



# EXpLoRa

**EXperimenting with LoRa products  
across realistic environments**

Stratos Keranidis, PhD



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*Stage 1 Experiment Review*

# EXpLoRa



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Experiment Description



**EXpLoRa**

# Concept and objectives

LoRa has gained significant momentum among industrial and research communities.

Market penetration of is increasing, with several solutions entering the energy metering and management domain.

However, LoRa's performance under realistic conditions and real-life scenarios has not been investigated in detail.

In domX SME, we develop custom IoT monitoring solutions for energy metering applications and consider the adoption of LoRa-based solutions within the company's product line.

In the EXpLoRa experiment, we aim to systematically characterize the potential of LoRa to cover the company's needs, by considering both market available and proprietary LoRa products under development.

# Background and motivation

Our existing solutions currently employ the Wi-Fi technology and rely on end-users to connect company modules through their own Wi-Fi routers for enabling connectivity with the management platform.

We consider LoRa as a candidate technology, able to:

- remove the connectivity burden from the end-user
- provide a common Internet GW for several meters-controllers installed within the same or collocated buildings.

The target environment is quite complex:

- city-wide metering
- cross-floor communication
- high interference

We need to compile a detailed performance analysis of candidate LoRa solutions under realistic conditions as close as possible to the targeted energy metering environment.

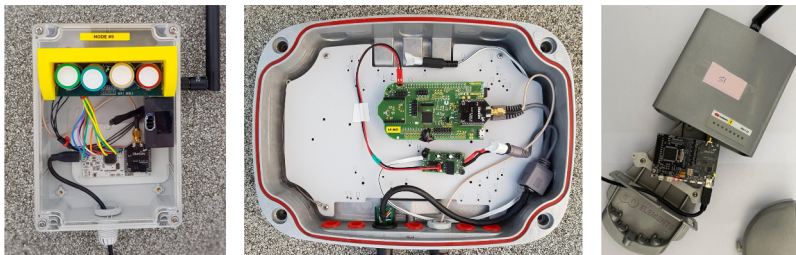
# Experiment set-up

## LoRa devices

- 10 NITOS LoRa end nodes
- 2 Libelium LoRa Wasmotes
- 1 NITOS LoRa GW
- 1 NITOS LoRa Monitor

## LoRa Experimental Settings

- 10 LoRa Transmission modes
  - BW, SF, Data Rate
- 8 channels (862.5 - 868 MHz)
- 3 TX Power levels
  - 0,7,14 dBm
- Varying payload (10-250B)



NITOS LoRa end node, GW and Libelium devices



NITOS LoRa testbed topology

Project Results



**EXpLoRa**

# Measurements

We used the NITOS Link quality evaluation framework to collect and analyze the following **key parameters**:

- Duty Cycle (from Monitor node)
- PDR per link and TX power
- PDR per TX Mode
- PDR vs RSSI

## Performance Analysis

- >100K LoRa packets
- RSSI range: -102 to -137 dBm

## Web dashboard





# Measurements



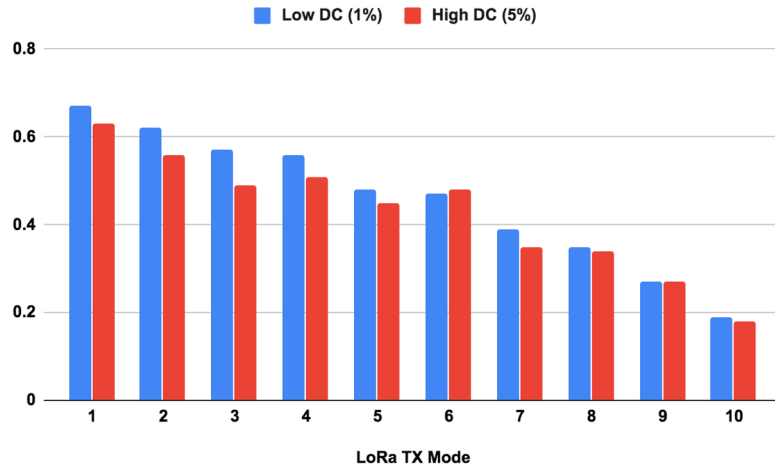
## LoRa sensitivity

Transmission Mode	Experimental Sensitivity (dBm)	Protocol Sensitivity (dBm)
1	-134	-137
2	-132	-135
3	-131	-133
4	-129	-129
5	-131	-130
6	-128	-128
7	-126	-128
8	-123	-122
9	-120	-119
10	-116	-116

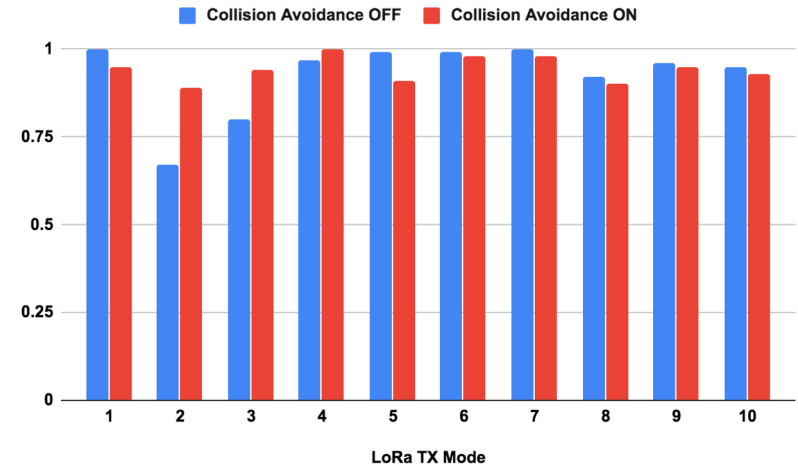


# Measurements

## PDR vs channel utilization



## PDR vs interference



# Lessons learned

Through the EXpLoRa experiment, we managed to:

- familiarize with the LoRa technology
- familiarize with NITOS LoRa testbed and experimentation tools
- collect a first set of experimental data under realistic city-scale and varying channel conditions (range of ~35 dB, LOS/ NLOS)
- analyze performance based on key metrics (PDR, DC, RSSI)

## Key findings:

- protocol sensitivity exceeded the performance potential described in specification sheets
- minimal channel interference across different SFs
- LoRa can offer sufficient PDR even at low RSSI conditions (-137 dBm)
- LoRa can support city-scale monitoring applications, even with a single GW for rooftop links

Business Impact



**EXpLoRa**

# Business Impact

- The first set of experiments was a remarkable learning experience for domX members
  - technology and testbed familiarization
  - fast data collection and analysis
- Our initial findings suggest that LoRa can support city-scale monitoring and control applications, by achieving sufficient PDR even at low RSSI conditions.

## Further experiments

- Need to experiment under typical energy metering setups:
- representative payload and metering intervals
  - communication across multiple floors
  - intra and inter building LoRa links
  - LoRa-based power metering equipment

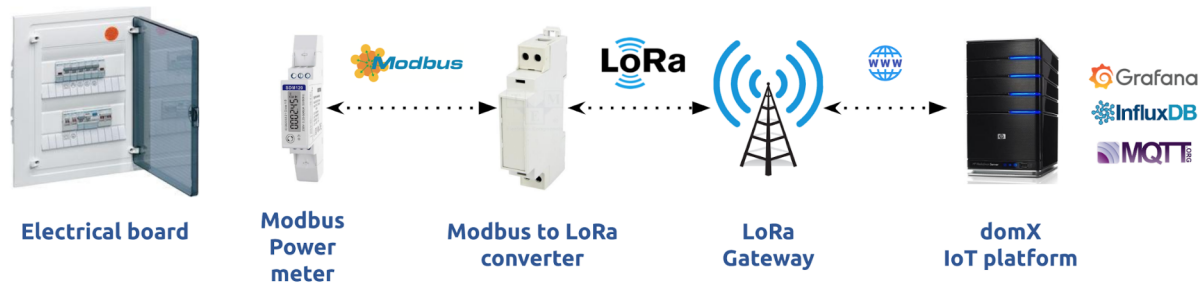
# Business Impact

## Prototype development

Through EXpLoRa and the great support of NITOS, we developed a prototype Modbus to LoRa converter that is able to interface with Modbus Energy meters.

## Motivation

Integrate the developed prototype with the NITOS LoRa GW and experimentation platform, so as to promote the prototype into a product.



# Value perceived



DomX perceived significant value from EXpLoRa:

- **gained knowledge on experimenting with the prevailing LoRa technology** of LoRa, by employing a wide set of city deployed devices and easy to use testbed tools
- **came up with new ideas for advanced LoRa experiments** that will take place through a Stage-2 experiment
- **came up with new ideas for product development** through the support of our patron that motivated us to develop our own LoRa solution, towards overcoming the vendor lock-ins and other restrictions that are commonly experienced with market available products
- **actually developed a LoRa prototype**, taking the first step towards adding the LoRa wireless protocol in the list of compatible technologies, which step has the potential to bring a significant advantage to the company.



# Value perceived



The direct value of EXpLoRa for domX will be vast:

- **introduction and commercialization of a new product line and relevant services**, starting with a LoRa to Modbus converter for sampling energy meters and actuating on compatible devices (heatpumps, ACs, etc.)
- **added value to the company's existing customers and attraction of new customers** with the newly introduced solutions that will be able to cover more demanding applications like city-wide energy metering and device control
- **development of advanced and innovative energy services and business models** (e.g. charging of network access through annual subscriptions) for key energy stakeholders (suppliers, aggregators, installation-service companies), given that the new LoRa-based device will not rely on end users to connect it with the home router for Internet connectivity, but will operate through a standalone communication network



Feedback



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# Feedback



## Testbed resources

EXpLoRa employed only NITOS testbed resources and specifically the NITOS LoRa testbed platform:

- fully exploited the set of reserved resources.
- constantly online and remotely accessible
- minimal time to set up and run the experiment

## Testbed tools

LoRa link quality evaluation framework:

- user friendly and straightforward
- experimenter needs to load the settings for the planned scenario
- transparent data collection
- SQL like queries for data analysis



# Feedback



## Experiment environment

1. realistic city-scale LoRa setup (range of ~35 dB, LOS/ NLOS)
1. 10 configurable LoRa nodes
2. 2 LoRa nodes with customizable firmware
3. varying channel conditions  
DC: 1-5%
1. LoRa Monitor node, for evaluating the impact of external parameters (interference, etc.) on the experiment outcomes.

## Experiment execution

1. The collected results exceeded the initial expectations (LoRa performance exceeded nominal potential)
2. Online documentation was minimal and can be improved
3. Great collaboration and support by NITOS testbed team



# Added value of Fed4FIRE+



## Usefulness

1. The Fed4FIRE+ offered experimentation platforms and tools are a great asset and perfectly match the company's experimentation needs.
1. The deployment of relevant resources by domX would not be affordable. In addition, the ability to financially support the execution of experiments is quite important especially for micro-SMEs like domX, which do not have the ability to finance R&D activities with their own funds.

## Key offerings

1. Availability of testbed resources
2. Realistic experimentation conditions
3. Availability of experimentation tools
4. Continuous remote testbed availability
5. Technical support by expert people
6. Easy setup of experiments

# Directions for improvement

## Data visualization

Connection of the DB with some visualization tool, such as Grafana to aid experimenters in LoRa performance analysis and comparison across multiple parameters (Link, TX mode, TX power, RSSI, PDR, etc.)

## Testbed link visualization

Real-time map visualization of the status and performance of all LoRa links, so as to aid experimenters in designing experiments under consideration, by selecting the best candidate nodes a priori.





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