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A Study of LoRaWAN Network Technology

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ABSTRACT
IoT is gaining high popularity in today's world. Embedded systems have become a major part of our lives. People are able to control, monitor, and do a lot more from remote distance. This is done by connecting various objects reducing physical distance. IoT is the connectivity of various objects with network connectivity [1]. LoRaWAN (Long Range Wide Area Network) is a type of wireless communication technology designed for long-range communication between devices, typically in IoT (Internet of Things) applications. In this technology a data-link layer with long range, low power, and low bit rate, appeared as a promising solution for IoT in which, end-devices use Lora to communicate with gateways through a single hop[2]. This article provides an impartial and fair overview of LoRaWAN. emerged as an alternative cost-effective communication technology for the IoT market. LoRaWAN is an open LPWAN standard developed by LoRa Alliance and has key features i.e., low energy consumption, long- range communication, built in security, GPS- free positioning. In this paper, we will introduceLoRaWAN technology, the state of art studies in the literature and provide open opportunities.
Keywords: IOT, LoRaWAN, Long-Range, Cost-Effective Communication

I. INTRODUCTION

LoRaWAN, short for Long Range Wide Area Network, is a wireless communication protocol designed for long-range communication between low-power devices. It operates on unlicensed radio frequencies and is particularly suitable for Internet of Things (IoT) applications where low data rates, long battery life, and long-distance communication are essential .achieve ranges of several kilometers in urban environments and even greater distances in rural areas, making it ideal for applications such as smart agriculture, smart cities, asset tracking, and environmental monitoring. At its core, LoRaWAN technology utilizes the LoRa modulation technique, which enables devices to transmit small packets of data over long distances with minimal power consumption. One of the key features of LoRaWAN is its star-of-stars network architecture, where individual sensor nodes communicate with gateways that act as intermediaries between the devices and the central network server. This architecture allows for efficient use of radio spectrum and scalability, as thousands of devices can be connected to a single gateway. Additionally, LoRaWAN networks typically operate in the subgigahertz ISM bands, such as 868 MHz in Europe and 915 MHz in North America, which offer better propagation characteristics compared to higher frequency bands, resulting in improved signal penetration and Coverage LoRaWAN technology provides several advantages over other wireless IoT connectivity options, including its long-range capability, low power consumption, scalability, and suitability for battery operated devices. As a result, it has gained significant traction in various IoT applications and continues to be adopted across industries worldwide.

II. LITERATURE SURVEY

LoRa or LPWA is a very recent technology that has been evolved. In 2013 or before that, the term did not even exist. Now the technology has developed and is being promoted and used worldwide because of its various technical advantages. This technology compliments various other technologies such as cellular network. As recently as in 2013 nobody thoughtthat such a technology would exist. The LoRa technology is preferred due to various advantages such as the battery lifetime, the long range, the security, robustness to interferences and more. The technology is a package in itself [1]. A LoRaWAN gateway, covering a range of tens of kilometers and able to serve up to thousands of end-devices, must be carefully dimensioned to meet the requirements of each use case [2].

This paper elaborated an analysis about LoRaWAN protocol based on its architecture, battery lifetime, network capacity, device classes and security. It was observed that this protocol showed an advantage of about 3 to 5-fold when compared with other LPWAN technologies regarding power consumption for long range communications. Moreover, LoRaWAN networks can be deployed with a minimal amount of infrastructure and with the achieved capacity [3]. Compared to other existing IoT connectivity technologies such as cellular, Wi-Fi, and Bluetooth Low Energy (BLE), LoRaWAN offers distinct advantages in terms of range, power consumption, scalability, and cost-effectiveness. It excels in scenarios where long-range communication, low power operation, and support for large numbers of devices are crucial factors. However, it's essential to recognize that no single IoT connectivity technology is universally superior; the choice depends on specific application requirements, including range, data rate, power constraints, and deployment scale. Nonetheless, LoRaWAN's versatility and performance have positioned it as a leading technology in the rapidly expanding IoT ecosystem, driving innovation and enabling diverse applications to thrive in various industries actions One of the challenges in deploying IoT applications is the cost of building and operating the communication infrastructure. This paper studies the feasibility of building a low-cost IoT network based on LoRa, a leading Low-Power Wide-Area Network (LPWAN) technology, using off-the-shelf components and open source software [4]. For efficient data transmission in long-range IoT services, this paper proposes a congestion classifier using logistic regression and modified adaptive data rate control. The proposed scheme controls the data rate according to the congestion estimation. Through extensive analysis, we show the proposed scheme's efficiency in data transmission [5].

III.COMPARISION OF LORAWAN NETWORK TECHNOLGY WITH OTHER TECHNOLOGY

A. LoRaWAN: LoRaWANoffers exceptional long-range communication capabilities, typically ranging from several kilometers in urban environments to tens of kilometers in rural areas. This makes it ideal for applications requiring communication over large distances. LoRaWAN devices are designed for low power operation, enabling long battery life for battery-operated IoT devices. They consume minimal power during both transmission and reception, making them suitable for applications requiring extended deployment periods without frequent battery replace.LoRaWAN typically offers low to moderate data rates, ranging from a few bytes to several kilobytes per second. While sufficient for many IoT applications such as sensor data monitoring and control, it may not be suitable for applications requiring high bandwidth data transmission or real-time communication. LoRaWAN typically employs a star-of-stars topology, where individual devices communicate with gateway devices that act as intermediaries between the devices and the central network server. This architecture allows for efficient use of radio spectrum and scalability

B. Cellular: Cellular technologies such as 3G, 4G, and 5G provide coverage over wide geographic areas but generally offer shorter ranges compared to LoRaWAN, especially in rural or remote areas. However, they have better coverage in densely populated urban areas. Cellular devices consume more power compared to LoRaWAN devices, especially during data transmission. While advancements in cellular technology have improved power efficiency, cellular devices still require more power, which can impact battery life, particularly for battery-operated IoT devices

C. Local Area Network LANs: such as Wi Fi or Ethernet, are intended for short-range communication within a confined area, typically within a building or a limited outdoor space. The range of a LAN is usually limited to a few hundred meters, although it can be extended with additional networking equipment like repeaters or access points LANs often use a star or mesh topology, where devices connect directly to a central network device like a router or switch. In a mesh topology, devices can also communicate with each other, offering redundancy and flexibility in network architecture.

Devices connected to a LAN, especially those using Wi-Fi, typically consume more power compared to LoRaWAN devices. This is especially true during data transmission, which can impact battery life for battery operated devices or require devices to be connected to a power source. LANs rely on existing networking infrastructure such as routers, switches, and access points. Wi-Fi networks, for example, leverage wireless access points connected to a wired network backbone. Ethernet networks use wired connections for data transmission, typically employing switches and routers to manage network traffic

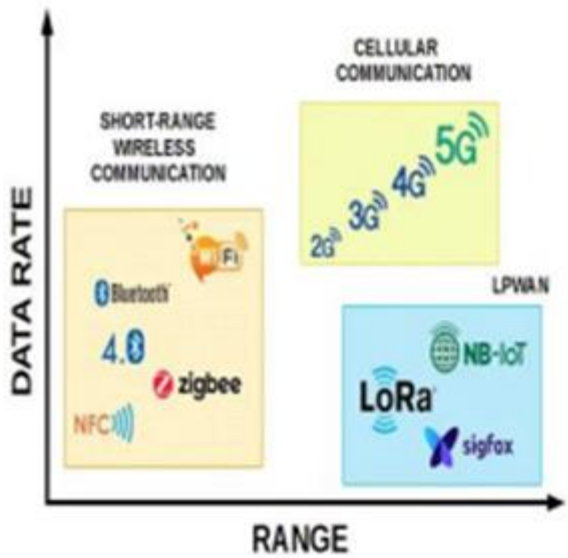

Fig 2: Comparison Chart of LoRaWAN with other existing technology

D. Z -Wave: Z-Wave is optimized for short to medium-range communication, typically covering distances up to 30 meters indoors. While this range can be extended with repeaters, Z-Wave is primarily intended for use within a single building or home. Z-Wave utilizes a mesh network topology, where devices communicate directly with each other and can act as repeaters to extend the network's range. This mesh architecture provides redundancy and reliability in communication within a localized area. Z-Wave devices also typically have low power consumption, making them suitable for battery-operated devices and energy-efficient applications.The power consumption may vary depending on the specific device and its usage patterns. It provides higher data rates compared to LoRaWAN, making it suitable real-time communication, such as home automation and smart home devices. Z-Wave's higher data rates enable faster response times and support for more complex commands and interactions. It is a proprietary wireless communication protocol developed and maintained by Silicon Labs. While Z-Wave devices are interoperable within the Z-Wave ecosystem, interoperability with devices from other protocols may require additional gateways or bridges.

E. IEEE 802.15.4: IEEE 802.15.4 is more suitable for shorter-range communications, often within tens to hundreds of meters. LoRaWAN provides lower data rates compared to IEEE 802.15.4. This is suitable for applications that require intermittent, low rate data transmission over long distances. It is designed for low-power operation. IEEE 802.15.4 supports various network topologies, including star, mesh, and cluster tree, offering more flexibility in network design IEEE 802.15.4 can operate in various frequency bands, including 2.4 GHz and sub GHz bands. These technology offer security features, but the implementation and strength of security mechanisms can vary as compared to LoRaWAN. IEEE 802.15.4 is an IEEE standard that specifies the physical and media access control (MAC) layers for low-rate wireless personal area networks (LR WPANs)

F. LTE-M: LTE-M is designed to provide better coverage in underground and indoor environments, typically reaching up to a few hundred meters. LTE-M provides higher data rates compared to LoRaWAN. LTE-M can support data rates up to 1 Mbps. LTE-M can be more power-hungry, especially when operating at higher data rates. LTE-M leverages existing LTE infrastructure, making it easier and more cost-effective to deploy for mobile network operators. LTE-M leverages existing LTE infrastructure, making it easier and more cost-effective to deploy for mobile network operators. LTE-M offers lower latency compared to LoRaWAN.

G. NB-IoT: NB-IoT is designed to provide coverage up to a few hundred meters to a few kilometers, depending on the deployment. NB-IoT can support data rates up to 250 kbps NB-IoT devices can also achieve long battery life, but the power consumption can vary depending on the use case and network conditions. NB-IoT leverages existing cellular infrastructure, making it easier and more cost-effective to deploy for mobile network operators. NB-IoT offers lower latency compared to LoRaWAN. NB-IoT is expensive compared to LoRaWAN.

Sigfox: Sigfox coverage can vary but is generally in the range of a few kilometers.

Sigfox provides lower data rates compared to LoRaWAN.Sigfox designed for applications that require small amounts of data to be transmitted infrequently. Sigfox devices can also achieve long battery life, but the power consumption can vary depending on the use case and network conditions. Sigfox operates its own global network infrastructure, making it easier for users to deploy devices in multiple regions without having to manage different network providers.The cost of deploying and operating a Sigfox network can vary depending on the region and the scale of the deployment.

Attribute	Bluetooth® Low Energy Technology	Wi-Fi	Z-Wave	IEEE 802.15.4 (Zigbee, Thread)	LTE-M	NB-IoT	Sigfox	LoRaWAN
Range	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Throughput	[illegible]	[illegible]	[illegible]	[illegible]	Up to 1 Mbps	Up to 200 kbps	Up to 100 bps	[illegible]
Power Consumption	Low	Medium	Low	Low	Medium	Low	Low	Low
Ongoing Cost	One-time	One-time	One-time	One-time	Recurring	Recurring	Recurring	One-time
Module Cost	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Topology	P2P, Star, Mesh, Broadcast	Star, Mesh	Mesh	Mesh	Star	Star	Star	Star
Shipments in 2019 (millions)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Fig 2: Comparison Table of LoRaWAN with other existing technology

IV. ARCHITECTURE

A. End Devices (Nodes): These are the devices at the edge of the network that collect data from sensors or perform specific tasks. End devices in a LoRaWAN network are typically battery-powered and designed for low-power operation. They use the LoRa modulation scheme to transmit data to gateways.

Gateways: Gateways act as intermediaries between end devices and the network server.

They receive LoRa-modulated signals from end devices, demodulate them, and forward the data to the network server using standard IP connections such as Ethernet, Wi-Fi, or cellular networks. Gateways are usually deployed in a star-of-stars topology, with each gateway serving multiple end devices within its coverage area.

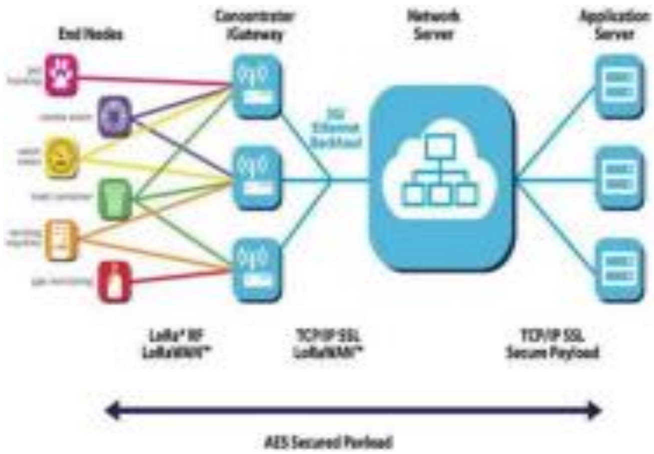

Fig 3: A typical LoRaWAN network architecture

B. Network server: The network server is a central component of the LoRaWAN architecture responsible for managing the communication between end devices and application servers. It performs several key functions

Authentication: The network server authenticates end devices before allowing them to join the network.

Encryption: It manages the encryption keys used to secure communication between end devices and the network Routing: The network server determines the optimal path for data to reach its destination, taking into account factors such as network congestion and signal strength.

Quality of Services: It manages the QoS requirements of different applications, ensuring that data is delivered reliably and with minimal latency.

C. **Join Server (Optional):** In some LoRaWAN deployments, a join server is used to manage the process of securely adding new end devices to the network. The join server generates and distributes the necessary keys for secure communication between the new end device and the network server

D. **Application Server:** The application server processes data received from end devices and implements specific applications or services based on that data. It can also send commands or messages back to the end devices. The application server is responsible for interfacing with external systems or services, such as cloud platforms or data analytics tools, to further process and analyzes the data collected from end devices.

V. CHALLENGES SOLVED BY LoRaWAN

In this Section, we concentrate on the challenges and obstacles faces the wireless sensor network (WSN) in general and the IoT specifically. Then, how can the revolution of LoRaWAN technology dissolve all of them. Challenges and Limitations faced WSN Wireless sensor networks (WSN) field faced some challenges and limitations are

1. Many difficulties when participating a great number of sensors.
2. Appearance of low efficiency and other issues due to the overcrowded state of Radio Frequency (RF) environment.
3. The nonexistence of the mathematical models that help in simulating a huge numberof nodes in WSN.
4. The current simulators used for WSN are limited and inadequate for scalability concerns.

VI. CONCLUSION

LoRa or LPWA is a very recent technology thathas been evolved. In 2013 or before that, the term did not even exist. Various LPWAN technologies are currently contending to gain an edge over the competition and provide the massive connectivity that will be required by the world in which everyday objects are expected to be connected through wireless network in order to communicate with each other. A possible solution for this problem is to increase the density of LoRaWAN gateways. However it can lead to the inter network interference. LPWA Networks have become a de facto communication standard for IoT since,power consumption, coverage are key features. Being an open platform LoRaWAN has become an important protocol among the LPWA Networks. LoRaWAN best fits scenarios where data transmissions are rare (a few packets in a day) and the size of the payload is around 10– 50 bytes. Smart city, smart grids, smart farming, and remote monitoring systems are the areas of the example where LoRaWAN could be best beneficial. At the cost of low data rates, LPWAN technologies supply long-range, low- power, and low-cost communication. At the end, a set of challenges that still need to be addressed in LoRaWAN is detailed, together with possible approaches on how to tackle those challenges. Finally, the paper summarizes the complete analysis, presenting a SWOT analysis of LoRaWAN. LoRa technology also offers high security. It is expected that by 2024 3.6 billion LPWA connections will be established.

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