LoRaWAN networks for the air quality monitoring with low-cost sensors

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Context: Air pollution

Clean air Vs polluted air Shanghai [5]

- Triggering diabetes in 3.2 million people each year [1]
- 600 000 deaths of children under 5 years per year [2]
- 500 000 deaths per year in Europe [3]
- 100 Billion € of annual cost in France [4]

[1] source: sciencenews.org, 2018

[2] source: WHO, 2018

[3] source : European Environment Agency, 2017

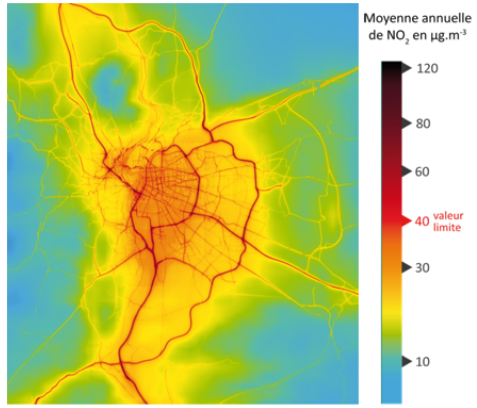
[4] source : French Senate, 2015

[5] http://www.shanghai.gov.cn

Context: Low cost wireless sensor networks

Traditional monitoring stations
Paris (France)
High Accuracy
High cost, low granularity

Air quality low-cost sensor
Tiny, low cost & High spatial/temporal granularity
Low installation & operational cost
Less accurate
Regular calibration



NO_2 annual concentrations , 2012
*Lyon, France (Source **ATMO-AuRA**)*
High Granularity
Low accuracy

Low cost WSN for air quality: Multiple use cases

UrPolSens (IMU,2015-2018)

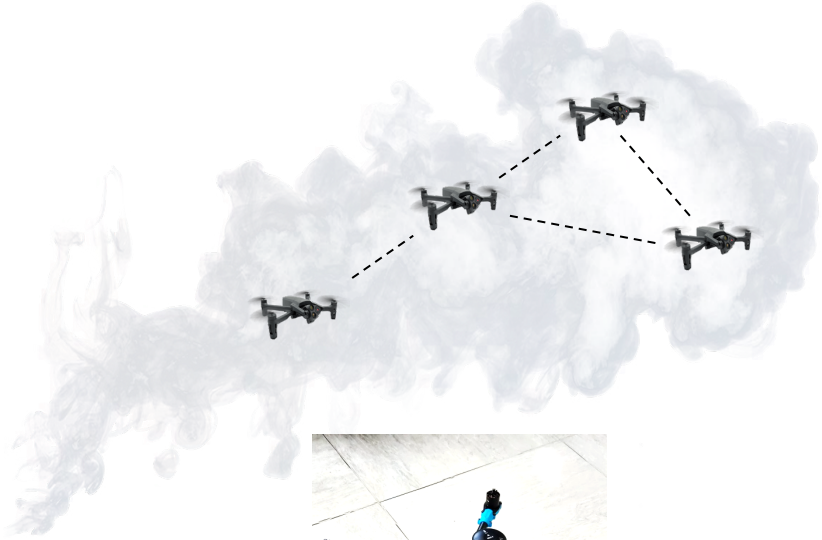
CaptPolAir (PEPS,2016)

Illustration by Malou ALLAGNAT, Grand Lyon ,member of 3M'Air

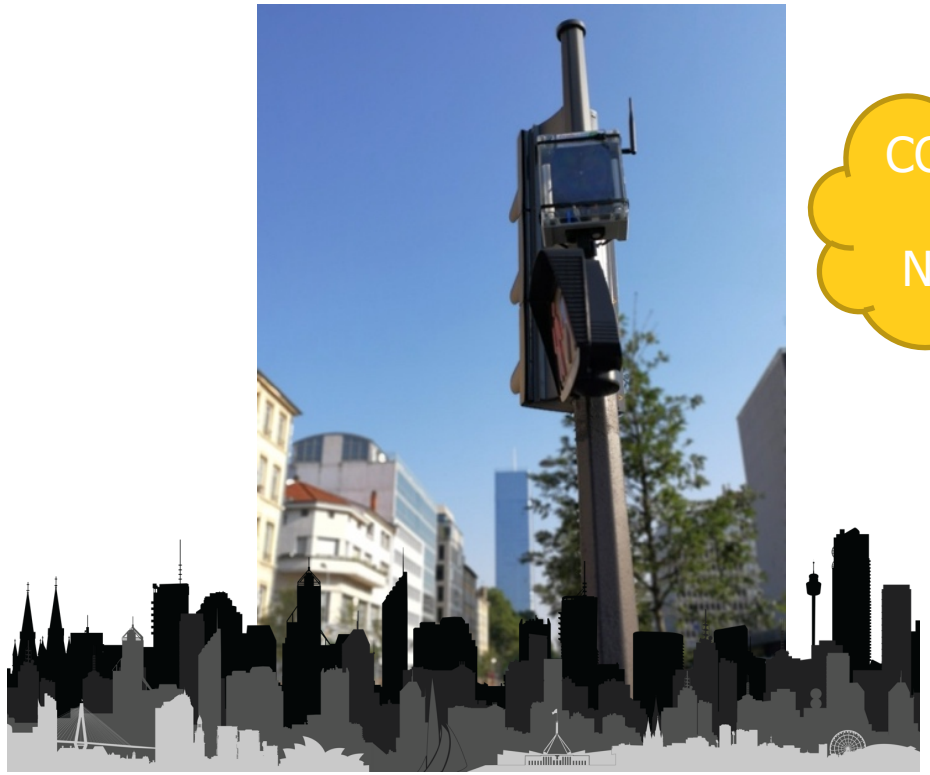
3M'Air sensor node

3M'Air (IMU,2018-2022)

DRON-MAP (ANR,2021-2025)



Our use case: static low cost sensors



Urban

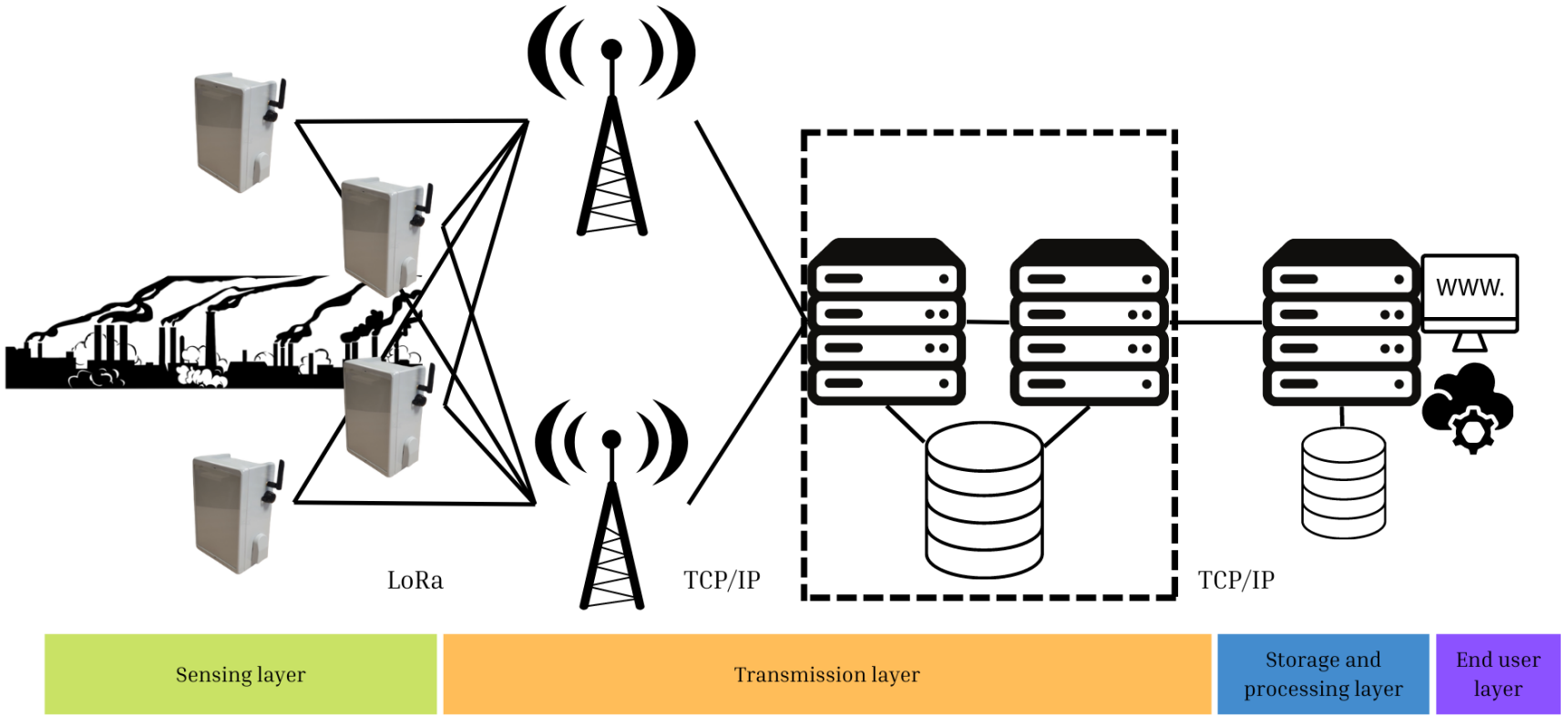
CO2, H2S,
COV,
NO2, PM

Industrial
Onshore + offshore

Outline

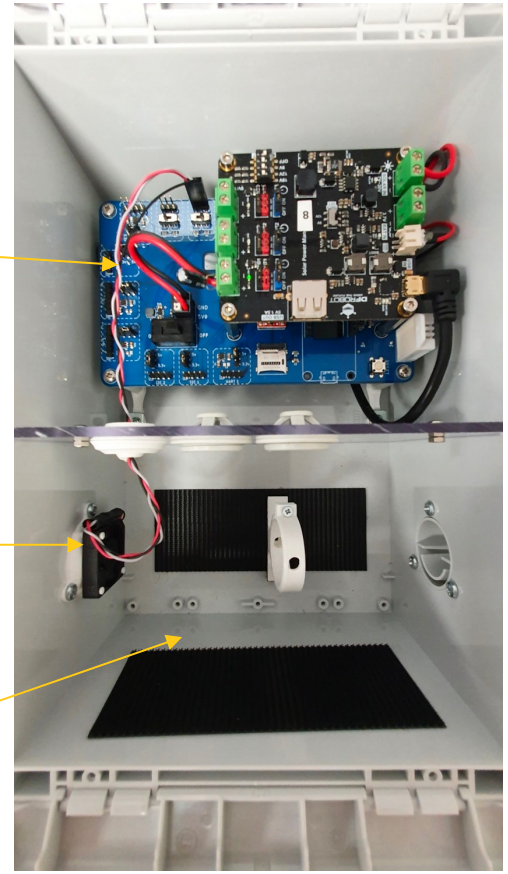
1. Context
2. Big picture
3. Sensor node: design and optimization
4. Data collection: LoRaWAN
    1. Private network (for offshore deployment)
    2. Operated network (for onshore deployment)
5. Results and feedback

2. Big picture



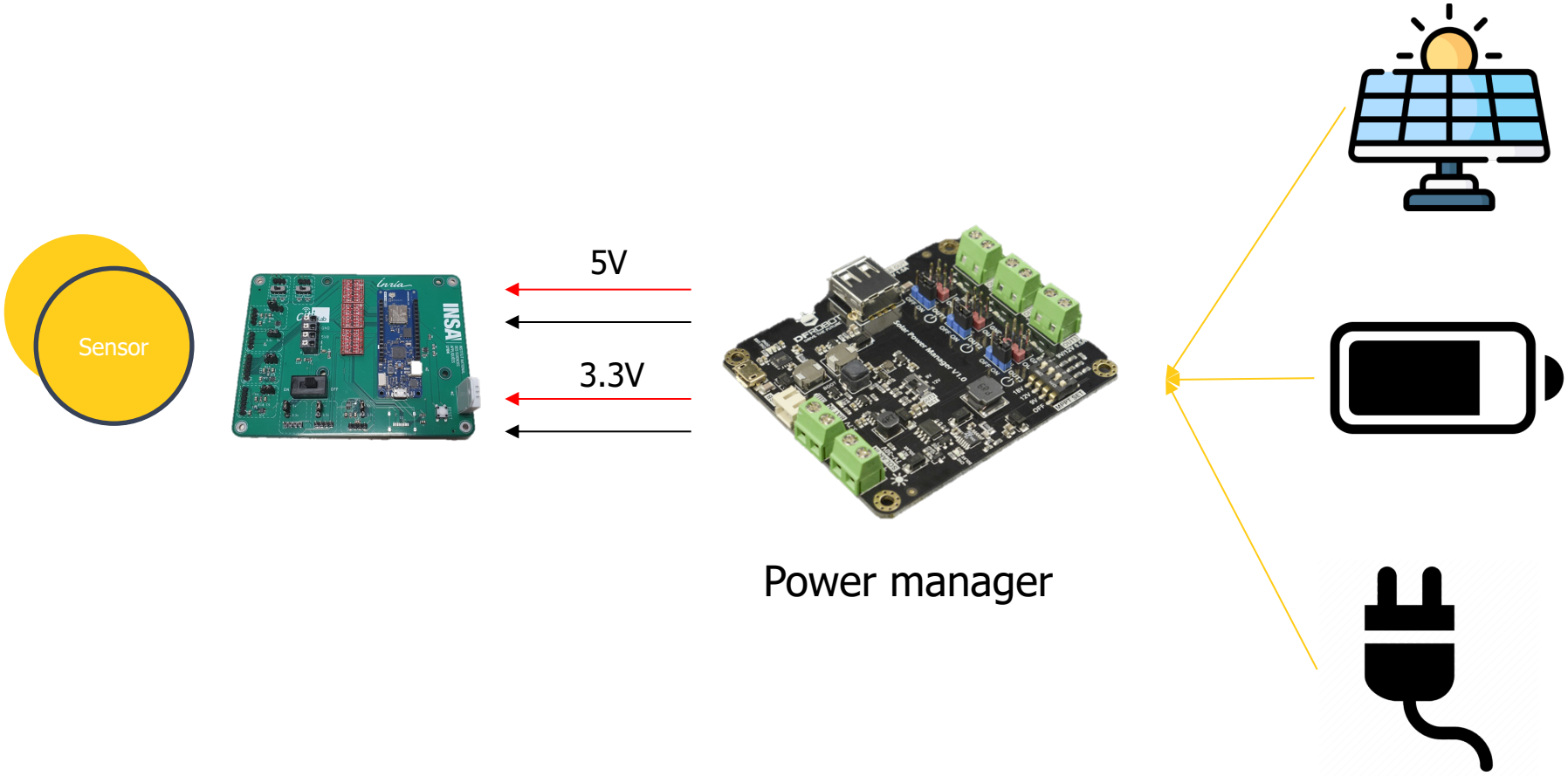
3. Sensor node: design and optimization

- Connect the sensor to the internet (sensor abstraction)
- UART, I2C, SPI, Digital, Analog
- Arduino MKRWAN 1310
- LoRaWAN class A device
- Low consumption on IDLE
- Measure & transmission time customizable
- EEPROM + SD storage



Picture of the node's interior

3. Sensor node: design and optimization

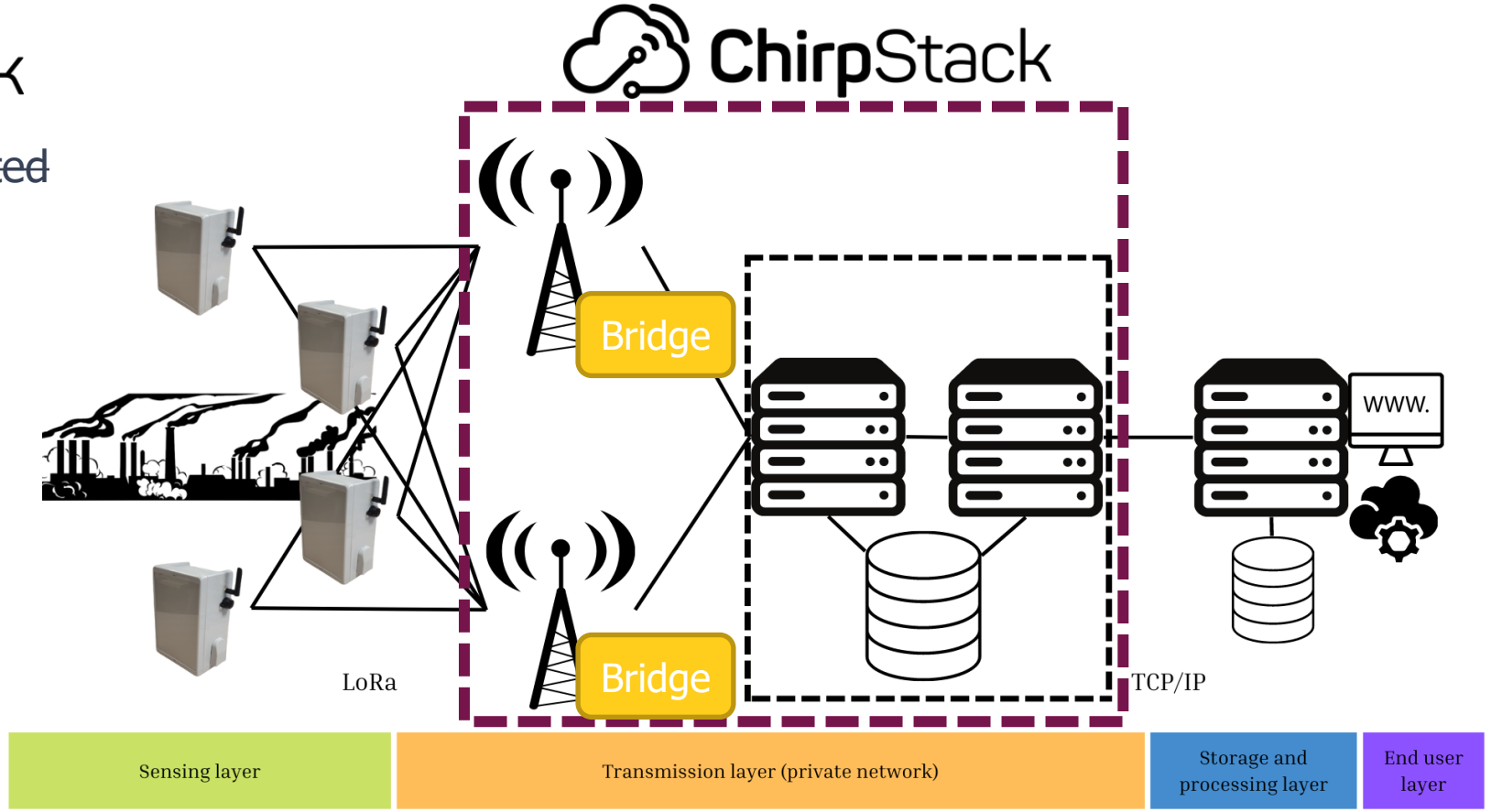


4.1 Data collection: LoRaWAN Private network offshore

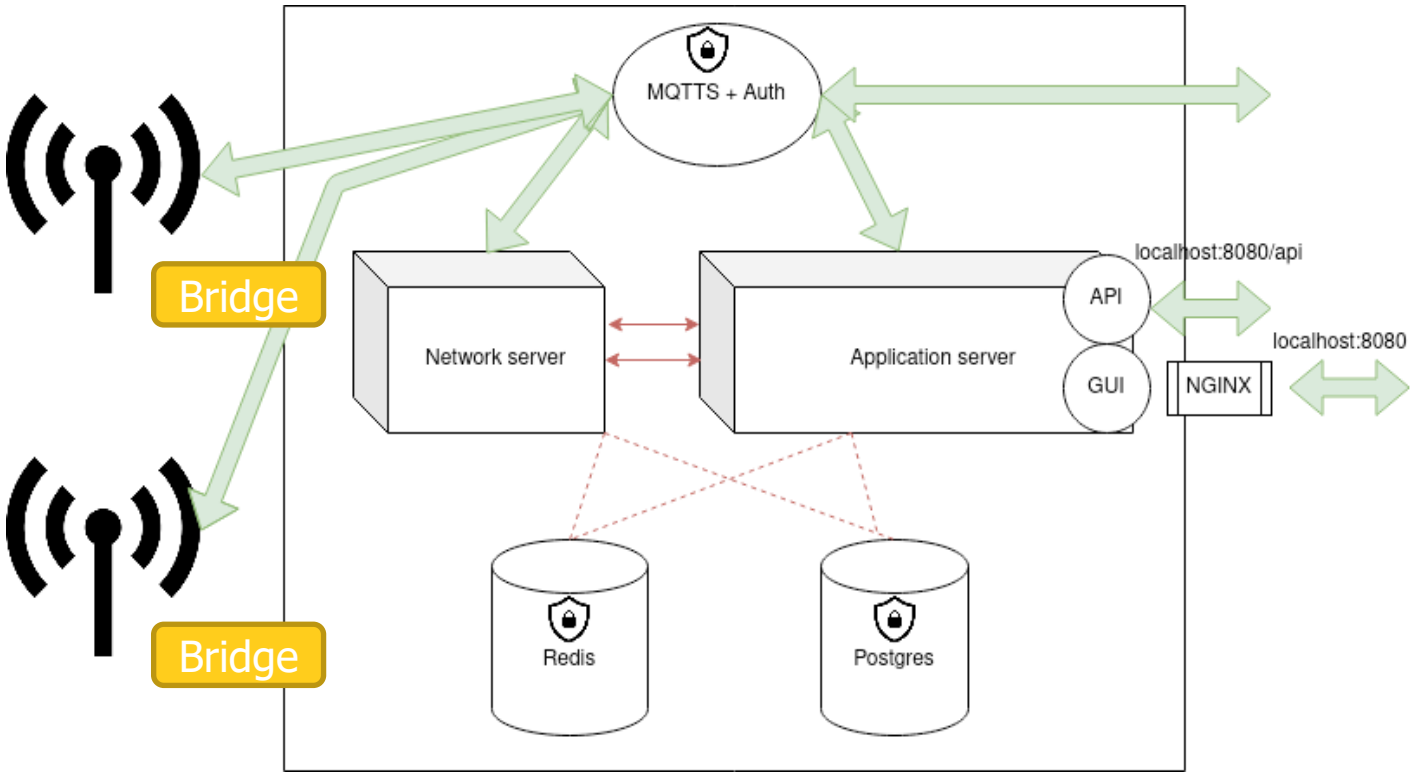
ChirpStack

- Offshore ➔ ~~operated network~~

- Open-source
- Self-hosted
- Free
- Reliable
- Customizable
  - ADR



4.1 Data collection: LoRaWAN Private network offshore

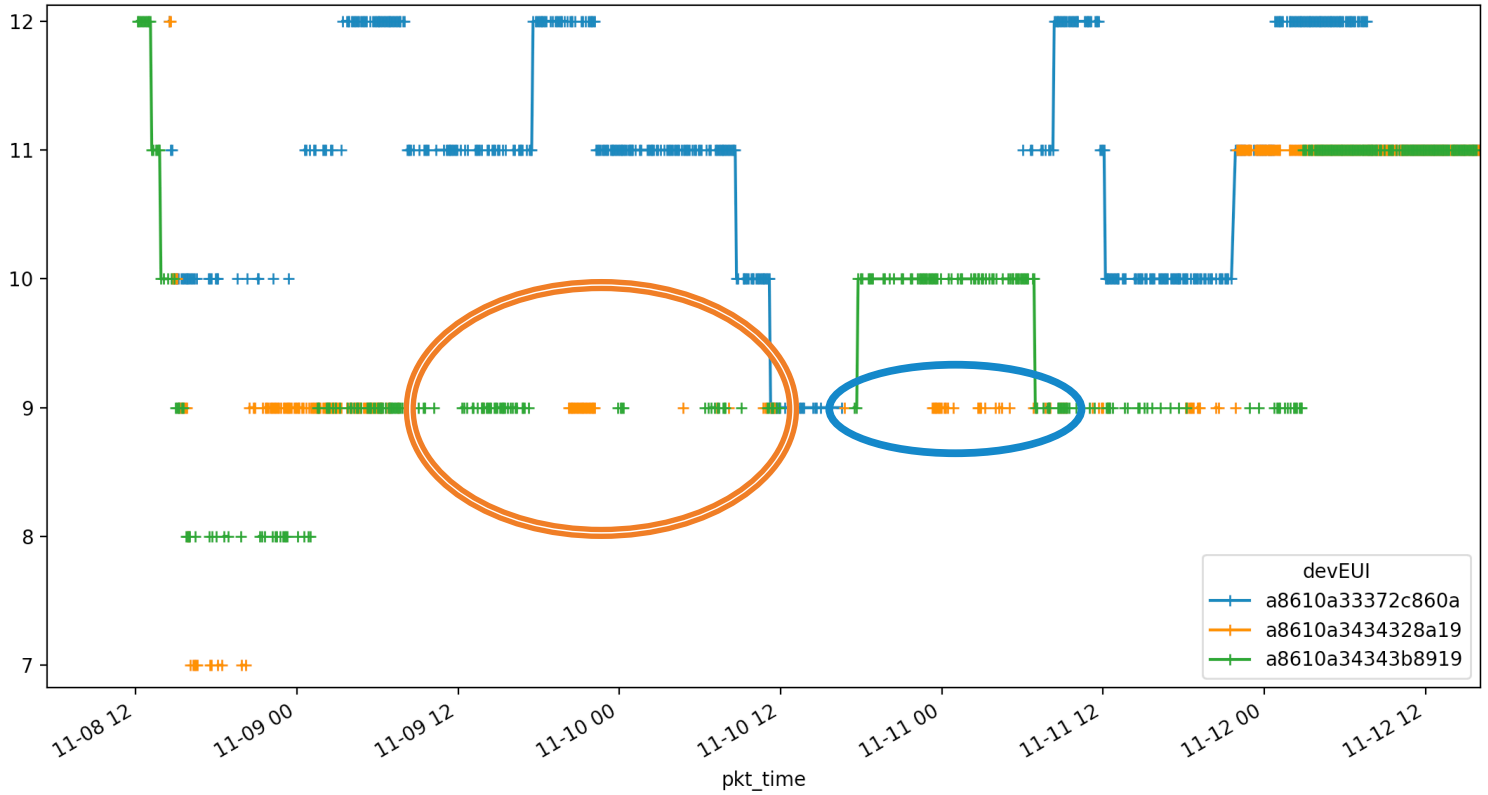


Software architecture of the private LoRaWAN network

- Onshore server
- Security
- GUI

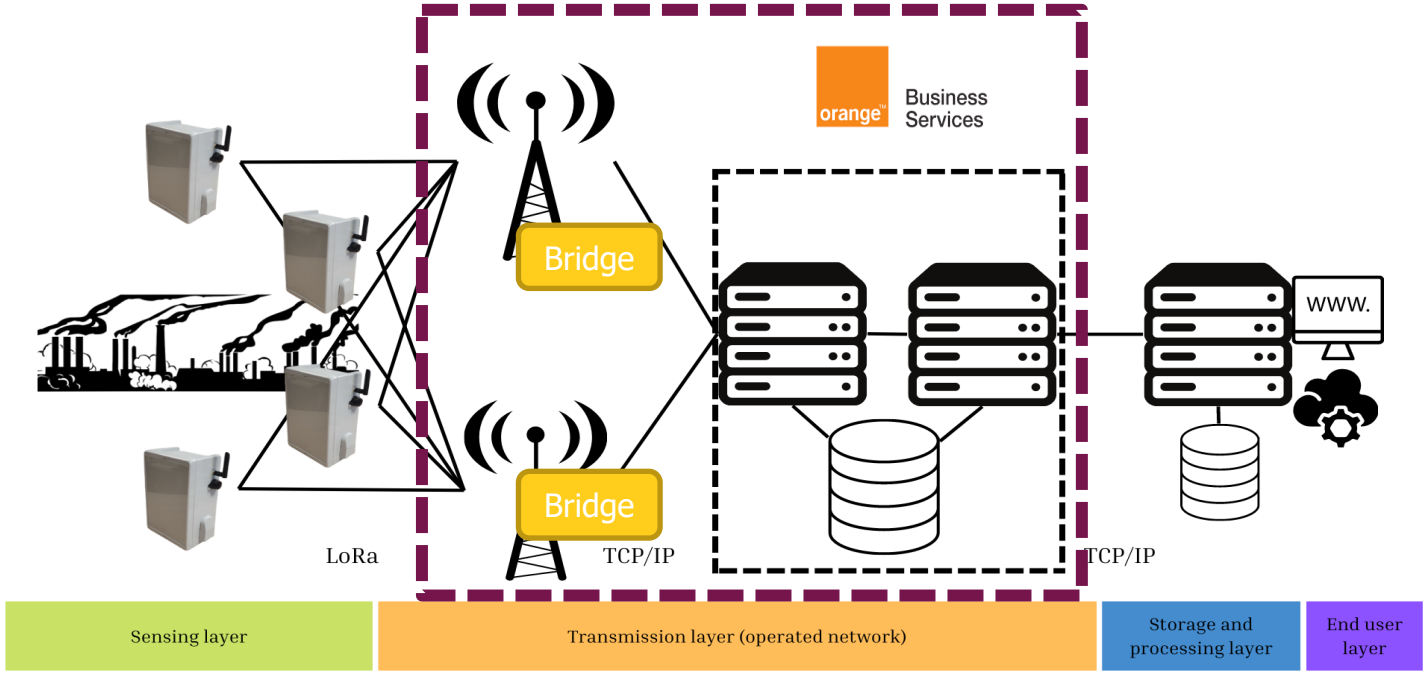
4.1 Data collection: LoRaWAN Private network

- Fixed deploy ➔ ADR
- Offshore
  - Variability
  - Metallic structure
- X hours (SF7) ➔ Y hours
  - No ACK ➔ 64 * x TX
- "Mobility like" ➔ Fixed SF (11)



Plot of the different node's SF with ADR enabled

4.2 Data collection: LoRaWAN operated network

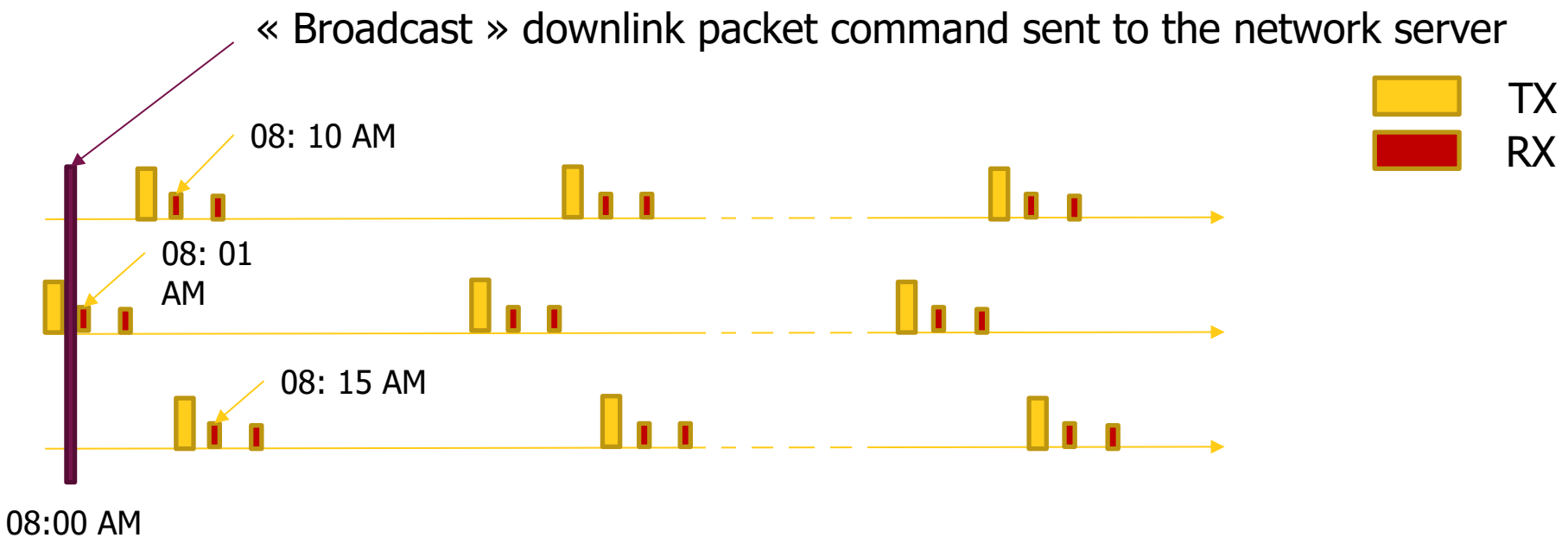


1. **Time synchronization issue**
2. **Remote configuration**

4.2 Data collection: LoRaWAN operated network onshore

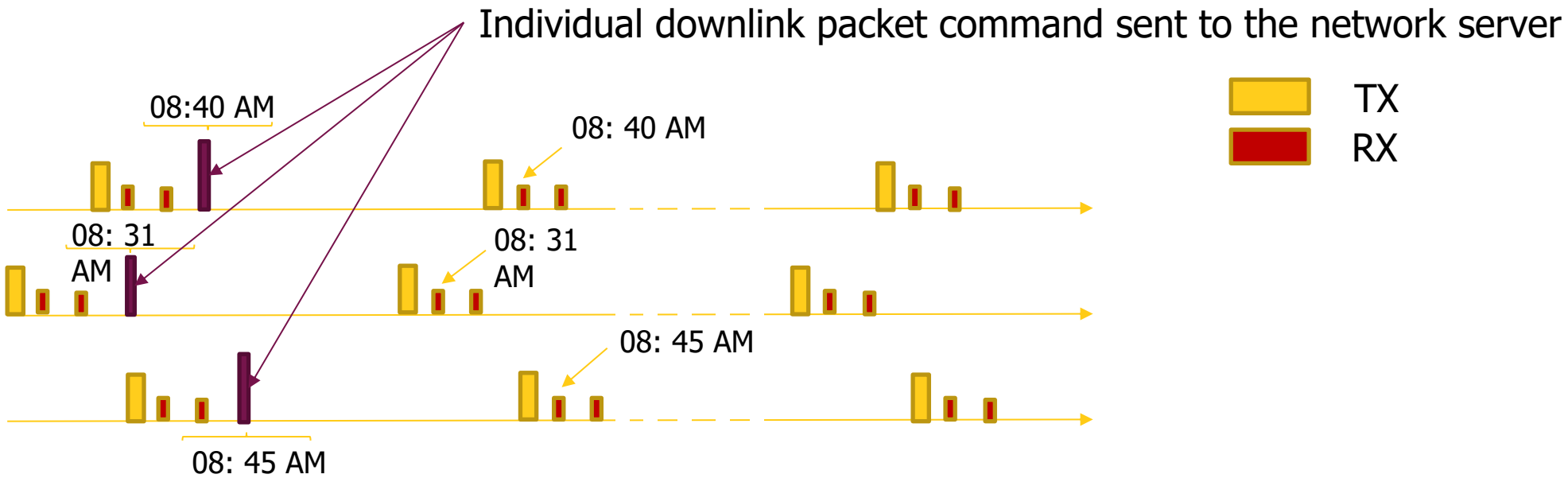
- All means saved to the SD card
- Internal oscillator drift ➔ Not reliable for time and date
- RX slot timing vary from device to another
- Time gap can be equal to TX or more

4.2 Data collection: LoRaWAN operated network



Chronogram of the TX, RX slots and the command with the « blind » time and date sender enabled

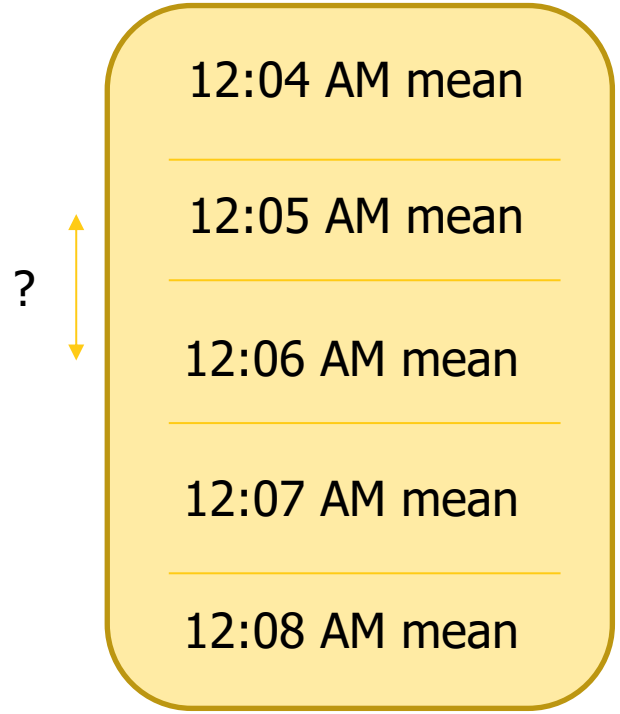
4.2 Data collection: LoRaWAN operated network



Chronogram of the TX, RX slots and the command with the improved time and date sender enabled

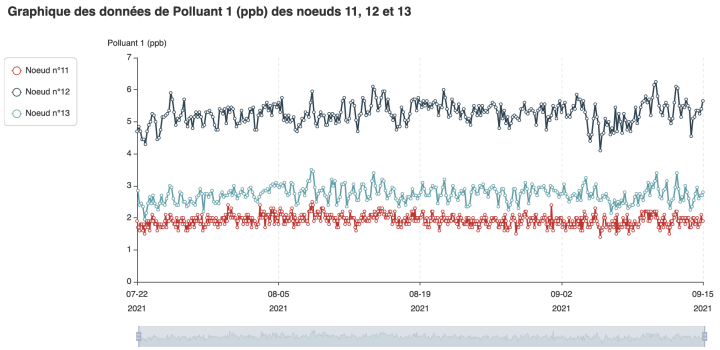
4.2 Data collection: LoRaWAN operated network

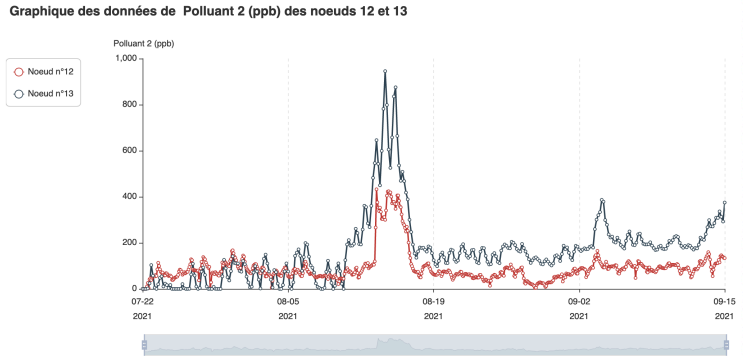
- Measuring, averaging & transmission frequency ➔ Flexible
- 1 Packet = X means (typ. 5)
  - Time gap between each mean ? (may vary)
- Gap needed for packet decoding
- ➔ Every distant setting change => node acquits sending the snapshot of current settings => Server actualizes the settings



12:08 AM packet data section

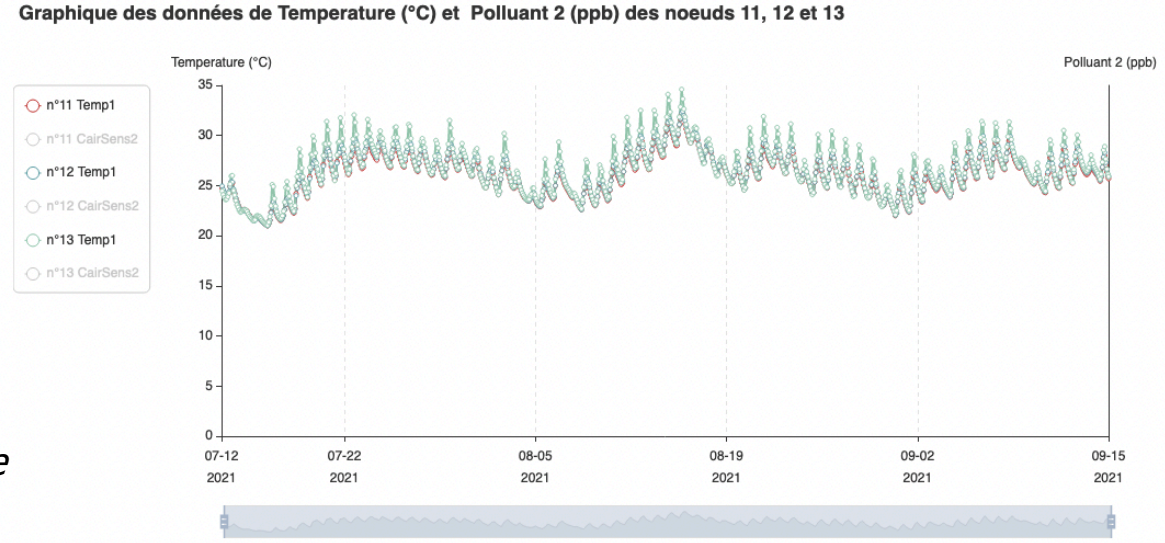
5. Results





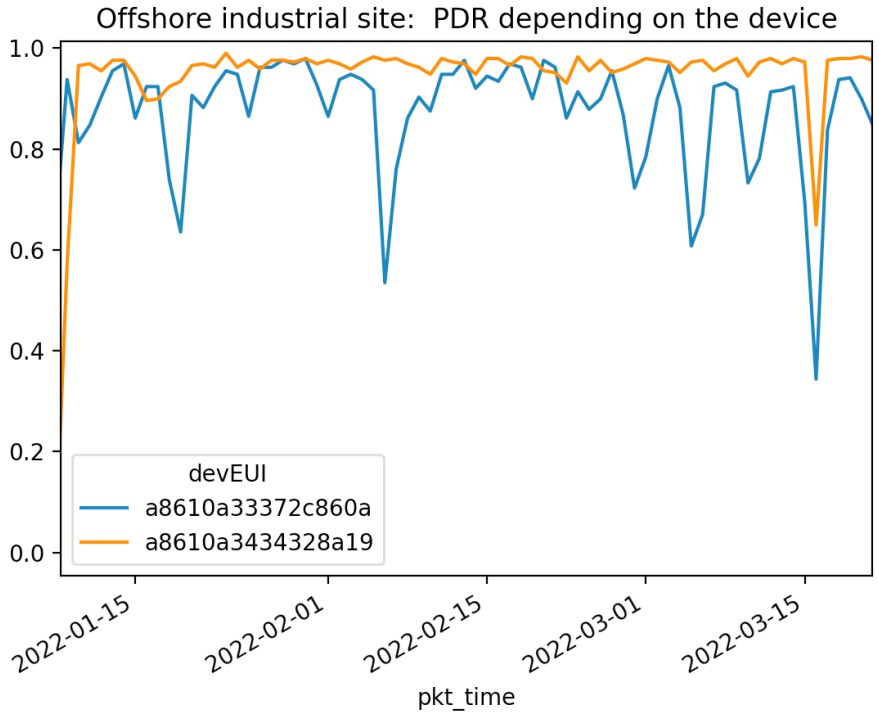
Plot of various air quality sensors' data (ppb) installed in the three nodes from July 2021 to September 2021

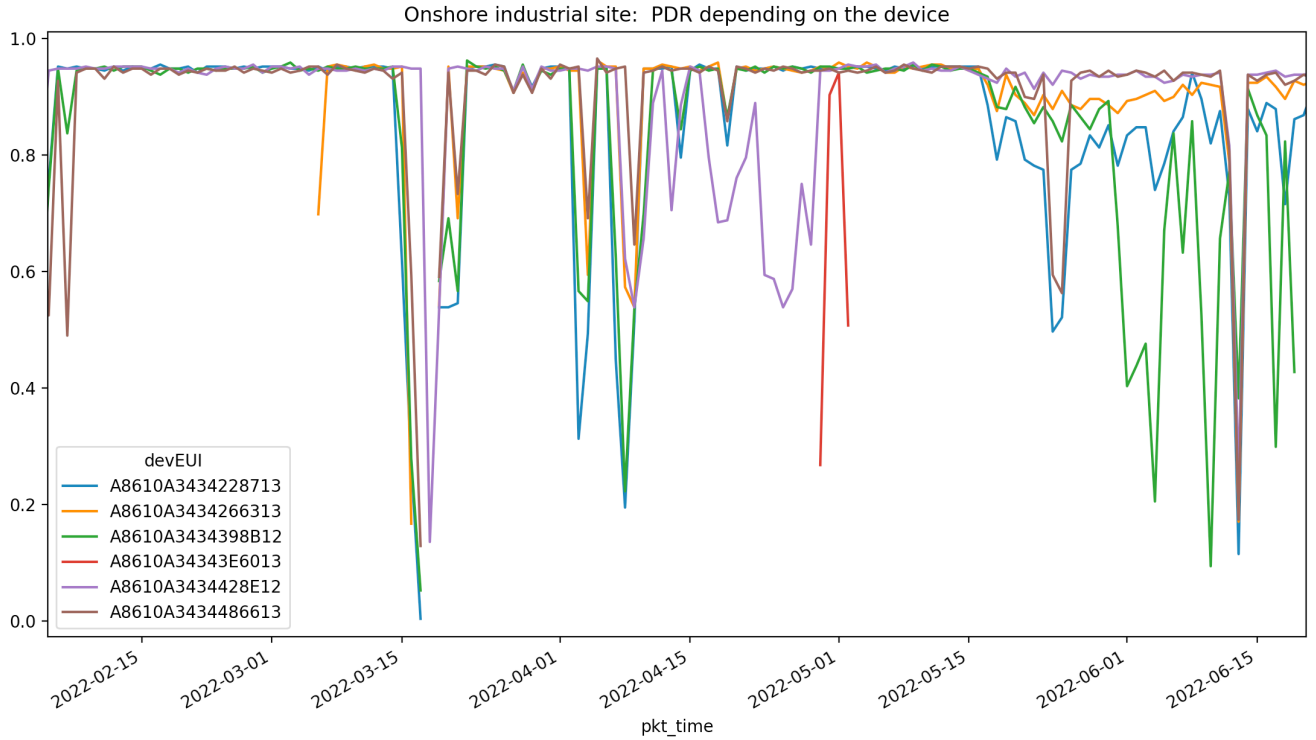
Plot of the temperature sensed by the three nodes from July 2021 to September 2021



5. Results

~~Retransmission~~ => Applicative needs(1% SF12)





5. Conclusion

- Emergence of solution based low-cost sensors
- Multiple use cases
- LoRaWAN suitable for industrial purposes
- ADR offshore
- Deployment on private & operated

5. Perspectives

- Industrial valorization
  - Success of two deployments
  - Genericity ➔ More use cases
- Chronic (fixed) ➔ Punctual (mobile)
  - DRON-MAP
    - Communication & coordination

Merci

Questions ?

INSA INSTITUT NATIONAL DES SCIENCES APPLIQUÉES LYON

Inria inventeurs du monde numérique