# The Long and Winding Path to Secure Implementation of GlobalPlatform SCP10

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# Overview

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

# Context

# The smart card world

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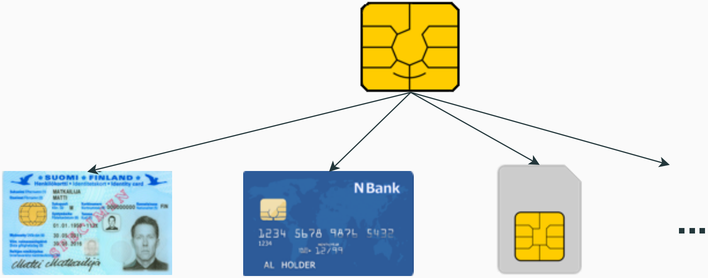
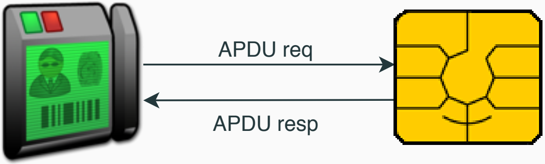


# SCP (Secure Communication Protocol)



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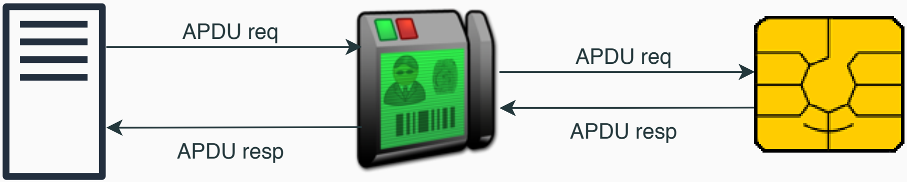

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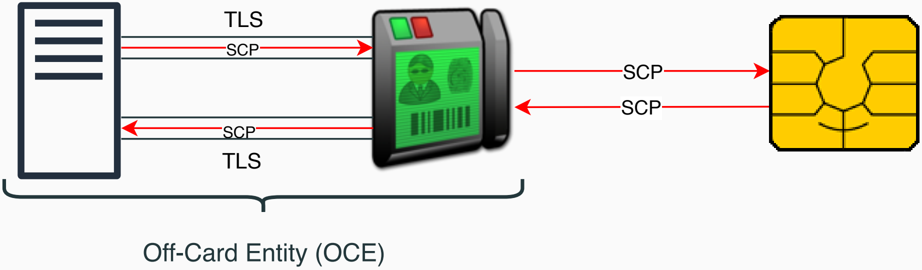

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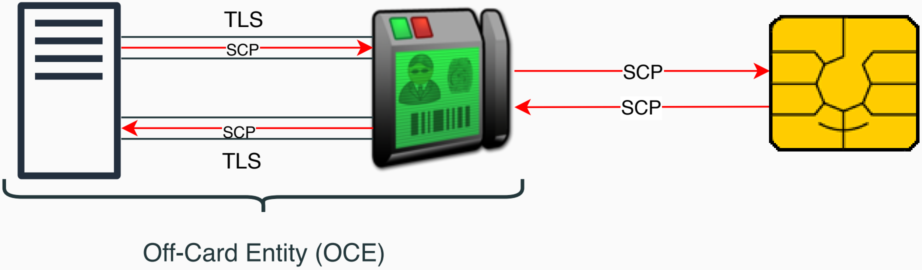


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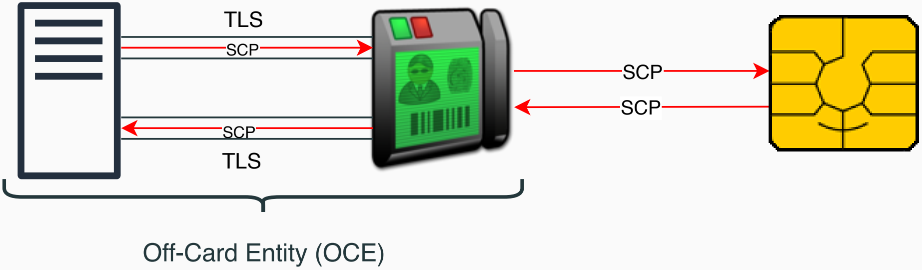
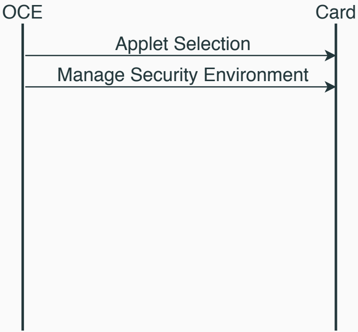



- Establish a secure session between a card and an Off-Card Entity
- 2-steps protocol: Key Exchange + Communication
- SCP10 relies on a Public Key Infrastructure:
  - Both the card and off-card entity have a key pair
  - They use each other public key to encrypt/verify messages

# Key Exchange Modes




**(a)** Key Transport mode

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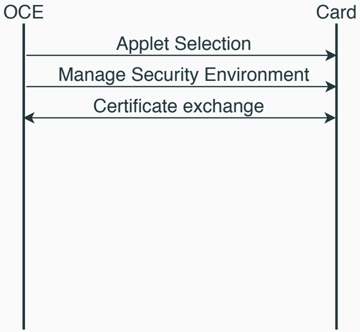


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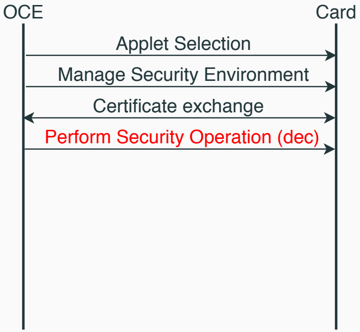


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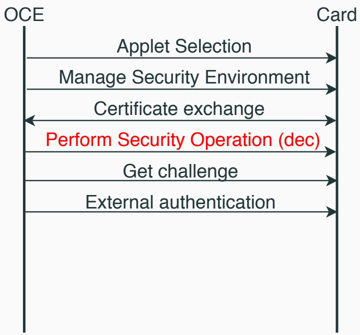


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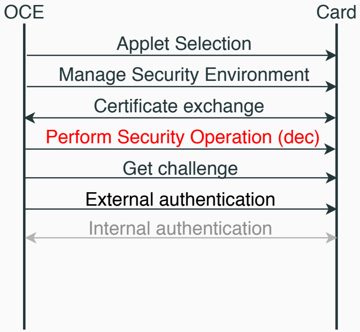


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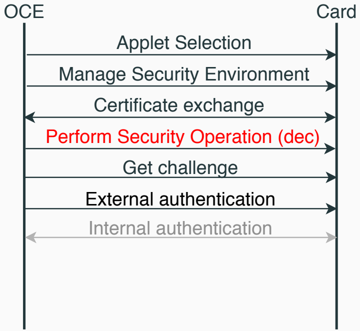


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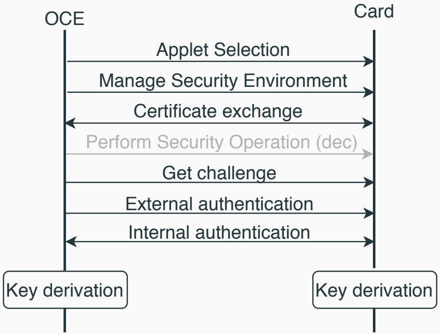


(b) Key Agreement mode

# 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:

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M: params || CRT [|| CRT ...]
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- header: [6,8] fixed bytes
- key: [16,24] bytes
- iv: 8 bytes

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→ Hybrid padding (mixing EME and EMSA)

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

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Assuming the card is using:

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

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

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

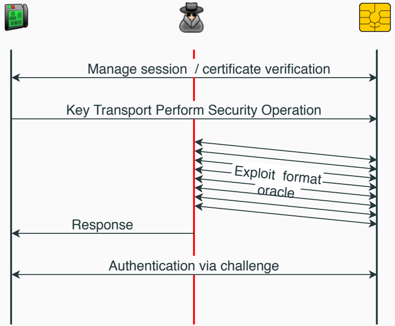
⚠ "Classic" PKCS#1v1.5 padding may not be a valid solution...

# Padding Oracle

# Bleichenbacher's attack

Abusing Perform Security Operation:

- Anybody can send this APDU (no authentication before)



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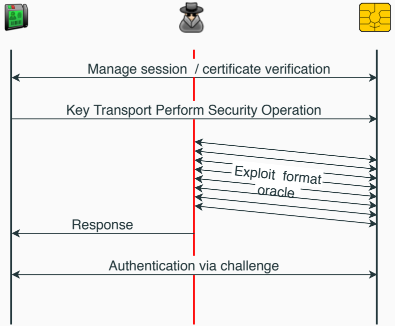

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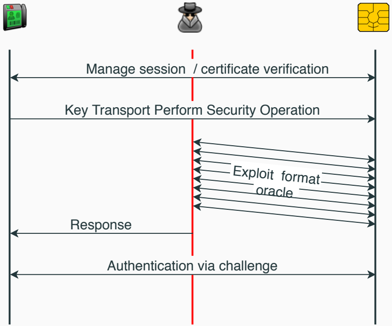

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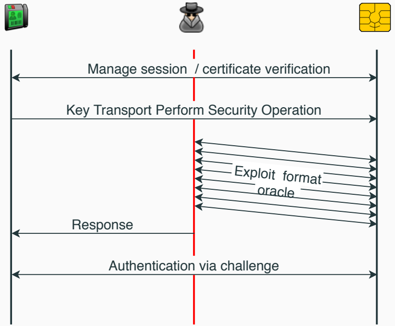
- Constant time verification is hard, even harder with TLV parsing



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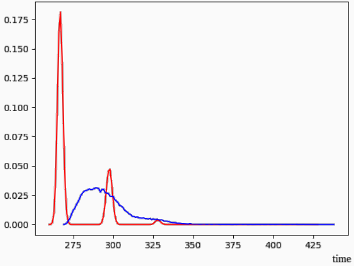


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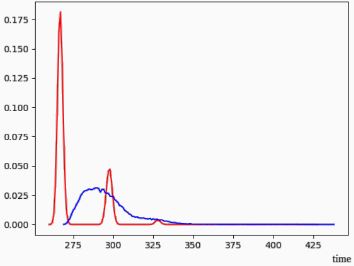


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$\Rightarrow$ Need robust RSA padding (OAEP would solve both problems)

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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 ($\approx 0.01$s)
- 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 !**