

Mapping SKS into a TEE/SE "Combo"

An SKS (Secure Key Store) may be self-contained like in a smart card, but it may also be architected as a TEE (Trusted Execution Environment) and SE (Security Element) combination.

The primary objectives for dividing an SKS into a TEE/SE combo include:

- Small SE footprint suitable for CPU integration
- Stateless SE-operation enabling simple virtualization
- Unlimited key storage
- Elimination of NVRAM
- Logical integration in modern operating systems

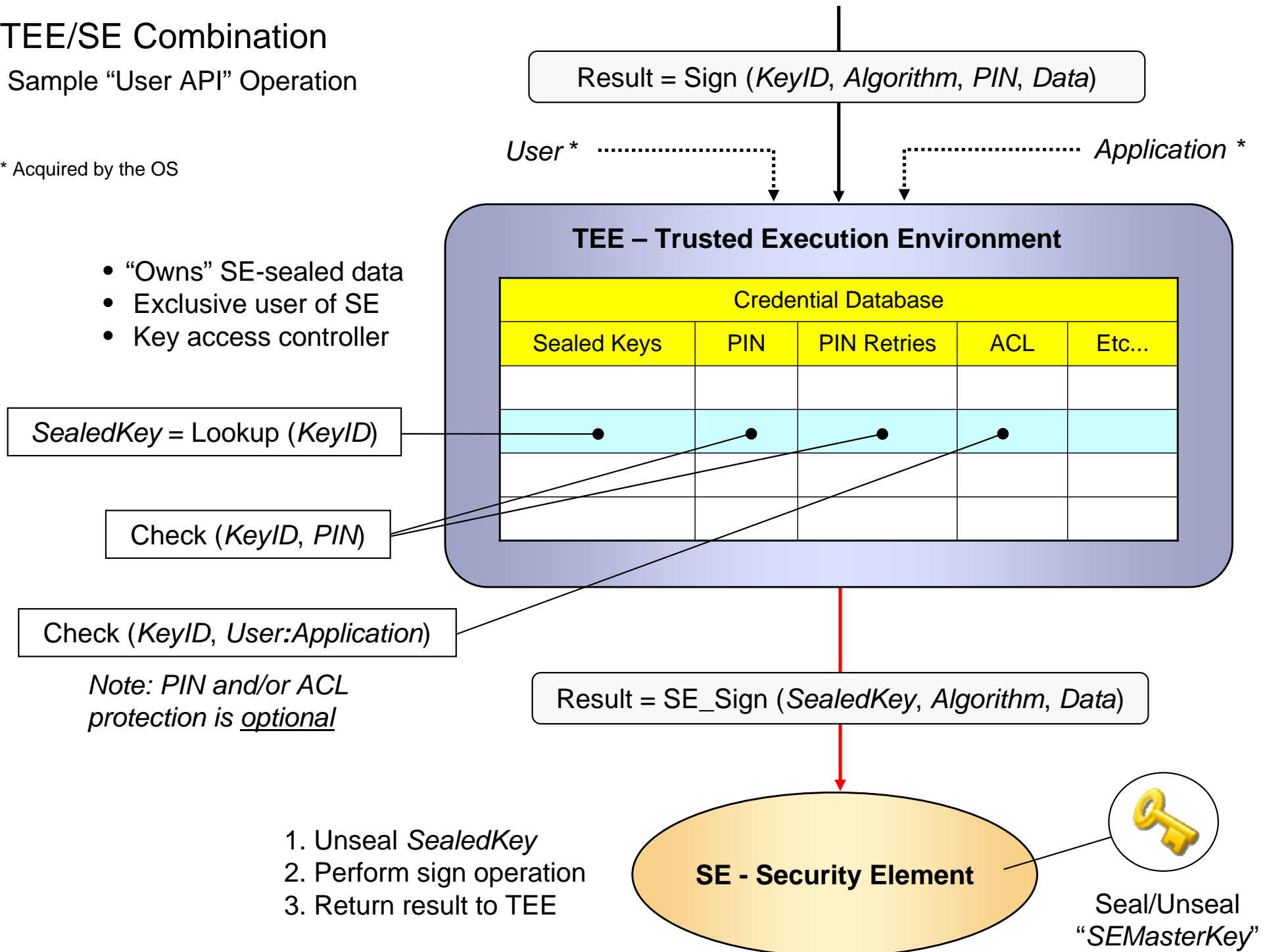
The described scheme is intended to work equally well in mobile phones as in high-performance servers.

The reader is supposed to be familiar with the SKS specification

TEE/SE Combination

Sample "User API" Operation

* Acquired by the OS



Anatomy of a *SealedKey*

```
class SealedKey
{
    byte[] wrappedKey;    // Encrypted PKCS #8 or symmetric key
    boolean isSymmetric;  // True if wrapped_key is symmetric
    boolean isExportable; // True if allowed to be unsealed to the TEE
    byte[] mac;           // Integrity control
}
```

Sealing Algorithm:

```
byte[] IV = randomNumber (16);
wrappedKey = IV || AES256-CBC (KDFencryption (SEMasterKey),
                               rawKeyValue, IV);

mac = HMAC-SHA256 (KDFmac (SEMasterKey),
                  isExportable || isSymmetric || wrappedKey);
```

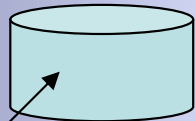
TEE/SE Combination

Simplified "Provisioning API" Operation

1. Create Provisioning Session

SessionData = createProvisioningSession (*ServerEphemeralKey*)

TEE – Trusted Execution Environment



SealedSessionKey, SessionData = SE_createProvisioningSession (*ServerEphemeralKey*)

1. Create a *SessionKey*
2. Seal *SessionKey*
3. Attest SessionData using *AttestationKey*
4. Return result to TEE

SE - Security Element



Seal/Unseal
"SEMasterKey"



SE Private
"AttestationKey"

TEE/SE Combination

Simplified "Provisioning API" Operation

2. Create Object in Session

KeyData = createKeyEntry (SessionID, KeySpecifier, KeyID, MAC)

TEE – Trusted Execution Environment

SealedSessionKey = Lookup (SessionID)

SealedKey, KeyData = SE_createKeyEntry (SealedSessionKey, KeySpecifier, KeyID, MAC)

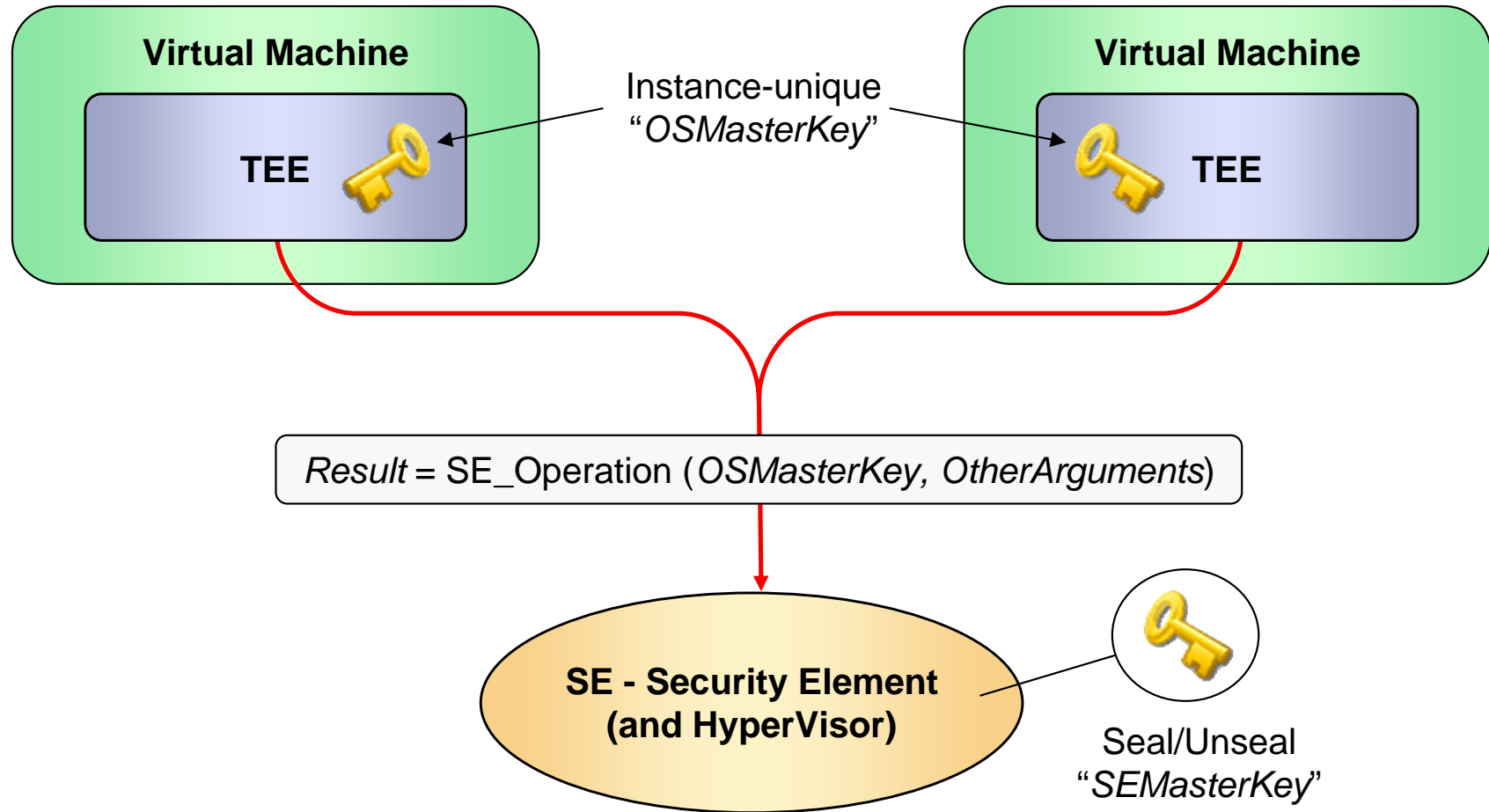
1. Unseal SealedSessionKey
2. Verify MAC using SessionKey
3. Create key-pair
4. Seal private key
5. Attest public key data using SessionKey
6. Return result to TEE

SE - Security Element

Seal/Unseal
"SEMasterKey"

TEE/SE Combination

Virtualization Support – Binding keys and provisioning sessions to Virtual Machines



Actual Seal or Integrity Key: $\text{KDF}_{\text{operation}}(\text{SEMasterKey}) \text{ XOR } \text{OSMasterKey}$

Q & A

Question: Is this really secure?

Rhetoric answer: Do TEE- or application-based embedded PINs and/or obfuscated code actually bring any sustainable and provable security values to the table?

Question: Could there even be advantages of using the TEE for access control?

Answer: Yes, it enables combining various kinds of access controls like restricting keys to specific applications or users, as well as using device-wide PINs. A TEE can also provide challenge-response authentication and encrypted tunnels without burdening the SE. A TEE typically also supports a “trusted GUI” removing PIN-entry from potentially untrusted applications

Question: How does the SE protect keys from theft?

Answer: The “seal” contains an attribute which tells if the key is non-exportable. Such keys will not be exported unsealed to the TEE even it asks for it!