Modern payments security: EMV, NFC, etc.?

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Modern payments security: EMV, NFC, etc.?

- Intro: Payment Cards
- The EMV standard
- Attacks on EMV
- Intro: NFC
- EMV & NFC = ?
- Attacks on EMV & NFC
- Future
Modern payments security: EMV, NFC, etc.?

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</tr>
</tbody>
</table>
About me

Not a black khat :)
Intro: Payment cards

• What will we cover today:
  – Payment technologies from the real world
    • EMV (Europay, MasterCard and Visa)
      – EMV-enabled integrated circuit cards & terminals
    • NFC (Near Field Communication)
      – Payment applications of NFC
  – Attacks and countermeasures
    • Classification
    • Known vectors
    • New vectors
Intro: Payment cards

• Why talk about it?
  – Real-world means:
    • Financial institutes – obscure and weird
    • Ubiquity
    • Hardware
    • Attacks in space and time
  – Strict standardization
  – Purely virtual payment technologies are all different and rapidly changing
    • Anyone can implement his own
  – And we are talking about serious business
• Nilson Report, 2011
  – The total number of purchases on all major worldwide card issuers (American Express, Diners Club, JCB, MasterCard, UnionPay and Visa) increased to a total of 135.33 billion, up 12.1 percent from 2010 on an additional 14.56 billion transactions, the report said.
Intro: Payment cards

- Cards International:
  - Predict 30% annual growth of Russian payment cards market
  - $100 Billion by 2012
Intro: Payment cards

• As of early 2011, 1.2 billion EMV cards were deployed across the globe along with 18.7 million EMV terminals (via IBID)
• Over a billion smartphones sold by 2012
• By 2014, 44% of smartphones will be NFC-compatible (via)
• Payment card users in Russia: Spring 2011 to Spring 2012: from 49% to 56% (via GfK Rus).
Intro: Payment cards

• History
  – Origins: 1890s
  – Appearance: 1920s
  – Popularity: Mid XX century
  – 1950: Diners Club
  – 1958: American Express
  – 1958: Bank of America BankAmericards (now Visa)
  – 1966: InterBank Card Association (now MasterCard)
  – 1967: Cash dispenser
  – 1969: First ATM and magnetic stripe
Meet the Card

Gentlemen, do you know what this thing is?
Card standards

- Standards family ISO/IEC 781X
- 7810: Physical characteristics of credit card size document
- 7811-1: Embossing
- 7811-2: Magnetic stripe—low coercitivity
- 7811-3: Location of embossed characters
- 7811-4: Location of tracks 1 & 2
- 7811-5: Location of track 3
- 7811-6: Magnetic stripe-high coercitivity
- 7813: Financial transaction cards
Card exterior

Front: PAN(4), expiry date(6), Cardholder name(7)

Back: Magnetic stripe (1), cardholder signature(2), CVV2 (2)
PAN

• PAN Personal Account Number
  – From 13 to 19 digits
  – First 4 to 6 digits = BIN
    • Bank identification number
  – Last digit is a checksum digit (Luhn digit)
    • Checksum is calculated with Luhn algorithm
Magnetic Stripe

- LoCo (Low coercitivity)
- HiCo (High coercitivity)
- Tracks
  - Track 1:
  - Track 2:
  - (Track 3) – mostly unused
# Magnetic Stripe

<table>
<thead>
<tr>
<th>Data entity</th>
<th>Track 1</th>
<th>Track 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAN</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Cardholder name</td>
<td>+</td>
<td></td>
</tr>
<tr>
<td>Expiry date</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Service code</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Discretionary data:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PVKI</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>PVV</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>CVC-1 (CVV-1)</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>
Meet the Terminal

• Terminal types:
  – ATM (Automated Teller Machine)
  – POS (Point Of Sale)
  – Imprinter
  – Others
    • SSD
Terminal Hardware

• All devices:
  – Card Reader
  – PED (PIN Entry Device)
  – Receipt printer
  – Screen

• ATM:
  – Note cassettes inside a safe box
  – Note dispencer
  – (Note acceptor)
Payment Systems

• Why?
  – If N banks around the world want to accept each other’s cards, how many connections they would need? (Hint: $\frac{N(N-1)}{2}$)

• IPS bring standards & interoperability
  – Each IPS defines its own protocols and procedures

• Direct connections are also used
  – Member bank connects directly to the IPS
  – Affiliates connect to the Member
  – IPS can act as an acquirer for the largest retailers
Payment Systems

Payment system network
(MasterCard/Visa/etc.)

Issuing bank

Acquiring bank

Cardholder

Merchant
Payment Systems

Payment system network
(MasterCard/Visa/etc.)

Issuing bank

Authorization

Acquiring bank

Card issued

Authorization

Card presented

Cardholder

Merchant
Payment Systems

• Notable IPS (International Payment Systems)
  – Visa
  – MasterCard (MC)
  – Japan Credit Bureau (JCB)
  – Diners Club (DC)
  – American Express (AMEX)
  – China Union Pay (CUP)
Cryptography & Security

• Plastic
  – Holograms
  – Watermarks

• Cryptography
  – DES (Replaced by DES)
  – 3DES
    • 3DES, mode: EDE, 2 keys: ABA
Cryptography & Security

• Cardholder Authentication (Verification)
  – PIN
  – PVK (PIN Verification Key)
  – PVV (PIN Verification Value)
  – PVV = ENC(PVK)[f(PAN, PIN)] by issuer

• Card Authentication (Verification)
  – CVV/CVC and CVV2/CVC2
  – CVK (Card Verification Key)
  – CVV = ENC(CVK)[f(PAN || ExpDate || SvcCode)] by issuer
  – CVV2 = ENC(CVK)[f(PAN || ExpDate || ‘000’)] by issuer
Cryptography & Security

• Encryption
  – PEK (PIN Encryption Key)
  – TPK (Terminal PIN Key)
  – TMK (Terminal Master Key)
  – Domain encryption
    • ZMK/ZCMK (Zone (Control) Master Key)
    • AWK (Acquirer Working Key)
    • IWK (Issuer Working Key)
  – Proprietary measures
    • MAC by terminal
    • Transport-level encryption
Cryptography & Security

• HSM (Host Security Module)
  – Host command interface
  – Console admin interface
    • Smart cards for security officer authentication and master key storage
  – PKCS#11 API
  – LMK (Local Master Key)
  – Standards compliance
    • FIPS 140-1, FIPS 140-2/140-3

• PIN Printer
  – A secure printer directly connected to HSM
Processing cycle

• Cardholder
  – Receive a card and sign it manually
  – Open PIN Envelope, read it and burn it

• Issuer
  – Personalization
  – Embossing
  – Encoding
  – Issuer’s Host software
    • Authorization processing
    • Presentment processing

• Card
  – Card is just a static read-only piece of plastic
Processing cycle

• Acquirer
  – Manages terminals and provides services to merchants
  – Acquirer’s host software
    • Authorization processing
    • Presentment processing

• Terminal
  – Reads card
  – Talks to acquirer’s host
Processing cycle

• Transaction phases
  – Authorization
  – Clearing
  – Settlement
  – Dispute resolution
Authorization

• Terminal reads card
• If cardholder enters PIN:
  – Terminal calculates a PIN Block inside PED
  – PIN Block is encrypted under corresponding TPK
• Auth message is sent to Acquirer’s host
• Acquirer processes it and sends to IPS
• IPS processes it and sends to Issuer
• Issuer approves or rejects it and sends the answer back
Clearing

• Terminal reconciliation
• Acquirer demands satisfaction from the issuer and sends the clearing presentments through the IPS
• IPS processes them and sends them to the Issuer
• Issuer may not respond, money transfer is automatically performed at the next stage
Settlement

• All parties settle their financial positions through the IPS
  – Consolidated funds transfer
Dispute resolution

- **Presentment**: Original Sale
- **First Chargeback**: A customer disputes a charge to his or her credit card company or bank and the bank responds with a retrieval request to dispute the transaction.
- **Second Presentation or Re-presentment**: This is when the merchant has an opportunity to respond to the first chargeback.
- **Second Chargeback**: If the second presentment is rejected by the cardholder, the issuing bank files a second chargeback.
- **IPS Arbitration**: IPS staff handle the case manually
Data transfer

• ISO 8583 Standard
  – Binary protocol
  – Presence of a fields is determined by bitmap
    • N x 64-bit bitmaps
  – Fields may be fixed or variable
  – Data may be encoded in raw binary, ASCII, BCD, etc.
    • The same for variable fields length
Terminal protocols

• Terminals usually talk to acquirer’s host in their special protocols
  – ATM
  – POS
  – SSD

• But some are built over ISO8583
Transaction types

- ATM
- Retail
- CNP Retail
- Note Acceptance
- Special
  - Balance request
  - PIN Set/PIN Change
  - Address Verification
Fraud

• PAN + Exp Date + CVV2 = enough for CNP fraud
  – CNP Fraud

• Skimming
  – Cloning of magstripe with and w/o stealing the PIN
  – Clone is identical to the original card
  – [http://www.google.com/trends/explore?#q=skimming](http://www.google.com/trends/explore?#q=skimming)

• Other methods
http://www.google.com/trends/explore?q=skimming
Advances & countermeasures

• DUKPT
  – Derived Unique Key Per Transaction

• Anti-skimming
  – Terminal-only
  – Card and terminal
    • Magstripe is analog, not digital

• e-commerce
  – (SET)
  – 3-D Secure

• Finally, smart cards (ICC)
3-D Secure

(2),(3) – VERRreq (PAN)
(4),(5) – VERRes (ACS URL)
(6) – PAReq
(8a) – PARes (CAVV)
(9) – ISO 8583 Message (CAVV)
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The EMV standard

• What?
  – A protected microcontroller inside a card
  – Since 1993

• Why?
  – New interactive products
  – Liability Shift

• The Four Books
  – ICC to Terminal Interface
  – Security and Key Management
  – Application Specification
  – Other Interfaces

• ISO 7816
The EMV standard

• What does the card use:
  – DES/3DES
  – RSA
  – SHA-1

• What does the card have:
  – Several kilobytes of EEPROM
  – Firmware
    • Java Card
    • MultOS
    • …
  – 1 Serial I/O port and a system of commands
The EMV standard

• EMV Lifecycle
  – EMV Personalization
    • Pre-personalization
  – Interactivity
    • Card makes the decision
    • New cardholder authentication methods
      – Biometrics
    • Issuer scripts and data storage
      – Counters
      – Card-level risk management
EMV basics

• Physical specs
• I/O
• Files
• Commands
• Applications
Physical specs

All dimensions in millimetres
Physical specs

C1–VCC
C2–RST
C3–CLK
C4–
C5–GND
C6–VPP
C7–I/O
C8–
Physical specs

- Voltage: 3 classes of operation
  - A
  - B
  - C

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Conditions</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>$V_{CC}$</td>
<td>Class A</td>
<td>4.50</td>
<td>5.50</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>Class B</td>
<td>2.70</td>
<td>3.30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class C</td>
<td>1.62</td>
<td>1.98</td>
<td></td>
</tr>
<tr>
<td>$I_{CC}$</td>
<td>Class A</td>
<td>50</td>
<td>50</td>
<td>mA</td>
</tr>
<tr>
<td></td>
<td>Class B</td>
<td>50</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Class C</td>
<td>30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The maximum current consumptions shown apply when operating at any frequency within the range specified in section 5.3.4.

<table>
<thead>
<tr>
<th>Supported Classes</th>
<th>ICC Shall Operate</th>
<th>ICC May Operate</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>A and B</td>
<td>4.50–5.50</td>
<td>3.30–4.50</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>2.70–3.30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A, B, and C</td>
<td>4.50–5.50</td>
<td>3.30–4.50</td>
<td>V</td>
</tr>
<tr>
<td></td>
<td>2.70–3.30</td>
<td>1.98–2.70</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.62–1.98</td>
<td></td>
<td></td>
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</table>
I/O

• Insertion of the ICC into the IFD
  – connection and activation of the contacts.
• Reset of the ICC
  – establishment of communication between the terminal and the ICC.
• Execution of the transaction(s).
• Deactivation of the contacts and removal of the ICC
I/O

• Contact activation
  – Vcc level validation for 200 cycles

• ICC Reset
  – Cold
    • > 200 cycles and pull up RST
  – Warm
    • > 200 cycles, pull down RST, > 200 cycles, pull up RST
# I/O

## Rx (Card to Terminal)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Conditions</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{IH})</td>
<td>(0.7 \times V_{CC})</td>
<td>(V_{CC})</td>
<td>(V)</td>
<td></td>
</tr>
<tr>
<td>(V_{IL})</td>
<td>0</td>
<td>0.8</td>
<td>(V)</td>
<td></td>
</tr>
<tr>
<td>(t_R) and (t_F)</td>
<td>—</td>
<td>1.0</td>
<td>(\mu s)</td>
<td></td>
</tr>
</tbody>
</table>

The ICC shall not be damaged by signal perturbations on the I/O line in the range \(-0.3\) V to \(V_{CC} + 0.3\) V.

## Tx (Terminal to Card)

<table>
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<th>Conditions</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>(V_{OH})</td>
<td>(-20,\mu A &lt; I_{OH} &lt; 0), (V_{CC}) min.</td>
<td>(0.7 \times V_{CC})</td>
<td>(V_{CC})</td>
<td>(V)</td>
</tr>
<tr>
<td>(V_{OL})</td>
<td>(0 &lt; I_{OL} &lt; 1,mA), (V_{CC}) min.</td>
<td>0</td>
<td>0.4</td>
<td>(V)</td>
</tr>
<tr>
<td>(t_R) and (t_F)</td>
<td>(C_{IN}) (terminal) = 30 pF max.</td>
<td>—</td>
<td>1.0</td>
<td>(\mu s)</td>
</tr>
</tbody>
</table>

The ICC shall not be damaged by signal perturbations on the I/O line in the range \(-0.3\) V to \(V_{CC} + 0.3\) V.

## Additional Notes

- **Rx (Card to Terminal):**
  - Class A cards until end December 2013; see Table 1.

- **Tx (Terminal to Card):**
  - New card values from January 2014; see Table 1.
  - New card values from January 2014; see Table 1.
Files

• All data on card is stored as records listed in files
• Mandatory
  – Application Expiry Date
  – Application Primary Account Number (PAN)
  – Card Risk Management Data Object List 1 (CDOL1)
  – Card Risk Management Data Object List 2 (CDOL2)
• Application Elementary Files
  – Referenced by SFI
  – Contain only BERTLV data objects
Commands

- Command APDU
  - CLA = Class Byte of the Command Message
  - INS = Instruction Byte of Command Message
  - P1 = Parameter 1
  - P2 = Parameter 2

<table>
<thead>
<tr>
<th>CLA</th>
<th>INS</th>
<th>P1</th>
<th>P2</th>
<th>Lc</th>
<th>Data</th>
<th>Le</th>
</tr>
</thead>
<tbody>
<tr>
<td>←</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mandatory Header²</td>
<td>→</td>
<td>←</td>
<td>Conditional Body</td>
<td>→</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 1: Command APDU Structure
Response

- Response APDU
  - Status bytes
    - SW1
    - SW2

<table>
<thead>
<tr>
<th>Data</th>
<th>SW1</th>
<th>SW2</th>
</tr>
</thead>
<tbody>
<tr>
<td>← Body →</td>
<td>← Trailer →</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 2: Response APDU Structure**
Commands

- APPLICATION BLOCK (post-issuance command)
- APPLICATION UNBLOCK (post-issuance command)
- CARD BLOCK (post-issuance command)
- EXTERNAL AUTHENTICATE – verify a cryptogram
- GENERATE APPLICATION CRYPTOGRAM
- GET CHALLENGE
- GET DATA
- GET PROCESSING OPTIONS
- INTERNAL AUTHENTICATE – calculation of SDA
- PIN CHANGE/UNBLOCK (post-issuance command)
- READ RECORD
- VERIFY – verify PIN data
EMV crypto primitives

• $MK_{AC}$ that it shares with the issuer, derived from the issuer’s master key $MK_I$.
• Session key $SK_{AC}$ can be computed, based on the transaction counter.
• The issuer has a public-private key pair $(P_I, S_I)$, and the terminal knows this public key $P_I$.
• Cards that support asymmetric crypto also have a public-private key pair $(P_{IC}, S_{IC})$. 
EMV Transaction Flow

- Initialization
- Card/Data authentication – optional
- Cardholder verification – optional
- Actual transaction step
Initialization

• Command flow
  – T → C: SELECT APPLICATION
  – C → T: [PDOL]
  – T → C: GET PROCESSING OPTIONS [(data specified by the PDOL)]
  – C → T: (AIP, AFL)
  – Repeat for all records in the AFL:
    – T → C: READ RECORD (i)
    – C → T: (Contents of record i)
• Return AFL and AIP
Card/Data authentication

• SDA (Static Data Authentication)
  – Card provides Signed Static Application Data (SSAD)

• DDA (Dynamic Data Authentication)
  – SDA + Sign($S_{IC}$)[ICC Dynamic Data, Hash(ICC Dynamic Data, data specified by DDOL)]

• CDA (Combined Data Authentication)
  – SDAD = Sign($S_{IC}$)[nonce_IC, CID, AC, TDHC, H(nonce_IC, CID, AC, TDHC, nonce_Terminal)].
Cardholder verification

• CVM (Cardholder Verification Methods)
  – CVM List
• Online PIN
  – the bank checks the PIN
• Offline plaintext PIN
  – the chip checks the PIN
  – PIN is transmitted to the chip in the clear form
• Offline encrypted PIN
  – chip checks the PIN
  – PIN is encrypted before it is sent to the card
Offline plaintext PIN

• T → C: VERIFY(pin)
• C → T: Success/ (PIN failed, tries left) / Failed
Offline encrypted PIN

• T → C: GET CHALLENGE
• C → T: nonce_IC
• T → C: VERIFY(Encrypt (P_{IC})[PIN, nonce_IC, random padding])
• C → T: Success/ (PIN failed, tries left) / Failed
Transaction step

• Offline
  – card sends a Transaction Certificate (TC)

• Online
  – card sends an Authorisation Request Cryptogram (ARQC)
  – If issuer approves, card sends a TC

• If card itself refuses
  – Card provides Application Authentication Cryptogram (AAC)
Attacks on EMV

• Classification
  – Hardware vs. Software
  – Active vs. Passive
  – Intrusive vs. Non-intrusive
  – By localization:
  – By methods used
Attacks on EMV

• Classification
  – By localization:
    • Malicious card
    • Malicious terminal
    • MITM
Attacks on EMV

• Classification
  – By methods used
    • Communication lines eavesdropping & tampering
    • Purely cryptoanalytical methods
    • Fault attacks
    • Side-channel attacks
      – Power analysis
        » SPA (Single Power Analysis)
        » DPA (Differential Power Analysis)
        » DFA (Differential Fault Analysis)
      – TAA (Timing Analysis Attack)
  • Social Engineering
Known vectors

- Fallback to magstripe
- Relay attacks
- Replay attacks ("YES"-cards = clones of SDA card)
- MITM (Wedge) with CVM list downgrade
- Pre-play attack
- Joint encryption and signature
- Fault analysis
- Power analysis
- Attacking HSM's
MITM (Wedge) with CVM list downgrade

- Terminal might not check if authentication method is the same that the card approved
  - Only auth result is signed
- Make the card think it was a signature-based transaction
- Make the terminal think it was a PIN-based transaction
- Easily prevented
  - by correct terminal software
- Detected at host
Pre-play attack

• Bond et al., Cambridge, 2012
• Random nonce sent by terminal?
• In reality it is not so random
  – Older implementations
• So a MITM device can gather a lot of cryptograms for known nonces
• Then just predict when this cryptogram will be correct and use it with fake transaction data
Joint encryption and signature attack

• Degabriele et al., CT-RSA 2012
• CDA cards
• Offline transaction, card verifies PIN
• Utilize known padding of encrypted EMV data
  – Bleichenbacher attack on RSA
• Same RSA keypair used for signature and encryption
Joint encryption and signature
Fault analysis

• Coron et al., CT-RSA 2010
• Currently CRT (Chinese Remainder Theorem) is used to reduce computational load on signer in RSA implementations
  – From \( mod \ N \) to \( mod \ p \) and \( mod \ q \)
  – Fault induced on one computation of two
  – “CJKNP” attack on RSA, 2009
    • Partially unknown plaintexts
• Consider EMV DDA:
  – Signed data includes partially known ASN.1 header
  – Attack uses orthogonal lattice techniques
  – Attack requires 10 faulty signatures to factor \( N \) under 1 second
Attacking HSM’s

- EMV introduced new crypto primitives to be implemented on existing, non-flexible systems with decades of backward compatibility
  - The new crypto functions may have been implemented improperly
- An attack by Ben Adida et al. and Ron Rivest (2005) on 3DES CBC MAC
  - Inject chosen plaintext in the MAC’ed message
  - Disclose encryption key
  - Two implementations
    - IBM 4758
    - Thales RG7000
- Modern systems are not vulnerable
Countermeasures

• Technical
  – Improve terminal software (!)
  – Improve host software
  – Improve personalization restrictions
    • Obey payment systems’ regulations
  – Distance Bounding
    • Saar Drimer and Steven J. Murdoch, Cambridge
  – Cardholder self-defence
    • Steven J. Murdoch, Cambridge
    • Invent an "Electronic attorney“ – legitimate cardholder’s shim (!?)

• Organizational
  – Verify from the business level
  – Improve standards coverage
Future

• Elliptic curves
  – ECIES (ISO/IEC 18033-2) for PIN

• More complex chip applets
  – More authentication schemes
    • Interactive cards with keyboard and display
  – More bugs?

• Fast and more expensive ICC chips
  – Stronger crypto
  – Difficult and less practical hardware attacks
# Modern payments security: EMV, NFC, etc.?

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</tbody>
</table>
Intro: NFC

• RFID – Radio Frequency Identification technologies
  – LF (Low frequency)
    • 125 KHz
    • 134 KHz
  – HF (High frequency)
    • 13.56 MHz
      – NFC
        » ISO/IEC 18092 (ECMA-340)
        » ISO/IEC 14443
        » ISO/IEC 15693
  – Others
NFC

• NFC Devices
  – Tags
  – Smart cards
  – Readers
  – Mobile devices

• NFC Security
  – NFC Ready and NFC Secure
  – Secure Element
  – Authentication
  – Encryption
NFC Data Transfer

• NFC Roles by RF field source:

<table>
<thead>
<tr>
<th>Device A</th>
<th>Device B</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>Active</td>
<td>RF field is generated by the device that sends data at the moment</td>
</tr>
<tr>
<td>Active</td>
<td>Passive</td>
<td>RF field is generated by Device A only</td>
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<tr>
<td>Passive</td>
<td>Active</td>
<td>RF field is generated by Device B only</td>
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• NFC Roles by protocol:

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<tr>
<th>Initiator</th>
<th>Target</th>
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<tr>
<td>Active</td>
<td>Possible</td>
</tr>
<tr>
<td>Passive</td>
<td>Not Possible</td>
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NFC Device Modes of Operation

• Data exchange (P2P – NFC peer-to-peer)
  – Duplex data exchange
  – WiFi, Bluetooth, P2P Payment, Contacts, vCards, ...

• Reader/Writer mode (PCD – Proximity Coupling Device)
  – Mobile device reads tags/smartcards
  – WiFi Config, media linking

• Tag emulation (PICC – Proximity Card)
  – Reader cannot distinguish between smartcard & tag emulation
  – Handset may contain/emulate multiple smartcards (smartcard chips)
NFC Security

• Eavesdropping is easy (up to 10 meters in active mode)
• DoS is easy
• Datastream modification is possible
• MITM is possible using full relay (when Alice and Bob cannot talk to each other at all)
  – No NFC shims, unless some RF-shielding nano-materials appear :)
  – A fast relay is a \textbf{practical} attack both for eavesdropping and data tampering
• Secure element
• Additional levels of security are out of scope of NFC standards
  – Proprietary implementations
Secure element

• Smart Card Alliance: “The secure element (SE) is a secure microprocessor (a smart card chip) that includes a cryptographic processor to facilitate transaction authentication and security, and provide secure memory for storing payment applications (e.g., American Express, Discover, MasterCard, Visa and other payment applications). SEs can also support other types of secure transactions, such as transit payment and ticketing, building access, or secure identification.”
Secure element

• Secure elements in consumer devices
  – Contactless smart card
  – NFC SIM card + Handheld device
    • RF interface on handheld
    • Integrated RF interface
    • Flexible antenna
  – NFC SD Card + Handheld device
    • RF interface on handheld
    • Integrated RF interface
  – SE Embedded in a chip in a handheld device
    • RF interface on handheld
NFC Security

• Secure Element is as secure as a regular (contactless) smartcard
  – Same security features
  – Same weaknesses
    • Side channels
  – Main weakness: Relay attack
    • Cannot be prevented by application-layer cryptographic protocols
    • Timing requirements by ISO 14443 are too loose to prevent relay over longer channel
      – Real devices may be even more relaxed to produce less timeouts in real life for the customers
NFC Reality

- Mifare
  - Proprietary near-ISO compliant cards by Philips (NXP)
  - Worldwide deployment
    - European transport: subways, intercity trains...
    - Asia, South America, ...
    - Ski passes at modern ski resorts
    - ... finally, Moscow & Saint-Petersburg subway tickets
NFC Reality

• Mifare security
  – MIFARE Ultralight – no encryption
  – Mifare Classic
    • Uses a weak crypto algorithm “Crypto-1”, 48-bit key
    • First attacks in 2000’s
    • Algorithm fully reverse-engineered from chip by 2008
      – Insecure, minutes to retrieve secret key and fully clone card
  – Mifare DESFire
    • 3DES / AES
    • Successful DPA attack on 3DES Mifare DESFire in 2011
NFC Reality

• Vulnerable smartphones
  – Various
    • Attacks on NFC P2P
    • JSR-177
  – Android
    • Currently deployed custom stacks and drivers
    • Linux standard NFC stack
    • Userland vulnerabilities on handling NFC data
Modern payments security: EMV, NFC, etc.?

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EMV & NFC = ?

- EMV & NFC = ?
  - EMV-compliant chip is a secure element
  - So we have contactless payment cards:
    - Visa PayWave
    - MasterCard PayPass
  - etc.
  - Mostly: dual interface (contacts + coil) for backward compatibility (some even have magstripe)
  - Personalized by contact and contactless interfaces alike
  - New threats
EMV & NFC = ?

• Low-amount payments with little to no cardholder verification
  – Local transport tickets
  – Small retail purchases
  – Even cash withdrawal
  – …

• An EMV card embedded inside a smartphone
  – Total payment convergence
  – Smartphone’s screentouch screen
  – Multi-application EMV
Modern payments security: EMV, NFC, etc.?

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- Future
Attacks on EMV & NFC

• Known vectors
  – PAN Gathering for subsequent CNP online fraud
    • Fake point-of-sale device
  – Relay attacks
    • Two NFC-enabled smartphones

• New vectors
  – Power analysis
  – Smartphones
Known vectors

• PAN Gathering for subsequent CNP e-commerce fraud
  – Fake point-of-sale device, e.g. selling candies
  – Customers pays with his card
  – Card details are used in CNP e-commerce fraud

• Relay attacks
  – Two NFC-enabled smartphones
  – Implements known EMV attacks using the relay
New vectors

• Power analysis
  – Card draws power from the same RF field that is used for data transfer

• Smartphones
  – Direct access to secure element
  – Consider all those rooted Androids...
Modern payments security: EMV, NFC, etc.?

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Future

• Industry strengths
  – Security by obscurity

• Industry weaknesses
  – Security by obscurity

• New technology
  – Stronger cryptography

• Perspectives
  – EMV
  – NFC
  – etc.?