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Internet of Things (IoT) - LoRaWAN Optimization

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ABSTRACT: Internet of Things (IoT) is an IT concept consisting in connecting material objects both together and to the internet. This term is complicated to define. Most people associate this term with smartphones or computers, but the world of IoT is definitely wider. IoT was used for the first time in 1999 by Kevin Ashton, who is an expert in technical solutions, but it took more than a decade for people to take this idea seriously. Currently, almost all of the elements surrounding us can be equipped with a chip that allows them to connect to the Internet. The idea of the IoT is that it should encompass all the items that can be connected to the global network. This article firstly discusses issues related to the low-power wide-area LoRaWAN network, which was created for the needs of communication with IoT. Next, the network architecture and its characteristic features are described, followed by a list of available transmission channels for individual regions and description of components of expressions allowing to select the transmission parameters for the application requirements. Next, the article describes practical implementation of IoT with the use of LoRaWAN standard on the example of a system for archiving impulse readings from gas meter index of a bellows gas meter. Finally, this article describes the construction of the device and the principle of its operation. Most importantly, the results of the test aimed at checking the correctness of data transmission from the pulse transmitter to the network server, proving the correct operation of the system, were given in this article. This article also presents an example of the implementation for the module built aimed at the optimization of gas consumption. The results of checking the maximum range of the system built were also given. This correctness of data transmission at a distance of 690 meters in urban areas and 915 meters in the area with single-family houses was found.

KEYWORDS: Internet of Things (IoT), LoRa, LoRaWAN, The Things Network, gas meter, remote reading.

I. INTRODUCTION

Internet of Things - IoT (Internet of Things) has moved from fiction to reality, making the ideas of tomorrow technically implementable today. The only limitation is the costs and energy demand, although here renewable energy sources come with help. The Internet of Things is based on the integration of all kinds of processes, enabling large-scale technological innovation that personalizes the user's interaction with material things. Io T contributes to an even greater expansion of the possibilities of using the Internet in everyday life not only of people, but also of intelligent autonomous devices or entire urban agglomerations. While smart networks have been around for almost a decade, they have been developed using traditional wired or short-range wireless technologies. Performing remote control operations or data exchange within the IoT requires connecting devices to network servers. A large-scale wired connection cannot be used for various reasons, and the use of existing cellular networks may in many cases turn out to be unprofitable. It was therefore necessary to create standards with IoT solutions in mind (Mecki et al., 2019). Low-power wide area network (LPWAN) technologies are ideal for this purpose. However, despite tremendous progress, it is still believed that the Internet of Things is still in its infancy (Čolaković and Hadžialić, 2018). It seems that the billing system will be the perfect place to use IoT solutions. In the case of consumption of natural gas by customers who do not have telemetry systems, the consumption is determined on the basis of readings made by collectors (Gacek and Jaworski, 2018). The use of the latest communication standards dedicated to IoT solutions may contribute to the greater development of remote gas meter reading. The following article describes the use of the LoRaWAN network on the example of a simple system for counting pulses from a gas meter with LoRa transmission. It may be a confirmation of the possibility of creating a comprehensive system for remote settlement of recipients.

II. SMART GAS METERS

Gas meter is an inherent attribute of gas networks and the entire billing system in the gas distribution system is the gas meter. Before being placed on the market, the gas meter series of types must undergo tests consisting in conformity assessment. Its purpose is to demonstrate by the manufacturer that his products meet the requirements. A number of tests and requirements for the products have been described in detail in the articles by Gack (2014), Kułaga (2015), Jaworski and Swat (2016) as well as Kułaga and Jaworski (2016). One of them is to test the durability of gas meters wat a temperature close to that of a 20^∘ Cstream Q_maxwith 5000" " hthe use of natural gas. The second method (for gas meters from G1.6 to G6) is cyclical durability in air for 450,000 cycles (2000h). During the test, for both types of durability, the errors in gas meter readings and pressure losses are checked. In the case of gas meters with an electronic index, it is extremely important to meet the requirements related to electromagnetic disturbances (EMC). After the tests, the errors of the gas meter should be within the permissible error (MPE) and have security for all measurement functions, so that all measurement data obtained before the disturbance was introduced can be recovered. In addition, the Oil and Gas Institute - PIB took the initiative to create additional requirements for bellows gas meters, the fulfillment of which is confirmed by the QING certificate (Jaworski et al., 2018b). Currently, bellows gas meters are the most common type of gas meters installed for measuring gas consumption by individual consumers. Measurement of gas consumption in this type of devices is based on mechanical actions. The emptying of the chambers inside the casing causes the movement of the mechanism which, through the magnetic clutch, sets the gas meter counter in motion (Matusik and Jaworski, 2017). In some countries, bellows gas meters are slowly being replaced by ultrasonic gas meters (Dudek and Jaworski, 2017). The operation of this type of measuring devices may be significantly influenced by the presence of certain compounds in the gas. A high content of carbon dioxide or hydrogen in the measured gas mixture may distort the measurement due to the effect of acoustic absorption (Kułaga, 2017). There are also thermal gas meters available on the market, but one of the most important disadvantages of these meters is their calibration, which is performed on a gas of a given composition. If the composition of the measured gas differs from the composition of the gas for which the calibration was performed, problems with the accuracy of the measurements may arise (Jaworski et at., 2018a). In the case of bellows gas meters, the gas composition is not as important as described by the authors using the example of hydrogen addition to natural gas (Jaworski et at., 2019). The systematic introduction of the latest solutions of gas networks with a view to remote reading and the possibility of remote network management gave an impulse to equip gas meters with the functionality of remote data transmission. It is enough to change the mechanical counter to an electronic counter or additional electronic modules mounted on the gas meter. Usually, gas meters with an electronic counter have additional functions that allow control the valve or enable the implementation of a prepayment system. Communication takes place via radio modules or a GSM module (Kułaga, 2014). Due to the emergence of new wireless communication standards for IoT solutions, there is a chance to replace GSM modules with other data transmission solutions.

III. LORAWAN - CHARACTERISTICS

LoRaWAN is certainly the leading technology of low-power wideband wideband networks. This standard was designed for wireless communication with battery powered things. The LoRa Alliance is responsible for developing and maintaining the LoRaWAN specification. Alliance - LoRaWAN; Karbowniczek, 2019) LoRaWAN uses CSS (chirp spread spectrum) modulation, which has so far been used in military and space technologies. on interference LoRaWAN uses an unlicensed frequency band (ISM 433MHz, 868MHzand 915MHz

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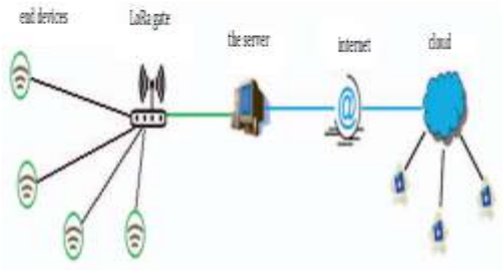

Fig. 1. Sample LoRaWAN network

The LoRaWAN standard can be used both in devices with a constant power source and in mobile devices. In the case of battery operation, it is assumed that it should work for approximately 10 years without changing the battery. Of course, this time depends on the ambient temperature of the device and the frequency of sending messages by it. The architecture of the LoRaWAN network is arranged according to the star topology (Fig. 1). Packets sent by end devices must be forwarded to gateways connected to the main server. The gateways are connected to the server using a standard IP connection. Communication across the network can go in both directions, but the dominant packet traffic should be from the end device to the server, and not the other way around. LoRaWAN has an implemented ADR (Adaptive Data Rate) scheme, allowing for a compromise between the transmission speed and the range and length of the message sent. Due to the fact that the LoRaWAN network is asynchronous, the network nodes do not have to go through the synchronization process, thanks to which a lot of energy was saved. Packet transmission takes place when the data is ready to be sent, regardless of the type of event (scheduled, unplanned). Due to the different nature of work, LoRaWAN end devices can be assigned three different operating profiles, which are a compromise between battery life and communication delays. The most energy-efficient devices with the longest transmission delays can be assigned to class A. Class B includes battery-powered devices with controlled transmission delays, while class C includes mains-powered devices that can listen all the time. In class C there are the lowest communication delays, but also the highest energy demand.

The end devices send messages that are forwarded via the gateway to the web server. After each packet, two collection windows are opened. The first one (RX1) is opened within 1 second (±20μs)after the transmission is finished, and the second one (RX2) within 2 seconds (±20μs). Both reception windows should be long enough for the device to detect the incoming message. If the packet is correctly detected, the radio receiver remains on until the received frame is decoded This is the only way to establish communication from the web server to the end node In LoRaWAN it is not possible to send a message to the device at any time.

For LoRaWAN, frequency channels for individual regions have been approved (table 1). They are included in the document Regional Parameters (LoRa Alliance, 2017) along with the specific radio parameters of the end nodes for each region. For Europe, the ISM band as defined by ETSI (European Standard, 2012) has been allocated. This institution imposes certain restrictions on the transmission parameters. In the case of the EU868 MHz band, end devices cannot radiate with a power greater than +14dBm, and the maximum time during which, the device will occupy a given channel, it is limited to 1% per day for the unlicensed frequency band, which is what it is here. Knots the final ones must be capable of operating in the frequency range from 863 MHz to 870 MHz and have to be implemented parameters for at least 16 channels. Channel selection is performed pseudo-randomly for each transmission (Adelantado et al., 2017).

END	BREED/CHANNELS [MHz]	Channel Plan
Poland	433,05–434,79 863–873 918–921	EU433 EU863-870 Inne
Japan	920,6–928,0 928,8–927,8	AS923 AS923
USA	902–928	US902-928, AU915-928
Australia	915–928	AU915-928, AS923

Table 1. Channels and frequency bands for selected regions

Signal modulation in the LoRaWAN standard depends on three parameters: BW, SF, CR. These ingredients do impact on the maximum range and bandwidth, expressed dependence:

$$R_b[b/s] = \mathrm{SF} \cdot \frac{\mathrm{CR} \cdot \mathrm{BW[Hz]}}{2^{\mathrm{SF}}}$$

These parameters take values from the following ranges:

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- BW: 7,8 kHz, 10,4 kHz, 15,6 kHz, 20,8 kHz, 31,25 kHz, 41,7 kHz, 62,5 kHz, 125 kHz, 250 kHz, 500 kHz;
- SF: 6, 7, 8, 9, 10, 11, 12;
- CR: 4/5, 4/6, 4/7, 4/8.

The bandwidth (BW) is the frequency range within the transmission band. Increasing the parameter causes an increase in the transmission speed and a reduction in sensitivity, while a decrease in the BW value leads to an increase in sensitivity at the expense of a lower baud rate.

Spreading coefficient (SF) spreading factor) allows you to adjust the signal-to-noise ratio (SNR). Increasing the value of the SF factor increases the SNR, results in increased sensitivity and range. A decrease in SF causes a decrease transmission speed, thus increasing the energy demand. Code rate (CR) is intended to provide protection against disturbances. The higher the CR, the better it is better protection, but at a cost frame time in the air (Bor et al., 2016).

According to data from April 17, 2019, the LoRaWAN network was made up of 68,845 members from 137 countries, and 6,855 access gates were created. On November 4, 2019, The Things Network already had 89,441 members and had 9,486 access gates from 147 countries around the world (The Things Network).

The basic features of the LoRa network are:

- ease of installation;
- use of an unlicensed frequency band (169,433,868MHz- Europe);
- data transfer speed <50" " kb/s;
- open technology, no fees;
- the devices do not require the installation of a SIM card;
- half-duplex transmission;
- economy;
- two-way transmission;
- security.

IV. BUILDING AND TESTING THE LORA NETWORK

Due to the fact that LoRaWAN networks can be created by non-profit organizations and private users using available devices (Ministry of Digitization, 2019), at the National Oil and Gas Institute At the Research Institute, a test LoRaWAN network was designed and built. The built-in web-based system aims at in order to remotely read the abacus status of the bellows gas meter with the use of the LF pulse transmitter.

A similar device for reading pulses was presented in the article by Matusik (2018), except that wireless transmission was not used there. For the construction of the impulse counting device, an LF transmitter was connected from a bellows gas meter to a single plate computer TTN-UNO868 with built-in RN2483 module (fig. 2). The task of this system is to count the generated pulses through the abacus of the gas meter and transmission with the use of LoRaWAN standard.

Fig. 2. Gas meter connection with the TTN-UNO868 system

The Registered number of pulses are sent to the network gateway TTN-GW868, which is integrated with the DataStorage disk. This platform allows access to archived data using API commands. Connecting to a DataStorage disk requires running a local server and writing commands to read the data and save it to a local MySQL database. Read data can be saved to the table and assigned to appropriate columns with time content, number of pulses and serial number of the gas meter. The table with the saved values is stored in the MySQL database. When loading data into the database, it is checked whether a given row has not been saved before. This filtering is done by the variable, time ”. If the data is already included in the table, they are not entered into it again. Access to the table is possible through database management tools. For this purpose, phpMyAdmin was used, which enables the database to be exported to a file, as well as visualized in the form of charts. Operation of the device was tested for 16 days with once-a-day data transmission. The transmitting device sends a number of pulses to the server, which can be easily converted later into the amount of gas consumed. After successful data transmission, the pulse counter of the single board computer is reset to zero, therefore the counting starts from zero. Single-board computer software was written using the Arduino IDE, which is free software (Badowski, 2011). The numbers of recorded pulses are presented in the figure3.

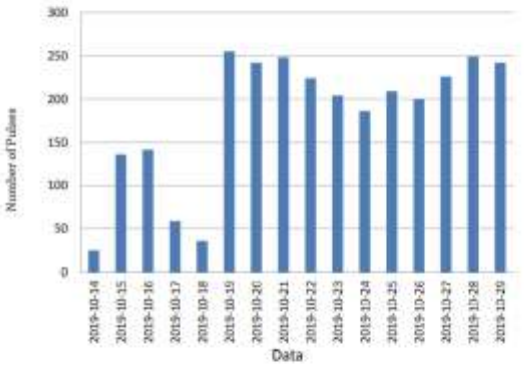

Fig 3. The number of recorded pulses from the gas meter

A bellows gas meter with a mechanical counter with the LF pulse constant was used for the tests =0,01 m^3. Tests of the measuring system were performed by connecting a blower with an inverter to the gas meter, which generated air flow through the gas meter, causing the counter indication to change. A gate valve is mounted on the outlet stub, which enables the stream to be changed. For the duration of the test, 2,883 pulses were recorded, which with the impulse weight being equal 0,01m^3to the gas consumption of 28,83m^3. Additionally, the counter indication was read before the start of the tests and at the end, and the measured wear was 28,83m^3, which proves the correct operation of the pulse counting system and the correct transmission of the read pulses (Fig. 4).

Fig. 4. Indication of the gas meter

The manufactured device with an integrated data archiving system may be a local alternative to smart gas meters with the function of remote reading and valve control (Kułaga, 2014). The created module can be easily connected to a bellows gas meter with a mechanical index, transforming it in a way like wan intelligent gas meter. The transmitted data can be used to keep statistics by the user and thus to optimize his gas consumption. Recorded data can be stored in a computing cloud, so it can be accessed from anywhere at any time. Creating a browser interface will provide access to resources via a web browser (Dietrich, 2016).

The developed system for the archiving of gas meter readings achieves a range of nearly 690 meters in the development of 4-story buildings with the use of a module with a built-in antenna. In the case of undeveloped terrain, a range of about 915 meters was obtained.

V. CONCLUSION

The LoRaWAN network presented in this article is relatively new and intended for wireless data transmission. In some countries it has been implemented in significant areas, but there are still countries where this standard is completely new and is only in the early stages of development. Such a situation occurs in Poland, where the infrastructure of this network is practically non-existent. Only about 35 gates are registered, which gives little coverage. Despite the fact that there are base stations in the LoRaWAN network, it is wrong to associate this standard with mobile telephony. This system is completely independent of mobile network operators. Anyone can create such a network on their own without paying subscription fees, as evidenced by the model of a pulse transmitter from a bellows gas meter described in the article, based on a transmission module in LoRaWAN technology. The most expensive element of the described system is the access gate, which is necessary for the transmission in this standard. With such a gateway, you can expand the network with additional end devices at any time.

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