Who we are

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  Italian student with passion of IT, networking and pentesting. In 2013 ended his studies in high school and apply for Politecnico of Turin at Computer Engineering.

- Eagle1753

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  Italian student, applied for Politecnico of Turin, Electronic Engineering. Has a great passion for Physics. He is studying with bughardy on WiFi networks and security. Loves to solve challenges.

History of NFC hacks

- 2008 NFC MIFARE CLASSIC exploit, further in following years.

- 2011 first hack of NFC ULTRALIGHT transport system by U.S. researchers using the RESET ATTACK

- 2013 a new hack of NFC ULTRALIGHT transport system made by us. We called it LOCK ATTACK.

What is MIFARE chip?

RFID chip designed to work at 13.56MHz.There are millions of MIFARE chip cards worldwide and they belong to several variants:

- MIFARE CLASSIC
- MIFARE ULTRALIGHT
- MIFARE ULTRALIGHT C
- MIFARE DESFIRE
- etc

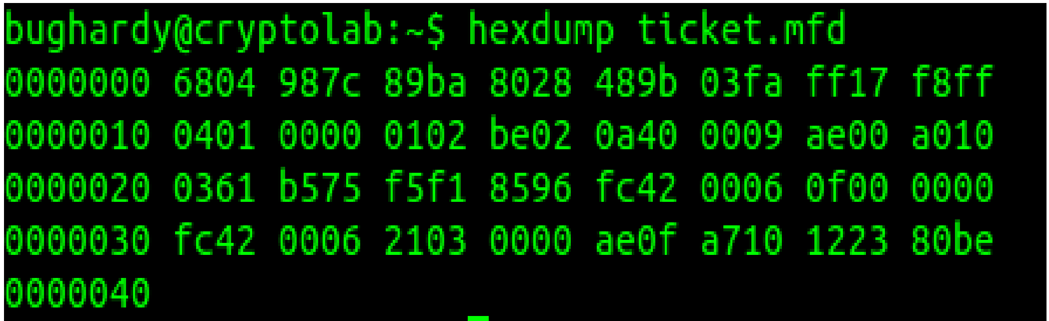
The history of an hack

- First tests, without knowing how OTP was working.
- OTP contains the number of rides left!!
- Attempt to write something over OTP.

FAIL

There is still a long way

- “One the roa.. Er.. On the bus” test!
- Stamping more tickets one after the other and looking and comparing their dumps
- Empiric results about how data is stored on tickets



```
bughardy@cryptolab:~$ hexdump ticket.mfd
0000000 6804 987c 89ba 8028 489b 03fa ff17 f8ff
0000010 0401 0000 0102 be02 0a40 0009 ae00 a010
0000020 0361 b575 f5f1 8596 fc42 0006 0f00 0000
0000030 fc42 0006 2103 0000 ae0f a710 1223 80be
0000040
```

Seize the day

- Assume that you know where the time (of the last stamp) is stored and how
- Use a NFC phone / NFC reader to change that field (it is in the data field so there are no problems)
- It isn’t so reliable and now we aren’t able to deal with this.

Mission Completed

- Preventing the machine to write the number of rides left would turn the ticket into an unlimited one.

- The answer is: LOCK BYTES

TICKET
2466059
2466060
2466215
2466162
2466344
2466352
24662

Yes, but what is MIFARE ULTRALIGHT?

How is it composed?

Page Address	Byte number				
Decimal	Hex	0	1	2	3
0	0x00	**UID**			
1	0x01	**UID**			
2	0x02	**UID**	**INTERNAL**	**LOCK BYTE**	**LOCK BYTE**
3	0x03	**OTP**	**OTP**	**OTP**	**OTP**
4 to 15	0x04 to 0x0F	**DATA**			

What is OTP?

- Only security function in MIFARE ULTRALIGHT tickets
- 4 bytes, all 00 at first (by default)
- OR operation prevents from turning a bit from 1 to 0 again
- Used for storing rides (just need to turn a bit from 0 into 1). The stamping machine checks the number of “0” left.

What is DATA sector?

- Biggest sector, 48 bytes
- It stores details like time (of last stamp), date, station ID, etc
- In the reset attack, it is used to store the number of rides left.

Regarding DATA sector

- Working still in progress.

- Decoding how and which data are encoded to the ticket.

- We will provide dumps and info (in the Q&A session) if you would like to help us.

“On the road” tests..

- Some empirical results in DATA sector decoding:

BYTES	DESCRIPTION	EXAMPLE
0-24 bytes	**Locked DATA**	**01 04 00 00 02 01 02 BE 40 05 AF 00 00 AE 10 A0 61 03 1C 1C B2 2B 61 8E**
25-28	**Stamping progressive number**	**43 3B (7B 00)**
29-32	**Validator ID (guessed) / or Ticket type**	**04 F8 00 00**
33-36	**Stamping progressive numer**	**43 3B (7B 00)**
37-38	**Still not guessed**	**00 3B 00 04**
39-40	**Ticket type (guessed) / or data**	**F8 AE**
41-48	**Time data (guessed)**	**10 7B B3 02 E6 56**

What is LOCK sector?

- 2 bytes

L - 7	L - 6	L - 5	L - 4	L - OTP	BL – 10 to 15	BL – 4 to 9	BL – OTP
L – 15	L – 14	L – 13	L – 12	L – 11	L – 10	L – 9	L – 8

- Each bit can turn 1 page (4 bytes) into read-only mode
- The last 3 bits of first lock byte freeze the bits of the lock bytes themselves

The LOCK ATTACK

- (ab)using the features of MIFARE ULTRALIGHT: the LOCK sector

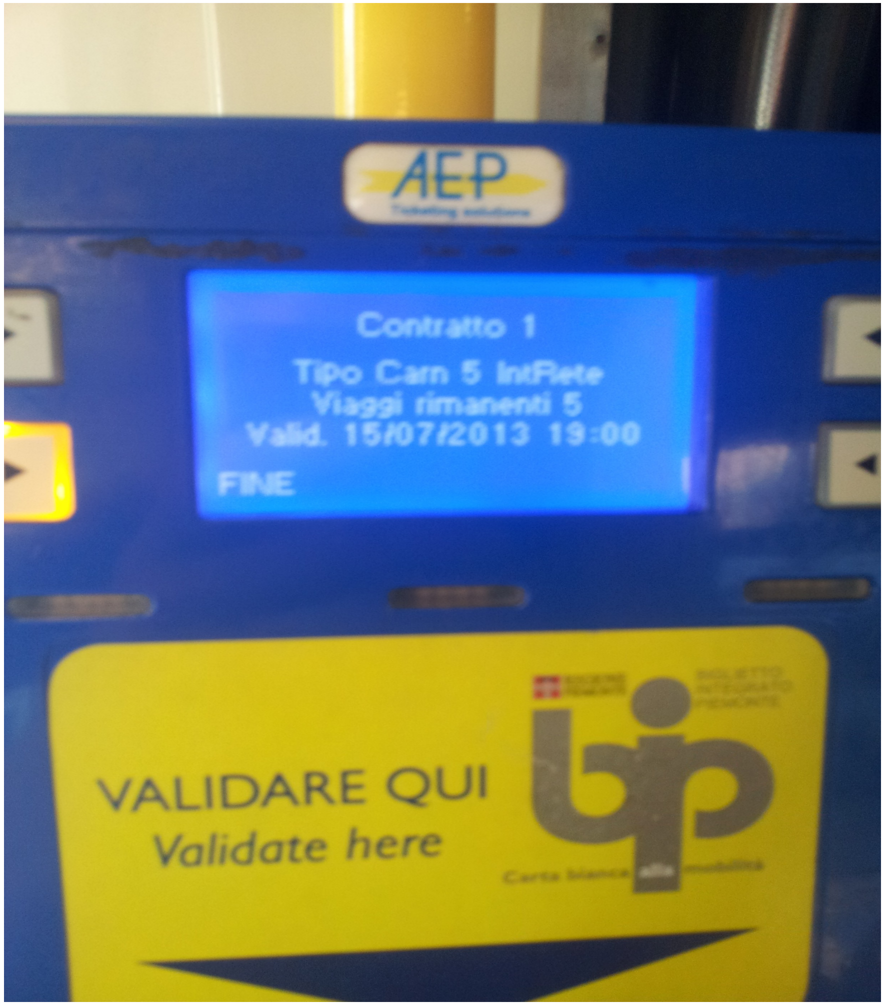
- Just lock the proper sector (OTP) in order to get infinite rides

The LOCK ATTACK: Why?

- Locking the OTP sector we prevent the stamping machine from removing rides stored on our ticket.
- Each time we stamp the ticket the validator checks if we have rides left
- If so it writes on DATA sector data time, etc and tries, without success, to turn bit from 0 to 1 in OTP sector.
- However...

Oops...

Yes, it is not okay to have always 5 rides on a 5 rides-ticket...



```
Contratto 1
Tipo Carn 5 IntRete
Viaggi rimanenti 5
Valid. 15/07/2013 19:00
FINE
```

LOL

How to fix it?

- LOCK ATTACK would be easy to be fixed.
  - Firmware update: check whether OTP sector is locked or not, if so, just refuse to validate the ticket.
  - Firmware update: try to unlock the sector, but only if block bits are not enabled.

- TIME ATTACK isn't really easy to be fixed.
  - Communication between validator and ticket is not encrypted: easy to be sniffed.
  - Solution: Implementing an encrypted communication

Future works...

We are actually working on:

- Rewrite the tool in C/C++ without using external tools
- Decoding DATA sector: dumps and infos are available in Q&A section to anyone who would like to help us.
- NFC-enabled phone or a proxmark for further studying.

Questions?