Relay Attacks in EMV Contactless Cards with Android OTS Devices

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About us

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Main research interests

- </JavaXSScript>and client-side attacks
- NFC security
- Android internals

Main research interests

- Security/safety modelling and analysis of ICS
- Advanced malware analysis
- NFC security

Agenda

1. Introduction
2. Background
   - EMV Contactless Cards
   - Relay Attacks and Mafia Frauds
3. Android and NFC: A Tale of L♥ve
   - Evolution of NFC Support in Android
   - Practical Implementation Alternatives in Android
4. Relay Attack Implementation
   - Demo experiment
   - Threat Scenarios
   - Resistant Mechanisms
5. Related Work
6. Conclusions

Agenda

Introduction to NFC (I)

What is NFC?

- Bidirectional short-range contactless communication technology
  - Up to 10 cm
- Based on RFID standards, works in the 13.56 MHz spectrum
- Data transfer rates vary: 106, 216, and 424 kbps

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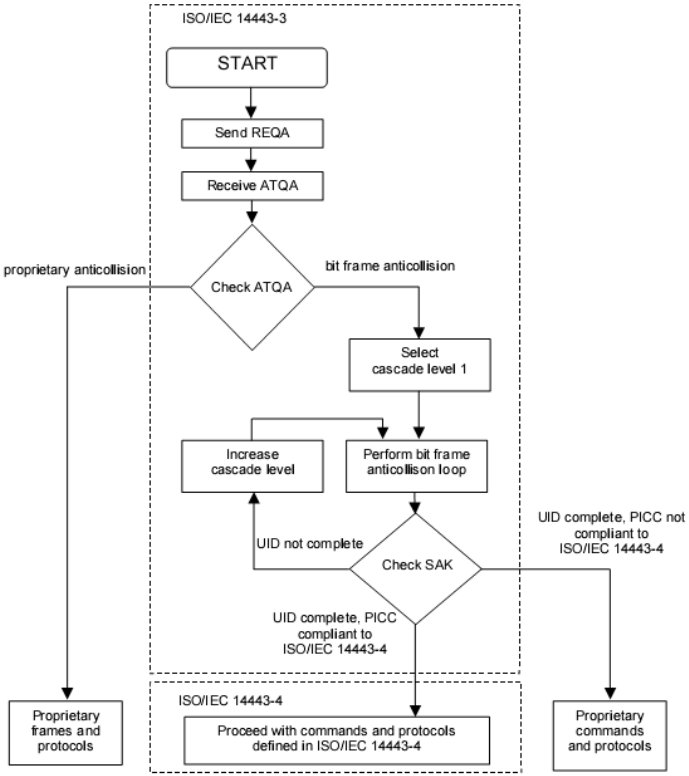
Security based on proximity concern: physical constraints

Introduction to NFC (II)

Wow! NFC sounds pretty hipster!

- Two main elements:
  - Proximity Coupling Device (PCD, also NFC-capable device)
  - Proximity Integrated Circuit Cards (PICC, also NFC tags)
- Three operation modes:
  - Peer to peer: direct communication between parties
  - Read/write: communication with a NFC tag
  - Card-emulation: an NFC device behaves as a tag

Introduction to NFC (III)



ISO/IEC 14443 standard

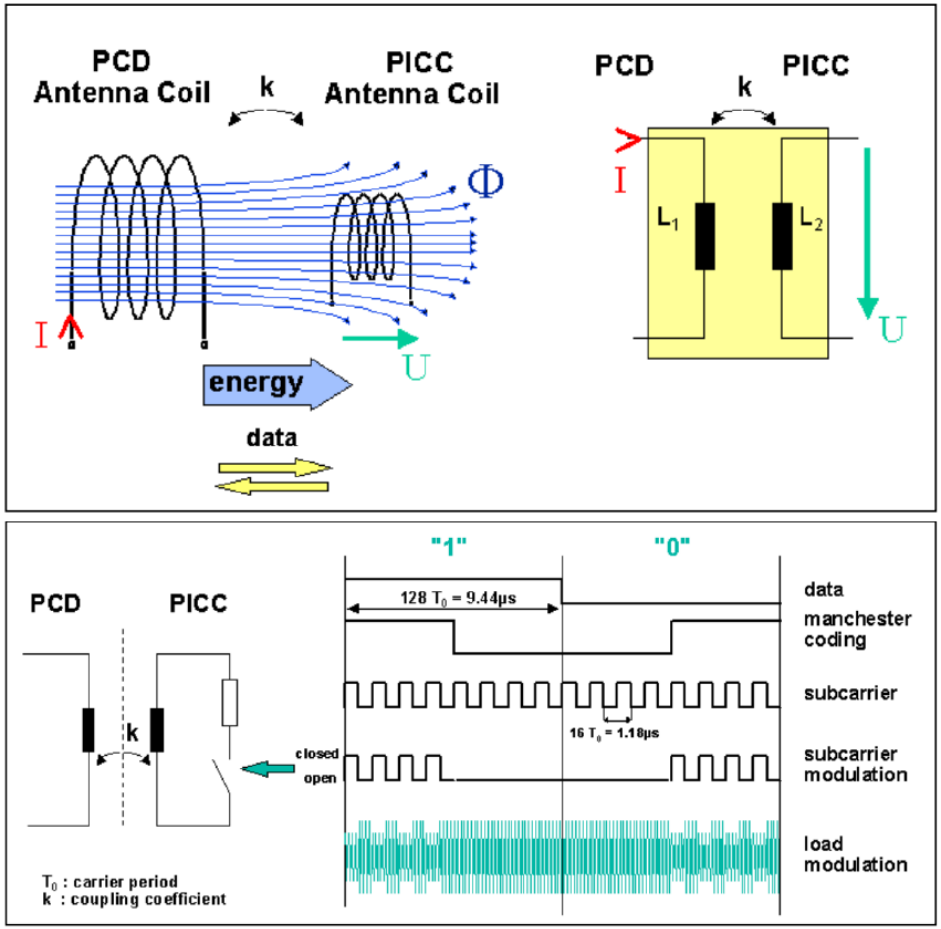
- Four-part international standard for contactless smartcards
  1. Size, physical characteristics, etc.
  2. RF power and signalling schemes (Type A & B)
     - Half-duplex, 106 kbps rate
  3. Initialization + anticollision protocol
  4. Data transmission protocol
- IsoDep cards: compliant with the four parts
  - Example: contactless payment cards

Introduction to NFC (IV)

ISO/IEC 7816

- Fifteen-part international standard related to contacted integrated circuit cards, especially smartcards
- Application Protocol Data Units (APDUs)

Introduction to NFC (V)



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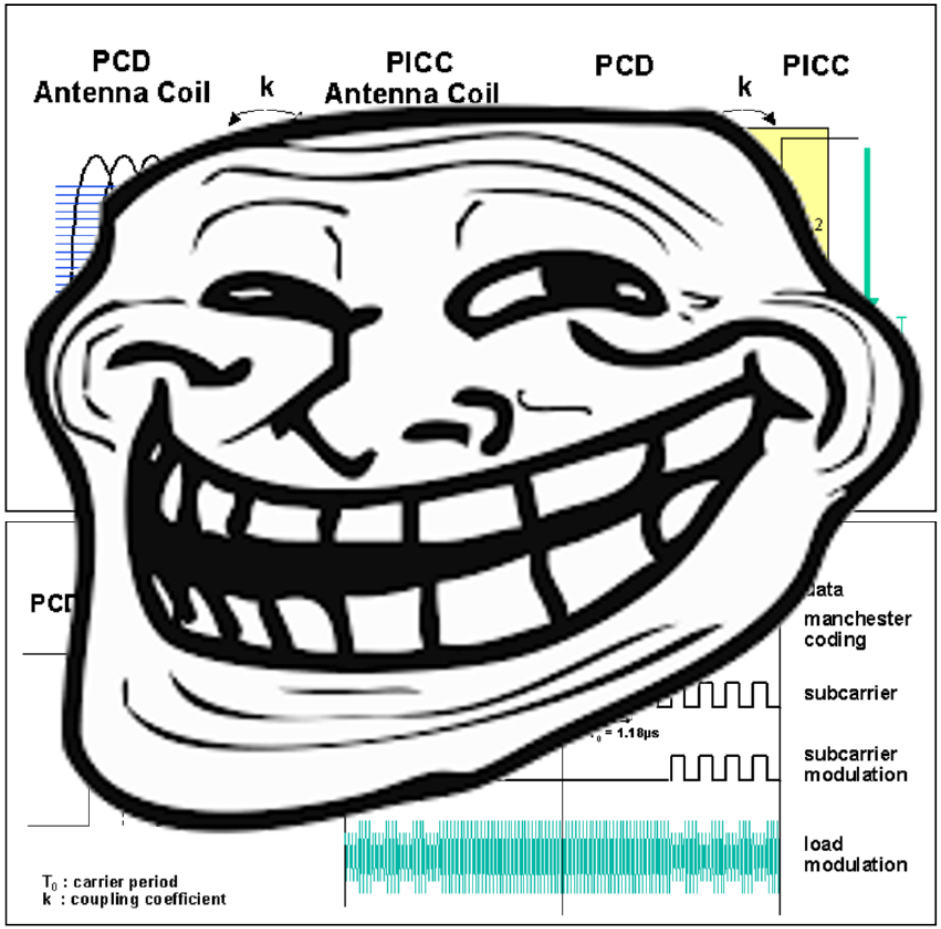

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Introduction to NFC (VI)

Ticketing

Identification

Time & Attendance

Loyalty & Memberships

NFC

Physical Access

Cashless Payment

Transit

Secure PC Log-On

Introduction to NFC (VII)

Ok. . . So, is it secure, right? Right??

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NFC security threats

- Eavesdropping
  - Secure communication as solution
- Data modification (i.e., alteration, insertion, or destruction)
  - Feasible in theory (but requires quite advanced RF knowledge)
- Relays
  - Forwarding of wireless communication
  - Two types: passive (just forwards), or active (forwards and alters the data)

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We focus on passive relay attacks

Introduction to NFC (VIII)

- NFC brings “cards” to mobile devices
- Payment sector is quite interested in this new way for making payments
  - 500M NFC payment users expected by 2019
- Almost 300 smart phones available at the moment with NFC capabilities
  - Check `http://www.nfcworld.com/nfc-phones-list/`
  - Most of them runs Android OS

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Research Hypothesis

- *Can a passive relay attack be performed in contactless payment cards, using an Android NFC-capable device?*
- If so, what are the constraints? (whether any exists)

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Background (I)

EMV contactless cards

- Europay, Mastercard, and VISA standard for inter-operation of IC cards, Point-of-Sale terminals and automated teller machines
- Authenticating credit and debit card transactions
- Commands defined in ISO/IEC 7816-3 and ISO/IEC 7816-4 (`http://en.wikipedia.org/wiki/EMV`)
  - Application ID (AID) command

Background (II)

MasterCard PayPass, VISA payWave, and AmericanExpress ExpressPay

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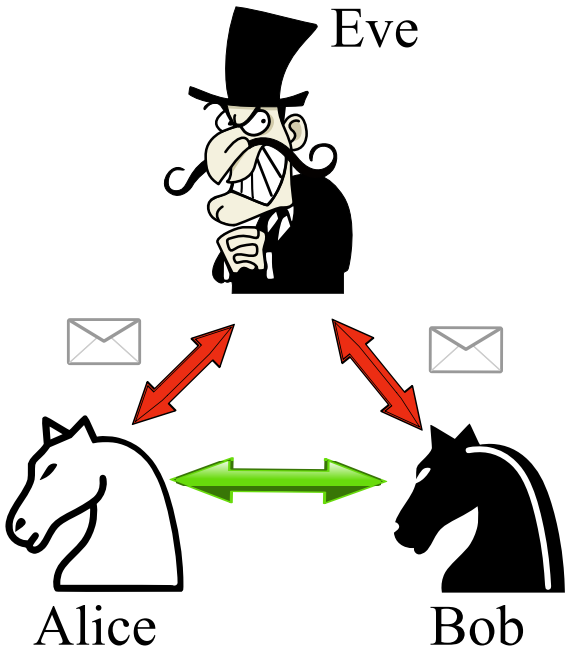
    (http://www.bankinfosecurity.com/android-attack-exploits-visa-emv-flaw-a-7516/op-1)
- Sequential contactless payments limited – it asks for the PIN
- Protected by the same fraud guarantee as standard transactions (hopefully)

Background (III)



Relay attacks

- "On Numbers and Games", J. H. Conway (1976)

Mafia frauds – Y. Desmedt (SecuriCom'88)

$$\mathcal{P} \longrightarrow \overline{\mathcal{V}} \ll \text{communication link} \gg \overline{\mathcal{P}} \longrightarrow \mathcal{V}$$

- Real-time fraud where a fraudulent prover $\overline{\mathcal{P}}$ and verifier $\overline{\mathcal{V}}$ cooperate

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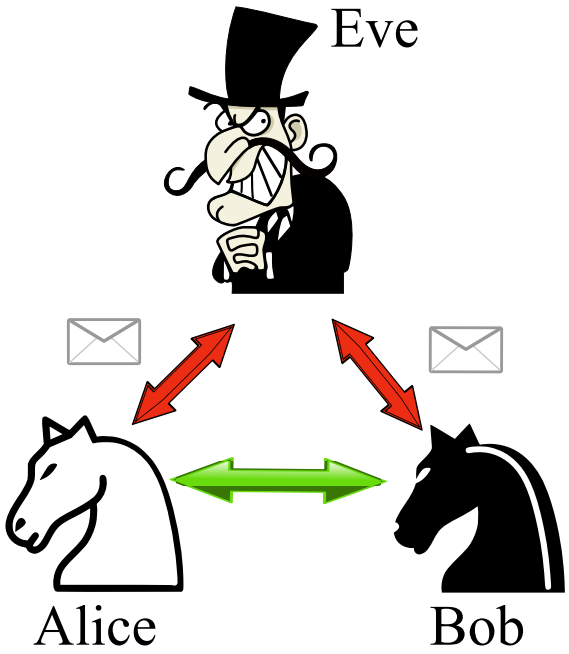

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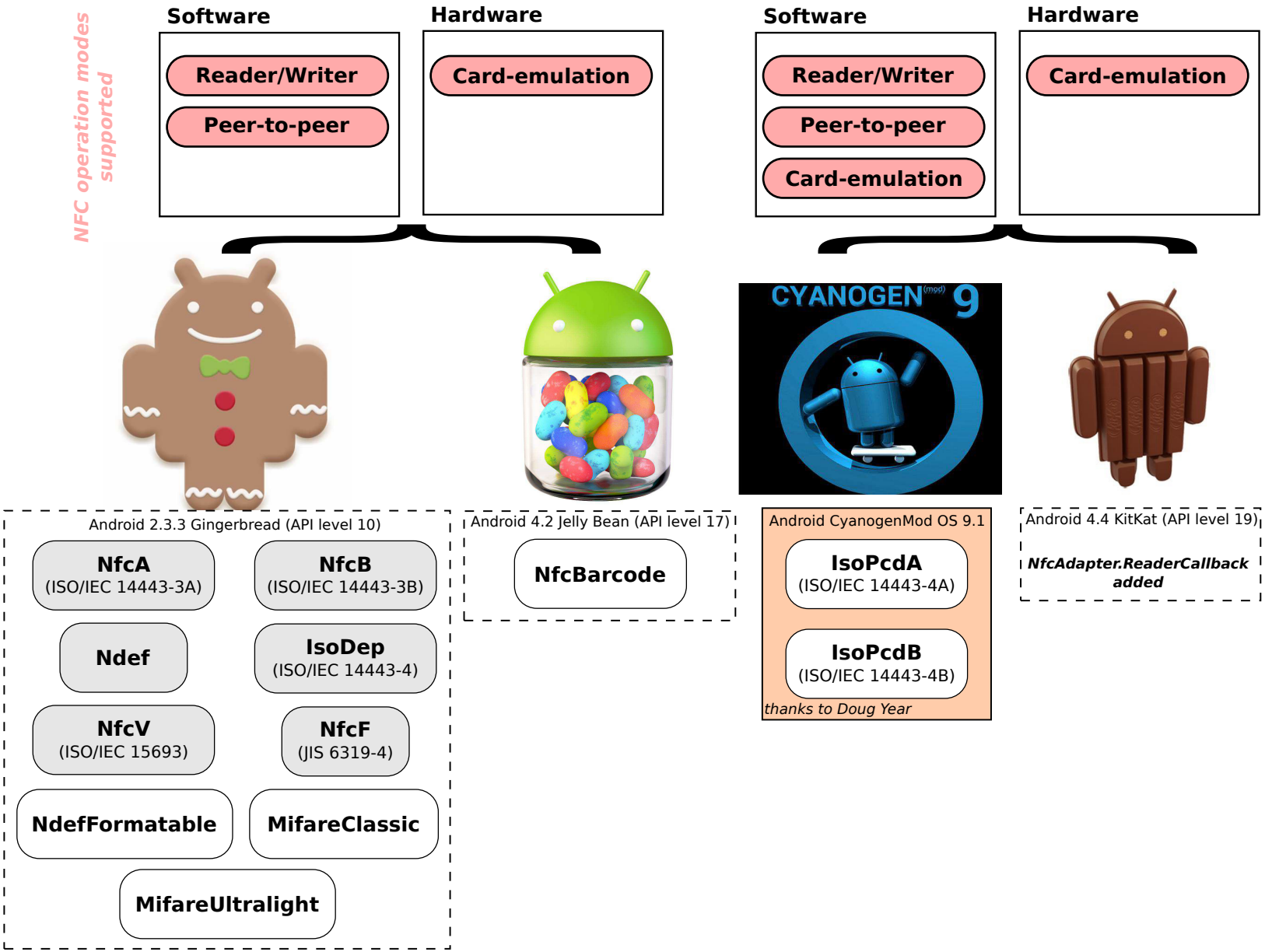
- Real-time fraud where a fraudulent prover $\overline{\mathcal{P}}$ and verifier $\overline{\mathcal{V}}$ cooperate
  - Honest prover and verifier: contactless card and Point-of-Sale terminal
  - Dishonest prover and verifier: two NFC-enabled Android devices

Agenda

Android and NFC: A Tale of L♥ve (I)

Recap on evolution of Android NFC support



Android and NFC: A Tale of L♥ve (II)

Digging into Android NFC stack

- Event-driven framework, nice API support
- Two native implementations (depending on built-in NFC chip)
  - `libnfc-nxp`
  - `libnfc-nci`

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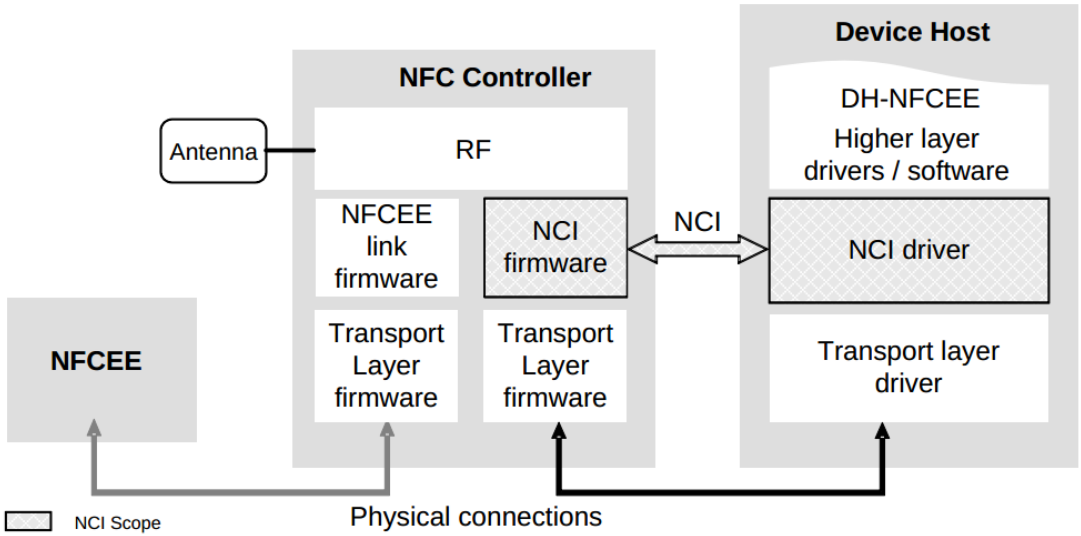
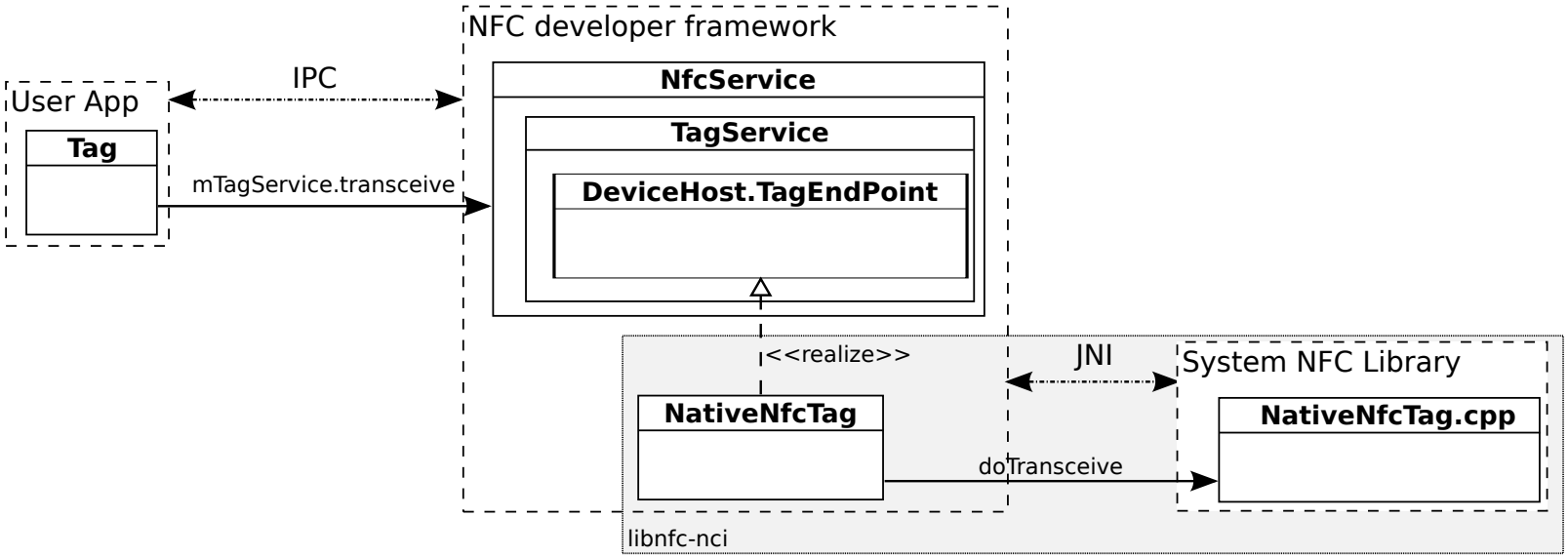
- Event-driven framework, nice API support
- Two native implementations (depending on built-in NFC chip)
  - `libnfc-nxp`
  - `libnfc-nci`
- NXP dropped in favour of NCI:
  - Open architecture, not focused on a single family chip
  - Open interface between the NFC Controller and the DH
  - Standard proposed by NFC Forum



Android and NFC: A Tale of L♥ve (III)

Digging into Android NFC stack – Reader/Writer mode

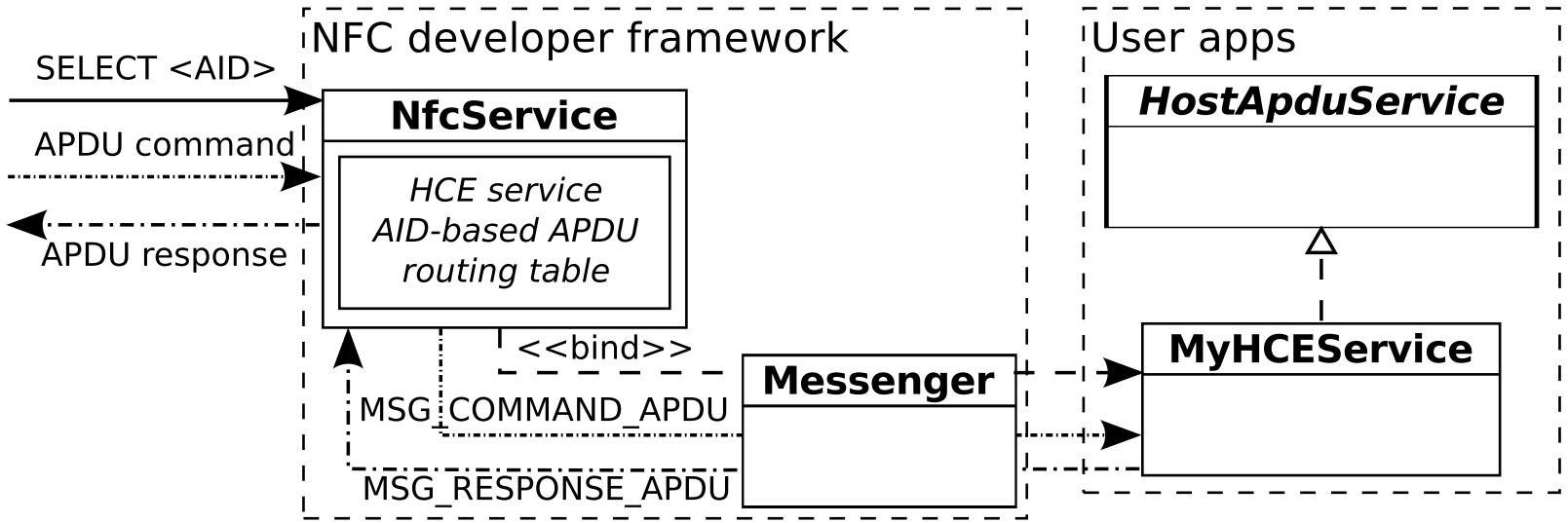
- Not allowed to be set directly → Android activity
- Android NFC service selects apps according to tag definition of Manifest file
- In low-level, `libnfc-nci` uses reliable mechanism of queues and message passing – General Kernel Interface (GKI)
  - Makes communication between layers and modules easier



Android and NFC: A Tale of L♥ve (IV)

Digging into Android NFC stack – HCE mode

- A service must be implemented to process commands and replies
- `HostApduService` abstract class, and `processCommandApdu` method
- AID-based routing service table
  - This means you need to declare in advance what AID you handle!



Android and NFC: A Tale of L♥ve (V)

Digging into Android NFC stack – Summary

Description	Language(s)	Dependency	OSS
NFC developer framework (`com.android.nfc` package)	Java, C++	API level	Yes
System NFC library (`libnfc-nxp` or `libnc-nci`)	C/C++	Manufacturer	Yes
NFC Android kernel driver	C	Hardware and manufacturer	Yes
NFC firmware (`/system/vendor/firmware` directory)	ARM Thumb	Hardware and manufacturer	No

Some useful links

- `https://android.googlesource.com/platform/frameworks/base/+/master/core/java/android/nfc/`
- `https://android.googlesource.com/platform/packages/apps/Nfc/+/master/src/com/android/nfc`
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- `http://nfc-forum.org/our-work/specifications-and-application-documents/specifications/nfc-controller-interface-nci-specifications/`
- `http://www.cardsys.dk/download/NFC_Docs/NFC%20Controller%20Interface%20(NCI)%20Technical%20Specification.pdf`
- `http://www.datasheet4u.com/PDF/845670/BCM20793S.html`
- `http://www.datasheet4u.com/PDF/845671/BCM20793SKMLG.html`

Android and NFC: A Tale of L♥ve (VI)

Some remarkable limitations

Limitation 1

- Dishonest verifier communicates with a MIFARE Classic
- `libnfc-nci` do not allow sending raw ISO/IEC 14443-3 commands
  - Caused by the CRC computation, performed by the NFCC
- Overcome whether NFCC is modified
- EMV contactless cards are IsoDep: *fully ISO/IEC 14443-compliant*

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Limitation 2

- Dishonest prover communicates with a honest verifier
- Device in HCE mode
  - AID must be known in advance
- Overcome whether device is rooted
- Xposed framework may help to overcome this issue, but needs root permissions

Android and NFC: A Tale of L♥ve (V)

Some remarkable limitations and remarks

Limitation 3

- Dishonest prover and a dishonest verifier communicate through a non-reliable peer-to-peer relay channel
- ISO/IEC 14443-4 defines the Frame Waiting Time as $FWT = 256 \cdot (16/f_c) \cdot 2^{FWI}, 0 \leq FWI \leq 14$, where $f_c = 13.56$ MHz

Android and NFC: A Tale of L♥ve (V)

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Concluding Remarks

- *Any NFC-enabled device running OTS Android* ≥ 4.4 *can perform an NFC passive relay attack at APDU level when the specific AID of the honest prover is known and an explicit SELECT is performed*

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And now, let's move to the practice ☺

Agenda

Relay Attack Implementation (I)

Experiment configuration

- PoS device: Ingenico IWL280 with GRPS + NFC support
- Android app developed (±2000 LOC)
- Two OTS Android NFC-capable devices
  - One constraint only: dishonest prover must run an Android ≥ 4.4

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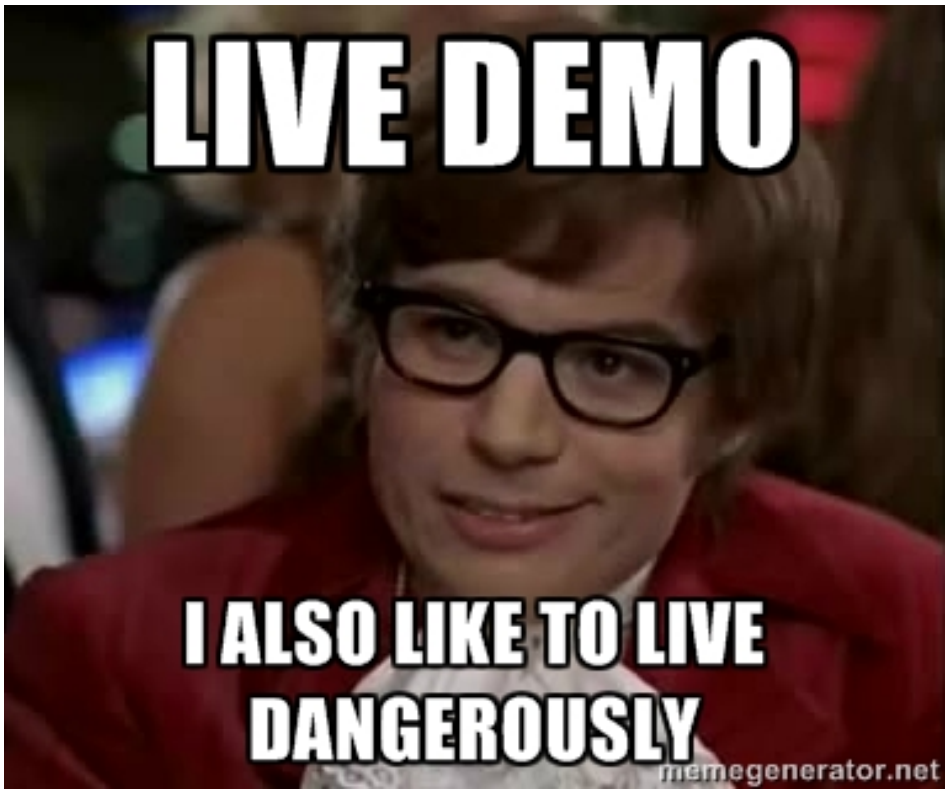
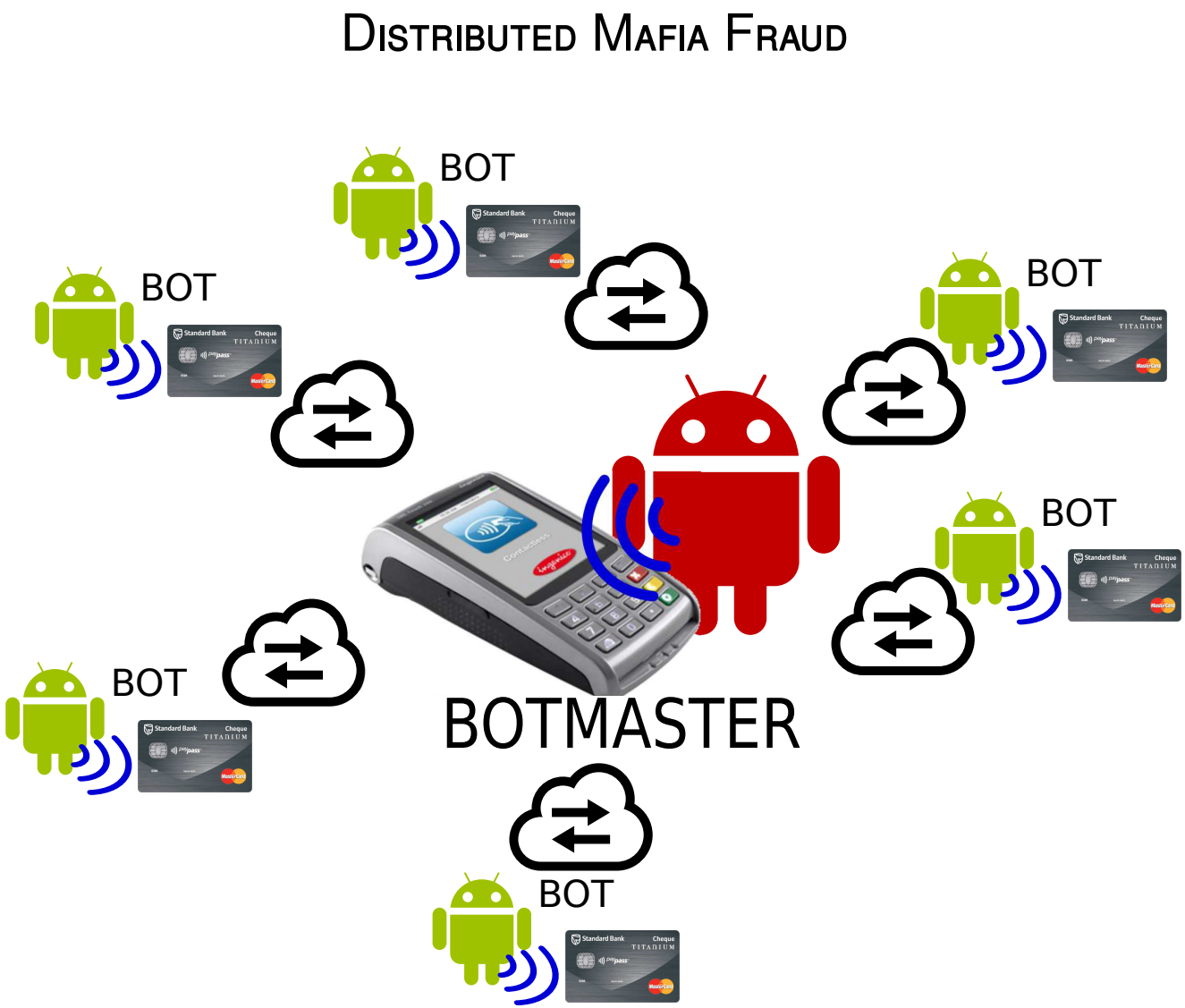


Relay Attack Implementation (II)

Threat Scenarios – Scenario 1



Relay Attack Implementation (III)

Threat Scenarios – Scenario 2

Hiding Fraud Locations

Relay Attack Implementation (IV)

Resistant Mechanisms

Brief summary of resistant mechanisms

- Distance-bounding protocols
  - Upper bounding the physical distance using Round-Trip-Time of cryptographic challenge-response messages
- Timing constraints
  - Not enforced in current NFC-capable systems
  - The own protocol allows timing extension commands
- Physical countermeasures
  - Whitelisting/Blacklisting random UID in HCE mode → unfeasible
  - RFID blocking covers
  - Physical button/switch activation
  - Secondary authentication methods (e.g., on-card fingerprint scanners)

Agenda

Related Work

On relay attacks

2005-2009 First works built on specific hardware

2010 Nokia mobile phones with NFC capability plus a Java MIDlet app

2012-2013 Relay attacks on Android accessing to Secure Elements

- A SE securely stores data associated with credit/debit cards
- Needs a non-OTS Android device

2014 Active relay attacks with custom hardware and custom Android firmware

- Several works studied delay upon relay channel:

Relay over long distances are feasible → latency isn't a hard constraint

*Ask us for *specific* references, too many names for a single slide!*

Agenda

Conclusions (I)

Security of NFC is based on the physical proximity concern

- NFC threats: eavesdropping, data modification, relay attacks
- Android NFC-capable devices are rising
  - Abuse to interact with cards in its proximity

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Virtual pickpocketing attack may appear before long!

Conclusions (II)

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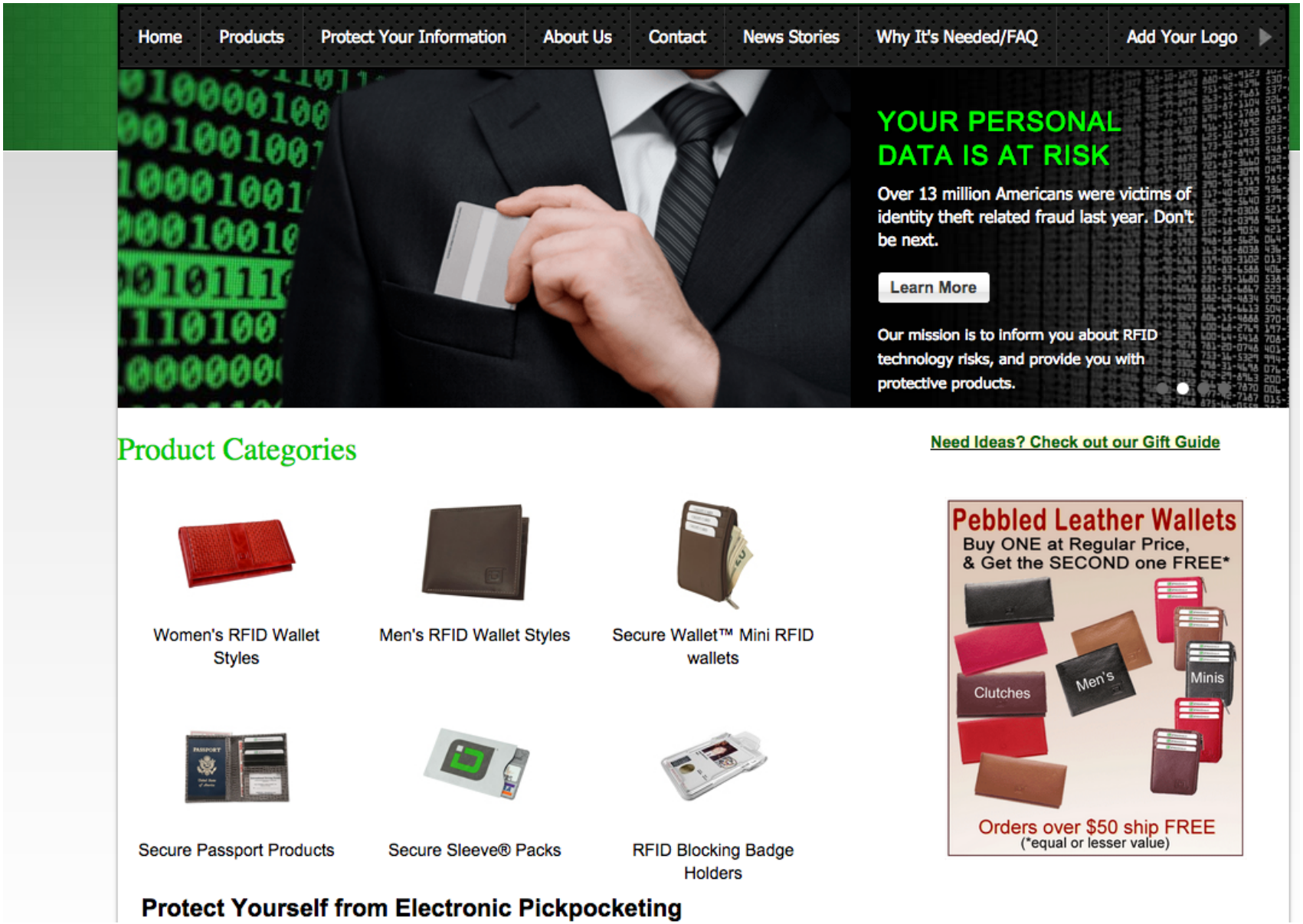

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Conclusions (III)

Future Work

- ~~Develop a botnet infrastructure and earn money~~
- Timing constraints of Android HCE mode
- Try active relay attacks within EMV contactless cards

Acknowledgments

- Spanish National Cybersecurity Institute (INCIBE)
- University of León under contract X43
- HITB staff

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