TPM Software Stack: Enabling the TPM2.0 Ecosystem in Linux

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Joshua Lock, Intel

Agenda

- Background
- Design & Architecture
- OSS Implementation, Community and Adoption
- TSS2 Use Cases and Examples

Speakers' Bios

Peter Hüwe, Infineon Technologies AG

- Senior Staff Engineer - Embedded Security Software, TPM Firmware & Linux Security
- Project Lead for sponsored ESAPI development by FHG SIT
- TPM Subsystem Maintainer (retired?)
- Contributor to tpm2-software

Joshua G. Lock, Intel

- Software Engineer – Open Source Technology Center
- Co-maintainer of tpm2-tools
- Long-time Yocto Project contributor

Philip Tricca, Intel

TPM2 Software Stack (TSS2) @ Linux Security Summit NA 2018
Thanks for the Slide Content!

TPM2.0 Background

- See materials & book by Ariel Siegal [1][2]
- TPM-JS Tutorial by Google [3]
- Use-case unchanged
  - Protect encryption keys while in use
  - Root of trust for storage & reporting
- TPM 1.2 limited algorithm support
  - Mandates RSA 1k, 2k & SHA1, no larger key / hash sizes, AES optional
  - Single hierarchy, limited policy
- TPM 2.0 addresses shortcomings of 1.2
  - Adds cryptoagility and support for complex policies
  - Integrity protected and encrypted sessions

TPM2 Software Stack Design & Architecture

TSS2 Design

- Layered design
  - Separate transport layer from APIs:
  - Both synchronous and asynchronous: event-driven programming
  - Details exposed if you need them, “sane defaults” otherwise
    - Chosen by: TCG / platform / distro / OS?
- Lower layers of stack provide data transport & thin layer over TPM2 commands
  - “Expert” applications in constrained environments
  - Minimal dependencies (libc)
- Upper layers provide convenience functions & abstractions
  - Crypto for sessions, dynamic memory allocation, transport layer configuration
  - More Features -> more dependencies

Architecture / Design

System API (tss2-sys)
- 1:1 to TPM2 cmds
- Command / Response serialization
- No file I/O
- No crypto
- No heap / malloc

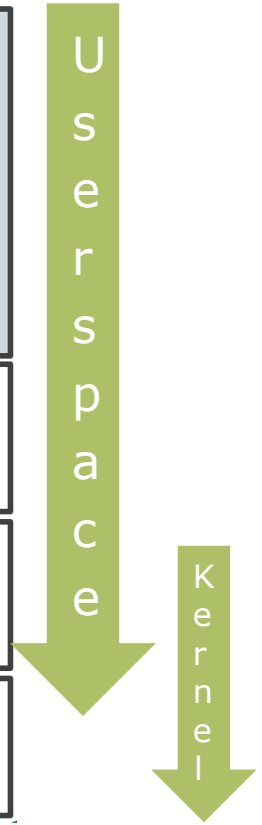
Enhanced SAPI (tss2-esys)
- Automate crypto for HMAC / encrypted sessions
- Dynamic TCTI loading
- Requires heap / does memory allocations
- No file I/O

Feature API (FAPI)
- Spec in draft form
- No implementation yet
- File I/O
- Requires heap
- Automate retries
- Context based state
- Must support static linking

TPM Command Transmission Interface (tss2-tcti)
- Abstract command / response mechanism,
- Decouple APIs from command transport / IPC
- No crypto, heap, file I/O
- Dynamic loading / dlopen API

TPM Access Broker and Resource Manager (TAB/RM)
- Power management
- Potentially no file IO – depends on power mgmt.
- Abstract Limitations of TPM Storage
- No crypto

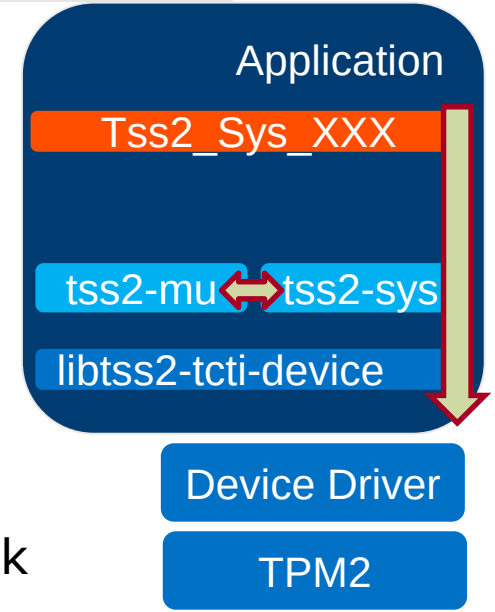
TPM Device Driver
- Device Interface (CRB / polling)
- Pre-boot log handoff



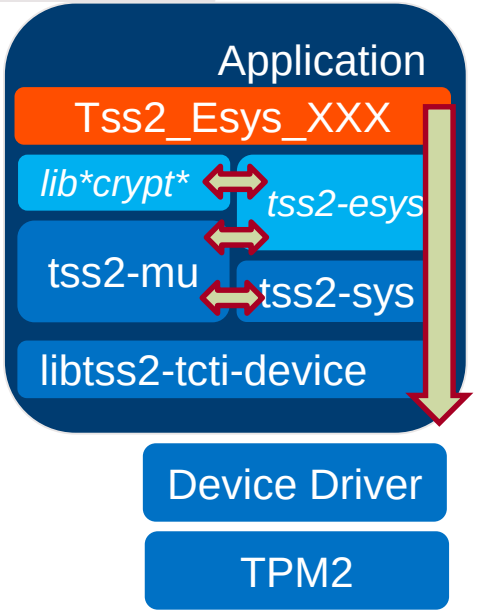
Source: Philip Tricca, Intel, Linux Security Summit 2018 – with Permission

TSS2 Application
System API, Type Marshalling

- **System API**: libtss2-*sys*
  - Translate C types to TPM command layout
  - One-to-one mapping to TPM commands
  - Suitable for **firmware** / **embedded** applications
    e.g. available for *Aurix*™ and *XMC*™ Microcontrollers
- **Type Marshalling**: libtss2-*mu*
  - Transform TPM types from C to wire format & back



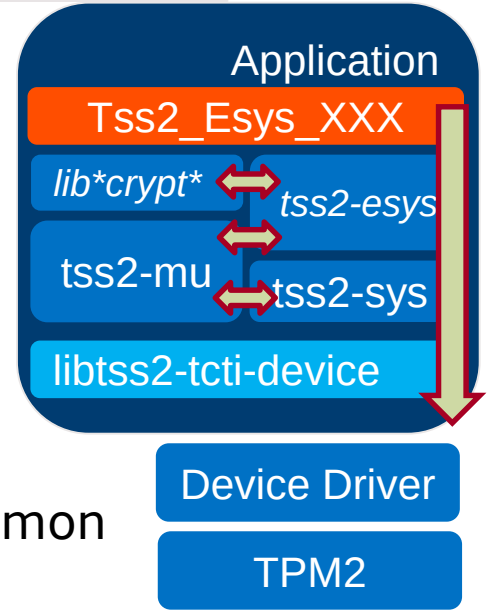
TSS2 Application
Enhanced System API: libtss2-esys



- **Enhanced System API:** *libtss2-esys*
  - Builds on top of lower-level tss2-* libs
  - Exposes all TPM2 functions + utility functions
    - HMAC calculations for HMAC session
    - Crypto for encrypted session
    - Maintain state for authorizations
  - Adds crypto library dependency
    - Current implementation supports
      - libgcrypt
      - Openssl

Contribution by Fraunhofer SIT, sponsored by Infineon Technologies

TSS2 Application
TPM Command Transmission Interface (TCTI)



- **TPM2 Command Transmission Interface**: libtss2-*tcti*-xxx
- Modular, dynamically loaded transport layer. Decouples API from command transport/IPC.
  - device: */dev/tpmX* (no AB & RM) or */dev/tpmrmX* (no AB & some RM)
  - abrmd: Access Broker and Resource Manager Daemon
  - tbs: TPM Base Services on Windows 2008/Vista+
  - mssim: IBM's Linux port of Microsoft's TPM2 simulator
  - efi: enabling use of tss2-sys API in UEFI (in-development)

TPM2 Resource Management

TPMs are resource constrained: small & inexpensive

- RAM on the order of “a few kilobytes”
- Scarce resources must be shared
  - TPM commands specific to object and session management:
    - ContextLoad, ContextSave & FlushContext
  - Resource Management: Saving & Loading “contexts”
- Isolation through Resource Management
  - Associate objects (keys, session) with connection
  - Prevent access by other connections (with exceptions)
- Components of resource mgmt. tasks moving into kernel driver
  - /dev/tpmrm0: performs simple object / session isolation & load / save
  - Aligning user-space daemon w/ in-kernel resource mgmt. (ongoing work)

OSS Implementation, Community and Adoption

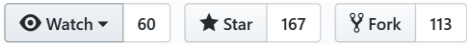
From Prototype to OSS Project

Stability & Reliability

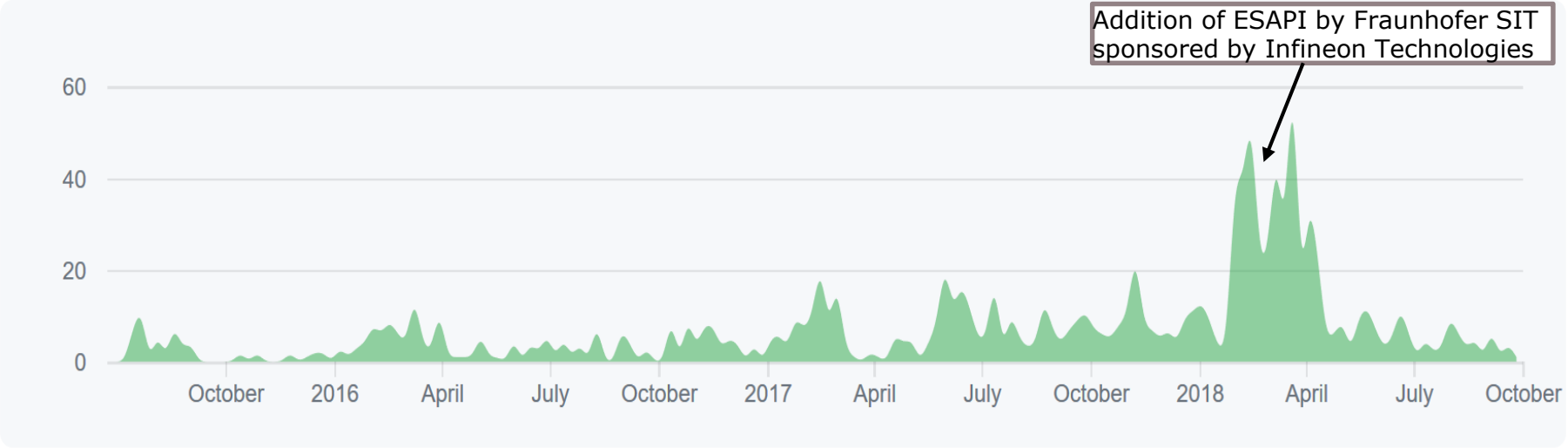
- Eliminate liabilities / high priority technical debt
  - Make it debuggable
  - Use the right tools for the task
  - Complete re-write of resource mgmt. daemon
- Model a healthy OSS project
  - Friendly to packaging for distros
  - Semantic versioning scheme: https://semver.org
  - Testing: unit & integration, make adding new tests easy
  - Continuous Integration (CI): travis-ci, coveralls, coverity & scan-build

TPM2-Software github org / project

- Community forming around development and use of TSS2 APIs
  - TPM2 Software Github Org: https://github.com/tpm2-software
  - Mailing list: https://lists.01.org/mailman/listinfo/tpm2
  - Core libraries: https://github.com/tpm2-software/tpm2-tss
  - Command line tools: https://github.com/tpm2-software/tpm2-tools
  - OpenSSL Engine: https://github.com/tpm2-software/tpm2-openssl-engine
  - Resource Mgmt: https://github.com/tpm2-software/tpm2-abrmd
  - PKCS#11 Engine: https://github.com/tpm2-software/tpm2-pkcs11 **(*NEW*BETA*)**
- Community
  - Maintainers from: Intel, Fraunhofer SIT, RedHat
  - Contributions from: Infineon, Facebook, Alibaba, RedHat, GE, Suse, Debian
- New Projects
  - UEFI TCTI, cryptsetup integration, RC decoding library & spec



TPM2-TSS Commit activities



Downstream adoption

- Packaging for distros
  - RHEL, Suse, Fedora, Debian, Ubuntu
  - 2.0 TSS2 release *should* make it into RHEL 8, missed SLES 15 ☹
- OpenEmbedded upstreaming effort underway
  - Maintained as part of meta-measured
  - Planning effort to upstream into OE proper: reduce duplication

Changelog

- Version 2.0.0 released on 2018-06-20
  - Compatibility with TPM 2.0 v1.38 spec
  - Support for some commands from 1.46 (Attached Component)
- New libraries / APIs
  - Type marshalling library: libtss2-mu
  - Enhanced System API: libtss2-esys (by FHG SIT, sponsored by IFX)
- Version 2.1.0 released on 2018-10-01 added Windows support for core
  - TCTI for communication with TBS: libtss2-tcti-tbs (by Facebook)
  - CI using AppVeyor

TSS2 use cases

Bootstrapping & Expanding Community

TPM Use cases / Examples

TSS2 built & installed … “Now what?”

- Reduce learning curve
- What TPMs are good for:
  - Data protection: root of trust for storage
  - Attestation: root of trust for reporting
  - Cryptography: protected keys & operations
- Start with basic crypto operations
  - No code required (maybe a little scripting)
  - Key creation & use
  - Interface to more familiar tools

tpm2-tools

- Command line tools for TPM2 operations
  - https://github.com/tpm2-software/tpm2-tools
  - Oftentimes a user's first experience with the TSS2
  - Started as a clone of the IBM command line tools from TSS for TPM 1.2
  - Has evolved into a near 1:1 mapping to TPM2 commands
  - Individual tool execs can be strung together to achieve a higher level task
    - Create policy assertion
    - Create object bound by policy
    - Save object to disk
    - …

tpm2-tools

- Next major release of the tools features:
  - port to new Enhanced System API
    - can implement HMAC/encrypted sessions without providing own crypto implementation
  - improved ease of use:
    - sane defaults
    - unified options
    - import/export objects in standard formats: DER & PEM

tpm2-tools example:
Sign data with TPM2 key / verify signature with OpenSSL

Refresh example from Davide Guerri @ FOSDEM 2017 [4]

1) Create primary key in storage hierarchy

```
tpm2_createprimary --hierarchy o --out-context pri.ctx
```

2) Create subkey for signing

```
tpm2_create --context-parent pri.ctx --pubfile sub.pub --privfile sub.priv
```

3) Load subkey

```
tpm2_load --context-parent pri.ctx --pubfile sub.pub --privfile sub.priv --out-context sub.ctx
```

4) Calculate the hash

```
openssl dgst -sha1 -binary -out hash.bin msg.txt
```

5) Sign the hash

```
tpm2_sign --key-context sub.ctx --format plain --digest hash.bin --sig hash.plain
```

6) Create OpenSSL compatible DER encoded public key

```
tpm2_readpublic -c sub.ctx --format der –out-file sub-pub.der
```

7) Verify the signature

```
openssl dgst -verify sub-pub.der -keyform der –sha1 -signature hash.plain msg.txt
```

tpm2-tss-engine

- Cryptographic engine for OpenSSL backed by the TPM.
  - https://github.com/tpm2-software/tpm2-tss-engine
  - Still no v1.0 release
- Currently supports:
  - RSA decryption
  - RSA signatures
  - ECDSA signatures
  - more to come…

tpm2-engine example:
Sign data and verify signature with OpenSSL (using TPM2 engine)

Same use-case as previous example using tpm2-tools

1) Create an RSA key

```
tpm2tss-genkey -a rsa -s 3072 key.bin
```

2) Export public key in PEM format

```
openssl rsa -engine tpm2tss -inform engine -in key.bin -pubout -outform pem -out key.pem
```

4) Calculate the hash

```
openssl dgst –sha256 –out hash.txt message.txt
```

5) Sign the hash

```
openssl pkeyutl -engine tpm2tss -keyform engine -inkey key.bin -sign -in hash.txt -out sig.bin
```

7) Verify the signature

```
openssl dgst -verify –pubin key.pem -sigfile sign.bin –in hash.txt
```

tpm2-pkcs11

- PKCS#11 Provider/Wrapper for the TPM
  - https://github.com/tpm2-software/tpm2-pkcs11
  - ***BETA* - not ready for production**
  - Based on PKCS#11 TPM2.0 work by irtimmer
- Currently status:
  - Works with OpenSSL and P11kit, more or less
  - Still a lot of bugs and unimplemented features
  - Not 100% spec conforming yet
  - Internal data format not yet fixed.
  - SAPI based

  ➔ HELP Wanted!

tpm2-pkcs11 example:
Use a TPM backed key for SSH authentication

1) Initialise a tpm2-pkcs11 store with a primary object slot

```
tpm2_ptool.py init --pobj-pin myobjpin
```

2) Add a token with the unique name “ssh”

```
tpm2_ptool.py addtoken --pid=1 --pobj-pin=myobjpin --sopin=mysopin --userpin=myuserpin --label=ssh
```

3) Add a key to the token for SSH to use

```
tpm2_ptool.py addkey --algorithm=rsa2048 --label=ssh --userpin=myuserpin
```

4) Generate the SSH key public portion

```
ssh-keygen -D /usr/lib64/pkcs11/libtpm2_pkcs11.so | tee my.pub
```

5) Configure SSH to accept the key (on the server)

```
ssh-copy-id my.pub user@host
```

6) Start a secure shell session

```
ssh -I /usr/lib64/pkcs11/libtpm2_pkcs11.so user@host
Enter PIN for 'ssh': myuserpin
Last login: Fri Sep 21 13:28:31 2018 from somehost
```

Further Downstream Projects

- clevis: auto unlock of LUKS encrypted disks [5]
- strongswan: read X.509 certificates stored in the TPM [6]
- openconnect: TPM wrapped private keys locked to the TPM device, via OpenSSL engine or GnuTLS (in-development, coming in 8.0 release) [7]
- cryptsetup/LUKS: store LUKS key in the TPM and use password/PCR authorization (in-development) [8]

Your Turn – Help Wanted

Working with TSS

- Develop against the simulator
- Prototype with tpm2-tools
- Use tpm2-software projects (BSD-3-Clause) for reference
- Use the debugger
  - Can put both the application and the simulator in the debugger and compare the expected state to try and reverse engineer where things have gone wrong
- Once everything works try with a real TPM
  - SLB9670 Iridium Board [9], Infineon
  - Letstrust TPM [10], Buyzero (with SLB 9670)
  - Intel discrete TPM
  - Intel PTT fTPM

Help wanted

More software could enable TPM2.0 support via our stack, e.g.:

- OpenVPN
- WireGuard
- Tinc
- NetworkManager/wpa_supplicant 802.1X
- gnome-keyring
- KDE wallet
- GNU TLS
- mbedTLS
- Language Bindings!
- **/* insert your project here */**

References

- [1] http://opensecuritytraining.info/IntroToTrustedComputing.html
- [2] https://www.theiet.org/resources/books/computing/tpmwhy.cfm
- [3] https://google.github.io/tpm-js/
- [4] https://archive.fosdem.org/2017/schedule/event/tpm2/
- [5] https://blog.dowhile0.org/2017/10/18/automatic-luks-volumes-unlocking-using-a-tpm2-chip/
- [6] https://wiki.strongswan.org/projects/strongswan/wiki/TPMPlugin
- [7] http://www.infradead.org/openconnect/tpm.html
- [8] https://github.com/AndreasFuchsSIT/cryptsetup-tpm-incubator
- [9] https://www.infineon.com/cms/en/product/evaluation-boards/iridium9670-tpm2.0-linux/
- [10] https://buyzero.de/products/letstrust-hardware-tpm-trusted-platform-module?variant=33890452626#

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