Security Analysis of Mobile Point-of-Sale Terminals

Mahshid Mehr Nezhad, Elliot Laidlaw, Feng Hao
University of Warwick, UK

Network and System Security 2023

- Background
- Encryption Security
- Network Security
- Software Security
- Conclusion

Introduction

Payment Systems:
- Card Present (CP)
- Card Not Present (CNP)

CP Acceptance Terminals:
- Traditionally: Point of Sale (PoS)
- Recently: mobile PoS (mPoS)


mPoS Terminals

Risks

Ecosystem

Related Work

mPoS Terminals

mobile PoS Terminals: small, compact, low-cost, wireless, easy to configure

Accept various payment methods: Contact, Contactless, QR Code

Accpet various devices: card, mobile, watch, wearables

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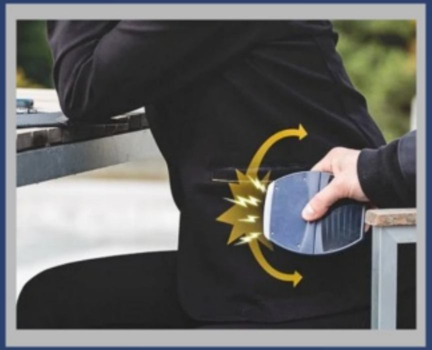
- Lock-screen bypass for mobile payments [22]
- PIN bypass for over the contactless limit [3-5]
- and ...
- Relay (Digital Pickpocketing) [17]



Proxmark
(Terminal Emulator)
Card Emulator
Merchant Phone
Victim's Phone
Terminal
Proxy Server

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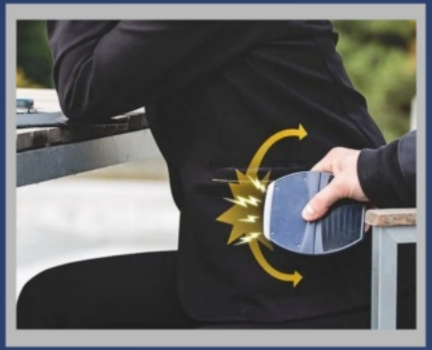


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CONTACTLESS
THE SAFEST WAY TO PAY
You can also use Oyster to pay on all Tube, DLR, London Overground, bus and tram services and on most TfL Rail services.
Let's make sure every journey matters
#LondonTogether
TRANSPORT FOR LONDON
MAYOR OF LONDON

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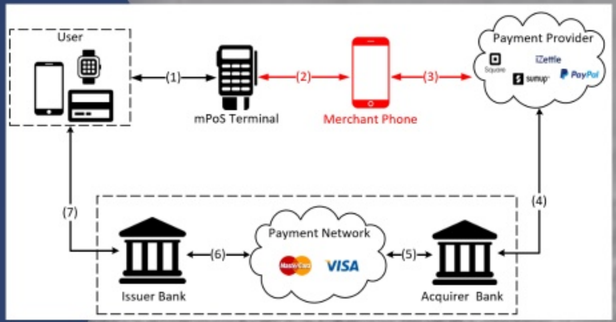
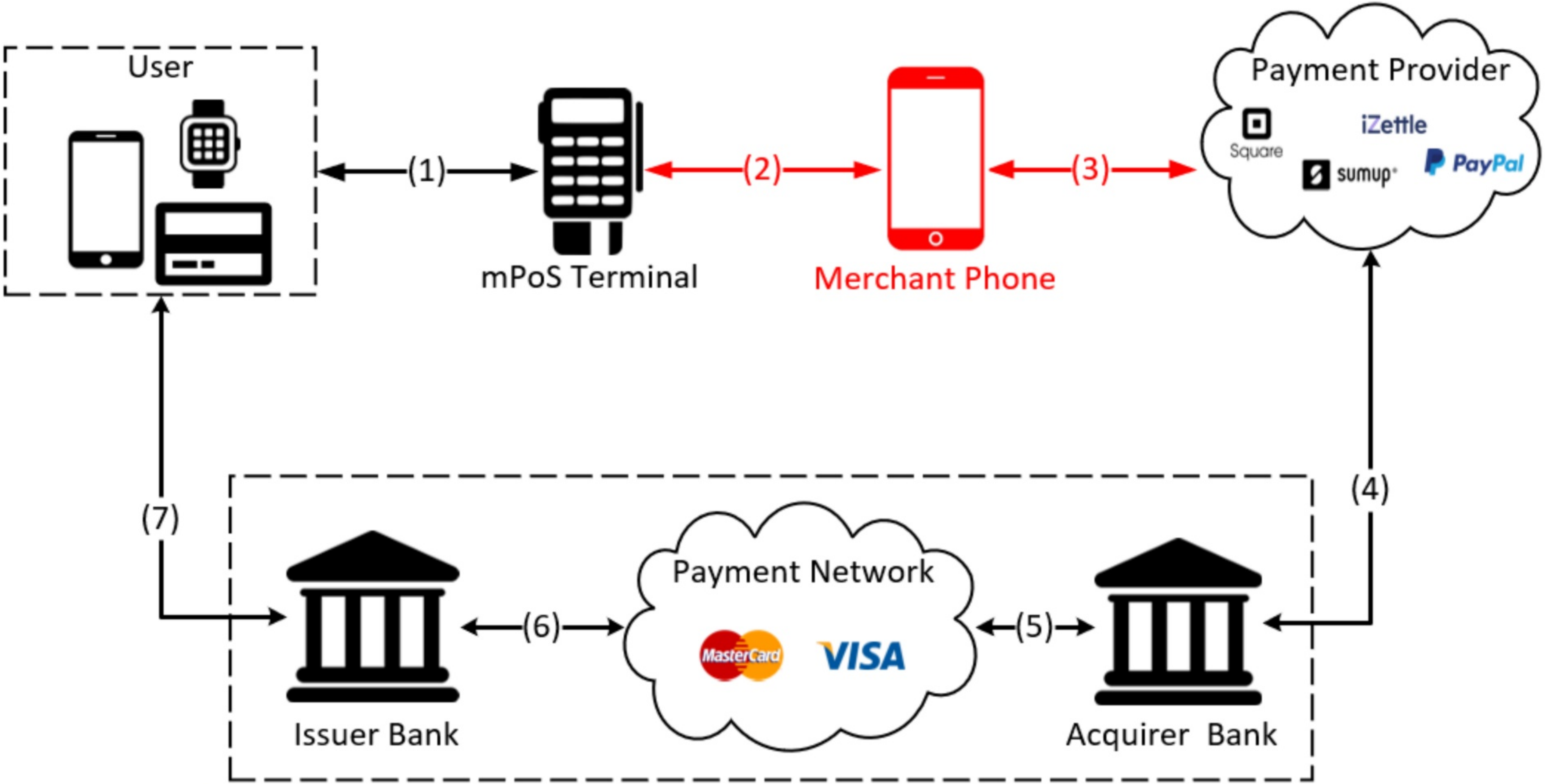
- **Crucial Component: Mobile Phone**
- **Roles**:
  - Communication with mPoS terminal
  - Connection to payment provider
  - Mobile Application
- Proof of concept: **SumUP**





User
(1)
mPoS Terminal
(2)
Merchant Phone
(3)
Payment Provider
Square
iZettle
sumup
PayPal
(4)
(7)
Issuer Bank
(6)
Payment Network
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VISA
(5)
Acquirer Bank

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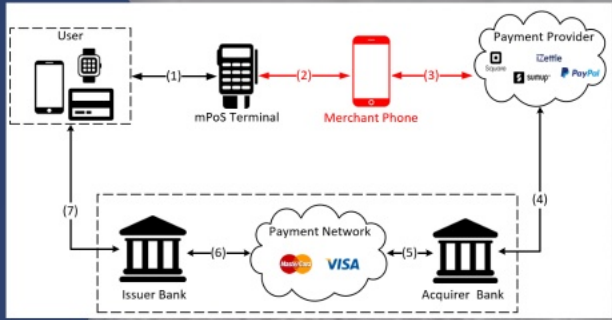

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2012	**Frisby et. al.** [10]: disable the magnetic stripe reader in audio-jack magnetic stripe reader (AMSR) by arbitrary application running and obtain cryptographic keys
2014	**MWR Lab** [15]: utilizie USB and Bluetooth interfaces, get root access, 1) execute arbitrary command 2) full control over screen ("Try again")
2015	**Mellen et. al.** [18]: bypass the encryption by crushing the encryption chip, recording unencrypted swipes and transmit the credit card information to an external server
2018	**Galloway and Yunusov** [11]: exploit BLE interface, send arbitrary commands ("please swipe card") and tamper with amounts (Sumup transmitted commands in plaintext!)

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THE UNIVERSITY OF WARWICK

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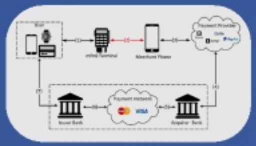

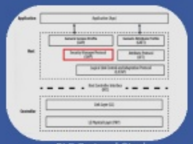

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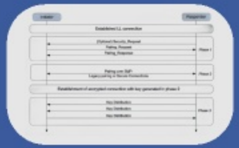
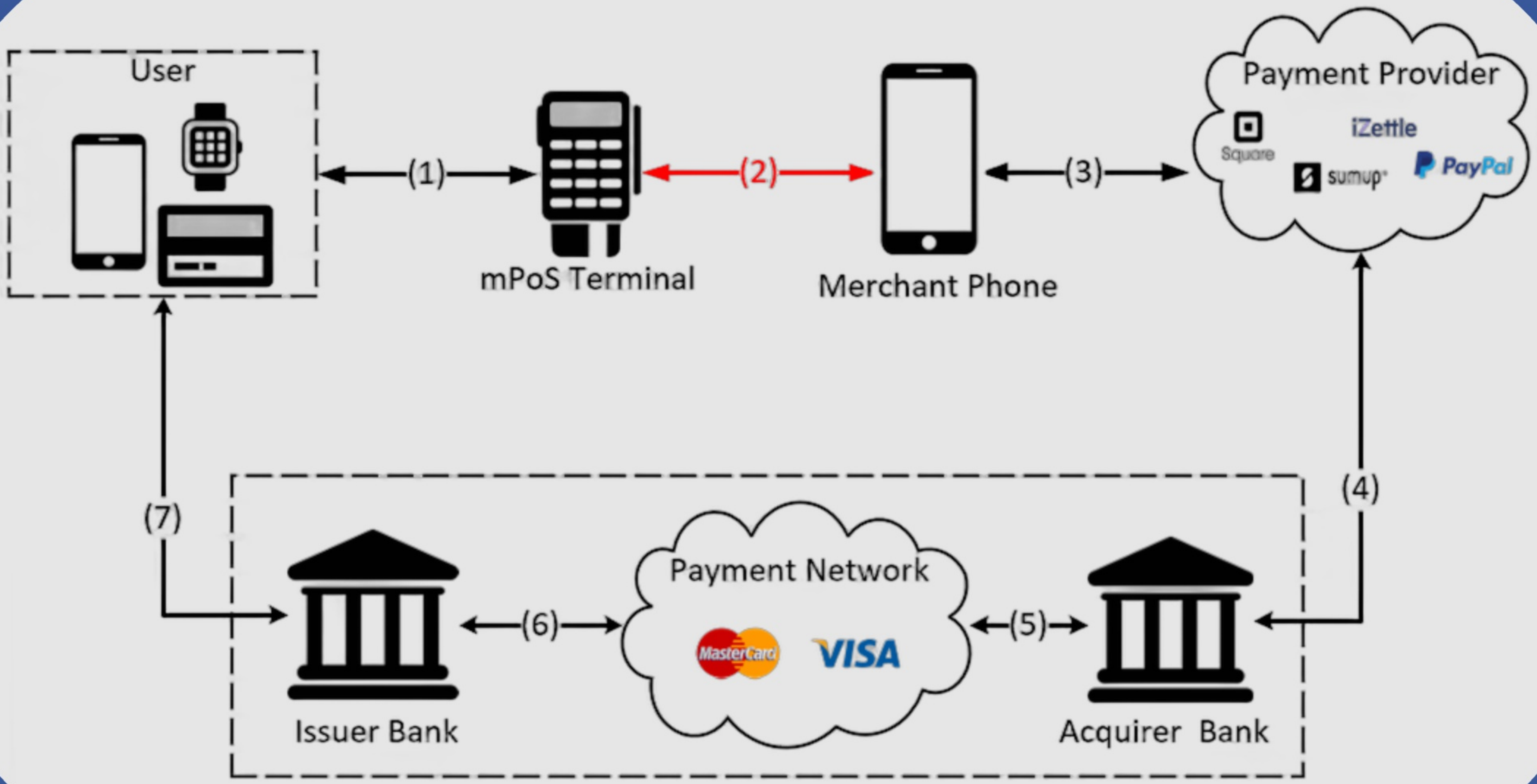


BLE Pairing

Pairing

Eavesdropping

Attack



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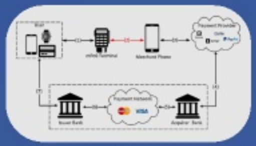

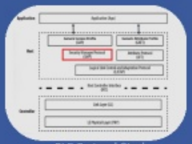

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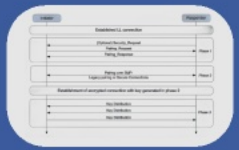

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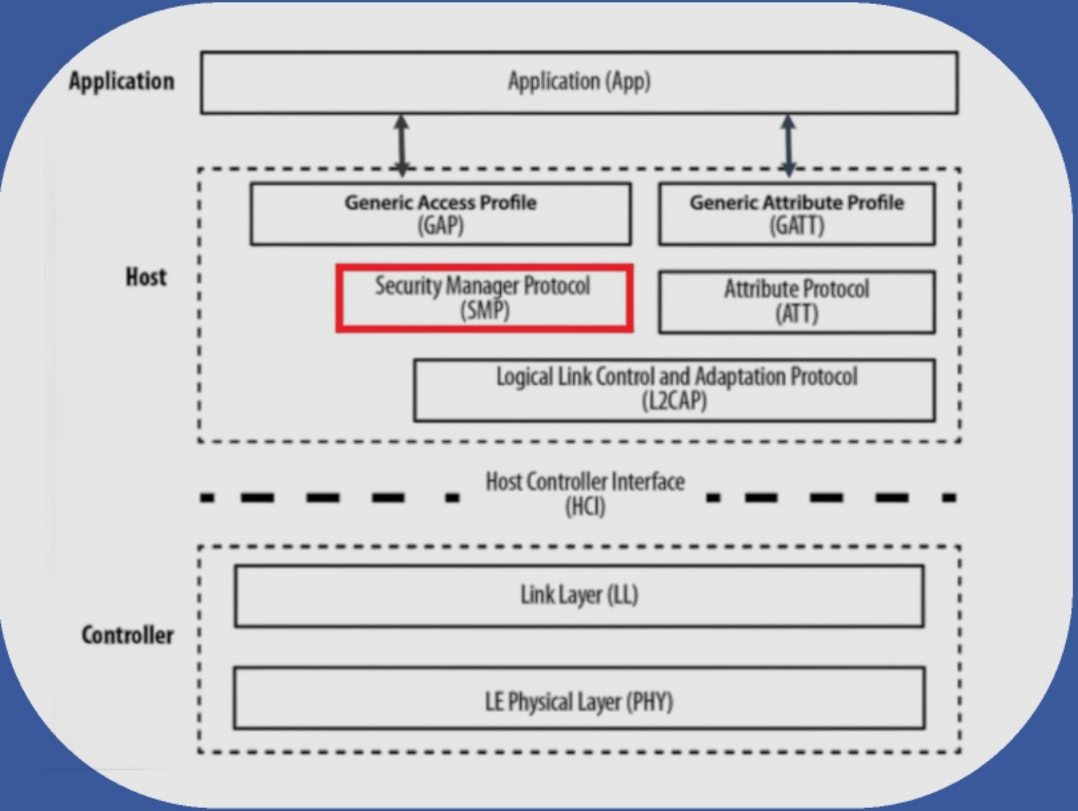

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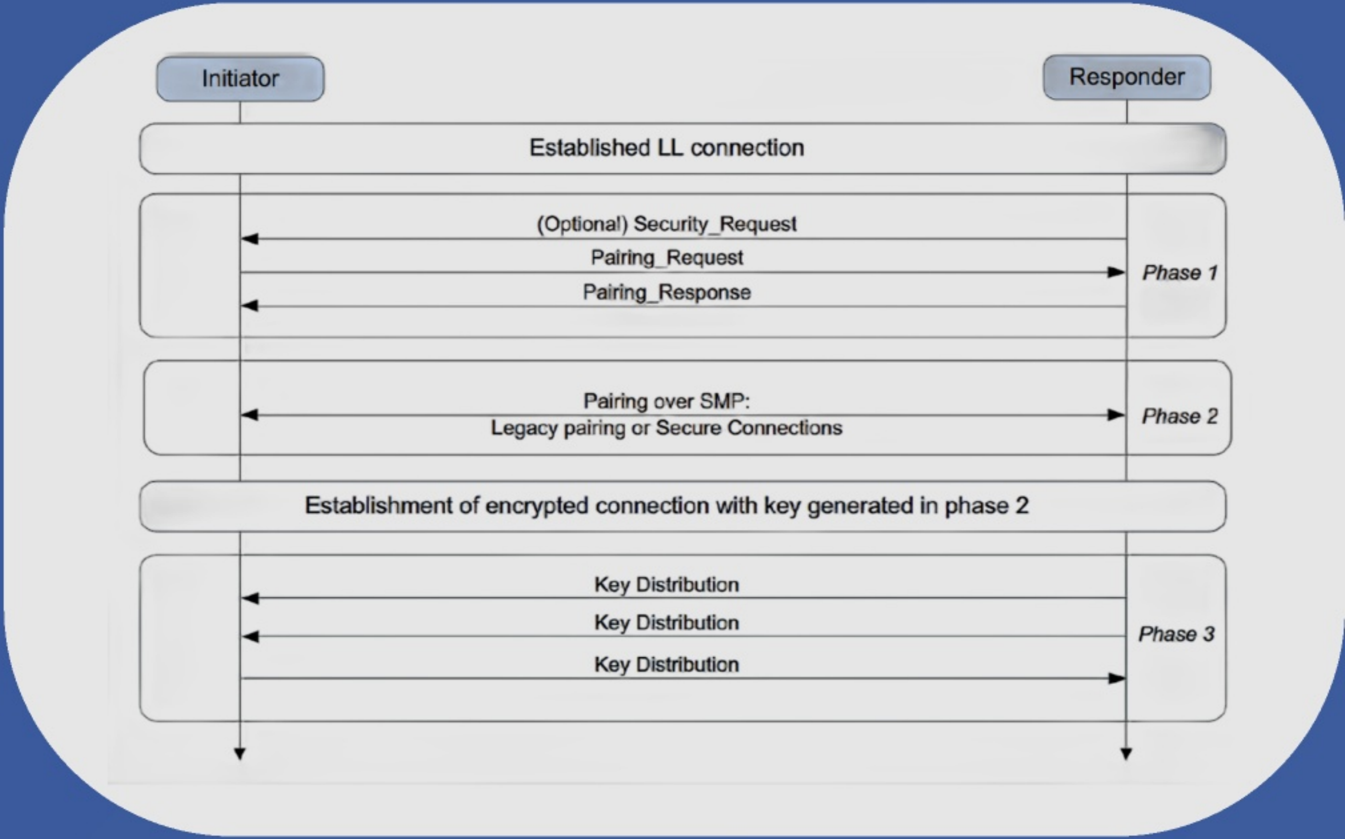

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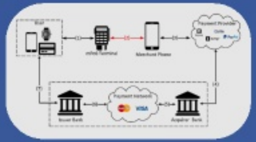


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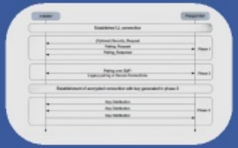
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Phase 1:

- Pairing Request (I/O, OOB, BF, SC, Key size, ...)
- Pairing Response (I/O, OOB, BF, SC, Key size, ...)

I/O: Input/Output

OOB: Out of Band

BF: Bonding Flag

SC: Secure Connection

Phase 2:

- Pairing mechanism:
  - Legacy Pairing (TK ==> STK ==> LTK)
  - SC: Secure Conncetion (ECDH: LTK)
- Pairing method:
  - Just Works Unauthenticated (TK=0)
  - Out of Band (OOB)
  - Passkey (TK: 6 digit)
  - Numeric Comparison

TK: Temparory Key

STK: Short Term Key

LTK: Long Term Key

ECDH: Elliptic Curve Diffie–Hellman

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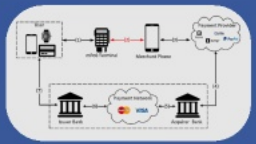

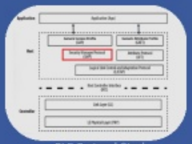

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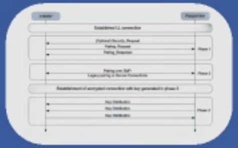

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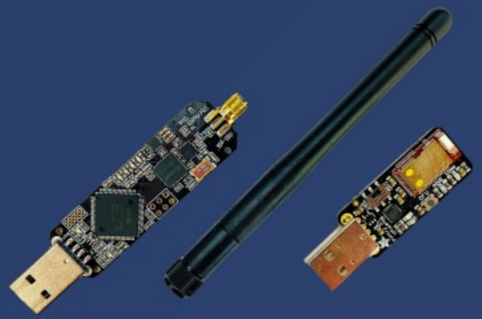
- **Threat Model**: malicious merchant or eavesdropper
- **Tools**:
    - HCI Snoop Log
    - BLE Over-the-air Sniffer



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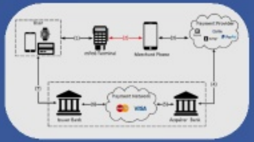

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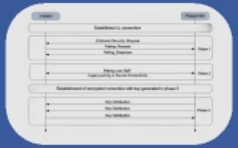

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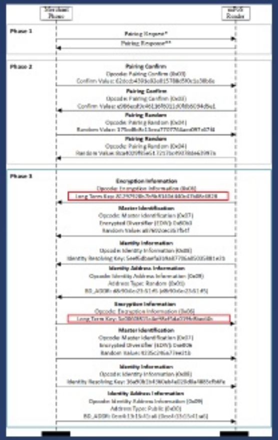
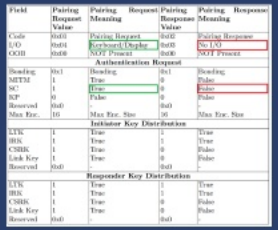
Extract Cryptographic Keys





- Request:Keyboard&Display ~ Response: No I/O
  - Pairing: **LE Legacy**
  - Key Generation: **Just Works (Unauthenticated)**
  - Temparory Key (TK): **Zero**
  - Extract **LTK**!
- Crackle: "**Decrypt with LTK**"
  - Input: encrypted file + LTK
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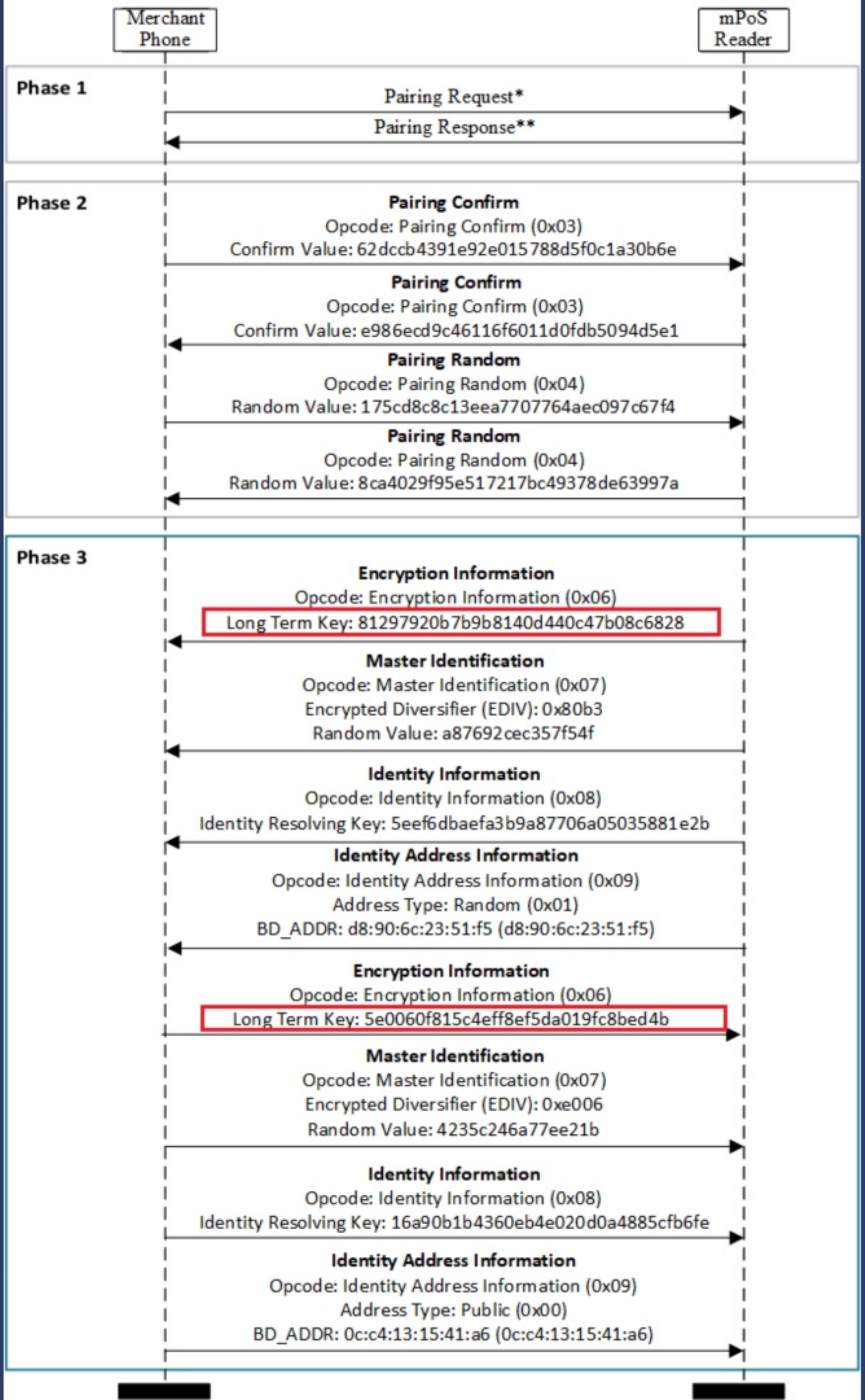

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I/O	0x04	Keyboard/Display	0x03	No I/O
OOB	0x00	NOT Present	0x00	NOT Present
Authentication Request				
Bonding	0x1	Bonding	0x1	Bonding
MITM	1	True	0	False
SC	1	True	0	False
KP	0	False	0	False
Reserved	0x0	-	0x0	-
Max Enc.	16	Max Enc. Size	16	Max Enc. Size
Initiator Key Distribution				
LTK	1	True	1	True
IRK	1	True	1	True
CSRK	1	True	0	False
Link Key	1	True	0	False
Reserved	0x0	-	0x0	-
Responder Key Distribution				
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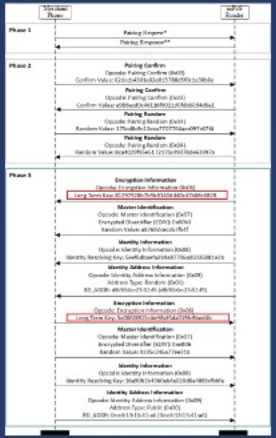

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iZettle:

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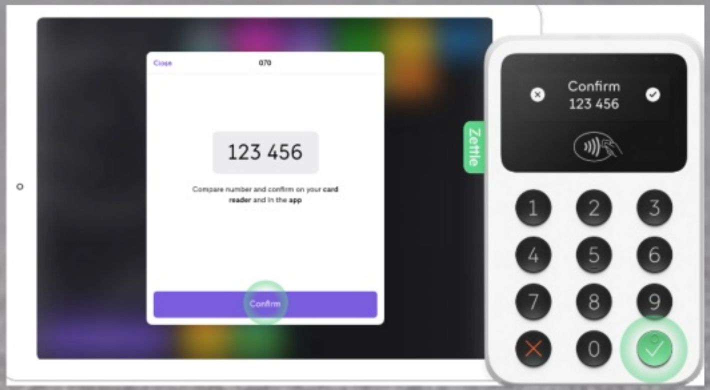
Not Common Practice!



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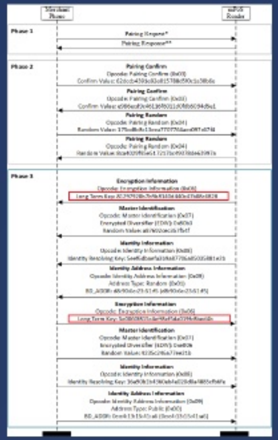

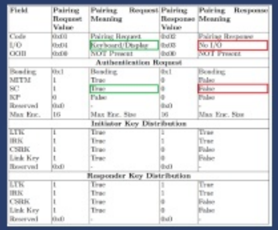

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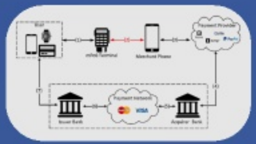

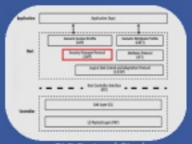

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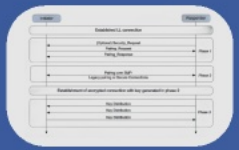

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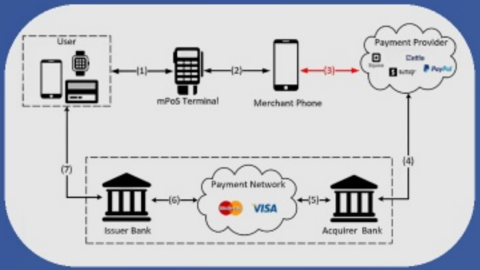
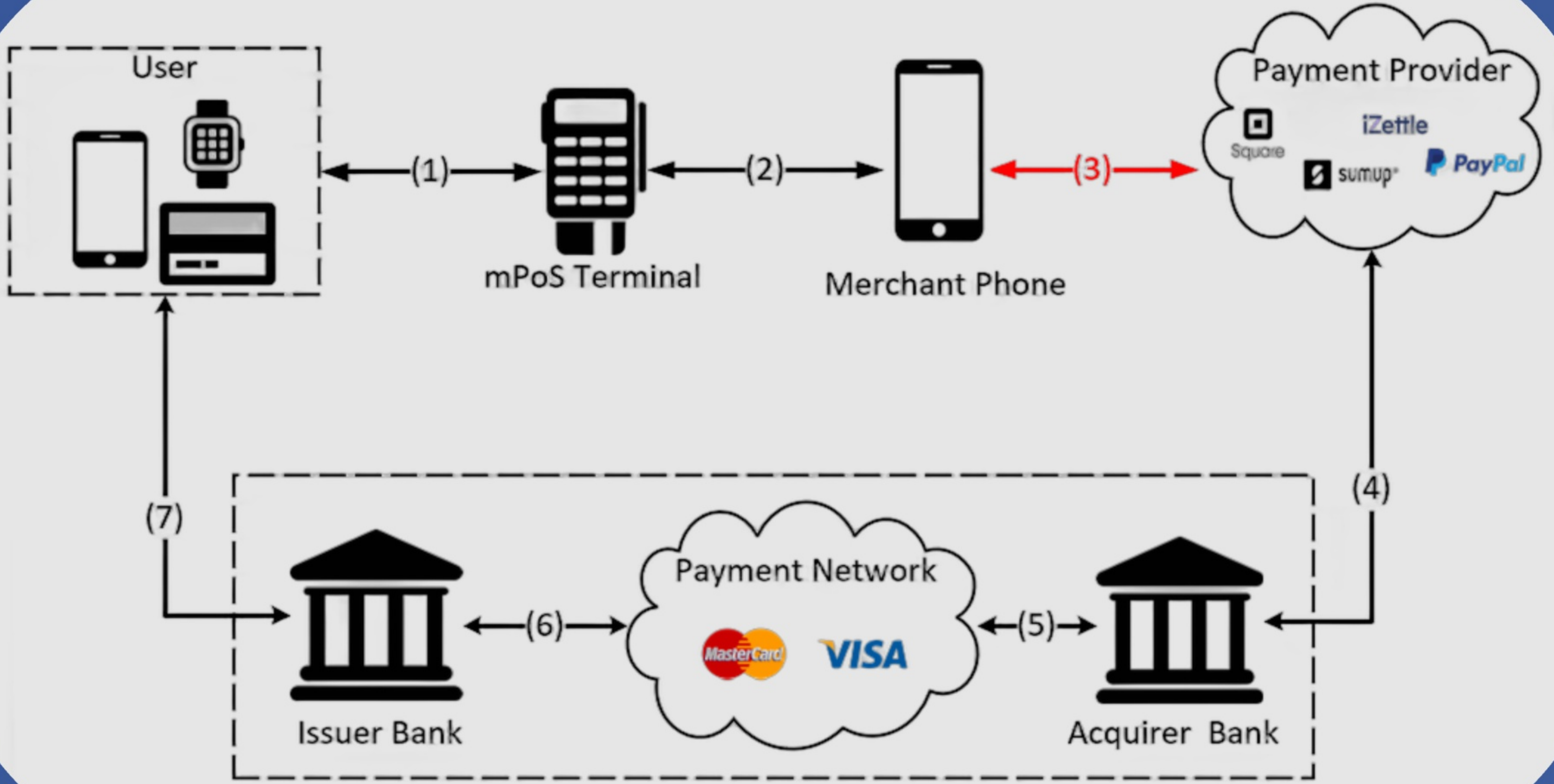
- Threat model: **man-in-the-middle (MITM)**

- Proxy server: **mitmproxy**
  - intercept and decrypt traffic



HTTPS Interception

Attack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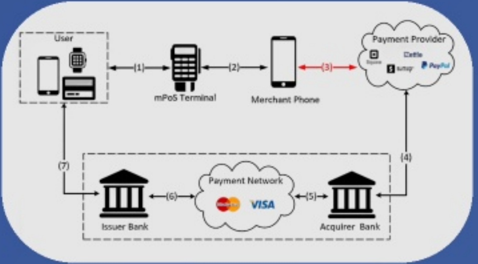

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1. Set up manual **proxy** configuration on the phone

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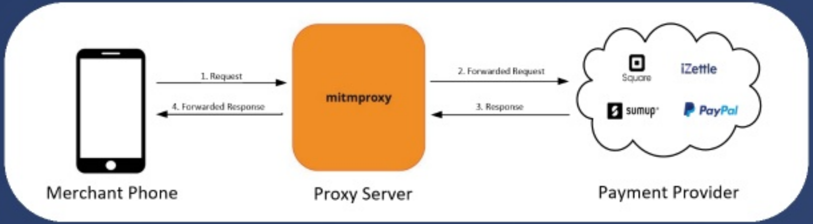
4. The modified app now **trusts** the mitmproxy certificate!



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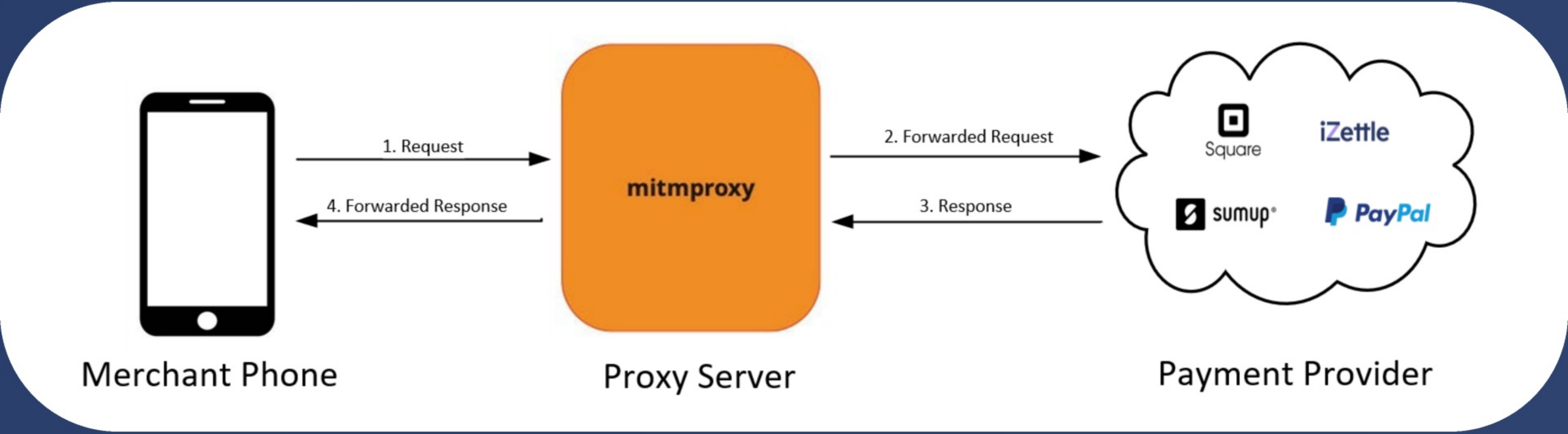

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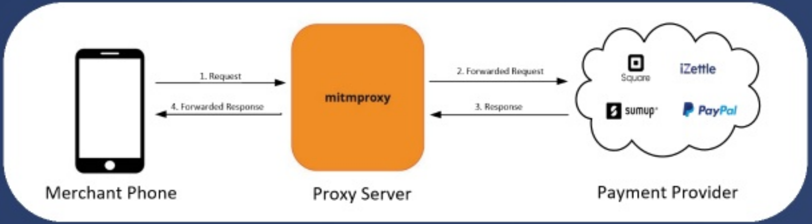

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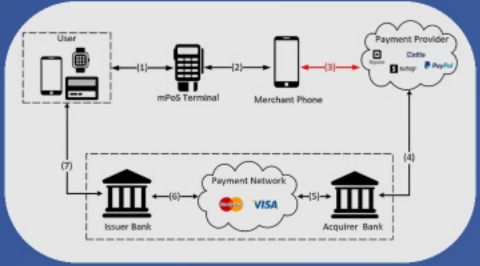

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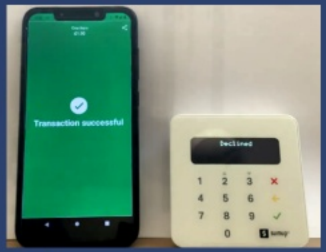
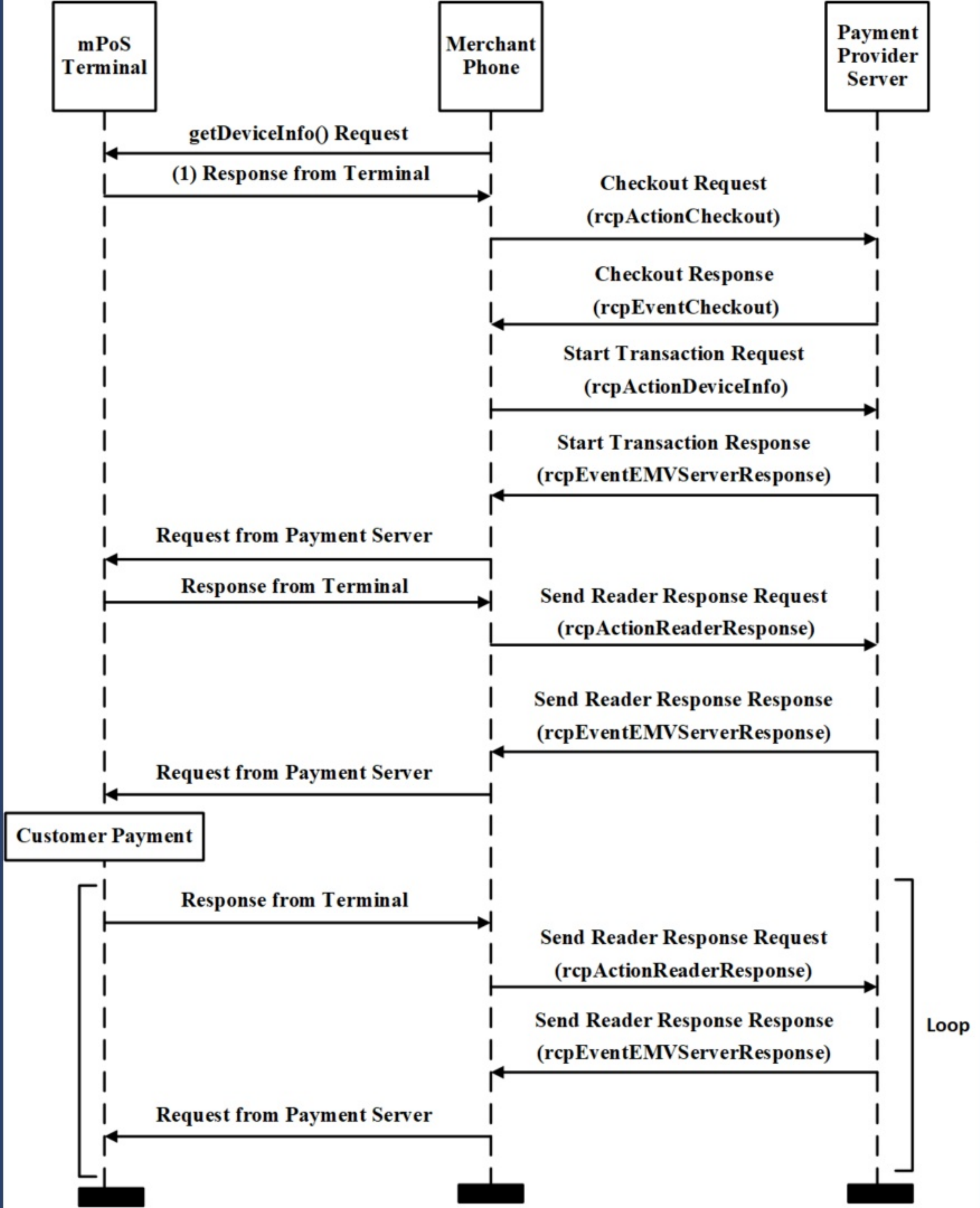
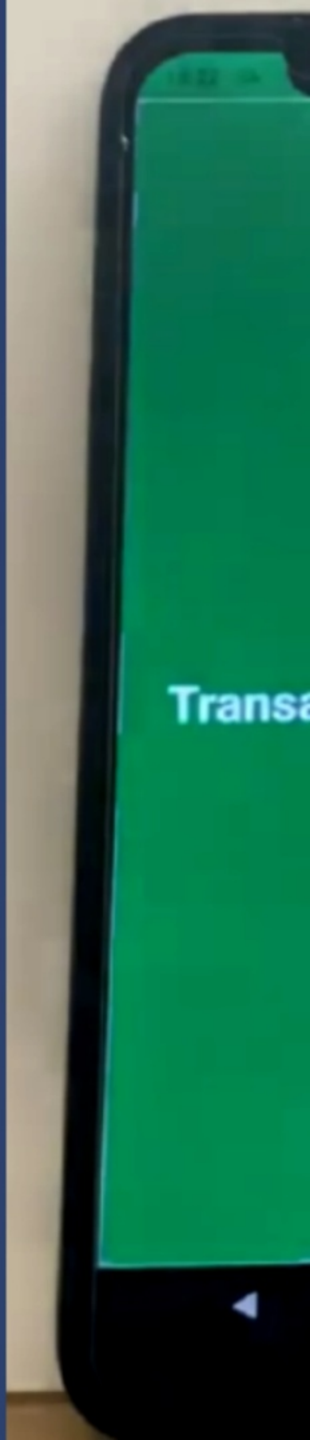
Tampering Attack

- **Tampering** with the (protected) messages
- Command "**PINPLUS SHOW DEFAULT MESSAGE**" coded in **plain text** Hexadecimal
- Inserting **arbitrary commands** to force the terminal to change the displayed message ("**Declined!**")
- **Challenge**: Protected messages are rejected
- **Solution**: Send “leave_protected_session” command first!



B


mPoS Terminal
Merchant Phone
Payment Provider Server
getDeviceInfo() Request
(1) Response from Terminal
Checkout Request (rcpActionCheckout)
Checkout Response (rcpEventCheckout)
Start Transaction Request (rcpActionDeviceInfo)
Start Transaction Response (rcpEventEMVServerResponse)
Request from Payment Server
Response from Terminal
Send Reader Response Request (rcpActionReaderResponse)
Send Reader Response Response (rcpEventEMVServerResponse)
Request from Payment Server
Customer Payment
Response from Terminal
Send Reader Response Request (rcpActionReaderResponse)
Send Reader Response Response (rcpEventEMVServerResponse)
Request from Payment Server
Loop




One item
£1.00
Transaction successful
Declined
1 2 3
4 5 6
7 8 9
0
sumup

Tampering Attack

- **Tampering** with the (protected) messages
- Command "**PINPLUS SHOW DEFAULT MESSAGE**" coded in **plain text** Hexadecimal
- Inserting **arbitrary commands** to force the terminal to change the displayed message ("**Declined!**")
- **Challenge**: Protected messages are rejected
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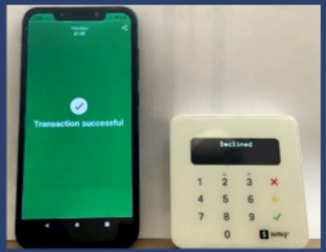

B

Tampering Attack: Barbie Version!

Not a barbie girl, but stuck in the barbie world!

Not a barbie girl, but stuck in the barbie world!

Tampering Attack

- **Tampering** with the (protected) messages
- Command "**PINPLUS SHOW DEFAULT MESSAGE**" coded in **plain text** Hexadecimal
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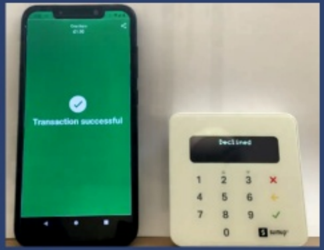
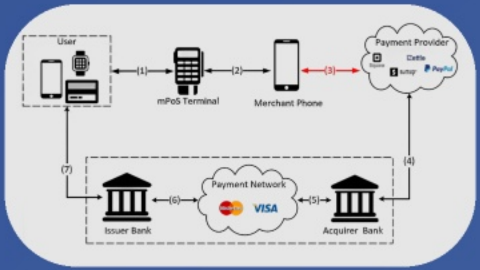


B

Network Security

- Communication: **HTTPS** (uses TLS)
- Threat model: **man-in-the-middle (MITM)**

- Proxy server: **mitmproxy**
    - intercept and decrypt traffic



HTTPS Interception

Attack

Security Analysis of Mobile Point-of-Sale Terminals

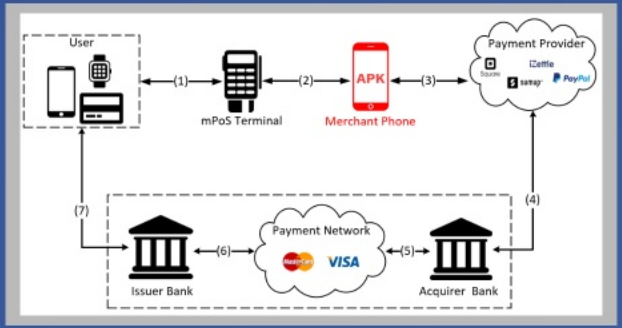
Mahshid Mehr Nezhad, Elliot Laidlaw, Feng Hao
University of Warwick, UK

Network and System Security 2023

- Background
- Encryption Security
- Network Security
- Software Security
- Conclusion

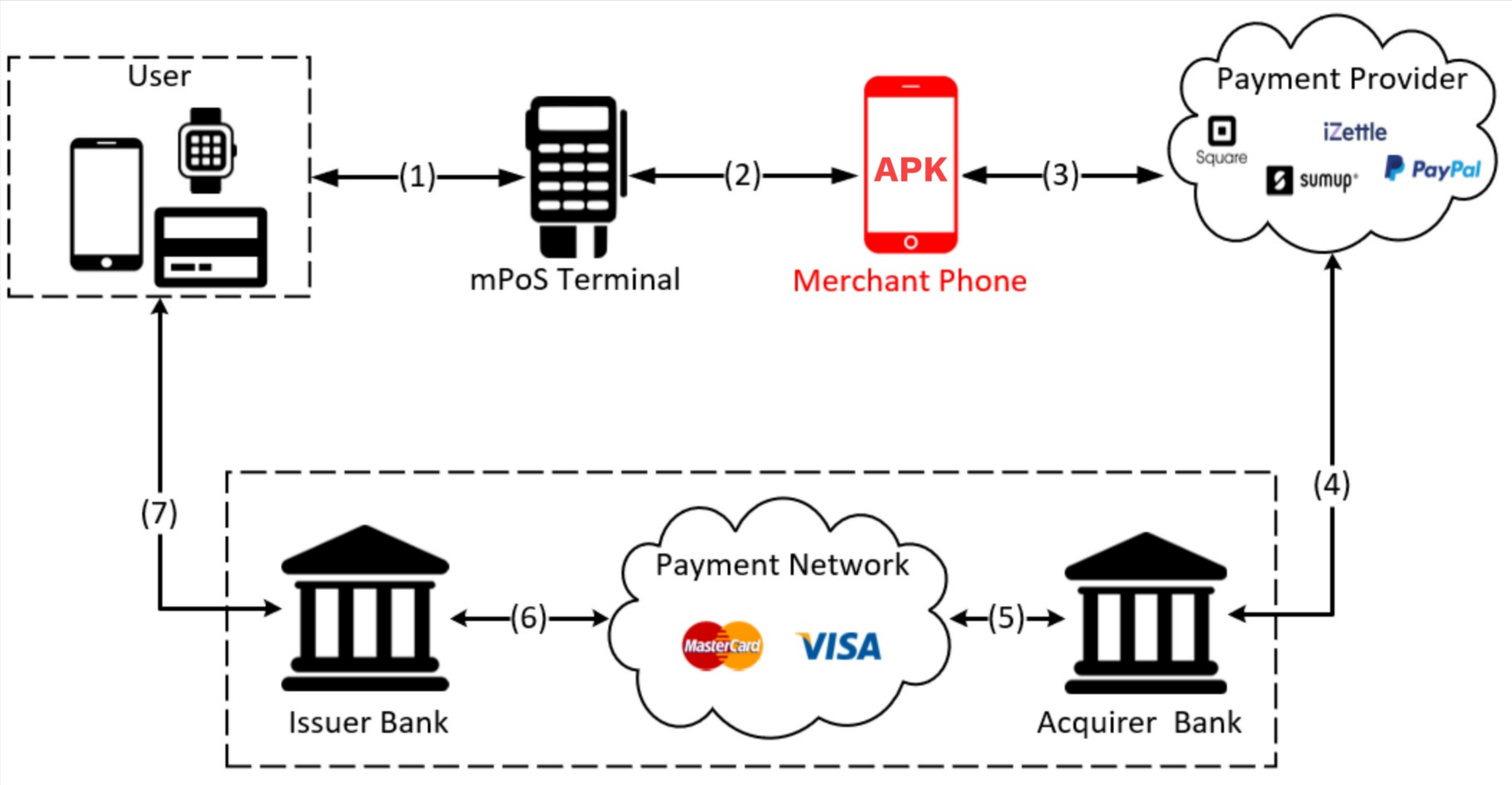
Software Security

- Mobile application: manages the terminal
- Reverse-engineering to identify vulnerabilities in the code
- proof of concept: Android phone, APK



Reverse Engineering

Attacks


User
mPoS Terminal
APK
Merchant Phone
Payment Provider
Square
iZettle
sumup
PayPal
(1)
(2)
(3)
(4)
(5)
(6)
(7)
Payment Network
MasterCard
VISA
Issuer Bank
Acquirer Bank

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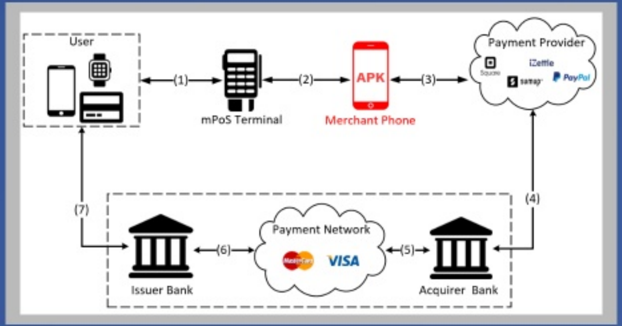

Reverse Engineering

Attacks

Reverse Engineering Steps

1. Download genuine APK
2. Decompile the APK
   apktool: Smali code (main)
   Java decompiler: Java code (complementary)
3. Make Modifications
4. Recompile the APK (e,g, apk-mitm)
5. Sign the APK (e,g, uber-apk-signer)
6. Re-install compromised App!

Software Security

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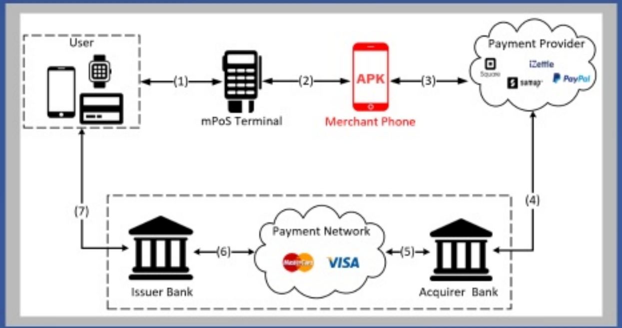

Reverse Engineering

Attacks

Attacks

1. Bypass Certificate Pinning

- Replace the application's network security config to allow user-added certs.
- Modify the code to disable cert. pinning implementation

2. Bypass Protected Messages

- Leave Protected Session

3. Disable Security Features: Beep Sound

- Find "AudioManager" Class ==> "PlaySoundEffect" method
- Modify or remove
- Sounds are muted!

4. ...

Software Security

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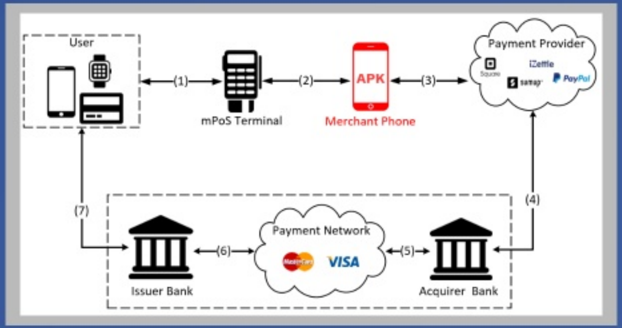

Reverse Engineering

Attacks

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WARWICK
THE UNIVERSITY OF WARWICK

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Network and System Security 2023

Conclusion

- mPoS terminals can be vulnerable in various ways
- The involvement of merchant's phone can make it worse!

Potential Solutions

What's next?

Thanks!

Potential Solutions

- Secure Pairing on BLE
- Code Obscuring
- Anti-tampering
- Abuse Detection

- Requires Further Research!

Conclusion

- mPoS terminals can be vulnerable in various ways
- The involvement of merchant's phone can make it worse!

Potential Solutions

What's next?

Thanks!

What's next?

Tap-to-phone!

- Potential Solution
- Susceptible to risks
- Requires furthur research

Conclusion

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- The involvement of merchant's phone can make it worse!

Potential Solutions

What's next?

Thanks!

Conclusion

- mPoS terminals can be vulnerable in various ways
- The involvement of merchant's phone can make it worse!

Potential Solutions

What's next?

Thanks!

Thank you!

Any questions?

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@mahshidmehr

Conclusion

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Potential Solutions

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