and implementation are correct."
  - From "Security in Computing" by Charles and Shari Pfleeger
  - I'd add "ways of convincing others *or yourself*…"
- Can you quantify "confidence levels"?
- Need language for assurance levels and properties, so we can see if a system is appropriate.
- Assurance tools: evaluation, testing, formal verification

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Evaluation Standards

- A key characteristic of "trusted systems" is a security-centric evaluation
- Valuable properties:
  - Fit systems into a well-understood framework
  - Use consistent language and criteria
- Influential evaluation standards:
  - TCSEC ("Orange Book"): U.S. DoD
  - ITSEC: European framework
  - U.S. Federal Criteria: NIST standard (not DoD-specific)
  - Common Criteria: Merges successful ideas from other standards

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Common Criteria

- Overview
  - Separates features from assurance
  - Functionality general-purpose, based on *Protection Profiles* and vendor-defined *Security Targets*
  - Assurance levels given as *Evaluation Assurance Levels*
- How it works:
  - Evaluations by commercial testing labs accredited by NIST's National Voluntary Laboratory Accreditation Program (NVLAP)
    - Called the "Common Criteria Testing Laboratories (CCTL)
  - U.S. National Information Assurance Partnership Common Criteria Evaluation and Validation Scheme (CCEVS) Validation Body – managed by NIST and NSA
    - Approves CCTLs
    - Maintains NIAP Validated Products List

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Common Criteria
Evaluation Assurance Levels (EALs)

- EAL-1: Functionally tested
- EAL-2: Structurally tested
- EAL-3: Methodically tested and checked
  - Thorough testing, but not requiring controlled design process
- EAL-4: Methodically designed, tested, and reviewed
  - Reflects good traditional software development practices from design forward
- EAL-5: Semiformally designed and tested
- EAL-6: Semiformally verified design and tested
- EAL-7: Formally verified design and tested

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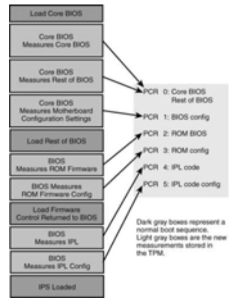
Design Goal 1

Securely report the environment that booted

- Obvious fact 1: You can't trust software to tell you whether it is trustworthy
  - Malicious software would lie!
  - Honest software in untrustworthy environment can't tell if corrupted!
- A TPM should be tightly tied into system from very beginning of boot sequence
  - Tight integration makes a TPM different from a smartcard
  - TPM uses Platform Configuration Registers (PCRs) to securely hold measurements / logs of boot process
    - Initial, very small, trusted part of BIOS kicks things off
      - Core Root of Trust for Measurement (CRTM)
    - Each stage in boot process measures/records next stage before executing

Design Goal 1

Securely report the environment that booted



Source: Figure 2.1 in book (p.16)

IPL: "Initial Program Load" (boot loader)

IPS: ??? Typo?

Note: Does *not* stop bad code from loading!!! Just makes it possible to determine when system is trusted (and can lock secrets to trusted environments).

Design Goal 1

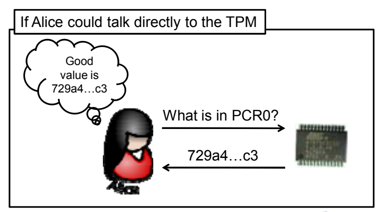
Securely report the environment that booted

- TPM (v1.1) has at least 16 PCRs
  - Can only be reset through system reboot
  - PC-specific implementation defines use of first 8
  - Remainder can be used in custom system-specific ways
- TPM (v1.2) adds 8 more – dynamic PCRs
  - With support from rest of the system (CPU+chipset) can be reset in carefully controlled situations
    - Intel calls this support "TXT" (Trusted Execution Technology)
    - AMD calls it "SVM" (Secure Virtual Machine)

Design Goal 1

Securely report the environment that booted

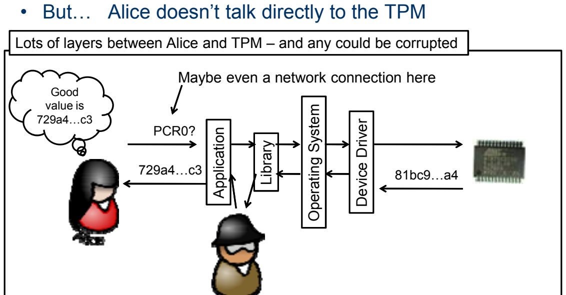
- How are measurements securely *reported*?
- Scenario: A user Alice wants to know what's in PCR0
  - Alice can be a local or remote user



Design Goal 1

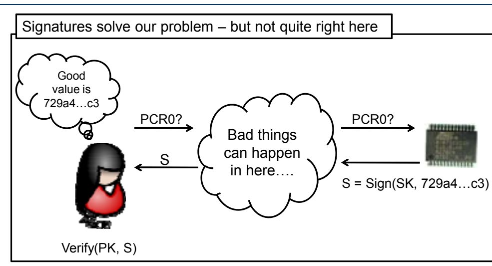
Securely report the environment that booted

- But… Alice doesn't talk directly to the TPM



Design Goal 1

Securely report the environment that booted



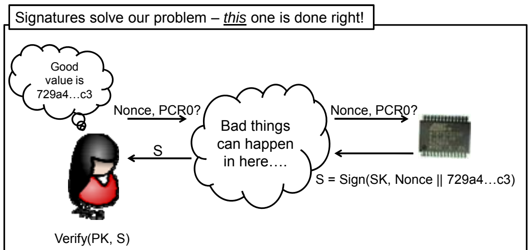
- *Problem 1*: Does the signature mean it came from a TPM?
  - *Solution*: (PK,SK) is an identity key, certified by a PrivacyCA

Design Goal 1

Securely report the environment that booted

- *Problem 2*: Could S be a replay of an earlier captured S?
  - *Solution*: Send a random (non-repeating) nonce along with request

Signatures solve our problem – *this* one is done right!



Design Goal 2

Securely store data

- Secure storage depends on cryptography and *keys*
- Keys are classified according to their *use* …
  - Storage keys, Binding keys, Identity keys, Signature keys
- … their *properties* …
  - Migratable? Restricted to certain environment (PCRs)?
- … and *authorization*
  - Do you need to know a secret to use the key?
- Best way to understand TPM keys is from the specification

TPM Keys

The Data in a TPM_KEY12 Structure

TPM_STRUCTURE_TAG	tag	Identifies this as a TPM_KEY12
UINT16	fill	
TPM_KEY_USAGE	keyUsage	How can this key be used?
TPM_KEY_FLAGS	keyFlags	Migratable?, etc.
TPM_AUTH_DATA_USAGE	authDataUsage	When is auth required?
TPM_KEY_PARAMS	algorithmParms	What kind of key (alg, size,…)
UINT32	PCRInfoSize	
BYTE*	PCRInfo	
TPM_STORE_PUBKEY	pubKey	Public key
UINT32	encDataSize	Encrypted secret key
BYTE*	encData	

TPM Keys

The Data in a TPM_KEY12 Structure

AG	tag
	fill
	keyUsage
	keyFlags
SAGE	authDataUsage
	algorithmParms
	PCRInfoSize
	PCRInfo
Y	pubKey
	encDataSize
	encData

keyUsage ← Possibilities:
- TPM_KEY_SIGNING
- TPM_KEY_STORAGE
- TPM_KEY_IDENTITY
- TPM_KEY_AUTHCHANGE
- TPM_KEY_BIND
- TPM_KEY_LEGACY
- TPM_KEY_MIGRATE

Important: Keys have a *single* use! So an identity key can only be used to sign TPM-generated data (unlike a signing key) – so if you get something signed by an identity key, you know where the data came from…

TPM Keys

The Data in a TPM_KEY12 Structure

AG	tag
	fill
	keyUsage
	keyFlags
SAGE	authDataUsage
	algorithmParms
	PCRInfoSize
	PCRInfo
Y	pubKey
	encDataSize
	encData

algorithmParms ←

TPM_ALGORITHM_ID	algorithmID
TPM_ENC_SCHEME	encScheme
TPM_SIG_SCHEME	sigScheme
UINT32	parmSize
BYTE[]	parms

TPM Keys

The Data in a TPM_KEY12 Structure

TPM_ALGORITHM_ID	algorithmID	Ex: TPM_ALG_RSA
TPM_ENC_SCHEME	encScheme	Ex: TPM_ES_RSAESOAEP_SHA1_MGF1 TPM_ES_RSAESPKCSV15 TPM_ES_NONE
TPM_SIG_SCHEME	sigScheme	Ex: TPM_SS_RSASSAPKCS1v15_SHA1 TPM_SS_RSASSAPKCS1V15_DER TPM_SS_NONE
UINT32	parmSize	
BYTE[]	parms	Algorithm-specific

TPM Keys

The Data in a TPM_KEY12 Structure

Example parm structure for the RSA algorithm:

UINT32	keyLength
UINT32	numPrimes
UINT32	exponentSize
BYTE[]	exponent

(exponentSize, exponent:) Public exponent – use 0 for "standard exponent" (65,537)

TPM Keys

The Data in a TPM_KEY12 Structure

tag
fill
keyUsage
keyFlags
authDataUsage
algorithmParms
PCRInfoSize
PCRInfo
pubKey
encDataSize
encData

Hash of other parts of TPM_KEY12 struct to bind the two together

Encrypted version of TPM_STORE_ASYMKEY:

TPM_PAYLOAD_TYPE	payload (usually TPM_PT_ASYM)
TPM_SECRET	usageAuth
TPM_SECRET	migrationAuth
TPM_DIGEST	pubDataDigest
TPM_STORE_PRIVKEY	privKey

For an RSA key, a challenge: Maximum length that can be encrypted by a 2048-bit modulus is 2048 bits – but "secret key exponent" *d* is 2048 bits – add in rest and then it's far too big!!! No what?

Solution: privKey is *one* of the prime factors of *n* – rest is recomputed

TPM Keys

Are you paying attention?

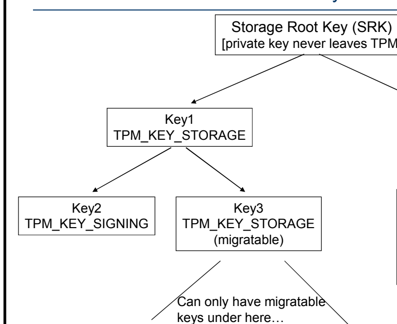
AG	tag
	fill
	keyUsage
	keyFlags
SAGE	authDataUsage
	algorithmParms
	PCRInfoSize
	PCRInfo
Y	pubKey
	encDataSize
	encData

Very sensitive info – how key can be used, can it migrate, does it need authorization…

What stops an attacker from simply changing this?

TPM Keys

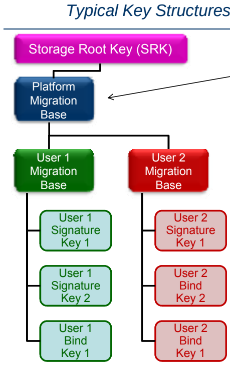
Hierarchy



Basic idea: Storage keys protect other keys, and non-migratable keys can only be under other non-migratable keys…

TPM Keys

Typical Key Structures: Migratable Multi-User Hierarchy



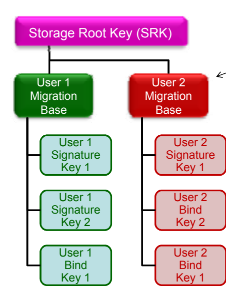
Migratable Storage Key
"Well-Known" use authorization
Migration auth known by administrator

As a result:

- Anyone can load keys under this PMB
- Owner can migrate whole tree by copying by migrating PMB and copying external version of full subtree
- If only users know user key auth secrets, then even owner can't load and use them

TPM Keys

Typical Key Structures: Migratable Multi-User Hierarchy



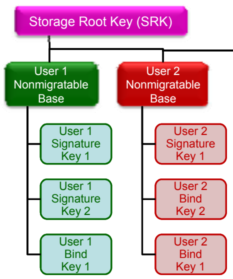
User base keys with migration auth unknown to administrator/owner

As a result:

- Owner cannot migrate user keys directly
- Parent of user keys is non-migratable SRK, so can't be migrated that way

TPM Keys

Typical Key Structures: Nonmigratable Keys



Note: Book shows AIK under user non-migratable keys – that's wrong!

Properties:
- All keys can be certified to be usable only by the TPM
- Strong tie to this particular platform

Down-side: Can't be backed up or migrated in case of machine failure/upgrade (although "maintenance" mode a possibility)

TPM Keys

Is a non-migratable key really tied to a TPM?

- Already talked about modifying the migratable flag
- Since parent key must be non-migratable it is tied to this TPM (induction hypothesis!), so can only be loaded on this TPM
- Final concern: Can we create a key externally (so we know the secret key) and create the TPM_KEY12 marked "non-migratable" ourselves?
  - No: This is one role for the tpmProof secret (stored in migrationAuth)

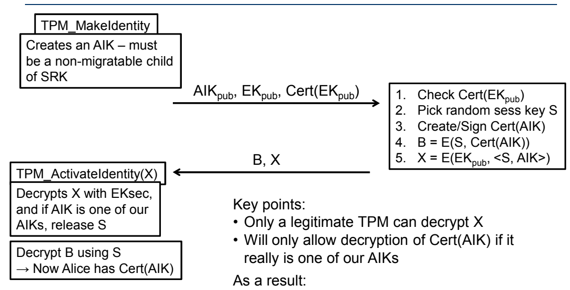
TPM Keys

How is a key made ready for use?

- TPM_LoadKey does this (simplified version):
  - Is specified parent key a TPM_KEY_STORAGE?
  - Are we authorized to use the parent key?
  - Decrypt encData using parent key
  - Check pubDataDigest for authenticity of public data
  - Is authentication required?
    - If yes, match provided secret with decrypted usageAuth
  - If key is non-migratable, is migrationAuth = tpmProof?
  - Are PCRs valid?
- Note: TPM_LoadKey can rate-limit attempts to protect against brute-force attacks

Design Goal 3

Securely identify user and system – Creating an identity (simplified)



Key points:
- Only a legitimate TPM can decrypt X
- Will only allow decryption of Cert(AIK) if it really is one of our AIKs

As a result:
- AIK certificates prove that the AIK is bound to a TPM

Design Goal 5

Support and isolate multiple users

- One argument for not being able to get SRK private key
  - If SRK private key were known, entire storage tree could be decrypted
  - More politically correct than "you can't get it because we don't trust you, the owner of the machine"
- Keys further down in the storage hierarchy have individual authorization secrets (set when the key is created)
  - No "superuser access" that can access all keys (outside TPM)
  - Can a rootkit capture user's keystrokes entering passphrase?
    - Theoretically the integrity protection can stop this (no rootkits!)
    - Future plans include hardware "trusted path" (encrypted keyboard so only encrypted data can be sniffed)

Additional TPM Capabilities

Secure (Pseudo) Random Numbers

- Secure random/pseudo-random numbers are important for many security protocols (session keys, etc.)
- Examples of bad "random" numbers in protocols:
  - Online blackjack game with non-cryptographic PRNG
  - SSL session key derived from small seed (date and PID)
- A standard, dependable, secure PRNG is very useful
- Then the book talks about using the TPM random generation for things like Monte Carlo simulation:
  - This is completely silly – no need for "security", just uniformity, and CPU can generate a good uniform sequence much faster than the TPM

Some New Capabilities of Version 1.2

- Certifiable Migratable Keys (CMKs)
  - Something in between 1.1 migratable and non-migratable
  - Committed to certain migration authorities (MAs) when key created
  - Certificate then says: This key is under the control of these MAs
- Monotonic Counters
  - State maintained across reboots and power cycles
  - Counters can be incremented and don't wrap – values don't repeat
- Direct Anonymous Attestation
  - A (much) more complex way of authenticating an AIK
  - Does not reveal AIK even to PrivacyCA
- Delegation of Owner-Authorized Commands