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Design and Development of a Platform for Test Applications in LoRa/LoRaWAN

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Abstract

This paper presents the design and development of a platform for the implementation of test applications based on LoRa/LoRaWAN technology. The main purpose is experimental development and analysis of radio network coverage for LoRa/LoRaWAN on the territory of the town of Gabrovo and the development and configuration of a gateway (concentrator), end devices (end nodes) and network server for communication and application testing. The architecture of the platform is based on the LoRaWAN™ requirements, defined by the LoRa Alliance™.

Keywords: LoRa; LoRaWAN; Radio network coverage; Smart city, IoT; IIoT.

1. Introduction

LoRaWAN (Long Range Wide Area Network) provides energy-efficient low-power (Low Power, Wide Area – LPWA) communication for wireless-connected devices (nodes) on regional, national or global networks [1]. For this reason, this technology is gaining increasing popularity and application in Internet of Things (IoT) [2] and Industry 4.0 (i.e. Industrial Internet of Things - IIoT) [3, 4, 5]. As part of Industry 4.0's concept is the development of intelligent urban technologies (i.e. Smart City technologies), which means that it is necessary to create a platform for testing and developing smart applications (for example, intelligent waste collection, smart LED street light management, parking systems etc. [6, 7]) .

LoRaWAN technology follows the IEEE 802.15.4 standard and represents wireless communication that allows IoT devices to communicate over a long distance with minimal use of power.

LoRa uses license-free radio bands in the frequency band below 1 GHz, such as 169 MHz, 433 MHz, 868 MHz (Europe) and 915 MHz (North America).

The LoRa physical layer protocol is proprietary. LoRa defines the lower physical layer. LoRaWAN is one of several protocols that were developed to define the upper layers of the network. LoRaWAN is a cloud-based media access control (MAC) layer protocol but acts mainly as a network layer protocol for managing communication between LPWAN gateways and end-node devices as a routing protocol, maintained by the LoRa Alliance™ [8].

The LoRa network architecture is shown in Fig. 1. It includes the following:

- End devices;
- LoRa Gateway;
- Cloud service connection network (network server);
- Application with a specific purpose.

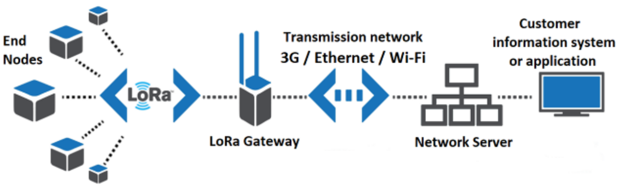

Fig. 1. General LoRa network architecture

In the end device, the data is generated by the sensor and read from the LoRa communication module connected to it. The data is encrypted and transmitted over the radio at LoRa frequency. One or more LoRa gateways receive the message and forward it over a backbone network (usually 3G or Ethernet) to a network server (cloud service). The network server stores, filters, processes the messages, and transmits them in the appropriate form to proper application.

There is no specific definition for a LoRaWAN device – it can be anything that sends or receives information using LoRa protocol – sensors, detectors, actuators and more.

The main challenges to the existing wide range of well-known technologies are:

- The wireless IoT applications typically need fast packet transmission and they use quite a small amount of data on a node; therefore, the bandwidth is not the main criterion.
- In some cases, a large area should be covered.
- Reliability, availability, limited real time latency and energy efficiency are key performance indicators.

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Unfortunately, the available solutions (for example, IEC62591 and IEC62743 based on IEEE 802.15.4) specifically designed for the industrial market have some limits [3]. The cellular networks look more attractive, but 3G and 4G (and even 5G to a certain extent) technologies are not designed for real time and determinism.

LoRa and LoRaWAN have appropriate features. Experimental results show compatibility with real-time application requirements in IoT and IIoT communications [2, 3, 4, 6]. In particular, proper time, frequency and spread factor planning can allow access to up to 6000 nodes within a 1 minute time cycle.

For this reason, the task of designing and developing of a platform for test applications in LoRa/LoRaWAN is challenging. The development of the platform includes:

- Radio coverage planning;
- Development of LoRa concentrator;
- Development of LoRa end node for testing;
- Configuring a network server;
- Communication testing using end node.

2. Design and development of LoRa / LoRaWAN platform

2.1. LoRaWAN radio coverage planning

LoRa uses a proprietary spread spectrum modulation that is similar to and a derivative of Chirp Spread Spectrum modulation (CSS). This allows LoRa to trade off data rate for sensitivity with a fixed channel bandwidth by selecting the amount of spread used. This is defined by the spreading factor [1]. This spreading factor determines the data rate and dictates the sensitivity of a radio. In addition, LoRa uses Forward Error Correction (FEC) coding to improve resilience against interference. LoRa's high range is characterized by extremely high wireless link budgets, around 155 dB to 170 dB [1, 8].

For a given available bandwidth, a larger spreading factor reduces the bit rate, but also increases power consumption by increasing the transmission time. A specified spreading factor (SF) and bandwidth (BW) will give a bit rate (BR) defined by:

$$BR = SF\frac{BW}{2^{SF}} \quad (1)$$

LoRa allows for six spreading factors (SF7 - SF12) and three different bandwidths (125 kHz, 250 kHz, 500 kHz). Thus, the bit rate will be between 250 and 11000 bps.

The link budget indicates the quality of a radio transmission channel. The link budget can be calculated by adding the transmit power, receiver sensitivity, antenna gain, and Free Space Path Loss (FSPL) – Fig. 2.

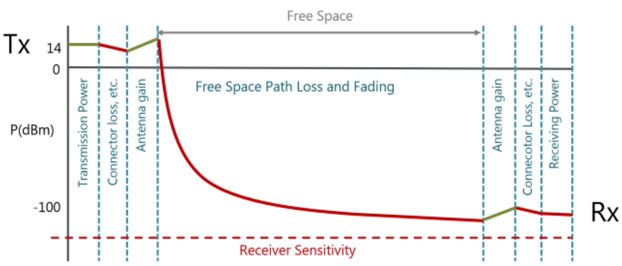

Fig. 2. Link budget calculation

FSPL is typically presented as follows:

$$FSPL = \left(\frac{44\pi d}{\lambda}\right)^2 = \left(\frac{44\pi df}{c}\right)^2 \quad (2)$$

where d is distance between transmitter and receiver in [m], f – frequency in [Hz].

There is also a widely used formula for calculating FSPL in logarithmic form (in dB):

$$FSPL_{[dB]} = 20\lg(d) + 20\lg(f) - 147{,}55 \quad (3)$$

In the receiver side (Rx), receiver sensitivity (S_{Rx}) is the value that affects the link budget. The sensitivity of the receiver is calculated as follows:

$$S_{Rx} = -174 + 10\lg(BW) + NF + SNR \quad (4)$$

where NF is noise ratio in dB, SNR – signal to noise ratio.

Eq. (4) shows the extreme case of path loss without taking into account antenna gain and other types of free space attenuation:

$$LE = S_{Rx\max[dB]} - P_{v\max[dB]} \quad (5)$$

where LE is the efficiency of the link, $S_{Rx\,max}$ – maximum receiver sensitivity, $P_{v\,max}$ – maximum transmitter power.

For example: if the BW = 125 KHz = 10lg (125000) = 51, NF = 6 dB, SNR = –20 dB (for SF=12) and $P_{v\ max}$ = 10 dBm, then substituting in Eq. 4 will result $S_{Rx\ min}$ = –174 + 51 + 6 – 20 = –137 dBm. The link efficiency LE can be calculated by substituting into Eq. 5, which will result as follows: LE = –137 dB – 10 d B = –147 dB.

2.2. Development of LoRa concentrator

The LoRa concentrator is designed by two main modules:

- Single-board computer Raspberry Pi 3 model B+;
- Multi-channel LoRaWAN module IC880A-SPI.

The IC880A-SPI module communicates with Raspberry Pi 3 through the SPI (Serial Peripheral Interface) interface.

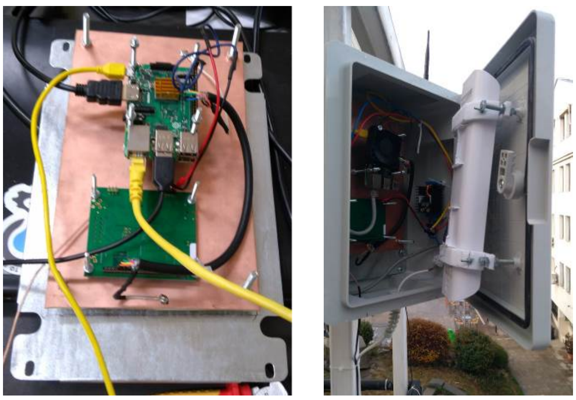

Fig. 3. Assembly of Raspberry Pi 3 and LoRa module IC880A-SPI

Table 1 shows the LoRaWAN concentrator pins, which are connected to the corresponding IC880A-SPI pins.

The Raspberry Pi 3 is powered by the micro-USB connector and the LoRa module IC880A-SPI – by pins 21 and 22 (see Table 1). An additional CPU heatsink was added for better cooling – Fig. 3.

Table 1. Description of connection between the LoRaWAN concentrator and the IC880A-SPI

iC880a-SPI pins	Description	R Pi physical pins
21	Supply 5V	2
22	GND	6
13	Reset	22
14	SPI CLK (synchronization)	23
15	MISO	21
16	MOSI	19
17	NSS	24

2.3. Development of LoRa end node for testing

A programmable Esp32 LoRa v.1 controller is used as a test end device – Fig. 4. The end device measures the temperature and air humidity using the sensor DHT11 – a digital sensor that transmits 2 bytes of information to the programmable controller.

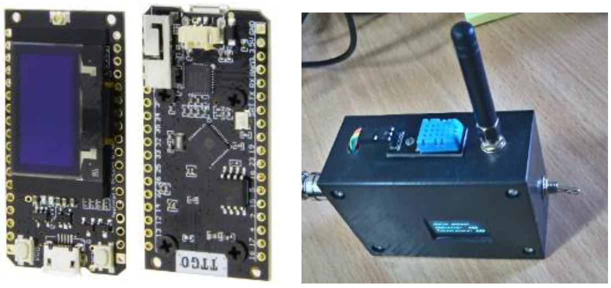

Fig. 4. A temperature and humidity measuring end device implemented with Esp32 LoRa module

2.4. Configuring a network server

In this particular case, the Open LoRa Server is used as network server. End nodes connect to the network server using the OTTA method (Over the Air Activation [1, 8]).

To enable the end device to connect to this gateway, it is used a 128-bit key that is placed in the device code. If the device is accepted from the server, packet data transmission will begin immediately – Fig. 5.

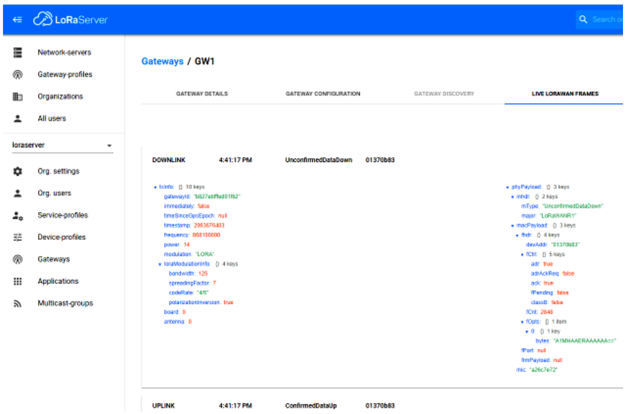

Fig. 5. Real-time data packets received in the Open LoRa Server

It is also necessary to implement a decoder of information from the received packets. JavaScript was used to create the packet data decoder. In our particular case, two bytes of information are decoded: one for temperature and one for humidity - Fig. 6.

Custom JavaScript codec functions

By defining a payload codec, LoRa App Server can encode and decode the binary device payload for you.

```
function Decode(fPort, bytes) {
return {"temperature":bytes[0], "humidity":bytes[1],"timestamp":Date()};
}
```

Fig. 6. Decoder of data packet information

2.5. General architecture of the test platform

The experimental development and implementation of the general architecture of LoRa/LoRaWAN test platform is realized on the territory of the town of Gabrovo, as it is shown on Fig. 7.

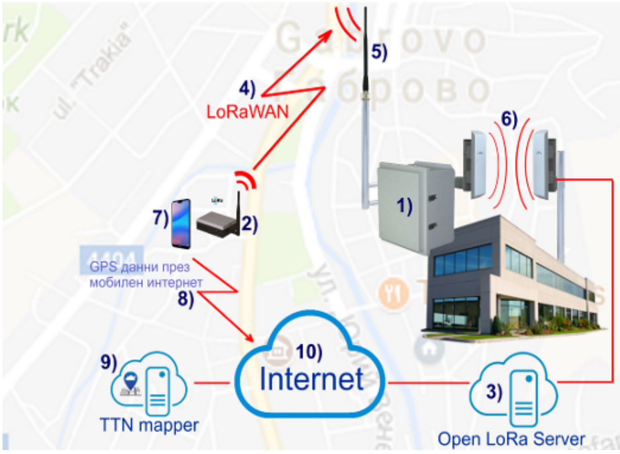

Fig. 7. General architecture of the LoRa/LoRaWAN test platform

The platform includes the following elements:

1) LoRaWAN gateway;
2) LoRa end node;
3) Open LoRa Server;
4) LoRaWAN network;
5) LoRaWAN gateway receiving antenna for communication with end devices;
6) Wireless connection between the LoRaWAN gateway and the Open LoRa Server;
7) Smartphone with GPS module and installed TTN Mapper application;
8) Mobile internet communication to connect the smartphone to the cloud service of the TTN;
9) Cloud TTN service for TTN Mapper;
10) Global Internet network.

The web service, through which the LoRa end node is monitored and the radio coverage of the LoRaWAN network is visualized, is the TTN Mapper.

To investigate the radio coverage and parameters of LoRaWAN radio communication, two components are used: GPS module that will send our location, and the LoRa end node itself, i.e. the end device that sends the data.

3. Results

The radio coverage for part of the territory of the town of Gabrovo has been researched and analyzed – Fig. 8. The main task is to ensuring proper data exchange between end devices (located in different locations in the given urban environment) and gateway and between the gateway and the network server.

The results for the status of the RSSI (received signal strength indicator, dBm) and SNR parameters (Signal-to-Noise Ratio, dB) imposed on the TTN Mapper application are shown in Table 2 and Fig. 9. 17 control points with report of signal level in the central part of the city were carried out.

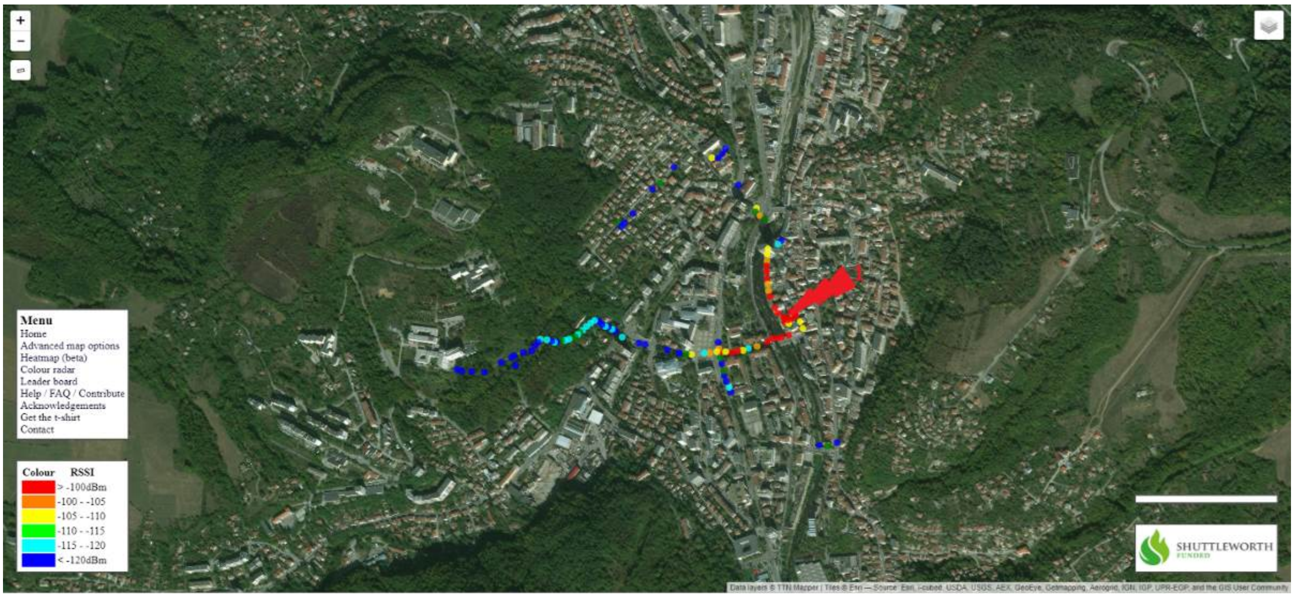

Fig. 8. LoRa radio network coverage for the part of town of Gabrovo

Table 2. Values of SNR and RSSI parameters in LoRaWAN network measured for the central part of town of Gabrovo

SNR, dB	8,8	8	3,5	6,2	-7,5	1,5	-2,8	-3,2
RSSI, dB	-73	-99	-109	-108	-118	-115	-118	-119

SNR, dB	0	-5	-4	2,5	-4,5	6,2	7,2	8,2	-4,2
RSSI, dB	-116	-118	-119	-115	-120	-111	-100	-102	-117

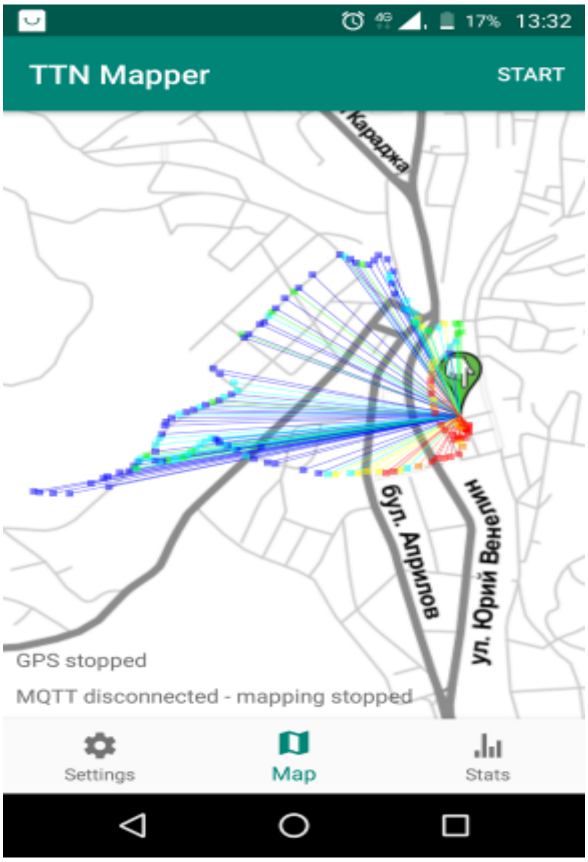

Fig. 9. Reported checkpoints along the analyzed coverage area

Taking into account the analyzed coverage area, 4 more specific control points at a given direction are selected, the location of which is shown in Fig. 10 (control point 1 represents the location of the LoRa gateway).

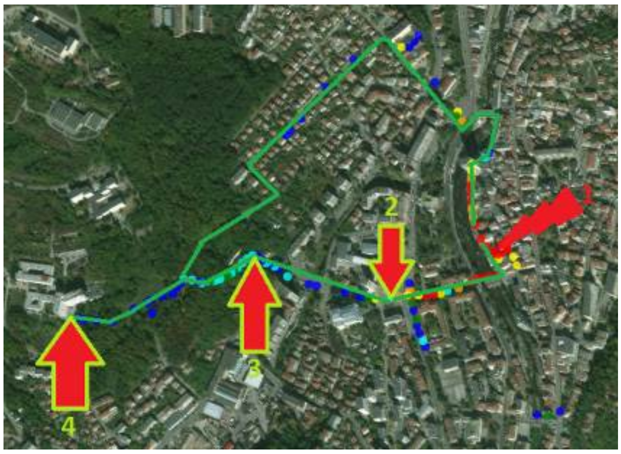

Fig. 10. Reported checkpoints along the analyzed coverage area

The results of the the measured values for control points 2, 3 and 4 for the measured direction are shown in Table 3 and are graphically represented in Fig. 11.

Table 3. Measured parameter values for control points of interest

Control Point	Distance m	SNR dB	RSSI dBm	Frequency MHz	Latitude	Longitude	Altitude m
2	250	7	-105	868.1	42.8708	25.3159	426
3	507	1.5	-117	868.1	42.8715	25.3122	436
4	880	-8.2	-121	868.1	42.8704	25.3078	483

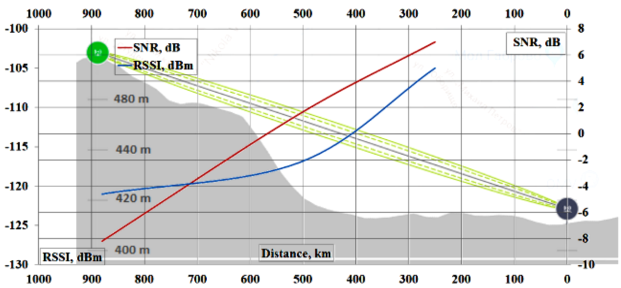

Fig. 11. Graphical dependences of RSSI and SNR in function of distance for the measured direction in radio coverage area

Fig. 12 shows a dialog box displaying the data log for the data packets exchanged between the LoRa gateway and the LoRa end-node.

a) b)

Fig. 12. Exchanged data packets in a) uplink and b) downlink

It is important to note that, even at very low levels of RSSI (Tables 2 and 3), packet transmission is performed reliably and without losses (Figs. 9 and 11).

4. Conclusions

The developed platform for test applications in LoRa/LoRaWAN has the following advantages:

- The platform is open – it can be used freely for testing and experiments with end nodes for different type of IoT and IIoT applications, designed by students and other developers.
- The system is implemented with pilot realization, which is the first one for the territory of Gabrovo and will be freely available for educational and research purposes.
- The platform uses low-cost solutions – cheap multi-channel modules, sensors, end nodes and is based on open source software.
- Using Open LoRa Server (which is open source) allows you to realize the network server, which in turn allows data control without dependence on external services.
- The system is primarily modular – various sensors, modules and applications for a wide variety of services can be used.

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The platform also has some drawbacks as well:

- Working with open-source applications leads to the use of a large number of different libraries and tools, creating some difficulties in the configuration and reconciliation process.
- The different types of hardware must be consistent with the application software.
- In order for a created network server to be publicly available, a public IP address is required. Hosting a public server requires a monthly subscription.

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