



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

IJRSET

International Journal of Innovative Research in
SCIENCE | ENGINEERING | TECHNOLOGY



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 9, September 2024

ISSN INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA

Impact Factor: 8.524

9940 572 462

6381 907 438

ijirset@gmail.com

www.ijirset.com

Technical Overview of LoRa – LPWAN Technology for IoT: Applications, Opportunities and Challenges

Mangala R. Dhotre, Yash Kamalja, Padmashree Sonar, Swapna C. Jadhav

Assistant Professor, Department of E&TC, Government College of Engineering, Jalgaon, Maharashtra, India

Student, Department of E&TC, Government College of Engineering, Jalgaon, Maharashtra, India

Student, Department of E&TC, Government College of Engineering, Jalgaon, Maharashtra, India

Assistant Professor, Department of E&TC, Government College of Engineering, Jalgaon, Maharashtra, India

ABSTRACT: LoRa, a Low-Power Wide Area Network (LPWAN) technology, has come up as a compelling solution for Internet of Things (IoT) applications. This paper provides a thorough overview of LoRa, delving into its technical underpinnings, and advantages, with diverse applications. At the core of LoRa is its chirp spread spectrum (CSS) modulation, which permits long-range communication, low power consumption, and high interference resilience. The LoRaWAN network protocol further enhances these capabilities, offering flexible data rates to accommodate various use cases.

LoRa's versatility has led to its adoption across numerous sectors. In smart cities, LoRa-enabled sensor networks collect valuable data on environmental parameters, aiding in urban planning and resource management. Asset tracking applications leverage LoRa's long-range capabilities for precise geolocation, even in challenging environments. Industrial automation benefits from LoRa's reliability and low power consumption for remote monitoring and control. Moreover, LoRa's potential for military applications is evident in its ability to provide robust communication in demanding conditions.

KEYWORDS: LPWAN, LoRa, Communication, LoRaWAN

I. INTRODUCTION

This paper investigates the execution and range of an IoT system utilizing a combination of LoRa and Wi-Fi technologies. By leveraging LoRa's long-range capabilities and Wi-Fi's established infrastructure, we aim to reduce the overall deployment costs of IoT networks. LoRa, a spread spectrum modulation technique deduced from chirp spread spectrum (CSS), offers several advantages. Its unique transmission method, which spreads the signal across the entire allocated bandwidth, enhances robustness to channel noise. This pseudo-random spreading also provides a degree of inherent security, as the transmitted data appears as random noise to unauthorized parties [1]. Due to its superior signal penetration capabilities, LoRa technology offers extensive coverage in challenging indoor environments. Comparing to Wi-Fi or Bluetooth-based IoT solutions with limited communication ranges, LoRa delivers optimal data transmission efficiency while maintaining a low development cost. Research findings substantiate these claims [2]. For IoT applications demanding extensive data communication over long distances while conserving energy, LoRa emerges as the optimal technology. Its exceptional range and minimal power consumption make it an ideal choice for such scenarios [3].

Data transmission between LoRaWAN nodes is usually aggregated by multiple gateways. These gateways then forward the received packets to cloud-based web servers using a variety of backhaul technologies, including cellular, Ethernet, satellite, and Wi-Fi Ericsson Action Report with Raws [4], the number of devices connected to the Internet of Things (IoT) is expected to increase from 7 billion in 2017 to 20 billion in 2023. This growth trajectory represents an annual growth rate of nineteen percent, underscoring the rapid expansion of IoT connectivity. Low Power Wide Area Networks (LPWAN) are a promising solution to the challenges inherent in Internet of Things (IoT) deployment. Providing continuous communication and low power consumption, LPWAN is ideal for applications that

require low bandwidth and can rely on non-essential communication [5]. Employing a proactive approach to risk mitigation by installing state-of-the-art warning systems capable of identifying and alerting personnel to potential hazards related to toxic gas exposure, water leaks, and temperature fluctuations [6].

II. LORA

LoRa, stands For Long Range is an electronic spread spectrum modulation technology developed by Semtech and derived from Chirped Spread Spectrum (CSS). LoRa physical layer is versatile and can be employed with various MAC layers, the current standard, LoRaWAN, is specifically designed to operate in a simple star topology network configuration. LoRa is a wireless technology based on chirp spread spectrum (CSS) technology, which uses chirp pulses to encode data into radio waves. This method, reminiscent of how dolphins and bats communicate, renders LoRa transmissions resilient to disturbances and capable of being received over extensive distances.

1. LoRaWAN

LoRaWAN is a low-power local area network (LP-WAN) protocol and project developed by LoRa Alliance and working on the physical layer defined by LoRa. Based on the LoRa-based communication control layer, LoRaWAN can realize network construction at frequency below 1GHz. To ensure security, LoRaWAN uses AES-128 encryption. The frequency bands of LoRaWAN are 433 MHz in Asia, 868 MHz in Europe, and 915 MHz in North America [2]. Due to its long-range and low-power capabilities, LoRaWAN has become a major target for machine-to-machine (M2M) and Internet of Things (IoT) applications.

LoRaWAN operates on physical systems using proprietary Chirped Spread Spectrum (CSS) modulation, a variant of spread spectrum modulation. CSS modulation spreads the signal over a wide bandwidth, making it resistant to noise interference and jamming. This technique, originally developed for military communication in the 1940s, operates below the noise floor, enhancing its robustness.

2. LoRa Technology

The utilization of LoRa radio technology in sensor networks presents several compelling advantages. Firstly, due to its extended range capabilities, spanning hundreds of meters indoors and kilometers outdoors, networks can cover vast areas without the need for extensive multi-hop routing. In most cases, a single connection from each of the six receivers is perfectly suitable. Secondly, the orthogonality of the transmission of the same carrier frequency with different frequencies leads to an effective division of the channel into virtual subchannels. Thirdly, concurrent transmissions on LoRa, even when carrying dissimilar content, are inherently non-destructive due to the mechanism that prioritizes the reception of the strongest signal.

LoRaWAN, illustrated in Figure 2, outlines the communication process and the design process of the network, while the LoRa physical layer is required for long-distance data transmission. End nodes in the LoRaWAN network can transmit data to multiple base stations. An open standard managed by the LoRa Alliance, LoRaWAN's first version 1.0 was released in June 2015, followed by version 1.1 in 2017. Edge node devices offer customizable configurations, enabling the implementation of various features. According to the LoRaWAN standard, there are three different devices. These categories allow for a balance between network downlink communication latency and battery life. As shown in Figure 2, these groups are divided into A, B and C.

The A Class devices, designed primarily for low-power applications like sensors, are battery-powered and optimize energy efficiency. While they offer the longest latency, they are well-suited for scenarios where infrequent data transmission is sufficient. All LoRaWAN-compliant devices must inherently support Class A functionality.

The B Class is specifically designed for battery-operated devices, including actuators and sensors. These devices prioritize energy efficiency while maintaining a controlled latency for downlink communications. The communication protocol uses a simple time synchronization method from another signal. This synchronization allows the server to accurately determine the best time to send data to the end device.

Class C devices, equipped with bi-directional capability and maximum receive slots, maintain nearly constant receive windows, closing only during transmission. Requiring external power, these devices ensure continuous air interface monitoring and exhibit zero latency in both receive and transmit modes.

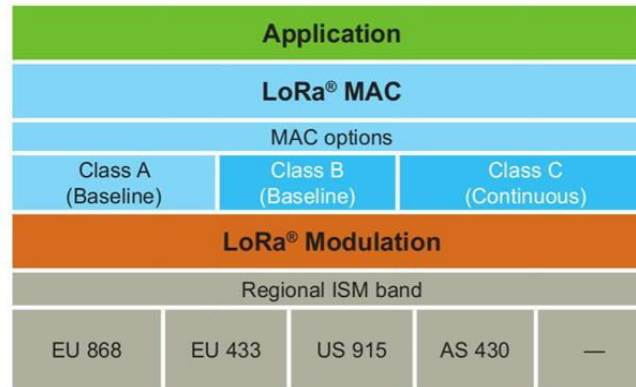


FIG. 1 LORAWAN COMMUNICATION PROTOCOL AND SYSTEM ARCHITECTURE [7]

LoRa terminal devices communicate with single-channel LoRa gateways in a star topology and use LoRa technology for data transmission. LoRa terminal devices communicate with single-channel LoRa gateways in a star topology and use LoRa technology for data transmission.

The LoRa gateway serves as a pivotal hub in the network architecture, facilitating data transmission, processing, and security. Connected via Ethernet or 5G, the gateway and server form the core of a star topology network [9]. This configuration offers advantages such as enhanced maintainability, reliability, and scalability. End nodes, including smart switches, sensors, and other devices, report data to the server and execute its commands. The versatility of these end nodes makes them adaptable to various applications, ranging from smart homes [10] and buildings automations [11] to smart agriculture [12], smart cities [13], and environmental monitoring [14].

3. LoRa Characteristics

IoT applications such as environmental monitoring and smart metering, often necessitate extensive deployments but require minimal data payloads, often as small as a single byte. Data reporting intervals can be as infrequent as once per day or hour. LoRa, a proprietary technology utilizing Chirp Spread Spectrum (CSS), addresses these requirements by offering long-range communication and low power consumption. Researchers have primarily focused on performance studies of LoRa, with physical layer optimizations often based on general CSS principles. Key industry interests in LoRa include its long-range capabilities, interference robustness, and use less electricity. Observational and simulation based studies were conducted to improve LoRa based BER expressions by Mruet et al.[16].

In [17], the authors conducted both simulations and practical experiments investigate the possibility of reliable LoRa communication when LoRa signals at different frequencies are interfered with. The results show that an average mutual rejection of 16 dB is required to ensure good communication. This is because the receiver misinterprets interfering LoRa signals as chirped waveforms, leading to peak detection and synchronization with the desired signal, which must be at least 16 dB stronger than the interference. These findings suggest that using only different transmission methods may not be sufficient to establish independent communication if the LoRa device is very close to the receiver.

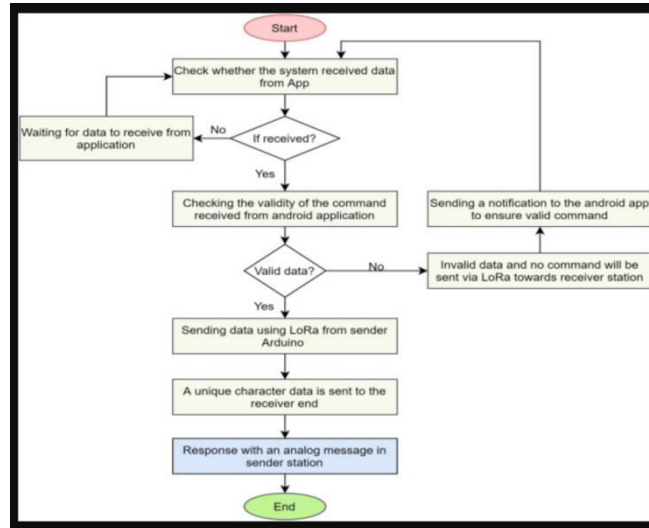


FIG. 2 A FLOW CHART TO SEND STATISTICS FROM ADVANCED CELL PACKAGES [18]

A low facts price implies an prolonged radio propagation time, which, in flip, elevates the likelihood of wi-fi interference among numerous radio communications. for instance, LoRa gadgets exhibit a sensitivity as little as -136 dBm whilst operating with a spreading issue of 12, a bandwidth of one hundred twenty five kHz, and a nominal statistics charge of 293 bps. A short message, comprising only a few tens of bytes, can persist over the air for several seconds, thereby significantly increasing the potential for radio collisions and interference.

III. KEY CHARACTERISTICS OF LORA

- Low Power Consumption : LoRa devices are highly energy-efficient, making them suitable for battery-powered applications and remote locations.
- Long Range : LoRa can achieve long-range communication, often extending beyond the reach of traditional wireless technologies.
- High Interference Resilience : LoRa's spreading spectrum modulation technique helps it to mitigate interference from other wireless signals.
- Flexible Data Rates : LoRa supports a range of data rates, allowing it to be adapted to various applications and environmental conditions.

Applications of LoRa

This era can be applied in a spread of programs along with agriculture, healthcare, smart cities, asset tracking, commercial automation, and remote sensing. In smart cities, LORA can enable efficient communication between devices for tasks like traffic management, waste collection, and environmental monitoring. Asset tracking systems leverage LORA to locate and monitor valuable items, such as equipment, vehicles, or livestock. In commercial automation, LORA is hired for real-time statistics transmission and manage of equipment and strategies. moreover, LORA's long-variety competencies make it best for far off sensing applications, along with environmental tracking and catastrophe response.

■ Geolocation

LoRaWAN offers a cost-effective and energy-efficient alternative to traditional GPS-based geolocation solutions for outdoor fixed and mobile assets. By leveraging Differential Time of Arrival and other hybrid techniques, LoRa eliminates the need for expensive, power-hungry GPS modules on sensor nodes. Cloud-based algorithms estimate location by analyzing the time of arrival of packets transmitted from a sensor node to multiple precisely synchronized gateways. LoRa geolocation solutions offer significant potential for enhancing asset utilization and reducing operational expenses, with reported cost savings of up to 50% in certain instances. By leveraging smart sensors, logistics companies can accurately track the location and condition of containers, monitoring factors such as vibrations, door openings, and temperature or humidity.

■ LoRa Indoor coverage and performance assessment in an industrial placing: A Case look at The experimental environment for this have a look at [19] was the Royal flowers Holland auction center in Naaldwijk, Netherlands, a bustling flower market where approximately 10,000 flower trolleys navigate daily. The monitored area, encompassing the buffering and distribution zones, measured 190 by 180 meters and exhibited high traffic density with flower trolleys moving in diverse patterns. To optimize the experimental setup, an initial evaluation was conducted using a Python-based simulation model. The simulation proven that a single gateway could successfully serve as much as 6000 nodes with a 10% loss ratio.

In the real-world experiment, multiple parameters, including received signal strength indicator (RSSI), sign-to-noise ratio (SNR), and loss ratio, were evaluated to assess LoRaWAN's robustness. The authors concluded that LoRaWAN can reliably cover large indoor areas, such as the 30,000 square meter space in this experiment, provided there are no significant line-of-sight obstructions.

A distinctive feature of this research is its focus on LoRaWAN scalability when deployed with a substantial number of nodes (3000+). To the authors' knowledge, this aspect had not been thoroughly investigated for LoRaWAN prior to this study, making it a valuable contribution to the field.

■ A LoRa-based totally, wireless, self-powered environmental monitoring gadget for clever metropolis packages Paper [20] details the implementation of a city monitoring system in Athens, utilizing two sensor nodes and a gateway to collect data on temperature, humidity, ambient light, and gases including carbon monoxide and smoke. The sensor nodes were equipped with solar panels and rechargeable batteries, ensuring complete autonomy and eliminating the need for human intervention. This research demonstrates the feasibility of organising a price-powerful LoRaWAN-based tracking device for smart towns. The authors file that the system exhibited wonderful reliability, with no packet loss due to a lack of measurement drop points.

■ Military Applications

Effective communication serves as the cornerstone of any military operation, facilitating coordination, information dissemination, and real-time decision-making. In dynamic and complex environments, such as combat zones or remote deployments, traditional communication methods may face limitations due to topographical obstacles, signal interference, and power constraints. To address these challenges, cutting-edge technologies like LoRa are being investigated to establish robust and resilient communication networks. LoRa's extended range capabilities enable reliable transmission of critical data, even in geographically demanding regions.

IV. CONCLUSION

As the Internet of things (IoT) maintains to revolutionize industries, LoRa, a Low-energy huge vicinity network (LPWAN) generation, has emerged as a pivotal enabler. This paper delved into LoRa's technical foundations, highlighting its exceptional capabilities in long-range communication, energy efficiency, and interference resilience. The LoRaWAN network protocol further enhances these strengths, offering a versatile platform for diverse IoT applications. LoRa's versatility has been instrumental in its widespread adoption across various sectors. Smart cities leverage LoRa sensor networks for data-driven urban planning and resource management. Asset tracking applications harness LoRa's long-range capabilities for precise geolocation and efficient operations. Industrial automation benefits from LoRa's reliability and low power consumption for remote monitoring and control. Moreover, LoRa's potential for military applications is evident in its ability to provide robust communication in challenging environments. Despite its numerous advantages, LoRa faces ongoing challenges such as protection, scalability, and interoperability. Addressing those troubles could be crucial for knowing LoRa's complete ability. because the range of connected gadgets keeps to grow exponentially, LoRa's ability to provide reliable, low-power connectivity positions it as a foundational technology for a more interconnected and efficient future.

REFERENCES

- [1] E. Notes, "LoRa Physical Layer & RF Interface," 2018. [Online] Available: <https://www.electronics-notes.com/articles/connectivity/lora/radio-rf-interface-physical-layer.php>
- [2] L. Alliance, "White Paper: A Technical Overview of LoRa and Lorawan," 2015. [Online]. Available: https://www.tuv.com/media/corporate/products_1/electronic_components_and_lasers/TueV_Rheinland_Overview_LoRa_and_LoRaWANtmp.pdf

- [3] “Why LoRa?” [Online]. Available: <https://www.semtech.com/lora/whylora>
- [4] Ericsson, “Ericsson mobility report,” 2017
- [5] Raza,U.,Kulkarni,P., andSooriyabandara,M. (2017). Low power wide area networks : An overview. IEEE Communications Surveys & Tutorials,19(2),855–873.
- [6] Lee, S.K.,Kwon,H.R., Cho,H.,Kim, J., andLee,D. (2016). International case studies of smartcities. Orlando, United States of America : Inter-AmericanBank
- [7] LoRa Alliance Technical Marketing Workgroup, “A technical overview of LoRa and LoRaWAN,” p. 20, 2015. [Online]. Available:<https://www.lora-alliance.org/lorawan-white-papers> [researchgate.net/figure/LoRaWAN-network-architecture_fig1_341298152](https://www.researchgate.net/figure/LoRaWAN-network-architecture_fig1_341298152)
- [8] Songlin, L. A guide to star lan networking. Comput. Knowl. Technol. 15, 41–42 (2000).
- [9] You, E. A. & Ilsun, Q. Internet of things for smart homes. Sensors 19, 25 (2019).
- [10] Himeur, Y. et al. Ai-big data analytics for building automation and management systems: A survey, actual challenges and future perspectives. Artif. Intell. Rev. 56, 4929–5021. <https://doi.org/10.1007/s10462-022-10286-2> (2022).
- [11] Himeur, Y. et al. Ai-big data analytics for building automation and management systems: A survey, actual challenges and future perspectives. Artif. Intell. Rev. 56, 4929–5021. <https://doi.org/10.1007/s10462-022-10286-2> (2022).
- [12] Bauer, M., Sanchez, L. & Song, J. Iot-enabled smart cities: Evolution and outlook. Sensors 21, 4511. <https://doi.org/10.3390/s21134511> (2021)
- [13] Gavrilas, S., Ursachi, C., Perta-Crisan, S. & Munteanu, F.-D. Recent trends in biosensors for environmental quality monitoring. Sensors 22, 1513. <https://doi.org/10.3390/s22041513> (2022).
- [14] Petäjajarvi, J.; Mikhaylov, K.; Pettissalo, M.; et al. Performance of a low-power wide-area network based on LoRa technology: Doppler robustness, scalability, and coverage. Int. J. Distrib. Sens. Netw. 2017, in press. doi:10.1177/1550147717699412
- [15] Mroue, H.; Nasser, A.; Parrein, B.; et al. Analytical and simulation study for LoRa modulation. In 2018 25th International Conference on Telecommunications (ICT), Saint-Malo, France, 26–28 June 2018; IEEE: Saint-Malo, 2018; pp. 655–659. doi:10.1109/ICT.2018.8464879
- [16] Croce, D.; Gucciardo, M.; Mangione, S.; et al. Impact of LoRa imperfect orthogonality: Analysis of link-level performance. IEEE Commun. Lett., 2018, 22: 796–799
- [17] <https://www.sciencedirect.com/science/article/pii/S1319157820306285>
- [18] J. Haxhibeqiri, A. Karaagac, F. V. den Abeele, W. Joseph, I. Moerman, and J. Hoebeke, LoRa indoor coverage and performance in an industrial environment: Case study, in 2017 22nd IEEE International Conference on Emerging Technologies and Factory Automation (ETFA), Sept 2017, pp. 18.
- [19] K. Tzortzakis, K. Papafotis, and P. P. Sotiriadis, Wireless self-powered environmental monitoring system for smart cities based on LoRa, in 2017 Panhellenic Conference on Electronics and Telecommunications (PACET), Nov 2017, pp. 14



INTERNATIONAL
STANDARD
SERIAL
NUMBER
INDIA



INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 9940 572 462  6381 907 438  ijirset@gmail.com



www.ijirset.com

Scan to save the contact details