Evaluate The Effectiveness Of Lora Network For Data Collection

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***Abstract* - LoRa Network is part of Low Power Wide Area Network (LPWAN). This technology is capable of long-range communication that works well in noisy conditions. Nowadays, LoRa plays an important role on most IoT systems which combining with the foundation of WiFi networks. With the emergence of LoRa technology, the Internet of Things (IoT) has been gradually improved and developed. In a LoRa network, a single receiver can handle multiple nodes at multiple locations in the area, unlike a WiFi-based system that requires multiple access points to increase coverage. Because LoRa technology is cheap, the cost of deploying IoT systems significantly decreases. In this article, the author emphasizes the importance of LoRaWAN networks in IoT, as well as the advantages and disadvantages of networks using this technique. Besides, this paper evaluates the performance of the LoRa network at long distances under different spatial conditions. For the coverage and propagation speed requirements of the LoRa, a set of LoRa parameters including Spread Factor and Bandwidth calibrated properly is very important. The quality of the LoRa Network depends not only on the distance but also on the terrain and obstacles in the signal propagation process.**

Keywords - LoRa, Internet of Things, low-cost LoRa node and gateway, monitoring system.

I. INTRODUCTION

Wi-Fi and Bluetooth have been wireless technologies that have been around for a long time [1], [2]. Due to their superiority, popularity, and easy-to-use protocols, such wireless technologies have dominated the IoT market. However, one challenge with that technology in IoT is coverage. Today, IoT applications not only need intelligent navigation systems, but also require highly energy-efficient sensor nodes that can communicate over long distances. The coverage of a Wi-Fi-based navigation system is only about 30 – 50 meters [3]. Bluetooth 4.0 technology has a coverage area of 10-15 meters, Bluetooth 5.0 can reach 40 - 60 meters. Although the coverage of these technologies has improved, in practice it is still quite modest. Zigbee technology later applied to IoT fields with an average coverage of about 70 meters brings significant improvement. This is still a challenge with IoT applications that require longer distances up to kilometers. In addition, implementing a solution with Wi-Fi or Bluetooth technology will require a higher cost to build a long-range communication network, requiring additional range extenders. This spurred the development of many low-power Wide Area Network (LPWAN) technologies, such as LoRa, to meet these requirements.

LoRa (short for Long-Range) is a spread spectrum modulation technique derived from chirp spread spectrum (CSS) technology. The data will be hashed with high frequency pulses to produce a signal with a higher frequency range than the original data frequency (this is called chipped). This high frequency signal is then further encoded by the chirp signal sequence, which is a time-varying sinusoidal signal before being transmitted to the antenna for sending. LoRa is a good choice for an IoT solution that requires long data communication range while still using very little power. In other words, the strong penetration of the LoRa signal makes it possible to provide enough coverage in a hard-to-reach location in the home. When compared to a Wi-Fi or Bluetooth based IoT solution with short communication range and data throughput (no range extenders or repeaters added), this technology can provide maximum efficiency in data communication while maintaining low development costs. The main target implementation of LoRa technology is smart devices that have limited power and do not require establishing constant communication at all times. All these features make LoRa an interesting candidate for the current Internet of Things (IoT) market and make it competitive with other IoT technologies like WiFi, Bluetooth, Zigbee.

In this paper, the focus is on introducing the LoRa technology, pointing out the advantages and disadvantages of using LoRa, and conducting some tests on data collection, evaluating the coverage performance of LoRa.

II. OVERVIEW OF LORA TECHNOLOGY

Both LoRaWAN and LoRa are distinct terms. The LoRa Alliance is responsible for developing the low power wide area network (LP-WAN) protocol, whereas Semtech is responsible for developing LoRa, which establishes the system's physical layer [4]. On top of the LoRa physical layer, a protocol known as LoRaWAN at the media access control (MAC) layer is built [5]. The LoRa unlicensed spectrum is located below 1000 MHz in all nations. As with AppsKEY and NwkKey, LoRaWAN employs AES-128 encryption for security [6]. AES has a key length of 128 bits and is a symmetric block cipher. For Asia, 780 MHz for China, 433 or 868 MHz for Europe, and 915 MHz for North America, the three most often utilized frequency bands are 433 MHz, 868 MHz, and 915 MHz. Due to the specification of long range and low power communication, Internet of Things (IoT) and automation have emerged as the primary targets of LoRa implementation. Additionally, the LoRa technology's adaptive data rate algorithm aids in maximizing the node's battery life and network capacity [7].

Zigbee uses DSSS (Direct Sequence Spread Spectrum) modulation, whereas LoRa uses Chirp Spread Spectrum (CSS) modulation at the physical layer [8]. The idea of chirp spread modulation is to spread a single bit of information throughout the full spectrum by changing it into another bit sequence. A further benefit of this modulation type is that it operates below the noise level, making it more interference-resistant. To put it another way, a broadband is being used to carry the signal or information. Originally employed for military communications, spread spectrum modulation was created in 1940. "Compression High-Intensity Radar Pulse" is the definition of the word "chirp." It says that during modulation, there is a cyclical increase and decrease in the signal's frequency [9], [10]. There are five important parameters in physical LoRa: carrier frequency, transmit power, spread factor (SF), bandwidth (BW) and code rate (CR) [11], [12]. As mentioned at the beginning, there are three main carrier frequencies of 433 MHz, 868 MHz and 915 MHz where LoRa operates. In Vietnam, the band for LoRa of 433 MHz is used without permission. This contributes to enriching the ecosystem of IoT and automation applications in the future.

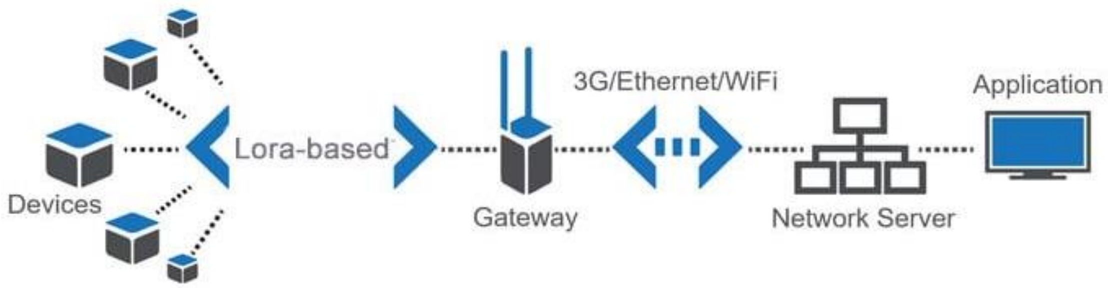

Figure 1. Diagram of an IoT system based on LoRa technology.

Environmental parameter monitoring is now essential in a wide range of industries, including agriculture, fisheries, animal husbandry, industrial pollution, and many more. The Internet of Things (IoT) and Industry 4.0 will make it easier to monitor environmental indicators from any location at any time. When the environmental parameters being monitored reach a worrisome level, alarms can be viewed with simply a smartphone. Users will have the convenience of monitoring outcomes to quickly act to decrease hazards and prevent environmental effects on human life.

In the situation of connecting all things, developing and applying high technology to industrial and agricultural production is an essential need to be equipped and applied in production. From those needs, the author develops the idea of using a wireless Lora network to apply in an aquaculture environment, to help monitor and monitor the status of aquaculture ponds, and improve quality. The quality of products to monitor pond and lake indicators contributes to high efficiency in aquaculture production. However, due to its high-tech application in numerous domains, including the environment, the Lora wireless network can be used extensively in real-world settings today (geological monitoring, concentration of substances in the air, water, soil...). Applications in forest fire warning, monitoring stations, coal mines (monitoring and warning indicators) can all use LoRa technology today widely and free of charge (no copyright). The sensor installation process is affordable, and the architecture is simple. Currently, LoRa technology has been widely applied in the Internet of Things, and there are even alliances of manufacturers using this technology because of its popularity. Lora works at long range with low power consumption. As mentioned, the biggest advantage of LoRa technology is that it consumes low power, but can still transmit data over long distances. In addition, the operating capacity is not degraded, and the LoRa technology can transmit millions of messages from the data station. Lora has a high level of security. These signals will be encrypted with 2 layers, including 1 layer for applications with AES encryption and 1 layer for network security.

III. EVALUATE THE EFFECTIVENESS OF IOT SYSTEM BASED ON LORA COMMUNICATION

In the next part, the article will go into the evaluation of communication efficiency when using LoRa technology in an IoT system. The described system includes all the components as shown in the diagram in figure 1. The goal of the system is to measure the parameters obtained from the application of LoRa technology to collect environmental temperature and humidity data.

A. System Architecture

LoRa Gateway block includes ESP8266 board connected to LoRa SX1278-02 module by SPI interface. The LoRa Node block includes an Arduino NANO board connected to the LoRa SX1278-02 module, which also follows the SPI interface. LoRa Gateway is responsible for collecting data from LoRa Node. Every second, the temperature and humidity values from the DHT11 sensor will be collected through the LoRa Node and sent back to the LoRa Gateway. These values are then sent back to the smart phone application via FireBase. Figure 2 shows the connection of the LoRa network in the first part of the network in the project. Based on this figure, the LoRa terminal is interfaced with the LoRa single channel input in a star topology using LoRa modulation. The spread factor and bandwidth of the LoRa network will be configured in the encryption section before communication begins. Once the LoRa gateway is installed and synchronized, it will forward the packet received from the terminals to the ESP8266. The ESP8266 is a Wi-Fi module that will be used to provide the internet interface for the LoRa gateway. The connection between the LoRa port and the ESP8266 via the SPI communication is the same as the connection to the Arduino.

The measured results are shown in figures 4 and 5 for the corresponding temperature and humidity values at a distance of approximately 100 meters between the Gateway and the sensor. We see that, in close range, the signal transmission in a short time at a fast speed and is quite good when compared to other networks like Wifi or Bluetooth.

B. LoRa network performance evaluation at long distances

1) Data received with different SF and BW

The results are carried out in the urban area of Ho Chi Minh City at the furthest distance and the packet loss rate is less than 10% with different spreading factors (SF) and bandwidth (BW) shown in table I.

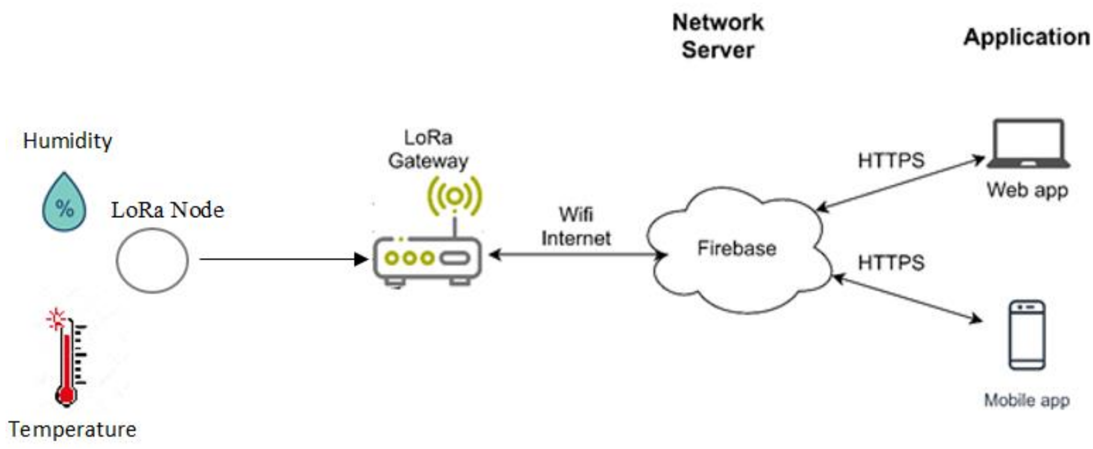

Figure 2. Block diagram of data collection system using LoRa.

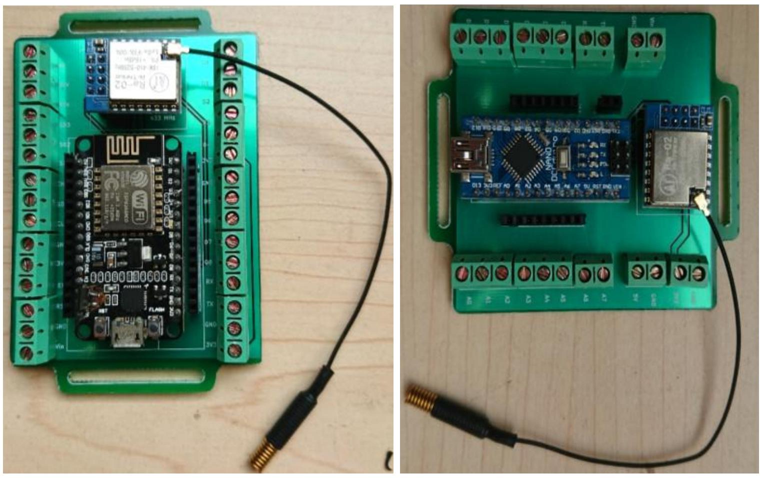

Figure 3. LoRa Gateway Module (left image) and LoRa Node Module (right image).

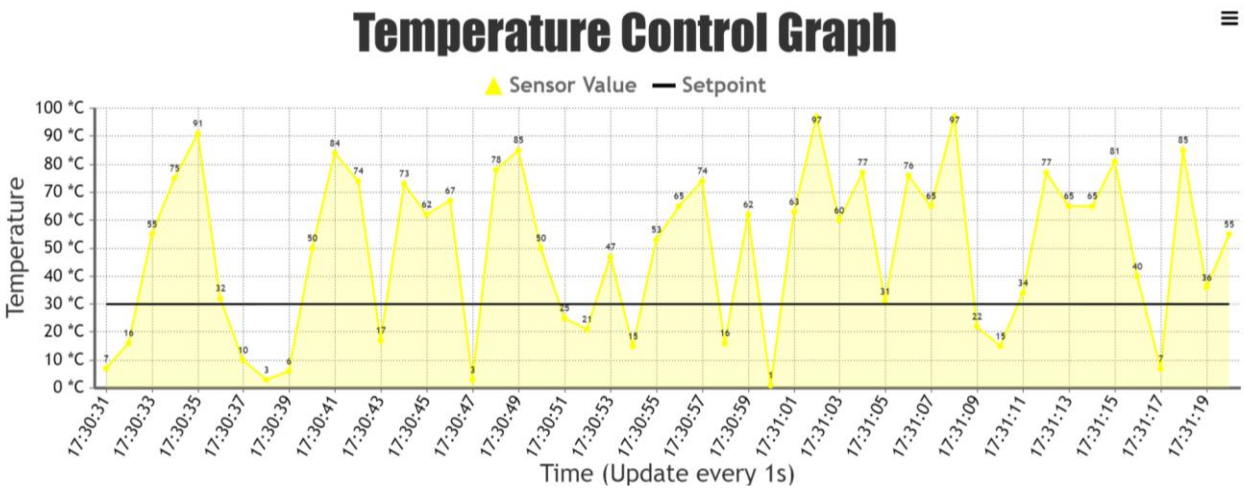

Figure 4. Graph of measured temperature every second at a distance of 100 meters.

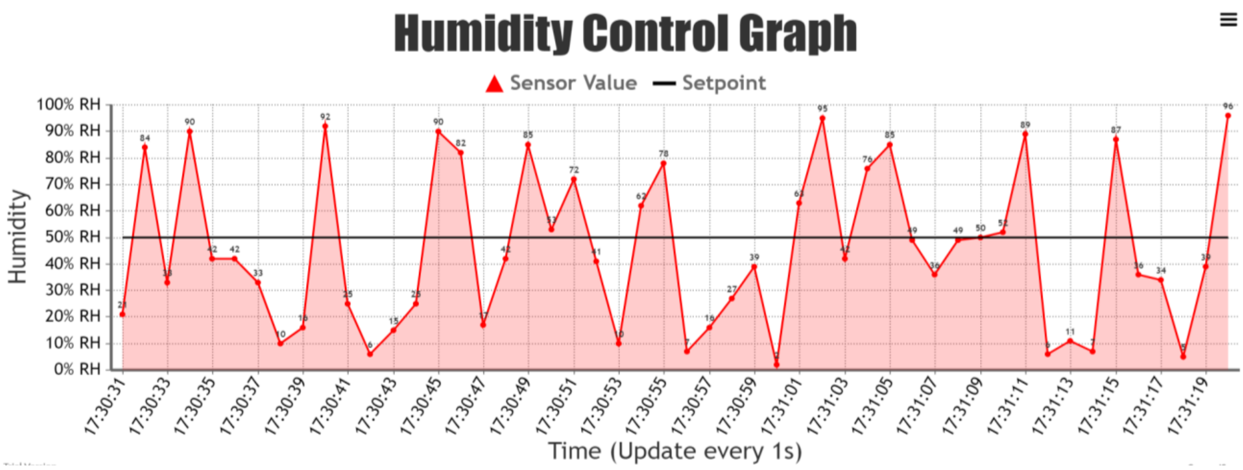

Figure 5. Humidity graph measured every second at a distance of 100 meters.

The data in table I shows that increasing the distance depends on decreasing BW or increasing SF, because smaller BW and higher SF can significantly increase the sensitivity. However, this will reduce the data rate and lead to increased transmission delay. In addition, LoRa having wide coverage and low power consumption and transmission latency is also taken into account in the IoT system. For this reason and based on the results in table 1, SF = 7 and BW = 125 kHz are used in the LoRa network, to create an optimal balance of the IoT system while ensuring the transmission and reception distances and guaranteeing the reliability of the network. The delay is not too high.

TABLE I. LORA COVERAGE WITH DIFFERENT PARAMETERS OF SF AND BW.

SF	BW (kHz)	Distance where data packet loss is less than 10% (m)
7	125	1200 - 1500
7	250	1100 - 1400
9	250	1500 - 1700
12	250	2000 - 2200

2) Transmission distance and error rate

To evaluate transmission distance and error rate, the Gateway is configured to 433 MHz frequency and 125 kHz bandwidth. The LoRa sensor node is moved in zones 1,2 and 3. Area 1 has many tall buildings with an average height of 20 meters. Areas 2 and 3 are large and open areas with almost the same distance and few obstacles.

TABLE II. RATE OF PACKET LOSS IN DIFFERENT AREAS.

Area	Average distance to Gateway (m)	Number of packets lost	Total number of packets	Data loss rate (%)
1	1900	651	1000	65,1
2	1450	42	1000	4,2
3	1750	18	1000	1,8

There is 4.2% packet loss rate in area 2, which is higher than in area 3. Although the distance in area 3 is larger than in area 2. That shows the influence of obstacles on the road transmission is much larger than the transmission distance. In area 1, the packet loss rate is 65.1%. The high rate of packet loss in this area may be due to being blocked by many tall buildings.

The above results also show that the IoT network system based on LoRa wireless network technology works well within 1.3 kilometers. And the effectiveness of LoRa wireless technology is also affected by the surrounding environment including tall buildings, trees, etc. So these factors should be taken into account when implementing LoRa wireless network for IoT system.

IV. CONCLUSION

The article presents the evaluation of the effectiveness of LoRa wireless technology for IoT systems that have been tested and developed in recent years. It can be seen that LoRa technology has overcome the limitations of current wireless technologies in the IoT field, bringing a potential new approach in deploying wireless networks with wide coverage and energy saving. LoRa technology in IoT has low power but can still transmit over long distances. The environment in which the LoRa network is deployed has an influence on the signal quality, especially the degree of dense interference between the transmission lines having the most influence on the signal quality degradation as seen in the experiment. The propagation factor and the Bandwidth are the core factors affecting the performance of the LoRa network. The higher propagation coefficient and lower bandwidth settings allow for longer communication range and higher resistance to interference. This shows the advantage of LoRa network over other wireless protocols. In summary, LoRa technology is a very promising technology in today's IoT and automation applications.

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