"PROGRESS AND PERSPECTIVES: LPWA AND LORA NETWORKS IN THE ERA OF THE IOT REVOLUTION"

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ABSTRACT

LoRa (Long Range) and LPWA (Low Power Wide Area) networks represent wireless communication technologies, specially designed for the needs of the Internet of Things (IoT). LoRa is a specific technology within the LPWA category. These networks make it possible to connect a large number of devices over long distances with minimal energy consumption. Key features include long reach, low latency, energy efficiency and the ability to connect devices from different manufacturers. Applications include smart cities, agriculture, industry, healthcare and energy. The success of these technologies in Bosnia and Herzegovina depends on various factors, including regulatory framework support, user understanding, investment in infrastructure, and cooperation between the public and private sectors. Further development is expected with a focus on increasing capacity, interoperability, security and application in different sectors, which will contribute to the growing adoption of IoT technologies. The implementation of LoRA and LPWA networks requires a multidisciplinary approach that includes aspects of communication technology, hardware, security and software. It is important to carefully plan, test and maintain the network to ensure its effectiveness and stability over time.

***Keywords**: Long Rage, Low Power Wide Area, Telecommunications Operators, Scalability, Frequency Modulation*

1 INTRODUCTION

LoRa and LPWA networks include understanding the key characteristics and benefits of these technologies that are specifically tailored to the needs of Internet of Things devices. LoRa is a wireless technology designed for long-term communication over long distances with low energy consumption. This technology enables the connection of a large number of IoT devices, which are often distributed over a wider geographical area. The key advantage of LoRa networks is the long range of communication, which can reach several tens of kilometers. LPWA networks represent a category of wireless technologies that stand out for their low energy consumption and the ability to connect a large number of devices over long distances.

2 LPWA communication technologies

IoT wireless networks are evolving to support the needs of a wide range of connected devices – from connected cars and smart homes to smart lighting and infrastructure. Low Power Wide Area Networks (LPWA) are particularly suitable for IoT systems that require low power consumption, extended battery life, and operator-level security. Several different technologies, including LTE-M and Narrowband IoT (NB-IoT), are currently being developed and deployed to support emerging IoT needs. LPWA will have a significant impact on the growth rate of future IoT innovations, and this is only part of what is expected. Building a successful IoT system means matching connectivity needs with the right technology or combination of technologies. The key criteria are: coverage, data flow, mobility, latency, battery life and price. For example, bandwidth is the speed at which data is exchanged over a network. For smart city parking, toll collection, lighting management, specifically where data exchange is minimal and can be managed using controlled time intervals, data flow may be one of the lower priorities. However, if the application is for media streaming, telemedicine, or scenarios involving video, then a higher bandwidth, lower latency network is required. LPWA represents a set of wireless IoT communication standards that enable battery-powered devices to transmit small amounts of data over large geographic areas and in situations where signal conditions are demanding, such as inside buildings or underground spaces. Wide Area Network (WAN), in this case Wireless WAN (Wireless Wide Area Network - WWAN) has lower transmitter power even compared to other "weak" transmitters such as mobile devices, hence the term "LP" (Low Power). LPWA is a term that refers to any network designed for wireless communication and with less power than other networks. Such as mobile, satellite or WiFi technologies. LPWAN is the same as LPWA, only the N is added as Netvork, which means network. LANs and WANs are very similar to LPWANs, so this technology does not have its own precise definition. There are low-power networks such as Bluetooth or NFC, which can communicate over short distances, and wide-area, low-power LPWAN networks, which can communicate over longer distances and consume less power. High data transfer rates (gigabits per second) of LTE Advanced and the well-known 5G networks are characteristic of modern mobile networks, while LPWA networks can transmit very little data, mostly a few thousand bits per channel, but LPWA technology has the ability to communicate over long distances. LPWA technology comes in many forms, such as ZigBee, SigFox, Nwave and NB-IoT. LoRa Alliance LoRaWAN (Long Range Wide Area Network) stands for long range wide area network. Alliance LoRa is a non-profit association that defines and works on the implementation of the LoRaWAN protocol. There is no dominant or standardized protocol for LPWA networks, but Alliance LoRa is working on it. Alibaba, Cisco, IBM, Charter Communications and SoftBank are some of the big tech names representing Alliance LoRa members. Wireless communication that is standardized to transfer small packets of data (approximately a few kilobytes) in infrequent bursts (no more than 100 times per day) is known as NB-IoT applications. Mobile operators have been improving their networks since 2016 to provide their customers with narrowband IoT coverage. There are two categories of LPWA technologies, namely licensed and unlicensed LPWA technologies.

2.1 CHARACTERISTICS OF LPWA

Low cost and extended battery life used to be major considerations in IoT system architecture. LTE-M and NB-IoT represent solutions for these factors. LPWA technology offers clear advantages over traditional IoT cellular connectivity options. Total connection costs are expected to be lower than traditional mobile broadband services due to wide area coverage and expected peak capacity per cell. In addition, LTE-M and NB-IoT provide up to 10 years of battery life for many IoT-enabled devices. While 12 to 24 hours of battery life may be sufficient for devices such as consumer wearables, battery life for remote asset monitoring devices will require much longer. For example, autonomous charging devices that track assets in the supply chain can take anywhere from 7 to 30 days or more, depending on transit time or whether the device is transported by land, sea, or air. Simple on-off or completely empty use cases, such as tracking trash cans or liquid storage containers, require years of field operation on a single battery charge.

The LPWA network has various characteristics which include: Signal penetration is possible in hard-to-reach underground areas with a long range of several kilometers to several tens of kilometers. This ability was previously impossible to achieve.

Depending on usage, the devices boast excellent battery life thanks to their energy-efficient design. This is achieved by applying optimal energy consumption practices.

Decreasing the cost of devices greatly simplifies the required communication infrastructure, hardware design, communication methods and protocols. This in turn reduces the monthly or annual maintenance costs of both the device and the communication infrastructure. These devices have different priorities and prioritize speed and latency over the aforementioned range, durability and coverage. In 2015, the wireless industry association GSMA established a list of standards that LPWA networks must follow in order to reduce energy costs and expand coverage. Acceptance of LPWA technology in IoT applications sets prerequisites that also require minimal energy consumption. In addition to NB-IoT, there are two additional LPWA standards based on base station connections: Enhanced Machine Type Communications (eMTC), now called LTE-M, and GSM Extended Coverage (EC-GSM-IoT). These standards are often referred to as "Mobile IoT", although this terminology is imprecise as older mobile technologies are used for M2M and IoT, although not optimized for this type of functionality. NB-IoT and LTE-M are compared because they are the two standards most widely promoted by system manufacturers, service providers and network operators in the mobile industry. In addition to NB-IoT and LTE-M, there are also LPWA implementations that do not use the access network of mobile operators for communication with IoT devices, the so-called non-cellular (non-cellular) LPWAN standards, available from various companies such as LoRa and SigFox , which do not use communication using network cells, but use their own network with access points and unlicensed frequency spectrum. In addition to NB-IoT and LTE-M, there are also LPWA implementations that do not use the access network of the mobile operator for communication with IoT devices, the so-called non-cellular (eng. non-cellular) LPWAN standards, available from LoRa and various companies, such as SigFox, which do not use network cells for communication, but use their own networks with access points and unlicensed spectrum.

2.2 LPWA AND IoT

There are several important factors for the existence of the IoT concept, namely:

- Services or services: The integration and implementation of certain components of the IoT project takes place through them.
- Software: Firmware and application software enable IoT hardware to operate and communicate with end users.
- Hardware: Includes various chips, sensors, modules that communicate with each other and devices that communicate with end users.
- Network: Satellites, various access points and other infrastructure that connects hardware components with users. The Internet is most often used, or the network structure of the Internet of Things system is connected to the Internet.
- Analytical solutions: software solutions of artificial intelligence and analytics for making the necessary decisions in the appropriate processes.

The applications of IoT are very wide, some of them are: personal use (various reminders), household (energy consumption, device control), cities (traffic mitigation, waste control, efficient street lighting, air pollution monitoring), industry (quality control) and environment (water level monitoring, environmental protection). When designing and implementing new IoT systems, factors such as network equipment cost, battery life, transmission speed, latency, mobility, range, coverage, and development models need to be considered. No single technology can serve all projected applications based on IoT systems. For example, WiFi and BLE (Bluetooth Low Energy) are widely accepted standards and serve applications related to communication with personal devices well. Mobile cellular technology is an excellent solution for applications that require high data throughput while simultaneously providing power. In order to better meet the communication requirements that IoT systems have to fulfill, a number of new protocols and technologies have appeared. LPWAN (Low Power Wide Area Network) is a term that includes networks with wide coverage and low power consumption.

Thus, LPWAN represents a term for a group of technologies with the following key characteristics:

- Long battery life (often over 10 years).
- Wide area coverage and connectivity.
- Low cost of chipset and network.
- Limited data transfer capacity.

Broadband communications become more efficient and cost-effective with the help of LPWAN technologies. These technologies are complementary to mobile cellular networks and short-range technologies, enabling better energy consumption and lower costs.

3 LoRa

LoRa is a method of transmitting radio signals using linear frequency modulation, a multi-symbol format. LoRa is a physical layer or wireless modulation used to create long distance communication links. Many existing wireless systems use digital frequency modulation (FSK) at the base layer because it ensures low power consumption. LoRa is based on Chirped Spread Spectrum (CSS) modulation, which, like FSK, consumes less energy, but has a greater communication range. The main advantage of LoRa technology is its long range. The reason for this is that, under ideal conditions, one node can cover an entire city or hundreds of square kilometers. The range is highly dependent on the environment and obstacles. However, LoRa and LoRaWAN technologies have a higher connection budget (up to 170 dB) than other standard communication technologies. Other advantages of LoRa technology are resistance to fading and Doppler effect. Therefore, LoRa is used in designing low-power and WAN-connected devices for machine-to-machine (M2M) or IoT needs. LoRa works in frequency bands of 868 MHz and 915 MHz, depending on the region of use. In Europe, the ISM (Industrial, Scientific and Medical) band of 868 MHz (863-870 MHz) is used. The band is divided into 8 channels with center frequencies 300 kHz (0.3 MHz) apart and the last two channels 1 MHz apart. The frequencies used in the United States, Canada, Australia, Singapore and Israel are also from the ISM band and are 900 MIHz (902-928 MHz), with the range divided into 12 channels, and the distance between center frequencies is 2.16 MHz.

3.1 Area of use of LPWA technology

Technologies that work on LPWA are necessary to consider adoption for a variety of reasons. They provide a multitude of benefits that can make your daily processes run more efficiently. LPWA is a technology that serves low power, wide area networks. It uses minimal amounts of energy, which saves costs, and can transmit data over long distances. Advantage of use. By adopting LPWA, operations can be improved and data can be collected in an even more accurate and timely manner. Providing IoT devices with a high level of security, both technologies have modern and advanced authentication mechanisms and encryption. Ideal for scalable connectivity, LTE-M and NB-IoT networks can support a large number of IoT devices being deployed. Delivering the massive machine communications (mMTC) backbone of 5G are standardized technologies known as LTE-M and NB-IoT. Although they are separate, they are inextricably linked. LTE-M and NB-IoT are complementary LPWA IoT technologies. LTE-M, on the other hand, is best for supporting asset trackers, fleet trackers, smart watches, alarm panels, pet trackers, smart home appliances, patient monitors, utility meters, and point-of-sale devices. However, there are some overlaps. For example, both can support smart metering depending on specific needs and requirements. Modules and devices are increasingly appearing on the market built for the dual use of two technologies.

3.2 Parking management

Parking management has various uses, such as a sensor near the parking space that reports the occupancy status. This data can be used for a variety of purposes, including showing how many free parking spaces are available in a garage or outdoor parking lot. For LPWA networks in this application, low power consumption capability is prioritized over long distance connectivity. It is quite problematic to change the batteries in a lot of parking monitors, which is why saving energy is crucial.

3.3 Water meters and pipelines

Leakage reporting can be done in advance using a transmitter pressure gauge. Leak testing pipelines over long distances without an existing network is essential, especially with a battery life of several years. Urban areas also benefit from long-range signals, which can track pipelines buried beneath the city's underground system. In rural areas, the same signals offer remote communication to monitor leaks.

- Smart palettes

Assuming frequent handovers, shipment tracking involves scanning the cargo each time. The assumption is then that the cargo is in the same location if there are no recorded changes, or if it is en route, it would be on the same train or truck. If a smart pallet is used, location updates will be continuous and will additionally provide feedback on possible cases of mishandling or if the container has been opened. LPWA is needed not only because of the possibility of communication over long distances, while the shipment is in motion between cities, but also because of the long life of the batteries, which ensures timely and accurate information.

- Street lighting and highway lighting

Smart lighting is powered by billions of semiconductor LED light sources, creating a unique and efficient way to illuminate your environment. The IoT industry in this country is gaining momentum as one of the biggest contenders in this field. Its wide range of available network technologies contributes to its rapid growth. Sigfox, NB-IoT, RPMA and Weightless are Low Power Networks (LPWA) that show potential. Public and private networks are used to connect thousands and thousands of IoT devices, with billions more to be connected. There are devices on many kilometers.

3.4 Radio modulation and LoRa

LoRa uses a unique radio modulation that contributes to its key characteristics, especially long range and low power consumption. This technology uses Spread Spectrum Modulation to achieve both characteristics. In particular, LoRa uses two main types of radio modulation: Chrip Spread Spectrum (CSS) and Frequency Shift Keying (FSK). CSS is a key technology that enables the long reach of LoRA networks. Instead of the classic modulation method where the signal is modulated by changing the frequency or amplitude, LoRA uses a "chirp" signal. A chirp signal is a signal that gradually changes in frequency over time, thus creating a specific waveform. This signal has unique characteristics that make it immune to interference and noise. FSK is another radio modulation used in LoRa networks. FSK uses two different signals, one is a logic 0 and the other is a logic 1, where the change in signal frequency is represented by digital data. FSK is used in LoRa technology to signal the beginning and end of a message and for communication over short distances where long range is not required. The combination of these radio modulations enables LoRa technology to send data over long distances with minimal energy consumption. Chirp Spread Spectrum especially contributes to long range because such a signal can penetrate obstacles and enables communication at distances that are significantly greater than traditional wireless technologies. This combination makes LoRa suitable for IoT applications where devices can communicate over short distances with minimal power consumption, which is critical for devices with limited power sources, such as sensors or battery-powered devices.

3.5 Properties of LoRa modulation:

Long Range technology uses a specific type of modulation called Chrip Spread Spectrum. CSS has properties that enable LoRa networks to achieve long range, low power consumption and immunity to interference. Key features of LoRa modulation:

- Chrip signal is the basic element of LoRa modulation. It is a signal that changes frequency over time. Instead of classic signals that are defined by a constant frequency, the chrip signal has a characteristic wave shape that gradually changes frequency.
- Long Range: The key property of modulation is long range. The Chrip signal enables communication over long distances, which is especially important in the context of IoT devices that can be distributed over wide geographical areas.
- Low power consumption: LoRa also stands out for its low power consumption, which is essential for IoT

devices with limited power sources, such as battery-powered ones. Chirp modulation enables energy-efficient communication.

- Resistance to Interference: Chirp Spread Spectrum contributes to resistance to interference. The chirp signal can pass through different frequency layers without significant interference, which increases the reliability of communication.
- Flexibility and adaptability: they can be configured to operate at different frequencies and bandwidths to adapt to specific application conditions and requirements.
- Adjustment of speed and range: LoRa modulation enables adjustment of speed and range according to the needs of the application.
- Incoming and outgoing modulation: LoRa supports incoming and outgoing modulation. This allows devices to communicate not only to the network (incoming communication) but also to each other (outgoing communication).

The overall property of LoRa modulation, especially through Chrip Spread Spectrum, make this technology extremely useful for IoT applications where efficient and reliable connectivity over long distances with minimal energy consumption is required.

3.6 Scalability of LoRa

The scalability of Long Rage networks refers to the ability of these networks to grow and adapt to the increase in the number of connected devices and data traffic. LoRa is designed to support a large number of IoT devices at various distances. Frequency flexibility uses frequency flexible bands, enabling the deployment of networks on different frequencies depending on regional regulations. This reduces congestion on a certain frequency and enables easy addition of new devices to the network through exchange. LoRa networks are designed to support a large number of devices. Given that many IoT devices using LoRa are simple sensors with low data traffic, the network can support thousands or even tens of thousands of devices. Implementing multiple gateways in the network enables scalability as it expands the coverage and capacity of the network. Adding new gateways can expand geographic coverage and improve overall network performance. These networks use adaptive adaptive modulation to automatically adapt to real-time conditions. This means that the data rate, range and signal strength can be adjusted to optimize communication depending on specific conditions. They also support different topologies, including star, multi-node network and others. This allows flexibility in achieving the optimal topology for different applications and environments. Flexibility in updating software on nodes and gateways contributes to the scalability of the network because it allows the addition of new features and optimizations without the need to physically change the infrastructure. The open standards applied in the LoRa alliance contribute to the interoperability of different manufacturers and products, which enables flexibility in the choice of equipment and technology.

3.7 Implementation of the network

The implementation of LoRa and LPWA networks involves several key steps:

- **Planning**

Application identification: define specific applications for which LoRa and LPWA networks will be deployed, such as resource tracking, smart cities, industrial IoT, agriculture, etc.

Coverage analysis: assessment of geographical requirements and distances to be covered by the network. This is important for choosing optimal locations for placing nodes.

- **Infrastructure**

Gateway setup: Gateways are nodes that connect the LoRa network to the backend system. They are placed in strategic locations to cover the desired area.

Backend development: it is necessary to develop a backend system that will accept and process data from LoRa devices. This may include databases, application servers, analytical tools, etc.

- **Device selection:**

LoRa nodes: select nodes, i.e. devices that match the specific needs of the application. This includes sensors, actuators and other devices that will communicate via the LoRa network. Integration with LPWA technologies: if an LPWA network is used, it is necessary to choose appropriate technologies such as LoRa, Sigfox or NB-IoT, depending on the specific requirements of the project.

- **Security**

Cryptography and authentication: Implementation of security mechanisms such as cryptography to protect data in transit and device authentication to prevent unauthorized access.

Security policy: define a security policy that includes regular software updates, monitoring of security events, and the like.

- **Testing**

Functional testing refers to the correctness of all nodes, gateways and backend systems through functional testing.

Network performance refers to testing the network under real-world conditions to ensure reliable communication and meet application requirements.

- **Maintenance and supervision**

Managing the installed network is monitoring the network to identify and solve possible problems, to achieve this it is necessary to include monitoring and management systems to ensure the stability of the system. Regular software updates on nodes and other components serve to correct vulnerabilities and improve performance. The implementation of LoRa and LPWA networks requires a multidisciplinary approach that includes aspects of communication technology, hardware, security and software. It is important to carefully plan, test and maintain the network to ensure its effectiveness and stability over time.

3.8 LoRa and telecommunications operators

With LoRa, operators want to provide an offer for companies that want to quickly implement Internet of Things applications in areas where long distances with mailm capacity are involved, for example in smart city and logistics. In the context of these networks, cooperation with telecommunication operators plays a key role in the development, implementation and maintenance of the infrastructure.

- **Regulations and frequencies**

LoRa networks use specific frequency bands to enable communication between nodes and gateways. These frequency ranges usually vary depending on the region and the chosen standards. For example, in Europe the 868 MHz bands are used, while in North America the 915 MHz bands are used. Telecom operators adapt their LoRa networks to meet regional regulatory standards. This includes adherence to frequency limits and technical specifications set by regulatory authorities. In some cases, the use of certain frequencies for LoRa networks may require appropriate permits or licensing by regulatory authorities. Telecommunications operators are responsible for the process of obtaining these permits and maintaining the licensed infrastructure. Regulations often set guidelines to prevent interference between different networks that share similar frequency bands. Telecommunications operators must ensure spectral efficiency and minimize interference in order to maintain network stability. Operators work with regulatory authorities to properly implement LoRa networks. This includes cooperation in setting standards, participation in consultations and monitoring changes in the regulatory environment. Also, operators require that devices connected to their networks be certified according to certain technical standards in order to ensure proper functioning and compliance with regulations.

- **Setting up the infrastructure**

Telecommunications operators participate in setting up gateways, nodes that connect the LoRa network to the Internet. Gateways are key infrastructure components that enable data transmission between LoRa nodes and the central system. Telecommunications operators develop or cooperate in the development of backend systems. This system receives, processes and stores data collected by LoRa nodes. This can include database, application servers and other components. The deployment of LoRa infrastructure by telecom operators enables geographic coverage and they often deploy gateways in strategic locations to cover larger geographic areas.

- **Adaptation and integration**

LoRa networks often use specific technical standards, including the LoRa Wide Area Network (LoRaWAN) protocol. Integration of LoRa networks with existing telecommunications infrastructure is essential for coordination and data transmission. Telecommunication operators direct LoRa data to their systems for further processing. The adaptation and integration of LoRa networks into telecommunications operators ensures that these networks work in harmony with the existing infrastructure, while at the same time enabling the connection of devices over long distances with low energy consumption.

- **Global coverage**

Telecommunications operators often work with partners from other countries to provide international coverage, which includes data exchange, joint network management or infrastructure sharing. Different regions may have different technical and regulatory requirements. Operators adapt their networks to adequately cope with regional differences and ensure compliance with local regulations. Global coverage of LoRa networks is achieved through cooperation between telecommunication operators, protocol standardization and international infrastructure cooperation. This integrated approach enables LoRa networks to be a key part of the global Internet of Things (IoT) infrastructure.

CONCLUSION

On the axis of information from 2022. LPWA and LoRa networks are globally present and have a significant number of implementations in various sectors, including smart cities, industry, agriculture and logistics. In industry, LoRa is often used for resource tracking, inventory tracking and management, vehicle tracking, and environmental control and monitoring. The LoRaWAN ecosystem is growing, including chip manufacturers, sensors, and development communities, fueling the development of new applications and devices. Further development of the technology is expected with an emphasis on increasing the reach and capacity of the network in order to enable wider coverage and the connection of an even greater number of devices. Advanced applications using LoRa technology are expected to be developed, especially in areas such as smart agriculture, industrial automation and smart cities. Also, further convergence of LPWA technologies is expected to meet different application needs. With the development of 5G networks, the integration of LPWA technologies is expected to create an even wider and more advanced infrastructure for IoT devices. It is important to monitor technological innovations, standardization and market adoption in order to get a clearer picture of their current and future development.

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