A LoRaWAN Security Assessment Testbench

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Lab

National Cybersecurity Agency of France (ANSSI), Wireless Security Lab :

- Radiocommunication protocols
- Electromagnetic Security (TEMPEST, IEMI, ...)
- Signal processing
- Simulations, measurements
- Embedded systems

Radiocommunication protocols in the IoT

- LoRaWAN
- Sigfox
- NarrowBand-IoT (NB-IoT)
- Zigbee
- Z-Wave
- Bluetooth-related (Classic, Low Energy, Mesh)
- ...

Outline

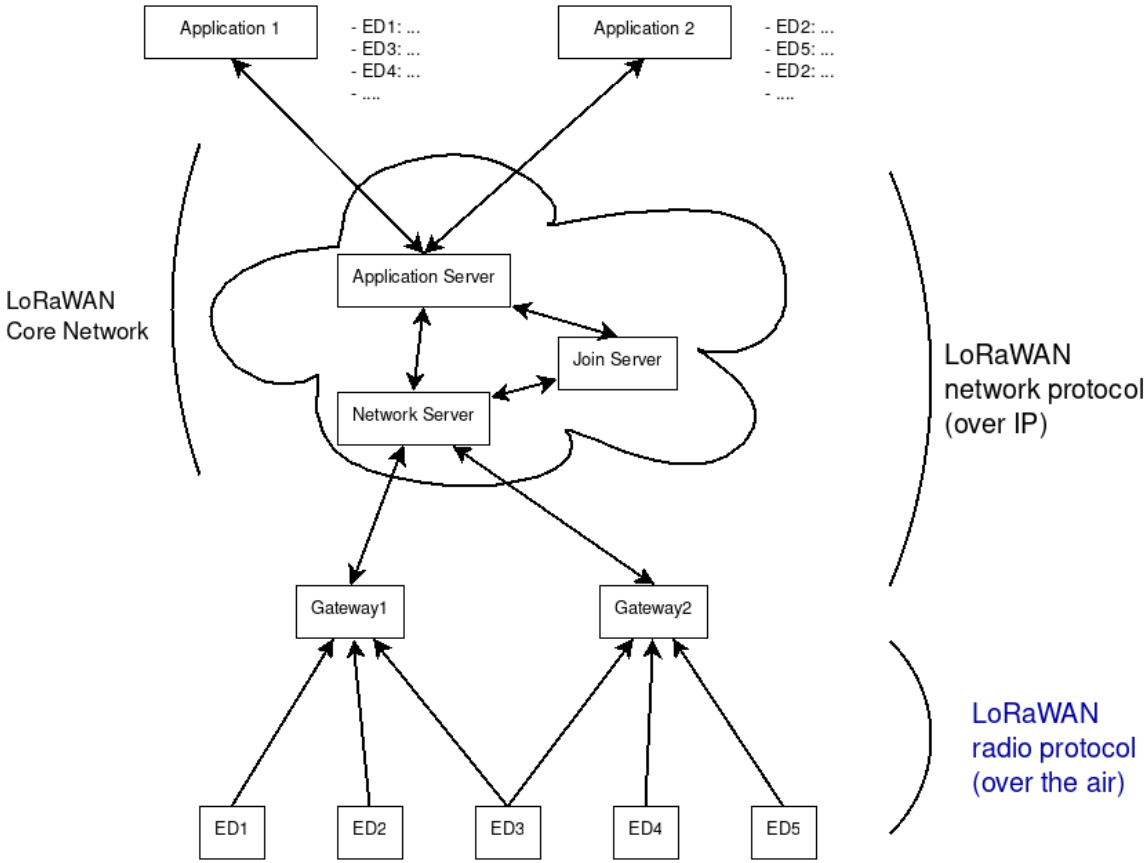
- LoRaWAN in 5 minutes
- Security-related Previous Work
- Working with LoRaWAN
- Experimental Setup
- Case study : Replay or decrypt
- Conclusion

1. LoRaWAN in 5 minutes

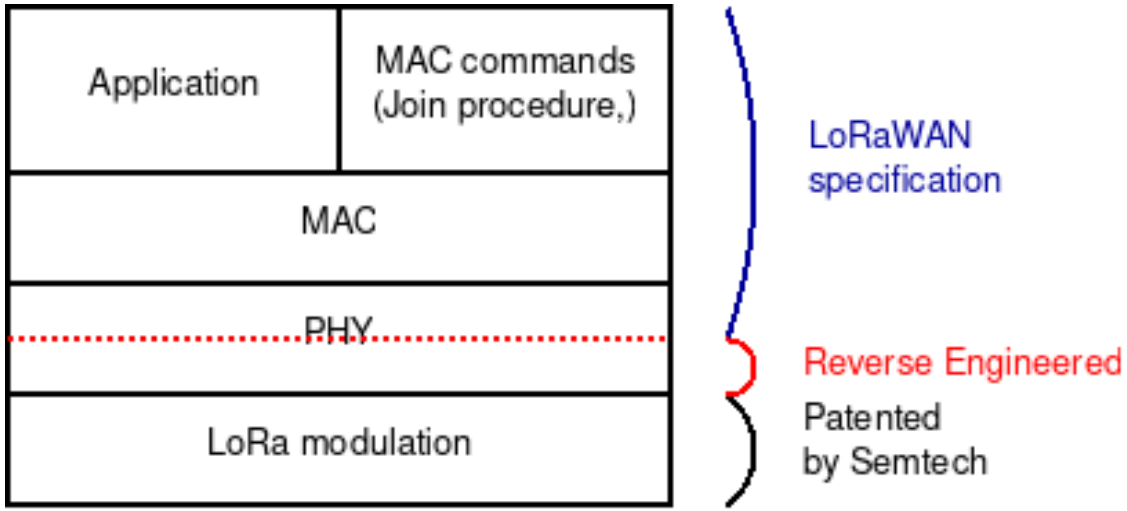
LoRaWAN : Introduction

- Part of the Low-Power Wide Area Network protocol family ;
- Open specifications, some existing open source implementations ;
- Mainly used for one-way communications : smart metering ;
- Developed and specified by the LoRa Alliance[2] ;
- Based on the LoRa (Long Range) modulation patented by Semtech ;
- Version 1.0 of the protocol in 2015, version 1.1 in 2017.

LoRaWAN : Architecture



LoRaWAN : Radio Protocol Stack



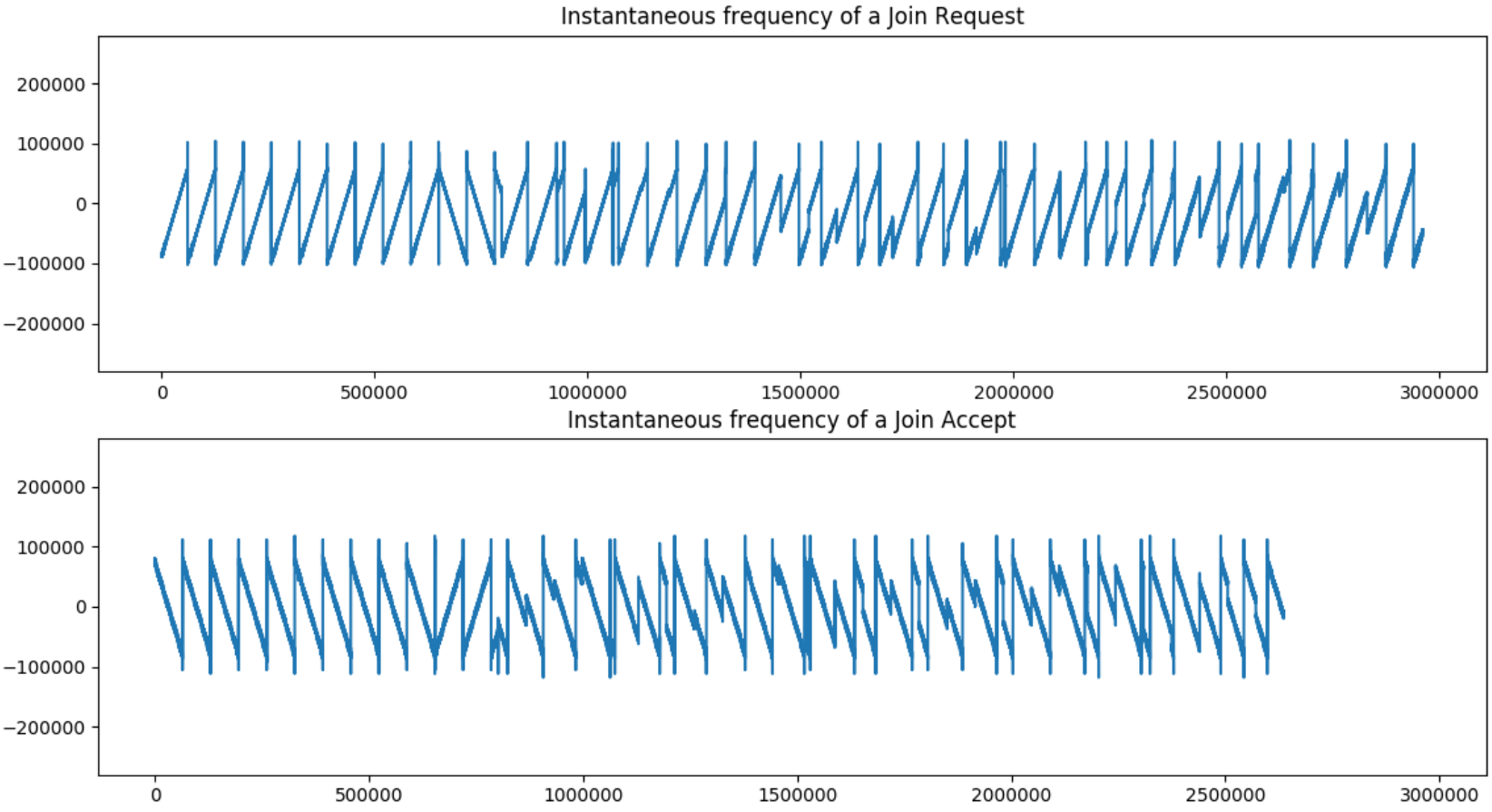
LoRa :

- Spreading factor : 7-12
- Bandwidth : 125, 250, 500kHz

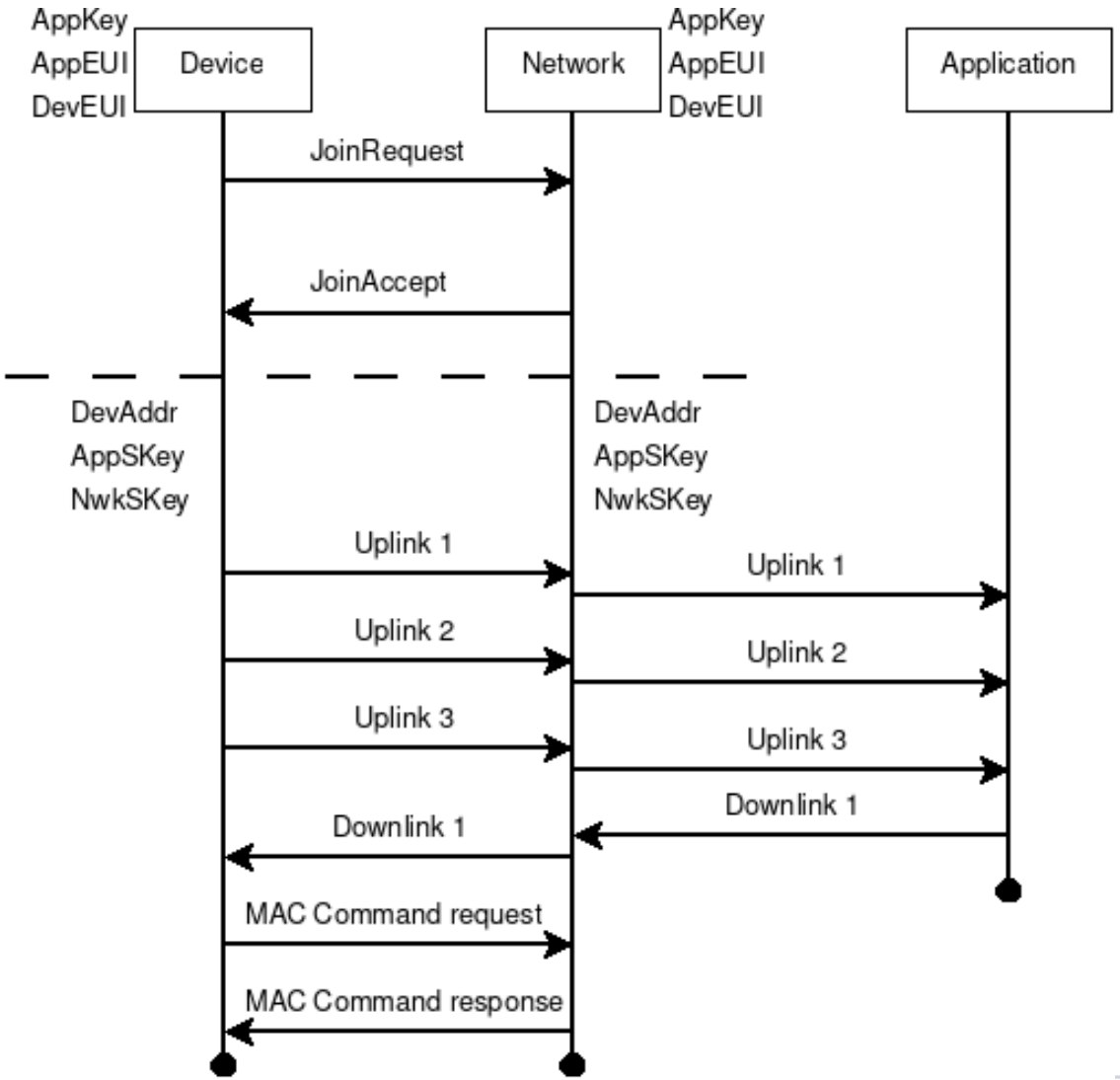
LoRaWAN radio :

- EU : 868/433MHz
- US : 915MHz

LoRaWAN : Uplink and Downlink



LoRaWAN : A complete session (1.0)



2. Security-related Previous Work

Previous Work

Subject	Involves radio	Tests mentioned
Desynchronisation between device and network[4, 17, 13, 10, 11]	yes	yes
Replay or decrypt[4]	yes	no
Gateways can be spoofed[11, 18]	yes	no
Formal analysis of the handshake[7]	yes	n/a
Jamming[3, 5]	yes	yes
Bias RNG using IEMI[17, 6]	yes	yes
Bitflip attacks[14, 9]	no	no

Previous Work : LoRaWAN radio testbenches

L'Hereec et Joulain[10]

- Able to sniff and replay
- Desynchronisation of devices
- Denial of service on the network

Lifschitz[11]

- Sniffing
- Packet dissection

Previous Work : Conclusion

- Lots of attacks involving radio proposed
- Very few practical implementations
- Results presented often lack details
- No information on the experimental setup

$\Rightarrow$ Previous work can't be reproduced and must be reimplemented.

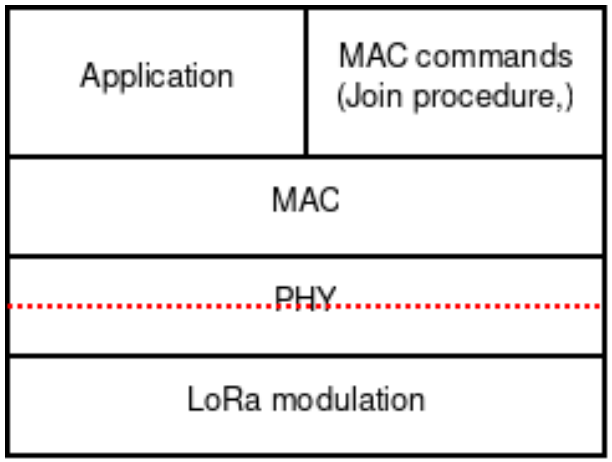
We need to build our own platform to properly study LoRaWAN security.

3. Working with LoRaWAN

Working with LoRaWAN : LoRa modulation

- Patented by Semtech
- Chirp spread spectrum
- Depends on two parameters : spreading factor and bandwidth (+ frequency)
- Modulation is open, coding is not

Working with LoRaWAN : Hardware modules



- LoRaWAN module = LoRa transceiver + LoRaWAN software implementation
- With a transceiver, complete control over MAC layer, configurable PHY layer
- Two kinds of transceivers : end devices (SX12xx) and gateways (SX13xx)

Working with LoRaWAN : Software Defined Radio

- Demodulation by Josh Blum (MyriadRF) [1]
- Reverse engineered by Matt Knight [16] then Pieter Robyns [8]
- $\Rightarrow$ Two gr-lora implementations

rpp0/gr-lora (Pieter Robyns)

- Only open source implementation which does demodulation + decoding
- One block per channel
- Uplink OR downlink for a single block

4. Experimental Setup

Experimental setup : Development kit

- One development kit from Microchip [12] (∼450€) :
  - One LoRaWAN gateway based on the SX1301
  - Two LoRa Mote based on the SX1276
  - A packaged core network
- A complete test network infrastructure
- Transmit arbitrary LoRa MAC frames whith Motes

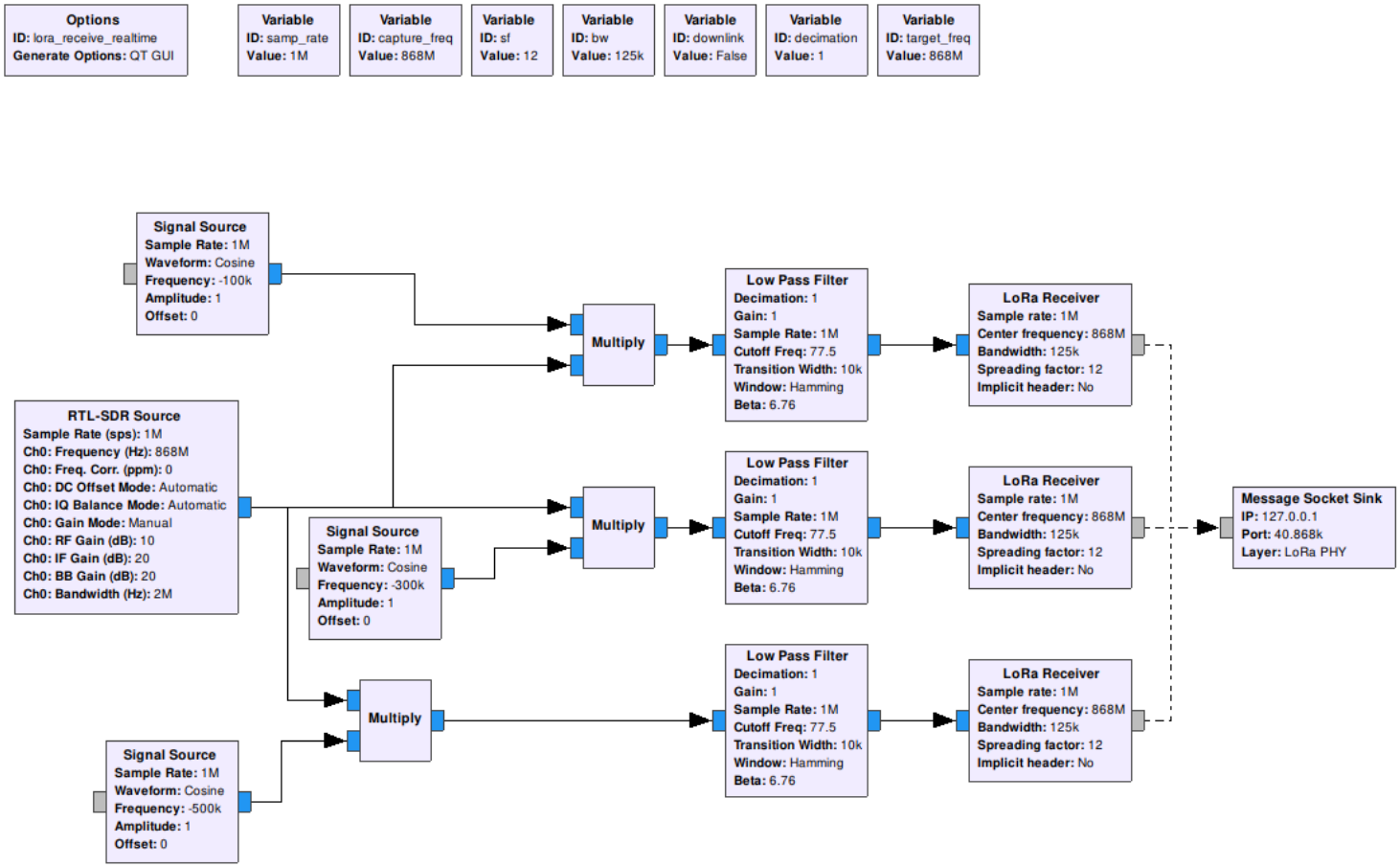
Experimental setup : FiPy

- One Fipy from Pycom [15] (∼50€) :
  - Multi-protocol development board
  - Micropython environment
  - Direct interaction with the LoRa/LoRaWAN module
- Program complex scenarios, starting at the LoRa MAC layer
- Can be turned into a single channel gateway

Experimental setup : RTL-SDR

- One RTL-SDR (∼30€) with GNUradio (gr-lora)
  - Capture signals for further processing
  - Real-time decoding of transmissions
  - Only RX
- gr-lora modified to allow listening uplink AND downlink with a single block
- Debug modules behavior through the waterfall
- Multi-channel decoder

Example : Sniffer (multi-channel decoder) with GNUradio



5. Case study : Replay or decrypt

Replay or decrypt attack : outline

- Published by Avoine/Ferreira [4]
- Partially decrypt some messages, allows replaying others
- No mention of any practical implementation
- Lots of precisions in the paper
- Patched in LoRaWAN 1.1

Replay or decrypt attack : Presentation

- Application layer messages are protected using AES-CCM
- Security of AES-CCM relies on unicity of the security parameters [a]
- Basic idea : force nonce reuse in a JoinRequest/JoinAccept
- => Security parameters ($\sim$ keystream) will be reused

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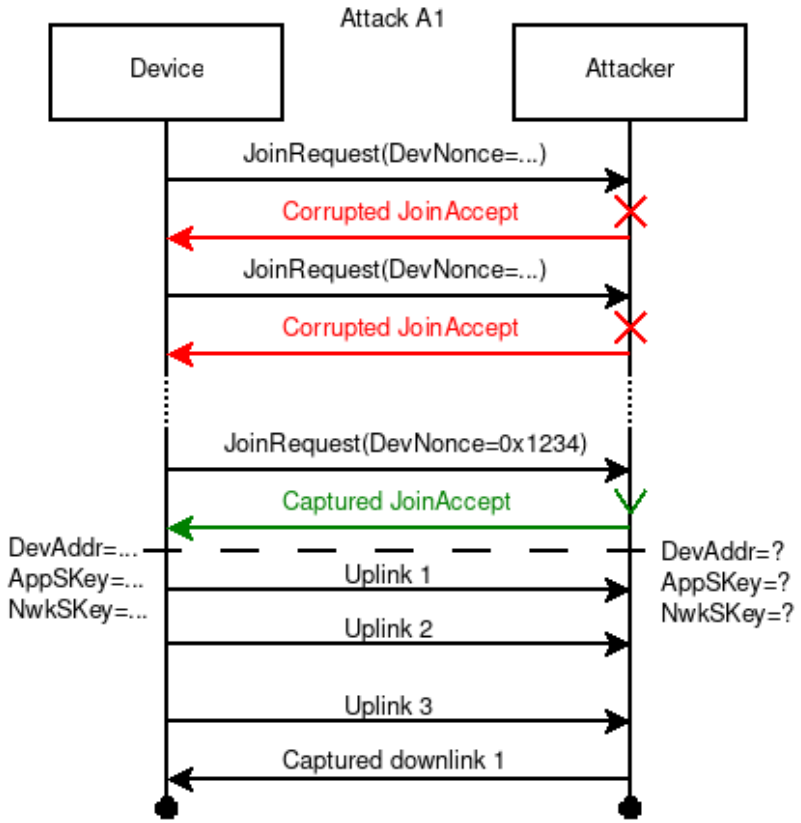
a. **More specifically, on the unicity of the tuple (session key, counter block, B_0)**

Replay or decrypt attack : Impact

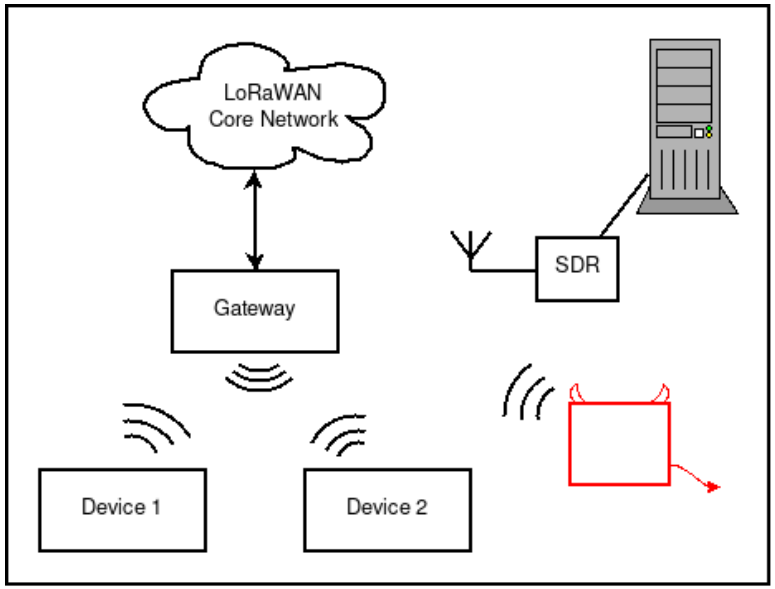
- Two-time pad on messages encrypted under the same keystream
- $c1 \oplus c2 = (m1 \oplus kstr) \oplus (m2 \oplus kstr) = m1 \oplus m2$
- For end device : allows partial decryption of uplink messages and replay of downlink messages (A1)
- For core network : allows partial decryption of downlink messages and replay of uplink messages (A2)

Replay or decrypt attack : Scenario

Captured a complete session:	- JoinRequest(DevNonce=0x1234) - JoinAccept(AppNonce=0x123456)	- Uplink messages - Downlink messages



Replay or decrypt attack : Implementation of A1



- Implemented with the FiPy in about 100 lines of MicroPython
- A first try involved SDR + LoRa Mote, but synchronisation was off.

Replay or decrypt attack : Results

- Took several days to complete, with one join attempt every 10 seconds
- $\Rightarrow$ Matches theoretical expectations
- Instead of actively jamming the JoinAccept, we powered off the fake gateway
- Attack A2 would take longer

Final thoughts : LoRaWAN modules notes/quirks

- LoRa Mote : After one emission, sets frequency to 869.525MHz
- FiPy : LoRaWAN module tends to crash silently
- FiPy : Joining a network tries indefinitely in the background
- LoRa Mote : Joining a network tries once
- LoRa Mote : Receive/Transmit downlink frames with 'iqi' parameter
- FiPy : Receive/Transmit downlink frames with rx_iq/tx_iq

6. Conclusion

Conclusion

Summary

- Up-to-date state of the art about LoRaWAN security
- Described a complete testbench
- Reproducible setup

Results

- Debug the odd behaviors of LoRaWAN stacks
- Easy to use and efficient, even with complex scenarios
- Combination of SDR and hardware proved very useful

Perspectives

- Optimise SDR decoding to enable precise sync
- Experiment with Intentional Electromagnetic Interferences
- Develop detection system
- Develop and share test vectors
- Study commercial devices

Questions

Thanks for listening !

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