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A Systematic Review on LPWAN Technologies

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ABSTRACT: For long range, a small amount of data transmission, low power and low energy consumption, support for a high number of nodes, low-bit rate and low-cost wireless telecommunication system for Internet of Things (IoT) in real time applications, Low power wide area networks (LPWANs) are suitable for many applications. Long range (LoRa) is one of the extensively used LPWAN technologies in Internet of things (IoT) applications. Low power as well as long-range communications are intense features of the Internet of Things (IoT) model that is becoming needed even for industrial applications. Today, the most rising long-range communication technologies are LoRaWAN and Narrow Band IoT (NB-IoT), which are dynamic a large IoT environment. This paper focuses on a systematic review about existing and ongoing research how to improve the performance of protocols for getting better results in practical environment. This paper also highlights comparison between LoRaWAN and NB-IoT in terms of standard performance parameters. Finally, this paper provides guidelines for future industrial applications with rigorous requirements of long-range and low power wireless connectivity.

KEYWORDS: Internet of Things (IoT), wireless sensor networks, Long Range (LoRa), Low Power Wide Area Network (LPWAN), LoRaWAN, Narrow Band Internet of Things (NB-IoT).

I. INTRODUCTION

As we know that, Internet of things (IoT) is composed of smart devices and communication technologies. Different protocols are analysed based on various parameters such as power consumption redundancy, accuracy, bit error rate, packet length etc. for IoT applications. Also analysed that after analysis of every protocol is better on its applications. IoT has massively counted on short-range radio protocols such as ZigBee and Bluetooth or existing networks such as cellular and Wi-Fi. These are sufficient for short-range IoT systems but are unsuitable for large and geographically spread networks of things, needed for many industrial and commercial applications. Short-range radio protocols are energy-efficient but limited by their transmission coverage range. Cellular networks are capable of long-range communications but are both expensive and power consuming. Wi-Fi is relatively inexpensive but is power consuming and limited by range. Since the widespread rise of IoT devices requires energy-efficiency and long-range communication, it demands inexpensive, energy-efficient IoT networks capable of long-range communications. Low Power Wide Area Networks (LPWANs) fulfil these requirements, often at the expense of more 'traditional' network requirements such as latency and throughput. These more specific requirements such as low power consumption and long range from the design goals of LPWAN networks. LPWANs are intended to coexist with existing short-range radio and cellular IoT networks, however choice of particular network(s) depends on the individual user or application.

For long range, a small amount of data transmission, low power and, low energy consumption, support for a high number of nodes and low cost of Internet of Things (IoT) in real time applications, Low power wide area networks (LPWANs) are suitable for many applications. Long range (LoRa) is one of the widely used LPWAN technologies in Internet of things (IoT) applications. Long Range (LoRa) is a wireless communication standard specifically targeted for resource-constrained Internet of Things (IoT) devices. The number of LoRa-based networks is growing due to its operation in the unlicensed radio bands and the ease of network deployments. However, the scalability of LoRa networks suffers as the number of deployed devices increases. In particular, network performance drops due to increased contention and interference in the unlicensed radio bands. Nevertheless, network performance can be improved by appropriately configuring each node's radio parameters.

Low power wide area (LPWA) technology is demanding to the need for efficient utilization of power resource, as it has characteristics such as the capability to provide low power connectivity to a large number of devices spread

over wide geographical areas at low cost. Various LPWA technologies, such as LoRa and SigFox, exist in the market, offering a proficient solution to the users. [13]

However, in order to obtain the need of new infrastructure a new cellular-based licensed technology, narrowband IoT (NB-IoT), is introduced by 3GPP in Rel-13. This technology provides a good feature to handle LPWA market because of its characteristics like enhanced indoor coverage, low power consumption, latency insensitivity, and massive connection support towards NB-IoT. Having technical features, resource allocation, and energy-efficiency techniques and applications. [13]

Hence, in recent years many approaches have been proposed to improve crucial factors, such as low power consumption and communication range. Following the rapid IoT market expansion, LPWAN has become one of the faster-growing areas in IoT. Low Power Wireless Area Network (LPWAN) is the common term to identify the wireless technologies that enable wide-area communication at low cost and low power consumption. The LPWAN typical application scenario needs to transmit a few bytes with a long-range. Many LPWAN technologies are emerging in both licensed and unlicensed markets, such as LoRa, LTE-M, SigFox, and Narrow-Band Internet of Things (NB-IoT). Among them, LoRa and NB-IoT are the two leading technologies. To improve energy efficiency, NB-IoT combines the benefits of the 4G mobile network, namely the global coverage and the long-range, with the energy efficiency typical of LPWANs. Moreover, NB-IoT is designed to provide better indoor coverage and support for a massive number of low-throughput devices. It is given to serve the high-value IoT market that pays for very low latency and high quality of service whereas LoRaWAN is focused to lower-cost devices, with very long-range (high coverage). Today, both LoRaWAN and NB-IoT are offering long-range and low power consumption with the primary aim to be employed as a wireless solution for IoT.

The LoRaWAN open standard enables large scale deployments through LoRa, a chirp spread spectrum modulation, with a communication range up to 15 km at low power operation. Many scientific works describe and model the energy performance for LoRaWAN [14] and the related scalability issues. LPWAN technologies can provide efficient connectivity solutions across critical and massive IoT deployment, determining their feasibility for specific applications. LoRaWAN has been selected over NB-IoT for environmental monitoring of assets and the interconnection of industrial facilities. LoRaWAN will serve as the low-cost and very long-range deployments, with infrequent transmissions and heavy constraints in terms of battery life. In contrast, applications requiring low latency and high quality of service. In this paper, section II described overview of LoRa, LoRaWAN section III presents LoRa network architecture, section IV provides design goals of LPWANs, section V put overview of typical Applications of LoRa Networks and paper concludes with Deployment overview of comparison of two standards.

II. SYSTEM OVERVIEW

With the rapid growth of the application fields of IoT, LPWAN has become a popular low-speed, long-range, low-power, and low-cost wireless communication mode. Due to these characteristics, LPWAN enjoys rising popularity in industrial and research fields. LoRa is a representative technology of LPWAN.

This section gives an overview of the LoRa protocol stack and basic network. LoRa, which stands for “Long Range”, is a long-range wireless communications system, promoted by the LoRa Alliance. This system aims at being usable in long-lived battery-powered devices, where the energy consumption is of paramount importance. LoRa can commonly refer to two distinct layers: (i) a physical layer & (ii) a MAC layer protocol (LoRaWAN), although the LoRa communications system also implies a specific access network architecture.

LoRa is a physical layer technology, which uses a spread spectrum technique to modulate signals in sub-GHz ISM bands. It uses unlicensed ISM bands: 868 MHz in Europe, 915 MHz in North America, and 433 MHz in Asia. The bidirectional communication of LoRa is provided by the chirp spread spectrum modulation that spreads a narrow-band signal over a wider channel bandwidth. It provides long-range communication up to 10–40 km in rural areas and 1–5 km in urban areas [9]. With the rapid growth of the application fields of IoT, LPWAN has become a popular low-speed, long-range, low-power, and low-cost wireless communication mode. Due to these characteristics, LPWAN enjoys rising popularity in industrial and research fields. LoRa is a representative technology of LPWAN.

As a LPWAN technology, LoRaWAN networks offer benefits such as large coverage areas and long battery life operation for end devices. Unlike conventional network technologies (e.g., cellular and LAN), the trade-off in data rate versus range leans heavily toward range in LoRaWAN. LoRaWAN networks further employ a proprietary physical modulation technique (named LoRa) which has been developed with long range and low power operation at its core. This section describes some of the aspects of LoRaWAN networks that are important for the remainder of this paper. [18]

III. LORA NETWORK ARCHITECTURE

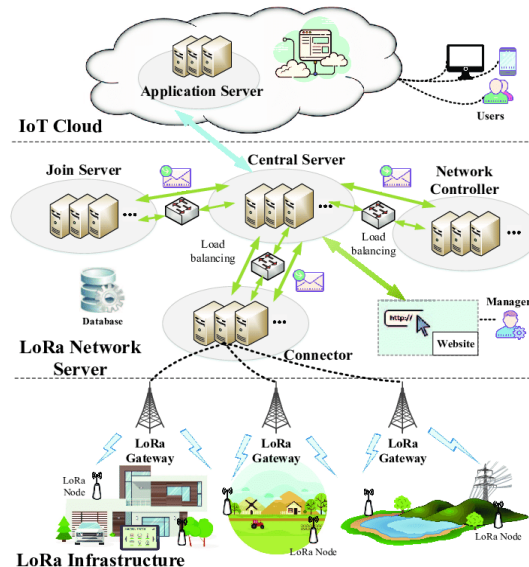


Fig 1- Illustration of LoRa Architecture

As shown in Fig.1, a hierarchical LoRa network architecture is proposed. The functionalities of each component is described in this section

F. LoRa NODE AND GATEWAY

LoRa Node and Gateway both are basic components of the whole LoRa networks since it can interact with the environment as well as forwarding data to LoRa network server for analysis. LoRa Node mainly includes sensors, actuators, battery, etc., and performs one or more tasks according to different application requirements. LoRa Gateway forwards all uplink radio packets to LoRa network server after adding metadata such as Signal-Noise-Ratio (SNR) and ReceivedSignal-Strength-Indicator (RSSI). Conversely, on the downlink, LoRa Gateway performs transmission requests coming from LoRa network server. Typically, it only transmits the received uplink/downlink packets as a relay without any interpretation of payloads [16].

B. LoRa NETWORK SERVER

LoRa network server receives packets forwarded from LoRa Gateway, and is responsible for packet processing and protocol analysis. Deep amount of functions need to be implemented on LoRa network server. For examples, checking the legality of end-devices, filtering duplicate uplink packets, performing network management mechanisms, scheduling acknowledgements and forwarding application layer data to the application server, etc. A well-designed architecture of LoRa network server is important for efficient processing and convenient management. Especially, the flexibility allows users to build various applications on existing LoRa hardware devices and the scalability can meet the needs of supporting massive LoRa Nodes. In addition, a management framework is necessary to help users to register, manage and monitor their LoRa devices including nodes and gateways.

C. APPLICATION SERVER IN IoT CLOUD

LoRa Application Server is responsible for encryption, decryption and processing of application layer payloads. It can support various applications with different encryption or encoding methods, such as Protocol Buffer, to ensure data security and improve transmission efficiency. IoT cloud provides essential services through Application Program Interfaces (APIs) and then applications are provided to users. LoRa Application Server acts as a bridge between IoT cloud and LoRa network server so that users can control LoRa Nodes and enjoy applications of LoRa network through web browsers or smart phones anywhere. A detailed explanation of IoT cloud can be obtained in [16].

IV. DESIGN GOALS OF LPWAN

LPWANs are ideal for IoT systems spread over a large area requiring energy efficient, low-cost devices at the expense of latency and data rate as well as LPWANs is long-range, low cost, low-power networks connecting many devices suited to tiny amounts of information. These studies converge on the same basic characteristics and usage requirements of LPWAN, leading us to categorize the design goals of LPWAN as follows:

A. ENERGY EFFICIENCY: In many applications, IoT devices need to be deployed in inaccessible or nomadic locations. Consequentially, most devices are battery powered and unlikely to have access to a constant power source. Replacing batteries consumes both time and resources, and when applied to large networks presents an unrealistic expense.

B. LONG RANGE: As wide-area networks, LPWANs must communicate over long distances. The target range for LPWANs is generally agreed upon as a few kilometers in urban areas, and tens of kilometers in rural areas.

C. SCALABILITY: Scalability can be broadly defined as a system's ability to maintain quality of service as it grows. Structural scalability defines how many end devices an LPWAN can support. This is determined by both devices per base station and base stations per network or geographic area. Support.

D. LOW COST Even if LPWANs support many nodes, it will be impractical to deploy them if nodes are expensive to manufacture and maintain. As all organizations have a limited budget, cheaper nodes always result in a larger possible system.

E. INTERFERENCE MANAGEMENT: Due to the high cost of licensing a frequency band, many LPWANs utilize the unlicensed Industrial, Scientific, and Medical (ISM) spectrum. LPWAN operating in ISM spectra should be especially resistant to noise. We assume a network must employ some form of interference management strategy to meet LPWAN goals.

F. INTEGRATION: It refers to an LPWAN's ability to work with other LPWANs and information systems. Data from sensors will be largely worthless if it can never be retrieved, and actuation systems should be controllable from external systems. Integration is achieved through the following:

- Many users, resulting in greater investment and wider support base.
- Ease of connection to the public Internet or application servers.
- Availability of APIs and user-facing solutions

V. APPLICATION OF LORA NETWORKS

In previous section, LoRa network architecture is presented and now this section presents some important applications and scenarios of LoRa network. As we know that LoRa network is promising for the long range, low power and low cost IOT applications with low data rate as well as long battery lifetime with communication range of over 10 km.

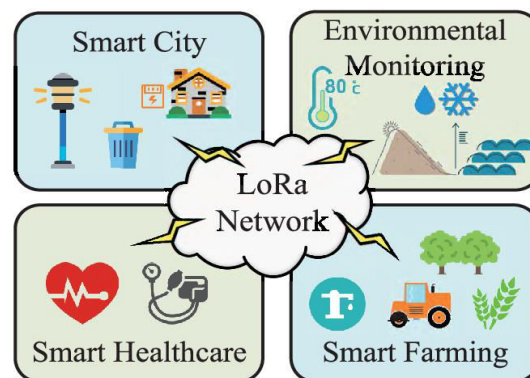


Fig 2- Application of LoRa Network

As shown in figure2, broader area of applications is as:

A. SMART CITY

LoRa network provides a reliable and feasible solution for various IoT applications in smart city, such as smart metering and waste management. By connecting city services, these applications offer the opportunities to improve the efficiency of municipal operations and reduce maintenance costs.[16]

B. ENVIRONMENTAL MONITORING Environmental monitoring is crucial for our society to provide real-time environmental indicators, such as air quality, temperature and humidity, and alert to critical situations, such as natural disasters and environment pollution. [16] It is also suitable to implement a network with LoRa technology across large geographical areas.

C. SMART HEALTHCAR

Low cost and reliable performance of LoRa network make it suitable for typical smart healthcare applications. Various biological information is collected by special on-body sensors and can be checked in time. All abnormal indicators are transmitted to health service providers or health professionals through LoRa network for the early detection and prevention of diseases.[16]

D. SMART FARMING

Smart farming is the application of modern technology into agriculture, aiming at improving the quantity and quality of agricultural products while reducing environmental impact and preserving resources. e.g., soil moisture monitoring and autonomous irrigation. Long-range, low-cost and low-power features of LoRa technology enable the use of sensors to transfer information from the farm to the cloud where it can make more efficient operations and management.[16]

	NB-IOT	LoRaWAN
Battery Life	Highly sensitive to the amount of buffering allowed by the application (energy per byte improves with large packets, the link is not energy-proportional)	Battery life upto 10X against NB-IOT for small packets (the link is energy proportional: energy per bit does not change much from small to large packets.)
Quality of Service	QoS Data delivery guaranteed.	PER depends on network density and average nodes throughput
Mobile cost	20€	3-5€
Infrastructure cost	Network operators supports the infrastructure. The service cost is approximately 10€/500	300 €/Gateway and maintenance needed
Coverage	National Scale (areas with infrastructure).	The coverage depends on the investment for the number and location of gateways
Time to market	Plug and Play service offered by network operations	Deployment infrastructure time needed.

VI. CONCLUSION

In this systematic review paper, it is described about both standards LoRa and NB-IoT have their own merits and demerits according to its different performance parameters. In literature review it is observed that the current literature

is lacking as there is no unique LPWA technology. Each new application has its own specific requirements, which lead to a specific technology choice. Both the standard LoRa and the NB-IoT have their place in the IoT market. LoRa highlights on long-range low-cost applications. Whereas NB-IoT focuses on the applications which require high QoS and low latency.

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