Localization of Transport and Logistics Units through IoT Technologies

Jiří Tengler[1], Andrej Dávid[2], Margita Majerčáková[3], Adam Torok[4], Sláva Gašparová[5]

[1] Department of Communications, University of Žilina, Žilina, 01026, Slovak republic
[2] Department of Water transport, University of Žilina, Žilina, 01026, Slovak republic
[3] Department of Communications, University of Žilina, Žilina, 01026, Slovak republic
[4] Institute for Transport Sciences, Budapest University of Technology and Economics, Budapest, 1111, Hungary
[5] Department of Communications, University of Žilina, Žilina, 01026, Slovak republic

Abstract The paper deals with the application of IoT (Internet of Things) technologies for localization or other monitoring functions for logistic units using the IoT element. At the beginning of the paper, we analysed currently the most used technologies for localization and monitoring of logistic units. Then, we described the basic requirements for LPWA (Low-Power Wide-Area) technologies, including the information they can collect and provide. The main part of the paper is devoted to the design and testing of IoT solutions based on one of the LPWAN (Low-Power Wide-Area Network) technologies for a real logistics company. The conclusion of the paper is dedicated to testing the evaluation and prognosis of further use of LPWAN technologies.

Keywords IoT, LPWAN, Logistics, Logistics unit, systems

JEL L90, L96, L99, L86

1. Introduction

The current trend of most companies is to increase the efficiency of their processes. It is no different for logistics companies or companies that use logistics within their business processes. The main reasons for carrying out these activities and measures can be different. In general, these reasons are linked to dynamic economic changes as well as increasing supply chain pressure. The above-mentioned changes are mainly related to an acceleration of production cycles of products while maintaining and increasing the high quality of processes (service products). The process of eliminating bottlenecks in the transport process and the related increase in competitiveness and more is also important. That is a set of processes that enable the logistics unit to be transported at the right time to the right place and in the required quality, all while maintaining optimal costs. Although the logistics discipline addresses the above parameters, it has not always been possible to effectively control them throughout the entire transport process. The reason for this is simple. In general, there was no way to efficiently collect data within these processes in real-time.

As it has been mentioned for effective management of these processes, a considerable amount of high-quality input data is required. That is such input data that could be collected and evaluated in real time to identify their point of origin. It is very difficult to imagine a similar concept that would automatically and effectively collect these input data 10 years ago. However, information technologies have matured to the point where we look at the whole issue from a different perspective. It is not only about new technologies, but also about new approaches, ideas, creativity, and a way of thinking that lead to problem-solving. All these developments have led to the possibility of attaching specialized small electronic devices of varying functionality to logistics units. Overall, this concept has evolved into an area known as the Internet of Things.

The main goal of the research was to verify the possibilities of using LPWAN technology for the localization of vehicles and logistics units. The actual verification of the created solution was subsequently verified at a selected logistics company. The research itself was carried out not only to verify the test equipment but also to map the signal coverage of the Sigfox network.

2. Internet of things

Although the name "Internet of Things" does not accurately reflect its true depth, its definition is quite the opposite. Several definitions generally describe the meaning and content of the Internet of Things concept. It is equally important to emphasize that the definitions may evolve, themselves. We can simply explain this concept in one simple definition. The Internet of Things is a network of physical objects, especially day-to-day needs that are legible, recognizable, addressable through information capture technologies and accessible over the Internet, regardless of the type of Internet communication protocol. The subject of this paper is selected technologies for localization and transmission of telemetric data in the area of logistics and that is why only mentioned technologies are mentioned here. [1]

LPWAN is a low-power, low-power broadband network. These are wireless technologies that allow you to connect low-voltage and low-bandwidth devices at low intervals. Even though LPWAN technology has existed for some time now, its implementation is largely intended for the Internet of Things. LPWAN has higher energy efficiency and lower costs than standard mobile networks. They can also support multiple connected devices per node. The size of messages transferred subsequently can range from 10 bytes to 200 kilobytes. The communication distance of the type of technology used is up to 40 km. Most LPWAN networks have a star topology where the endpoint is connected to the access points (node gates). In view of the possibility of using LPWAN networks in logistics, we selected three networks that pose the greatest potential for the monitoring of logistics processes. [2,3]

Within LPWAN, several technological solutions differentiate their character. The differences may be apparent at the following points:

- use licensed, unlicensed bands,
- use of closed or open Standards,
- limitations on the number or size of messages,
- possibilities and distance of message sending,
- the capabilities of creating your local networks, etc [2,3]

Sigfox is a global operator with the same network name based in France. A specific feature of this network is that all the data from all sensors are sent and stored in the cloud on servers in France. Then, the data is distributed from the servers to the parent company's user systems. The key element and the very character of LPWAN technology is the quality of Sigfox transmission and low power consumption. The transmission is not synchronized between the device and the network. The device sends a message at a random frequency and then sends two identical messages at different frequencies. The principle of cooperative reception is that, unlike the cellular protocol, the object is not connected to a specific base station. The broadcast message is received by all base stations nearby. [3,4,5]

In general, Sigfox technology has a rich base of technology partners developing simple or combined communication modules. Thus, such combined modules contain the most common types of sensors. This is because Sigfox tries to get into the position of a global service provider for the Internet of Things. However, each technology has its weaknesses. The maximum message size that can be sent has a size of 12 bytes. Similarly, the maximum number of messages sent per day is only 144. It is based on one message sent every 10 minutes. [3,4,5]

In the field of logistics, these are primarily Sigfox modules that allow localization of logistics objects through GPS coordinates. A huge range of connectable sensors also allows you to increase the value added when monitoring logistics units. They can be sensors: temperature and humidity, opening sensor, sunshine sensor, vibrations, and shocks ad.

Sigfox in its basic form enables geolocation. The geolocation is realized based on the radio signal of the sent message. The key is the RSSI value of the sent message captured by several stations. These values are then compared to one another. Depending on the location of the base stations, it is possible to analyse the location of the message with accuracy from a few meters up to several kilometres. [2]

LoRaWAN is another low-power wireless network protocol designed for the Internet of Things. Communication between end objects and gates is spread over different frequency bands and transmission rates. Choosing the data transfer rate is a compromise between the communication range and the length of the message. Individual communication streams with different baud rates do not interfere with each other, but they create a set of "virtual" channels to increase gateway capacity. The LoRaWAN network server manages the baud rate and RF for each end device individually through ADR (Adaptive Data Rates). All of this leads to maximizing battery life and efficient network capacity utilization. The LoRa system is based on spread spectrum modulation. LoRaWAN defines the communication protocol and network architecture of the system, while the LoRa physical layer allows long-distance communication. [6,7,8]

Like the Sigfox technology, Lorawan has endpoints, access gates, and a network server. Communication is similar, again asynchronous. The sent message is received by all gateways in the vicinity and sent to the network server. Unlike other solutions, the entire access network and its components belong to the customer. The entire communication and data flow is managed by end users. This gives users a great deal of flexibility to customize the network settings. [6,7,8]

Similarly, both Sigfox and LoraWan have the means to geolocation their transmitting devices. For the success of geolocation, it is necessary to receive at least three base stations. The principle consists in naming the transmitted message with a time stamp and comparing this value with a time stamp by receiving messages within the abovementioned base stations. [1,6]

NB-IoT (NarrowBand IoT) is a standard-based LPWA technology designed to connect a wide range of new devices and services. Significantly it improves user equipment power consumption, system capacity, and spectrum efficiency, especially with inflated overlays. Battery life is over 10 years for a wide range of applications. It is designed to meet the demanding requirements of extended coverage, remote or deep in the interior, and very low complexity of the equipment. [8,9]

NB-IoT works in compatibility with LTE (Long Term Evolution) mobile networks, utilizing all the security and privacy features of mobile networks. One of the main advantages of this new standard is its compatibility with traditional cellular networks. Data transmission is limited to 250 kbps for transmitting and 20 kbps for receiving signals. [8,9]

3. Materials and Methods

Design and testing of IoT equipment were realized for an unnamed manufacturing company which is engaged in the production of parts for the automotive industry. Its integral part is also the implementation of logistics operations. This company manufactures and supplies its parts for different landscapes in Europe. These are mainly Germany, Poland, the Czech Republic, Hungary, and others. That is why this company needs to have enough information about its logistics units. One of the shortcomings that this company feels is due to the lack of real-time information on the current location of its means of transport. If these data were available, it would be easier for the company to eliminate bottlenecks in the transport process. It would also improve interoperability between the company and the buyers of their goods. [10]

Main requirements for location devices:

- they can be connected not only with the means of transport itself but also with the trailer itself or with a specific logistics unit (container and pallet),
- a long battery life,
- use of localization and also sending of information from the countries of the customer (coverage of the technology network),
- easy scalability (option to add additional sensors). [10]

Nowadays, many states, not only in the European Union but in other parts of the world, report that their state has already implemented one or another technology. However, the truth is a little more complicated and is primarily related to the coverage of a network. Just as mobile operators try to cover the largest part of their territory with the signal, these LPWAN operators have the same task. If we mention Lorawan technology, there is no ambition to become a global operator. Therefore, it will always be a technology that can only help in the territory where the technology is applied, for instance in the area of large cities or industrial zones. Other mentioned technologies NB-IoT has already had ambitions to become a global operator, but the speed of their implementation at present in the territory of the Slovak Republic and other EU countries is not enough. The last mentioned Sigfox technology has a relatively large coverage of the territory of Slovakia and the states to or through which it carries out transport activities. Information on the level of Sigfox network coverage can be found on the Sigfox website. For this reason, Sigfox technology has been chosen for this design and testing.

The design of this device was conceived in such a form to allow the additional connection of other peripherals. The basic part of the whole design was the Arduino nano integrated circuit which was modified to reduce overall consumption. The GPS module GPS6MV2 with the appropriate receiving antenna was chosen for localization. The Sigfox WiSOL SFM10R1 communication module including the antenna and a test license valid for one year was chosen for communication. There are several Sigfox modules on the market that allow communication in various ways. The main advantage of the above-mentioned module is the relatively low price and the possibility of simple communication via AT commands. Atmel Studio and Arduino IDE were used for the programming of integrated circuits. The first assembled model is shown in Figure 1 and the improved version of this model is presented in Figure 2.

Figure 1. Model sample no. 1 [10]

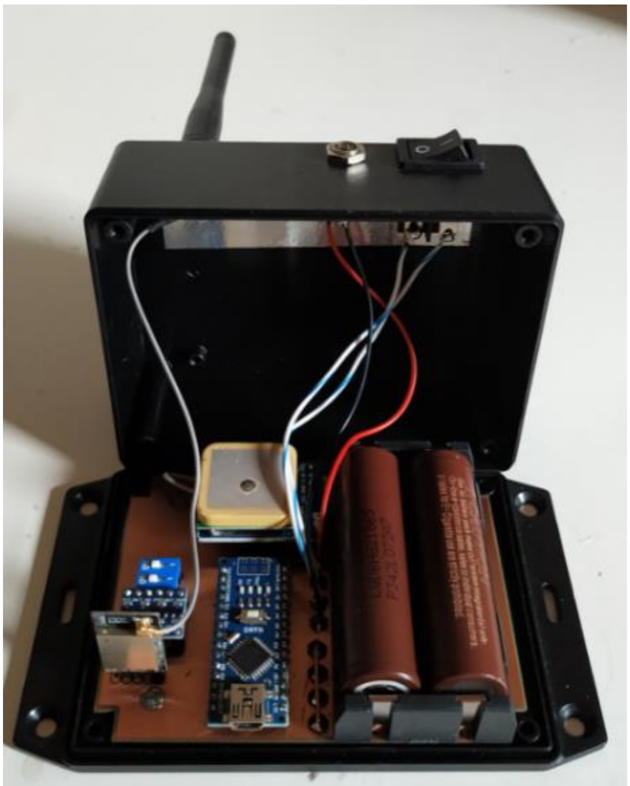

Figure 2. Improved model sample no. 2 [10]

The main information that is sent by the device is the GPS coordinates. The maximum message size is 12 bytes. Most of the capacity can be used for more accurate GPS coordinates or in varying proportions of less accurate coordinates in combination with other outputs of potentially connected sensors. The messages are always sent to the Sigfox cloud. They can be routed from the cloud to superior systems by various methods. You can also connect to so-called emulated networks. One of the devices that emulate the Sigfox network is the SDR dongle. This device was used in laboratory tests. Within the backend of the Sigfox cloud, you can view the messages of connected devices, set methods, routing and types of output data read by individual modules. An example of the display of individual messages sent by a specific module is shown in figure 3. The software to the SDR Dongle hardware emulator has a very similar functionality and visual appearance.

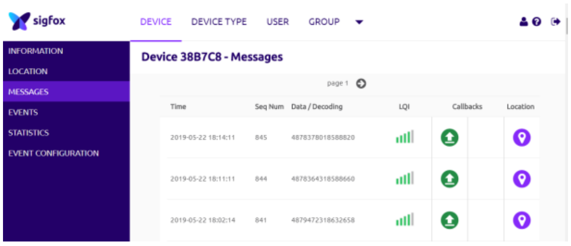

Figure 3. Example of graphical interface sifox backend [10]

There are several options for routing data. These are mainly the services of IoT platforms. Of course, you can connect to your own servers. This can be used, for example, by using known HTTP methods such as "GET", "POST" or "PUT". This research used the GET method on the one hand and a PHP server with a script on the other hand. All incoming messages from the Sigfox cloud are processed and stored in the MariaDB web database server. The Apache server also runs on the same server. The stored data can then be visualized via web applications or other services on the Internet. Within the created application, it is also possible to export the selected data to an XML file in GPX format (GPS Exchange format). The exported file can be used again for visualization within the Internet services or through desktop applications. The whole process is better seen in the following figure.

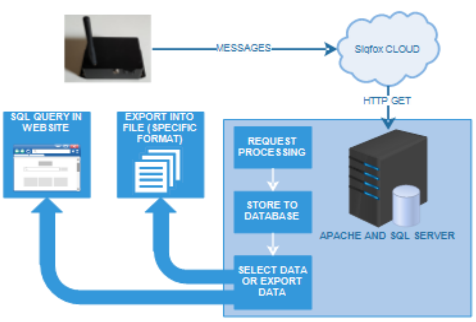

Figure 4. The principle of storing and retrieving data in the created solution

Within the web application, it is possible to monitor a means of transport, a semi-trailer or a logistics unit located within a means of transport in real time, including their location. The output of web applications can be seen in Figure 5.

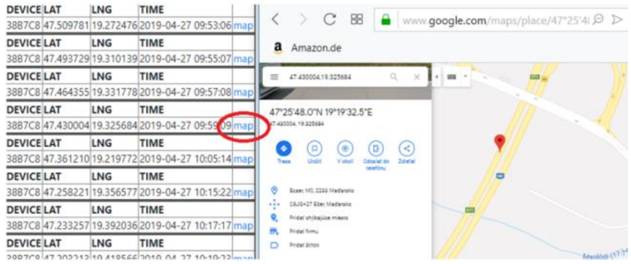

Figure 5. Example of output data in the presentation module of the created solution [10]

4. Results

Testing of the created solution took place in a laboratory and real environment in the company producing components for the automotive industry. Laboratory testing consisted of finding errors and optimizing the equipment for the real environment. The SDR dongle emulator was used in laboratory tests.

The first real testing took place between two branches of the company, one of them was located abroad. The test subject was a vehicle carrying parts. The location device was attached to the front instrument panel. The starting point of the journey was a place near the town of Prievidza and the destination point was a place near the Hungarian town of Kecskemet. The standard route is 322 km long and the time needed to implement this trip was set at 4 hours and 45 minutes. As was mentioned the maximum number of messages set for one day is a maximum of 144 messages (1 message every 10 minutes). Because the trip was planned for a shorter period, the recording time was set at 1 message for 2 minutes. The expected number of messages was about143 pieces per journey. The tested vehicle set off from the starting point at 06:43 and arrived at the destination at 020: 53. The total travel time was shorter by 35 minutes, ie the travel time was 4:10 minutes. The expected number of messages was adjusted to 125 in time, only 47 messages were recorded. The shortest difference between adjacent scanned points was in the value 00:02:05, ie the corresponding setting. The largest difference between adjacent scan points was 00:16:06 which was significantly more than the scanned value. The device was set to send the message only if it read the GPS coordinates and was also close to the Sigfox base station. From this, it can be concluded that the vehicle was not always in an ideal environment, which would allow it to read the coordinates and send a message at the same time. In the end, the average retrieval time of one message corresponded to the time value 00:05:29. The output of this testing can be seen on the used geolocation application programming interfaces in Figure 6. At present, the countries of Europe are constantly expanding to cover and improve the optimal operation of the Sigfox network. The use of other components could also significantly increase the ability to obtain GPS coordinates. However, this is the subject of further research. It can be assumed that the gradual expansion of networks, but alternative solutions for remote messaging will allow a more massive deployment of these technologies. [10]

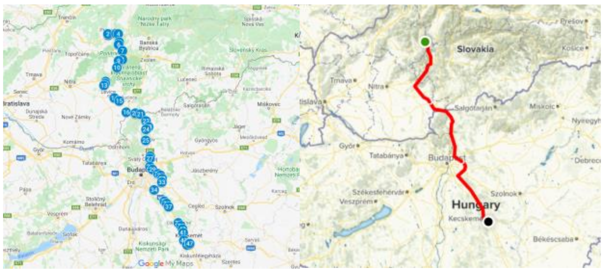

Figure 6. Rendering coordinates into google maps using the created application (on the left) and Rendering coordinates into the Alltrails app (on the right) [10]

5. Discussion

The main goal of the research was to verify the possibilities of using selected LPWA technology for the location of vehicles and logistics units. Although the results of the research did not reveal such great ambitions, they can be considered successful. Thus, it is possible to identify at least every quarter hour where a particular vehicle is located. It is also possible to identify the average time shift between the recorded points.

Based on the results of testing in a real environment and their subsequent analysis, provides us with additional facts. Then, these facts will be used for further research in this area. This research will consist of the use of alternative hardware modules (ie GPS, Sigfox module as well as different antennas for these modules) and the different ways of placing the device in a vehicle. After changes and new measurements, the analysis of individual experiments will be performed again to maximize the obtained data. Given the current logistics requirements, it can be assumed that LPWA technology will be essential for real-time data acquisition in the future.

The research was carried out on the territory of two states that have Sigfox technology widely spread on their territory. Unfortunately, the situation in other countries, where the production company carries out its logistics, is currently under construction. For this reason, the research could not be applied to other places. However, this will change in the future and testing on other routes is planned. For the same reason, the manufacturing company does not currently plan to implement this technology in its processes. It can be logically concluded that the future rate of use of this technology in international logistics is determined primarily by the existence and degree of coverage within the territory.

6. Conclusion

Based on the facts found above and the results of research and testing, it can be concluded that the use of Sigfox technology is highly applicable to the field of logistics. Location localization can be assisted with the help of these devices via RSSI or time stamp or via a connected GPS module. By using the individual options, it is possible to obtain the location of logistics units from the orientation position very accurate. From the point of view of existing similarly furnished based on classic GMS communications, there is no revolution at first glance. When looking at the whole issue deeper, just the price and high consumption of classic GMS modules, was the main reason for the bad use of such devices in logistics. The main positive aspects of LPWAN technology are not only low consumption with a battery life of 15 years but also a lower purchase price compared to GMS technology. Of course, the semi-object is one piece of information, but additional information can be sent via additional modules. Additional information such as transported subjects may include information about the environment in which the transported subjects are and how it affects them. All this information is the source of decision-making or the basis for the possible elimination of bottlenecks in the transport process. These old-new technologies make it possible for logistics to be upgraded to a remarkable level. Because they can track real-time logistics subjects, whether in a shipping process or a warehouse. In the end, an important aspect is whether the information so accumulated will be correctly interpreted.

ACKNOWLEDGEMENTS

"This publication was realized with the support of Operational Program Integrated Infrastructure 2014 - 2020 of the project: Innovative Solutions for Propulsion, Power and Safety Components of Transport Vehicles, code ITMS 313011V334, co-financed by the European Regional Development Fund".

EUROPEAN UNION
European Regional Development Fund
OP Integrated Infrastructure 2014 – 2020

MINISTRY
OF TRANSPORT
AND CONSTRUCTION
OF THE SLOVAK REPUBLIC

REFERENCES

[1] Barker Peter, Hammoudeh Mohammad, "A survery on low power network protocols for the Internet of Things and wireless sensors networks", Manchester Metropolitam University, ICFNDS '17: Proceedings of the International Conference on Future Networks and Distributed Systems, no.44, pp.1-8, 2017.

[2] Sigfox technical overview, Online Available: https://www.disk91.com/wpcontent/uploads/2017/05/4967675830228422064.pdf.

[3] Kais Mekki, Eddy Bajic, Frederic Chaxel, Fernand Meyer, "A comparative study of LPWAN technologies for large-scale

IoT deployment", ScienceDirect, ICT Express, vol.5, pp.1-7, 2019.

[4] Sigfox white paper, Online Available: https://www.sigfox.com/en/sigfox-iot-technology-overview

[5] LPWAN Sigfox node datasheet, Online Available: https://www.lpwan.cz/LPWAN_sigfox_node_datasheet_v1.pdf.

[6] Kranz Macej, Building internet of things, 1st ed., Willey, USA, 2017.

[7] Gnimpieba D. Nait-Sidi-Moh, Durand David, Fortin Jérôme, "Using Internet of Things technologies for a collaborative supply chain: Application to tracking of pallets and containers", ScienceDirecect, Procedia Computer Science, vol.55, pp.550-557, 2015.

[8] Bernat C. Fargas, Petersen N. Martin, "GPS-free geolocation using LoRa in low-power WANs" GIoTS -. 2017 Global Internet of Things Summit, pp.1-6, 2017.

[9] NB-IoT – enabling new business opportunities, Online Available: http://www.huawei.com/minisite/4-5g/img/NB-IOT.pdf

[10] S. Gašparová, "Lokalizácia dopravných prostriedkov s využitím technológií IoT vo vybranom logistickom podniku", M. thesis, University of Žilina, Slovakia, 2019.

[11] Ferran Adelantado, Xavier Vilajosana, Pere Tuset-Peiro, Borja Martinez, Joan Melia-Segui, Thomas Watteyne, "Understanding the Limits of LoRaWAN", IEEE Communications Magazine, vol.55, no.9, pp.34-40, 2017.

[12] Kamil Židek, Ján Piteľ, Peter Lazorík, "IoT System with Switchable GSM, LoRaWAN, and Sigfox Communication Technology for Reliable Data Collection to Open-Source or Industrial Cloud Platforms", New Approaches in Management of Smart Manufacturing Systems, EAI/Springer Innovations in Communication and Computing, pp.311-333, 2020.

[13] Lucia Madleňáková, Anna Paďourová, "The implementation of automatic identification in the distribution process", Pošta, Telekomunikácie a Elektronický obchod, vol.16, no.1, pp.59-64, 2020.

[14] Radovan Madleňák, Lucia Madleňáková, Zuzana Kolarovszká, "System of management and traceability of logistic items through new technologies", Procedia - social and behavioral sciences, vol.230, pp.128-135, 2016.