Journal of Physics: Conference Series

PAPER • OPEN ACCESS

Low-Power Wide Area Network Construction Method Based on LoRa Technology for Agricultural Science and Technology Parks

To cite this article: Zhiguo Sun *et al* 2020 *J. Phys.: Conf. Ser.* **1673** 012066

Journal of Physics: Conference Series **1673** (2020) 012066 doi:10.1088/1742-6596/1673/1/012066

Low-Power Wide Area Network Construction Method Based on LoRa Technology for Agricultural Science and Technology Parks

Zhiguo Sun[1], Zhiqiang Ji[1], Hongyan Wang[2], He Huang[3], Zheng Wang[2], Yongbo Ding[1], Tao Yu[1] and Chenxue Yang[1*]

[1]Agricultural Information Institute, Chinese Academy of Agricultural Sciences
[2]West China Electronic Business CO.,LTD
[3]Institue of Intelligent Machines, Chinese Academy of Sciences
[*] Corresponding Author Email: yangchenxue@caas.cn

Abstract. The Internet of Things (IoT) requires different but complementary types of wireless network technologies, having their own merits from distance, power consumption, capacity and cost perspectives. This paper introduces a comparative study of LoRa wireless communication network technology for the long-distance and low-power wide-area network scenario deployment. In this paper, we propose a low-power wide-area network construction method based on LoRa technology for an agricultural science and technology park in Ningxia, Western China. Specifically, we design the optimal placement of LoRa sensors in the facility greenhouse by measuring the LoRa signal quality on the spot in the traditional brick wall sunlight greenhouse. In the traditional brick wall solar greenhouse, the success rate of data communication between LoRa terminal and LoRa gateway reaches 100%. Experiment shows that the coverage distance of the LoRa network reaches 3km in the most common conditions in agricultural science and technology park, *i.e.*, the height of the LoRa gateway is 10 meters, and the maximum transmission power is 27dbm.

1. Introduction

In recent years, the Internet of Things (IoT) technology has been developing rapidly, which imposes different requirements on network communication technologies due to different application scenarios with diversified types of data interactions. The IoT requires different types of wireless network technologies, having their own merits from distance, power consumption, capacity and cost perspectives. The IoT can provide devices with a low-power consumption technology for medium and long-distance communications in environmental monitoring scenarios. Therefore, Low Power Wide Area Network (LPWAN) technology has emerged to meet the connection requirements of more and more remote IoT devices. LPWAN is designed for IoT applications with low bandwidth, low power consumption, long distance, and a large number of connections.

LPWAN [1-2] is a wireless network that can communicate over long distances with low bit rates, and can be divided into two categories. One is LoRa, SigFox and other technologies that work in unlicensed spectrum. The other is 2/3/4G cellular communication technologies supported by 3GPP which work in licensed spectrum, such as EC-GSM, LTE Cat-m, NB-IoT, etc. The transmission distance of LPWAN can generally reach more than 5km, which is farther than traditional mobile cellular technologies (such as 2G, 3G, 4G, etc.) and short-distance communication technologies (such as Bluetooth, Zigbee, etc.). Furthermore, LPWAN has low node power consumption and can be used for more than 3 years, even as long as 10 years, using AA batteries or small lithium batteries in a typical IoT scenario. The LPWAN network structure is a simple star topology with low operating and maintenance costs. It can be applied to civil infrastructure such as parking lot resources, traffic flow control, utility monitoring, power distribution control, environmental monitoring and so on.

LoRa is the most promising and rapidly developing low-power wide area network communication technology. As a wireless technology, LoRa [3-4] is based on spread spectrum technology, that is, using the Sub-GHz frequency band to make it easier to communicate with lower power consumption over long distances, and can be powered by batteries or other energy harvesting methods. LoRa works in unlicensed free frequency bands including 433, 868, 915MH [5-6] . The general wireless distance range is 2-5Km in cities, and the wireless distance will be longer reaching 15Km in suburbs or open areas [7]. Although the LoRa transmission rate is small, it has extended battery life and increased network capacity. Usually, the capacity of the LoRa gateway can be connected to thousands of LoRa nodes and the battery life of LoRa can be as long as 10 years [7-8]. The penetration of LoRa signals into buildings is also very strong. These technical characteristics of LoRa are more suitable for low-cost large-scale IoT deployment.

LoRa network deployment topology layout can be designed according to specific applications and scenarios. LoRa is suitable for applications with low communication frequency and small data volume. About the number of nodes or terminal devices that can be connected to a gateway, according to the official explanation of Semtech, an SX1301 has 8 channels, and by using the LoRaWAN protocol, it can receive about 1.5 million packets of data per day. If a certain application sends one packet per hour, then an SX1301 gateway can handle approximately 62500 terminal devices.

LoRa can be divided into large networks and small networks from the perspective of network applications. Small network refers to the user's own nodes, gateways and servers, forming a network system on its own; and large network is a large-scale basic network deployment, just like China Mobile's communication network. There are many telecom operators involved for the practitioners in LoRa industry. With the increasing number of LoRa devices and networks, mutual spectrum interference exists, which puts forward requirements for the allocation and management of communication spectrum. Also, it requires a unified coordinated management mechanism and the management of a large network.

Agricultural environment is complex, which requires sensors to upload data regularly. Compared with other communication networks such as WiFi, ZigBee and Bluetooth technologies, the LoRa technology has a great breakthrough in the short transmission distance. It has the characteristics of wide area coverage, low power consumption, low cost and strong anti-jamming ability. Based on this, LoRa can be used in conjunction with sensors and control equipment for remote intelligent control and monitoring in the agricultural field, such as the water quality, dissolved oxygen, nitrate and weather information in intelligent aquaculture; the environmental parameters such as light temperature and humidity, H2S, NH3, water quality, etc in intelligent poultry breeding; the farmland soil moisture data in farmland intelligent irrigation.

As a practice site for LPWAN technology application, an agricultural science and technology park in Ningxia has implemented refined management for agricultural planting by using a large number of IoT equipment in planting production many years ago. However, the construction of the agricultural IoT facilities in the Agricultural Science and Technology Park was used a combination of wired network and ZigBee wireless network, which has many drawbacks. First, the wired network cable laid is often broken because of the adjustment on the agricultural planting facilities in the greenhouse, resulting in inability to complete the data transmission. Second, due to the limitation of the maximum communication distance in ZigBee wireless communication technology, this IoT facility cannot be widely used in this large national agricultural science and technology park. Third, the IoT terminals (such as greenhouse temperature and humidity monitors) used in the park are not designed for energy saving, resulting in high power consumption of terminal equipment. It can be used with wired power supply with a relatively fixed position of the power supply interface. The IoT terminal equipment in the park cannot be moved to use location due to practical needs.

In addition, the large area of the agricultural science and technology park leads to higher fixed network wiring costs. The park only carries out the management and living area wiring, and the production area generally does not carry out fixed network wiring. Therefore, the agricultural science and technology park urgently needs a long distance, low-power and low-cost wireless IoT coverage technology to meet the application needs of Internet of Things equipment in agricultural production.

In this paper, a low-power wide-area network construction method based on LoRa technology is proposed for an agricultural science and technology park in Ningxia, Western China. Specifically, we design the optimal placement of LoRa sensors in the facility greenhouse by measuring the LoRa signal quality on the spot in the traditional brick wall sunlight greenhouse. The proposed low-power wide-area network construction method can not only meet the needs of long-distance wireless IoT network coverage in the park, but also fully consider the issue of energy saving. The Internet of Things terminal (such as the greenhouse temperature and humidity monitor) can be convenient to move and used for a long time under the condition of battery power supply. By using the proposed optimal placement of LoRa sensors in the facility greenhouse, the success rate of data communication between LoRa terminal and LoRa gateway reaches 100% in the traditional brick wall solar greenhouse. It can effectively ensure the complete data transmission. Experiment shows that the coverage distance of the LoRa network reaches 3km in the most common conditions in agricultural science and technology park, *i.e.*, the height of the LoRa gateway is 10 meters, and the maximum transmission power is 27dbm.

2. Low-power Wide Area Network Construction

2.1. Application Environment Analysis and Technology Selection

The agricultural science and technology park in Ningxia, Western China, is located in a large area with sparsely populated land and belongs to an arid zone. In order to save water resources and achieve the purpose of efficient utilization of various planting resources, the park needs to implement agricultural facility planting and ecological breeding.

After communicating with the park management personnel, our requirements can be summarized into the following. The layout of the planting environment will be adjusted regularly according to the needs of different planted varieties. The park requires the use of separate wiring, the use of equipment that is not easy to move for power supply, and to ensure that the equipment can be used for long-term standby and battery power. It requires that the various components of the equipment are in normal operation to reduce power consumption as much as possible, including communication components.

Due to the large area and sparse population of the park, the operator's network signal is not good. If the park uses the operator's network, the amount of IoT equipment is huge and the cost will be higher. Therefore, the park needs to build its own IoT network. At the same time, it is necessary to ensure that existing facility planting sites are not undergoing major transformations during the construction of the self-built Internet of Things network.

The Internet of Things is now very hot, and various wireless communication technologies are fiercely competitive. In the past two years, the LPWAN technology keeps on developing. LoRa and NB-IoT have become the two mainstream technologies and attracted attention from major manufacturers. The wide applicability of LPWAN in IoT makes many professionals believe that it has the potential to replace existing local area network solutions.

Although NB-IoT technology meets the requirements of low power consumption, it belongs to the operator's network and does not meet the rigid requirements of the park. Therefore, it is based on low power consumption of the park and self-built for the needs of the network, we consider it to be a feasible solution to choose LoRa technology for the construction of the IoT network in the park. Therefore, based on the low power consumption and self-built network requirements of the park, we choose a low-power wide-area network construction method based on LoRa technology as a feasible solution.

2.2. LoRa Low-Power Wide Area Network Construction

In the construction of a LoRa low-power wide area network, the location of the LoRa gateway must first be determined. The LoRa gateway is usually set up in a higher position in the middle of the coverage area, taking into account the convenience of power supply for the LoRa gateway equipment. Therefore, we chose a location with a higher terrain as the installation location of the LoRa gateway equipment in the management area of the agricultural science and technology park, and the erection height is about 10m, as shown in Figure 1.

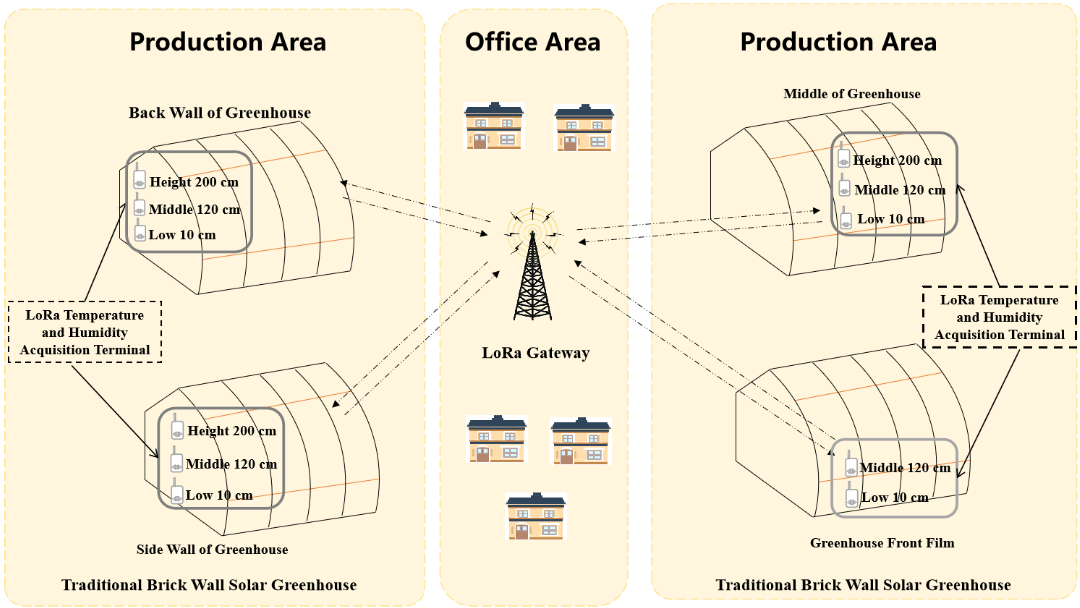

Figure 1. Schematic diagram of LoRa gateway erection

In the selection of LoRa gateway equipment, we chose the SX1301-based module as the LoRa gateway, which is based on the low-power wide area network LoRaWAN protocol. It has high reliability and can provide low-power, mobile, and secure local two-way communication services for IoT devices.

LoRaWAN can simplify the interaction between devices, users, and networks, and provide standards. In terms of LoRa protocol, the device supports standard LoRaWAN protocol. Set the LoRa communication rate to 292bps-5.4kbps, the number of channels is 8, the maximum transmission power is 27dbm, and the maximum receiving sensitivity is -141dBm (SF=12). It meets the project requirements.

In terms of the uplink data network channel, in order to support Ethernet and 4G uplink data backhaul and support automatic switching, we lowered the installation and chose 4G network as the data uplink Internet channel. It supports remote management and complies with GB50343-2004 Class B lightning protection, up to IP67 protection.

We chose an omnidirectional antenna made of glass fiber reinforced plastic as the antenna of the LoRa gateway device. The antenna should be installed higher than the fixed rod of the antenna, because if the metal fixed rod and the antenna overlap in the vertical direction, the signal will be greatly attenuated.

3. Experiment

In the experiment, we selected a traditional greenhouse with a straight-line distance of about 1Km from the gateway as the signal test base, and used a LoRa signal tester to test the signal strength of the LoRa network at different locations and heights in the greenhouse. The LoRa signal tester tests the signal strength of the LoRa network at different locations and different heights in the greenhouse. We find out the optimal position and height of the LoRa network signal in the greenhouse through the analysis of the LoRa network signal strength data. It can guide the placement of LoRa terminal equipment in the actual production environment. In addition, we obtain the coverage and signal strength of the LoRaWAN gateway in a visual environment by testing the network signal strength at different distances from the LoRa gateway in an real scene.

3.1. Signal Test in Traditional Greenhouse

The experiment chooses the common traditional brick wall sunlight greenhouse. The thickness of the back wall of the greenhouse is 1 m, the thickness of the side wall is 0.5 m, and the remaining parts are all steel frames and covered with membrane structures. We carried out LoRa network signal tests on 11 points behind the greenhouse, including the high, medium and low places on the back wall; the high, medium and low 3 places on the side wall, the high, medium and low in the middle of the greenhouse; the high and low locations on the grounding side of the greenhouse. The test method adopted is to use the LoRa signal tester to send 10 data packets to measure the packet loss rate at each test point. It can be shown in Table 1.

Table 1. Packet loss rate of each test point in the greenhouse.

Test point	**Side Wall** of Greenhouse	**Back Wall** of Greenhouse	**Middle** of Greenhouse	Greenhouse **Front Film**
Low 10 cm from the ground	100.0	100.0	100.0	95.0
Middle 120 cm from the ground	100.0	100.0	40.0	-
Height 200 cm on the ground	100.0	87.5	0.0	50.0

It can be seen from Table 1, the best signal point is located at the middle high point of the greenhouse without any packet loss, and the packet loss rate is 0%, followed by the middle point of the greenhouse and the high point of the film in front of the greenhouse, respectively 40% and 50%. The high point of the front film of the greenhouse is the same as the test point of the middle part of the greenhouse, and neither is blocked by the thick brick wall. However, it has a certain impact on the signal due to its near-steel structure, and the packet loss rate has increased significantly.

Therefore, from the perspective of signal quality, we determine that the best deployment position of LoRa terminal equipment in traditional brick wall solar greenhouses is the middle high point of the greenhouse, followed by the middle of the greenhouse and the high point of the film in front of the greenhouse.

3.2. Different Transmission Distance Signal Test

We tested the quality of LoRa signals at different transmission distances under the visual range. The test method is still to measure the packet loss rate by sending data packets to test the packet loss situation. We choose 900 m, 1 500 m, 3 000 m, 3 700 m, and 5 000 m points to test the signal quality of the gateway. The test data are shown in Table 2.

From Table 2, it can be seen that when the distance to the gateway is 3 km, the packet loss rate is as high as 80%. After 3.7 km, the packet loss rate reaches 100% and the network is no longer available. The closer to the gateway, the lower the packet loss rate. Therefore, we determine that the farthest reachable position of the LoRa signal in practical applications is 3Km.

The signal coverage of the LoRa gateway is directly related to the actual application environment and the installation of the gateway. When selecting the location for the LoRa gateway, we should avoid obstruction by larger and higher fixed objects in the coverage area of the gateway. For example, the coverage area of the gateway should not have buildings higher than the height of the gateway. When installing the LoRa gateway equipment, the outdoor antenna should be an omnidirectional antenna made of glass fiber reinforced plastic, and the antenna installation should be higher than the fixed pole, because if the metal fixed pole and the antenna overlap in the vertical direction, the signal will be greatly attenuated. In addition, the signal coverage and signal quality of the LoRa gateway are also related to the maximum transmit power and maximum receiving sensitivity of the LoRa gateway device.

Table 2. Packet loss rate at different distances from LoRa Gateway.

Position	900 m from gateway	1500 m from gateway	3000 m from gateway	3700 m from gateway	5000 m from gateway
Packet Loss Rate	23.5	50.0	80.0	100.0	100.0

4. Conclusion

This paper proposes a low-power wide-area network construction method based on LoRa technology for the agricultural science and technology park in Ningxia, Western China. The test data are all data obtained in this experimental environment, and are only used as a guide for the implementation of the LoRa network deployment. Experiment shows that when deploying LoRa networks in agricultural parks, the best deployment position for LoRa terminal equipment in traditional brick wall solar greenhouses is the middle high point of the greenhouse, followed by the middle point of the greenhouse and the high point of the film in front of the greenhouse. In terms of transmission distance, we believe that the farthest 3Km is the reachable position of the LoRa signal. If we want to transmit a farther position, you need to further optimize the installation of the LoRa gateway.

5. Acknowledgments

This work was partially supported by Ningxia Smart Agriculture Key Technology Research and Integration Demonstration Project (2017BY067).

6. References

[1] Mekki K , Bajic E , Chaxel F , et al. A comparative study of LPWAN technologies for large-scale IoT deployment[J]. *ICT Express,* 2018:S2405959517302953.

[2] Santa, José, Sanchez-Iborra R , Rodriguez-Rey P , et al. LPWAN-Based Vehicular Monitoring Platform with a Generic IP Network Interface[J]. *Sensors,* 2019, 19(2).

[3] Abboud S , Rachkidy N E , Guitton A . Efficient Decoding Of Synchronized Colliding Lora Signals[C]. *2020 IEEE 91st Vehicular Technology Conference (VTC2020-Spring). IEEE,* 2020.

[4] Kais Mekki, Eddy Bajic, Frédéric Chaxel, et al. Overview of cellular LPWAN technologies for IoT deployment: Sigfox, LoRaWAN, and NB-IoT[C]. *IEEE International Workshop on Mobile & Pervasive Internet of Things. IEEE,* 2018.

[5] Hardie M , Hoyle D . Underground Wireless Data Transmission Using 433-MHz LoRa for Agriculture[J]. *Sensors,* 2019, 19(19):4232-.

[6] Eremin V , Borisov A . A research of the propagation of LoRa signals at 433 and 868 MHz in difficult urban conditions[J]. 2018.

[7] Gambiroza J C , Mastelic T , Solic P , et al. Capacity in LoRaWAN Networks: Challenges and Opportunities[C]. *2019 4th International Conference on Smart and Sustainable Technologies (SpliTech)*. 2019.

[8] A. Lavric and V. Popa, "Internet of Things and LoRaTM Low-Power WideArea Networks: A Survey", *International Symposium on Signals Circuits and Systems (ISSCS),* 2017.