Writing Trusted Applications

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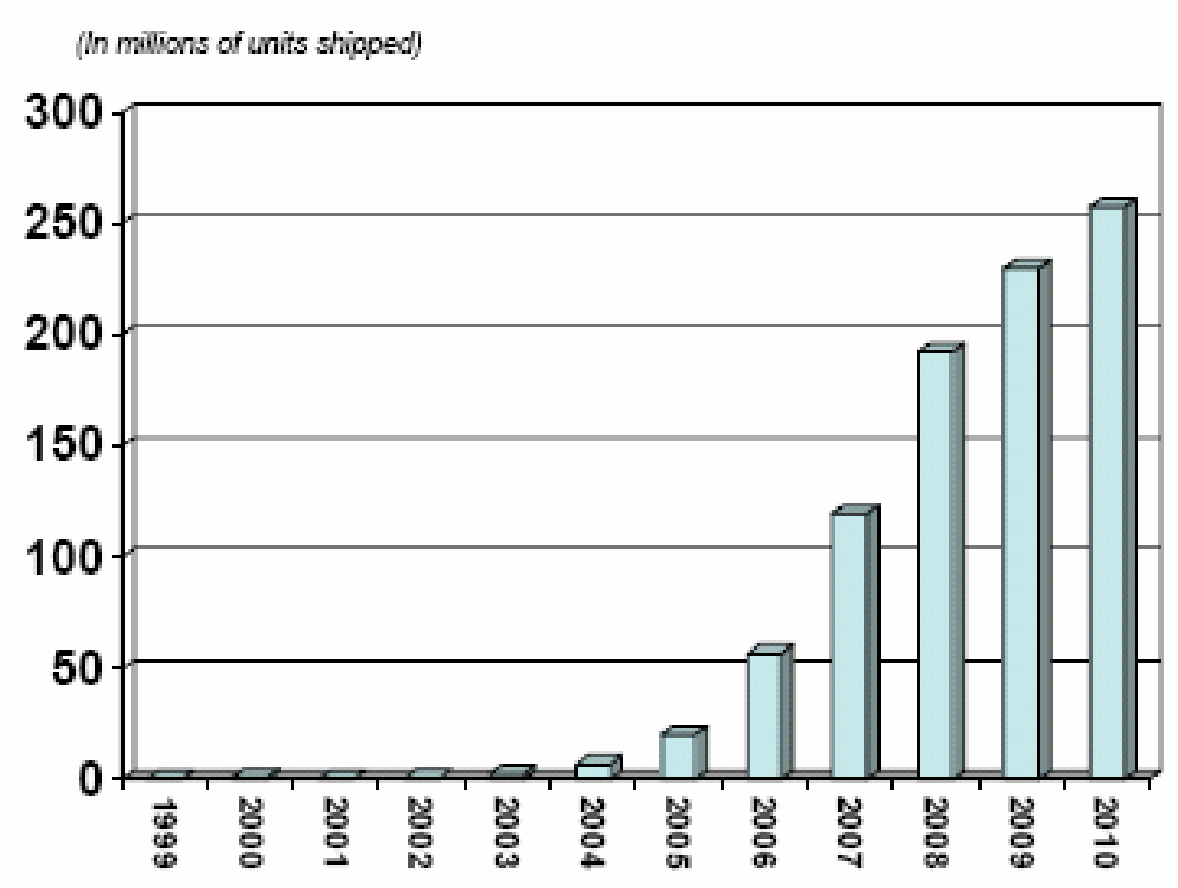
Outline

- Motivation
- TCG architecture
- TPM overview
- TSS overview
- Coding to the TSS
- Mapping to use cases
- Conclusions

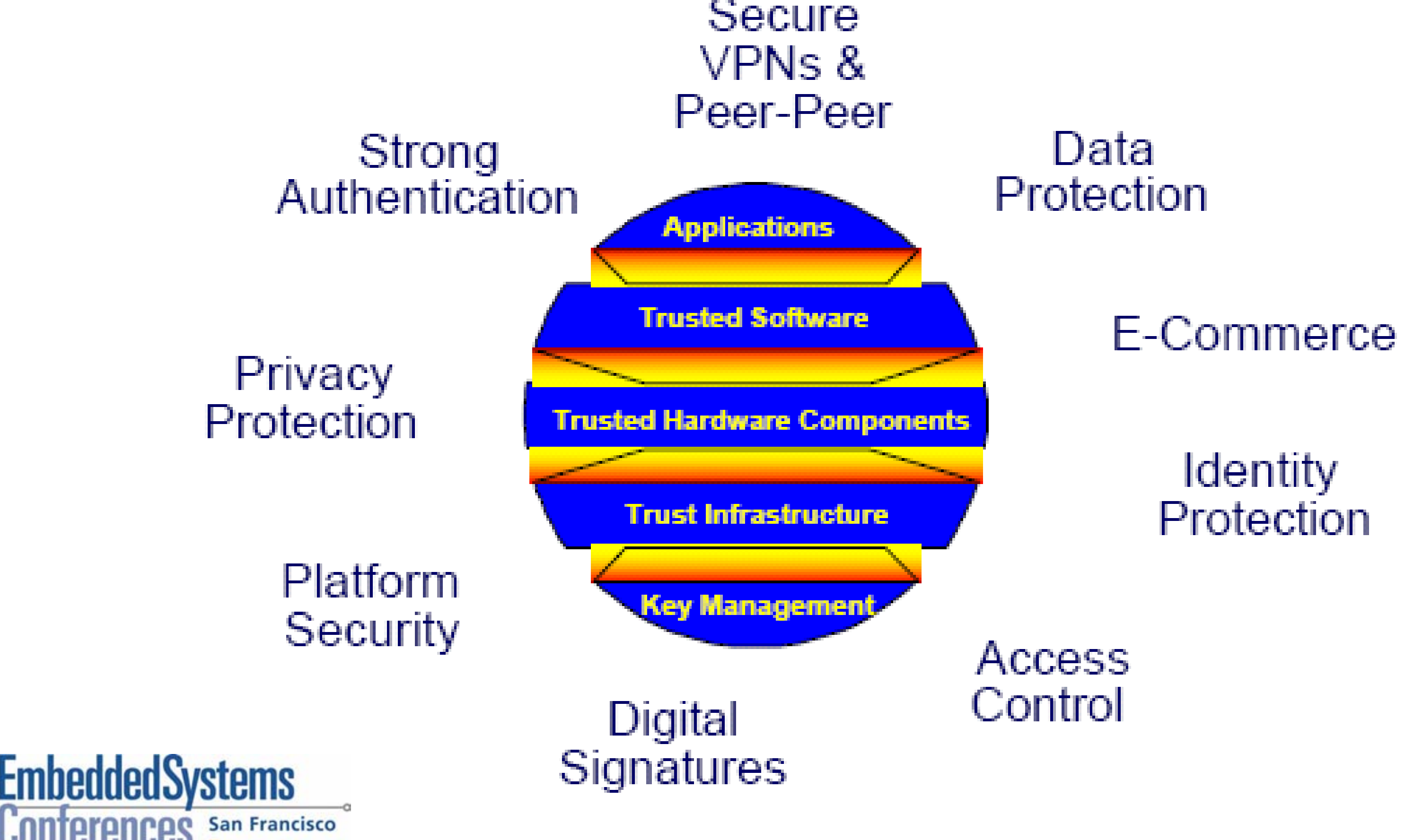
Why do we care about trusted computing?

- Trust is key to driving usage of computing devices for security-sensitive applications
- Trusted computing (TC) opens up new usage models
- Wide deployment of TC building blocks

TPM shipment forecast



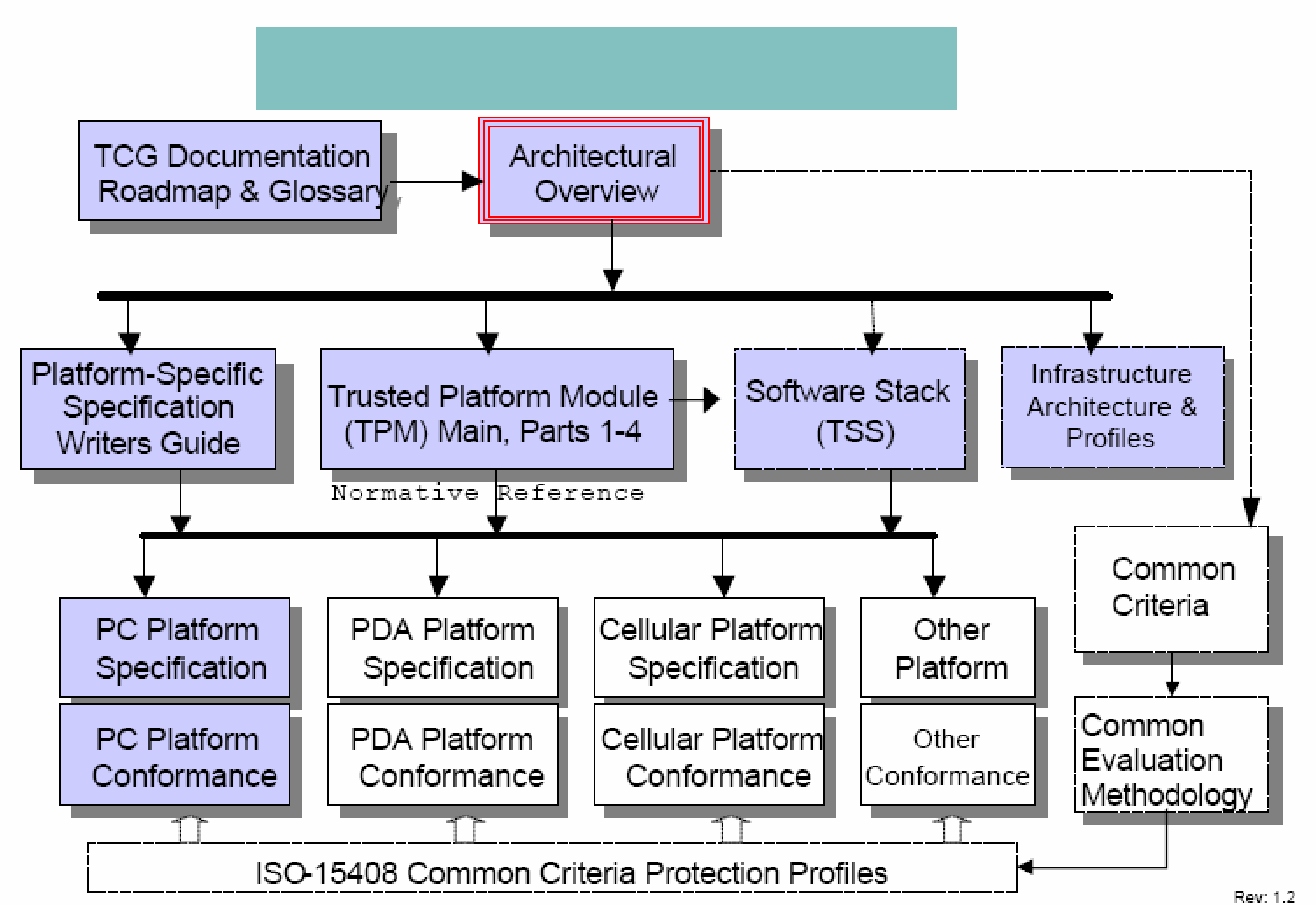
Trusted computing applications



Some motivating use cases

- How do I…
  - Store a key securely, so a user can access it with a password?
  - Back up a key securely, so IT can help the user out when he forgets his password?
  - Ensure that I am communicating with a particular user with access to a particular machine?
  - Make sure my software only runs on a specific machine?
  - Make sure my software runs only on machines in a specific state?
- We'll first do a lot of background, then come back to these use cases

TCG document architecture



Building on existing building blocks

- There are many components that go into building a “trusted” system
- Great progress has been made building up an ecosystem of trusted computing products and services
- The task ahead of us is to build on that ecosystem

Trusted PC building blocks

- A trusted personal computer (PC) may have many components
  - TCG core roots of trust
    - RTS and RTR inside TPM
    - RTM part of motherboard
  - TCG-enabled BIOS
  - TCG-aware OS
  - TCG Software Stack (TSS)
  - TCG-enabled CSP(s)
  - TCG development tools
  - TCG-enabled applications

Core roots of trust

TPM

Root of Trust for Storage (RTS)

- Protects TPM data in external storage devices
- Provides confidentiality and integrity for the external blobs
- Ensures the release of information occurs only in named environments
- RTS protected data can migrate to other TPMs

Root of Trust for Reporting (RTR)

- Establishes platform identities
- Reports platform configurations
- Protects reported values
- Establishes a context for attesting

The RTR shares responsibility of protecting measurement digests with the RTS
The TPM package protects RTS ←→ RTR interaction

Root of Trust for Measurement (RTM)

- Measures the platform's trust state
- Is considered immutable
- CRTM
  - The component that contains the RTM code

Platform

Trusted Platform Module (TPM)

- Core hardware security component
- Provides
  - Protected storage
  - Protected operations
  - Verifiable reporting of TPM state
  - Controlled access to and use of various keys

Trusted hardware

- To ensure security, the TPM must be securely bound to the platform
- Additional trusted hardware is used for measuring code before running it
- In the PC world, this might be part of the motherboard

TCG-enabled BIOS

- When the PC first boots, the trust in the code is valid as long as the code that is running has been measured
- The BIOS measures the code and performs certain "physical" actions on the TPM

TCG-aware operating system

- If the BIOS measures the operating system (OS) properly, the OS can take advantage of the TPM state
- In embedded systems, this may pose fewer problems than in the PC space

TCG Software Stack (TSS)

- The TSS is a software stack that exposes the functionality of the TPM and provides a common interface to access TPM functionality.
- The main goals of the TSS are:
  - Supply one entry point for applications to the TPM functionality
  - Provide synchronized access to the TPM
  - Hide building command streams with appropriate byte ordering and alignment from the applications
  - Manage TPM resources
  - Release TPM resources when appropriate
  - Manage application use of secrets and keys

TCG-enabled CSP

- Cryptographic Service Providers (CSP) provide standard interfaces to applications for the use of keys (e.g. CAPI, PKCS #11)
- TCG-enabled CSPs abstract away the TPM and TSS
- May or may not reduce TPM functionality

TCG development tools

- Software companies may make development tools available to simplify the writing of TCG applications
- This may make it even easier for application writers to write TCG-enabled applications

TCG-enabled applications

- Applications that ultimately build on the security and trust provided by all of the layers below

TC in embedded systems

- TCG Mobile Phone WG
  - Working on platform-specific specification
- Embedded Linux
  - TrouSerS
  - NTRU CTSS

Embedded trusted computing

- Embedded trusted computing probably won’t look exactly like the PC space
- TPM must be there
- TSS probably will be there
- CSP and development tools may or may not be there
- So ... I will focus on the TPM and TSS

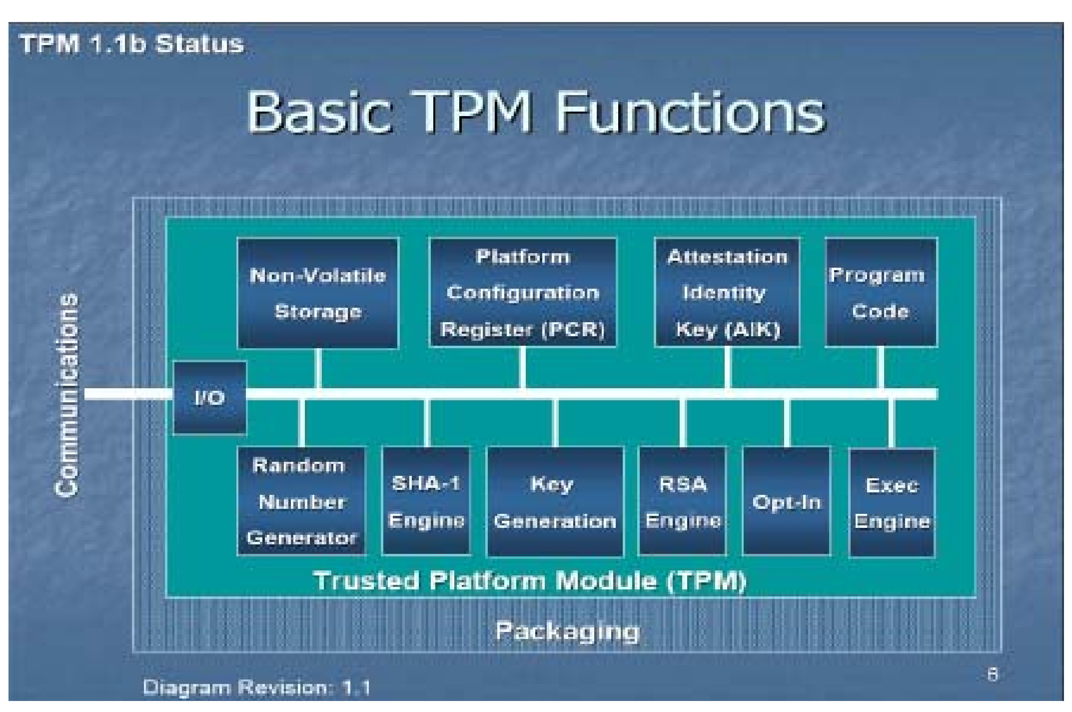
Understanding the TPM

- The TPM specification is rather complex
- Early embedded trusted computing developers would be well served to understand the TPM
- So, here are some of the basics . . .

What makes TPMs special?

- Hardware-based state measuring (root of trust for measurement)
- Hardware-based attestation (root of trust for reporting)
- Fundamental part of the platform
- Wide variety of cryptographic/security functionality
- Robust management interface

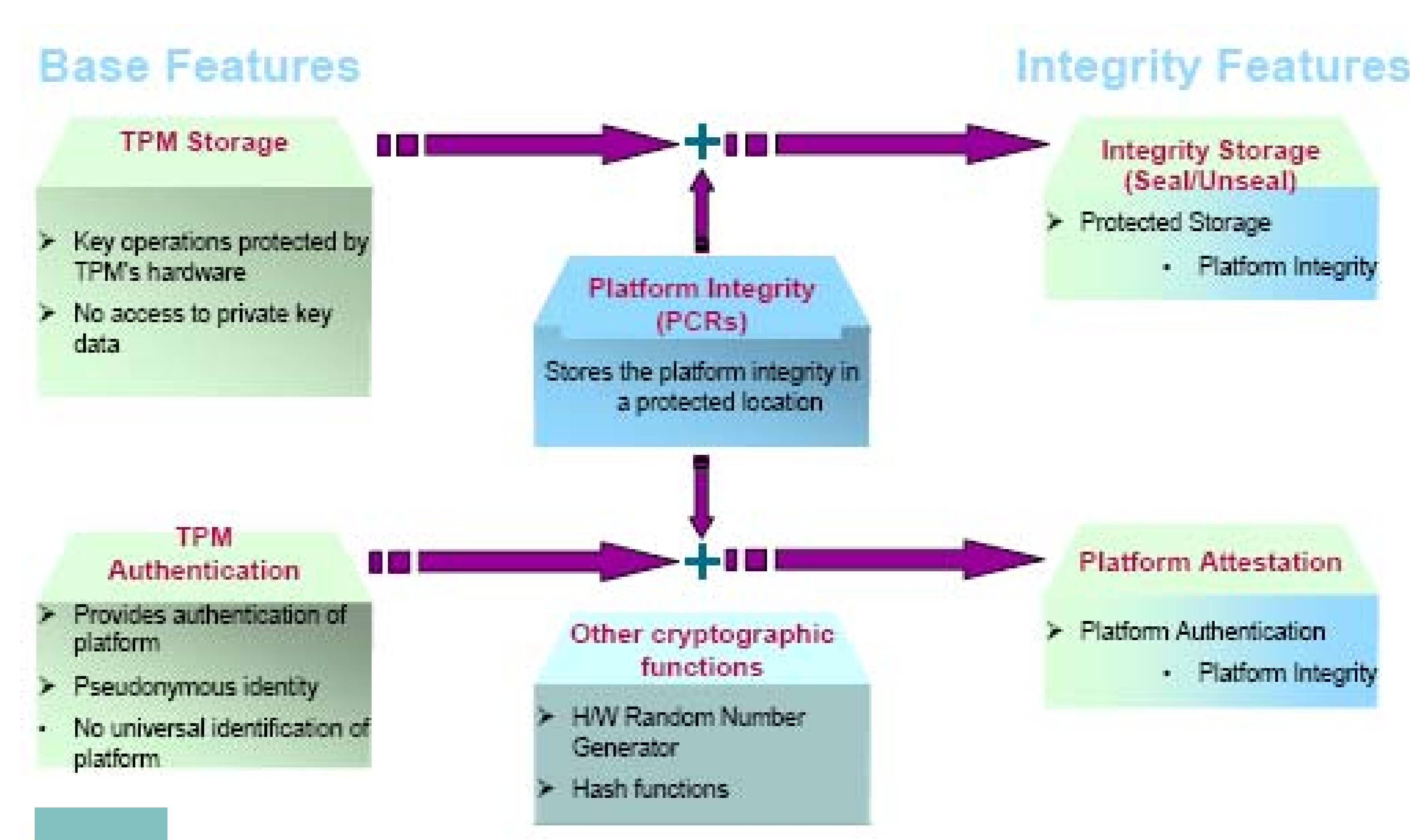
TPM overview



TPM 1.1 core elements

Functional Units	Non-volatile memory	Volatile memory
RNG	Endorsement Key (2048b)	RSA Key Slot-0 . . . RSA Key Slot-9
Hash	Storage Root Key (2048b)	PCR-0 . . . PCR-15
HMAC	Owner Auth Secret (160b)	Key Handles
RSA Key Generation		Auth Session Handles
RSA Encrypt/Decrypt		

TPM features and functions



TPM entities: Owner

- Can control access to the root keys on the TPM (EK and SRK)
  - Protected by use of an authorization secret: essentially a password, stored in TPM tamperproof memory
  - Lockout/response degradation implemented by some manufacturers to make brute force attacks infeasible.
- “Taking ownership” = creating the SRK
  - Requires “physical presence” to be enabled
    - Typically a switch in the BIOS
  - Clearing ownership means that all data protected with the previous key hierarchy cannot be accessed, unless it was previously backed up externally
- In 1.2, owner can perform “delegation”
  - Allows to associate extra passwords with specified operations using specified keys
  - The person who knows the extra password can perform approved actions, but no others.
  - Allows enterprises to have IT as owner, user as privileged operator

TPM entities: Non-owner

- Can create storage (encryption) and endorsement (signing) keys
- Must be under key approved by owner for that use
- Caveat: SRK is generally available for all to use

TPM keys: Endorsement key

- The endorsement key (EK) is the master key that the TPM uses to allow people to take ownership and to prove the security of identity keys.
- EK is a 2048-bit RSA key, often certified during the manufacturing process by a CA
- EK usually unchangeable

TPM keys: Storage keys

- Key hierarchy
  - Each child key is encrypted under its parent.
    - Parents also known as "Storage keys"
    - SRK (Storage Root Key): Top of the tree
  - Keys are migratable or non-migratable
    - Non-migratable includes
      - SRK
      - The parent of any non-migratable key
  - TPM 1.2 has special certifiable migration keys (CMK) that add assurance as to who has access to the private portion of the key

TPM keys: Other keys

- Identity keys: non-migratable signing keys that can be certified by a CA as belonging to a TPM.
- Binding keys for binding,
- Signing keys for signing arbitrary data
- Legacy keys that can both sign and encrypt.
- All keys except the SRK and EK are encrypted by a storage key and stored outside the TPM

TPM objects: PCRs

- Platform Configuration Register
  - In one sense, simply 20 bytes of RAM
  - In another sense, the core of the TPM
  - Used to store hashes (“measurements”)
  - Cannot be overwritten, only “extended”
    - Hash new data with current state
  - Can Seal data to set of PCRs, so that it will only be Unsealed if PCRs are in specified state;
  - Can sign and transmit state of a set of PCRs
  - Assume that PCR state is related to software and hardware configuration: then this is very useful

TPM functions: Seal

- TPM_Seal
  - Encrypting data (usually a symmetric key)
  - …using a non-migratable TPM storage key (an RSA key)
  - … so that ONLY that specific TPM can unseal the data.
  - Can be linked to sealing secret (password) and PCR state

TPM functions: Bind

- TSS_Bind, TPM_Unbind
  - Encryption for a binding key that a TPM can use (an RSA key that may or may not be migratable).
  - Not linked to a specific platform
  - Does not use a binding secret and it does not use PCRs.
  - Binding is done outside of the TPM

TPM functions: Migration and quote

- Migration
  - The owner can select keys that the TPM will migrate keys to.
  - Migratable keys can be converted from one "parent" to another.
- Quote
  - A signature using an identity key that attests to the PCR state of the TPM.

TPM 1.2: Capabilities

- CMK - Certifiable migration key
  - TPM can attest they have only been inside the TPM or encrypted for a particular Migration Authority.
  - Enables key backup to other TPMs
- Transport Sessions
  - SSL-like functionality for interaction with the TPM
  - Enables remote administration without eavesdropping

TPM 1.2: Capabilities (2)

- Delegation
  - The ability to give authorization to an entity to do certain things that the owner can do or that a key can do.
  - Enables remote administration by authorized actors
  - Allows IT departments to restrict the damage end-users can do
- DAA – Direct Anonymous Attestation
  - Allow to prove that a command has come from a TPM, without specifying which TPM
    - Uses cryptographic technique known as “group signatures”
  - Partially inspired by European regulatory requirements for privacy

TPM 1.2: Capabilities (3)

- Tick Count
  - A time stamp mechanism.
- Monotonic Counter
  - Non-spoofable, non-resettable counters that can be signed.

Understanding the TSS

- The TSS abstracts some of the TPM complexities away
- If you learn the TPM basics and the TSS API, you can create secure applications

TSS block architecture

TSS SPI
TSS CSI
TPM DDLI

Process 1
TSS Service Provider

Process 2
RPC Client

TSS Core Services

TPM Device Driver Library

TPM Device Driver

TPM

User Process
System Process
Kernel Mode

Remote Process
TSS Service Provider
RPC Client

TSS enables application development and interoperability

TSS Device Driver Library (TDDL)

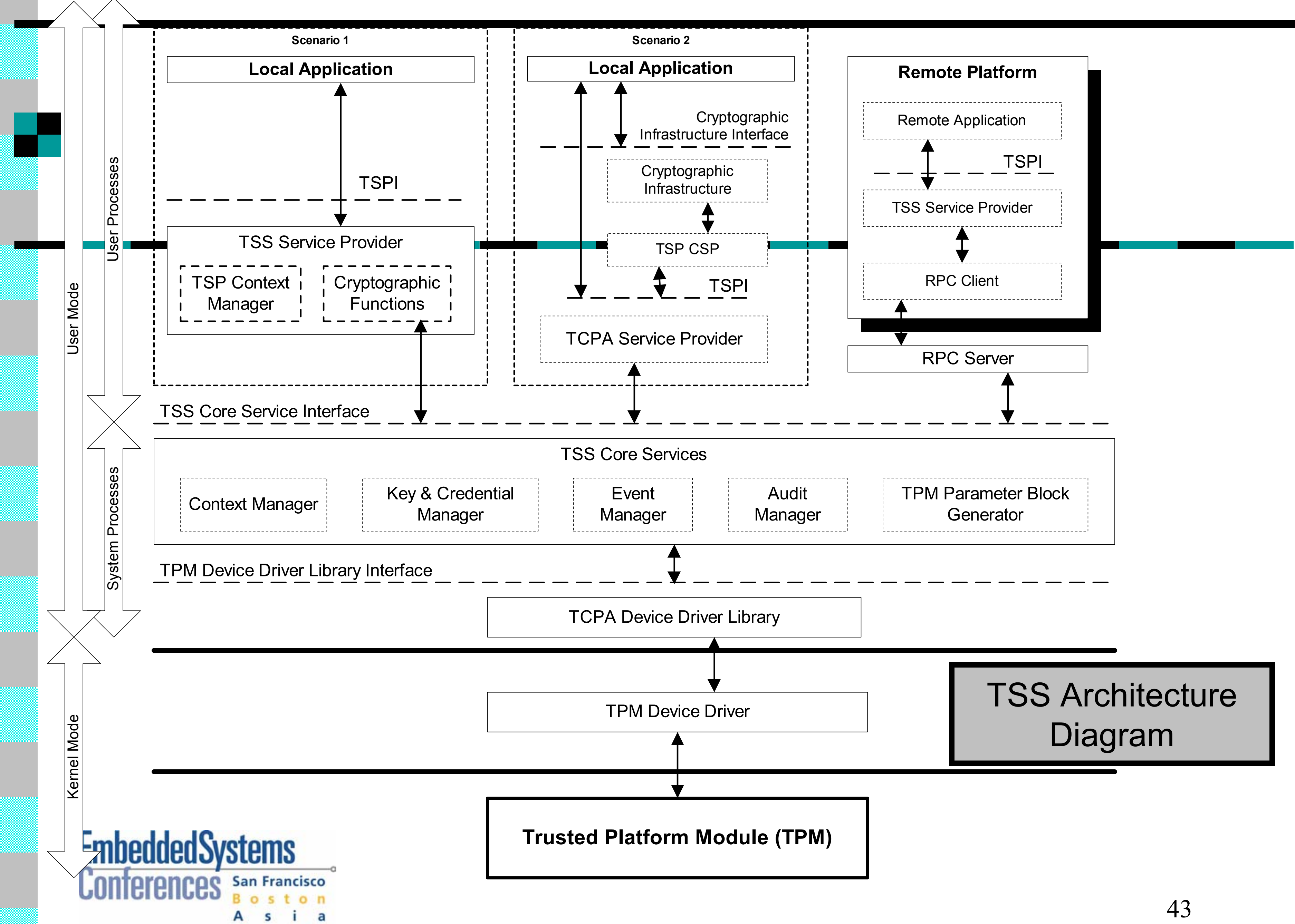
- Creates an abstraction layer hiding OS-specific device driver interfaces from the TCS
- Single point of compatibility for TSS developers
- Allows the TPM vendor to get/set device driver capabilities

TSS Core Services (TCS)

- Parameter Block Generator (PBG)
  - Converts 'C' style parameters into TPM format.
- Key and Credential Manager (KCM)
  - Allows the user to alias and persistently store a TPM key.
  - Dynamically swaps keys into and out of the TPM
- Context Manager
  - Allows multiple TSP modules to access TCS simultaneously
  - Performs memory management on a per context basis
- Event Manager
  - Generates, manages and exports "PCR Events"
- Audit Manager
  - Intended to leave records of TPM activity

TSS Service Provider (TSP)

- Exposes TSPI
  - User Friendly API that incorporates object oriented principles
  - Abstracts the underlying protocols and data structures
- TSP Context Manager
  - Allows multiple instances of TSP layer
  - Performs memory management at the TSP Layer
- Public-key cryptography and hashing/HMAC
  - Not all cryptography requires the TPM
  - Performs public-key, hashing and HMAC algorithms to enhance cryptographic security and authorization for the TPM


Scenario 1
Local Application
TSPI
TSS Service Provider
TSP Context Manager
Cryptographic Functions
Scenario 2
Local Application
Cryptographic Infrastructure Interface
Cryptographic Infrastructure
TSP CSP
TSPI
TCPA Service Provider
Remote Platform
Remote Application
TSPI
TSS Service Provider
RPC Client
RPC Server
User Processes
User Mode
System Processes
Kernel Mode
TSS Core Service Interface
TSS Core Services
Context Manager
Key & Credential Manager
Event Manager
Audit Manager
TPM Parameter Block Generator
TPM Device Driver Library Interface
TCPA Device Driver Library
TPM Device Driver
Trusted Platform Module (TPM)
TSS Architecture Diagram
EmbeddedSystems Conferences
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TSS and key management

- Virtualizes resources used inside the TPM
  - Multiple applications can run simultaneously, each using different keys
  - Applications do not have to manage key load/unload themselves
- To take ownership of the TPM, must write directly to the TSS
  - Currently not possible through higher-layer interfaces such as CSP

TSS for calling TPM functions

- Actions such as Seal are authorized using an authorization secret
  - TSS provides means to enter, cache, and expire the secret
- TPM commands are all formed inside the TSS – they are not exposed directly to the applications

Code samples

- Now, here are some details about how to actually use this stuff . . .

Seal to PCR code

```
int
main(void)
{
    TSS_HCONTEXT    hContext;
    TSS_HTPM        hTPM;
    TSS_HPOLICY     hPolicy;
    TSS_HKEY        hSRK, hSealKey;
    TSS_HENCDATA    hSealData;
    TSS_HPCRS       hPCRs;
    BYTE            wellKnownSecret[] = TSS_WELL_KNOWN_SECRET;
    BYTE            rawData[64];
    UINT32          unsealedDataLength, pcrLength;
    BYTE           *unsealedData, *pcrValue;
    int                               i;

    for (i = 0; i < 64; i++)
      rawData[i] = (BYTE) i;

/* create context and connect to TPM */

    Tspi_Context_Create(&hContext);
    Tspi_Context_Connect(hContext, NULL);
```

Seal to PCR code (2)

```
/* create empty keys and data object */

       Tspi_Context_CreateObject(hContext, TSS_OBJECT_TYPE_RSAKEY, TSS_KEY_TSP_SRK,
                                         &hSRK);
       Tspi_Context_CreateObject(hContext, TSS_OBJECT_TYPE_RSAKEY,
                                         TSS_KEY_TYPE_STORAGE |
                                          TSS_KEY_SIZE_2048 |
                                          TSS_KEY_NO_AUTHORIZATION |
                                          TSS_KEY_NOT_MIGRATABLE,
                                         &hSealKey);

       Tspi_Context_CreateObject(hContext, TSS_OBJECT_TYPE_ENCDATA,
                                         TSS_ENCDATA_SEAL, &hSealData);

/* get TPM object */

       Tspi_Context_GetTpmObject(hContext, &hTPM);

/* set up the default policy - this will apply to all objects */

       Tspi_Context_GetDefaultPolicy(hContext, &hPolicy);
       Tspi_Policy_SetSecret(hPolicy, TSS_SECRET_MODE_SHA1, 20, wellKnownSecret);
```

Seal to PCR code (3)

```
/* create and load the sealing key */

        Tspi_Key_CreateKey(hSealKey, hSRK, 0);
        Tspi_Key_LoadKey(hSealKey, hSRK);

/* seal to PCR values */

    /* set the PCR values to the current values in the TPM */

        Tspi_TPM_PcrRead(hTPM, 5, &pcrLength, &pcrValue);
        Tspi_PcrComposite_SetPcrValue(hPCRs, 5, pcrLength, pcrValue);
        Tspi_TPM_PcrRead(hTPM, 7, &pcrLength, &pcrValue);
        Tspi_PcrComposite_SetPcrValue(hPCRs, 7, pcrLength, pcrValue);

    /* perform the seal operation */

        Tspi_Data_Seal(hSealData, hSealKey, 64, rawData, hPCRs);

    /* unseal the blob */

    unsealedData = NULL;
        Tspi_Data_Unseal(hSealData, hSealKey, &unsealedDataLength, &unsealedData);
```

Seal to PCR code (4)

```
        /* free memory */

        Tspi_Context_FreeMemory(hContext, unsealedData);

/* clean up */

        Tspi_Key_UnloadKey(hSealKey);

        Tspi_Context_CloseObject(hContext, hPCRs);
        Tspi_Context_CloseObject(hContext, hSealKey);
        Tspi_Context_CloseObject(hContext, hSealData);

/* close context */

        Tspi_Context_Close(hContext);

    return 0;
}
```

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Sign/verify code

```
int
main(void)
{
    TSS_HCONTEXT    hContext;
    TSS_HHASH       hHash;
    TSS_HKEY        hSigningKey, hSRK;
    TSS_HPOLICY     hPolicy;
    TSS_UUID        srkUUID = TSS_UUID_SRK;
    BYTE            secret[] = TSS_WELL_KNOWN_SECRET;
    UINT32          sigLen;
    BYTE            *sig;
    BYTE            hash[] =
      {0x32, 0xd1, 0x0c, 0x7b, 0x8c, 0xf9, 0x65, 0x70, 0xca, 0x04,
       0xce, 0x37, 0xf2, 0xa1, 0x9d, 0x84, 0x24, 0x0d, 0x3a, 0x89};

/* create context and connect */

      Tspi_Context_Create(&hContext);
      Tspi_Context_Connect(hContext, NULL);
```

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Sign/verify code (2)

```
/* create a signing key under the SRK */

     Tspi_Context_CreateObject(hContext, TSS_OBJECT_TYPE_POLICY,
                                         TSS_POLICY_USAGE, &hPolicy);
     Tspi_Policy_SetSecret(hPolicy, TSS_SECRET_MODE_SHA1, 20, secret);
     Tspi_Context_GetKeyByUUID(hContext, TSS_PS_TYPE_SYSTEM, srkUUID, &hSRK);
     Tspi_Policy_AssignToObject(hPolicy, hSRK);
     Tspi_Context_CreateObject(hContext, TSS_OBJECT_TYPE_RSAKEY,
                               TSS_KEY_TYPE_SIGNING |
                                TSS_KEY_SIZE_2048 |
                                TSS_KEY_AUTHORIZATION |
                                TSS_KEY_NOT_MIGRATABLE,
                               &hSigningKey);
     Tspi_Policy_AssignToObject(hPolicy, hSigningKey);
     Tspi_Key_CreateKey(hSigningKey, hSRK, 0);
     Tspi_Key_LoadKey(hSigningKey, hSRK);

    /* open valid hash object */

     Tspi_Context_CreateObject(hContext, TSS_OBJECT_TYPE_HASH,
                                                       TSS_HASH_SHA1,
     &hHash);
```

Sign/verify code (3)

```
/* set hash value and get valid signature */

        Tspi_Hash_SetHashValue(hHash, sizeof(hash), hash);
        Tspi_Hash_Sign(hHash, hSigningKey, &sigLen, &sig);

/* verify signature */

        Tspi_Hash_VerifySignature(hHash, hSigningKey, sigLen, sig);

/* free sig memory, close signing key object and context */

        Tspi_Context_FreeMemory(hContext, sig);
        Tspi_Context_CloseObject(hContext, hSigningKey);

/* close context */

        Tspi_Context_Close(hContext);

    return 0;
}
```

Using this knowledge to write trusted applications

- Given a TPM and TSS, choose correct ways to use functionality to meet security objectives
- Requires some security architecting, but the building blocks are all there
- So, let’s look at our original motivating use cases . . .

Secure key storage

- How do I store a key securely, so a user can access it with a password?
  - Select a starting password
    - Set a policy with that password: Tspi_Policy_SetSecret
  - Get the key onto the platform
    - Create a key object with chosen parameters: Tspi_Context_CreateObject
    - Create a new one: Tspi_Key_CreateKey
    - . . . or import a known one: Tspi_Key_WrapKey
  - Optionally let the user change the password
    - Use Tspi_ChangeAuth
  - Store the key blob somewhere
    - Register it in the TSS Key Store: Tspi_Context_RegisterKey
    - Store the key blob somewhere else and load it when needed

Key backup

- How do I back up a key securely, so that IT can help the user out with a forgotten password?
  - Can use remote connection to the TPM . . .
    - Tspi_Context_Connect(hContext, userMachineName);
  - . . . then import key using previous method, keeping a copy of the key
  - Or, use migration capabilities
    - Set up a trusted key to migrate to: Tspi_TPM_AuthorizeMigrationTicket
    - Begin migration process: Tspi_Key_CreateMigrationBlob
    - Complete migration process: Tspi_Key_ConvertMigrationBlob
  - That's it!

User and machine authentication

- How do I ensure that I am communicating with a particular user with access to a particular machine?
  - Choose TPM authentication method
    - Decryption of a challenge: Tspi_Data_Unbind
    - Signature of a challenge with selected configuration: Tspi_TPM_Quote
  - Set up a key for the user on a particular TPM
    - Use previous methods
    - Perhaps ensure that the key is non-migratable: TSS_KEY_NOT_MIGRATABLE
  - Require that the user use the key as a means to authenticate
    - Could leverage existing authentication mechanisms
      - Smart cards
      - VPN
      - Digital signature
    - Could use a new protocol if desired

Binding to a specific platform

- How do I make sure my software only runs on a specific machine?
  - Use the previous authentication mechanisms, but embed them in the application
    - Require a signature from a key tied to the platform before continuing: Tspi_Hash_Sign, Tspi_Hash_VerifySignature
  - Encrypt key data to the platform
    - Seal a symmetric key that the application needs to function: Tspi_Data_Seal, Tspi_Data_Unseal

Binding to a platform state

- How do I make sure my software only runs on machines in a specific state?
  - Leverage secure use of PCRs
    - Could involve secure boot
    - Could involve use of locality
  - Leverage platform credentials
    - Assume that each EK has a certificate
    - Create identity keys for your application: Tspi_Key_CreateKey, Tspi_TPM_CollateIdentityRequest, Tspi_TPM_ActivateIdentity
    - Certify other keys (e.g. an encryption key) if necessary: Tspi_Key_CertifyKey
  - Require platform authentication of state before allowing software to be run
    - Encrypt software and require certified key to decrypt when in correct state using previous methods
    - Require signature of state before continuing application: Tspi_TPM_Quote

Conclusions

- TCG technologies provide a very rich set of functionality to implement security features
- For embedded applications, perhaps the TSS interface is the appropriate one to use
- Early application writers will need to understand a few of the specifics of TCG technologies
- The increasing deployment trend of TCG technologies will allow for more and more trusted applications to come into existence

Questions?

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