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Automated Agricultural Management Systems Using Smart-Based Technology

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***Abstract*—This research focuses on the design and implementation of an Internet of Things (IoT) smart-based system for the agriculture industry, especially chilli plantations. Every year, chilli farmers experience huge losses due to pest infestation and a lack of technology to precisely manage their farms. To solve several problems, the IoT system was designed to continuously monitor pest detection status, temperature, humidity index, and soil moisture level simultaneously. Besides these, the IoT system is also designed for long-distance remote water, pesticide, and fertiliser pumps. An IoT platform was applied in this project to provide a monitoring dashboard and switches to empower several pumps with long-distance remotes using the LoRa communication systems in a wide coverage range of chilli farms. Three experiments were designed to determine the range of the LoRa network. All experiments and data collection were done on the campus of Universiti Teknikal Malaysia Melaka (UTeM) and the Melaka area. All experiments were analysed based on the results collected, such as packet reception rate (PRR), signal-to-noise ratio (SNR), and received signal strength indicator (RSSI). Based on the experiment results and conclusion, the LoRa communication system is suitable for applying to chilli farms in order to monitor all the elements such as soil moisture and pest detection status. The experiment also concludes that this LoRa network can be worked effectively up to cover a range of 260m with the elevation of the gateway.**

***Keywords*—Management systems; Internet of Things; crop field; LoRa; agriculture industries; precision engineering**

I. INTRODUCTION

The Gross Domestic Product (GDP) of developing nations is highly dependent on the agriculture sector [1]. Crop production (agriculture), forestry, and animal farming are all forms of agriculture that are used for domestic or commercial reasons as raw materials as well as other processes. This was the main precursor of human evolution.

In order to meet the needs of an ever-growing population while also keeping up with technological advancements, the agricultural industry is under tremendous strain. 8.5 billion people are predicted to populate the earth by 2030 and in 2050, to 9.7 billion [2]. India and China are the world's two most populous nations, each with more than one billion residents, accounting for 18 percent and 19 percent of the world's total population, respectively. By 2022, it is expected that India's population would outnumber China's population. Agricultural production is critical to the economies of both nations in order to provide a steady supply of livelihoods for their rapidly growing populations. All species that are plagued by diseases and pest attacks will be jeopardized by the quantity of harvestable crops that are reduced as a result of the infections [3]. Crops that flourish and can be harvested from all of the affected species will also suffer greatly as a result of the disease. While most crops have innocuous fungal mycelium, fungal traces may be more hazardous and even toxic in rare circumstances. Pests that induce a loss in the plant's capacity to photosynthesis result in a reduction in the delivery of nutrients to the fruits, which in turn results in a decrease in the rate of synthesis of the endosperm starch part of the fruit. The upshot is that harvesting crops is less efficient, causing them to become shrunken and thin when they reach maturity.

II. LITERATURE REVIEW

A. Management System In Agriculture

Foreign developed nations began collecting agricultural data earlier, and their studies and implementation of intelligent agriculture are more advanced. The agricultural environmental monitoring system was conceived and designed by Jeonghwan Hwang and colleagues [16]. Khajol, Akshay, and their colleagues [4] developed a smart monitoring system that made use of modern technologies.

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For example, the Internet of Things (IoT) and image processing. The current population's needs cannot be supplied by traditional farming practises [17]. Smart agricultural solutions based on Wireless Sensor Networks (WSN) and the Internet of Things (IoT) are becoming more popular among farmers due to the increasingly changeable weather and environmental circumstances [18]. The system was created not only to monitor the farm, but also to make suggestions to farmers regarding the moisture content of the soil, the detection of pests, and the sort of crop that would be most suitable for the particular soil. A line-follower robot, powered by a Raspberry Pi, was created to analyse the moisture content of the soil. The robot is capable of monitoring the moisture content of the soil at intervals of 100 metres. For the purpose of detecting pests, a camera was directly attached to the system. Following completion of the farm survey, the system collects all previously saved data from the SQLite and cloud databases in order to analyse the moisture content and insect information in order to make recommendations to the farmer for the appropriate pesticide. A number of projects have suggested an ad hoc platform that is easy to use, cheap, and small. It has a minimal environmental impact, low energy consumption, and superior efficiency of a multi-function wireless sensor [5]. Each Sensor Node (SN), which consisted of a collection of sensors, was a critical component of the system. The SN was equipped with environmental sensors and a camera. The Base Station (BS) was developed by using a Raspberry Pi to receive data from multiple SN. The communication between SN and BS used radio wave technology. The power sources of SN and BS were supplied by solar panels and batteries.

Many experts, both domestic and international, have dedicated their lives to the exploration of agricultural datasets as a result of advancements in information technology. In order to build the agricultural structure, Lamehari et al. looked at the agricultural environmental data that had been collected [16]. This could help farmers and businesses by helping them make good decisions, speed up the decision-making process, and improve agricultural productivity and the use of natural resources. Soil monitoring and analysis were created by Alves, Gabriel et al., who provided farmers with pertinent advice for improving the soil [16]. Li Xiufeng and his team came up with a visual interactive system that could help people send and analyse data [16].

B. Crop Disease and Pest

Modern IoT-based smart solutions, including drones, robots, and wireless sensors, enable farmers to significantly reduce pesticide consumption by detecting crop pests [6].

Drone data is used for plant health indicators, yield prediction, counting harvests or crops, measuring crop or plant height, assessment reports, pigment measurement, detecting nutrients, pests, or diseases, and so on [17]. In contrast to conventional pest control methods that use a calendar or prescription, IoT-enabled pest management allows for real-time traceability, simulations, and illness detection and is more effective than traditional pest control methods. The Internet of Things (IoT) has already been extensively studied in the field of agriculture. The connection between information technology and agriculture resulted in the creation of new agricultural directions [19]. In general, the dependability of pest management and crop disease depends on three factors: diagnosis, evaluation, and treatment. The use of solar insecticidal lights (SIL) reduces pesticide use by killing migratory pests with a high voltage pulse current [20]. High-tech disease and pest monitoring devices employ image processing to look at raw pictures that were taken around the crop area by field cameras, drones, or satellites. Due to the fact that remote sensing images often cover huge regions, they are of superior quality at a cheaper cost. Nevertheless, field sensors are essential for promoting extra information collection features, such as pest conditions, environmental monitoring, and plant health, throughout any stage of the plant life cycle. For instance, an automated trap system driven by IoT technology may capture, identify, and even characterize various insect species, transferring information to the server for in-depth research that is not possible with remote sensing.

C. Communication and IOT Platforms in Agriculture

Collected data by sensor nodes is generally transferred through a wired or wireless network to the desired location (e.g., an IoT platform, server, or database). The network protocols utilised in the IoT method, such as CAN and Ethernet, were the most widely used, for long-distance wireless networks, LoRaWAN and guidelines for cellular networks such as 3G, GPRS, and 4G network protocols for wired networks. Similarly were the most often used. Meanwhile, the most popular mechanisms for short-to medium-range wireless connections were Wi-Fi, ZigBee, and Bluetooth. Network rules are used to make it easier for IoT solution parts like sensor devices and gateways to communicate with each other in a wide range of agricultural settings (e.g., arable land, greenhouses, orchards). These network rules allow both short-and long-distance connections to be built.

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ThingSpeak, Azure IoT, Mobius, Google, AWS IoT, and Thinger.io are the most frequently encountered cloud-based systems utilised in various project related to precision agriculture [7]. Because of its open-source nature and low technological requirements, ThingSpeak is the most widely used server framework in the community. A cloud-based platform enables the connectivity for IoT projects by using cloud computing for the processing and storage of data. It is usual practise for these services to provide visuals and boards that enable monitoring of information obtained as well as the creation of customised panels from an aggregate of diverse indications as time progresses [8]. Sensors produce vast amounts of information, which is processed in computer systems to create what is known as "big data," an unorganized collection of data used to gather agricultural inputs [9, 10]. In order to shorten the time it takes to respond to a large amount of data, it is necessary to include emerging innovations. For instance, a parallel system called Hadoop enables the analysis of huge amounts of data; it has been shown to be more successful in analyzing index data of rainfall from several weather stations.

III. Design And Development

The previous subsection briefly discussed the design of IoT technology for monitoring and management of the agriculture industry. This provides an overview of how this project should be implemented by identifying the design challenge of the system to be implemented and the design target that will lead to proposing the methodology to be applied in order to make the objectives practical.

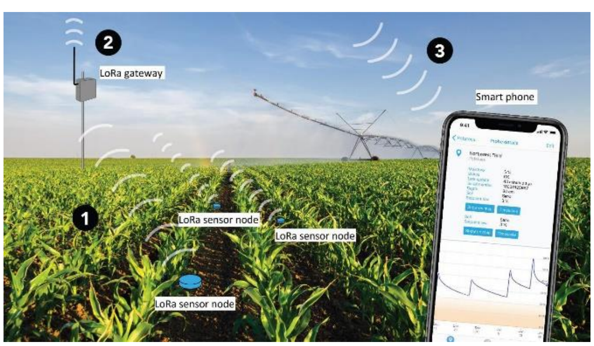

Fig. 1. IoT system for managing agriculture sector

Therefore, this paper emphasises the method that will be utilised to design the IoT systems for crop management through the design of hardware integration and experimentation in terms of hardware and software.

In three tests, the LoRa network's performance and coverage limitations will be measured. The main goal of looking for a bibliography is to locate studies and journals that detail the limitations and the processes that led to them. The research focused on papers that performed real-world experiments since models of LoRA networks are still far from accurate. Modify the test as necessary in light of the given limitations and logic. In addition, the experiment sought to study the effectiveness of LoRa and IoT advancements with the goal of analysing them. As shown in Fig. 1, multiple units of LoRa sensor nodes were installed on the farm to collect environmental parameters such as soil moisture index, pest detection status, temperature, and humidity of the environment. There was a LoRa gateway installed in the area of the farm to collect all these environmental parameters from multiple units of sensors and forward this information to an IoT dashboard. Then the dashboard will be accessible using a smartphone, computer, or tablet. Users can monitor the condition of their farm and remote pumps in real-time using this comprehensive system from any location with an Internet connection. In this project, the LoRa gateway will forward the message to the specific built-in MQTT of the IoT dashboard. The MQTT is the element that acts as a middle man between the LoRa gateway and the IoT dashboard, where the LoRa gateway will publish information to MQTT while the dashboard will subscribe to the information from MQTT. Hence, the user is able to monitor the information from the dashboard.

A. Integration Lora Gateway And Sensor Nodes

The RFM LoRa shield is an Arduino [11] shield compatible design that integrates with a RFM95W LoRa module as shown in Fig 2. The open-source library in Arduino IDE makes it simple to design a project.

Fig. 2. LoRa – RFM95W Shield

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Fig 3 shows the LoRa shield integrated with an ESP32 Arduino shield as the hardware design of the gateway. The gateway is used to request sensor conditions from a sensor node and forward these messages to the IoT dashboard. The ESP32 was used for Serial Peripheral Interface (SPI) communication with the LoRa module. This enabled the ESP32 to send or receive a message with LoRa communication [12]. At the same time, ESP32 uses its built-in Wi-Fi module to connect to the Internet in order to publish and subscribe to data with its dashboard.

All tests were carried out in accordance with the following guidelines:

Setup temperature: 25 degrees Celsius

The voltage of the power supply: 3.3V

The bandwidth is 125kHz

Channel frequency is 915MHz

Transmission power: 13 decibels (dBm)

Spreading Factor, which is set at 12

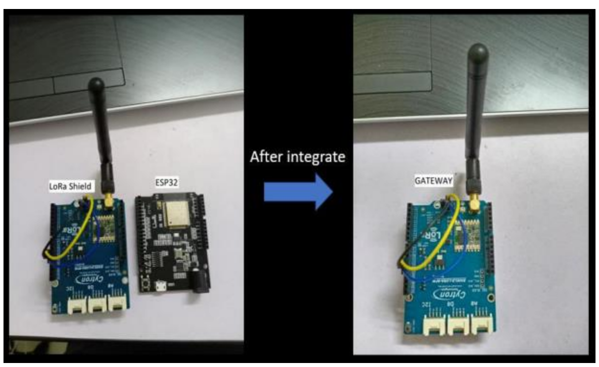

Fig. 3. Gateway design using Lora shield and ESP32.

The full integration of sensor nodes was built from the integration of the Arduino Mega, LoRa shield, and sensors PCB board (Fig. 4). The sensor nodes can also be attached to the Raspberry Pi to collect the pest detection status from the Raspberry Pi. The sensors on the PCB board include 5 units of soil moisture sensor and 1 unit of DHT22 to measure temperature and humidity.

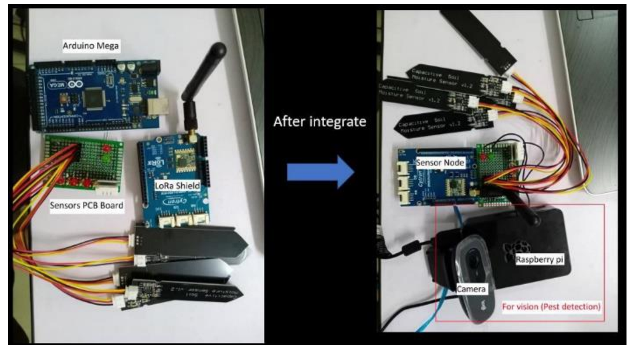

Fig. 4. Hardware integration of gateway and sensor nodes.

B. Lora Gateway Coverage Experiment

Figure 5 shows the outside AC outlet that powers the gateway (a). Featuring an antenna of 10.9 cm, the RFM95W LoRa shield and the Arduino Mega 2560 are used for the receiving node. In order to gather the message packet and parameters like SNR and RSSI, a laptop is connected to the receiving station. At 13 dBm, the gateway broadcasts a 5-byte payload every second throughout the trial. SF12 is the default value for the spreading factor. During the month of May, all tests are conducted from 11 a.m. to 5 p.m. As illustrated in Figure 6, these tests must be carried out in direct sunshine, during the daytime, between 28 and 33 degrees Celsius. In order to minimise the influence these features could have on the final result, this is done. A total of 30 samples of analysis were collected for each distance in order to increase the precision of the results. To arrive at a conclusion, the average of these numbers is used. Each measurement's average, minimum, maximal, and standard deviation are shown in the result table. The gateway needs to be at least 200 metres away from the receiving node in open space. This experiment may be hindered by certain plants and trees, but they will not be discussed in this study. To obtain a packet of data from the gateway, the receiving node must go through five different stages. As seen in Fig 5, the greatest distance travelled in this experiment was 360 metres (a). The neighbourhood's single- and double-story homes were subjected to a study of compact space.

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The barrier in this experiment measures roughly 15 metres in height. In order to carry out the experiment, the receiving network was set up into 5 different sites. As indicated in Figure 5, 80m to 200m, is a typical range for the distance between the web server and indeed the receiving endpoint (b).

Fig. 5. a) Measurement of five places near the UTeM Kampus Induk's open space entrance and b) five places from the residential neighbourhood via use of Google Maps' representations of Taman Desa Idaman, Durian Tunggal Melaka.

Meanwhile, for elevation and dynamic motion, the receiving node is located at a distance of 260 metres from the gateway. The receiving node will then test a range of gateway heights ranging from 0 metres to 30 meters. The receiving node will be conducted first on the bottom level, followed by the first level, and so on up to the building's third storey. As seen in Fig. 6, the open area bridges between the entrance and the receiving station are examined. A moving car is used to do dynamic motion tests on two straight roads. The LoRa gateway is configured in front of the straight road. The receiver enhances from the start to the gateway at an average speed of 8 m/s. Experimentation is over when communication with the gateway fails and all packets are received by receiving nodes. Recording of the experiment's effective connection distance and signal strength is expected to take place.

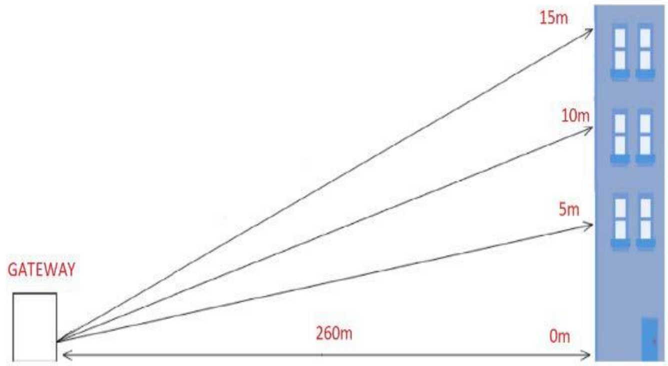

Fig. 6. Vertical elevation of the receiving node for the purpose of elevation inquiry.

C. Iot Dashboard

Ubidots is an Internet of Things (IoT) platform that enables enterprises to test and grow IoT applications for commercialization.

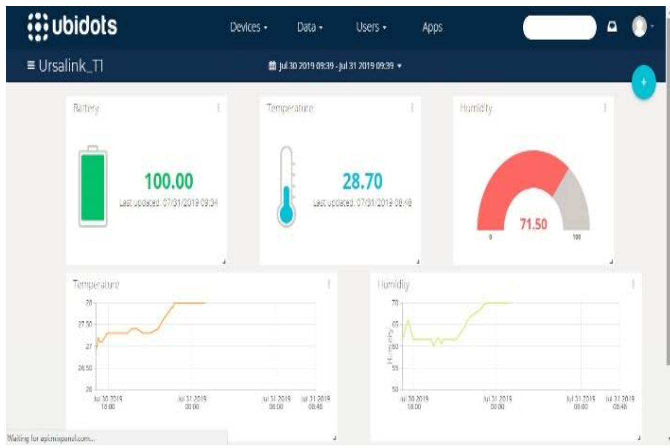

Fig. 7. Ubidots IoT dashboard

Ubidots are capable of receiving information in real-time from any Internet-connected device and sending alert notifications by email or phone call. Figure 7 depicts the Ubidots dashboard, which can monitor temperature, humidity index, soil moisture level, and pest detection in real-time. This method has been applied to most projects [13]. By using portable devices such as tablets and smartphones, they will be able to access the Ubidots dashboard to monitor the farm's condition.

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IV. RESULTS

This subsection will discuss the effective communication range of the systems and the results of the implementation of IoT-based management systems for agriculture.

A. Lora Coverage Performance

When such a receiving node is distant from the gateway, as illustrated in Figure 8, the RSSI value drops to roughly-100 dBm until the network is down. When the results are compared, the open space has a better connection because the RSSI value can be higher than the residential area at the same distance, and the open space connection can be achieved at 360m.

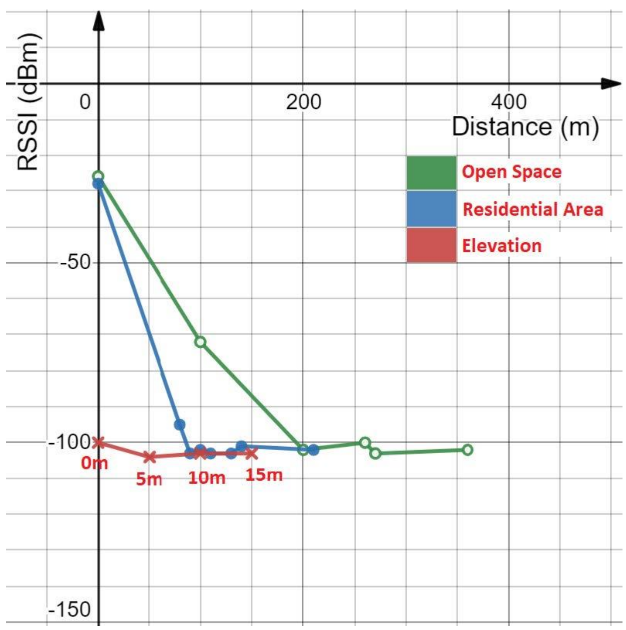

Fig. 8. RSSI performances of LoRa in different environment

When the recipient unit is located a great distance from the core network, the SNR value will decrease. A decrease in SNR from a positive to a negative number indicates that the noise level was higher than the signal level.

When the results are compared, open space has a better connection because the SNR value is higher than the residential area at the same distance, and an open space connection can be achieved at 360m.

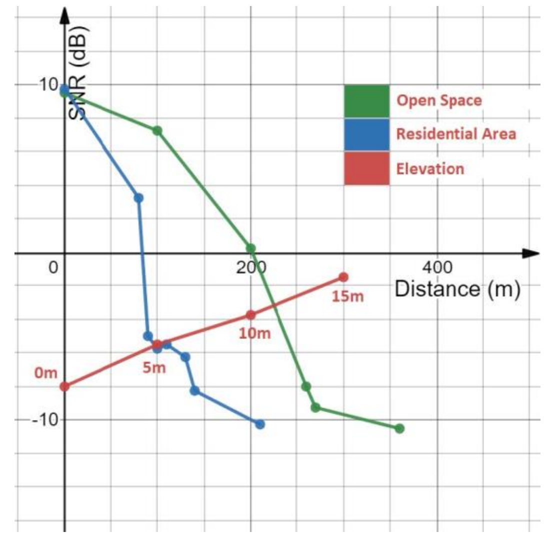

Fig. 9. SNR performances of LoRa in different environment

Elevation experiments have revealed that the greater the vertical height of the receiving node, the better the SNRreduct. In an open environment, the LoRa network can receive 100 percent of packet messages within 200 metres, but the PRR decreases beyond 200 metres and approaches zero after 360 metres, as shown in Figure 10's PRR graph.

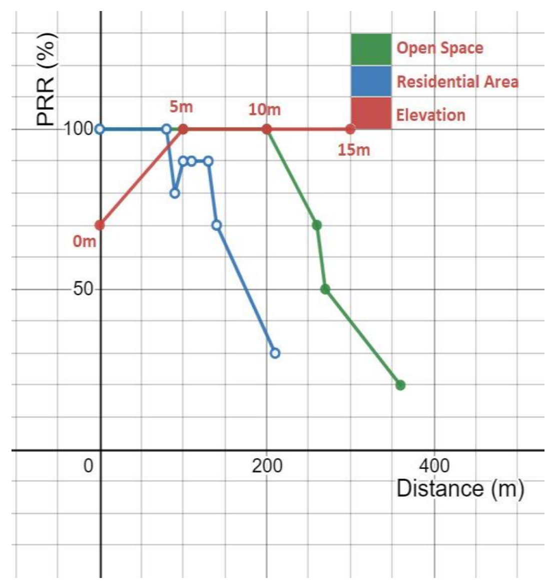

Fig. 10. PRR performances of LoRa in different environment

B. Management Dashboard

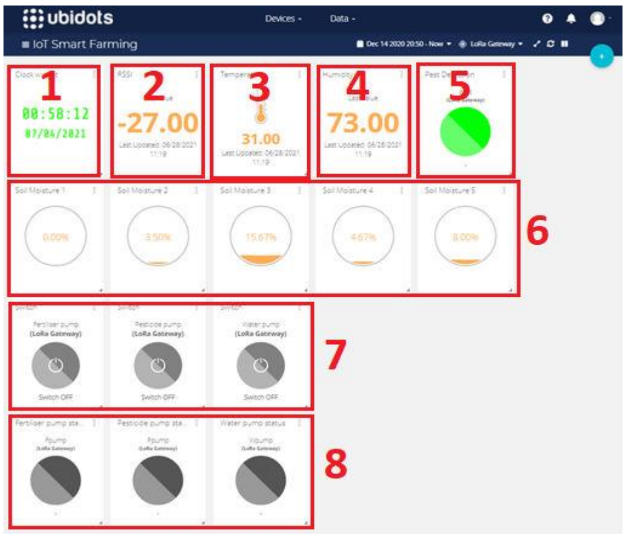

Fig. 11. Developed IoT dashboard management system

Fig. 11 shows the developed IoT management dashboard for the system. It is able to monitor a five-unit soil moisture value, temperature, humidity, pest detection status, and three different pump statuses. It can also be used to monitor the condition of the farm and control the pump if necessary to achieve the desired objectives. The description and feature explanation of the labelled part on the dashboard were tabulated as Table 1.

Table I
Features Of Labelled Part In Dashboard

Label No.	Widget Description	Features
1	Date & Time	To show the current date & time
2	RSSI	To show the signal strength of LoRa communication system
3	Temperature	To show the current temperature in farm
4	Humidity	To show the current humidity index of farm
6	Pest Detection Indicator	To post the result of pest detection result with pest detected in red colour and no pest in green colour
7	Soil Moisture	To monitor the soil moisture of each sensor
8	Pump Switches	To remote switch in pumps such as fertilizer, water and pesticide
9	Pump Indicator	To indicate the pumps in ON or OFF.

V. Discussion And Conclusion

LoRa networks are capable of operating outdoors in a variety of situations and topologies, including open spaces and residential neighbourhoods. As the distance between the core network and the recipient node increases, and when there are more barriers between the access point and the receiving terminal, signal strength in the LoRa network decreases, as shown by the network. Also shown in this research is that when the recipients are positioned at a greater vertical elevation than the transmitting node, the performance of the LoRa signal strength may be improved. As a result of these discoveries, it is determined that the LoRa RFM95W configuration may be utilised in an accessible space chilli farmlands with a higher altitude of the gateway to minimise noise generated during data transmission and to enhance system coverage. The results of this research may be used as a standard for future development in integrating networks systems for Internet of Things applications in agricultural sectors such as chilli fertigation, and this can be done at a low price, as shown by virtue of its cheap development cost. The range of the LoRa network may be extended by boosting the effectiveness of the gateway. It may also be enhanced by lowering the bandwidth and increasing the Spreading Factor (SF), which would lessen the loss of packet messages and provide a broader coverage range. In turn, this may result in the LoRa network's being capable of handling additional sensors at the same time. In the design of IoT-based monitoring and management systems, they are able to achieve the desired objectives by monitoring soil moisture, temperature, humidity, pest detection status, and control pumps such as fertilizer, water, and pesticide pumps. Apply Ubidots as the IoT dashboard to achieve long-distance monitoring and management with mobile devices. In order to make sure all the sensors are able to effectively update condition and status, the LoRa communication system was applied to make sure the multiple units of sensors can transmit messages to the dashboard over the wide area covered by the chilli farm. Three experiments were carried out to determine the communication region's limitations and range. Based on the findings, it is possible to infer that this LoRa RFM95W configuration may be used in an outdoor space chilli farm with an elevated gateway to decrease noise while transmitting data and expand the cover range. The elevation experiment was conducted with the sender node at a greater altitude and the receiver node at the base surface; the assessment results also demonstrate that the concept may be used to enhance the transmission message's quality.

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As a result, the concept may be used to sender or receive node configurations at greater vertical heights in order to increase the signal quality.

VI. Recommendations

The number the range of LoRa may be increased in the future by employing a more powerful gateway. Additionally, it may be enhanced by lessening the bandwidth and increasing the Spreading Factor (SF) [14], which will result in less packet message loss and a wider coverage range. This could make the LoRa network able to handle more sensors at the same time, which could make it more useful. In terms of the power supply to each sensor node, this is one of the important elements to implementing a wireless IoT monitoring [15] system in agriculture and other fields. There are several methods to supply power to the sensor node, such as solar, rechargeable batteries, or a mix of both. All these methods can be proven by experiments and analysis of each pro and con to determine the best way to supply power in the future. One of the elements that will need to be studied in the future is the life cycle of hardware systems. This research may take a few years in order to determine the life cycle of each piece of hardware, but it is important to estimate the maintenance cost of the overall system.

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REFERENCES

[1] Shiva P.J, Vikas S.B, Amit A and Hemant A., "Internet Of Things (IoT) For Smart Agriculture And Farming In Developing Nations", International Journal of Scientific & Technology Research (IJSTR), Vol.8, Issue 12, December 2019.

[2] United Nations, Department of Economic and Social Affairs DESA, "World population projected to reach 9.7 billion by 2050", New York, USA, 29 July 2015. Accessed on 12th Dec. 2020. [Online]. Available: http://www.un.org/en/development/desa/news/population/2015-report.html

[3] Kurt A. Rosentrater, A.D. Evers, Chapter 1 - Introduction to cereals and pseudocereals and their production, Editor(s): Kurt A. Rosentrater, A.D. Evers, In Woodhead Publishing Series in Food Science, Technology and Nutrition, Kent's Technology of Cereals (Fifth Edition), Woodhead Publishing, 2018, Pages 1-76, ISBN 9780081005293, https://doi.org/10.1016/B978-0-08-1005293.00001-3.

[4] Kajol R, Akshay Kashyap K, Keerthan Kumar T G," Automated Agricultural Field Analysis and Monitoring System Using IOT", International Journal of Information Engineering and Electronic Business (IJIEEB), Vol.10, No.2, pp. 17-24, 2018. DOI: 10.5815/ijieeb.2018.02.03

[5] A. R. de la Concepcion, R. Stefanelli and D. Trinchero, "Adaptive wireless sensor networks for high-definition monitoring in sustainable agriculture," 2014 IEEE Topical Conference on Wireless Sensors and Sensor Networks (WiSNet), 2014, pp. 67-69, doi: 10.1109/WiSNet.2014.6825511.

[6] G. Nagasubramanian, R. K. Sakthivel, R. Patan, M. Sankayya, M. Daneshmand and A. H. Gandomi, "Ensemble Classification and IoT-Based Pattern Recognition for Crop Disease Monitoring System," in IEEE Internet of Things Journal, vol. 8, no. 16, pp. 12847-12854, 15 Aug.15, 2021, doi: 10.1109/JIOT.2021.3072908.

[7] Irma T. Plata, Edward B. Panganiban, Darios B. Alado, Allan C. Taracatac, Bryan B. Bartolome, Freddie Rick E. Labuanan, "Drone-based Geographical Information System (GIS) Mapping of Cassava Pythoplasma Disease (CPD) for Precision Agriculture" International Journal of Emerging Technology and Advanced Engineering (IJETAE), 12(2), 2022.

[8] Venkatesan, R; Kathrine, G. Jaspher W; Ramalakshmi, K, " Internet of Things Based Pest Management Using Natural Pesticides for Small Scale Organic Gardens", Journal of Computational and Theoretical Nanoscience, Vol. 15, Numbers 9-10, Sep. 2018.

[9] Luis Bustamante, A.; Patricio, M.; Molina, J. Thinger.io: An Open Source Platform for Deploying Data Fusion Applications in IoT Environments. Sensors 2019, 19, 1044.

[10] Adam Ibrahim Fakherldin, M.; Adam, K.; Akma Abu Bakar, N.; Abdul Majid, M.Weather Data Analysis Using Hadoop: Applications and Challenges. IOP Conf. Ser. Mater. Sci. Eng. 2019, 551, 012044.

[11] Kučera, E., Haffner, O., & Leskovský, R. (2019). Modelling and Control of Discrete-Event Systems Using Petri Nets and Arduino Microcontrollers. Journal of Automation, Mobile Robotics and Intelligent Systems, 14(3), 20-27. https://doi.org/10.14313/JAMRIS/3-2020/29

[12] A. I. Petrariu, A. Lavric, E. Coca and V. Popa, "Hybrid Power Management System for LoRa Communication Using Renewable Energy," in IEEE Internet of Things Journal, vol. 8, no. 10, pp. 8423-8436, 15 May15, 2021, doi: 10.1109/JIOT.2020.3046324.

[13] D. Adami, M. O. Ojo and S. Giordano, "Design, Development and Evaluation of an Intelligent Animal Repelling System for Crop Protection Based on Embedded Edge-AI," in IEEE Access, vol. 9, pp. 132125-132139, 2021, doi: 10.1109/ACCESS.2021.3114503.

[14] G. Zhu, C. -H. Liao, T. Sakdejayont, I. -W. Lai, Y. Narusue and H. Morikawa, "Improving the Capacity of a Mesh LoRa Network by Spreading-Factor-Based Network Clustering," in IEEE Access, vol. 7, pp. 21584-21596, 2019, doi: 10.1109/ACCESS.2019.2898239.

[15] J. Mabrouki, M. Azrour, D. Dhiba, Y. Farhaoui and S. E. Hajjaji, "IoT-based data logger for weather monitoring using arduino-based wireless sensor networks with remote graphical application and alerts," in Big Data Mining and Analytics, vol. 4, no. 1, pp. 25-32, March 2021, doi: 10.26599/BDMA.2020.9020018.

[16] J. Chen and A. Yang, "Intelligent Agriculture and Its Key Technologies Based on Internet of Things Architecture," IEEE Access, vol. 7, pp. 77134–77141, 2019, doi: 10.1109/ACCESS.2019.2921391.

[17] S. I. Hassan, M. M. Alam, U. Illahi, M. A. Al Ghamdi, S. H. Almotiri, and M. M. Su'ud, "A Systematic Review on Monitoring and Advanced Control Strategies in Smart Agriculture," IEEE Access, vol. 9, pp. 32517–32548, 2021, doi: 10.1109/ACCESS.2021.3057865.

[18] B. Almadani and S. M. Mostafa, "IIoT based multimodal communication model for agriculture and agro-industries," IEEE Access, vol. 9, pp. 10070–10088, 2021, doi: 10.1109/ACCESS.2021.3050391.

[19] S. Liu, L. Guo, H. Webb, X. Ya, and X. Chang, "Internet of things monitoring system of modern eco-agriculture based on cloud computing," IEEE Access, vol. 7, pp. 37050–37058, 2019, doi: 10.1109/ACCESS.2019.2903720.

[20] X. Yang et al., "A Survey on Smart Agriculture: Development Modes, Technologies, and Security and Privacy Challenges," IEEE/CAA J. Autom. Sin., vol. 8, no. 2, pp. 273–302, 2021, doi: 10.1109/JAS.2020.1003536.