Quarkslab

MIFARE Classic: exposing the static encrypted nonce variant

Y'en a un peu plus, j'vous l'mets quand même?

Philippe Teuwen

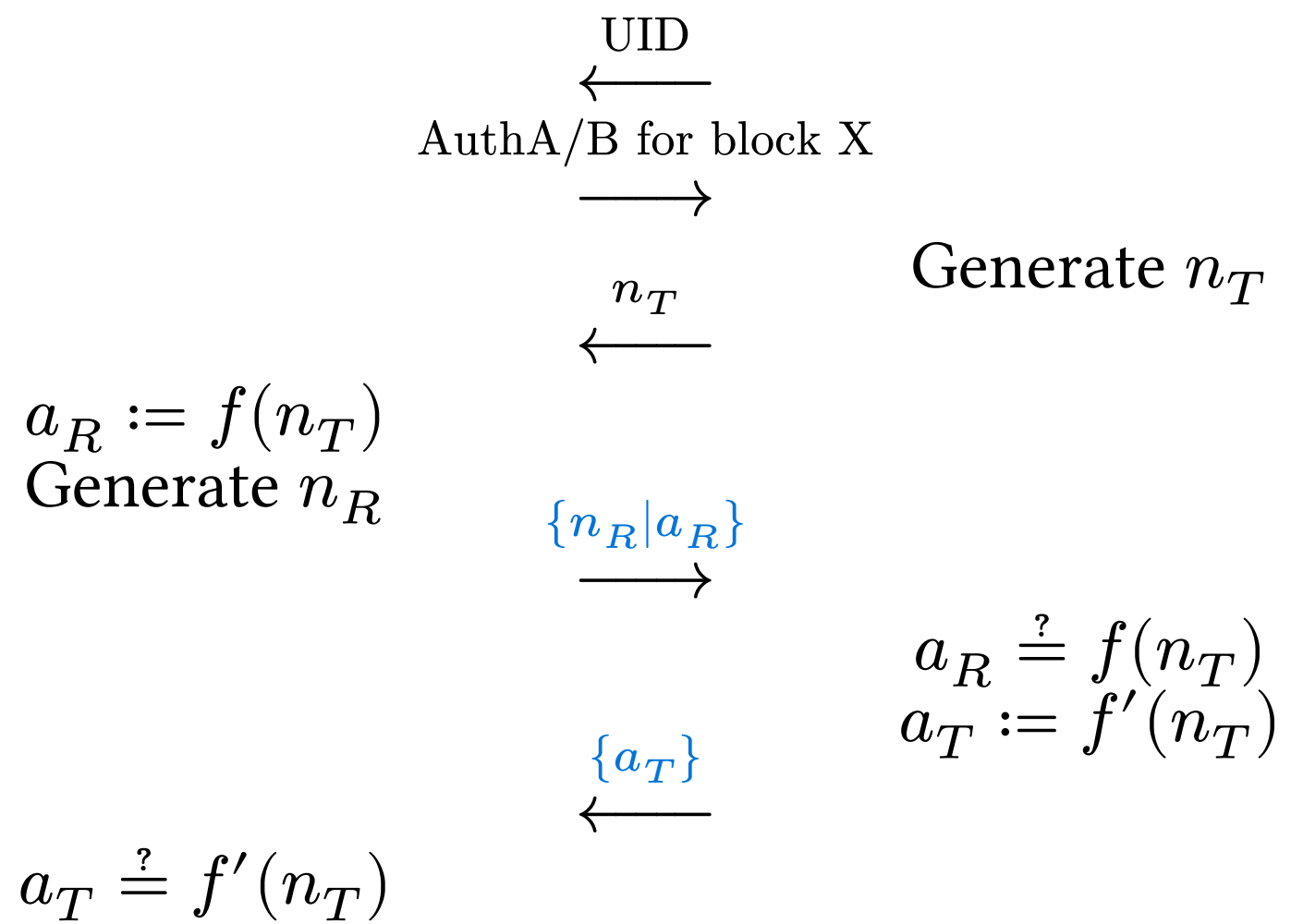
21-11-2024

What to expect?

Breaking MIFARE Classic in 2024 ??

FM11RF08S 芯片 EEPROM 存储器的出厂配置数据如下：

Sector	Block	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	0	UID				Chip Info											
	1	00															
	2	00															
	3	FF						FF	07	80	69	FF					
1	0	00															
	1	00															
	2	00															
	3	FF						FF	07	80	69	FF					
⋮																	
15	0	00															
	1	00															
	2	00															
	3	FF						FF	07	80	69	FF					


Reader
Tag
UID
AuthA/B for block X
Generate n_T
n_T
$a_R := f(n_T)$
Generate n_R
$\{n_R|a_R\}$
$a_R \stackrel{?}{=} f(n_T)$
$a_T := f'(n_T)$
$\{a_T\}$
$a_T \stackrel{?}{=} f'(n_T)$

Reader		Tag
	$\{\text{AuthA/B for block Y}\} \longrightarrow$	
		Generate n_T
	$\{n_T\} \longleftarrow$	
$a_R := f(n_T)$ Generate n_R		
	$\{n_R \vert a_R\} \longrightarrow$	
		$a_R \stackrel{?}{=} f(n_T)$ $a_T := f'(n_T)$
	$\{a_T\} \longleftarrow$	
$a_T \stackrel{?}{=} f'(n_T)$		

Timeline

1994 first Philips MIFARE Classic

1997 Infineon SLE44R35

2004 Fudan FM11RF08

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- **24C3 *Mifare (Little Security Despite Obscurity)***

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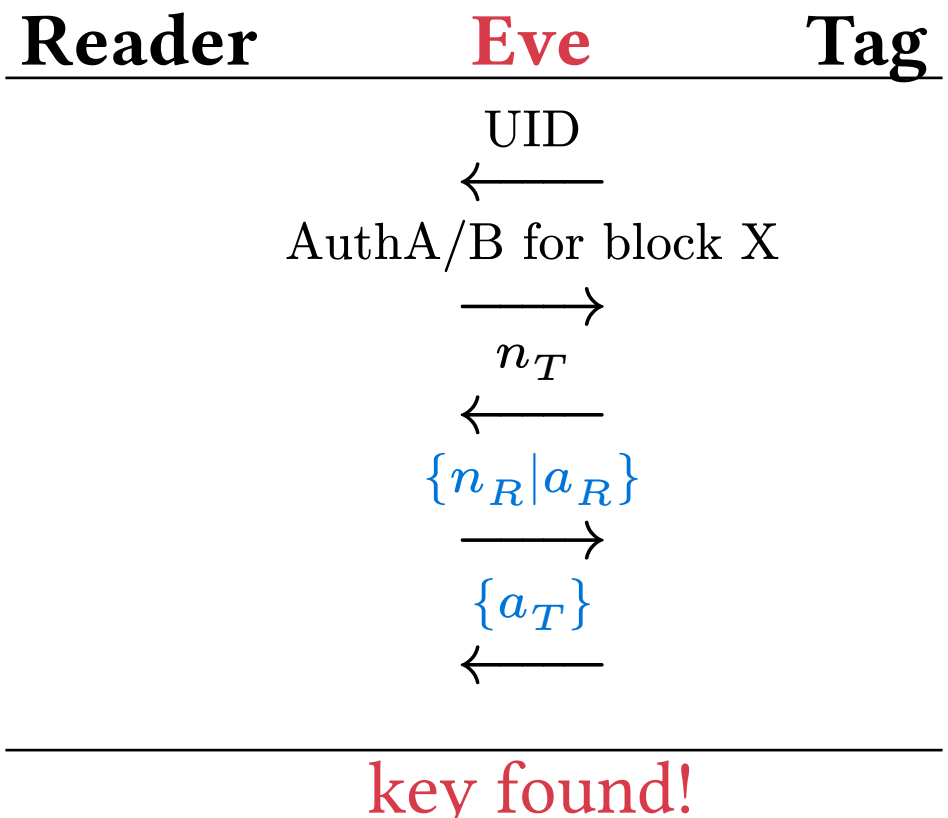
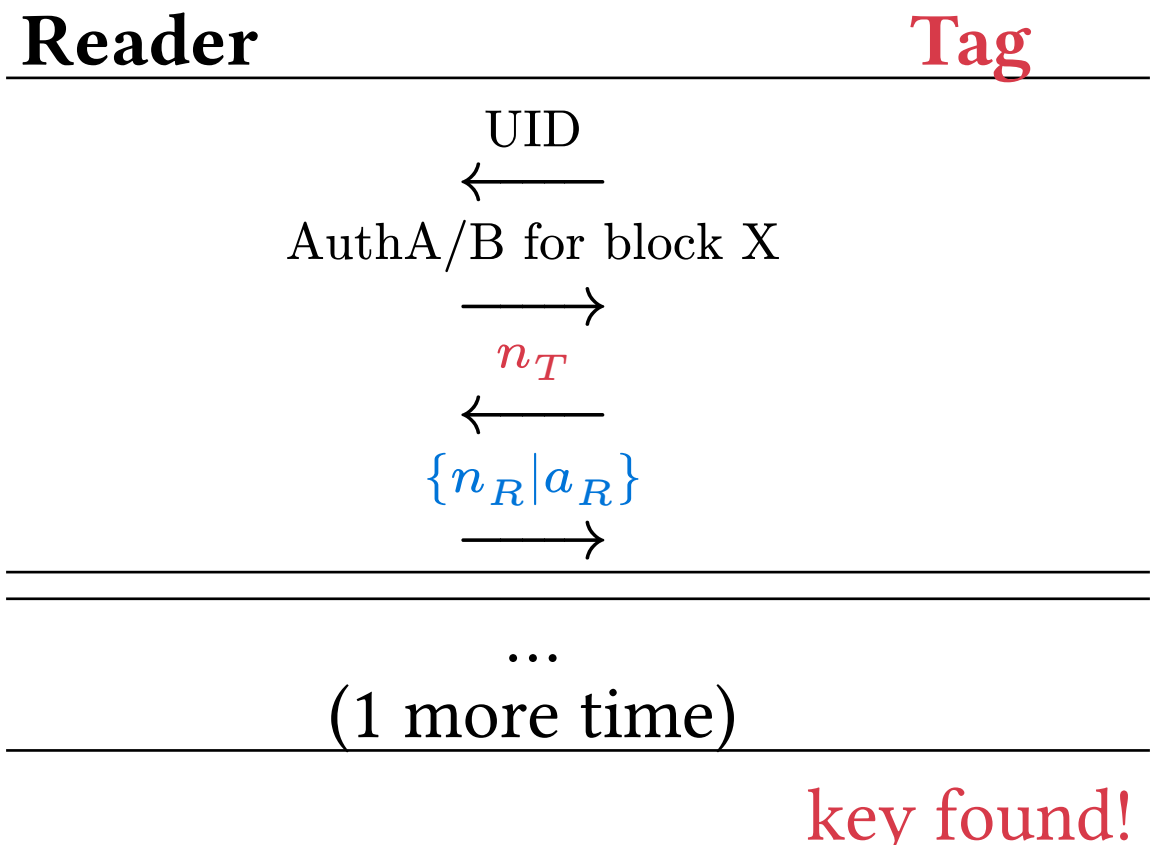
- ***Dismantling MIFARE Classic***

Reader+Tag



Reader-only


Reader
Tag
UID
AuthA/B for block X
n_T
$\{n_R|a_R\}$
...
(1 more time)
key found!

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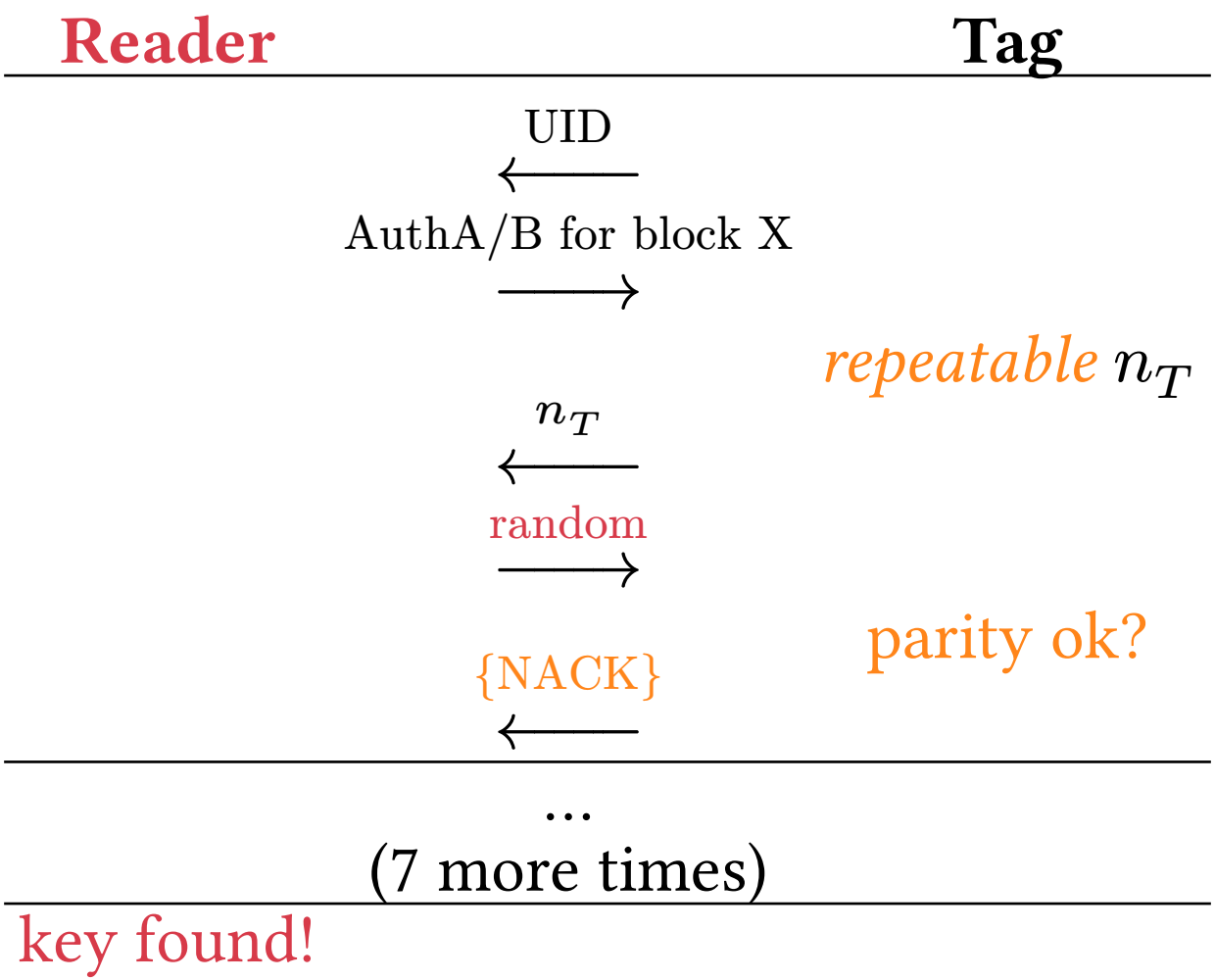
- ***Dark Side Of Security by Obscurity and Cloning MiFare Classic Rail and Building Passes Anywhere***

Card-only: Darkside attack



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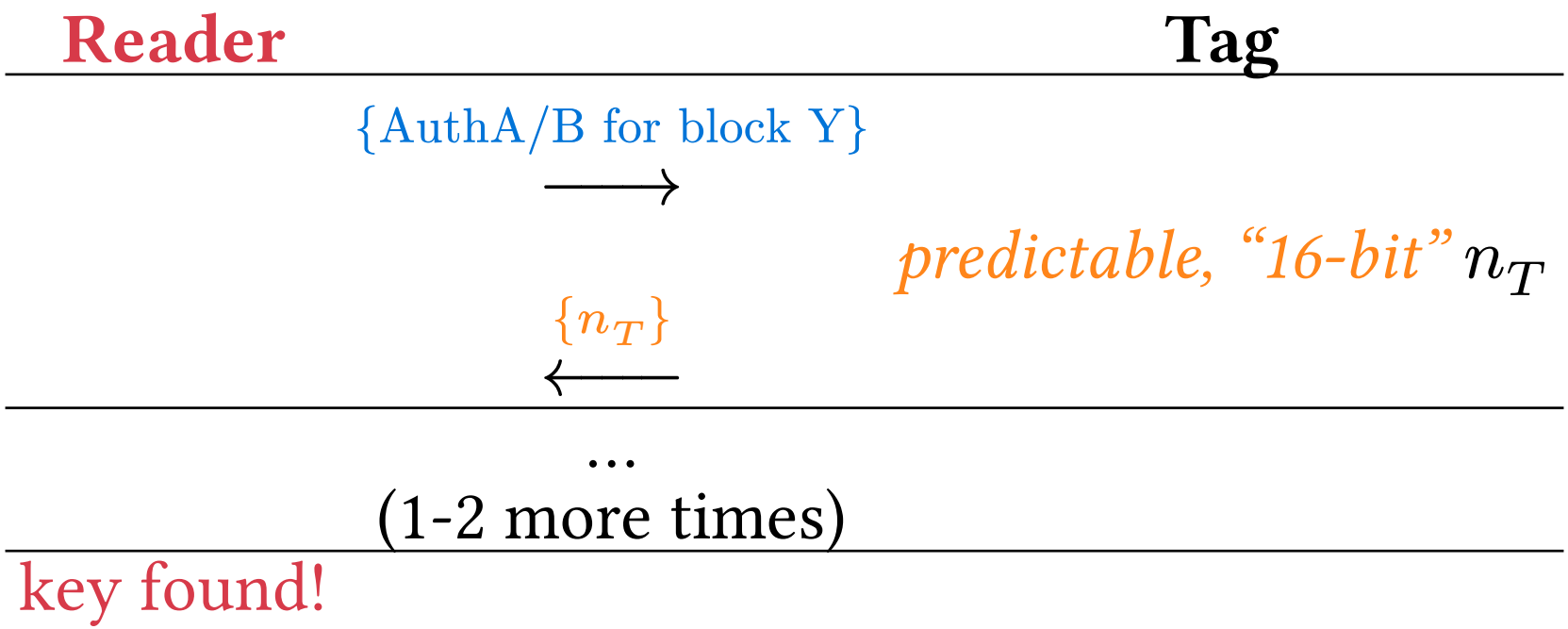
- 24C3 *Mifare (Little Security Despite Obscurity)*
- *Dismantling MIFARE Classic*
- *Dark Side Of Security by Obscurity and Cloning MiFare Classic Rail and Building Passes Anywhere*
- ***Wirelessly Pickpocketing a Mifare Classic Card***

Card-only: Nested attack



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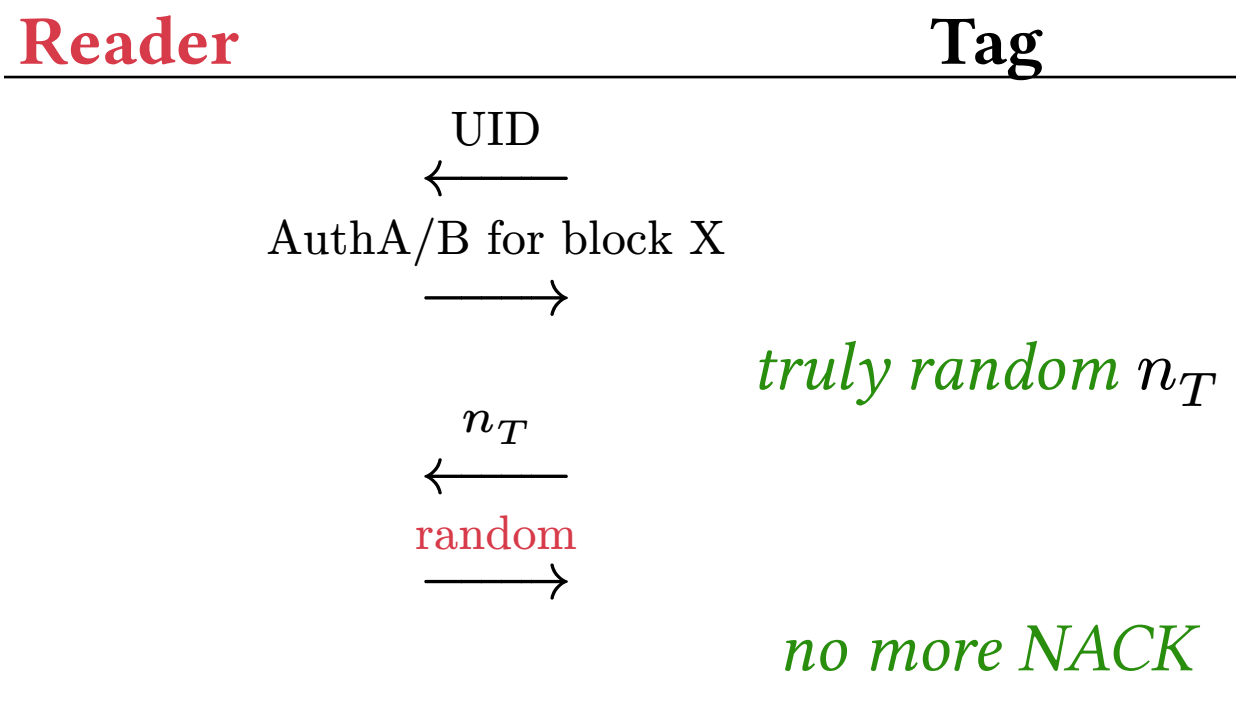
2010 MIFARE Plus (with Classic compatible SL1)

2014 MIFARE Classic EV1

Hardened cards



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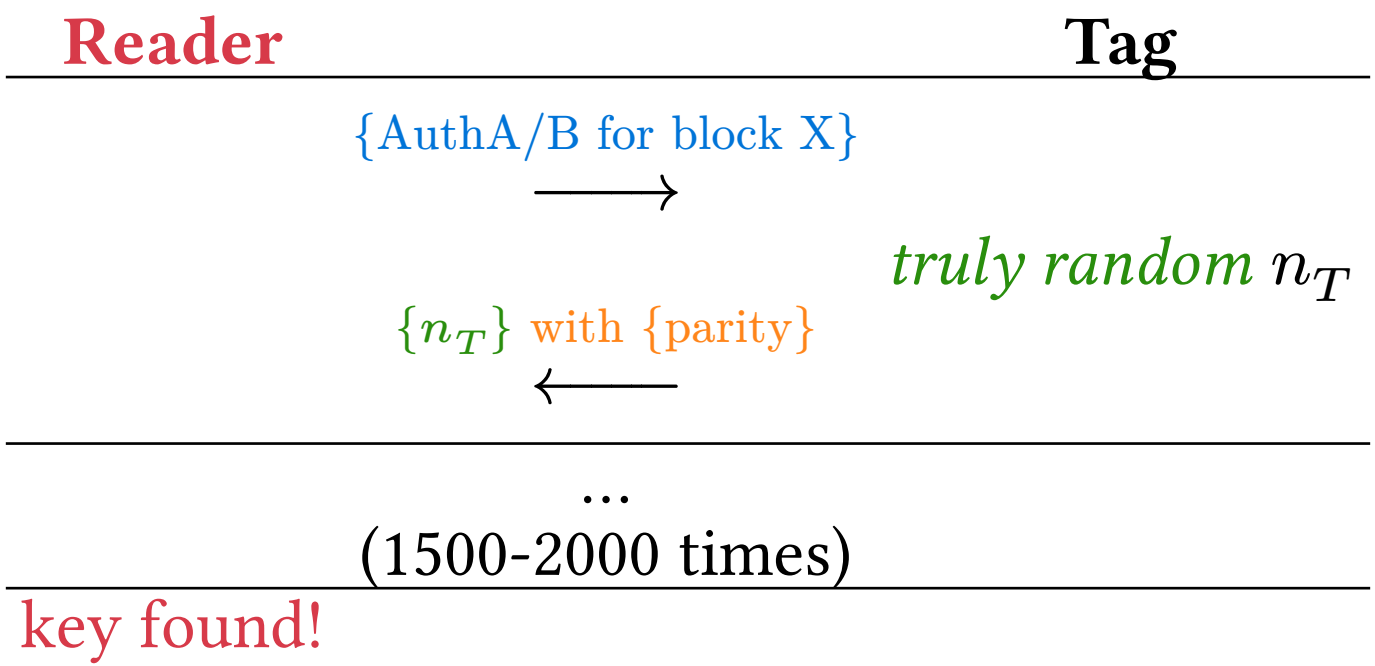
2015 ***Ciphertext-only Cryptanalysis on Hardened Mifare Classic Cards***

Hardnested attack



Static Encrypted Nonce cards

Resist all known card-only attacks

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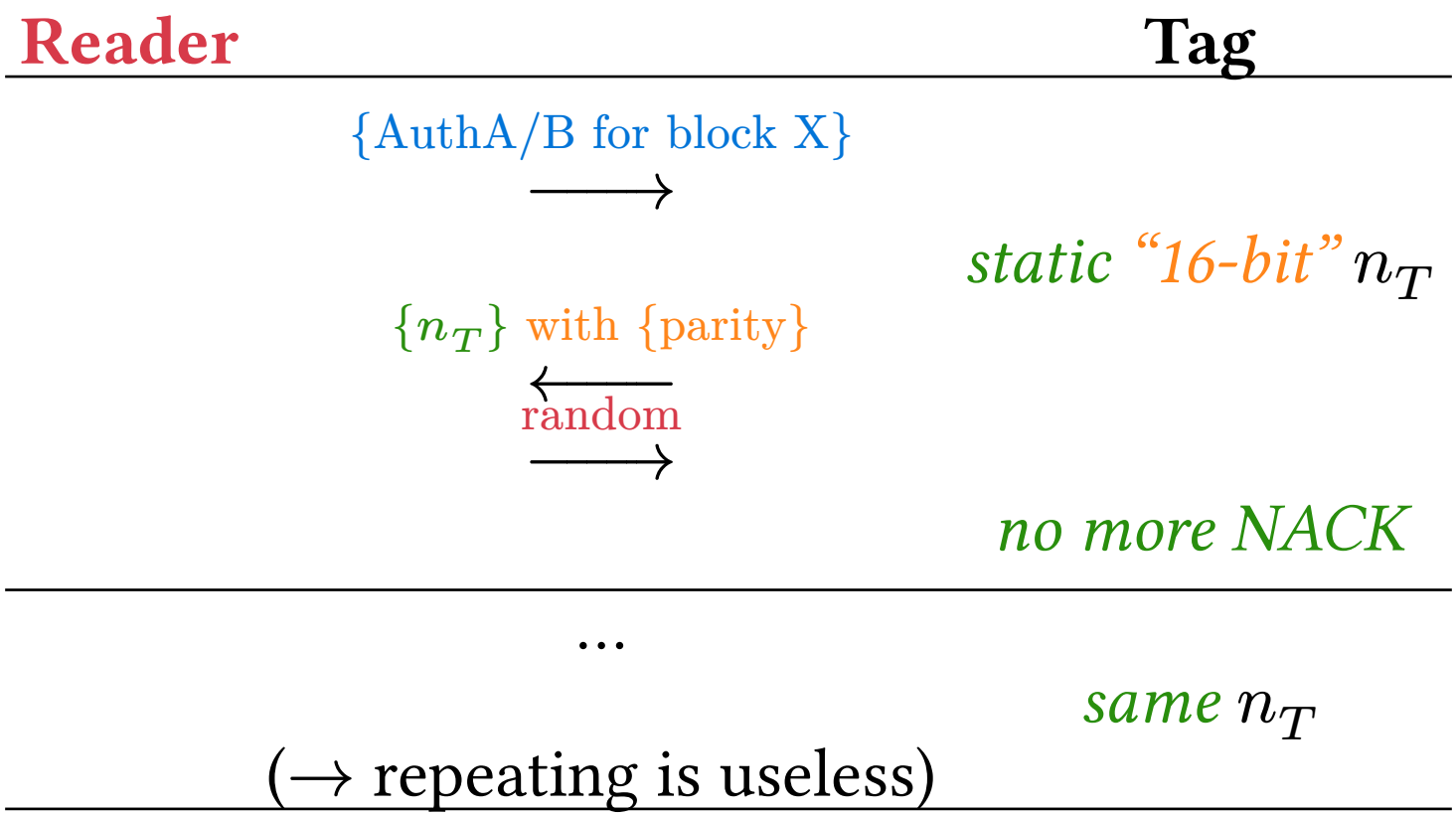
2015 *Ciphertext-only Cryptanalysis on Hardened Mifare Classic Cards*

2020 Fudan FM11RF08S

FM11RF08S aka Static Encrypted Nonce cards



Static Encrypted Nonce depends on

- the card
- the sector
- the key itself

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- the key itself

Assume a key is repeated across some sectors / cards

Reused Keys Nested Attack

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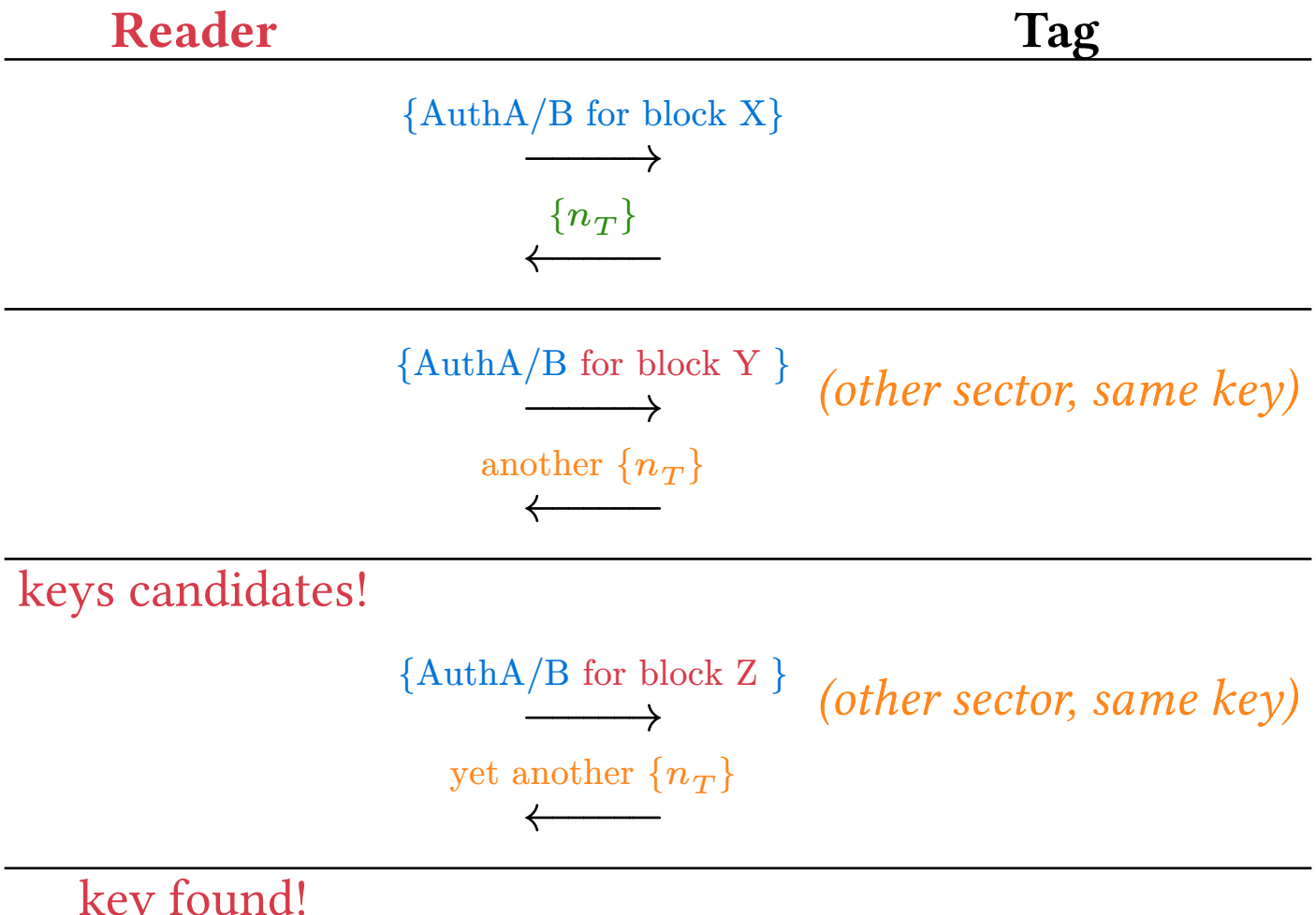


Lightweight fuzzing

Nested AuthA/B for block X

$\longrightarrow$

60xx = keyA

61xx = keyB

Nested AuthA/B for block X

$\longrightarrow$

60xx = keyA

61xx = keyB

6000, 6200, 6800, 6a00 $\rightarrow \{n_T\}$ = 4e506c9c, auth successful with keyA

6100, 6300, 6900, 6b00 $\rightarrow \{n_T\}$ = 7bfc7a5b, auth successful with keyB

Nested AuthA/B for block X

$\longrightarrow$

60xx = keyA

61xx = keyB

6000, 6200, 6800, 6a00 $\rightarrow \{n_T\}$ = 4e506c9c, auth successful with keyA

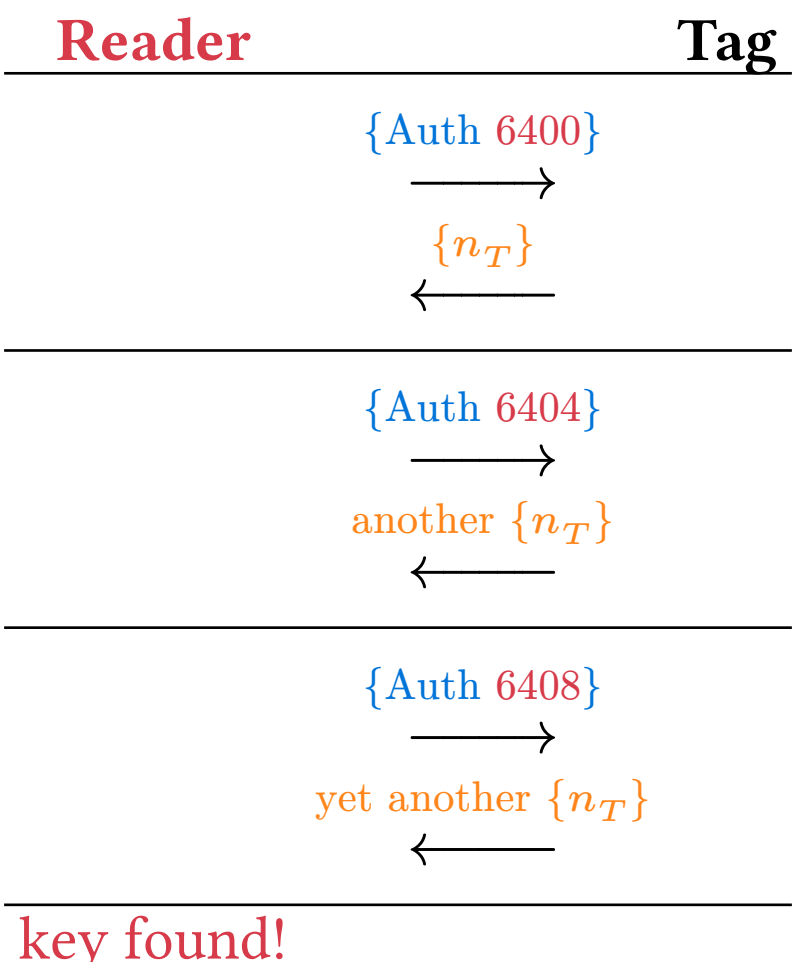
6100, 6300, 6900, 6b00 $\rightarrow \{n_T\}$ = 7bfc7a5b, auth successful with keyB

6400, 6600, 6c00, 6e00 $\rightarrow \{n_T\}$ = 65aaa443, auth failed

6500, 6700, 6d00, 6f00 $\rightarrow \{n_T\}$ = 55062952, auth failed

Reused Keys Nested Attack

Reused Keys Nested Attack



A396EFA4E24F

A396EFA4E24F

all sectors

A396EFA4E24F

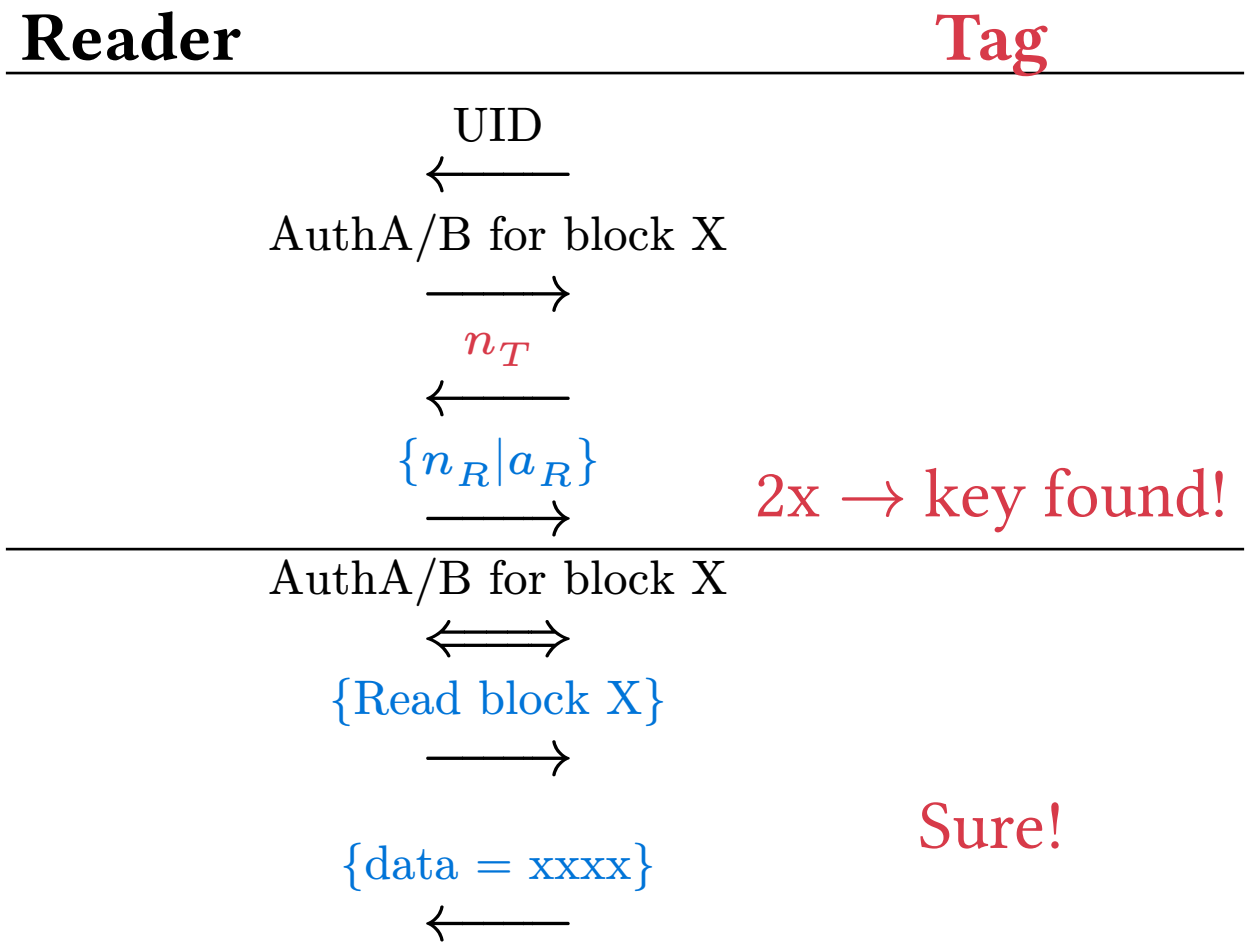
all sectors

all FM11RF08S tags

DEMO: Data Read

Data-first attacks

Data-first + Reader-only



DEMO: Data-first + Reader-only

Backdoored nested attack

6000, 6200, 6800, 6a00 $\longrightarrow n_T$ = 75bfa373, auth successful with keyA

6100, 6300, 6900, 6b00 $\longrightarrow n_T$ = 999c7562, auth successful with keyB

6000, 6200, 6800, 6a00 $\longrightarrow n_T$ = 75bfa373, auth successful with keyA

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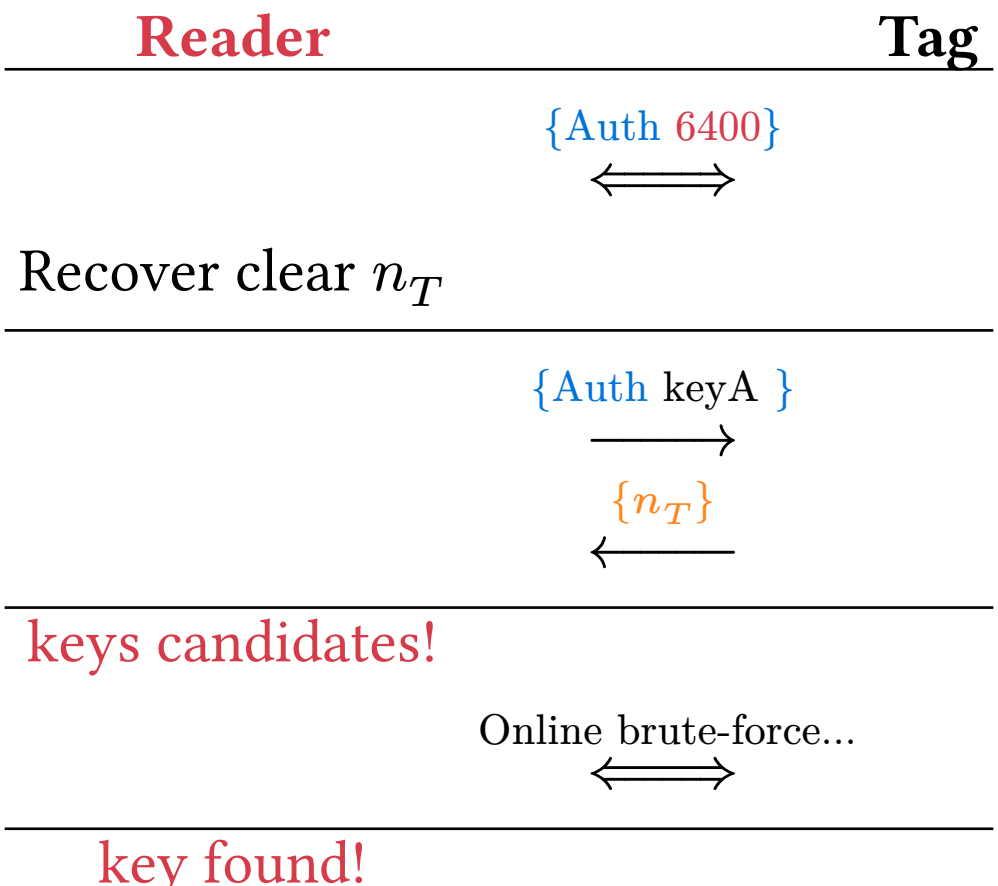
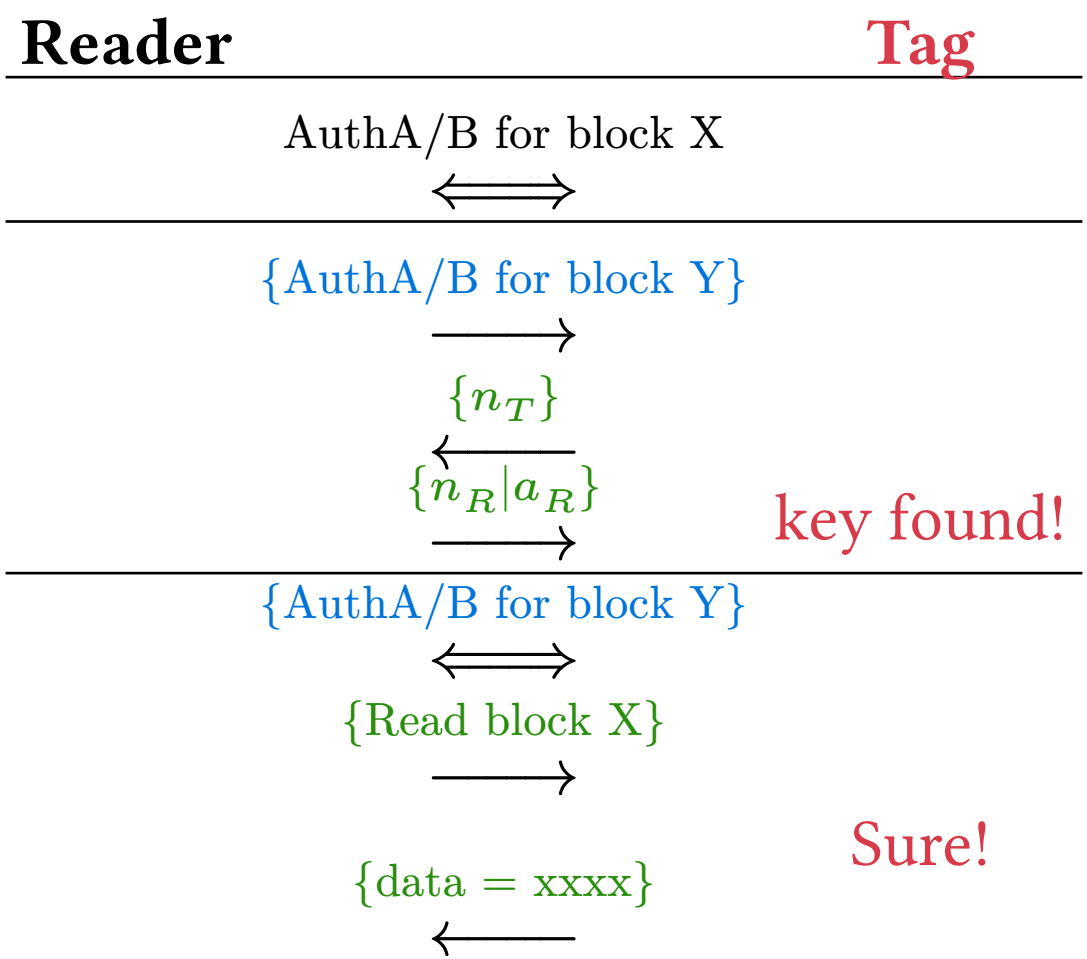
6500, 6700, 6d00, 6f00 $\longrightarrow n_T$ = 999c7562, auth successful with **A396EFA4E24F**

Backdoored nested attack



Data-first attacks, supporting nested

Data-first + Reader-only, **with nested auth support**



Reversing Nested Nonce Generation

$$n_{T_0}, K_0, K_1 \rightarrow n_{T_1}$$

Faster Backdoored Nested Attack

DEMO: Full Card Recovery

Light-Fast Supply Chain Attack

DEMO: Light-Fast Supply Chain Attack

More Backdoors

FM11RF08 ⇒ A31667A8CEC1

FM11RF08 ⇒ A31667A8CEC1

FM11RF32N ⇒ 518B3354E760

FM11RF08 ⇒ A31667A8CEC1

FM11RF32N ⇒ 518B3354E760

With help of community:

FM11RF08S-7B ⇒ A396EFA4E24F

FM11RF08 ⇒ A31667A8CEC1

FM11RF32N ⇒ 518B3354E760

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FM11RF08S-7B ⇒ A396EFA4E24F

FM1208-10 ⇒ A31667A8CEC1

FM1216-137 ⇒ A31667A8CEC1

FM11RF08 ⇒ A31667A8CEC1

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one **FM11RF08S ⇒ A31667A8CEC1**

Official manufacturers…

MF1ICS5003 ⇒ A31667A8CEC1

MF1ICS5004 ⇒ A31667A8CEC1

SLE66R35 ⇒ A31667A8CEC1

Resources

- 47-page https://eprint.iacr.org/2024/1275 (v1.2 2024-11-08)

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- **Proxmark3 - Iceman fork** ❤️
- 7 new commands/tools/scripts
- 4 updated commands with backdoor support

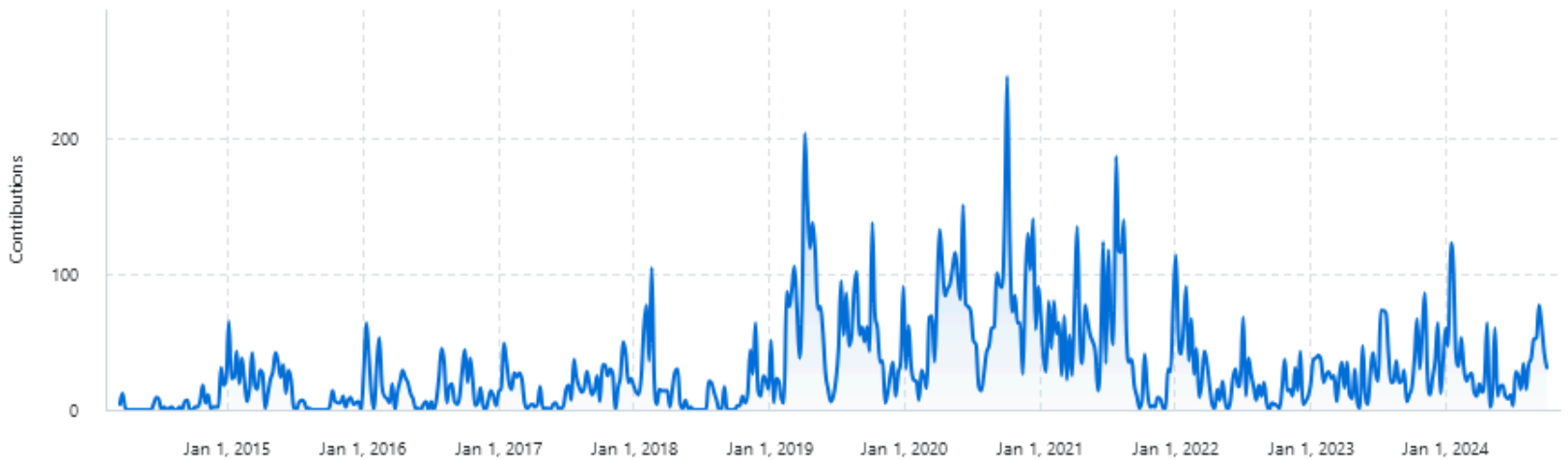
Contributors Beta Give feedback

Period: All

Contributions per week to master, line counts have been omitted because commit count exceeds 10,000.

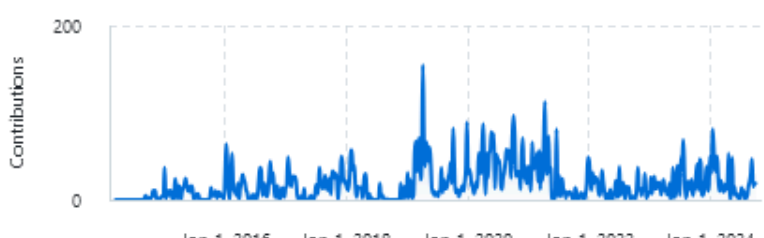
Commits over time

From 16 Mar 2014 to 29 Sept 2024



iceman1001 #1

10 000 commits



doegox #2

2 586 commits

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- **RFID Hacking by Iceman Discord**
  - Great community ❤️

Conclusion