EXpLoRa

EXperimenting with LoRa products across realistic environments

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domX

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Stage 2 Experiment Review

EXpLoRa

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Experiment Description

EXpLoRa

EXperimenting with LoRa products
across realistic environments

Concept and objectives

LoRa has gained significant momentum among industrial and research communities.

Market penetration of LoRa 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 **systematically characterized 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
- high medium contention

Our aim was to compile a detailed performance analysis of candidate LoRa solutions under realistic conditions as close as possible to the targeted energy metering concept.

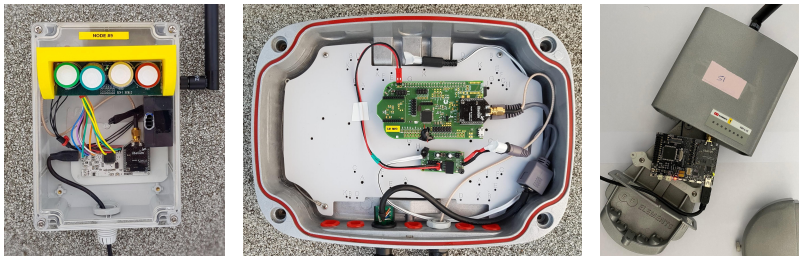
Stage1 Experiment set-up

NITOS city-wide LoRa testbed

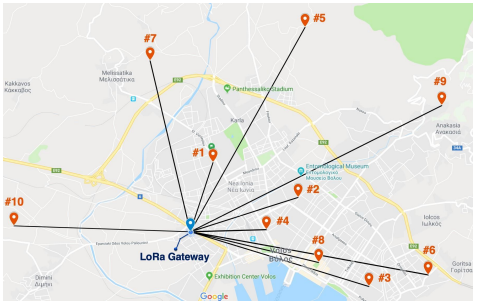
- 10 NITOS LoRa end nodes
- 2 Libelium LoRa Waspmotes
- 1 NITOS LoRa GW
- 1 NITOS LoRa Monitor

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

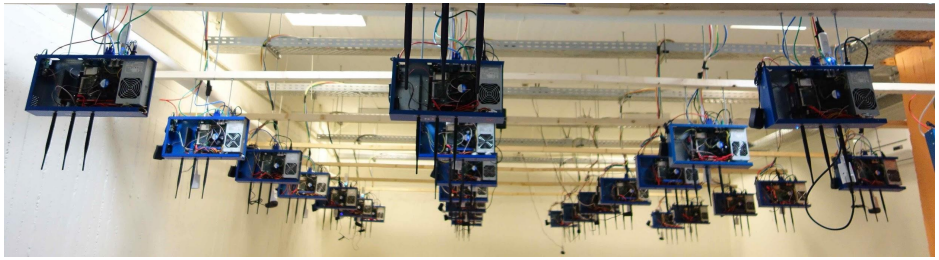


NITOS city-wide LoRa testbed topology

Stage2 Experiment set-up

NITOS isolated indoor testbed

- 4 Libelium LoRa Waspmotes
  - 1 jamming link
  - 1 link under test
- configurable attenuators
- controlled interference
- no external transmissions detected



NITOS isolated indoor testbed

NITOS office indoor testbed

- LoRa GW at the roof
- 6-floor office building
- 2 electrical boards per floor
- 8 LoRa prototype nodes spread across 4 floors
- ideal for emulation of typical energy metering applications

NITOS office indoor testbed

Project Results

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Stage 1 outcome

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

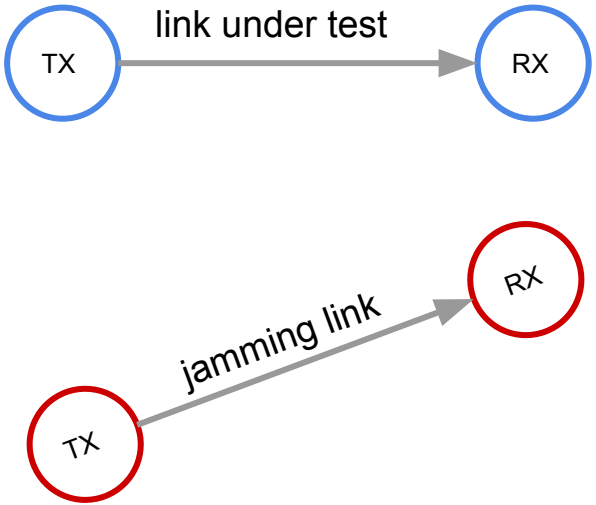
1. Indoor testbed - controlled interference

Experimental settings

- configurable attenuation (step of 5dB, max 20dB) at the SUT transmitter
- 3 TX Power levels: 0,7,14 dBm
- 10 LoRa Transmission modes
- 8 channels (862.5 - 868 MHz)
- Varying payload (10-250B)

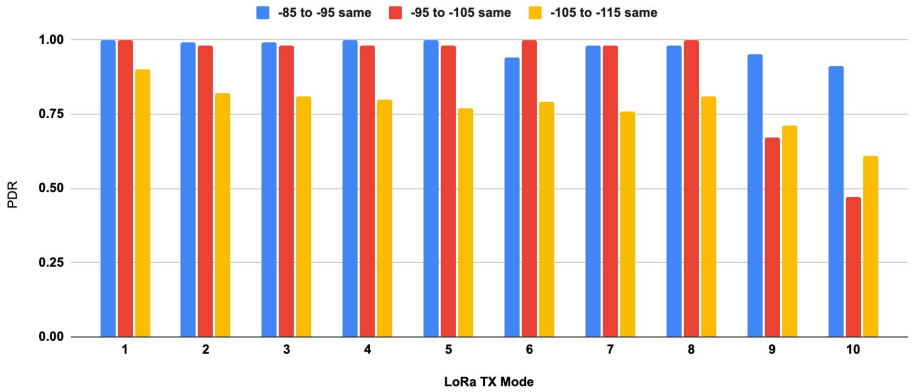
RSSI range

- -85 to -95 dBm
- -95 to -105 dBm
- -105 to -115 dBm

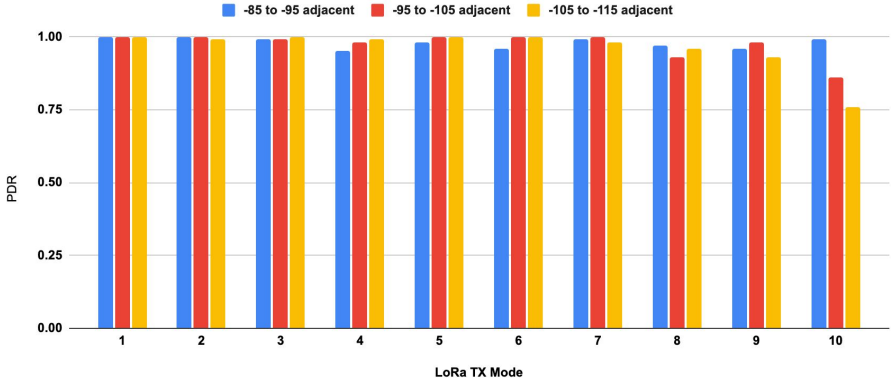


1. Indoor testbed - controlled interference

PDR across LoRa TX modes
when jammer TX mode = link under test TX mode



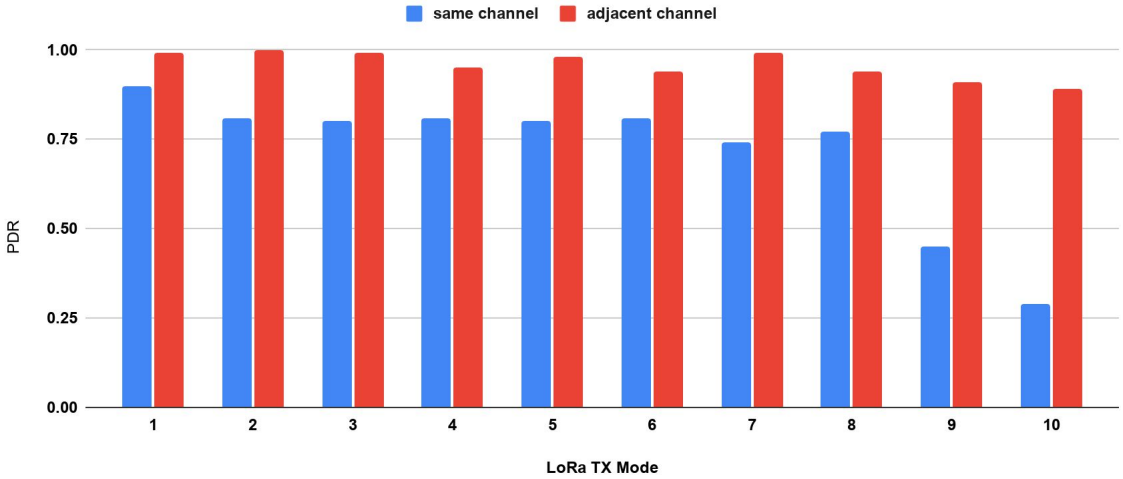
Jammer on same channel



Jammer on adjacent channel

1. Indoor testbed - controlled interference

PDR across LoRa TX modes
when jammer TX mode = link under test TX mode



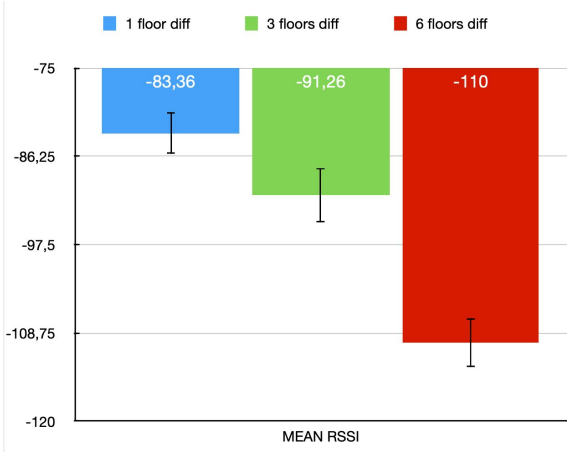
focus on the lower RSSI range
-105 to -115 range

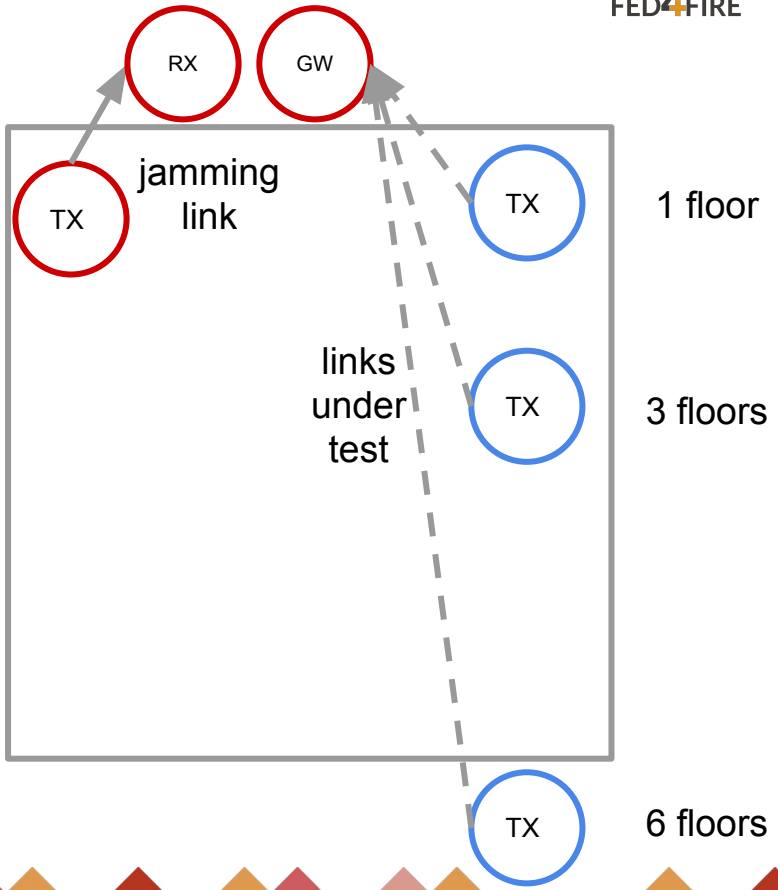
2. Office testbed - cross floor communication

Experimental settings

- Jammer 3 TX Power levels: 0,7,14 dBm
- Jammer TX mode same with link under test
- 10 LoRa Transmission modes
- Same channel (862.5 MHz)
- Constant jamming DC=0.8

RSSI range:

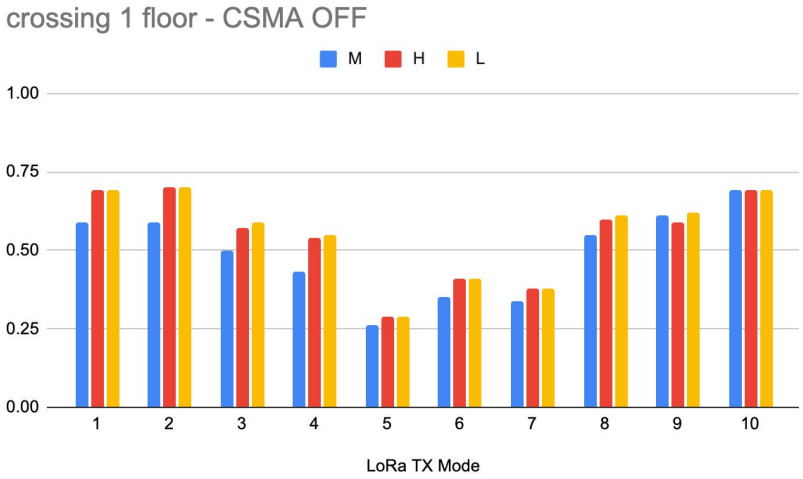




2. Office testbed - cross floor communication

PDR across LoRa TX modes

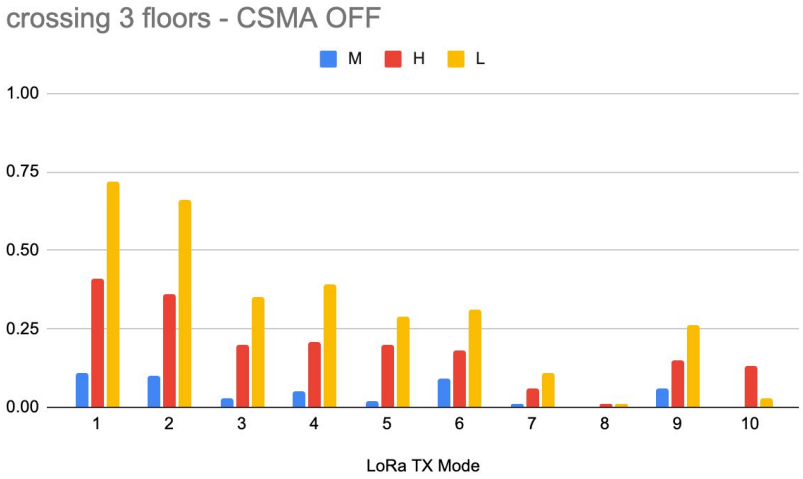
1 floor distance from GW



2. Office testbed - cross floor communication

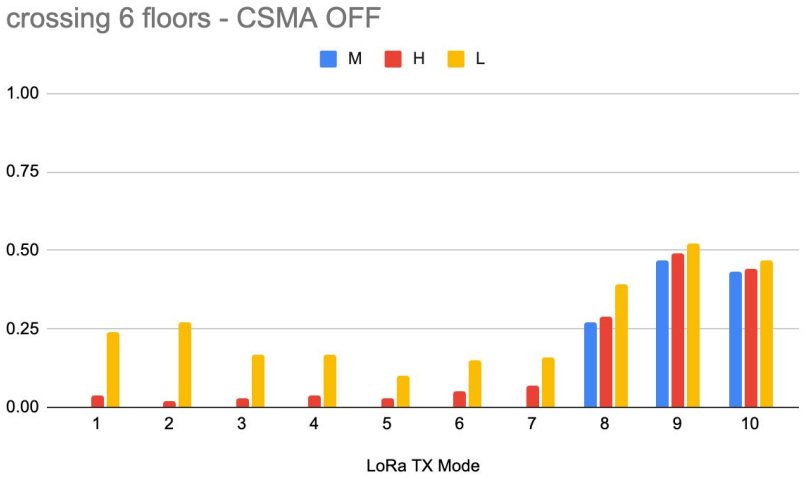
PDR across LoRa TX modes

3 floors distance from GW



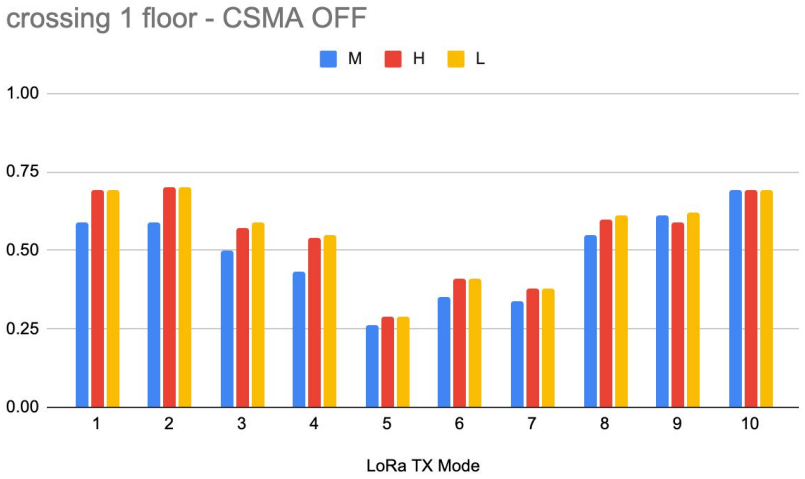
2. Office testbed - cross floor communication

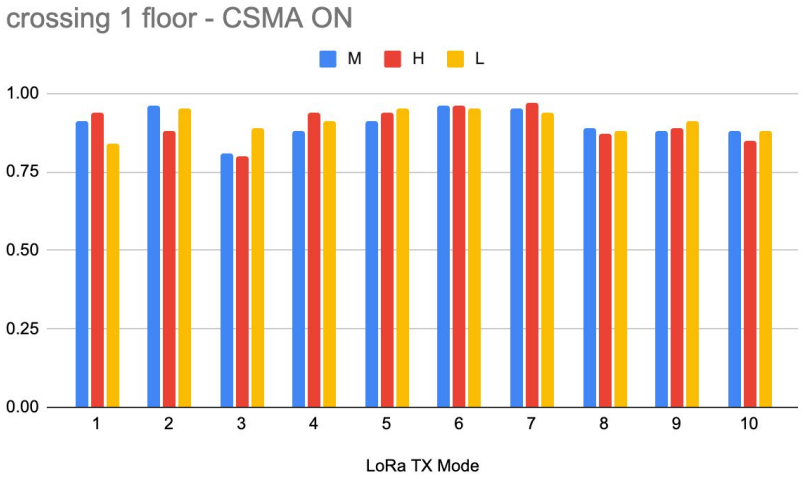
PDR across LoRa TX modes
6 floors distance from GW



2. Office testbed - cross floor communication

PDR across LoRa TX modes
1 floor distance from GW



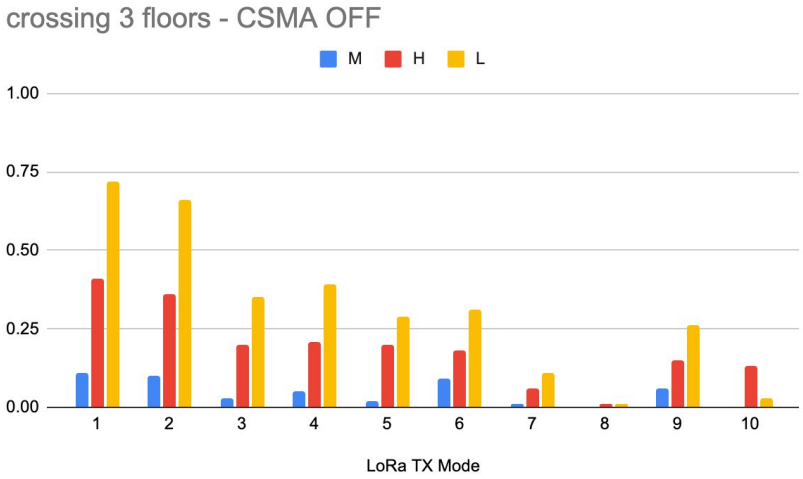


CSMA OFF

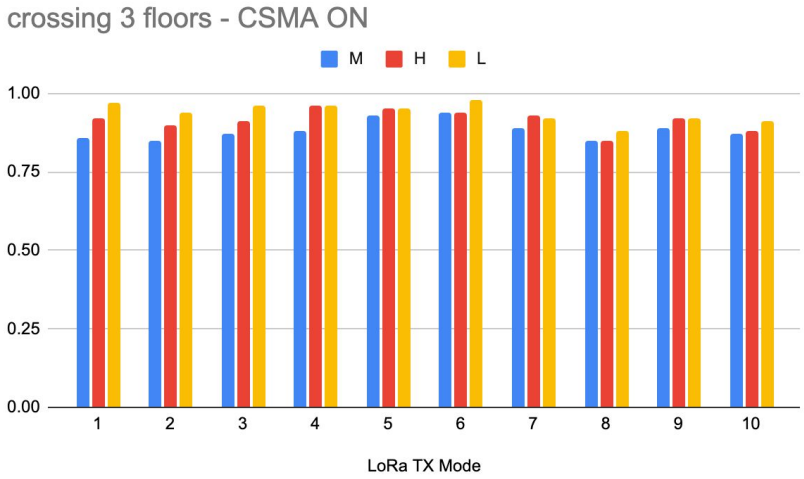
CSMA ON

2. Office testbed - cross floor communication

PDR across LoRa TX modes
3 floors distance from GW



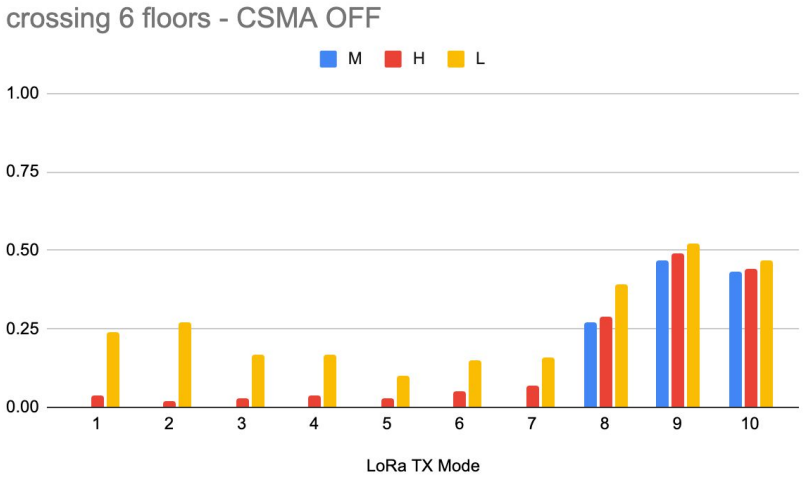
CSMA OFF

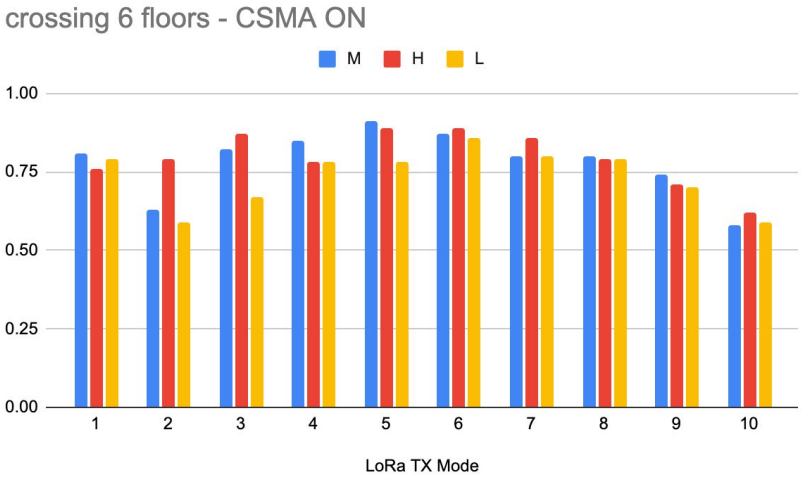


CSMA ON

2. Office testbed - cross floor communication

PDR across LoRa TX modes
6 floors distance from GW





CSMA OFF

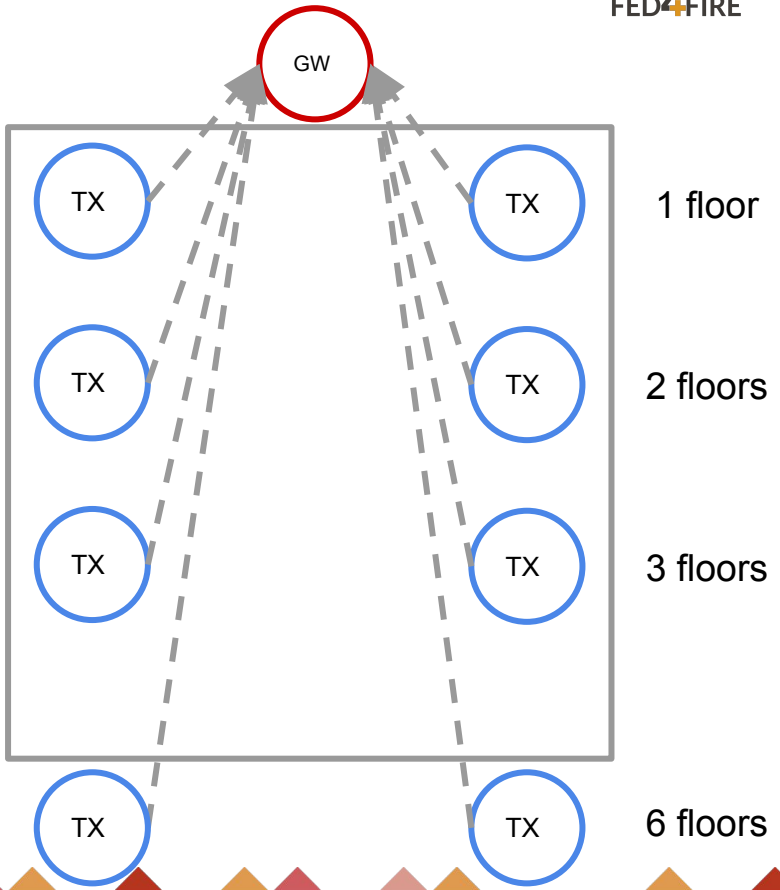
CSMA ON

3. Office testbed - intra building energy metering

Experimental settings

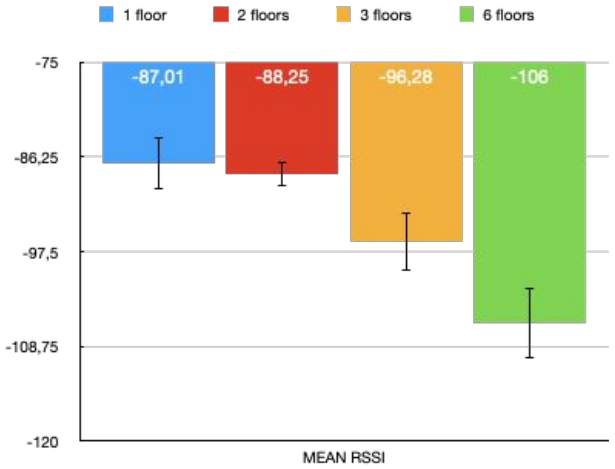
- All links use the prototype LoRa node to transmit simultaneously on:
  - same channel (862.5 MHz)
  - same TX mode (1)
  - payload (50B)
    - 7 energy measurements
    - control overhead
  - interval 5 mins
- Time on air: 2,301.95 ms
- Duty cycle limit: max every 03:50 mins

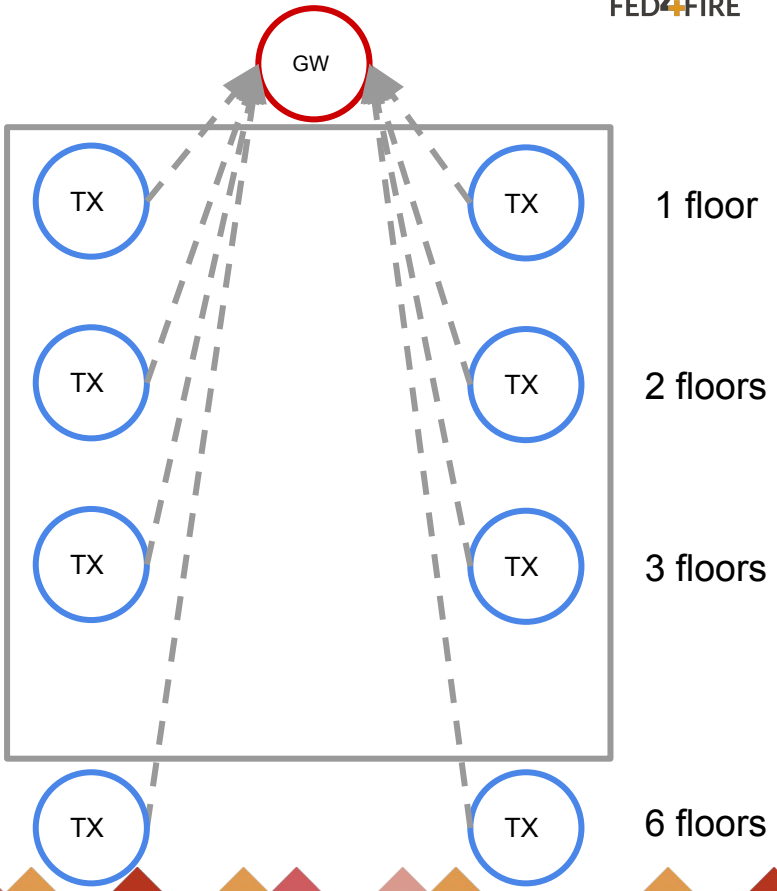
- CSMA ON/OFF
- Retries ON/OFF



3. Office testbed - intra building energy metering

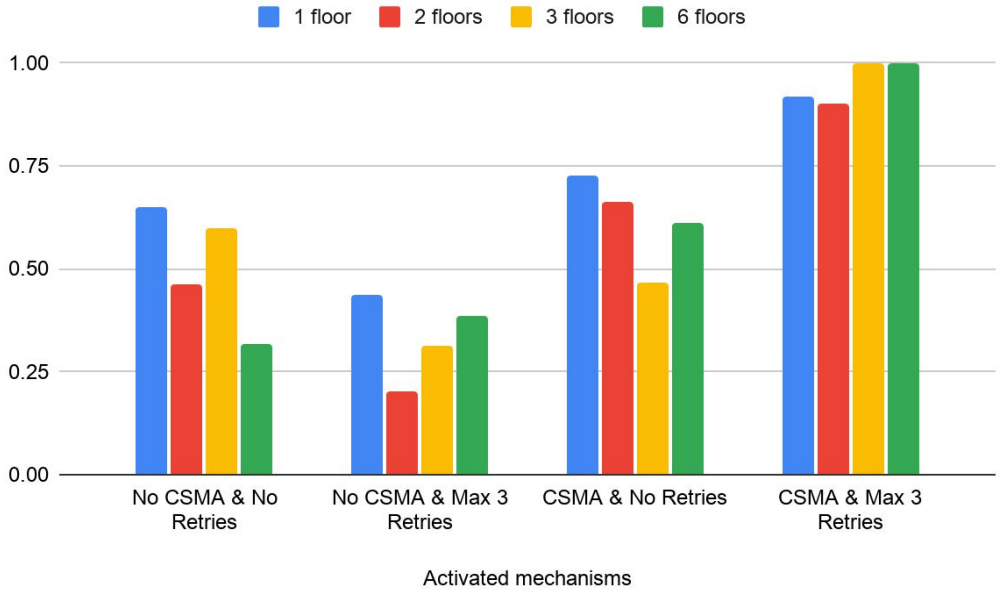
RSSI range:





3. Office testbed - intra building energy metering

PDR per activated mechanism



Mean PDR achieved per mechanism			
0.51	0.33	0.62	0.95

> 86% performance improvement on average

Lessons learned

Through the Stage 2 EXpLoRa experiment, we managed to:

- extend the considered experimental conditions in 2 testbeds and 3 scenarios:
  - isolated controlled interference
  - cross-floor communication
  - intra building energy metering
- characterize the impact of overlapping transmissions using varying channel and TX mode and link settings.
- experiment and improve the proprietary prototype LoRa-based energy metering solution
- cross compare the performance of multiple LoRa-based devices in terms of (PDR, RSSI)

Key findings:

- LoRa can offer sufficient PDR even at low RSSI conditions(-137 dBm) and high interference (DC close to 1)
- SF isolation performs better than channel isolation for interference mitigation
- CSMA is a must extension for LoRa clients providing great performance improvement for simultaneously activated and collocated links
- LoRa can support energy metering applications both at city-scale and within multi-floor buildings

Business Impact

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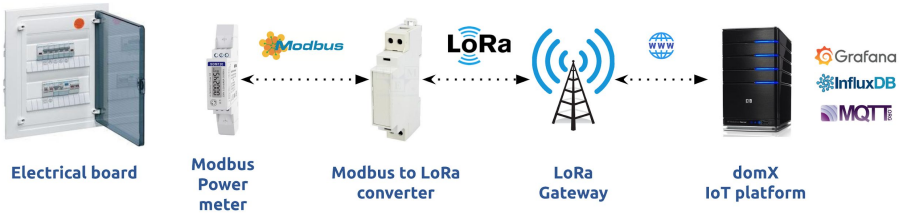
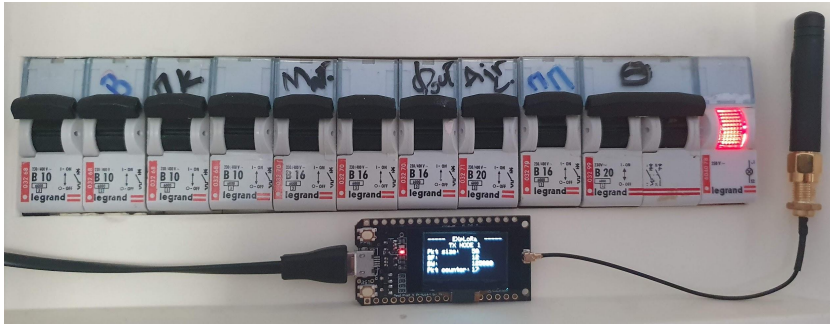
Business Impact

- ExpLoRa provided domX with the means and the motivation to develop our prototype LoRa-based energy metering solution
- Experimented under a wide variety of high interference and typical energy metering scenarios
- Tested the application of multiple performance improvement strategies
- Greatly improved (**86% on average**) the LoRa client's performance under typical energy metering applications through the implementation of collision avoidance (CSMA)





Business Impact

ExpLoRa offered vast business impact:

- competitive advantage by being able to cover more demanding applications (building and city wide metering and control)
- ability to extend the company's solution portfolio
- added value to the company's existing customers
- potential to attract new customers with the newly introduced product line and services

Further plans

- pilot the LoRa-based solution in customer setups
- integrate LoRa with the company's boiler heating controller
- deploy own LoRa GWs to cover customer needs
- develop new business model and services on top of the prototype
- exploit the solution in relevant H2020 research projects of the energy efficiency domain

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
  - isolated testbed links
  - easy to use testbed tools
- **experimented under typical energy metering setups** in a multi-floor office testbed across a wide range of conditions (interference, link range)
- **tested multiple interference mitigation strategies,** quantified their improvement and adoption potential
- **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.
- **greatly improved the performance of the LoRa prototype** performance under typical energy metering applications, **through the support of our patron!**

Value perceived

The direct value of EXpLoRa for domX has been vast:

- **introduction of a new product line and relevant services**:
  - starting with a LoRa to Modbus converter for sampling energy meters
  - exploit the developed solution with our proprietary heating controller to monitor and actuate on legacy gas boilers
- **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 all 3 NITOS available testbed resources:

- fully exploited the set of reserved testbed resources.
- installed and integrated own equipment with ease
- 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. isolated indoor testbed:
   - configurable attenuation
   - controlled interference
2. office testbed
   - 8 configurable LoRa nodes
   - 8 own prototype LoRa clients
3. varying experimental conditions:
   - power levels: 0,7,14 dBm
   - 10 LoRa Transmission modes
   - 8 channels (862.5 - 868 MHz)
   - varying payload (10-250B)

Experiment execution

1. The collected results exceeded the initial expectations
   - LoRa performance exceeded nominal potential
   - multi-floor office testbed offers unique experimentation conditions
2. Integration of own prototypes was smooth
3. Online documentation was minimal and can be improved
4. 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.
2. 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.
3. Great environment and support required for promoting R&D of startups

Key offerings

1. Availability of resources in 3 different testbeds
2. Realistic experimentation conditions
3. Availability of experimentation tools
4. Ability to integrate own assets
5. Continuous remote testbed availability
6. Technical support by expert people
7. Ease of experimental setup

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.)
- 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.

Office testbed

- great experimentation environment
- requires site visits for:
  - deploying LoRa nodes
  - tuning of experiments
- least developed among the 3 testbeds:
  - lack of documentation
  - not easy to experiment without support from the testbed team


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Co-funded by the Swiss Confederation

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