The Long and Winding Path to Secure Implementation of GlobalPlatform SCP10

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TCHES 2020

Overview

- Context
- Deterministic RSA Padding
- Padding Oracle
- Key Reuse
- Secure Implementation
- Conclusion

Context

The smart card world

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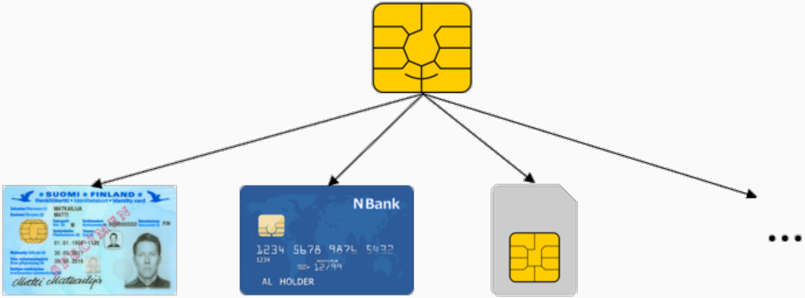
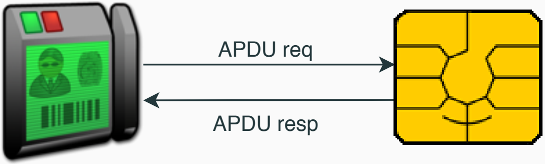


SCP (Secure Communication Protocol)



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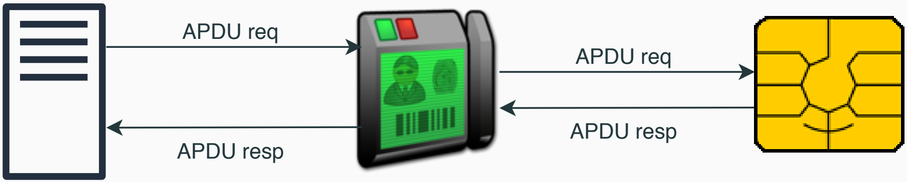

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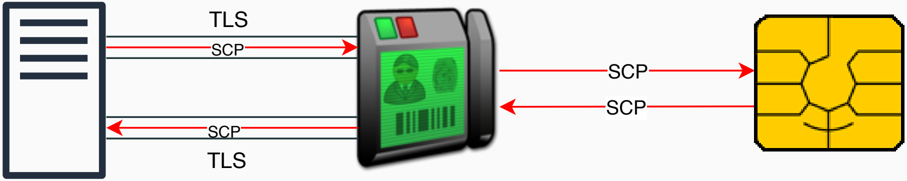

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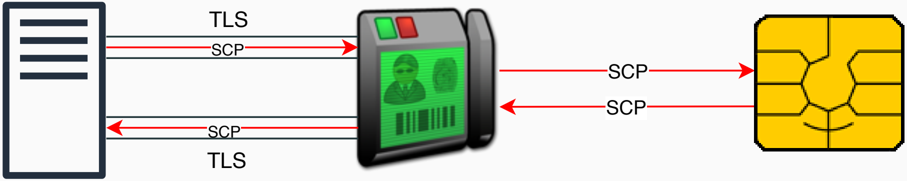

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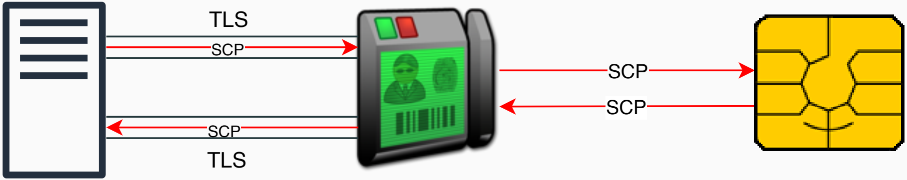
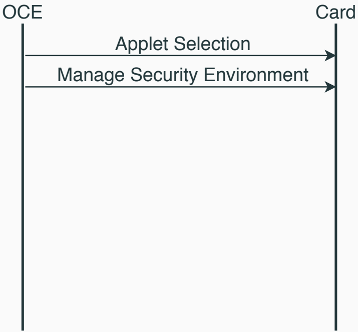


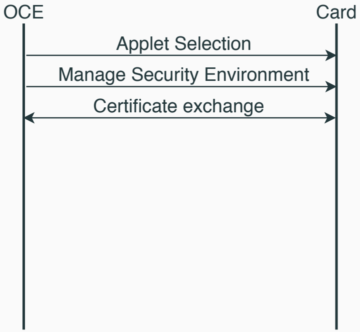
- Establish a secure session between a card and an Off-Card Entity
- 2-steps protocol: Key Exchange + Communication
- SCP10 relies on a Public Key Infrastructure:
    - Both the card and off-card entity have a key pair
    - They use each other public key to encrypt/verify messages

Key Exchange Modes



(a) Key Transport mode

Key Exchange Modes



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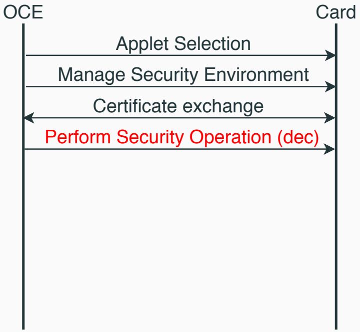

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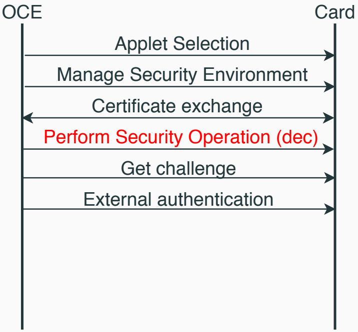

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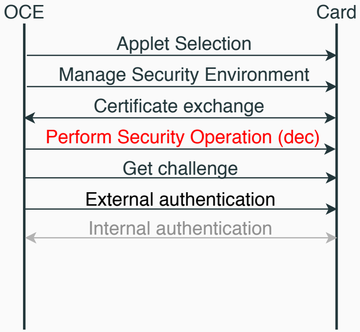

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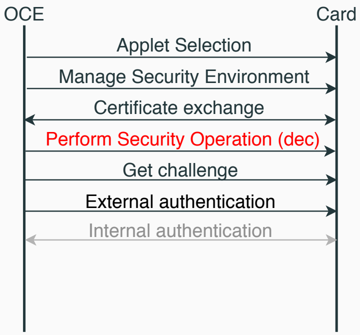

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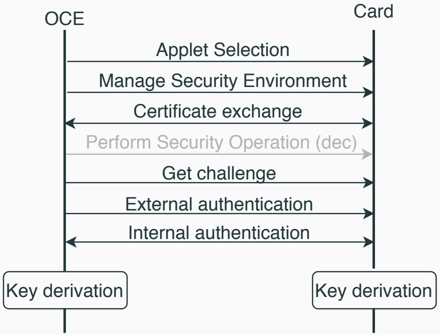

(b) Key Agreement mode

Our contributions

Our contributions:

1. Abuse blurs and flaws in the RSA encryption in Key Transport
2. Recovered session keys by two independent means
    - In less than a second with the first attack
    - In an average of 2h30 for the second
3. Exploit a design flaw to forge a certificate, signed by the card
4. Implement a (semi-)compliant version of SCP10 as an applet
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However, we did **not**:

× Attack real cards (no implementation in the wild)
× Try to exploit weakness in the symmetric encryption

Our Threat Model

Our attackers can:

- ✓ Initiate an SCP10 session with a card
- ✓ Intercept, read and modify plaintext message transmitted between a legitimate Off-Card Entity and the card
- ✓ Measure the time needed by the card to respond

They cannot:

- × Have physical access to the card
- × Break the cryptographic primitives

Deterministic RSA Padding

Perform Security Operation

PERFORM SECURITY OPERATION APDU:

$$\texttt{M: } \underbrace{\texttt{params}}_{\texttt{3 bytes}} \texttt{ || } \underbrace{\texttt{CRT}}_{\texttt{[22,42] bytes}} \texttt{ [|| CRT ...]}$$

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EM: 0002 || FF..FF || 00 || M
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→ Hybrid padding (mixing EME and EMSA)

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EM: $\underbrace{\texttt{0002 || FF..FF || 00}}_{128-len(M)-3\ \texttt{bytes}}$ `|| M`

→ Hybrid padding (mixing EME and EMSA)

⇒ Only few unknown bytes (compared to the modulus size)

Coppersmith's Low Exponent Attack

Recover the message if the unknown part is small enough: we need $x \leq n^{\frac{1}{e}}$

1

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Assuming the card is using:

- A 1024 bits modulus
- A small public exponent[1] ($e = 3$)

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We can recover up to $\left\lceil \log_2(n^{\frac{1}{3}}) \right\rceil = 341$ bits (≈ 42 bytes)

- An encryption key: 16-24 unknown bytes
- An integrity key (with IV): 26-34 unknown bytes

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In practice...

- Recover the message in 0.35s on average for a 128 bits key
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⚠ Bigger RSA modulus makes the attack easier

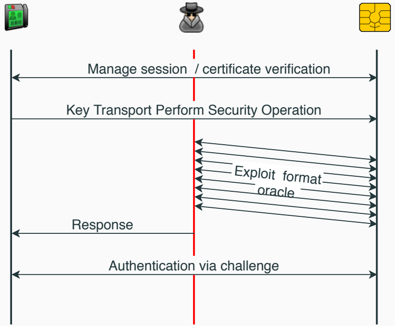
⚠ "Classic" PKCS#1v1.5 padding may not be a valid solution...

Padding Oracle

Bleichenbacher's attack

Abusing Perform Security Operation:

- Anybody can send this APDU (no authentication before)



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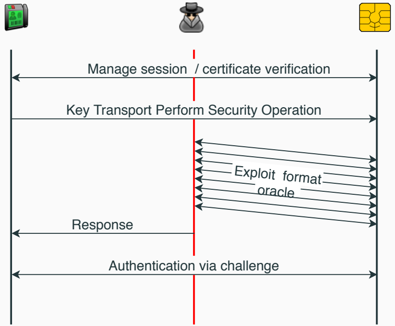

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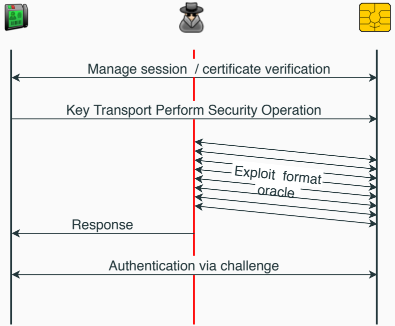

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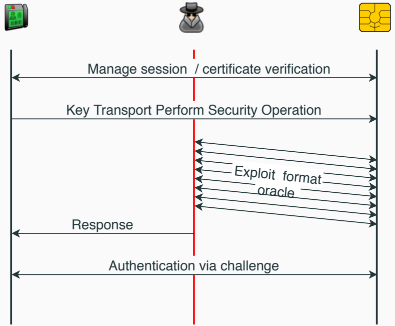
- Constant time verification is hard, even harder with TLV parsing



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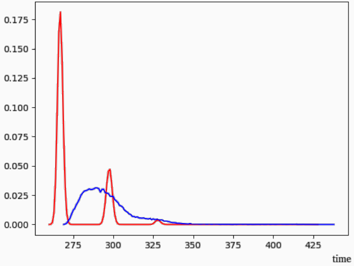

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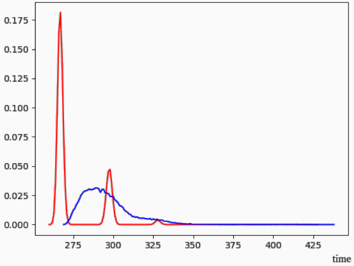

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⇒ Need robust RSA padding (OAEP would solve both problems)

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$\Rightarrow$ Need key isolation

Secure Implementation

Major countermeasures

- Key isolation
  - Significant overhead during certificate verification
  - No need to repeat it at each session
- RSA-OAEP
  - Negligible overhead (≈ 0.01s)
- Enforce public exponent $e = 65537$
  - Negligible overhead
  - Not mandatory when using OAEP

Conclusion

Sum-up

- We tried to apply well known attack to the smart cards world
- Successfully performed two attacks speculating on the implementation
  - We believe our assumption to be reasonable giving past attacks
  - Key isolation is not implementation dependent
- Suggest mitigations:
  - Easy to add in the specification
  - Reasonable overhead
- GlobalPlatform released a new standard version based on our recommendations

Thank you for your attention !