ETH zürich ProtonMail

Key Extraction Attacks through Encrypted Private Key Corruption

Lara Bruseghini, Kenny Paterson, Daniel Huigens

Key corruption in insecure storage

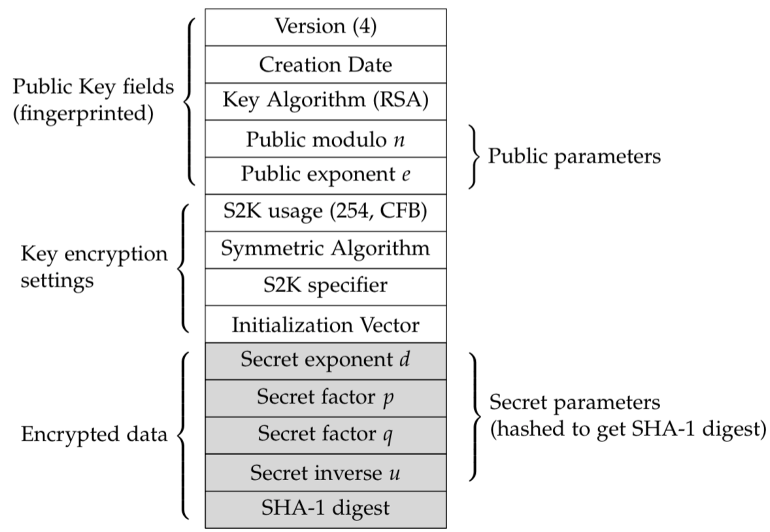
Threat model:

- Attacker has write access to encrypted private long-term key of the victim
- The victim uses the key as long as it decrypts successfully

Insecure storage examples: key in transit, stored on the cloud, on USB drive..

Key corruption in insecure storage

Attacker can corrupt encrypted private long-term key of the victim



Klíma and Rosa (2001) show how to target DSA keys:

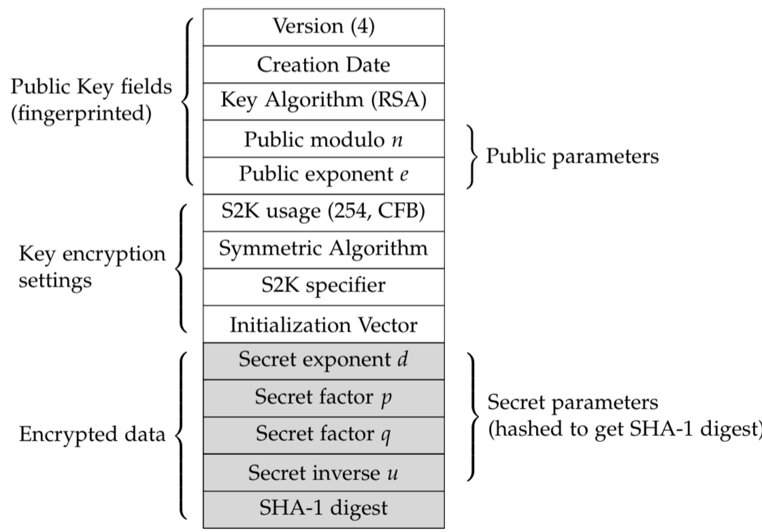
1) attacker overwrites some public params

2) waits for the victim to *sign* using the corrupted key

3) extracts secret values from the faulty signature

Key corruption in insecure storage

Attacker can corrupt encrypted private long-term key of the victim



Our findings — any key is potentially vulnerable to faulty signature attacks (& more):

- direct attacks against DSA, EdDSA, RSA keys
- indirect attacks against ECDSA/ECDH/EdDSA and ElGamal keys (can be converted into DSA ones)

Existing protocol-level protections

- Private values encrypted either with AEAD or CFB (always authenticated)
- No integrity protection over public fields → decryption won't fail
- Key binding signatures can be forged/replaced by the attacker
- However:
  - checking fingerprint reveals public key corruption
  - third-party certifications won't be verifiable

Our threat model: user/app might trust a key as long as it decrypts

Key validation in implementations

We have found that many libraries implement some key checks, but not always effective

- Trial signature or decryption
- Algorithm-specific checks

$$n \stackrel{?}{=} pq$$

$$de \stackrel{?}{=} 1 \bmod (p-1)(q-1)$$

Key validation issues

ElGamal: full validation is infeasible

DSA: difficult and expensive to validate

EdDSA: expensive to validate

In practice:

- none of the libraries we have reviewed is fully safe against attacks
- we found two real-world apps where this vulnerability was exploitable

Possible protocol-level solution

Our proposal:

- for AEAD-encrypted keys, put public key in the Associated Data
- for CFB-encrypted keys, hash the public key together with private one

Advantages over implementation-level key validation:

- works for any key algorithm
- much faster
- avoids all key validation pitfalls