ST25TB series NFC tags for fun in French* public transports

Benjamin `*gentilkiwi*` DELPY

**maybe elsewhere too*

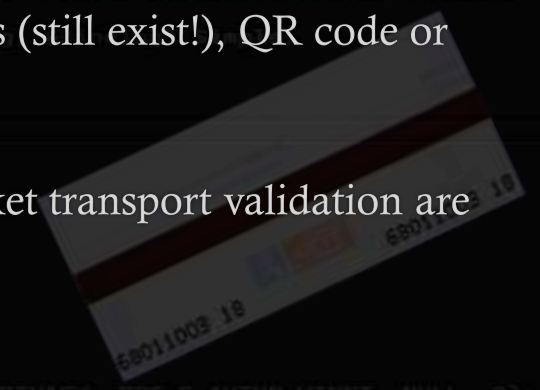
Mandatory notice

- This presentation is not intended to help to fraud in public transports ;
- There is no hack, no CVE, no bypass of intended security features ;
- All this presentation is about normal behavior of ST25TB and SRx cards and their reading system ;
- Research about ST25TB usages was not exhaustive, even in France
  - Can be used elsewhere too (like Brussel, etc.)

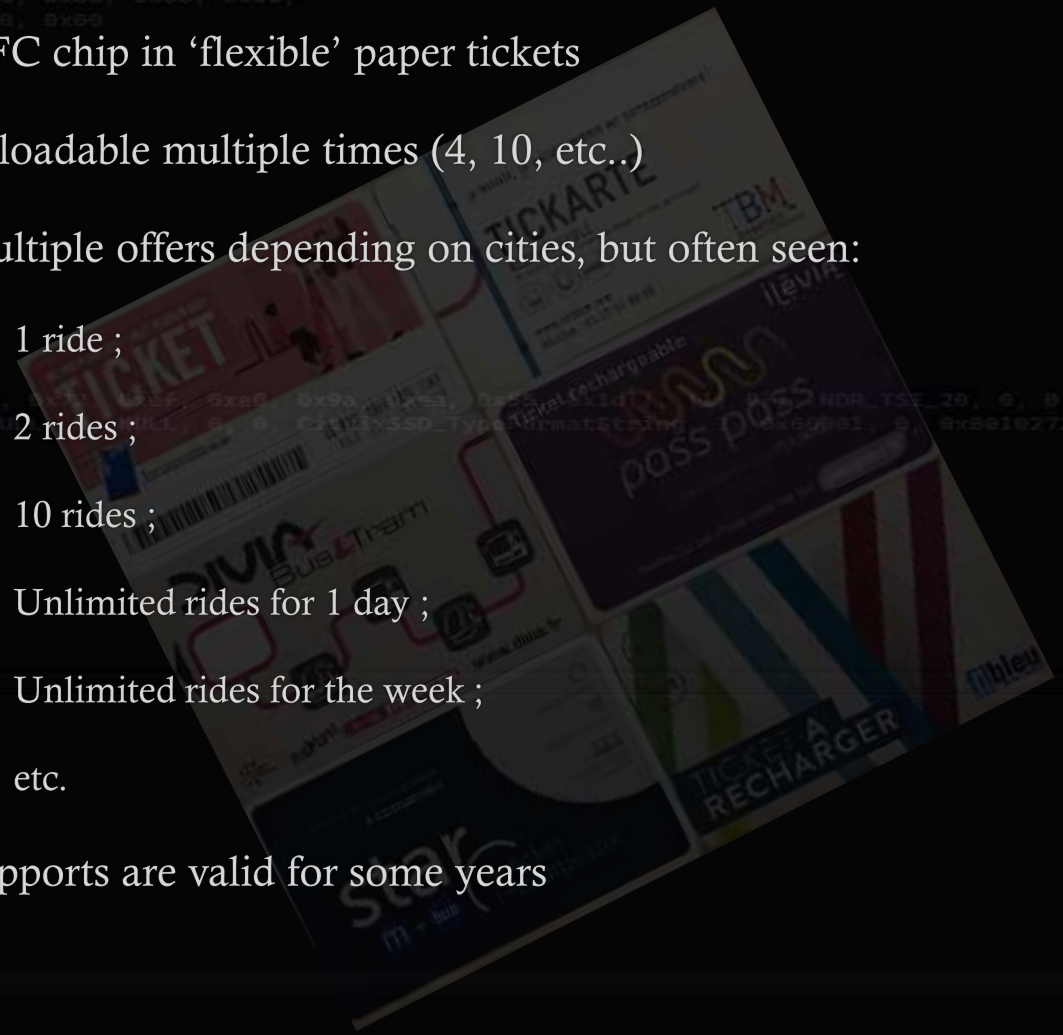
Reloadable convenience tickets

- This is NOT about season tickets
  - Usually, in France, Calypso (Innovatron) or Desfire (NXP) related technologies are used
    - but not only!
  - The card/chip is far more secure, but also more expensive
    - Not always usable for convenience tickets, even reloadable

- This is NOT about magnetic tickets (still exist!), QR code or payment at usage with debit cards
  - Good news, debit cards for ticket transport validation are more and more common



- This is about convenience tickets, usually:
  - NFC chip in ‘flexible’ paper tickets
  - Reloadable multiple times (4, 10, etc..)
  - Multiple offers depending on cities, but often seen:
    - 1 ride ;
    - 2 rides ;
    - 10 rides ;
    - Unlimited rides for 1 day ;
    - Unlimited rides for the week ;
    - etc.
  - Supports are valid for some years



ST25TB series NFC tags

- The ST25TB series of RFID tags are compatible with the ISO14443 standard, so support applications such as public transport and event ticketing.
- They provide state-of-the-art RF performance and include a counter able to count more than 4 billion events.
  - ISO14443-2 Type B with Proprietary Protocol
  - 512-, 2K-, and 4K-bit EEPROM with write protect
  - Two 32-bit counters with anti-tearing feature
  - OTP bytes with conditional erased features

From official ST25TB documentation

ST25TB512-AT

The ST25TB series, and its ancestor SRx, has multiple products available

- SR* – obsolete (~2002/2003…)
  - SR176 (176 bits) - *the most basic one (never seen)*
    - memory area with configurable bits locks
  - SRI512, SRIX512, SRI2K, SRI4K, SRIX4K (for 512 bits, 2 Kbits and 4Kbits)
    - memory area with configurable locks bits
    - resettable one-time programming areas
    - 2 x count down counters, with anti tear down, one counter can be used to reload some OTP part
    - *SRIX* have « France Telecom proprietary anti-clone function », only cards of the series supporting authentication (challenge/response)*
  - **SRT512** (for 512 bits)
    - memory area with configurable locks bits
    - 2 x count down counters, with anti tear down
    - **Designed for transports**
- ST25TB* (~2016…)
  - ST25TB512-AC, ST25TB02K-AC, ST25TB04K-AC
    - Replacement for SRI*
    - No (public ?) traces for a SRIX replacement
  - **ST25TB512-AT**
    - Replacement for SRT*

Addr	32 bits block	Description
0	User area	Lockable EEPROM
1		
2		
3		
4		
5	32 bits binary counter	Count down counter
6	32 bits binary counter	Count down counter
7	User area	Lockable EEPROM
8		
9		
10		
11		
12		
13		
14		
15		
255	OTP_Lock_Reg, 1, ST Reserved	System OTP bits
UID0	64 bits UID area	ROM
UID1		

How to read them?

- Nearly all 14B capable readers can read (and write) to them, this include:
  - The infamous ACS - ACR122U
  - Proxmark3
    - (now that we understand some PCB problems, even the RDV4 ;)))
  - DL533N
  - etc.

- Usually, all NXP PN53x based readers are compatible (but ST and TI chipsets are also in the game)

How to read them?
libnfc : nfc-st25tb

```
c:\security>nfc-st25tb
|mode   : info
Reader  : NXP / PN533 - via pn53x_usb:bus-
0:\\.\libusb0-0255--0x04cc-0x2533
  ...wait for card...
Target  : ISO/IEC 14443-2B ST SRx (106 kbps)
UID     : d5 b4 fb 7d 78 33 02 d0
Manuf   : 0x02 - STMicroelectronics
ChipId  : 0x33 - ST25TB512-AT
Serial  : 0x787dfbb4d5
|blk sz : 32 bits
|nb blks: 16
|sys idx: 255

[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
  | ST reserved  : 111111111111111
  | b15          : 1 - not OTP (?)
  | OTP_Lock_Reg : 111111111111111
```

How to read them?
libnfc : nfc-st25tb

```
c:\security>nfc-st25tb -h
Usage:
  nfc-st25tb [-i]
  nfc-st25tb -b N -r
  nfc-st25tb -b N [-r] -w ABCD[EF01]
  nfc-st25tb -h
Options:
  -i              (default) information mode - will try to dump the tag content and display informations
  -b N            specify block number to operate on (tag dependent), needed for read (-r) and write (-w) modes
  -r              read mode - will try to read block (specified with -b N parameter)
  -w ABCD[EF01]   write mode - will try to write specicied data (2 or 4 bytes depending on tag) to block (specified
with -b N parameter)
  -h              this help
Examples:
  nfc-st25tb -i
        Display all tag informations
  nfc-st25tb -b 0x0e -r
        Read block 0x0e (14) of the tag
  nfc-st25tb -b 0x0d -w 0123abcd
        Write block 0x0d (13) of the tag with hexadecimal value '01 23 ab cd'
  nfc-st25tb -b 0x0c -r -w 0123abcd
        Read, then write block 0x0c (12) of the tag with hexadecimal value '01 23 ab cd'
Warnings:
  Be careful with: system area, counters & otp, bytes order.
```

How to read them?
Proxmark3

```
[usb] pm3 --> hf 14b info

[+]  UID: D0 02 33 78 7D FB B4 D5
[+]  MFG: 02, ST Microelectronics SA France
[+] Chip: 0C, SRT512
[usb] pm3 --> hf 14b dump --ns
[+] found a SRT512 tag
[=] reading tag memory from UID
D00233787DFBB4D5
[=] ................
[+] SRT512 tag
[=]  block#  | data        |lck| ascii
[=] ---------+-------------+---+----------
[=]   0/0x00 | 11 01 00 00 |   | ....
[=]   1/0x01 | 24 00 00 25 |   | $..%
[=]   2/0x02 | 8E 06 80 15 |   | ....
[=]   3/0x03 | 00 01 43 39 |   | ..C9
[=]   4/0x04 | 00 00 C0 85 |   | ....
[=]   5/0x05 | 01 00 00 0A |   | ....
[=]   6/0x06 | FD FF FF FF |   | ....
[=]   7/0x07 | 00 00 00 00 |   | ....
[=]   8/0x08 | 00 00 00 00 |   | ....
[=]   9/0x09 | 00 00 00 00 |   | ....
[=]  10/0x0A | 5A 17 00 00 |   | Z...
[=]  11/0x0B | B8 08 D3 B6 |   | ....
[=]  12/0x0C | 64 80 B3 C2 |   | d...
[=]  13/0x0D | 30 85 3D 04 |   | 0.=.
[=]  14/0x0E | DA DD 00 C1 |   | ....
[=]  15/0x0F | D4 4E BC E4 |   | .N..
[=] 255/0xFF | FF FF FF FF |   | ....
[=] ---------+-------------+---+----------
```

How to understand them?

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

Example in Lille, other layouts are available, and used

How to understand them?

- Intercode & **Intertic** @ AFNOR
  - *Intercode*
    - *NF P99-405-1, NF P99-405-2, NF P99-405-3, NF P99-405-4, NF P99-405-5 & XP P99-405-6*
  - **Intertic**
    - *NF P99-410*
      - **FD P99-416 - E-ticketing for the transportation sector - Interoperability rules for the codification of e-ticketing data - Contactless tickets - FD INTERTIC - 597,12 € HT**
        - **Chapitre 9. SRT512 - ST25TB512-AT**

How to understand them?

(a very old draft is available on the internet)

[DISTRIBUTION DATA]
0x250 = FR
Company/City, Version, End of ticket validity, Tariff, etc.

COUNTER1(CNT1)
0x000001 ride left

COUNTER2(CNT2) / SWAP

[USAGE A DATA]
Validation information, timestamp, etc.

[USAGE A DATA] CERTIFICATE

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

[SEDENTARY BLOCK]
ProductID, Key information, etc.

RELOADING1(RLD1)
0x0a reloading left

[USAGE B DATA]
Validation information, timestamp, etc.

[USAGE B DATA] CERTIFICATE

DISTRIBUTION CERTIFICATE

Example in Lille, other layouts are available, and used

How to understand them?

Included in Proxmark3: proxmark3/client/pyscripts

```
$ python intertic.py ~/hf-14b-D00233787DFBB4D5-dump-Lille.bin
Basic script to try to interpret Intertic data on ST25TB / SRT512 in french transports
--------------------------------------------------------------------------------

Using '/home/gentilkiwi/hf-14b-D00233787DFBB4D5-dump.bin' as binary dump file...
PID (product): 0x11 (flipflop?: True)
KeyId        : 0x8

DISTRIBUTION
  CountryCode                    : 250 - France
  OrganizationalAuthority        : 000
  ContractApplicationVersionNumber: 9
  ContractProvider               : 5
      ~ Authority & Provider ~   : Lille (Ilévia / Keolis)
  ContractTariff                 : 24577
  ContractMediumEndDate          : 10467 (2025-08-29)
  left...                        : bitarray('10010100001100000
  [CER] Distribution             : e4bc4ed4

[1] Counter: 0x000001   - Reloading available: 0x0a
[S] SWAP   : 0xfffffffd - last usage on USAGE_B
```

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

```
USAGE_A
  DateStamp                : 0 (2025-08-29)
  TimeStamp                : 0 (00:00)
  unk0...                  : bitarray('00000000')
  Code/Nature              : 0x0 (?)
  Code/Type                : 0x0 (?)
  unk1...                  : bitarray('00000000000')
  GeoVehicleId             : 0
  GeoRouteId               : 0
  Direction                : 0 (undefined)
  Passengers(?)            : 0
  ValidityTimeFirstStamp: 0 (00:00)
  left...                  : bitarray('000000000000000')
  [CER] Usage              : 175a

USAGE_B
  DateStamp                : 731 (2023-08-29)
  TimeStamp                : 584 (09:44)
  unk0...                  : bitarray('00010111')
  Code/Nature              : 0x3 (metro)
  Code/Type                : 0x1 (entry validation)
  unk1...                  : bitarray('01011001110')
  GeoVehicleId             : 400
  GeoRouteId               : 1212
  Direction                : 2 (inward)
  Passengers(?)            : 1
  ValidityTimeFirstStamp: 584 (09:44)
  left...                  : bitarray('100000100000000')
  [CER] Usage              : 1211
```

How to understand them?

- `CERTIFICATE` parts are ~a signature on the card data with an external key
  - usually on an external SAM card in vending & validating machines
  - 2 to 4 keys can exist:
    - `DISTRIBUTION`
      - Create signature – (normally) only on vending/loading machines
      - Validate signature
    - `USAGE`
      - Create signature
      - Validate signature
- `CERTIFICATE` are UID dependent
  - An exact copy on another (full) card will not have valid `CERTIFICATE` validation – **UID is not the same**

What can we do to play with?

- Reload a dump of a full card on the original card?

Saved dump before usage

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

- **No**: counters cannot be refilled at same values (new value is > to current one)
  - `0x0a000002` is > to `0x0a000001`
  - `0xfffffffe` is > to `0xfffffffd`

What can we do to play with?

- Reload a dump of a fresh card to the original card?

Tear-off attacks exist!

See the wonderful work of Philippe Teuwen & Christian Herrmann with the Proxmark3

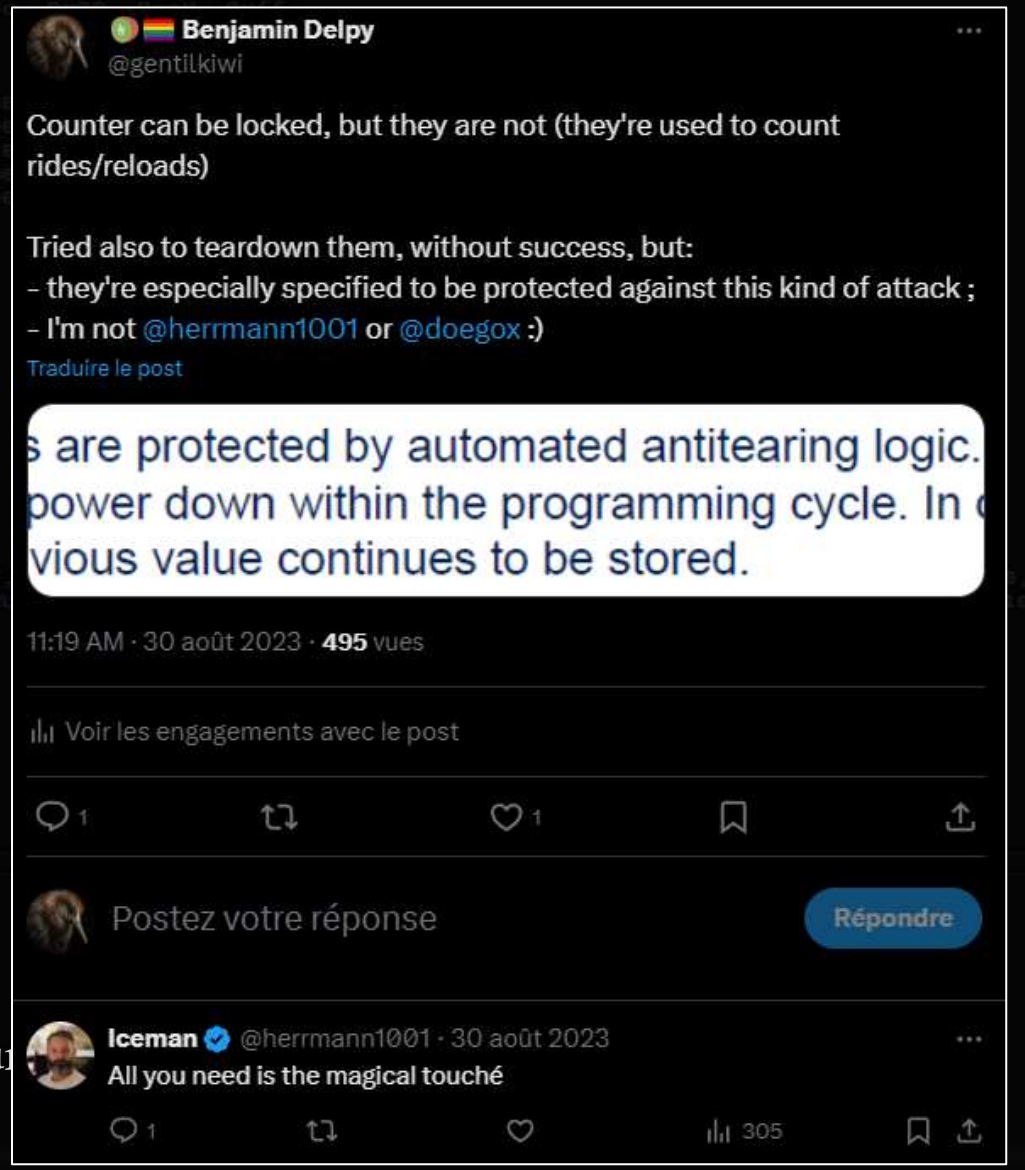
- https://blog.quarkslab.com/rfid-new-proxmark3-tear-off-features-and-new-findings.html

It is theoretically possible to arbitrary flip bits in counters, bypassing the anti incrementation protection of the chip, then to 'really' refill the card

I tried at the time, but I'm not ~~patient~~ good enough at it.
As Chris says, I don't have 'the magical touché'

Fortunately, AMOSSYS will present an adaptation of Philippe & Chris work at SSTIC 2024

- https://www.sstic.org/2024/presentation/tears_for_fears_breaking_an_rfid_counter/



- 0xfffffffe is > to 0xfffffffd

What can we do to play with?

- Reload counters like a reloading machine?

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 09
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

- **No**
  - counters refill are *OK*, because the new `RELOADING1 (0x09xxxxxx)` part is < to previous `RELOADING1 (0x0axxxxxx)`
  - but `CERTIFICATE` part(s) are now **KO – will not validate**, because the signature is invalid / were not recalculated

What can we do to play with?

- Reload a dump of a full card on a new ST25TB512-AT card?

Saved dump before usage

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

UID: d00233787dfbb4d5

New blank/full card

```
[0x00] ff ff ff ff
[0x01] ff ff ff ff
[0x02] ff ff ff ff
[0x03] ff ff ff ff
[0x04] ff ff ff ff
[0x05] ff ff ff ff
[0x06] fe ff ff ff
[0x07] ff ff ff ff
[0x08] ff ff ff ff
[0x09] ff ff ff ff
[0x0a] ff ff ff ff
[0x0b] ff ff ff ff
[0x0c] ff ff ff ff
[0x0d] ff ff ff ff
[0x0e] ff ff ff ff
[0x0f] ff ff ff ff
[0xff] ff ff ff ff
```

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

UID: d00233abcdefabcd

- **No**: all data are **OK**, but signature verification will fail: **UID is not the same**

What can we do to play with?

- Reload a dump of a full card on a new ST25 magic card?

Saved dump before usage

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

UID: d00233787dfbb4d5

```
[0x00] ff ff ff ff
[0x01] ff ff ff ff
[0x02] ff ff ff ff
[0x03] ff ff ff ff
[0x04] ff ff ff ff
[0x05] ff ff ff ff
[0x06] fe ff ff ff
[0x07] ff ff ff
[0x08] ff ff
[0x09] ff ff
[0x0a] ff ff
[0x0b] ff ff
[0x0c] ff ff
[0x0d] ff ff
[0x0e] ff ff
[0x0f] ff ff
[0xff] ff ff
```


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

UID: d00233787dfbb4d5

- **OK**: all data are **OK**, and signature verification will **validate**, UID are the same
  - But for real, **KO** – this kind of card still not exist, and the form factor is incompatible with ticket controller (human)

What can we do to play with?

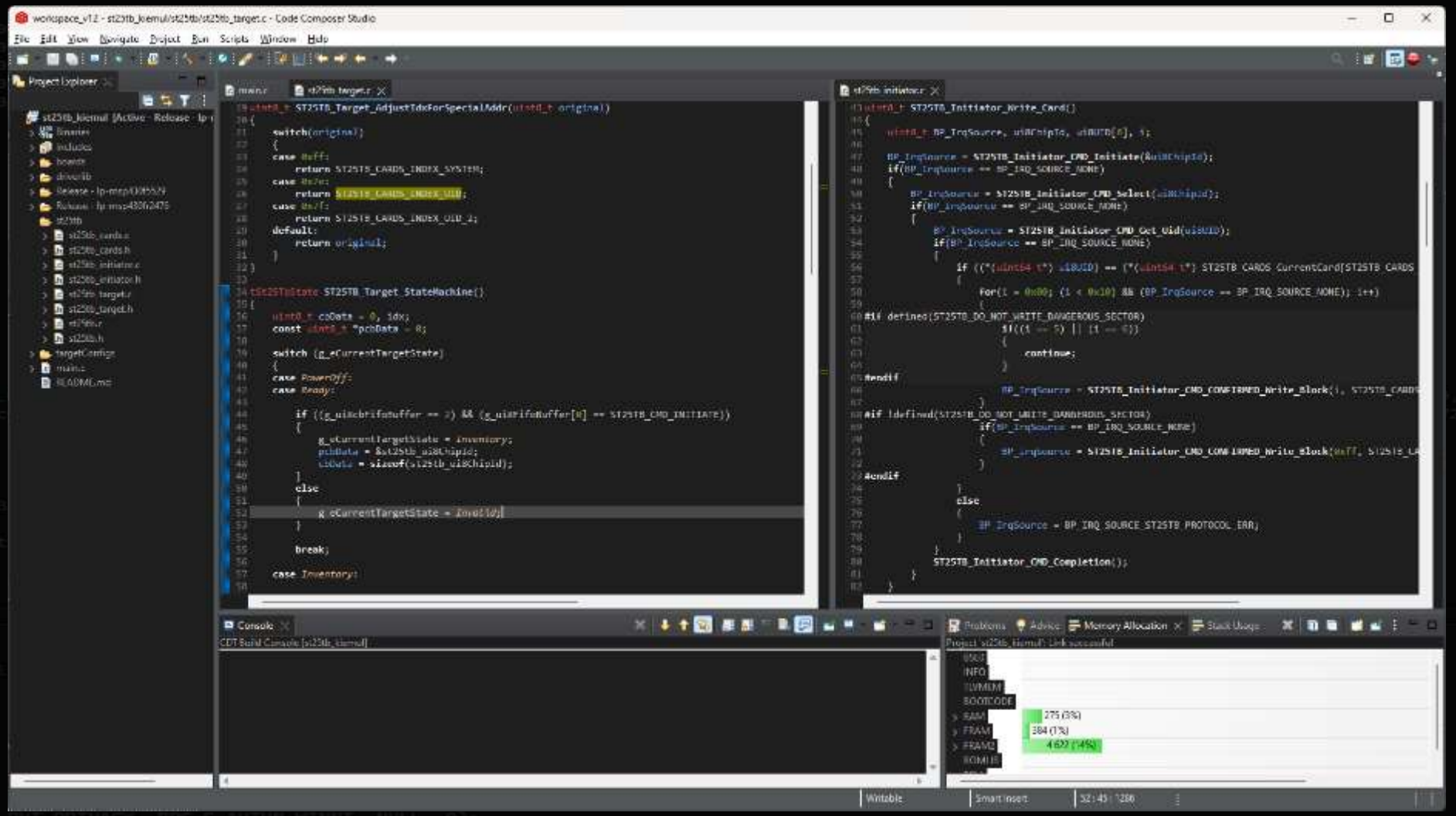
the good idea is here

- Why this is possible ? (in theory)
  - The reader does not **authenticate** the card
  - …and the card does not **authenticate** the reader, so we can dump all its data

- So what ?
  - We can **emulate** (via a potential magic card), or dedicated hardware the ST25TB system
    - Let’s create one!
      - Soon a standalone module for the Proxmark3 RDV4 ?
  - Then write the result to the real card
  - … then loop

What can we do to play with?

st25tb_kiemul



What can we do to play with?

st25tb_kiemul

- Why Texas Instruments ?
  - I don’t know lots of components to do NFC and emulate
    - NXP PN532, very simple to emulate 14A (with some UID limitations)
    - STM ST25R3916(B), very efficient to emulate 14A *(the one in HydraNFCv2 and Flipper Zero)*
      - Seems possible to do other things like 14B, but not ‘natively’
    - nRF 52840 (and friends), good to emulate 14A *(the one in Chameleon Ultra)*
      - even not able to read :’)
  - TI ?
    - TI TRF7970A *(the one in HydraNFCv1)*
      - not a very good one to be honest, lots of errata and things to do yourself but…
      - “[…] In the case of the TRF7970A, **it is possible to emulate both Type 4A and Type 4B** tags concurrently. This feature is a differentiator when compared to static tags that typically offer a single tag type platform. Card emulation for Type 4A uses ISO/IEC 14443A technology at a baud rate of 106 kbps. Card emulation for Type 4B uses ISO/IEC 14443B technology at a baud rate of 106 kbps. After technology selection for either mode has been completed, the higher layers are the same […]”

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

(r) learn

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

(r) expose

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

(w) values

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

(w) values

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

valid for control

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

Reset to original

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

(r) expose

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 08 d3 b6
[0x0c] 64 80 b3 c2
[0x0d] 30 85 3d 04
[0x0e] da dd 00 c1
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

(w) values

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 40 d2 b6
[0x0c] 64 80 b3 c2
[0x0d] 24 85 bc 04
[0x0e] 11 12 00 41
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 08 d3 b6
[0x0c] 64 80 b3 c2
[0x0d] 30 85 3d 04
[0x0e] da dd 00 c1
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

Beep!

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 08 d3 b6
[0x0c] 64 80 b3 c2
[0x0d] 30 85 3d 04
[0x0e] da dd 00 c1
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

(w) values

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 08 d3 b6
[0x0c] 64 80 b3 c2
[0x0d] 30 85 3d 04
[0x0e] da dd 00 c1
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

Write is allowed because new values are NOT > to previous ones

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 08 d3 b6
[0x0c] 64 80 b3 c2
[0x0d] 30 85 3d 04
[0x0e] da dd 00 c1
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

valid for control

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 08 d3 b6
[0x0c] 64 80 b3 c2
[0x0d] 30 85 3d 04
[0x0e] da dd 00 c1
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

What can we do to play with?

st25tb_kiemul

original card


```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 01 00 00 0a
[0x06] fd ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] b8 08 d3 b6
[0x0c] 64 80 b3 c2
[0x0d] 30 85 3d 04
[0x0e] da dd 00 c1
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

virtual card

```
[0x00] 11 01 00 00
[0x01] 24 00 00 25
[0x02] 8e 06 80 15
[0x03] 00 01 43 39
[0x04] 00 00 c0 85
[0x05] 02 00 00 0a
[0x06] fe ff ff ff
[0x07] 00 00 00 00
[0x08] 00 00 00 00
[0x09] 00 00 00 00
[0x0a] 5a 17 00 00
[0x0b] 00 00 00 00
[0x0c] 00 00 00 00
[0x0d] 00 00 00 00
[0x0e] 00 00 00 00
[0x0f] d4 4e bc e4
[0xff] ff ff ff ff
```

Reset to original

etc.

What can we do to play with?

st25tb_kiemul only ?

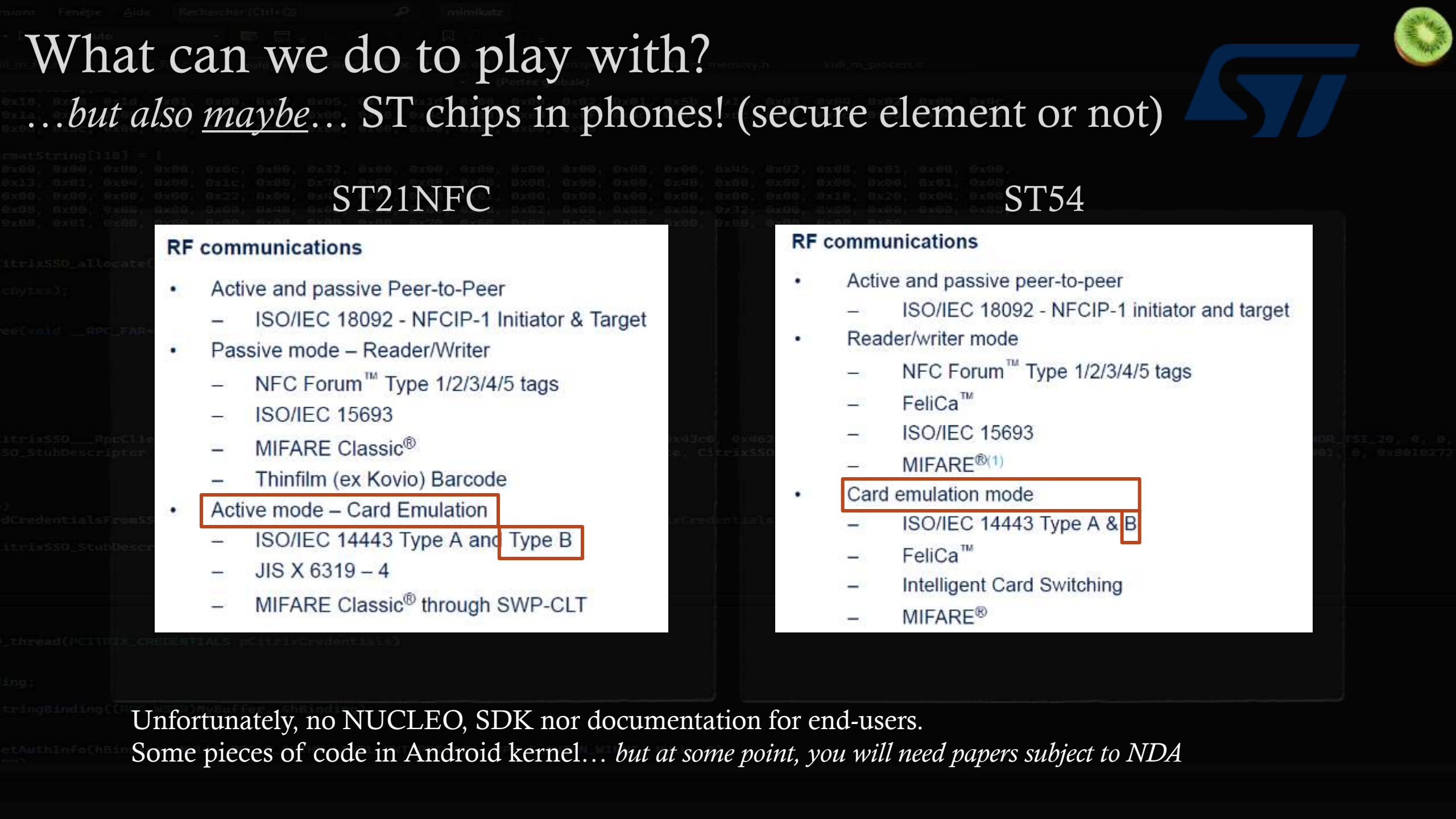
- **`Proxmark3`** also supports 14B', SR*
  - very well for RDV4 since 08/28/2023 ;)
  - And standalone modules…

  - **Can be implemented very quickly, if not already existing in private repositories**

- ***Flipper Zero uses ST25R3916***
  - *Not supporting **natively** 14B emulation*
  - It doesn't mean it will be unavailable forever

What can we do to play with?

…*but also <u>maybe</u>*… ST chips in phones! (secure element or not)



ST21NFC

RF communications

- Active and passive Peer-to-Peer
  - ISO/IEC 18092 - NFCIP-1 Initiator & Target
- Passive mode – Reader/Writer
  - NFC Forum™ Type 1/2/3/4/5 tags
  - ISO/IEC 15693
  - MIFARE Classic®
  - Thinfilm (ex Kovio) Barcode
- Active mode – Card Emulation
  - ISO/IEC 14443 Type A and Type B
  - JIS X 6319 – 4
  - MIFARE Classic® through SWP-CLT

ST54

RF communications

- Active and passive peer-to-peer
  - ISO/IEC 18092 - NFCIP-1 initiator and target
- Reader/writer mode
  - NFC Forum™ Type 1/2/3/4/5 tags
  - FeliCa™
  - ISO/IEC 15693
  - MIFARE®(1)
- Card emulation mode
  - ISO/IEC 14443 Type A & B
  - FeliCa™
  - Intelligent Card Switching
  - MIFARE®

Unfortunately, no NUCLEO, SDK nor documentation for end-users.
Some pieces of code in Android kernel… *but at some point, you will need papers subject to NDA*

What can we do to play with?

…*but also* *maybe*… NXP chips in phones!

- Here again, not a lots of documentation, some NXP GitHub, some Android source code…

Table 2. Card emulation protocol differences

Protocol	PN553/PN557 NFC controller	PN7160 NFC controller
T4T - ISO/IEC 14443 A	Yes	Yes
T4T - ISO/IEC 14443 B	Yes	Yes
MIFARE Classic 1K / 4K	Yes	No
MIFARE DESFire	Yes	No
T3T - Sony FeliCa	Yes	Yes

Where is it used ?

in France, a lot

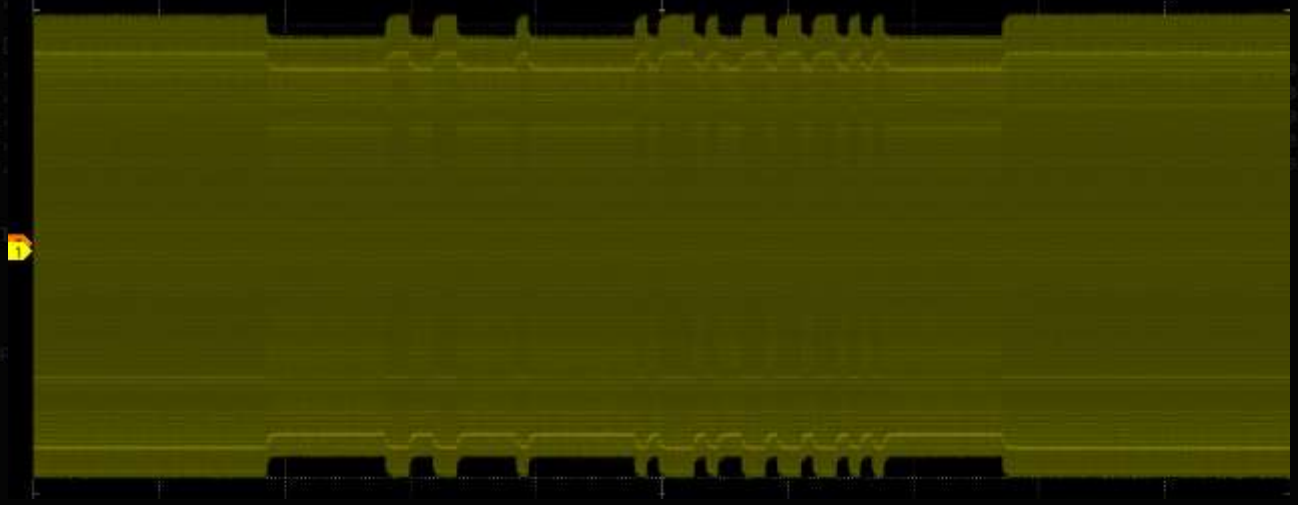
- Not exhaustive…
  - **Verified: Lille, Lens-Béthune, Amiens, Angoulême, Bordeaux, Lyon, Tours, Reims, Strasbourg, Annecy, Clermont-Ferrand, Dijon, Rennes, Saint-Malo, Besançon, Le Havre, Cherbourg-en-Cotentin, Nîmes, Metz, Angers, Saint-Nazaire**
  - **Not Intertic: Brussels (BE) / Flemish region (BE)** / maybe (?) Walloon (BE), **Roma (IT), Lisbon (PT) …**
  - Maybe (but ~sure): Valenciennes, Avignon, Aubagne, Caen, Aix-en-Provence, Bayonne, Blois, Perpignan, Pau
  - *?: Montbéliard, Lorient, Chambéry, Châlons-en-Champagne, Bourg-en-Bresse, Boulogne-sur-Mer, Alençon, Chauny, Verdun*

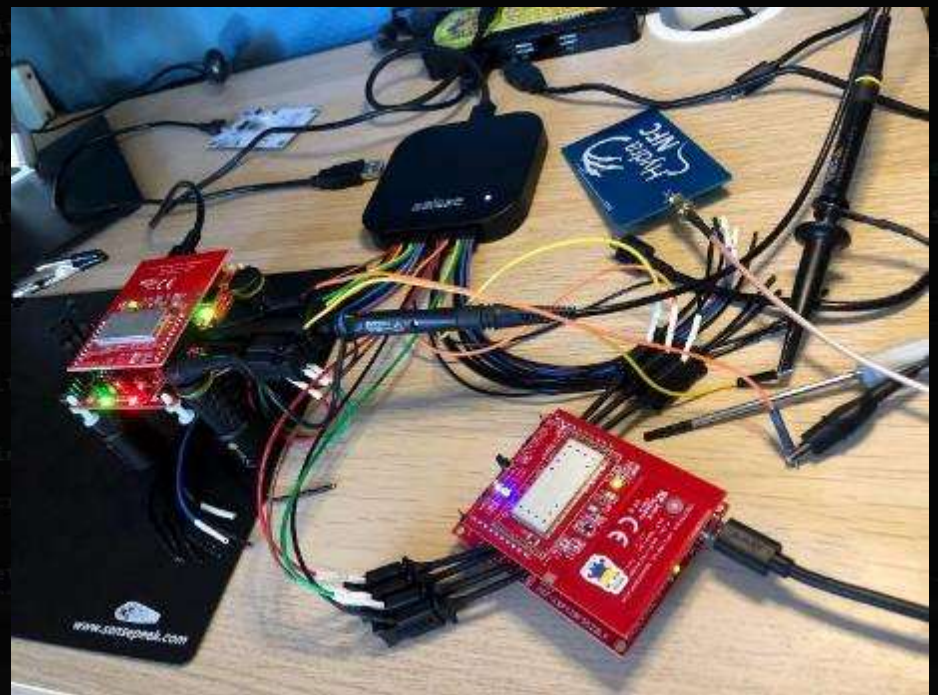
What to do ?

- Stop using ST25TB* / SR* technologies for convenient transport tickets
- Continue to deploy cEMV / Account-Based Ticketing (ABT)
  - with payment card & smartphone support!
- …or use authenticated methods (like Mifare Ultralight EV1, …)

Pictures

Because it sounds too easy to make otherwise





Pictures

Because it sounds too easy to make otherwise

But now also a kameleon! (DIY)

Questions ?

- @gentilkiwi
- benjamin@gentilkiwi.net
- https://github.com/gentilkiwi
  - st25tb_kiemul firmware: https://github.com/gentilkiwi/st25tb_kiemul
  - st25tb_kiemul hardware: https://oshwlab.com/gentilkiwi/st25tb_kiemul
  - st25tb_kameleon firmware: https://github.com/gentilkiwi/st25tb_kameleon
  - st25tb_kameleon hardware: https://oshwlab.com/gentilkiwi/st25tb_kameleon

References

- ST25TB series NFC tags: https://www.st.com/en/nfc/st25tb-series-nfc-tags.html
- ST25TB512-AT (nearly SRT512): https://www.st.com/en/nfc/st25tb512-at.html
- libnfc (nfc-st25tb): https://github.com/nfc-tools/libnfc/
- proxmark3: https://github.com/RfidResearchGroup/proxmark3
- AFNOR – FD P99-416: https://www.boutique.afnor.org/en-gb/standard/fd-p99416/eticketing-for-the-transportation-sector-interoperability-rules-for-the-cod/fa203907/339737
- TI TRF7970A: https://www.ti.com/product/TRF7970A

Few Roma convenience tickets info's

new one – before usage

Tech: ST25TB04K ***(not** ST25TB512-AT)*
UID: D0 02 1F AA BB CC DD EE
Convert to decimal for card serial number (minus last digit)

```
[0x00] ff ff ff ff
[0x01] ff ff ff ff
[0x02] ff ff ff ff
[0x03] ff ff ff ff
[0x04] ff ff ff ff
[0x05] fd ff ff ff
[0x06] ff ff ff ff
[0x07] ff ff ff ff
[0x08] ff ff ff ff
[0x09] ff ff ff ff
[0x0a] ff ff ff ff
[0x0b] ff ff ff ff
[0x0c] ff ff ff ff
[0x0d] ff ff ff ff
[0x0e] ff ff ff ff
[0x0f] ff ff ff ff
```

not the best initial value idea (tear-off)

then, 0xfffffffc, 0xfffffffb, ...

Also seen:
00 40 08
00 44 08
00 48 08
00 4c 08

```
[0x10] 86 81 00 44
[0x11] 08 f0 16 b0
[0x12] 4f 5f c5 09
[0x13] 66 46 a7 2a
[0x14] 94 87 2a 22
[0x15] a5 46 a7 2a
[0x16] 94 87 2a 22
[0x17] a5 8d 07 60
[0x18] ae 1e 9b bc
[0x19] 98 60 6e 98
[0x1a] 70 39 c1 a9
[0x1b] 07 1e 8a 66
[0x1c] bd b9 d1 67
```

```
[0x1d] b4 82 00 48
[0x1e] 08 0d 29 cd
[0x1f] 14 97 06 b7
[0x20] 4f b0 2a c8
[0x21] 12 4e 52 2c
[0x22] 6e bc 79 8a
[0x23] e5 31 b4 25
[0x24] 64 c3 e1 92
[0x25] b8 8a 2b 1b
[0x26] bc 7b f7 1d
[0x27] e4 12 f6 fe
[0x28] 06 32 04 ff
[0x29] b6 f4 15 9b
```

blocks 0x2d & 0x2e are not used with convenience tickets

```
[0x2a] ff ff ff ff
       ...
[0x7f] ff ff ff ff

[0xff] ff ff ff ff
```