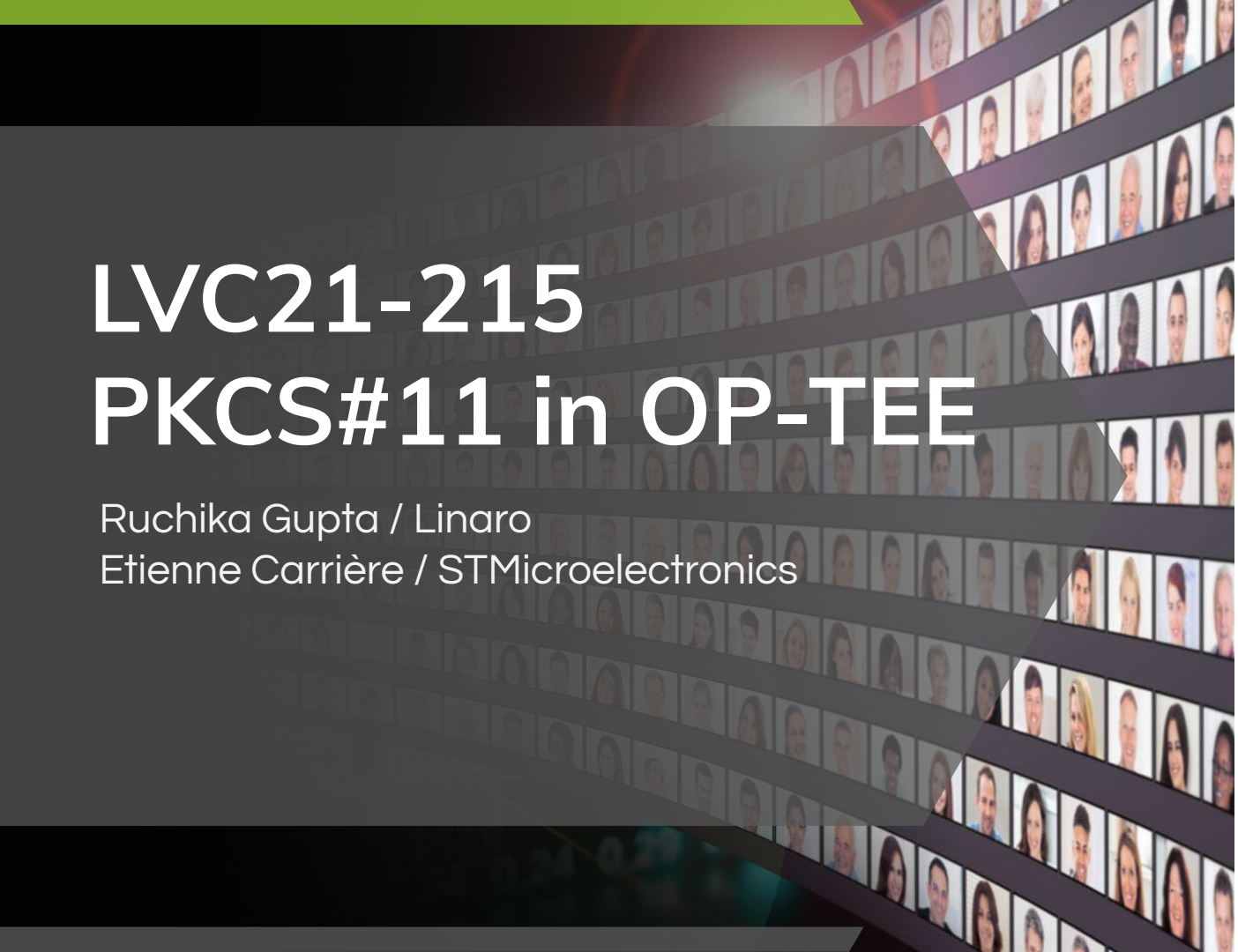

LVC21-215
PKCS#11 in OP-TEE

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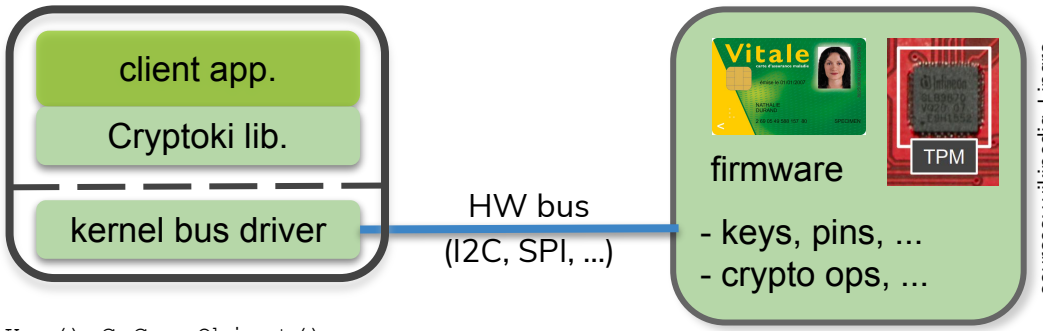
Linaro Connect
VIRTUAL • SPRING 2021

Agenda

- PKCS#11 specifications
- OP-TEE and GPD TEE specifications
- Status in 3.12.0
- libckteec
- pkcs11 TA
- Next steps

PKCS#11 specifications

- Specifications
  - Considering the 2 latest version: v2.40-errata-01 & v3.0
  - 5 documents (base, profiles, 2 mechanisms docs, user guide) + Cryptoki C/C++ header files
- Interface to manage remote cryptographic operations & objects
  - Remote objects (raw data, formated keys, certificates)
  - Remote operations using the remote objects (ciphering, authentication, key derivation, ...)
- User authentication
  - 1 SO + 1 user per token
  - PIN based authentication
  - Alternate authentication




```
C_Initialize() C_OpenSession() C_Login() …
C_CreateObject() C_GenerateKeyPair() C_DeriveKey() C_CopyObject() …
C_FindObjects() C_GetAttributes() C_SetAttributes() …
C_Encrypt() C_Decrypt() C_Sign() C_Verify() …
```

PKCS#11 as a standard

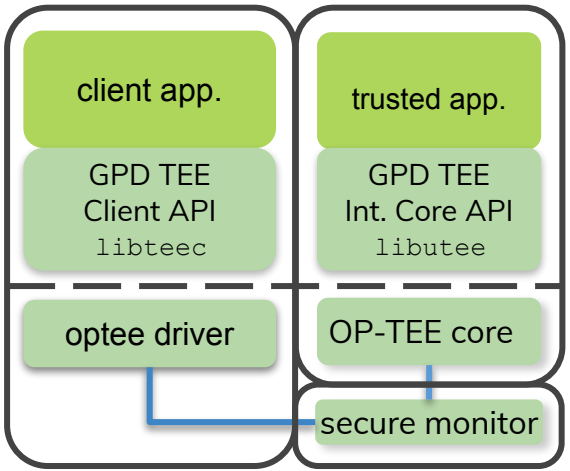
Several standard packages support interfacing PKCS#11 tokens

OpenSSH	github.com/OpenSC/OpenSC/wiki/OpenSSH-and-smart-cards-PKCS%2311 fossies.org/linux/openssh/ssh-pkcs11-helper.8
gnuTLS	www.gnutls.org/reference/gnutls-pkcs11.html
OpenSSL	No PKCS#11 engine in native OpenSSL. OpenSC proposes one (RedHat, Ubuntu, ...)
python	pypi.org/project/python-pkcs11/
AWS	Use PKCS#11 for the cryptographic operations control and alternate user authentication
LUKS	0pointer.net/blog/unlocking-luks2-volumes-with-tpm2-fido2-pkcs11-security-hardware-on-systemd-248.html
OP-TEE	:-)

Warning: specifications may have weaknesses if not flaws and should be carefully handled

OP-TEE & GPD TEE specifications

- OP-TEE is an enclave that:
  - Manages isolated trusted applications (PKCS#11 token is not the sole secure service)
  - Manages secure objects as keys for secure operations
  - Leverages platform capabilities (HW accel., ...)
  - Supports Arm7/v8 Cortex-A CPUs, RiscV in progress
  - Mostly 2 clause BSD license terms
  - https://github.com/OP-TEE
    Started in 2014, 3.x.0 series since 2018, latest is 3.12.0

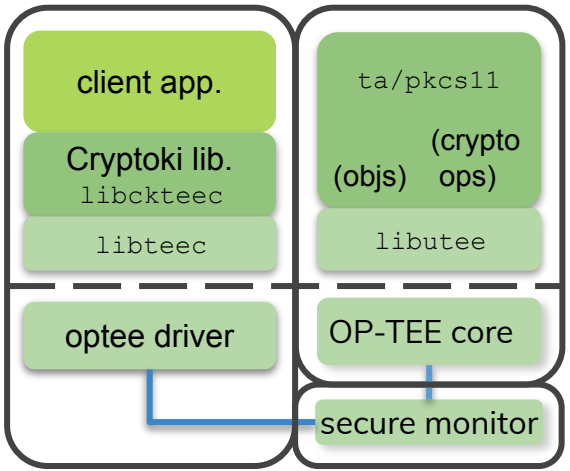


- OP-TEE is based on GPD TEE APIs
  - Does not expose object/crypto API functions to client
  - Client opens/closes sessions toward trusted app. and invokes commands (4 params)
  - In 2017 Linaro investigated on a pkcs11 TA, presented at HKG18-402

PKCS#11 Token in an OP-TEE TA

- Goal: deliver a PKCS#11 solution, reliable and maintained by the OP-TEE community

- Expose Cryptoki API to Linux user space application
  - ckteec library, 2 clause BSD license,
    hosted in optee_client.git
  - Converts Cryptoki API function call in a GPD TEE TA
    invocation command/arguments message



- PKCS#11 token is implemented in an OP-TEE TA
  - Based on GPD TEE APIs for secure storage & crypto
  - Implements PKCS#11 specification,
  - 2 clause BSD license, hosted in optee_os.git

- Regression tests: pkcs11 testsuite in OP-TEE `xtest`, hosted in optee_test.git

Achievements

- Slot and token discovery
- User session management
- User authentication (PIN & Linux ACL)
- Object (session and permanent) creation and generation (AES keys and generic secrets)
- Key derivation (by AES encryption)
- Ciphering (a bit of AES: CBC & ECB)
- MAC computation (SHA*_HMAC)
- Digest (SHA*)
- Random number generation
- Self-made pkcs11 regression tests running in OP-TEE CI

Give a try!

Download OP-TEE manifest for Qemu Arm (**default.xml**[(1)]), build and run Qemu with `host> make run CFG_PKCS11_TA=y`

From embedded shell: `sh> pkcs11-tool --list-token-slots`

(1): qemu_v8.xml: `make run CFG_PKCS11_TA=y CFG_USER_TA_TARGET_pkcs11=ta_arm64`

libckteec

- Cryptoki API in Linux userland
  - 1 Cryptoki API function for 1 pkcs11 TA command ID
  - Serialize client arguments to sent to TA (attributes lists, various structures passed)
  - Deserialize data sent back from TA (object attributes retrieved)
  - No complex processing expected : a thin API wrapper
- As of pre-3.13.0, almost all the main API functions are defined in pkcs11 TA API or will soon be.

```
C_Initialize() C_Finalize() C_GetInfo() C_GetFunctionList() C_GetSlotList() C_GetSlotInfo() C_GetTokenInfo()
C_GetMechanismList() C_GetMechanismInfo() C_InitToken() C_InitPIN() C_SetPIN() C_OpenSession() C_CloseSession()
C_CloseAllSessions() C_GetSessionInfo() CK_C_Login() C_Login() C_Logout() C_CreateObject() C_CopyObject()
C_DestroyObject() C_GetObjectSize() C_GetAttributeValue() C_SetAttributeValue() C_FindObjectsInit() C_FindObjects()
C_FindObjectsFinal() C_EncryptInit() C_Encrypt() C_EncryptUpdate() C_EncryptFinal() C_DecryptInit() C_Decrypt()
C_DecryptUpdate() C_DecryptFinal() C_DigestInit() C_Digest() C_DigestUpdate() C_DigestKey() C_DigestFinal() C_SignInit()
C_Sign() C_SignUpdate() C_SignFinal() C_VerifyInit() C_Verify() C_VerifyUpdate() C_VerifyFinal() C_GenerateKey()
C_GenerateKeyPair() C_WrapKey() C_UnwrapKey() C_DeriveKey() C_SeedRandom() C_GenerateRandom()
```

- Few are still missing, contributions are welcome:

```
C_GetOperationState() C_SetOperationState() C_SignRecoverInit() C_SignRecover() C_VerifyRecoverInit() C_VerifyRecover()
C_DigestEncryptUpdate() C_DecryptDigestUpdate() C_SignEncryptUpdate() C_DecryptVerifyUpdate()
C_GetFunctionStatus() C_CancelFunction() C_WaitForSlotEvent()
```

pkcs11 TA

- Client sessions
  - TA can implements several PKCS#11 tokens
  - Authentication based on a hash of client PIN/credentials
  - Session and object references are registered in lists in the TA space
- Objects
  - An object is a list of attributes built as a serialized byte stream
  - When object is created, attributes are added in a PKCS#11 consistent way
  - When object is used, TA checks object is visible/usable to the client for the operation
- Crypto operations
  - A token can executes a single operation at a time : the active processing.
    It must be initialized and finalized, as specified in PKCS#11.
  - Object used or generated during a operation is verified against PKCS#11 rules:
    Token state, object constraints, mechanism constraints, operation constraints, ...
  - TA relies on GPD TEE API for crypto and object storage

User authentication

- Standard default PIN based authentication (SO and user)

- Linux ACL based authentication: no PIN, only caller user and/or group IDs
  - Contributions from Vesa and Eero from Vaisala Oyj
  - Use of ACL TEE client identity: github.com/OP-TEE/optee_os/pull/4222 and related
  - Proposed configuration tool: github.com/OP-TEE/optee_client/pull/259

- Other alternate authentication can be considered
  - Coupled ACL + PIN
  - Dedicated platform means (I.e. HW under OP-TEE control)
  - ...

Testing

- A new pkcs11 testsuite is added in OP-TEE's xtest
  - For each new feature in pkcs11 TA, a xtest is implemented
  - Tests legitimate and invalid manipulations of objects/operations through Cryptoki API
  - Also tests the crypto algorithm minimal compliance (xtest test vectors and means)
  - Integrated in OP-TEE CI

    Build with `CFG_PKCS11_TA=y`

    From embedded shell: `sh> xtest -t pkcs11`
- pkcs11test
  - pkcs11test is PKCS#11 tester tool which uses Google Test.
    - Build: `sh> make CXX=/path/to/aarch64-linux-gnu-g++ AR=/path/to/aarch64-linux-gnu-ar`
    - From embedded shell: `sh> pkcs11test -m libckteec.so -s 0 --gtest_filter=<test name>`

Note: This testing is WIP. We are using these tests as we develop features for basic sanity.
You may see failures when testing.

Testing

- SoftHSM
  - Is a software based implementation of HSM
  - Has a rich unitary test library which we are building standalone and using with libckteec.so
  - Steps to compile and use it can be found at https://github.com/ruchi393/softhsm-ut-arm

- pkcs11-tool
  - Integrated in Buildroot environment
  - Get tokens/slots info

    `pkcs11-tool --show-info` `pkcs11-tool --list-token-slots` `pkcs11-tool --list-mechanisms`
  - Initialize token and user PIN

    ```
    pkcs11-tool --init-token --label test-token --so-pin 1234567890
    pkcs11-tool --label test-token --login --so-pin 1234567890 --init-pin --pin ABCDEFGHIJ
    ```
  - Generate AES Key

    ```
    pkcs11-tool --token-label foo --pin 123 --keygen --key-type AES:16 --id 1 --label
    my-key
    ```
  - List Objects

    `pkcs11-tool --token-label test-token --list-objects`

Next steps

- Wrap/unwrap keys
- RSA ciphering and authentication <--- next steps before real world application
- ECDSA & ECDH <---------- next steps before real world application
- DSA, DH
- More symmetric ciphers, MACs and KDFs
- Improve data storage
- Garbage collection of secure storage content <--- needed for long term stability
- Documentation in optee docs.
- Enhance tokens isolation and parallelization
- Test results improvements - pkcs11test and SoftHSM
- ...

Contributions are welcome!

`ta/pkcs11`

`libckteec`

Many thanks to contributions, being code, review comments or issue reports,

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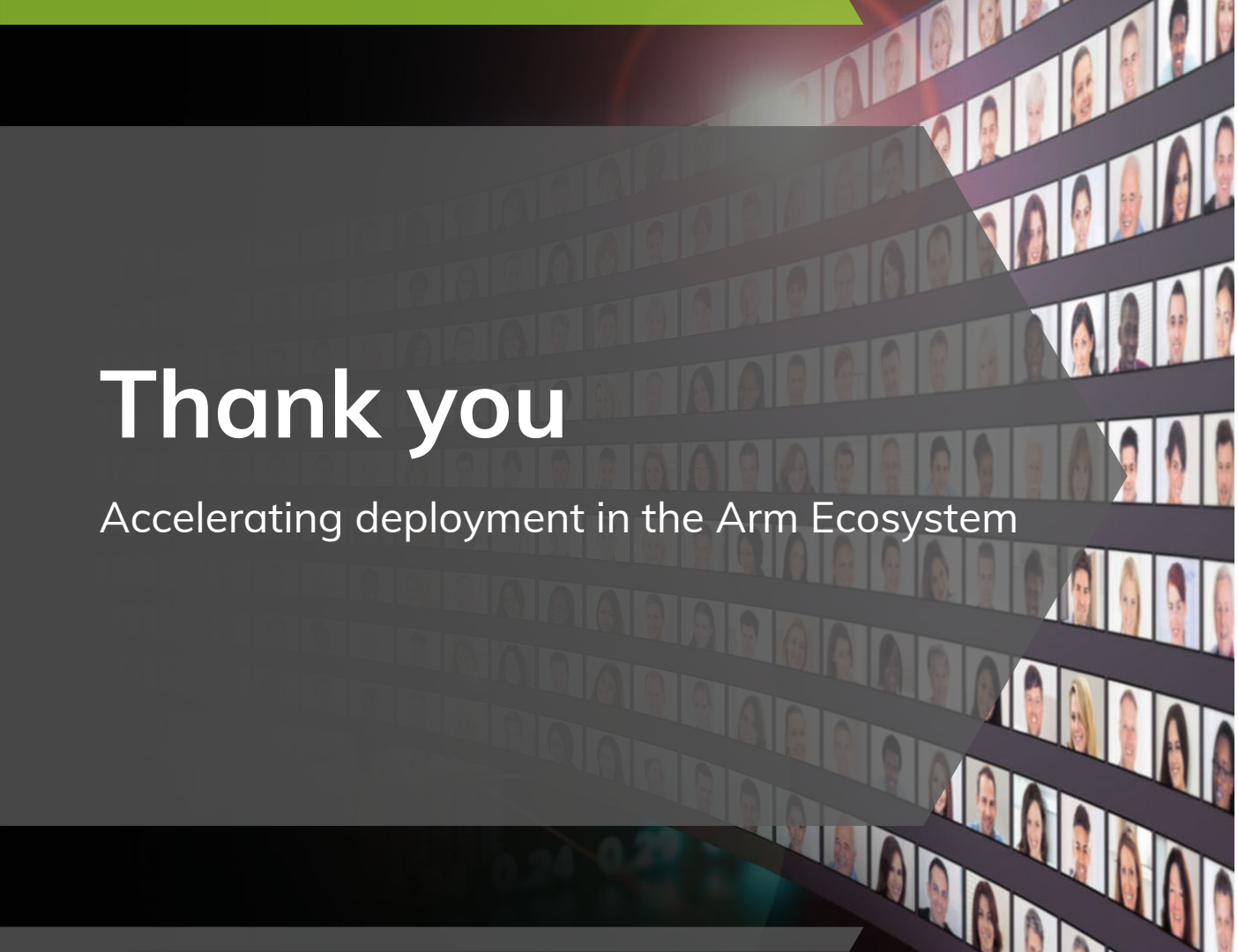

Thank you

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