Exploring the performance of LoRa™ modules for indoor based wireless sensor networks

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Abstract—**This paper is focused on LoRa technology and analyses of its performance as technology for indoor environments. LoRa™ made appearance as a Low-Power Wide Area Network (LPWAN) technology with the appliance in wide area environments such as Smart Cities and Smart Transportation. Those applications are designed for outdoor areas, where two main LoRa™ advantages (long range and small energy cons1umption) are very favorable. Recently, authors have started to explore LoRa technology performances in indoor environments. Other characteristics of these researches are extensive usage of open-source hardware based platforms, such as Arduino, in design of devices for testing and evaluation. In this paper is presented the prototyping platform based on open-source hardware and low-cost components for testing LoRa™ in indoor environments.**

Key words - LoRa™; open-source hardware; indoor propagation;

I. INTRODUCTION

This paper is focused on the LoRa™ [1, 2] technology and associated platform designed for analyses of its performance in indoor environments. LoRa™ is one of variety of technologies that made appearance as a Low-Power Wide Area Network (LPWAN) group of technologies [14]. There are currently many LPWAN [3] technologies on the market such as LoRa™, LoRaWAN, SigFox, Ingenu and LTE-M [4]. LPWAN initially has the application in wide area environments such as Internet of Things covering wide areas, and designed for systems such as Smart Cities and Smart Transportation. Those environments are designed for outdoor space, and LoRa™ two main advantages such as long range and small energy consumption are perfect for those environments.

No matter of LoRa initial purpose and target area, in recent years, more and more authors have started to explore LoRa technology performances in indoor environments. In these researches there is considerable usage of open-source hardware based platforms and single-board computers, such as Arduino and its clones or Raspberry Pi. Those devices are used in design, in testing and performance analyses.

In this research, authors developed prototype platform based on open-source hardware and low-cost communication and sensor components for testing LoRa™ in indoor environments. In this paper prototype platform, experiment setup and measurement results are presented. The paper is structured as follows: after the introduction, the related work with similar researches is presented. The third section describes platform design in details, while the experiment and results are presented in the fourth and fifth section. At the end, the conclusion and further work are presented.

II. RELATED WORK

In this section, similar researches and platforms developed worldwide are described. The one of the interesting prototyping system designed for measurements in the 868 MHz and 433 MHz band was developed at the Technical University of Dortmund, Germany [5]. Platform is developed for measurements in the 868MHz ISM band, and it is based on Pycom LoPy modules. The same platform is used or both LoRa nodes and LoRa gateway. For the 433 MHz measurements as a gateway device Dragino LoRa 433MHz with GPS Hat expansion module is connected to Raspberry Pi. Although the EU regulation allows in 433 MHz ISM band maximal output power up to 10 dBm, the gateway device was set to 3 dBm because of limitations caused by the hardware itself. The 433 MHz node uses the Adafruit Feather 32u4 RFM96 433 MHz LoRa radio module. The measurements were made in 8 locations in the open and indoor space for 868MHz and 433MHz.

The second research, at the University of Oulu in Finland [8], used Kerlink's LoRa IoT as a base station. Platform is connected to the D100-1000 antenna, mounted at the University's antenna pillar at a height of 24 m above sea level. The LoRaMote was used with the Semtech SX1272 module [15] Planar-F type PCB antenna. In addition to the SX1272 module, a GPS module and set of sensors were used. The measurements were carried out in four phases with car as a mean of transportation with the variable number of packets sent (894, 1215, 3898 and 932), and in two phases with ship as a mean of transportation with the number of 2998 and 690 packages sent. In the study of the same authors [6], a LoRaMote sensor node was used with the Semtech SX1272 module Planar-F type PCB antenna. LoRa module parameters are set to SF=12, BW=125 kHz, and output power to 14 dBm. The maximum receive sensitivity of the module is -137 dBm, which gives the total radio link budget of 150 dB. As a base station, Kerlink LoRa IoT station, which was located at the Faculty of Information Technology and Electrical Engineering, was used. It is linked to a local network that is used as a backbone. The base station is connected to the antenna as in the previous case. The measurements were conducted in several phases at 6 and 12 locations in indoor environment. The number of packages sent ranged from location to location and was approximately 500-600 by location or specific measurement configuration.

In the study [7], the experiment was performed using a platform based on Moteino MEGA. It is a platform with an ATMega1284P microcontroller and a HopeRF RFM95 LoRa transmitter operating in the 868 MHz band. The device is powered by a 3.7V battery. Platform has built-in sensors such as Bosch BME280 temperature and humidity sensor connected via I2C interface. For data logging, the SD card was used, and for the time Maxim DS3231 RTC (real-time clock) was used. The data was sent every 3 seconds, and every 6 minutes the stations reset its configuration and downloaded new settings. Stations are located indoor, outdoor and underground.

Another similar platform was developed at the University of Applied Sciences, Ofenburg in Germany, at the Laboratory for Harmonized Systems and Communication Electronics. The platform is used to test LoRa technology at 12 locations outdoor with three different lengths of packets, and for each measurement 1,000 packages are transmitted [9]. Additional measurements were made at different 5 locations in two scenarios with 1,000 packages per measurement.

The platform presented in this paper is based on the experiences of presented solutions as well as on personal experience of authors from previous researches [10, 11]. The experiment setup is also based on presented related researches and on authors previous experiments made with other wireless technologies.

The custom built platform is designed for this experiment with the purpose to investigate performance of lower cost category LoRa™ modules. One of the cheapest LoRa modules available on the market is used for this system design. Platform is modular and can be used with the presented modules or with other modules from different manufacturer. The sensor number and types can be easily changed as well. Besides analyses of selected LoRa module performance, its co-operability with open-source hardware based platform, in this particular case Arduino/Genuino development board, was another research target.

III. PLATFORM

Only one device for this research is developed - Tx station. On this device E45-100-TTL LoRa™ module [12] is connected to the Arduino MEGA development board [7] directly. The module has SMA-K antenna connector and uses ANT700, a telescopic antenna designed for operation from 300 MHz to 1.1 GHz with a total length that is configurable from 9.5 cm to 24.5 cm.

According to the specification, module uses Semtech SX1276, operating at 868MHz, has supply voltage of 2.1 ~ 5.5V DC, operation range of 3 km (LOS), four levels of transmitting power (20, 17, 14 and 10 dBm) and air data rate of 6 optional levels (0.3, 1.2, 2.4, 4.8, 9.6 and 19.2kbps), UART communication interface and -138 dBm receive sensitivity. Module is chosen not only because of its characteristics, but also because of its very low cost.

In addition to the microcontroller board and the communication module, device has RTC and I2C LCD 16x2. The Tx station also has DHT22 sensor for measuring the temperature and humidity. Components and its description are given in Table I.

TABLE I. LORA TESTING PLATORM COMPONENTS

No.	**LoRa Testing Platform**	
	Component	***Desciption***
1	Arduino MEGA 2560 R3	Development board
2	E45-TTL-100	LoRa communication module
3	LCD I2C 20x4	LCD
4	RTC DS2321	Real-time clock
5	DHT22	Temperature Sensor

The insight view of Tx device is presented on Fig. 1. The Rx device is made of second E45-100-TTL LoRa module, directly attached to PC with USB adapter and 3m long USB cable. The Rx LoRa module is mounted on 70 cm high pole, placed on the top of the office furniture reaching the total height of approx. 205 cm.

The module has SMA-K 2dBi omni antenna. Serial port logging software is installed on PC in order to log and analyze received packets, and to present the statistics used in this research. The components of the Rx station are presented at Fig. 2.

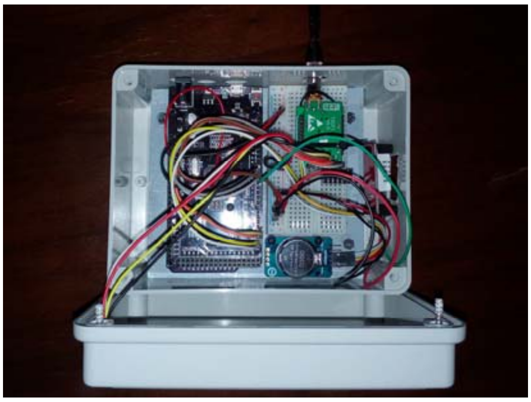

Figure 1. The Tx Device insight view

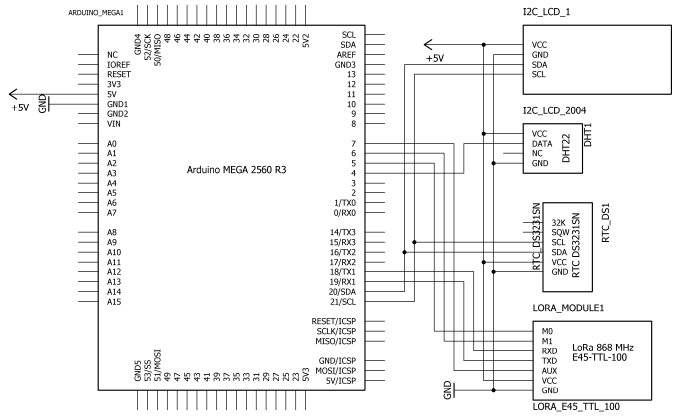

Figure 2. Schematics of development board and communication module

IV. EXPERIMENT

The experiment was conducted in institutional building in multi-floor environment. The institutional building consists of three parts in rectangular shape. The right wing presents the core of the building and has ground floor and two additional floors. The central part is primarily built up to host amphitheater, with few minor rooms. Right wing is newly built wing with three levels. Building layout and measurement locations are given in Fig. 3.

The Rx station is located on the south side of the central part very close to the separating wall from the right wing. The measurement locations are presented in Table II, with locations 1-4 as a part of left wing, and others as a part of right wing.

Table II gives the location data, such as: location name, level (ground, 1st or 2nd floor), distance from Rx station, number of packets sent and received, Packet Delivery Ratio (PDR) presented in percents, Packet Error Rate (PER) also in percents.

Parameters of the module are set to minimal transmitting power of 10 dBm, and the highest air rate of 19.2 kbps. The length of the packets sent range from 42 to 44 B, depending on data sent from sensor node. Sensor node is sending the data from sensors such as: stationID, packet number, date and time from RTC, temperature and humidity from DHT22 sensor.

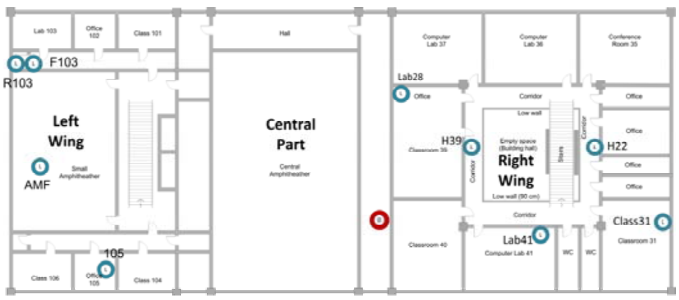

Figure 3. Building layout with measurment locations

The locations are planned in order to investigate link quality interesting for future deployment of LoRa based wireless sensor network in the building. To evaluate the link, PDR is calculated. It represents the ratio between packets sent and packets received. The experiment is based on the authors experience from [13] with indoor propagation modeling at 868 MHz, and with LoRa propagation in [10] and [11]. The difference from the first research is in the change of technology because in previous research the two models of 868 MHz proprietary protocol modules are used. The difference from other two researches is in using different modules (Libelium LoRa SX1272) and in environment and station type: static outdoor [10] and moving outdoor [11].

V. RESULTS

The results (Table II) shows that that only one location (R103) gives the PER of 99% or only 1% packet received. This location is on distance of 40,11m in most distanced and hidden room from the central (Rx) location. Other location (F103) in front of the room's (R103) door and only few meters closer to the central location (F103) gives PDR of 100%.

Next station with not so good result is Amphitheater with PER of 16,33%. This PER is still acceptable for majority of potential applications. The presented results justify the usage of LoRa technology for indoor based wireless sensor networks.

TABLE II. MEASUREMENT RESULTS

No.			LoRa Testing Platform				
	Loc.	***Level***	***Dist (m)***	***Pkts Sent***	***Pkts Rcvd***	***PDR (%)***	***PER (%)***
1	105	ground	28.41	300	299	99.67	0.33
2	AMF	ground	35.62	300	251	83.67	16.33
3	R103	ground	40.41	300	3	1.00	99.00
4	F103	ground	38.78	300	300	100.00	0.00
5	Lab41	2nd fl.	17.13	300	300	100.00	0.00
7	Class31	2nd fl.	2.12	300	300	100.00	0.00
8	H32	2nd fl.	23.51	300	300	100.00	0.00
9	H40	2nd fl.	13.02	300	300	100.00	0.00
10	H22	1st fl.	22.93	300	300	100.00	0.00
11	Lab28	1st fl.	13.27	300	298	99.33	0.67

VI. CONCLUSION

In this paper the research on LoRa technology performance in indoor based wireless sensor networks scenario is presented. The experiment is designed upon world-wide and up to date researches as well as on authors own experiences with LoRa technology and 868 MHz indoor propagation models.

The custom built platform is designed for this experiment with the purpose to investigate performance of lower cost category LoRaTM modules as well as their co-operability with open-source hardware based platform. In this case Arduino/Genuino is used. The experiment results shows that communication modules and associated platform can be used for LoRa technology wireless sensor networks in indoor environment with high availability and efficiency.

The future work will include more extensive indoor propagation measurements in office and residential buildings. Also, the indoor propagation should be analyzed in industrial environment, in production facilities and similar surroundings.

Since the platform is based on open-source hardware and made as a highly modular prototyping system, one of the future research directions can be pointed towards measurements with other types of LoRa modules and with other communication technologies as well.

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