# A Dynamic Syntax Interpretation for Java based Smart Card to Mitigate Logical Attacks


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# Outline

- Introduction
- Java Card Security
    - *Byte code verifier, CAP File, API, Linker, Firewall*
- Types of attacks on Java Cards
- Objective
- Developing a new attack
- Existing countermeasure
- Newly proposed countermeasure & its implementation
- Conclusion

# Introduction

- Smart Card/ Java Card
  - Most of the Smart Cards are  Java Card
  - Secure, efficient, cost effective embedded device
  - Limited memory size (RAM, ROM, EEPROM)
  - Prone to attacks
  - Hardware & software security
  - Multi-application environment

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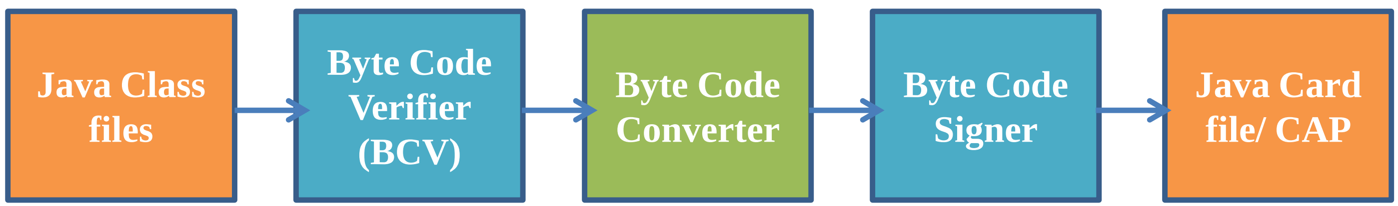
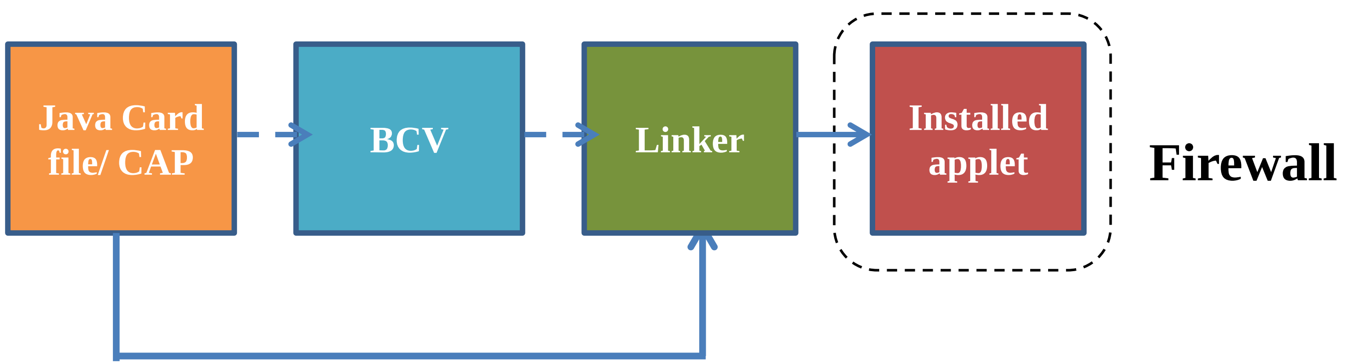
# Java Card Security

## Off-Card Security Model




## On-Card Security Model

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# Java Card Security: CAP File

- CAP: Converted Applet
- Binary representation of a package of classes
- Consists of 12 components
- Some of the main components
  - Class
  - Method
  - Constant Pool
  - Reference Location etc.

# Types of attacks on Smart Card

- **Logical**
  - software/ sensitive informations
  - two categories of logical attacks
    - well formed CAP File: shareable interface mechanism, transaction mechanism
    - ill formed CAP File: CAP File manipulation
- **Side Channel**
  - cryptographic secrets obtained through electromagnetic leaks, timing information, power consumption, heat radiation, etc.

# Types of attacks on Smart Card (Contd.)

- **Physical**
  - fault attacks (optical, electromagnetic)
  - input current modifications

- **Combined**
  - logical and physical
    - fault injection (bypass on-card BCV)

# Objective: introducing a new logical attack

- Abused the Java Card linker to change the correct bytecode into malicious one
- Set of instructions modified
- Each instruction is referenced by an offset in the method component
- Linking step is done during the loading of a CAP file
- Linker interprets the instructions as tokens and resolve it
- CAP File Manipulator: developed by our team
  - Allows to read and modify Cap Files or any component of a CAP File
  - Respect the interdependencies between the components

# Objective: introducing a new logical attack (Contd.)

## Linking step

(1) Token

**MethodComponent** {
[ … ]
@**1F** invokestatic **0002**
[ … ]
}

(2)

**ReferenceLocationComponent**
{
[ … ]
offsets_to_byte2_indices = {
[ … ]
**@0020**
[ … ]
} }

Method referenced by token

(3)

**ConstantPoolComponent** {
[ … ]
**0002** CONSTANT_StaticMethodRef:
packageToken 80, classToken 20, Token 8
}

Offset value of token

If linking finished **0002** will change to **4E56**

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# Developing a new attack

Method Component

| Offset | Bytecode | Mnemonic |
|---|---|---|
| 0020 | **[0x00]** | nop |
| 0021 | **[0x02]** | sconst_m1 |
| 0022 | [0x02] | sconst_m1 |
| 0023 | [0x3C] | pop2 |
| 0024 | [0x04] | sconst_m1 |
| 0025 | [0x3B] | pop |

**Linking needs two bytes**

Constant Pool Component

**/* 0008, 2 */CONSTANT_StaticMethodRef:**
**external: 0x80, 0x8, 0xD**

Reference Location Component

**Offset value: 0020**

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# Developing a new attack (Contd.)

## Set of instructions after linking resolution

| Offset | Bytecode | Mnemonic |
|---|---|---|
| 0020 | **[0x8E]** | Invokeinterface |
| 0021 | **[0x03]** | *// nargs* |
| 0022 | [0x02] | *// indexByte1* |
| 0023 | [0x3C] | *// indexByte2* |
| 0024 | [0x04] | *// method* |
| 0025 | [0x3B] | pop |

Token method **0x0002** is linked by the value **0x8E03**

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# Existing countermeasure

$$ins_{hidden} = ins \oplus K_{bytecode} \qquad (1)$$

where $K_{bytecode}$ is the key, ***ins*** is the instruction

- Impossible to execute the malicious code without the knowledge of $K_{bytecode}$
- To find xor key: change the Control Flow Graph (CFG)
- Through brute force attack: easily obtain xor key with 256 possible values

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# Newly proposed countermeasure

$$ins_{hidden} = ins \oplus K_{bytecode} \quad (1)$$

$$ins_{hidden} = ins \oplus K_{bytecode} \oplus jpc \quad (2)$$

*Scrambling Bytecode with*

***equation 1***

| Address | Bytecode | Mnemonic |
|---|---|---|
| 0x8068 | **0x42** | nop |
| 0x8069 | **0x40** | **sconst_m1** |
| 0x806A | **0x40** | **sconst_m1** |
| 0x806B | **0x7E** | pop2 |
| 0x806C | **0x46** | sconst_1 |
| 0x806D | **0x79** | pop |

***equation 2***

| Address | Bytecode | Mnemonic |
|---|---|---|
| 0x8068 | **0x2a** | nop |
| 0x8069 | **0x29** | **sconst_m1** |
| 0x806A | **0x2a** | **sconst_m1** |
| 0x806B | **0x15** | pop2 |
| 0x806C | **0x2d** | sconst_1 |
| 0x806D | **0x12** | pop |

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# Countermeasure implementation (Contd.)

## Unscrambling shell code

| Offset | Bytecode | Mnemonic |
|---|---|---|
| 0xAB80 | 0x7D | getstatic 8000 |
| 0xAB83 | 0x78 | sreturn |

## After unmasking each instruction

| Offset | Bytecode | Mnemonic |
|---|---|---|
| 0xAB80 | 0xBF | *//undefined* |
| 0xAB81 | 0x43 | ssub |
| 0xAB82 | 0xC0 | *// undefined* |
| 0xAB83 | 0xB9 | *// undefined* |

# Conclusion

- Based on the vulnerability of the linker, a powerful logical attack demonstrated
  - *Correct bytecode to into malicious one*
- Protect Java Card from logical attacks
  - *Impossible to execute malicious bytecode without the knowledge of jpc stored in the EEPROM*
- Cost effective countermeasure, suitable for security interoperability

# Future Work

- To do reverse engineering using electromagnetic side channel attacks

# THANK YOU

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