© Journal of the Technical University - Sofia
Plovdiv branch, Bulgaria
"Fundamental Sciences and Applications"
Vol. 23, 2017

INDUSTRIAL NETWORK DESIGN USING LOW ENERGY PROTOCOLS

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Abstract: *In this work a network development for industrial application is presented. Solutions related to the network protocols and standards for industrial applications are summarized. The main goal is focused on net operation by combining low energy protocol and transmission method. In the developed network project for industrial data exchange was use MQTT protocol and LoRaWAN. An application for security purpose is obtained. The real test and verification with sending and receiving data between the connected nodes are made. The advantages of the developed network with MQTT and LoRa are given.*

Key words: *Industrial Network, MQTT protocol, LoRa*

1. Introduction

Using network in security applications is usual, complex and sometimes dangerous tasks. There are many different ways to solve, depending of cases. An example a security in places without electricity in order to be organized, is not easy task. How to secure buildings or value staff against tiffs and there no electricity? These tasks over a long period of time are performed. It is case of highly dynamic phenomena, such as change of security status because of fire alarm or intruder, means that the results do not reflect the real value. A solution of such problem is to use low cost nodes equipped with relevant networked sensors for data collection. Several nodes can be organized and formed a grid which will bring more complexity, and we will gather all needed information. If the goal is to secure object, or to gather info under the sky, it could be use nodes with GPS to know exact location, but considering power plan that is not energy efficient. Where is needed can be used mobiles and flying robots for deploying these nodes, and at moment when nodes are deployed, it can be marked GPS position. Thus are covered large areas and different surfaces. One of the main factors for such system development is the implementation cost. In order to achieve it is appropriate to use small, low-power nodes, which are controlled and supervised by a main network grid organized by LoRaWAN.

The paper presents a WSN extension to provide communication between the nodes and the gateway over LoRaWAN, instead of IEEE 802.11 (WiFi), instead of 3,4G.

This paper is focused on configuration and development of the networked sensors for monitoring and control the environment and security system. Many articles show variety of protocols and communication networks [2, 3, 4, 5]. Generally efforts are focused on problems with network possibility and delays, packet dropouts, address channel limitations related to the packet-rates, but there is no universal solution. In the paper problems definition, development suggestions and maintenance for networked sensors are made. This work summarizes solutions related to the network protocols and standards for predefined application. Proposition of node based sensor network with specified low energy protocols are also presented.

2. Layer protocols

Regarding to the OSI model is important to discuss the way of data transmission through layers. In this point of view the transmission method will be summarized.

2.1 LoRa™ is a proprietary spread spectrum modulation scheme that is derivative of Chirp Spread Spectrum modulation (CSS). It trades data rate for sensitivity within a fixed channel bandwidth. It implements a variable data rate utilizing orthogonal spreading factors, which allows the system designer to trade data rate for range or power. Furthermore the network performance is optimized in a constant bandwidth. LoRa™ is a PHY layer implementation and is agnostic with to higher-layer implementations. This allows LoRa™ to coexist and interoperate with existing network architectures. This application note explains some of the basic concepts of LoRa™. Modulation and

 ISSN 1310 - 8271

the advantages of the scheme can provide when deploying both fixed and mobile low-power real-world communications networks [6].

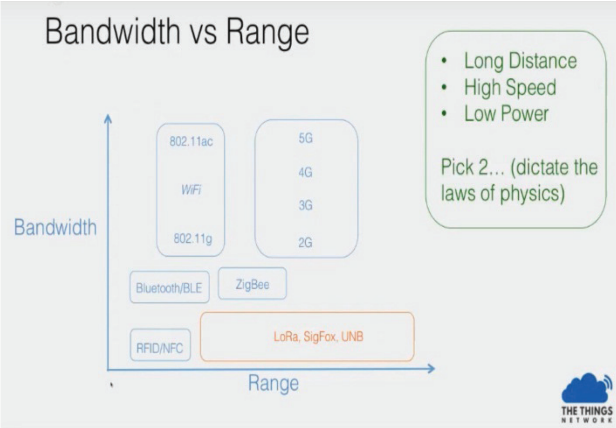


Fig. 1. *Representation of the relationship between Range and bandwidth of the signal*

Fig.1 presents relations between signal range for successful connection establishment and frequency bandwidth. In case of frequency decreasing regarding to the modulation the signal path increases with LoRa.

2.2 LoRaWAN™ /layer2/ is a Low Power Wide Area Network (LPWAN) specification intended for wireless battery operated Things in a regional, national or global network LoRaWAN would correspond to the Media access control (MAC) layer. LoRaWAN targets key requirements of Internet of Things such as secure bi-directional communication, mobility and localization services. It specification provides seamless interoperability among smart Things without the need of complex local installations and gives back the freedom to the user, developer, businesses enabling the roll out of Internet of Things.

The choice of transport protocol, when internet connectivity is need basically, is reduced to two options TCP and UDP. The Protocols allow multiple devices to communicate effectively using the Internet. However, the determination way for different data types, how are divided and stored in frames, are required. In case of a system design for collecting data in order to reduce the workload, related to the data exchange organization, it is possible to use application-layer protocols. There is variety of options. One is to use industrial automation protocols. In problem definition arises high cost of implementation.

By analyzing network protocols, extra attention should be pay to the model they use for data exchange. Many of the technologies used in modern computer systems use a data exchange model referred to as Request-Response. However, when you try to use such a model for data exchange in the sensor network you can encounter some difficulties. A possible solution is using the Publish-Subscribe method. In this method, the data publishing modules send it to a server called the broker, which then sends the data to clients subscribed to certain information. Using these methods of data exchange allows the clients to receive not all the information sent by the node, but only the data that interest. There is also no need to constantly calling the modules that generate information about the data.

2.3 MQTT protocol

Among different options described one of the most appropriate is MQTT protocol (Message Queue Telemetry Transport), details in [5]. It was designed in 1999 for transferring data from telemetry devices. The main goal of the designers was to create an efficient protocol to transfer data from devices with limited hardware resources, which is equipped with a low-performance microprocessors and a small amount of memory. Also expected to work in networks with severely limited bandwidth for data transmission. The protocol uses a publish-subscribe method and transmits the data over TCP/IP or UDP. In its implementation requires a special computer called a messages broker. The task of the broker is to collect messages and sending them to devices interested in specific information. Fig. 2 shows the organization diagram for data exchanging between Publishers and Subscribers by MQTT Broker.

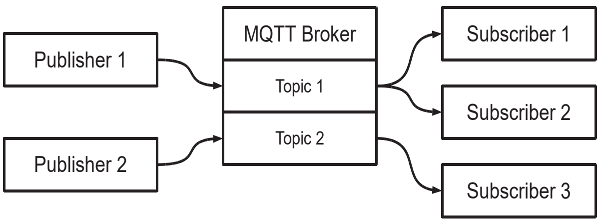


Fig. 2. *Organization of data exchange in MQTT.*

MQTT protocol messages are assigned to names that are topics. In context of the client and the broker, there is no need to configure the topic. The client sends a message to a specific topic. If there is a particular topic the broker will update its data, in the absence a new topic will be created automatically, to which will be assigned the information transmitted in the message. Topics may be organized in a hierarchical manner using the separator in the form of a forward slash (/). This allows us to organize data in a broker in a manner similar to the file system. Example topic for networked grid nodes may have the following form:

Network22/NODE11/sensor33/DATA

An important feature of the MQTT protocol is the ability to manage the quality of service by implementing QoS (Quality of Service). It allows you to manage the way to deliver a message and confirmation of its receipt.

3. System design and configuration

The developed solution for industrial network combines LoRa and MQTT protocol.

An important step in designing communication layer using MQTT protocol is to determine the structure of topics and related messages. In current system only test messages were send, which allows reading data from nodes sensors.

Therefore is achieved LPWAN based LoRaWAN, presented on fig.3. It is evident there is variety of tasks: many sensor types, devices through Gateway to the many user defined applications.

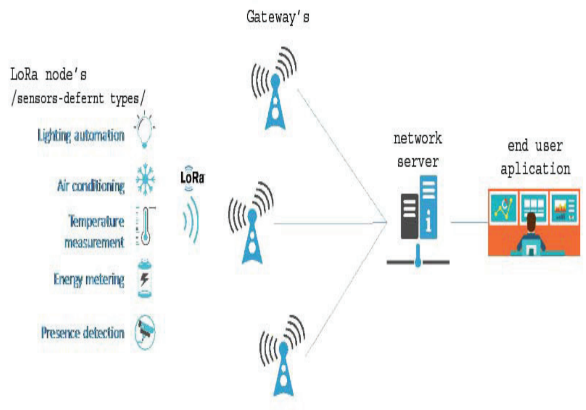


Fig. 3. *Overview of the developed network with industrial applications*

The network can consist of thousands nodes. In case of new LoRaWAL project is need a Gateway in case with no LoRa coverage. The proposed solution includes Gateway. This can be viewed as an advantage of the application, fig.4. LoRaWAN uses licence-free spectrum, usually ISM (Industrial, Scientific, Medical) bands to communicate over the air. In Europe, ETSI regulates the ISM band access on the 868MHz and 433MHz bands.

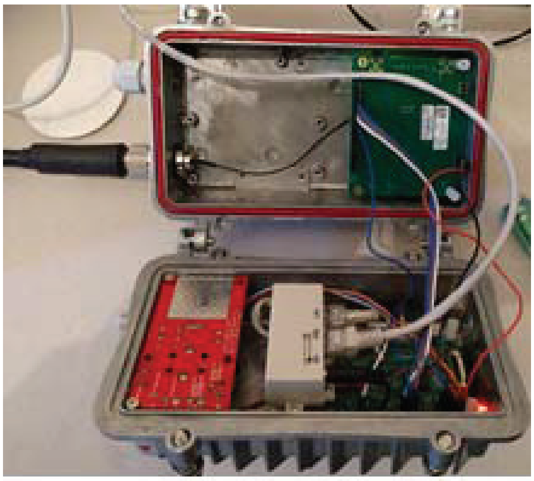


Fig. 4. *Designed and Assembled Gateway included in LPWAN*

The usage of these bands is submitted to limitations: The output power (EIRP) of the transmitter shall not exceed 14dBm or 25mW, and the duty cycle imposed in Europe by ETSI is limited to 1% (for devices) or 10% (for gateways) depending on the used sub-band. In this project the Gateway is placed on the laboratory roof. As an option in a startup it was assumed. The achieved signal coverage was good enough. In future work it will be improved. On the next fig. 5 are shown the used and connected LoRa nodes based on Microchip ®. In this way is developed and obtained network based on LoRAWAN.

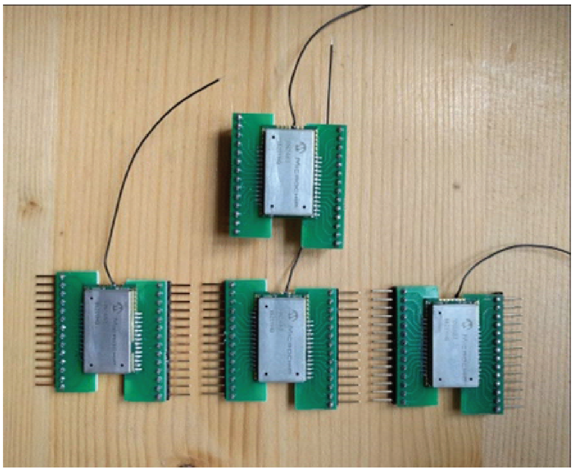
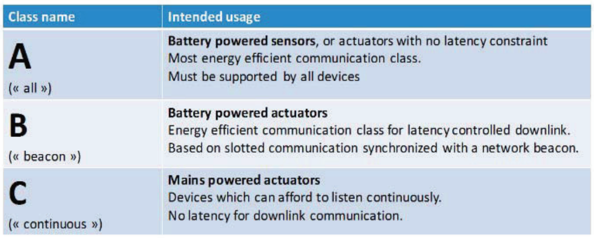


Fig. 5. *Numbers of the used nodes based on Microchip in the developed network.*

The architecture including three different classes (A,B,C), of communication profiles are available in LoRa networks between devices and applications, are presented on fig.6.

Fig. 6. *Typical system architecture of a LoRaWAN node*



Class name	Intended usage
A (« all »)	**Battery powered sensors**, or actuators with no latency constraint Most energy efficient communication class. Must be supported by all devices
B (« beacon »)	**Battery powered actuators** Energy efficient communication class for latency controlled downlink. Based on slotted communication synchronized with a network beacon.
C (« continuous »)	**Mains powered actuators** Devices which can afford to listen continuously. No latency for downlink communication.

Fig. 7. *Description of A,B and C profiles*

Each class serves different application needs and has optimised requirements for specific purposes. The key difference between A,B and C profiles is the trade-off made between latency and power consumption, fig.7. It is a difficult task to gather information from many and different points. In a stage of problem definition the task is related to a network design and configuration of nodes equipped with sensors. The proposed solution is based on a grid of networked nodes. If there is a lot of equipment, it is important to find a low-cost solution with low energy consumption. In order to reduce costs it is necessary to minimize the tasks of networked nodes. Therefore cable connections are not relevant or suitable. In such case of many distributed nodes cooperation, the option is to use radio communication. The solution performs the data transmission from the sensors to the gateway /one or many/. This allows using of nodes with low-cost microcontrollers. The power consumption. Easy operation and reconfiguration of the system are also given and discussed in [6].

Nowadays there are many radio communication standards, but not all are well suited to the task. The ability and widely used popular, not expensive modules with easy connection to the Internet is very important.

First one solution that comes to mind is the standard IEEE 802.11 (WiFi). It allows connecting multiple devices to the network, and easy integration with the Internet. However, it has the disadvantage of relatively high demand for energy, which is particularly important in the case of using small nodes to collect data. Among the standards for devices with low power the most interesting solution is using **LoRaWAN** network

IEEE standards are for the physical layer of the OSI model. They allow transferring data. But do not provide a convenient way to control communications and meeting the requirements of QoS (Quality of Service). Accordingly, the next step is the selection of a transport layer protocol.

Level2 Sections

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Level3 Sections

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4. Application in security area

There are many places around cities (levers, fields, car morgues, etc.) without electricity and 220V power supply. From security point of view this is a big problem and complex task. To establish and maintain the communication with such plant. The options are very less. Generally is used security system equipped with transmitters and detectors using 220V power supply. They are not applicable in such case.

It is possible to use GSM operators. We are facing with need to use special equipment with batteries. These batteries should therefore be charged. Even in this way the operability depends of the power supply. The lifecycle is not so long. This weakness is other come with the developed solution combining LoRaWAN and MQTT. In this way can be achieved promising security without 220V power supply.

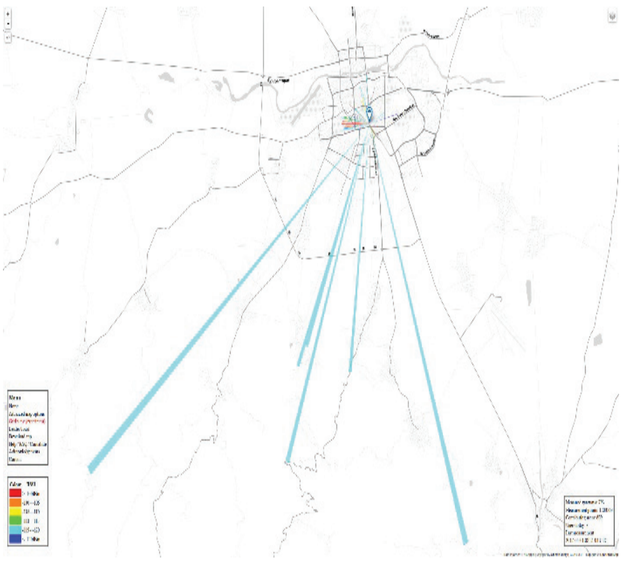

Fig. 8. *The coverage measurement with TTN mapper*

.LoRa uses low energy hence the workability is expected to be 5-10 years. To one node could be connected more than one detector and passive detectors as well.

The radio coverage of developed network, fig.8 can be viewed as an industrial solution in case with IoT implementation. The signal covers the laboratory location and connected nodes. To investigate and conduct the preliminary experiments is used software named TTN /The Things Network/ mapper, fig.9. The signal coverage and connected node was monitored. The results demonstrate the good enough signals. It shows the achieved passing of the signal at a large distance with low power.

TX- is the emitted power by the transmitter. The signal is gained by the Gateway. The signal above the dashed red line confirms the established and “good” connection.

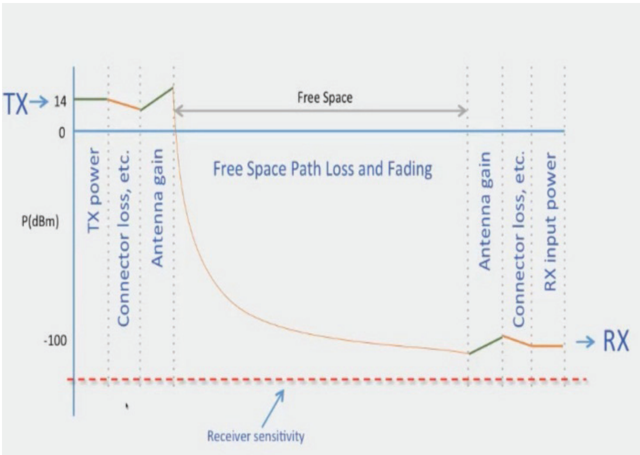

Fig. 9. *The TX and RX signals*

5. Conclusion

This work is devoted on developing, configuration and investigation of the network for security purpose in the case of missing 220V supply. A solution is found out by combination between the LoRaWAN network and MQTT protocol. All developed nodes covered IP 67 standard.

Some advantages of the system are: easy maintenance; low cost; low energy consumption; reliability and security; easy connection to the Internet, long lifecycle. The system nodes (the grid) can be enlarged with up to more than 1000 nodes connected with one gate.

In the particular test application for the industrial network development it is obtained promising results. There are eight connected nodes in this case study. Furthermore it will be possible and very easy to extend the node numbers if necessary. The idea could be associated with networked sensors for robots to perform various tasks. To industrial environment for monitoring process values like temperature, air conditioning systems and etc. Each “node” could present sensor one or many, or robot sensors, connected the main node through the Gatrway with LoRa. It is possible to use robots to spread sensors in case of hostile environment.

The paper shows an example of the use of open network protocols in networked mobile robot sensor system. MQTT protocol allowed for the use of standardized methods for data exchange in the sensor network. Also greatly simplified the integration of new nodes, the use of nodes information from other systems and integrating with the Internet.

The use of open protocols simplifies software development work, especially when it consists of a large number of independent nodes. Also simplifies the maintenance process, since it is possible to read information about the industrial values and the status of individual sensors without having to use special tools. Future work will be focused on industrial network implementation.

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ACKNOWLEGEMENTS

The authors would like to acknowledge Ministry of Education and Science of Bulgaria, Research Fund Project No: DFNI-I 02/6/2014.

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