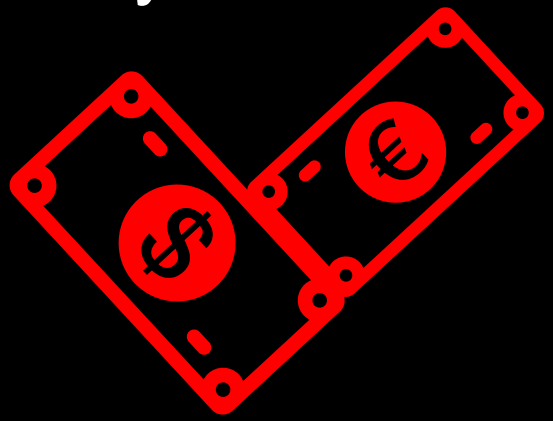
FOR THE LOVE OF MONEY

Finding and exploiting vulnerabilities in mobile point of sales systems



LEIGH-ANNE GALLOWAY & TIM YUNUSOV

POSITIVE TECHNOLOGIES

MPOS GROWTH



2010

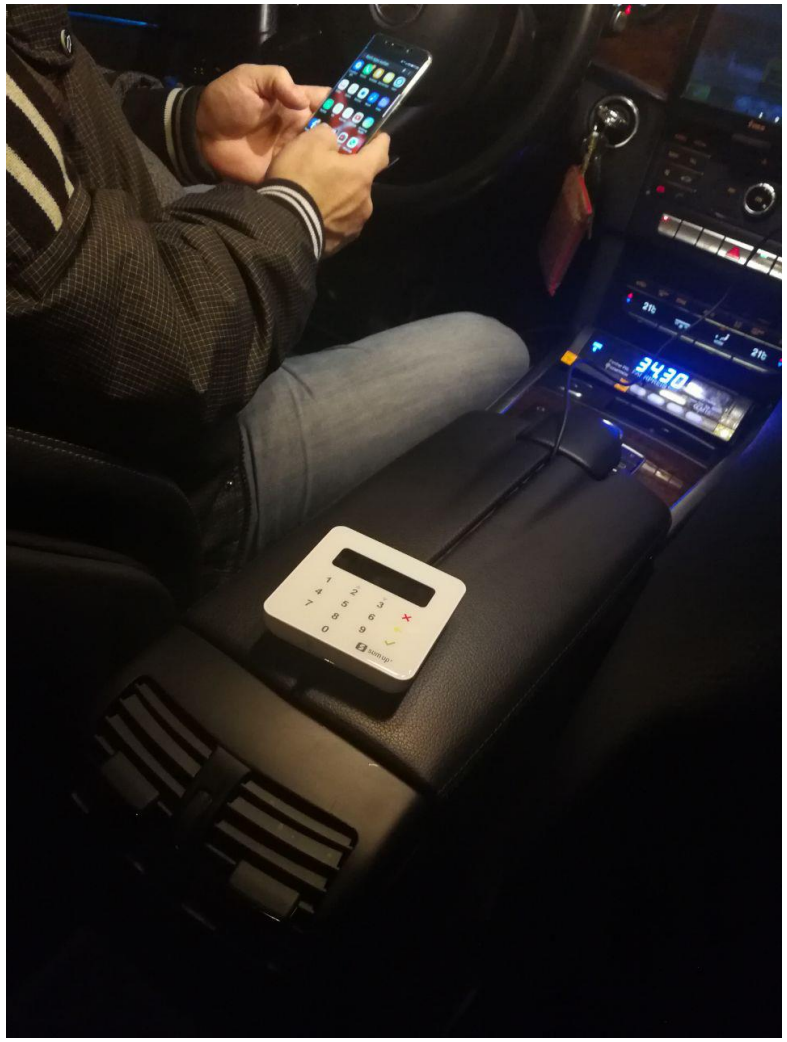
Single vendor

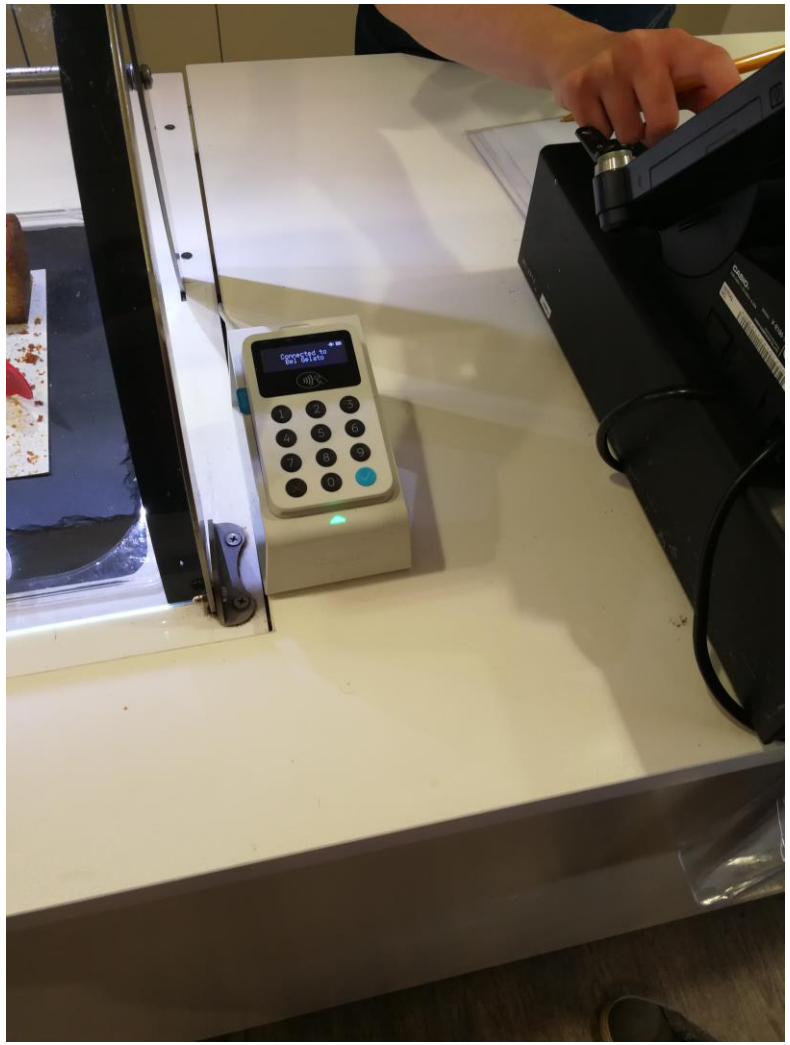


2018

Four leading vendors
shipping thousands of units per day

Motivations





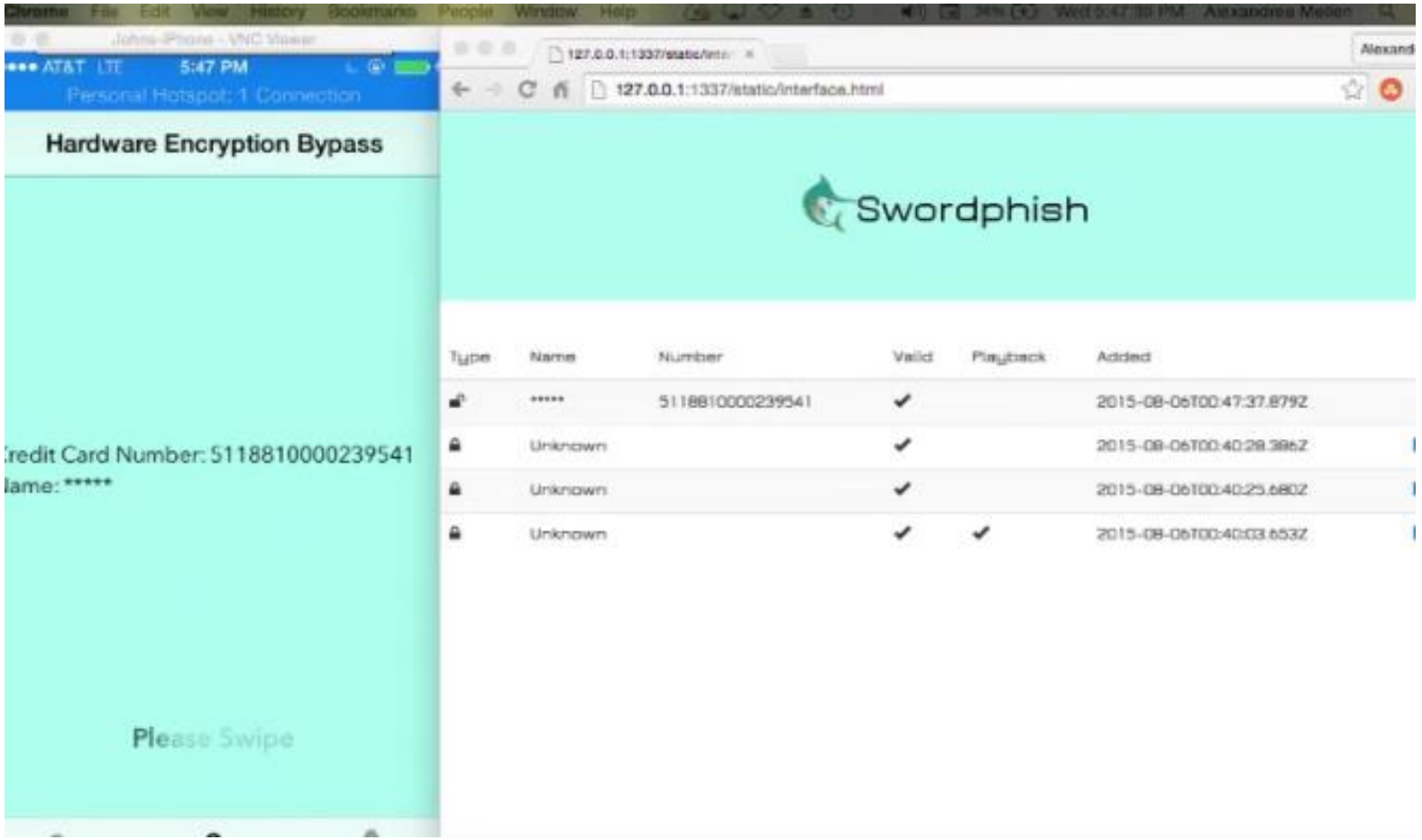


Related Work



MWR Labs “Mission mPOSsible” 2014

Related Work



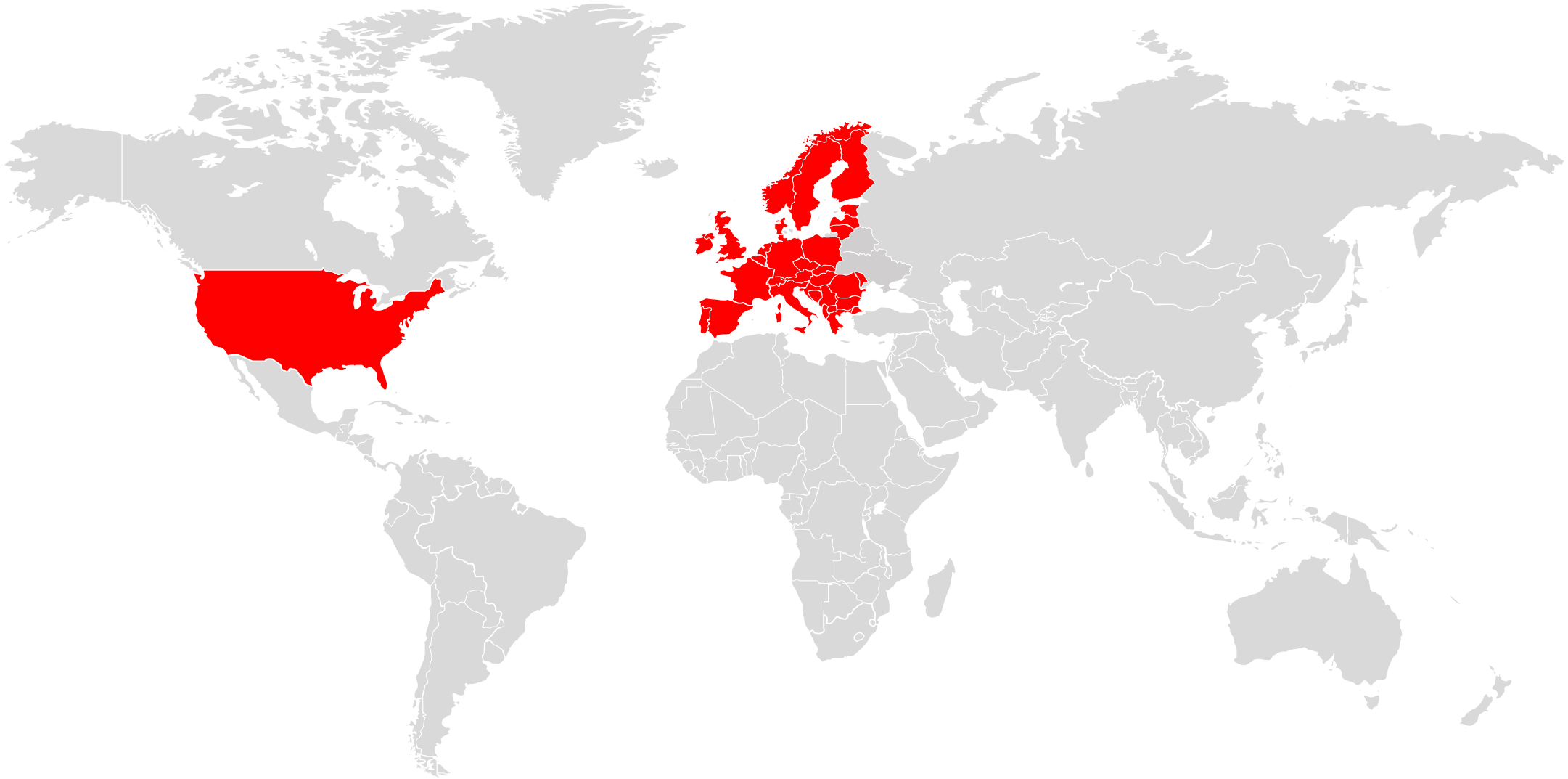


Mellen, Moore and Losev “Mobile Point of Scam: Attacking the Square Reader” (2015)

Research Scope



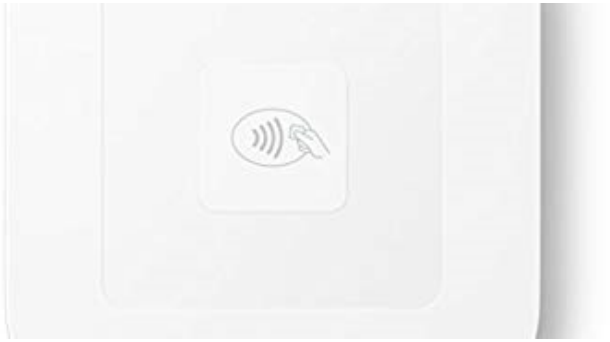
Research Scope



Research Scope



PAYPAL



SQUARE



IZETTLE



SUMUP

Research Scope

“How much security can really be embedded in a device that is free?”



Accept credit cards anywhere. Sign up and we’ll send you a free reader.

Get a free magstripe reader to swipe credit cards anywhere. Take chip cards and NFC payments with Square Reader for contactless and chip. Slip an iPad into Square Stand to make a countertop point of sale. Or sell with Square Register, the first fully integrated point-of-sale system.

Research Scope

SECONDARY FACTORS



PHONE/SERVER

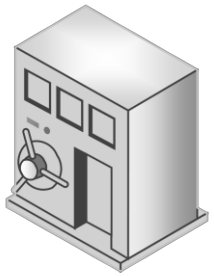
DEVICE/PHONE

HARDWARE

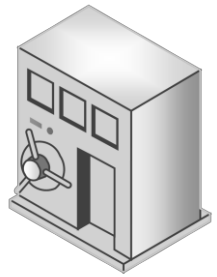
MOBILE APP

Background





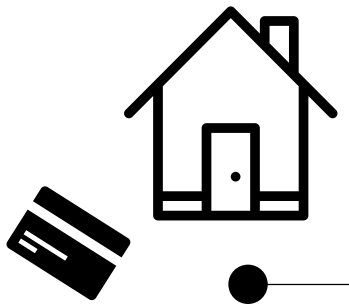




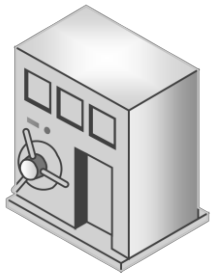
MERCHANT **ACQUIRER** **CARD BRANDS** **ISSUER**

Background

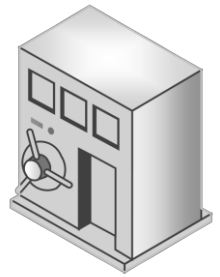
MERCHANT











MERCHANT

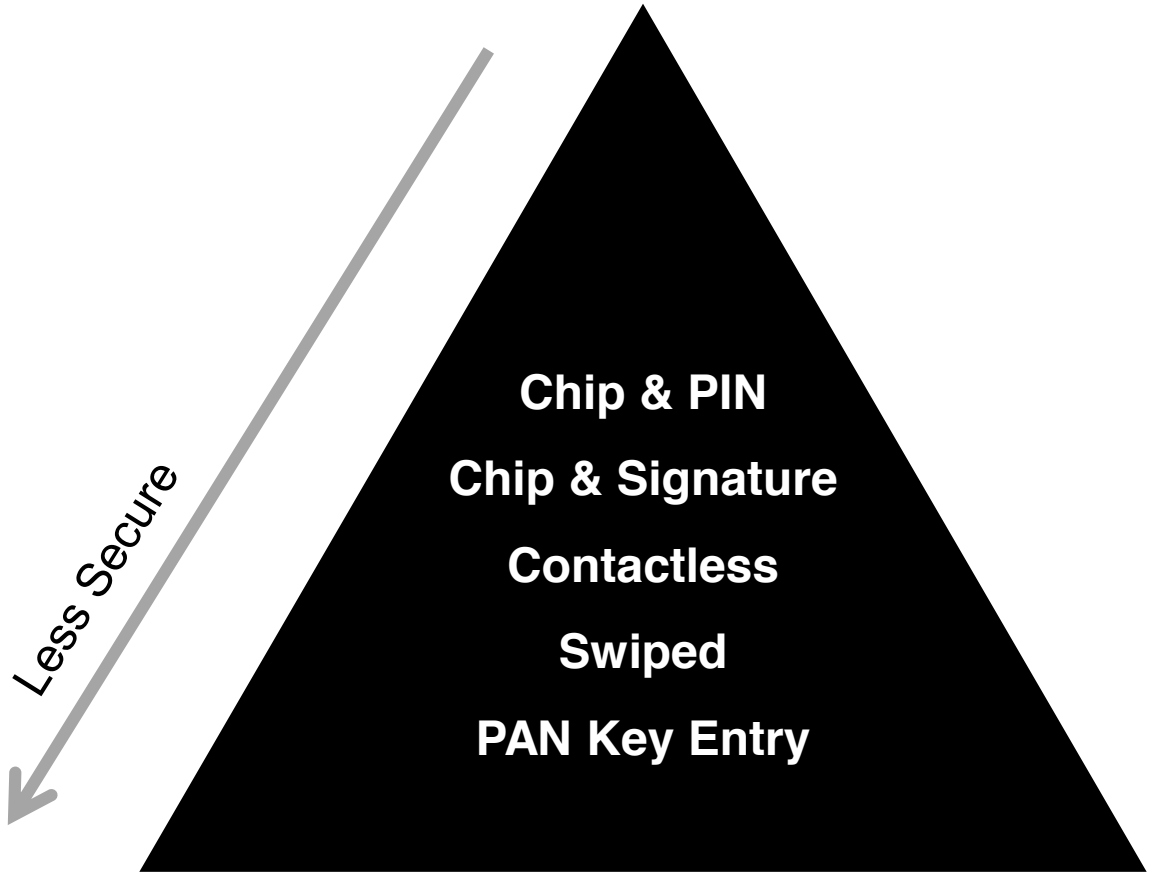
MPOS PROVIDER

ACQUIRER

CARD BRANDS

ISSUER

CARD RISK BY OPERATION TYPE



GLOBAL ADOPTION OF EMV - POS TERMINALS

EU EMV ACCEPTANCE

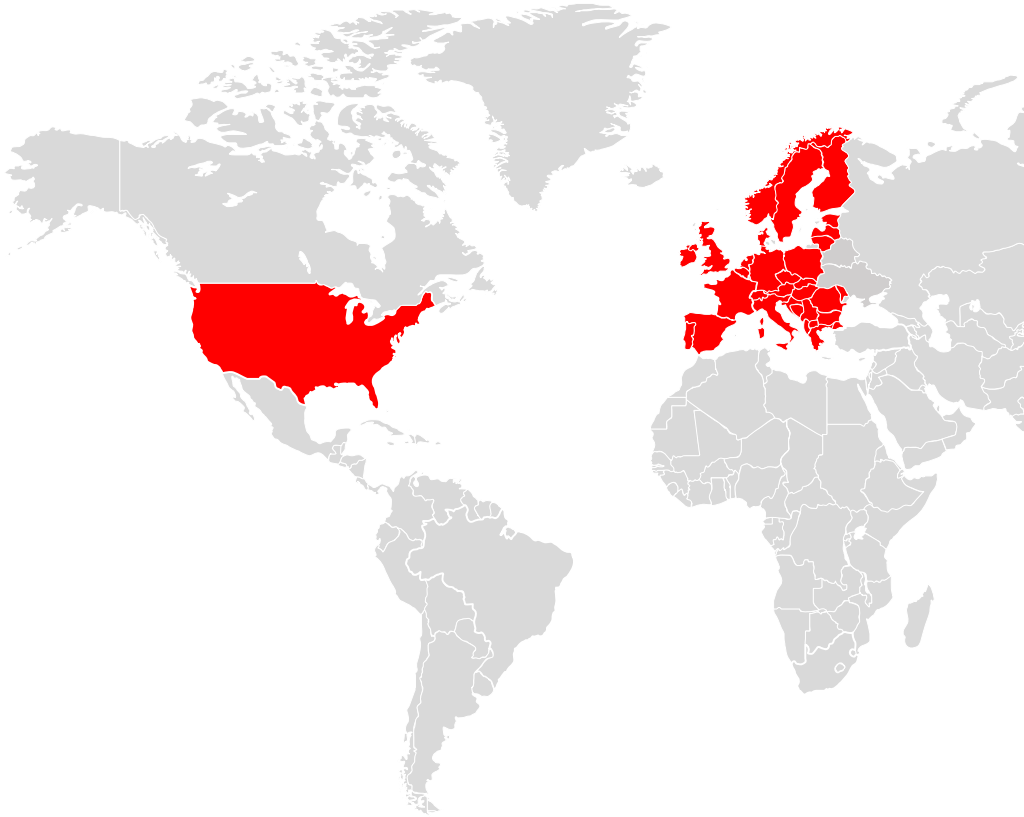
EMV enabled POS devices make up between 90-95% of POS population

90%

US EMV ACCEPTANCE

EMV enabled POS devices make up 13% of POS population and 9% of the ATM population

13%



Background

EMV CREDIT CARD ADOPTION

96% of credit cards in circulation support EMV as a protocol

96%

EMV CREDIT CARD USAGE

However less than half of all transactions are made by chip

41%

Background

EMV DEBIT CARD ADOPTION

79% of debit cards in circulation support EMV as a protocol

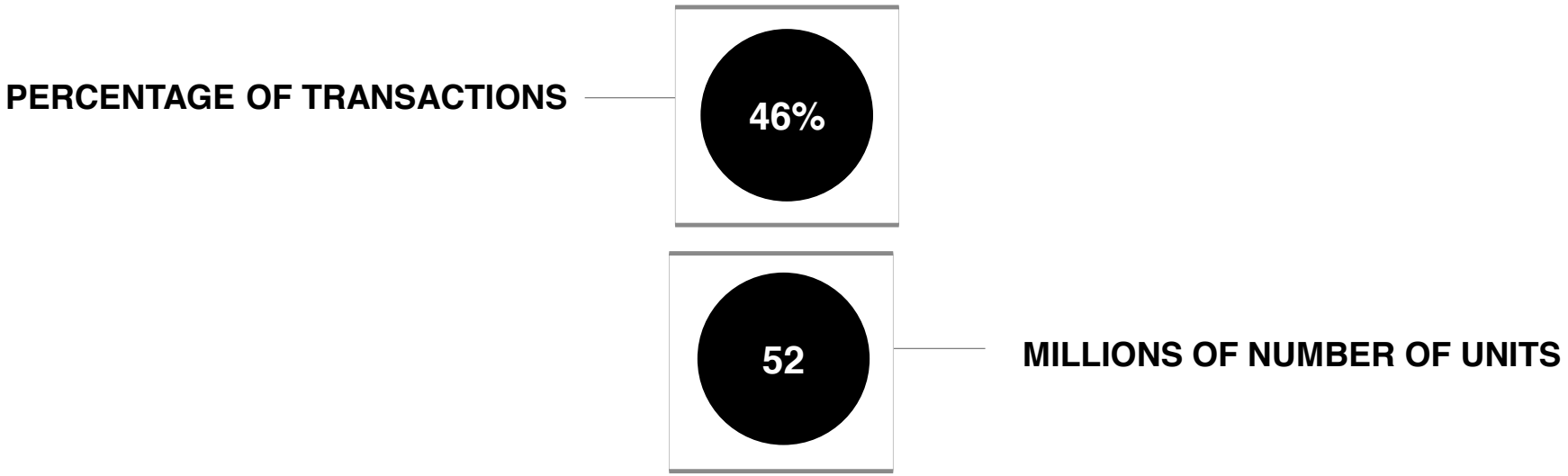
79%

EMV DEBIT CARD USAGE

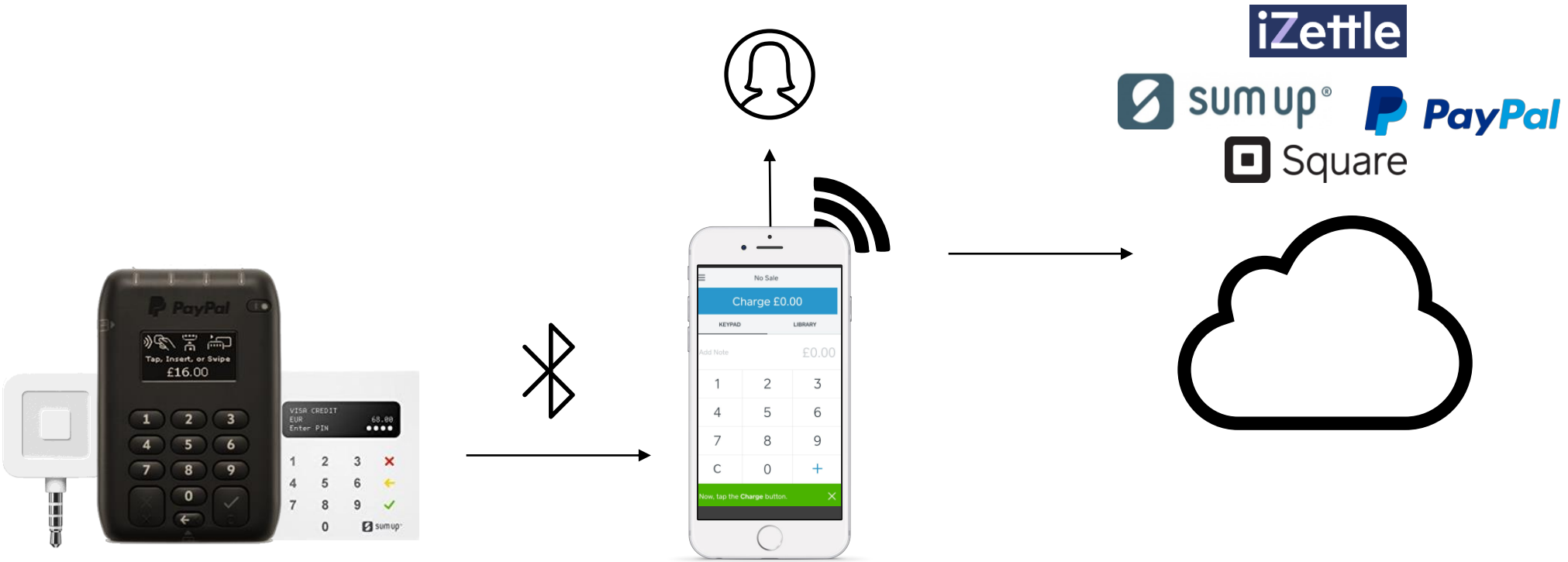
However less than half of all transactions are made using chip

23%

MPOS TIMELINE 2019



SCHEMATIC OVERVIEW OF COMPONENTS

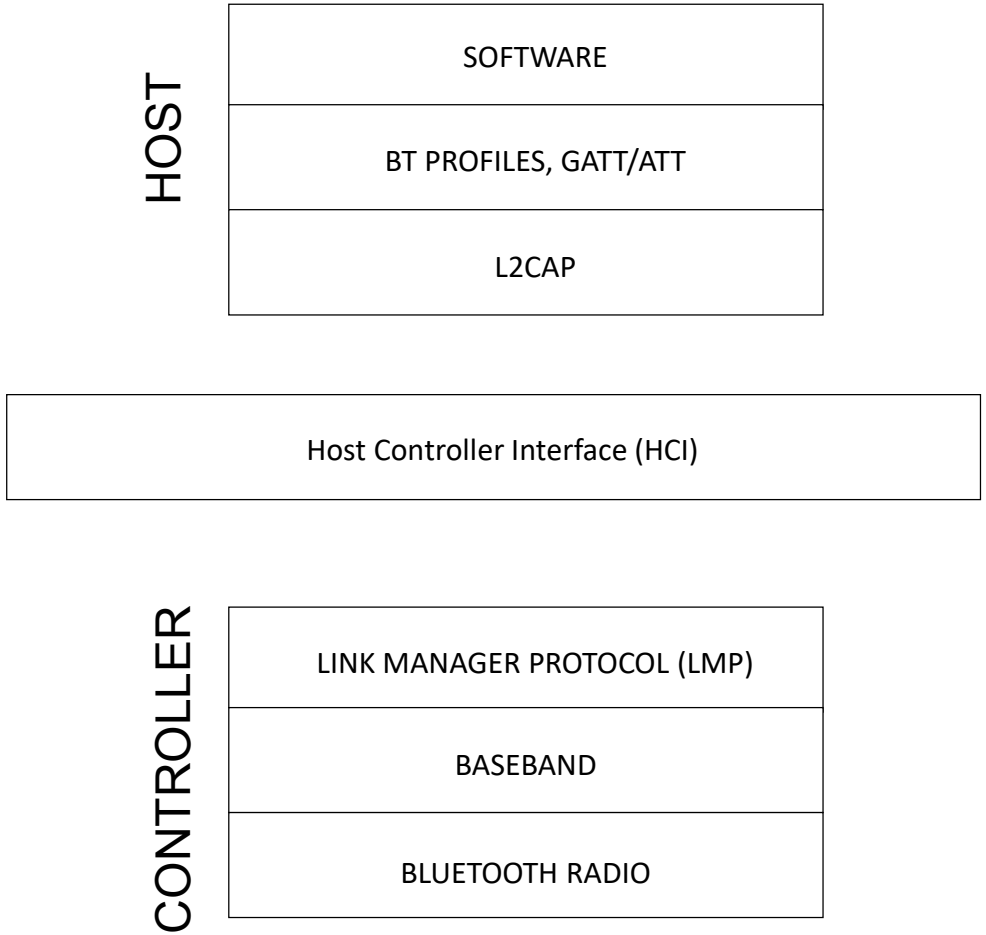


FINDINGS

- SENDING ARBITRARY COMMANDS
- AMOUNT MODIFICATION
- REMOTE CODE EXECUTION
- HARDWARE OBSERVATIONS
- SECONDARY FACTORS

BLUETOOTH

BLUETOOTH PROTOCOL

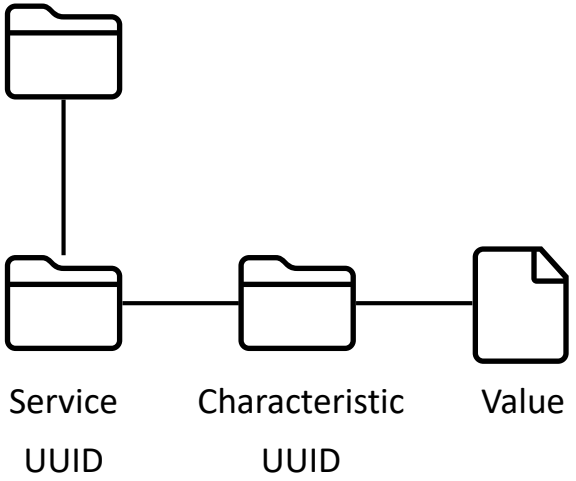


RFCOMM

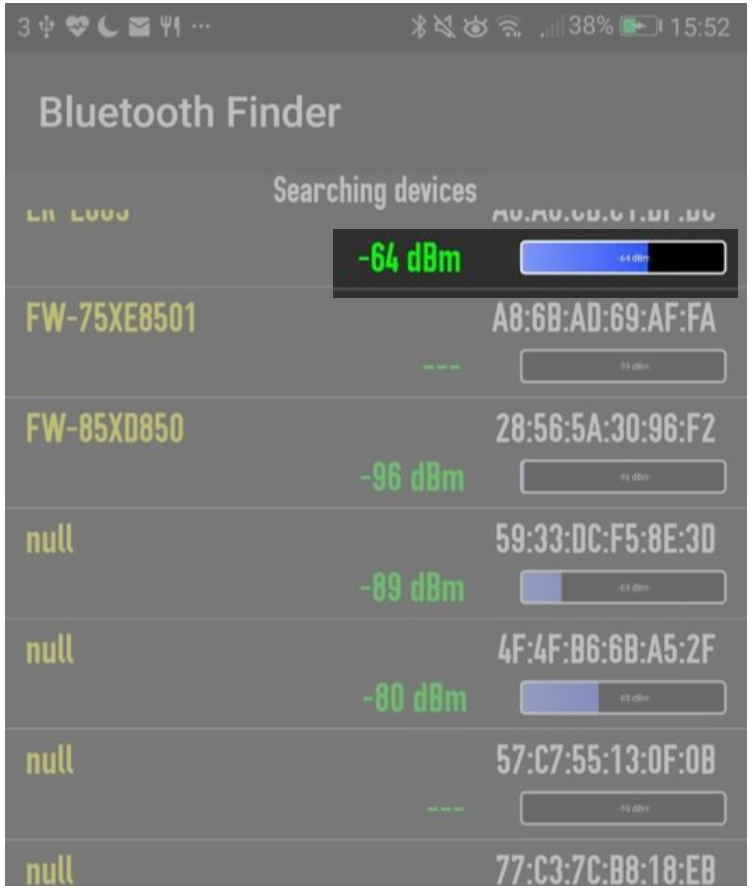


GATT (Generic Attribute)

/ATT(Attribute Protocol)



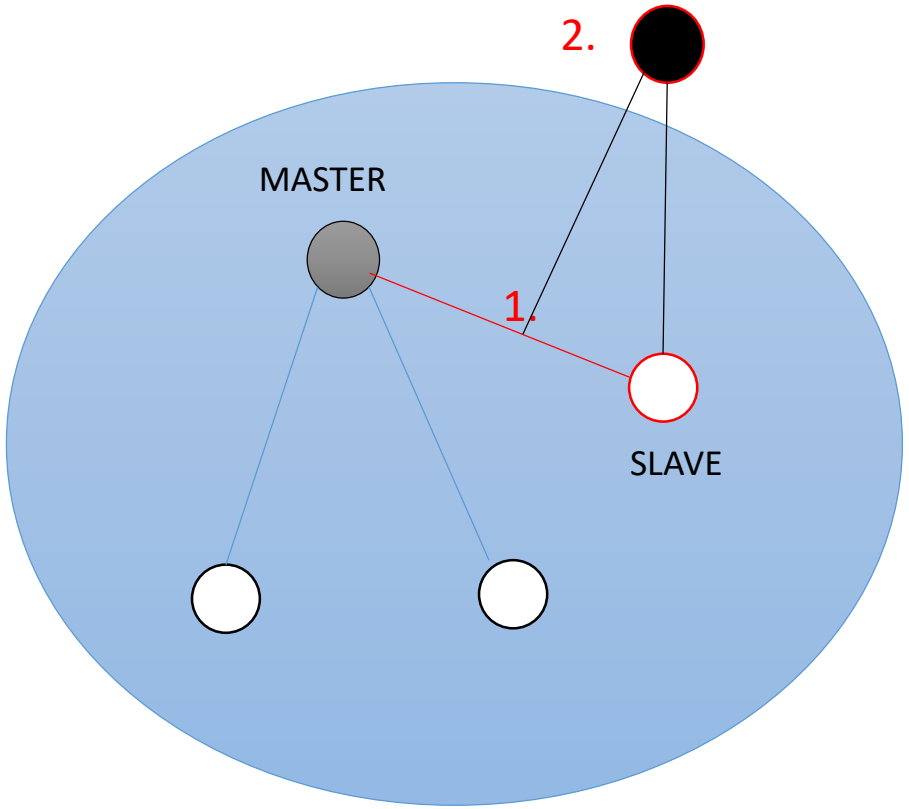
BLUETOOTH AS A COMMUNICATION CHANNEL



NAP	UAP	LAP
68:AA	D2	0D:CC:3E
Org Unique Identifier		**Unique to device**

BLUETOOTH ATTACK VECTORS

- Eavesdropping/MITM
- Manipulating characteristics



Frontline BPA 600



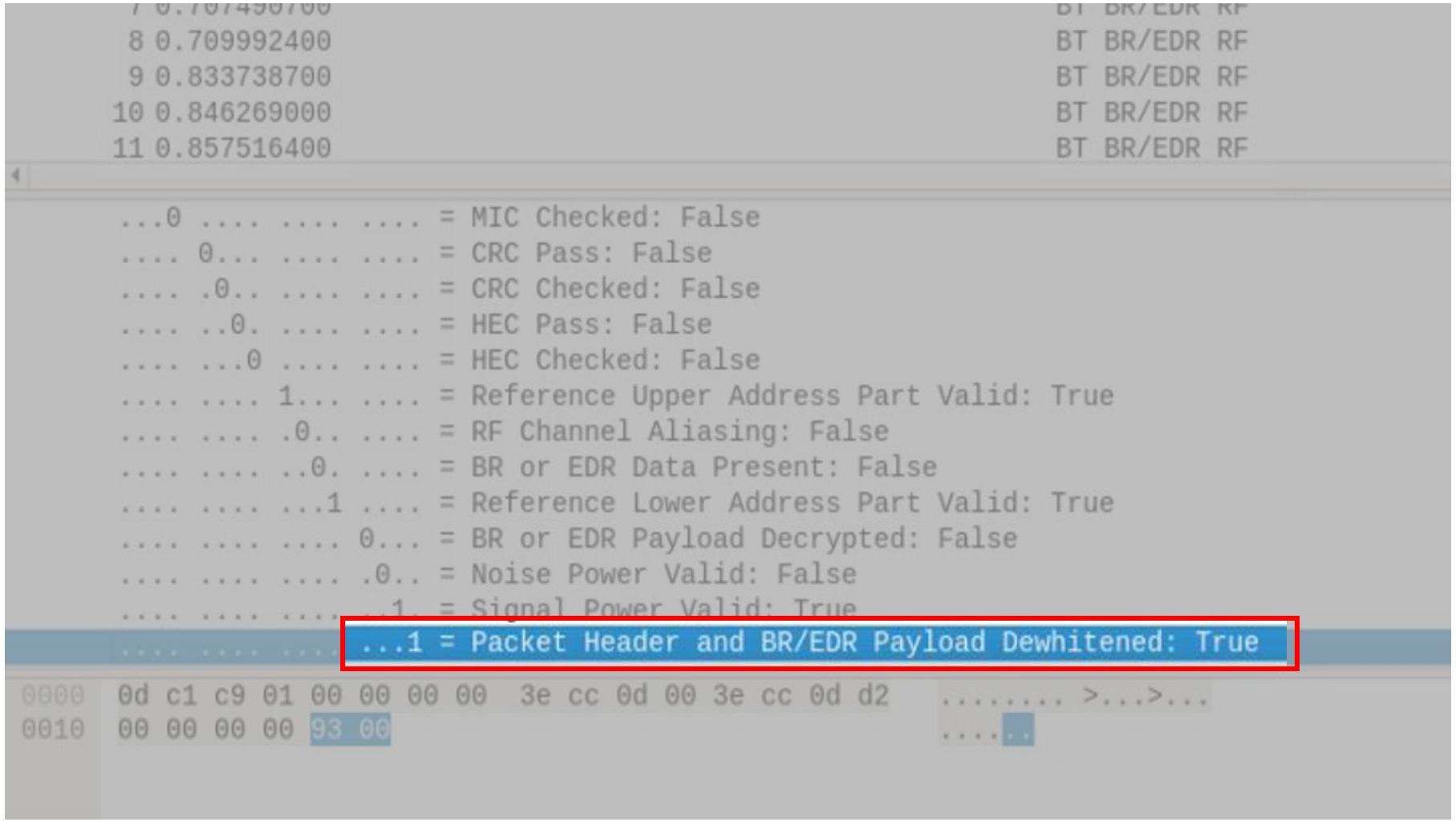
$20,000

Ubertooth One



$120

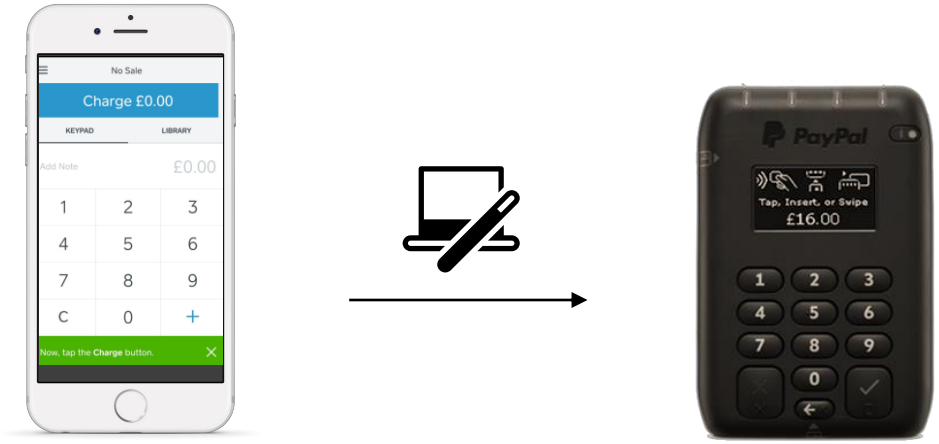
Methods & Tools



SENDING ARBITRARY COMMANDS

MANIPULATING CHARACTERISTICS

- Initiate a function
- Display text
- Turn off or on



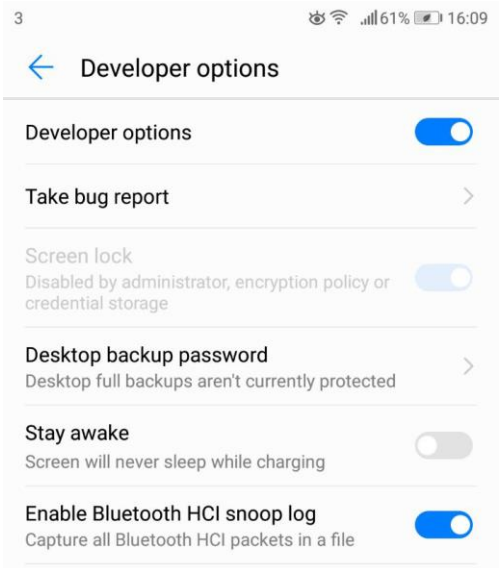
User authentication doesn’t exist in the Bluetooth protocol, it must be added by the developer at the application layer

Findings

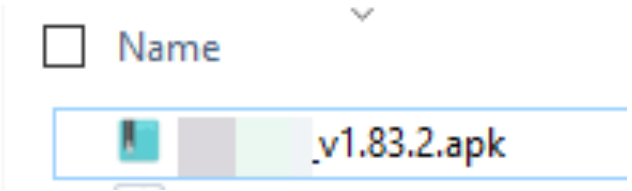
1.



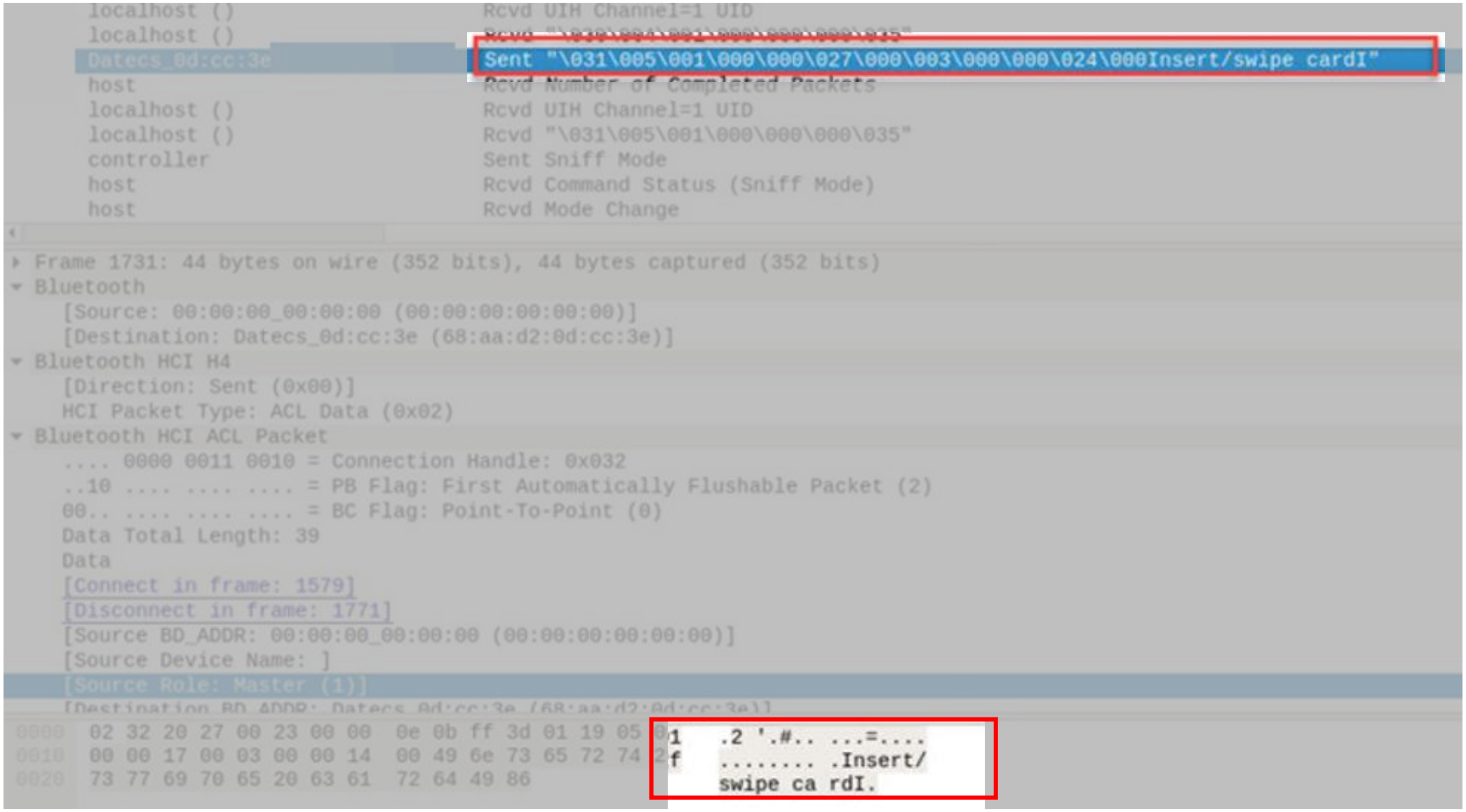
2.



3.



Findings


localhost ()
Rcvd UIH Channel=1 UID
localhost ()
Datecs_0d:cc:3e
Sent "\031\005\001\000\000\027\000\003\000\000\024\000Insert/swipe cardI"
host
Rcvd Number of Completed Packets
localhost ()
Rcvd UIH Channel=1 UID
localhost ()
Rcvd "\031\005\001\000\000\000\035"
controller
Sent Sniff Mode
host
Rcvd Command Status (Sniff Mode)
host
Rcvd Mode Change
Frame 1731: 44 bytes on wire (352 bits), 44 bytes captured (352 bits)
Bluetooth
[Source: 00:00:00_00:00:00 (00:00:00:00:00:00)]
[Destination: Datecs_0d:cc:3e (68:aa:d2:0d:cc:3e)]
Bluetooth HCI H4
[Direction: Sent (0x00)]
HCI Packet Type: ACL Data (0x02)
Bluetooth HCI ACL Packet
.... 0000 0011 0010 = Connection Handle: 0x032
..10 .... = PB Flag: First Automatically Flushable Packet (2)
00.. .... = BC Flag: Point-To-Point (0)
Data Total Length: 39
Data
[Connect in frame: 1579]
[Disconnect in frame: 1771]
[Source BD_ADDR: 00:00:00_00:00:00 (00:00:00:00:00:00)]
[Source Device Name:]
[Source Role: Master (1)]
0000 02 32 20 27 00 23 00 00 0e 0b ff 3d 01 19 05 01 .2 '.#.. ...=....
0010 00 00 17 00 03 00 00 14 00 49 6e 73 65 72 74 2f .... .Insert/
0020 73 77 69 70 65 20 63 61 72 64 49 86 swipe ca rdI.

Findings




```
Frame 272: 32 bytes on wire (256 bits), 32 bytes captured (256 bits)
Bluetooth
    [Source: SamsungE_ee:d3:be (34:2d:0d:ee:d3:be)]
    [Destination: cf:e9:ef:4f:6a:93 (cf:e9:ef:4f:6a:93)]
Bluetooth HCI H4
    [Direction: Sent (0x00)]
    HCI Packet Type: ACL Data (0x02)
Bluetooth HCI ACL Packet
Bluetooth L2CAP Protocol
Bluetooth Attribute Protocol
    Opcode: Write Command (0x52)
    Handle: 0x001b (Unknown: Unknown)
        [Service UUID: d839fc3c84dd4c369126187b07255127]
        [UUID: b378db854ec34daa828e1b99607bd6a0]
    Value: 02001d06010b000000010013506c656173652072
```

```
0000  02 10 00 1b 00 17 00 04  00 52 1b 00 02 00 1d 06   ........ .R......
0010  01 0b 00 00 00 01 00 13  50 6c 65 61 73 65 20 72   ........ Please r
```

```
    274 36.177643     SamsungE_ee:d3:be (… cf:e9:ef:4f:6a:93 () ATT      28 Sent Write Command, Handle: 0x00
    278 36.237365     SamsungE_ee:d3:be (… cf:e9:ef:4f:6a:93 () ATT      23 Sent Write Command, Handle: 0x00
```

```
Frame 274: 28 bytes on wire (224 bits), 28 bytes captured (224 bits)
Bluetooth
    [Source: SamsungE_ee:d3:be (34:2d:0d:ee:d3:be)]
    [Destination: cf:e9:ef:4f:6a:93 (cf:e9:ef:4f:6a:93)]
Bluetooth HCI H4
    [Direction: Sent (0x00)]
    HCI Packet Type: ACL Data (0x02)
Bluetooth HCI ACL Packet
Bluetooth L2CAP Protocol
Bluetooth Attribute Protocol
    Opcode: Write Command (0x52)
    Handle: 0x001b (Unknown: Unknown)
        [Service UUID: d839fc3c84dd4c369126187b07255127]
        [UUID: b378db854ec34daa828e1b99607bd6a0]
    Value: 656d6f7665206361726400ff083c6203
```

```
0000  02 10 00 17 00 13 00 04  00 52 1b 00 65 6d 6f 76   ........ .R..emov
0010  65 20 63 61 72 64 00 ff  08 3c 62 03               e card.. .<b.
```

Findings

```
Handle: 0x001b (Unknown: Unknown)
   [Service UUID: d839fc3c84dd4c369126187b07255127]
   [UUID: b378db854ec34daa828e1b99607bd6a0]
Value: 02001d06010b000000010013506c656173652072
```

```
Handle: 0x001b (Unknown: Unknown)
   [Service UUID: d839fc3c84dd4c369126187b07255127]
   [UUID: b378db854ec34daa828e1b99607bd6a0]
Value: 656d6f7665206361726400ff083c6203
```

LEADING PART	MESSAGE	TRAILING PART	CRC	END
02001d06010b000000010013	506c656173652072656d6f76652063617264	00ff08	3c62	03
“Please remove card”				

ATTACK VECTORS

1. Force cardholder to use a more vulnerable payment method such as mag-stripe

2. Once the first payment is complete, display “Payment declined”, force cardholder to authorise additional transaction.




root@lakb: ~/Desktop/AL
File Edit View Search Terminal Help
root@lakb:~/Desktop/AL# python ./ble_connector_demo_001.py
AL
MacBook Air
1 2 3
4 5 6
7 8 9
0

Findings




```
Bluetooth RFCOMM Protocol
  Address: E/A flag: 1, C/R flag: 1, Direction: 0, Channel: 1
    0000 10.. = DLCI: 0x02 (Direction: 0, Channel: 1)
        0000 1... = Channel: 1
        .... .0.. = Direction: 0x0
      .... ..1. = C/R Flag: Command (0x1)
      .... ...1 = EA Flag: Last field octet (0x1)
  Control: Frame type: Unnumbered Information with Header check (UIH) (0xef), P/F flag: 0
      ...0 .... = P/F flag: 0x0
      111. 1111 = Frame type: Unnumbered Information with Header check (UIH) (0xef)
  Payload length: 32
  Frame Check Sequence: 0x9a
Bluetooth SPP Packet
  Data: 0d0501000017010300000c00496e736572742f7377697065...
```

Data: 0d0501000017010300000c00496e736572742f737769706520636172644d0a

Findings

LEADING PART	MESSAGE	CRC
0d0501000017	010300000c00496e736572742f737769706520636172 64	44
	“Insert/swipe card”	


Insert/swipe card
1
2
3
4
5
6
7
8
9
0

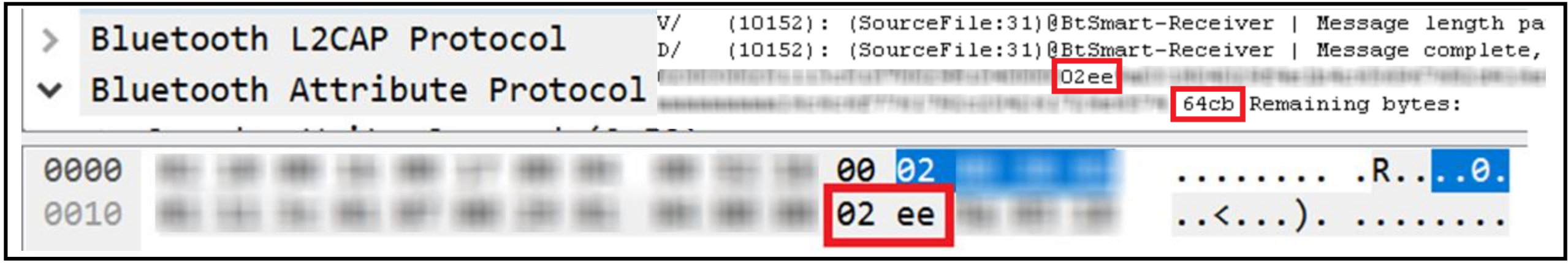
AMOUNT TAMPERING

HOW TO GET ACCESS TO TRANSACTIONS AND COMMANDS

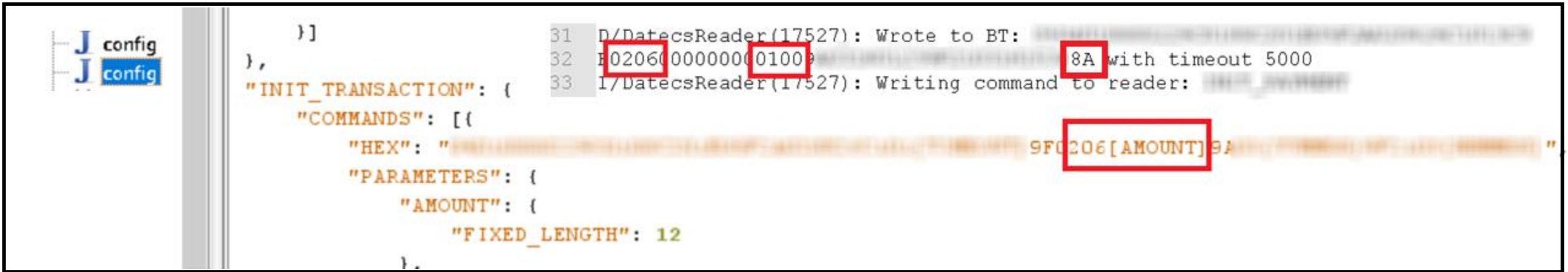
- HTTPS
- DEVELOPER BLUETOOTH LOGS
- RE OF APK ENABLE DEBUG
- BLUETOOTH SNIFFER

HOW TO GET ACCESS TO COMMANDS

1. 0x02ee = 7.50 USD 0x64cb = checksum

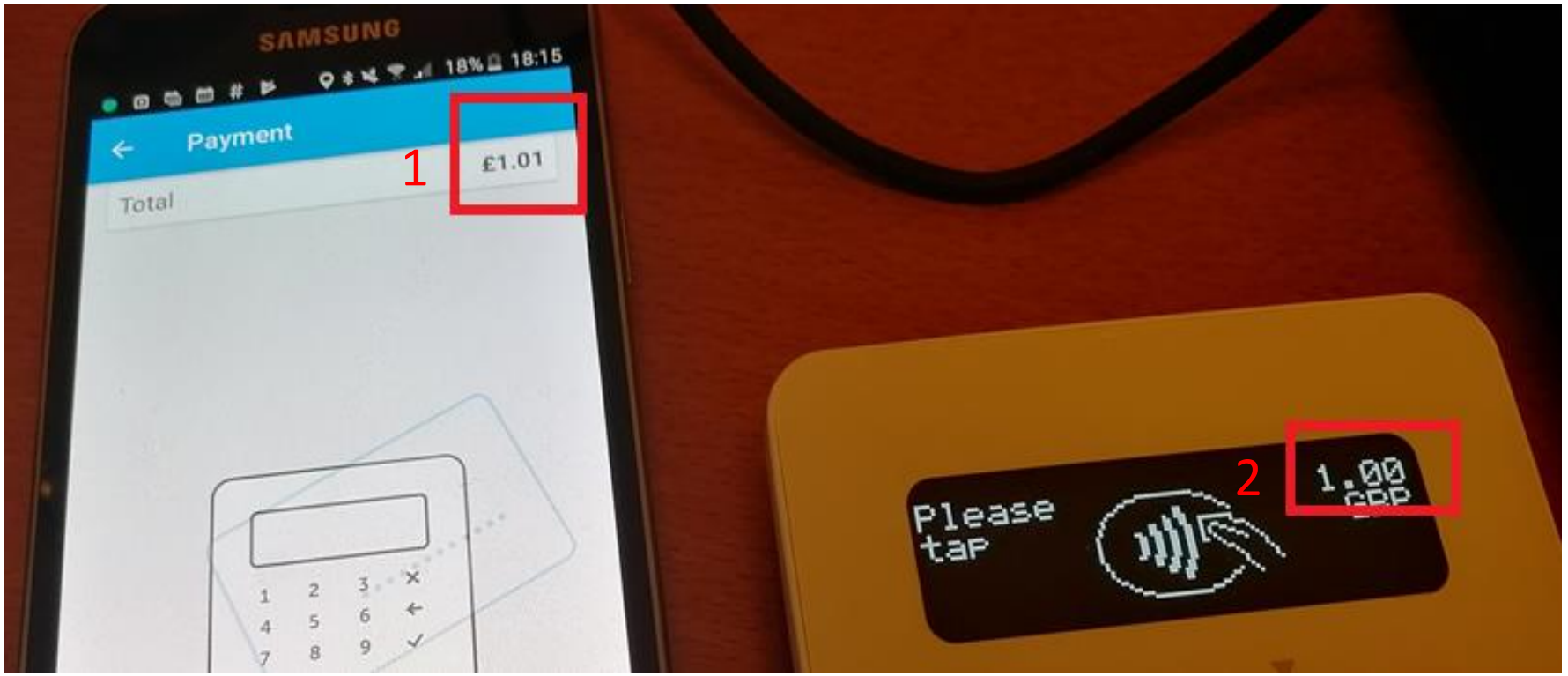


2. 0100 = 1.00 USD 0x8a = checksum

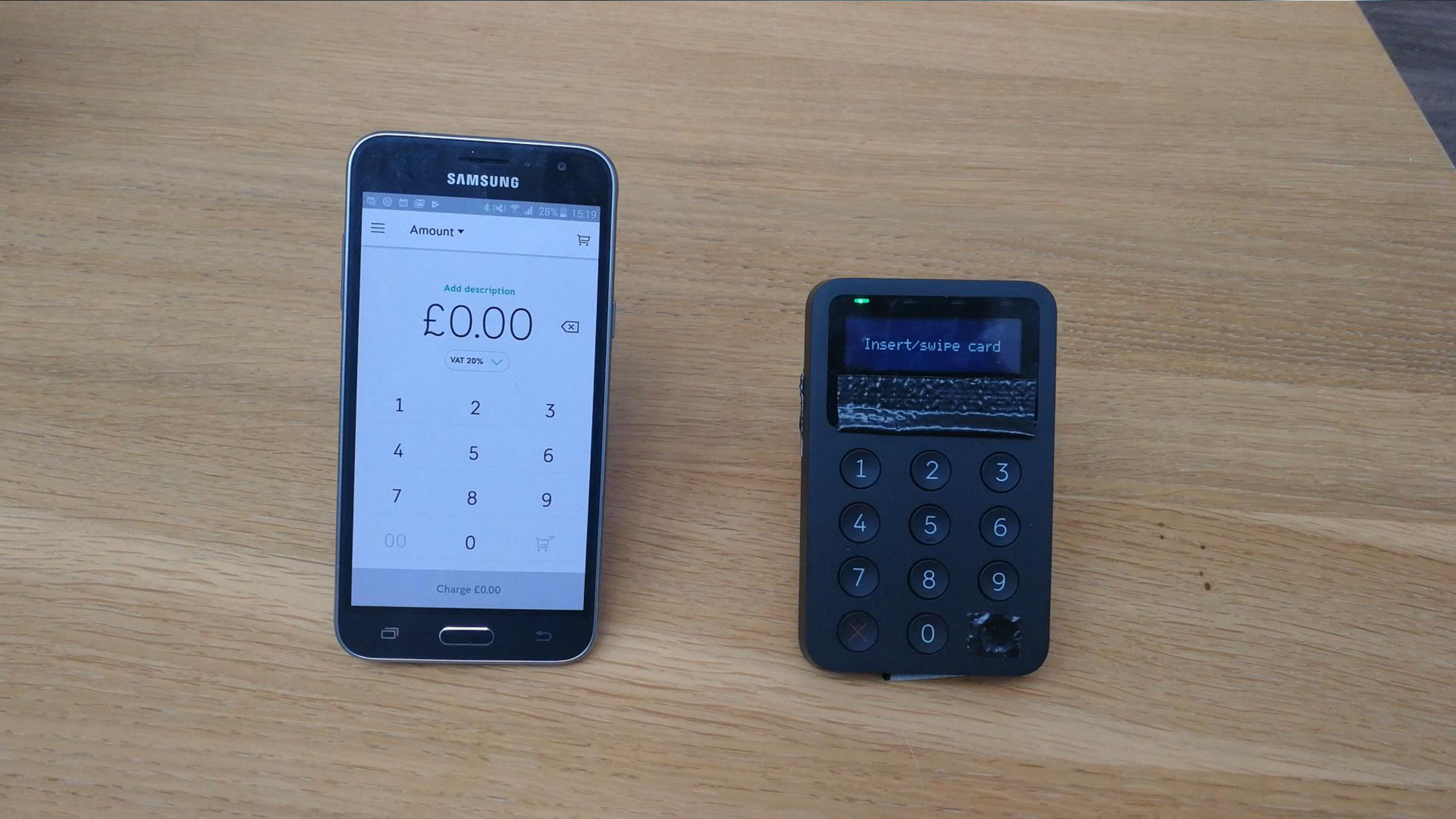


MODIFYING PAYMENT AMOUNT

1. Modified payment value
2. Original (lower) amount displayed on card reader for the customer
3. Card statement showing higher authorised transaction amount



3 Date	Card Detail	Amount
14/03/18	3005 180313165040275 69 Card purchase	-£1.01


SAMSUNG
28% 15:19
Amount
Add description
£0.00
VAT 20%
1 2 3
4 5 6
7 8 9
00 0
Charge £0.00
Insert/swipe card
1 2 3
4 5 6
7 8 9
0

Findings

MODIFYING PAYMENT AMOUNT

TYPE OF PAYMENT	AMOUNT TAMPERING	SECURITY MECHANISMS
MAG-STRIPE	TRACK2	----
CONTACTLESS	POSSIBLE	AMOUNT CAN BE STORED IN CRYPTOGRAM
CHIP AND PIN	-----	AMOUNT IS STORED IN CRYPTOGRAM

LIMIT PER TRANSACTION: 50,000 USD

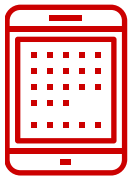
ATTACK



Customer



$1.00 payment



$1.00 payment





Fraudulent merchant



50,000 payment





Service Provider

MITIGATION ACTIONS FOR SERVICE PROVIDERS

- REQUEST SOLUTION FROM VENDOR
- CONTROL YOUR ECOSYSTEM
- NO MAG-STRIPE

REMOTE CODE EXECUTION

RCE = 1 REVERSE ENGINEER + 1 FIRMWARE





@ivachyou

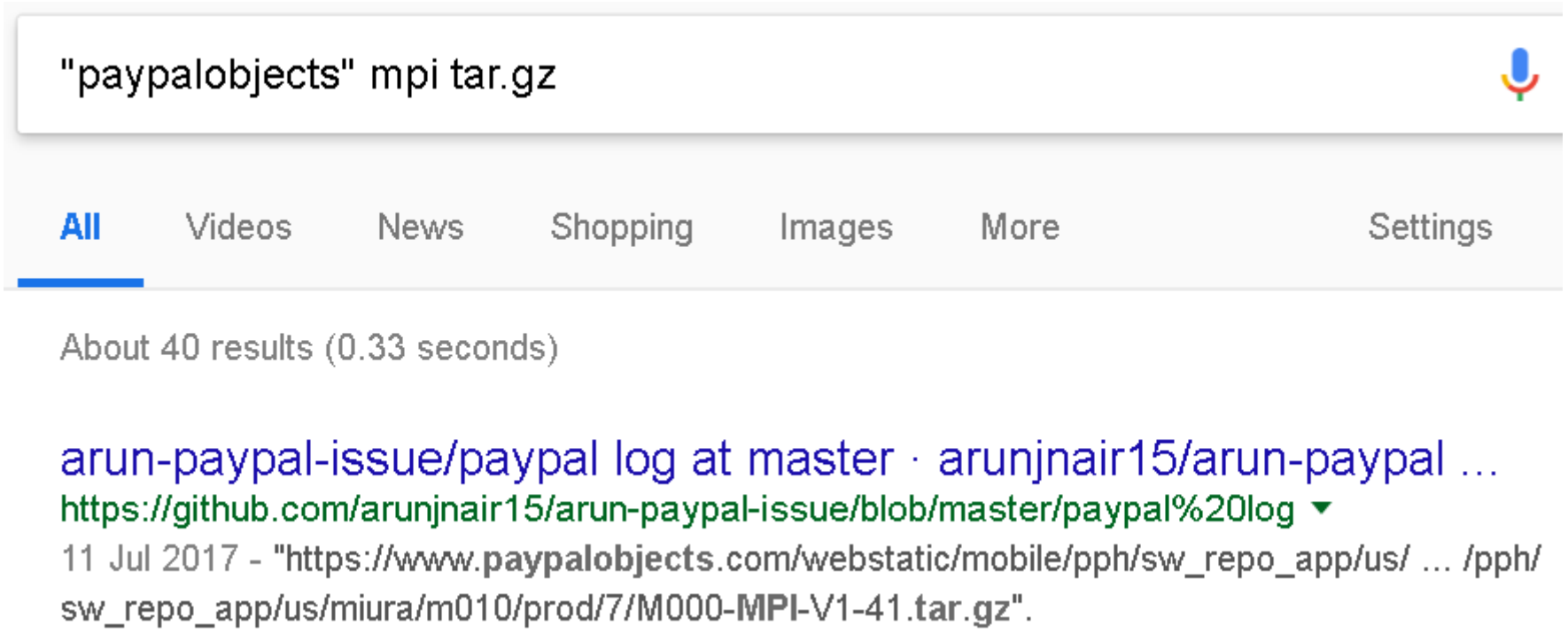
HOW FIRMWARE ARRIVES ON THE READER

https://frw.******.com/_prod_app_1_0_1_5.bin
https://frw.******.com/_prod_app_1_0_1_5.sig

https://frw.******.com/_prod_app_1_0_1_4.bin
https://frw.******.com/_prod_app_1_0_1_4.sig

Header - RSA-2048 signature *(0x00 - 0x100)*
Body - AES-ECB encrypted

HOW FIRMWARE ARRIVES ON THE READER



https://www.paypalobjects.com/webstatic/mobile/pph/sw_repo_app/us/miura/m010/prod/7/M000-MPI-V1-41.tar.gz
https://www.paypalobjects.com/webstatic/mobile/pph/sw_repo_app/us/miura/m010/prod/7/M000-MPI-V1-39.tar.gz

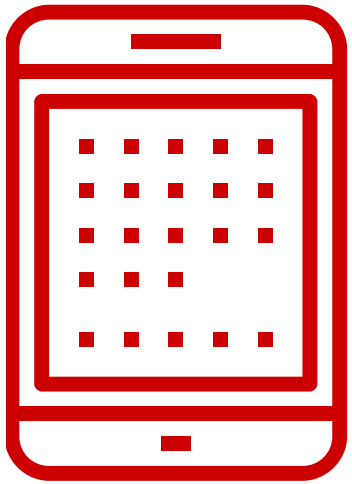
HOW FIRMWARE ARRIVES ON THE READER

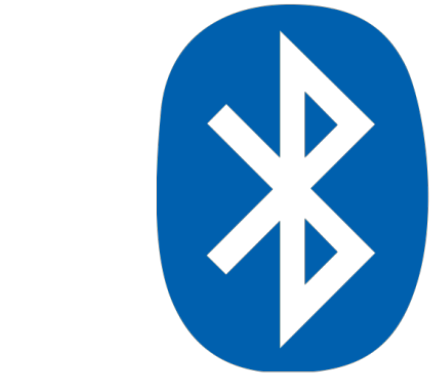
```
no_prompt
TRANSACTION  DECLINED
     ENTER PIN
 PROCESSING  ERROR
     REMOVE CARD
no_prompt

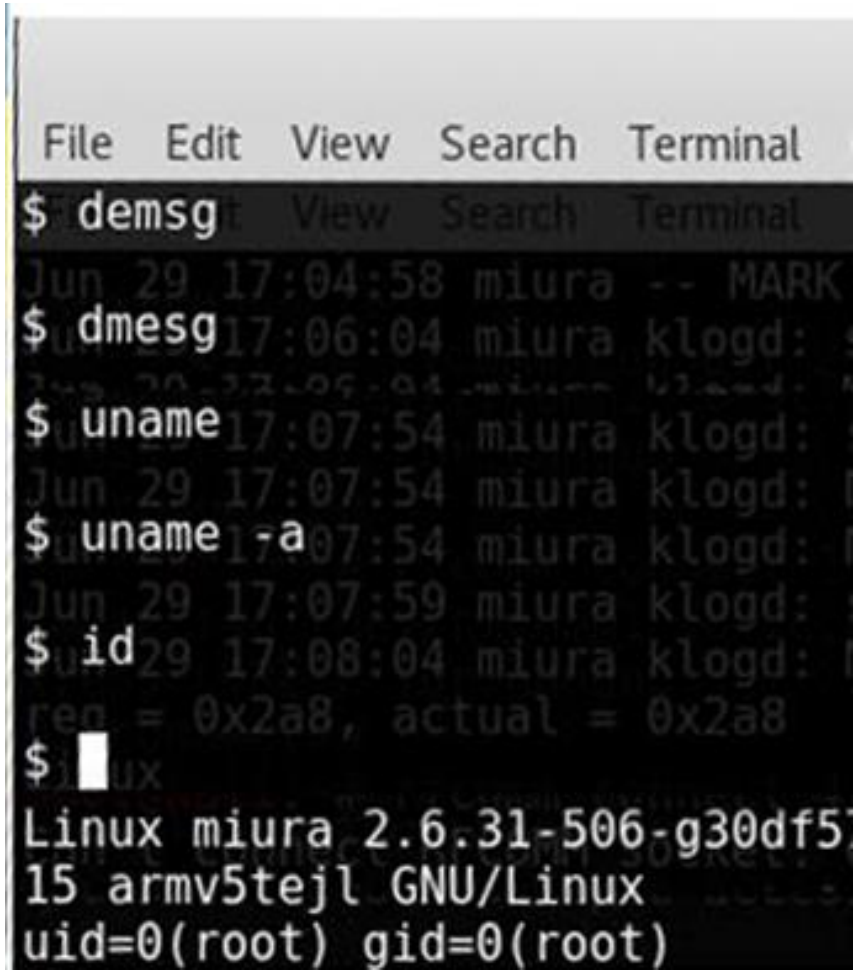
   PROCESSING CARD
Card was read. OK to remove card.
TRY ANOTHER INTERFACE
PRESENT ONLY ONE CARD
TRANSACTION  APPROVED PLEASE SIGN RECEIPT
no_prompt
no_prompt
no_prompt
clear_screen
     SEE PHONE
 PRESENT CARD  AGAIN
    REFER TO YOUR       PAYMENT  DEVICE
```



HOW FIRMWARE ARRIVES ON THE READER





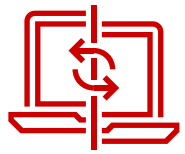


INFECTED MPOS

- PAYMENT ATTACKS
- COLLECT TRACK 2/PIN
- PAYMENT RESEARCH

Findings

DEVICE PERSISTENCE



REBOOT



GAME OVER

ATTACK



Fraudulent customer

Device with Bluetooth

RCE

Reader

UPDATES

Service Provider



Merchant

MITIGATIONS

- NO VULNERABLE OR OUT-OF-DATE FIRMWARE
- NO DOWNGRADES
- PREVENTATIVE MONITORING


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Findings

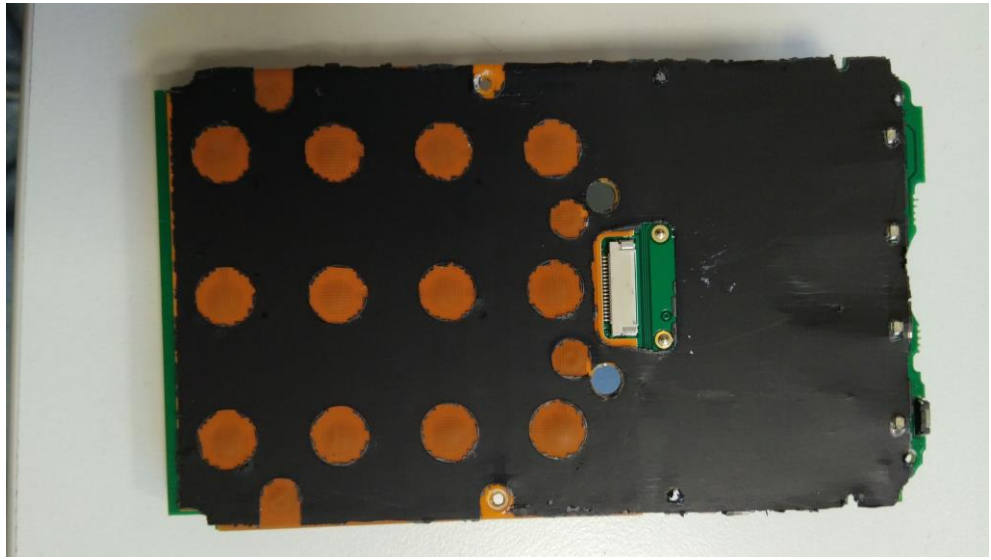
HARDWARE OBSERVATIONS











SECONDARY FACTORS

- ENROLMENT PROCESS
- ON BOARDING CHECKS VS TRANSACTION MONITORING
- DIFFERENCES IN GEO – MSD, OFFLINE PROCESSING
- WHAT SHOULD BE CONSIDERED AN ACCEPTED RISK?
- ACCESS TO HCI LOGS/APP, LOCATION SPOOFING

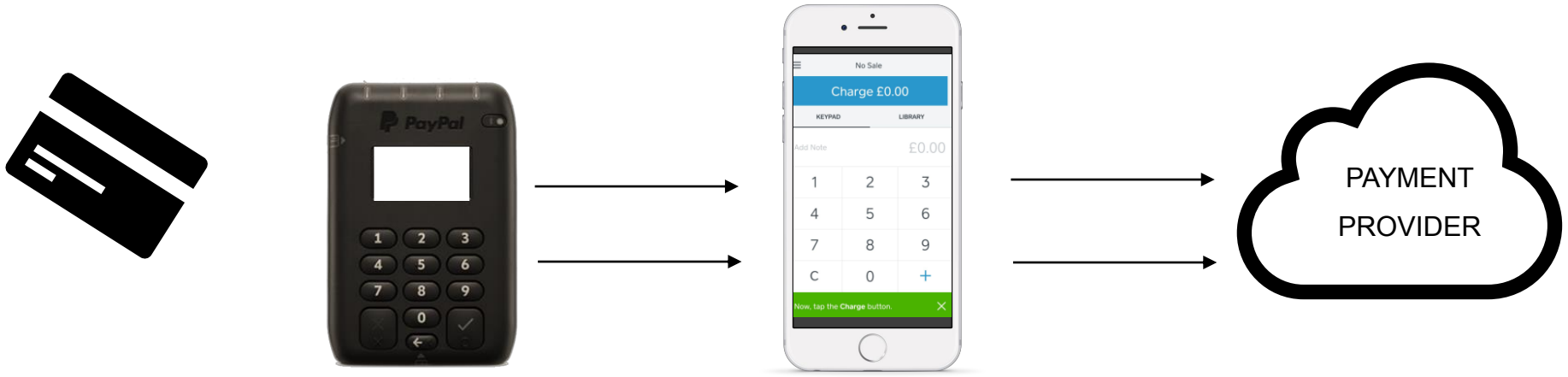


Conclusions

Reader	Cost reader/Fee per transaction	Enrollment process	Antifraud + Security checks	Physical security	FW RE	Mobile Ecosystem	Arbitrary commands	Red teaming	Amount tampering
Square [EU]	$51 1.75-2.5%	Low - no anti money laundering checks but some ID checks	Strict – active monitoring of transactions	N/A	-	strict	-	-	-
Square [USA]	$50 2.5-2.75%		Strict – correlation of “bad” readers, phones and acc info	N/A	-	medium (dev)	-	+	-
Square mag-stripe [EU + USA]	Free 2.5-2.75%		Strict (see above)	Low	-	low	-	+	+ [no display]
Square miura [USA]	$130 2.5-2.75%		Strict (see above)	N/A	+	N/A	+ [via RCE]	+	+ (via RCE)
PayPal miura	$60 1-2.75%	High - anti-money laundering checks + credit check (to take out credit agreement)	Strict – transaction monitoring	N/A	+	low	+ [via RCE]	+	+ (via RCE)
SumUp	$40 1.69%			Medium	-	low	+	+	+
iZettle datecs	$40 1.75%	Medium - ant-money laundering check + ID checks	Low – limited monitoring, on finding suspect activity block withdrawal - acc otherwise active	High	-	low	+	-	+

MPOS FOR RED TEAMING

1. Carry out an assessment of reader to gather preliminary data + info from cards.
2. Use data to carry out normal transactions to obtain baseline.
3. Use info obtained during this process to identify potential weaknesses and vulnerabilities.
4. Carry out “modified” transactions



ASSESSING RISK - WHAT DOES THIS MEAN FOR YOUR BUSINESS?



Conclusions



CONCLUSIONS

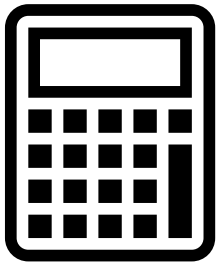
RECOMMENDATIONS FOR MPOS MANUFACTURERS



- Control firmware versions, encrypt & sign firmware
- Use Bluetooth pairing mode that provides visual confirmation of reader/phone pairing such as pass key entry
- Integrate security testing into the development process
- Implement user authentication and input sanitisation at the application level

CONCLUSIONS

RECOMMENDATIONS FOR MPOS VENDORS



- Protect deprecated protocols such as mag-stripe
- Use preventive monitoring as a best practice
- Don’t allow use of vulnerable or out-of-date firmware, prohibit downgrades
- Place more emphasis on enrolment checks
- Protect the mobile ecosystem
- Implement user authentication and input sanitization at application level

CONCLUSIONS

RECOMMENDATIONS FOR MPOS MERCHANTS



- Control physical access to devices
- Do not use mag-stripe transactions
- Assess the mPOS ecosystem
- Choose a vendor who places emphasis on protecting whole ecosystem

THANKS

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