HKG18-402: Secure Key Services in OP-TEE

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Agenda

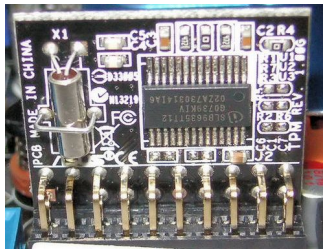
- Overview of Secure Key Services
- What is OP-TEE?
- Which Client Interface?
- Implementation: the SKS
- What’s next?

HSM, SE, TPM, TEE: Secure Services

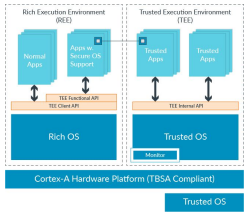
- Hardware Security Module (HSM)

- Secure Elements as Smartcard, SIM cards.
  https://www.globalplatform.org/mediaguideSE.asp

- Trusted Platform Modules (TPM devices)
  https://trustedcomputinggroup.org/work-groups/trusted-platform-module/



- Trusted Execution Environment (TEE)
  Several standards including the GPD TEE
  https://www.globalplatform.org/specificationsdevice.asp



Pictures: source wikipedia (public domain) and ARM ©

HSM, SE, TPM, TEE: Secure Keys

HSMs, SEs, TPMs provide secure key management services:

- Key materials and cryptographic operations are very hard to tamper with.
- Client can import, generate, derive keys and cipher, sign, authenticate data.
- Secure keys have usage constraints.
- Use of secure keys may require user authentication.

How can the open source help in secure key management services?

TEEs as OP-TEE are suitable to propose such HSM services.
Sadly there is no uniform interface on which OP-TEE could build such a service.

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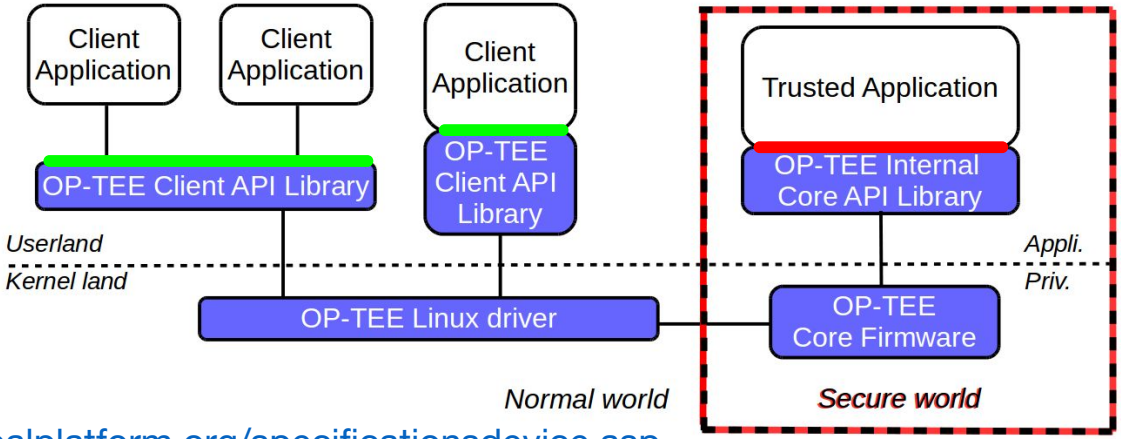
What is OP-TEE?

- Open source Trusted Execution Environment for Armv7/Armv8-A platforms.
- OP-TEE relies on the GPD TEE Client API specifications
- OP-TEE relies on the GPD TEE Internal Core API specifications.



https://www.globalplatform.org/specificationsdevice.asp

What is OP-TEE?

OP-TEE relies on the GPD TEE Client and Internal Core API specifications

Step 1: Client opens a session toward a trusted application (TA).

➥ Trusted application identifies client and returns a session handle.

Step 2: Client invokes TA commands each with up to 4 parameters.

➥ Trusted application checks the 32bit command ID and its parameters.

➥ Trusted application executes the command.

➥ Trusted application returns a status, eventually output data.

Step 3: Client closes the session.

What is OP-TEE?

GPD TEE Internal Core API functions for secure storage and cryptography:

- Secure Storage relates functions

  `TEE_CreatePersistentObject()`, `TEE_OpenPersistentObject()`, `TEE_CloseAndDeletePersistentObject1()`, `TEE_ReadObjectData()`, `TEE_WriteObjectData()`, `TEE_TruncateObjectData()`, `TEE_SeekObjectData()`.

- Cryptographic operations functions

  `TEE_DigestInit/Update/DoFinal()`, `TEE_CipherInit/Update/DoFinal()`, `TEE_MACInit/Update/ComputeFinal/CompareFinal()`, `TEE_DeriveKey()`, `TEE_AEInit/AEUpdateAAD/AEUpdateAAD/AEEncryptFinal/AEDecryptFinal()`, `TEE_AsymmetricEncrypt/Decrypt/SignDigest/VerifyDigest()`, `TEE_GenerateKey()`.

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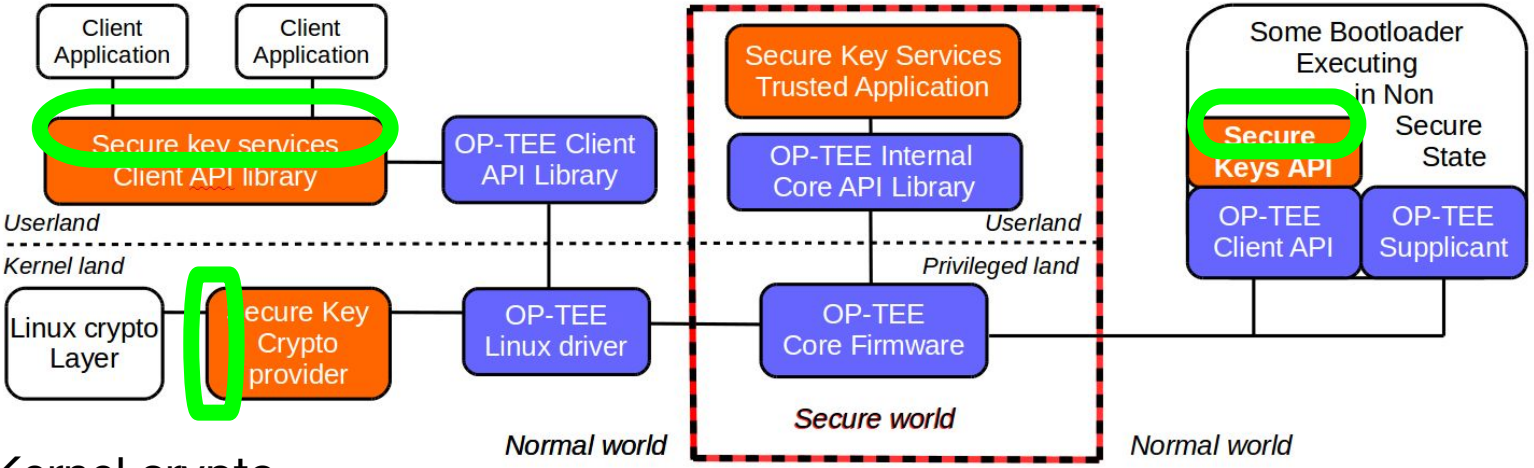
Secure Key Services: Which Client Interface?

Userland Applications

Bootloader



Kernel crypto services

… also for Trusted Applications?

Secure Key Services: Which Client Interface?

Linux kernel services:

- OP-TEE could register transformation providers to the Linux kernel Crypto API. https://www.kernel.org/doc/html/v4.15/crypto/index.html
- Requires integration of the kernel client API in OP-TEE Linux driver.

Bootloader clients

- An OP-TEE portable client library to leverage TEE from bootloaders?
- OP-TEE secure storage currently relies on physical media access through REE. Secure key service at boot implies TEE supplicant services in the bootloader.

Secure Key Services: Which Client Interface?

Userland clients: which API?

- Mainly proprietary libraries and interfaces in vendor solutions.
- TPM Interface (https://trustedcomputinggroup.org/tpm-library-specification)
  - TPM already comes with an integration framework (TSS).
  - TPM lacks secure time to bound object time validity.
- Android Keystore (https://developer.android.com/.../keystore.html)
  - Very rich featured API but requires some of the Android support.
- PKCS #11/Cryptoki (https://www.oasis-open.org/committees/pkcs11)
  - Quite rich and extendable interface.
- Others libraries or APIs defined in the open source community?

Secure Key Services: Which Client Interface?

Lot of convergence of Android Keystore and PKCS #11 APIs:

- Crypto algorithms, operations atomicity, objects generic attributes.

PKCS #11:

- Referenced in many frameworks (i.e simalliance, amazon-freertos, linuxonibm).
- User authentication is restricted to a Security Officer and a single user.
- Flexible for extensions of object attributes and crypto schemes.

Android Keystore (far not exhaustive):

- More key attributes and rich binding with client application identity.
- Attestation of keys and device information using certificates.

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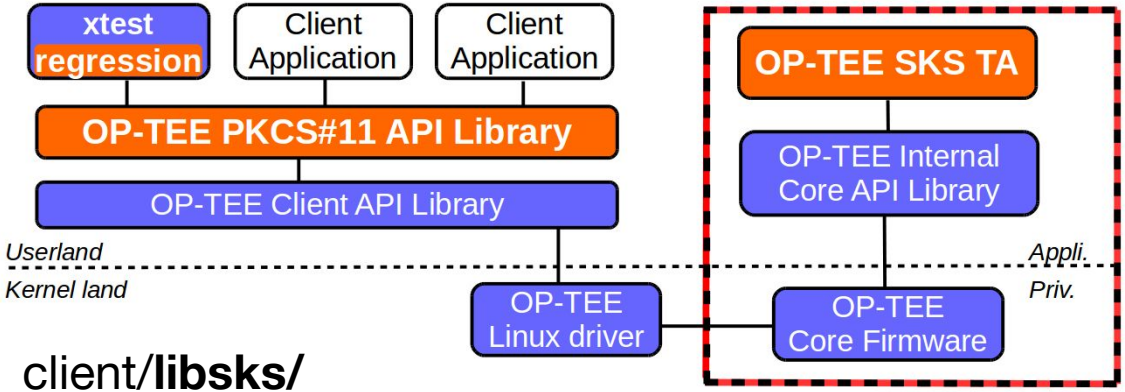
OP-TEE SKS Proposal



PKCS #11 API userland library

➔ github.com/OP-TEE/optee_client/**libsks/**

Trusted Application: the SKS TA

➔ github.com/OP-TEE/optee_os/**ta_services/secure_key_services/**

OP-TEE regression test environment

➔ github.com/OP-TEE/optee_test/**host/xtest/regression_xxxx.c**

OP-TEE SKS Proposal

First start by a workbase delivery:

- Very reduced cryptographic support (AES flavors, maybe a bit of RSA or ECC).
- Reduced set of PKCS #11 functions.
- Integration with Linux userland applications only.

Then will come more cryptographic support.

Then will come kernel and bootloader interfaces.

Then will come extended object attributes?

Contributions will be welcome!

OP-TEE SKS Proposal

PKCS #11 Cryptographic Token - https://www.oasis-open.org/committees/pkcs11/

Latest as of today (March 2018) is the Specifications Version 2.40 Plus Errata 01:

- The Interface Base Specification defines the functions and most ABI.
- The Current Mechanisms Specification lists mechanisms and their parameters.
- The Interface Historical Mechanisms lists historical mechanisms (i.e DES).
- Three C/C++ code header files:

Name	Last Modified	Size
pkcs11.h	13-May-2016 16:00	8k
pkcs11f.h	13-May-2016 16:00	27k
pkcs11t.h	13-May-2016 16:00	70k

SKS TA API

- PKCS #11 defines API functions and their arguments.

  ➥ The SKS TA API defines one command per PKCS #11 function.

  TA command parameters reflect the PKCS #11 function arguments.

```
C_InitToken()      → SKS_CMD_CK_INIT_TOKEN
C_CreateObject()   → SKS_CMD_IMPORT_OBJECT
C_EncryptInit()    → SKS_CMD_ENCRYPT_INIT
C_EncryptUpdate()  → SKS_CMD_ENCRYPT_UPDATE
C_EncryptFinal()   → SKS_CMD_ENCRYPT_FINAL
C_CloseSession()   → SKS_CMD_CK_CLOSE_SESSION
```

SKS TA API

Objects: An object is a collection of **attributes**

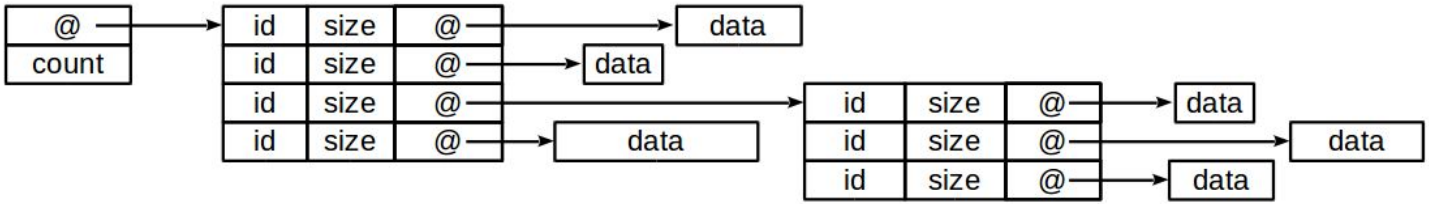
- Class and type in class, i.e a symmetric key for an AES processing.
- Secret object secret value(s), i.e an AES key value.
- Identification means: label, ID, and very few others.
- Storage attributes: persistent, non modifiable, etc...
- Use constraints: allowed operations, time validity, user authentication, etc...

```
CKA_CLASS, CKA_KEY_TYPE, CKA_VALUE, CKA_LABEL, CKA_ID, CKA_START_DATE, CKA_END_DATE,
CKA_TOKEN, CKA_PRIVATE, CKA_ENCRYPT, CKA_DECRYPT, CKA_DERIVE, CKA_SIGN, CKA_VERIFY,
CKA_EXTRACTABLE, CKA_SENSITIVE, CKA_MODIFIABLE, CKA_COPYABLE, CKA_DESTROYABLE,
CKA_MECHANISM_TYPE, CKA_ALLOWED_MECHANISMS, CKA_UNWRAP_TEMPLATE, etc...
```

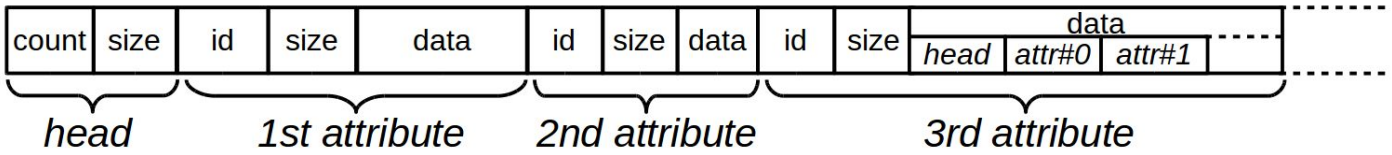
SKS TA API

Objects: An object is a collection of **attributes.**

An attribute is a triplet **attribute-ID/value-byte-size/value-data**.



Representation of an object in the PKCS#11 ABI



Representation of an object in the SKS TA ABI

SKS TA API

Mechanisms are cryptographic operation schemes defined by:

- An identification number;
- Formatted parameters required to initialize a crypto operation;
- Ability to execute processing modes or functions (i.e encrypt, sign, derive).

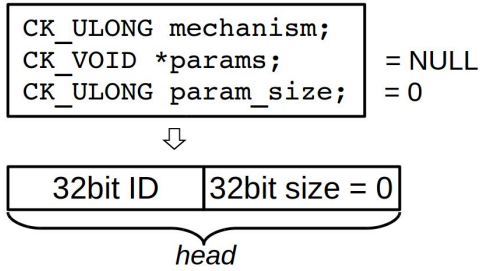
Examples of PKCS #11 mechanisms:

- AES MAC: `CKM_AES_MAC`, no parameter, supports sign and verify.
- AES CBC: `CKM_AES_CBC`, requires an IV, supports encryption and decryption.
- AES GCM: `CKM_AES_GCM`, requires an IV, an AAD and a tag size, can be used to encrypt and decrypt Authenticated Encryption (AE) messages.

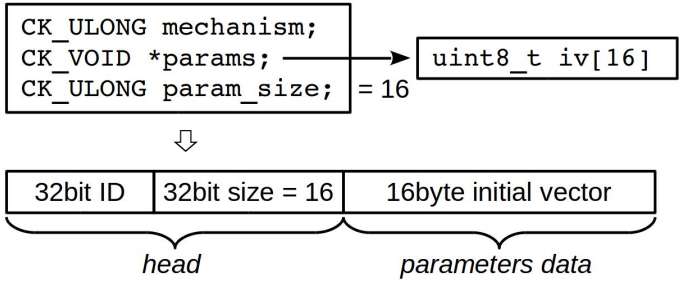
SKS TA API

Format of mechanism parameters in the PKCS #11 and SKS TA ABIs

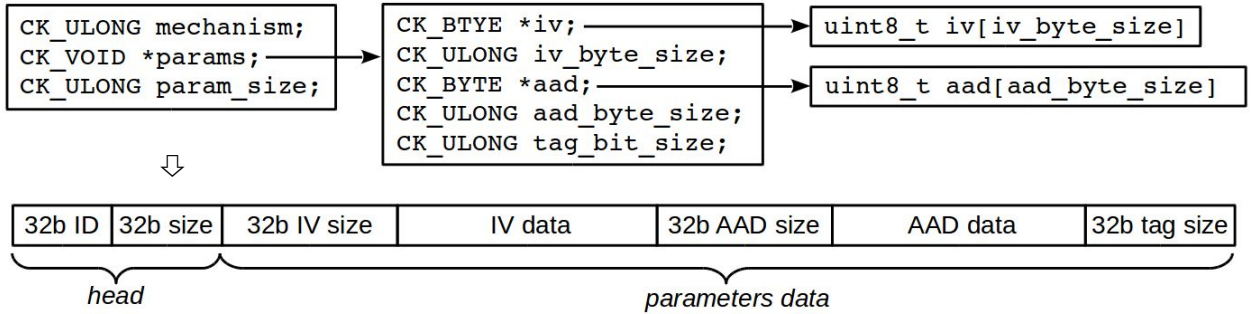
AES MAC has no parameter



AES CBC needs a 16-byte IV



AES GCM requires a structured parameters set



SKS TA: Processing

Processing functions follow the same sequence in the SKS trusted application:

```
C_DeriveKey()
    C_EncryptInit()
        C_GenerateKey()
            C_VerifyUpdate()
                ...
```

- Get/check parameters.
- Check function against session state.
- Prepare created key (if any) attribute list.
- Check created key (if any) against session state.
- Check created key (if any) against function.
- Check used key (if any) against session state.
- Check used key (if any) against function.
- Process requested crypto operation → wrap to GPD TEE crypto API.
- Register created key (if any).
- Return a status and an object handle or processed data.

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Current Status

As of March 2018:

- Proposed an API for the TA that reflects the PKCS #11 API.
- Supports token info retrieve and sessions functions.
- Supports persistent storage of keys and token state.
- Import and generation of generic secrets and AES keys.
- AES in modes ECB, CBC, CTS, CTR, GCM and CCM.
- SHA*xxx* HMACs, AES CMAC, AES CBC MAC.
- Several token management and set/get attributes functions are **not** supported.
- Test environment still weak.

What's Next - Short Term

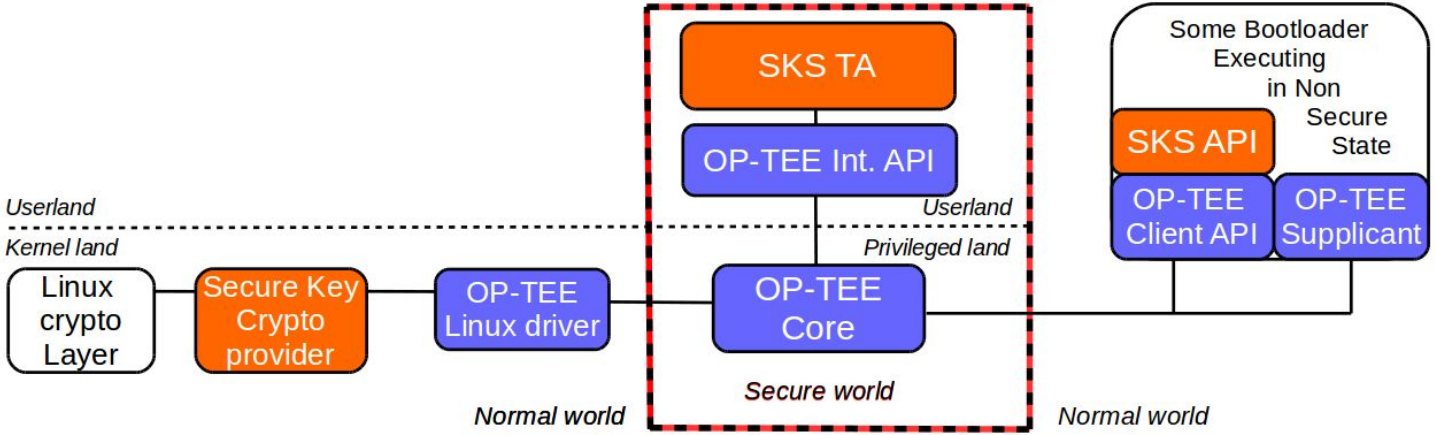
- Enhance the tests and constraints on client parameters. Existing PKCS #11 test frameworks?
- Consider delivery in OP-TEE 3.1.0 if mature enough.
- Contributions will be welcome to enhance the set of crypto algorithms and mature the implementation.

What's Next - Long Term

- Issue #1: certificate support
  - Current OP-TEE does not provide any certificate support.
  - Secure parsing of X.509 certificates is known to be touchy.
- How to provision the SKS key database with platform secrets (i.e OTP fuses)?
- Interface keys and operations deported in a more secure backend HSM/SE?
- Consider convergences with an Android keystore solution.
- Looking forward PKCS #11 Version 3.0 (cryptsoft.com).

What's Next

- Integrate in a filesystem encryption setup
  - May requires SKS TA services at boot stage (on going work by Igor Opaniuk for a portable OP-TEE client library).
  - Requires the OP-TEE kernel client API in the Linux optee driver.
  - SKS TA can be a transformation providers in the Linux Crypto API.



What's Next - Short Term

Provisioning and token ownership

- Clarify the provisioning sequences.
- How should we handle several PKCS #11 tokens?
- Can we create on request provisioned tokens with delegated ownership?

Release the SKS TA during long lasting operations

- An OP-TEE TA is not reentrant.
- Could the SKS TA delegate a crypto processing to a TA instance?

Thank You

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For further information: www.linaro.org

Some extra slides...

PKCS #11 Attributes (1/3)

- Attribute CKA_CLASS

  CKO_DATA, CKO_CERTIFICATE, CKO_PUBLIC_KEY, CKO_PRIVATE_KEY, CKO_SECRET_KEY, CKO_HW_FEATURE, CKO_DOMAIN_PARAMETERS, CKO_MECHANISM, CKO_OTP_KEY, CKO_VENDOR_DEFINED.

- Attribute CKA_KEY_TYPE

  CKK_RSA, CKK_DSA, CKK_DH, CKK_EC, CKK_AES, CKK_SHA256_HMAC, CKK_HOTP, CKK_DES3, CKK_GENERIC_SECRET, and more.

- Attribute CKA_CERTIFICATE_TYPE

  CKC_X_509, CKC_X_509_ATTR_CERT, CKC_WTLS, CKC_VENDOR_DEFINED

PKCS #11 Attributes (2/3)

- Boolean Attributes

CKA_TOKEN	CKA_PRIVATE	CKA_ALWAYS_AUTHENTICATE
CKA_ENCRYPT	CKA_DECRYPT	CKA_DERIVE
CKA_WRAP	CKA_UNWRAP	
CKA_SIGN	CKA_SIGN_RECOVER	
CKA_VERIFY	CKA_VERIFY_RECOVER	
CKA_EXTRACTABLE	CKA_NEVER_EXTRACTABLE	
CKA_SENSITIVE	CKA_ALWAYS_SENSITIVE	
CKA_MODIFIABLE	CKA_COPYABLE	CKA_DESTROYABLE
CKA_LOCAL	CKA_TRUSTED	CKA_WRAP_WITH_TRUSTED

PKCS #11 Attributes (3/3)

- Other Attributes

  CKA_VALUE, CKA_VALUE_LEN,

  CKA_LABEL, CKA_OBJECT_ID, CKA_APPLICATION, CKA_ID,

  CKA_START_DATE, CKA_END_DATE,

  CKA_WRAP_TEMPLATE, CKA_UNWRAP_TEMPLATE, CKA_DERIVE_TEMPLATE,

  CKA_MODULUS, CKA_PRIVATE_EXPONENT, CKA_PRIME, CKA_EC_PARAMS, etc...,

  CKA_CERTIFICATE_CATEGORY, CKA_ISSUER, CKA_SERIAL_NUMBER, etc...,

  CKA_OTP_FORMAT, CKA_OTP_LENGTHCKA_OTP_TIME_INTERVAL,

  CKA_KEY_GEN_MECHANISM, CKA_LOCAL,

  CKA_MECHANISM_TYPE, CKA_ALLOWED_MECHANISMS,

  CKA_VENDOR_DEFINED

Android Keystore: Object Attributes

- Same common attributes as PKCS #11 for algo/function constraints on keys.
- PIN/password assignment per key.
- Key wrapped inside the secure device.
- Secret can be bound to boot stages.
- Specific encrypt/sign and decrypt/verify expiration dates.
- Bandwidth restrictions, access count restrictions.

https://source.android.com/security/keystore/tags

Android Keystore: Object Attributes

```
Tag::PURPOSE  Tag::ALGORITHM  Tag::KEY_SIZE
Tag::UNIQUE_ID  Tag::APPLICATION_DATA  Tag::APPLICATION_ID
Tag::BLOB_USAGE_REQUIREMENTS  Tag::BOOTLOADER_ONLY
Tag::MAX_USES_PER_BOOT  Tag::MIN_SECONDS_BETWEEN_OPS
Tag::USER_SECURE_ID  Tag::USER_AUTH_TYPE  Tag::NO_AUTH_REQUIRED
Tag::ORIGINATION_EXPIRE_DATETIME  Tag::USAGE_EXPIRE_DATETIME
...
```

https://source.android.com/security/keystore/tags

Android Keystore: API Functions

- Import/export raw symmetric keys and formated asymmetric keys.
- Generate and derive keys and usual ciphering and/or authentication algo.
- Attest a key: export a certificate for a given key.
- Attest a device hardware information in a certificate.

`addRngEntropy()`, `getHardwareFeatures()`,
`generateKey()`, `importKey()`, `getKeyCharacteristics()`,
`exportKey()`, `deleteKey()`, `deleteAllKeys()`, `destroyAttestationIds()`,
`begin()`, `update()`, `finish()`, `abort()`.

https://source.android.com/security/keystore/implementer-ref

End of extras

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