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IoT Monitoring System for Fig in Greenhouse Plantation

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ABSTRACT

Fig is rich in nutrients and has a high market value due to its extensive application in promoting a nutritious food supply and supporting various medical disciplines. However, the equatorial climate in Malaysia poses significant difficulties for the large-scale cultivation of figs. Therefore, a Smart Monitoring System for controlled Greenhouse Plantation was proposed in this study to enable more efficient cultivation. The proposed system was equipped with LoRa and GSM to overcome the distance and data transmission limitations, developed using the Arduino Uno microcontroller. The proposed system consists of sensors to measure soil moisture, temperature, and humidity, while the data is transmitted using long-range LoRa communication to the control unit. The sensors circuit also has a solar power supply for convenient application in rural areas. The control unit is placed at a location with good data coverage. The system functioned well, and the monitoring parameter was accurately read, collected, and updated every 30 minutes. The optimal temperature, humidity, and soil moisture for growing fig is 22°C - 33°C, > 60%, and 50% - 60%, respectively. Real-time data monitoring enabled the sensors and control unit to achieve LoRa data transmission over a distance of 2.5 km. Any data exceeding the controlled parameters will trigger an alarm so that the user can perform corrective actions.

1. Introduction

Figs are high-value commercial farm yields whose market value can reach RM 80/kg with harvesting time as short as four months. Compared to other high-value crops, figs have higher commercial value if planted in tropical countries like Malaysia, where those countries enjoy 90% of year-round sunshine. However, one of the critical challenges of a fig plantation is identifying its optimal growing conditions, which ensure its best quality. Hence, a greenhouse plantation was proposed to control the farming environment and maintain the plants' best growing conditions [1].

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Furthermore, the greenhouse plantation protects crops against unfavourable weather and pests. This paper presents our prototype of an intelligent system and the experiments had been carried out to examine the data communication between sensors with control centre nodes. The best-growing condition for fig plants is 22 °C – 33 °C for temperature, 60% and above for humidity, and 50% - 60% for soil moisture level [2].

2. Literature

Nowadays, various Smart Monitoring Systems have been developed, and they comprise Bluetooth, Global Mobile System (GSM), General Packet Radio Services (GPRS), ZigBee, and LoRa (Long Range). These systems' user interfaces (UI), such as webpages and mobile applications, can monitor the plants' growth conditions.

A smart monitoring system based on GSM communication that measures and monitors soil moisture parameters, pH, and atmospheric pressure was developed by Sakthipriya [3]. Based on these data, the system allows users to check crops' conditions and applies irrigation control. This system only used 2G networks and Radio Frequency for data transmission. Another GSM-based agriculture monitoring system was developed by Anand *et al.,* [4]. It only monitors the soil moisture level and temperature, where the plants' growth data were sent through SMS. Simultaneously, the farmers used the SMS to control the motor that carries out the appropriate action to the crop's growing environment based on the sensed data received. An Arduino is connected to the sensors to transmit, receive, and process all plats' data and signals from the user.

Another Smart Farm Monitoring System was proposed by Mythili *et al.,* [5]. This system, encompassing hardware and software applications, is designed with an IoT (Internet of Things) framework. In the design, the Arduino Microcontroller Unit (MCU) sends the signal to the connected GSM module. Messages were sent to the user within 10 seconds to update the farm's real-time climate conditions. However, the developed system had the sole purpose of monitoring and did not consider an irrigation system for the plants. The system can be applied in rural areas since it transmits GSM data. However, since the GSM module only uses the 2G network to send the SMS, the real-time data cannot be requested in short intervals. In addition, the system will incur additional costs if short SMS intervals are used, as the service provider charges for each message sent.

A web-based monitoring system has been developed to improve real-time data acquisition and room control efficiency in the greenhouse environment. Web-based monitoring was implemented with a wireless mesh network to track production performance using Radio-frequency identification (RFID). Furthermore, a Zigbee-based MCU Wireless Sensor Network (WSN) application for irrigation systems has been conducted by Chikankar *et al.,* [6]. The system comprises a central device connected to environmental data collection stations through the ZigBee. An automatic irrigation algorithm was also incorporated into the system. However, the irrigation algorithms solely measured soil moisture and did not consider other growth parameters of the plants.

Then, Dan *et al.,* [7] designed a monitoring system based on ZigBee technology. They used the CC2530F256 as the wireless sensor's centre and controlled the environment data by regulating the nodes. The system comprises data collection, processing transmission, and reception from the front to the end through the Internet. The information obtained is transmitted via a wireless network to the intermediate node. In their system, a wireless sensor network replaces the conventional wired network. As a result, the operational performance and system application versatility has been improved, thereby reducing labour costs.

Another innovation in the field is the introduction of SMS that trigger alerts when abnormal conditions occur in smart monitoring systems. Improving RFID and Wireless Mesh Sensor Networks

(WMSN) are two essential factors that promote this intelligent system advancement [8]. With 2.45 GHz and active RFID, the ZigBee platform can manage the WSN by creating a fully automated IoT solution for irrigation systems. The system incorporated an integrated wireless irrigation system for efficient water usage. However, depending on the network architecture, the ZigBee has a limited data transmission distance of 2 km at maximum.

Another system proposed by Liu and Wang [9] uses a LoRa system to control smart greenhouses' environmental parameters. The LoRa system has been evidenced with the advantages of operating with low power consumption, transmitting the data over long distances, and having high anti-interference ability.

Another project focuses on farmers' difficulties while manually monitoring and managing water pumping systems [10]. The initiative uses an IoT system to automate the procedure and increase agricultural yield. The system uses Android software to regulate and monitor temperature, humidity, and soil moisture and Arduino software to programme the NodeMCU board. Data is also collected and monitored through the ThingSpeak Cloud. However, the prototype was tested in a controlled setting, and the information was sent through Wi-Fi to the cloud.

Table 1 summarises the comparison between the recent works of wireless data communication and technology in the agriculture field. There is no distance limitation for the data transmission using the GSM and GPRS. However, these technologies require a telco signal support of at least 2G for GSM and 3G for GPRS.

Table 1
Comparison between data communication technology in literature

Basic Signal Requirement	Types of Data	Service Provider?	User Interface	Ref. list
No	Text only	No	Computer	Isa *et al.,* [2],Sakthipiriya [3]. Anand *et al.,* [4], Libertyprim [11], LoRa [12]
3G / 4G	Text, Image, Audio	Yes	Webpage, Computer, Mobile Phone	Mythili *et al.,* [5], Chikankar *et al.,* [6], Zulkifli and Noor [8], Dan *et al.,* [13], Zulkifli *et al.,* [14]
2G	Text only	Yes	Mobile Phone	Choudary [15], Zieman [16], Postcapes [17]
No	Text, Image, Audio	No	Webpage, Computer, Mobile Phone	Muangprathub *et al.,* [18], Li *et al.,* [19], Mathana and Nagarajan [20], Zainal *et al.,* [21], Andrianto and Faizal [22], Ilie-Ablachim *et al.,* [23]

Since it worked on its network connection between the nodes, ZigBee and LoRa technology did not have telecommunication provider issues. Nevertheless, LoRa technology's network connection has a limited data transmission distance of 15 km in rural areas and 5 km in urban areas, while the ZigBee technology has only 2 km. Furthermore, the GSM and ZigBee technology only support text for data transmission. Meanwhile, GSM's and ZigBee's UI is limited to mobile phones screen and computer monitors, respectively. In contrast, the GPRS and LoRa are supported by various transmitted contents such as text, images, audio, and multiuser interface devices like web pages, computers, and mobile phones.

Thus, we propose a new method to enhance the data communication between sensor and control nodes using LoRA. Moreover, we also presented our UI for monitoring the plants' growth environment. However, the COVID-19 pandemic restricted our ability to move around the project location. Since this project will examine data communication, several adjustments were performed to mimic the location of sensors and control unit nodes in the greenhouse.

3. System Design

The block diagram in Figure 1 shows that the system consists of three nodes: sensors, control centre, and UI. The first node is the sensor circuitry, and it will be located in the greenhouse. The sensors node circuitry consists of temperature & humidity (DHT11) sensors, soil moisture sensor, Arduino MCU 1 (Arduino1), and LoRa module. All sensors are used to detect the greenhouse environment, temperature, humidity, and soil moisture. All these parameters will be collected by Arduino1 and sent through the LoRa module to the control centre node. Arduino1 will also evaluate the collected data. If the collected data is within the threshold values, the data will be sent to the control node consistently in 30-minute intervals. However, suppose the monitoring data exceeds the pre-set threshold value, Arduino1 will promptly send a signal to request the control centre to send the user an alert SMS reporting on the greenhouse environment parameters.

The second node is the control centre. The control centre must be located within LoRa operating distance for good data reception and synchronisation from the sensor node. Arduino2 should be equipped with a GSM or GPRS module to transfer the data using a 2G or 3G/4G network for data transmission to the server and user. For simplicity, we choose the GSM module in our design. At this node, Arduino MCU 2 (Arduino2) will process the received parameters from the sensor through the LoRa module. Based on the received data, the MCU algorithm will determine the SMS types to be sent through the GSM module, whether the usual 30-minute greenhouse condition interval or immediate alert notification. In other conditions, when Arduino2 receives the SMS from the user requesting the current greenhouse condition at any instance, the MCU algorithm will reply to the user with the latest data received from the sensor's node. The control centre is suggested to be located at the farmer's office or house.

The last node is for the UI. As a starting point, we chose the user SMS application interface. The user receives the greenhouse parameters through SMS, which reports normal monitoring parameters (30-minute intervals) and over-the-threshold SMS alerts. As previously mentioned, the user can also request the current greenhouse parameter through GSM communication by sending an SMS to the control unit's GSM module. Thus, this is a two-way communication between the user and the control unit. As shown in Figure 1, the black arrows indicate the data flow where the sensor detects greenhouse parameters. Arduino1 sends the data to Arduino2 before sending it to the user through the GSM network. The red arrows represent the path when the user requests the greenhouse parameter from the system.

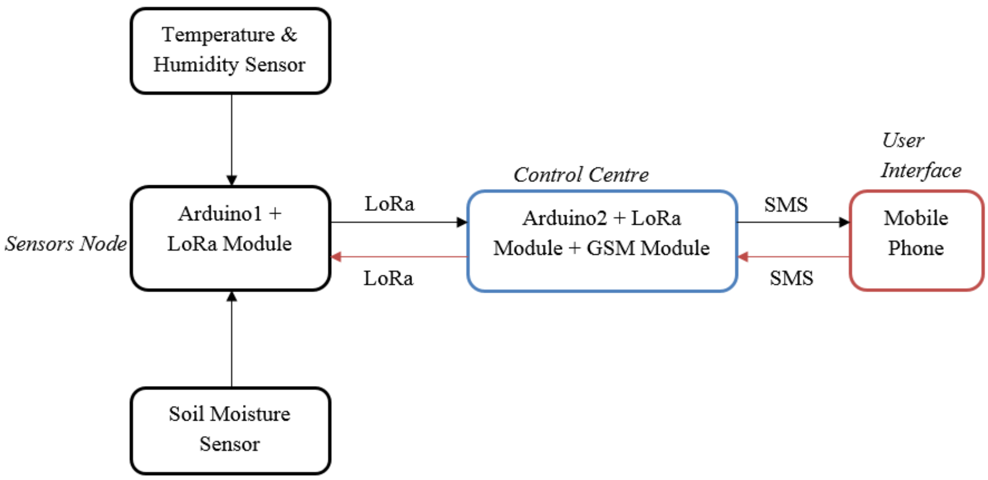

Fig. 1. Block diagram of the monitoring system

4. Sensor and Control Unit Design

The circuitry for the sensors' node is shown in Figure 2. This circuit will be placed inside the greenhouse. This sensor node circuit consists of temperature and humidity sensors (DHT11), soil moisture sensors, Arduino UNO board, and LoRa modules (SX1278). The circuit is solar-powered and connected to the Arduino UNO board.

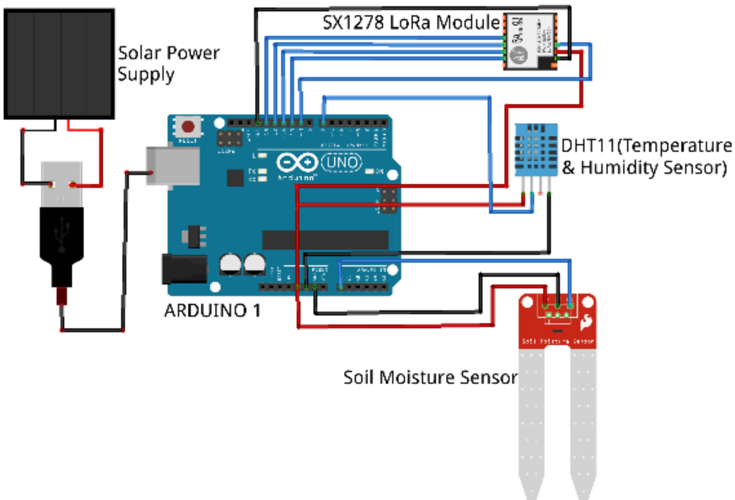

Fig. 2. Sensor node

In Figure 2, the data pin of the DHT11 is connected to the Arduino Uno (Arduino1) digital input pin, A7, since the temperature and humidity data are modulated into digital signals by the sensors. In addition, the VCC pin is connected to the MCU's 5 V pin, and the GND pin is connected to the Arduino1 GND pin. The solar-powered voltage supply of Arduino1 is 5 V. Implementing solar power supply will enhance node mobility and facilitate easy relocation within the greenhouse.

For the Soil Moisture sensor, the pin is connected to Arduino1's Analogue Input pin, A0. The soil sensor data is in analog signal format. The sensor is powered by the Arduino1's 5 V pin, while its GND is connected to the Arduino1's GND pin. All sensors' probes will be immersed in the fig plant's soil, indicating the actual soil condition for growth parameters. In short, the Arduino1 in the circuit will control the overall activity of the circuit and LoRa data transfer. The input data from sensors will be read, evaluated, and then sent to the control centre through the LoRa by the MCU.

The pin connection between the Arduino1 and SX1278 is shown in Table 2. The SCK Pin 13 is the Serial Peripheral Interface (SPI) clock pulse pin that provides the clock pulse for the SPI communication between SX1278 and Arduino1. The Master in Slave Out (MISO) Pin 12 is the pin that SX1278 transmits the data to the Arduino1. At this point, the Arduino receives the data as Master and SX1278 as the Slave. The Master Out Slave In (MOSI) Pin 11 is vice versa of MISO; here, SX1278 acts as a Master that receives the data from the Slave (Arduino1). The NSS Pin 10 is the chip SELECT or ENABLE pin used to activate the Slave in the SPI communication. The RST Pin 9 is used to RESET the SX1278 module based on the signal from the Arduino1. The INTERRUPT Pin 8, the DIO0, is used for the general digital Input / Output (I/O) function [24]. The SX1278 LoRa module has an antenna and facilitates communication with Arduino Uno and Arduino2 using LoRa data transmission technology.

Table 2
Lora – Arduino1 pins connection

Pins at SX1278	Pins at Arduino1
VCC	5V
SCK	SCK (Pin 13)
MISO	MISO (Pin 12)
MOSI	MOSI (Pin 11)
NSS	$\overline{SS}$ (Pin 10)
RST	OC1A (Pin 9)
DIO0	CLKO (Pin 8)
GND	GND

The circuit shown in Figure 3 is the circuit for the control node. The diagram indicates that this node consists of a LoRa SX1278 module, Arduino Uno Board (Arduino2), a GSM module, and a 3.7V rechargeable battery. This node acts as a central processing unit that receives and analyses all data from the sensor node before the users view it. Hence, the MCU is designed to have two modules that transmit and receive data: the LoRa SX1278 and the GSM module. At this point, Arduino2 acts as the translator and controller for these two modules.

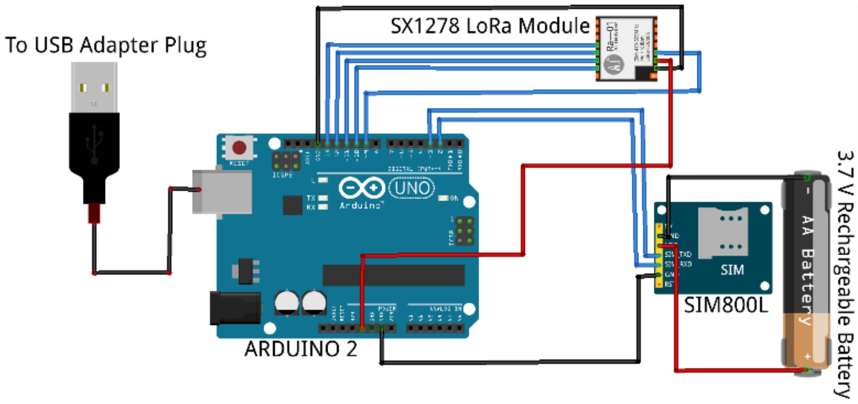

Fig. 3. Control centre circuitry

Like the sensor node, the SX1278 module has an antenna for receiving the sensor node's signal through LoRa technology. The Arduino2 algorithm will read the received data and encode it to the user through the GSM module. Since the smart system is designed to monitor the greenhouse, typically located in rural areas, it is important to note that the distance between the sensor nodes and the control centre could reach up to 15 km. This distance corresponds to the maximum range supported by LoRa technology in rural areas.

A rechargeable 3.7 V battery powers the GSM module by connecting the battery to the VCC and GND pins. Simultaneously, the pins SIM_RXD and SIM_TXD (shown as dashed lines) are connected to the Arduino2 DIGITAL Pin 2 and Pin 3 to receive/send the Arduino data to the user. When the GSM module receives the data from Arduino2 through the pin SIM_TXD, the GSM module will send the SMS to the user. On the other hand, when the GSM module receives the SMS from the user, it will send the data to Arduino2 through the SIM_RXD pin.

At this control node, the Arduino2 will compile the received data from sensors from LoRa data communication in normal conditions. Then, the MCU will send the data to the user in SMS format every 30 minutes through the GSM module. In an alternative scenario, Arduino2 will retrieve the signal and data from the sensor nodes via LoRa communication. When the monitoring data exceeds the threshold values, Arduino2 will transmit a signal to the GSM module, prompting it to send an alert SMS to the user. On the other hand, when the GSM receives an SMS from the user requesting the real-time monitoring parameters, the GSM will send a signal to the Arduino2 to request the latest monitoring condition before the parameters are sent back to the user by SMS.

5. Data Sampling

The functionality of the system's prototype has been verified with a series of testing on data transmission and communication. In this section, 24-hour data monitoring is used as an example. Due to the Malaysian government's COVID-19 pandemic Movement Control Order (MCO), some modification was performed on positioning the sensors node, control node, and monitoring threshold values. The modifications are shown in Table 3. The modifications to the system are not significantly divergent from the current implementation. The table shows that only minor adjustments were made in the monitoring condition and parameters setup.

Table 3
Modification of the system's node position and threshold parameter

Parameters	Original Design	Modification in Design
Sensors Node position	Greenhouse	Outdoor location near the designer house.
Control Node position	Farmer Office/House	Designer house
Controlled Threshold parameters:	1. Within 25 - 33 °C	1. Below 33 °C
1. Temperature	2. Above 60%	2. Above 60%
2. Humidity	3. Within 50 - 60%	3. Above 50%
3. Soil Moisture		

The sensor node was demonstrated in outdoor conditions (ground) near the designer's house. In actual implementation, the sensors' circuitry will be placed inside the greenhouse. The threshold values in the system coding have been adjusted to prevent over-the-threshold parameters, which will trigger an SMS alert later. The temperature threshold value has been set to below 33°C. If the temperature surpasses this value, the system will generate an SMS alert to notify the user. In practical situations, the optimal temperature for growing fig plants is 25 – 33 °C.

For the same reason, the surrounding humidity is set to be above 60%, and the soil moisture level is set to be above 50%. In the implementation, the humidity is controlled above 60%, and soil moisture is within 50 - 60%. The growth of plants can be adversely impacted if the surrounding conditions are not met. For example, there will be white-dotted fungal formation leaves if the fig plants are placed under high humidity for too long, whereas the leaves will quickly be dried at low humidity. Likewise, root growth will be affected if the soil is too dry and wet. An SMS notification will be sent to the user when the conditions are unfavourable.

In normal conditions, the greenhouse-controlled parameters will be collected, and an SMS will be sent to the user every 30 minutes. Some examples of the received SMS are shown in Figure 4. The SMS shows that the greenhouse parameters were within the controlled parameter, and no abnormalities parameters were recorded.

Figure 5 shows an example of the collected temperature of the greenhouse for 24 hours. As shown in the graph, the temperature slowly rises from 23 °C at 7.00 am (sunrise), peaks at 30.5 °C at 2.30 pm (middle of the day), and decreases to 25 °C at 8.00 pm. The temperature fluctuates between 24 – 25 °C overnight. Thus, in this example, the temperature did not exceed the threshold value throughout the day, and the average temperature for the day was 25.9 °C.

Fig. 4. SMS notification reporting the parameters every 30 minutes

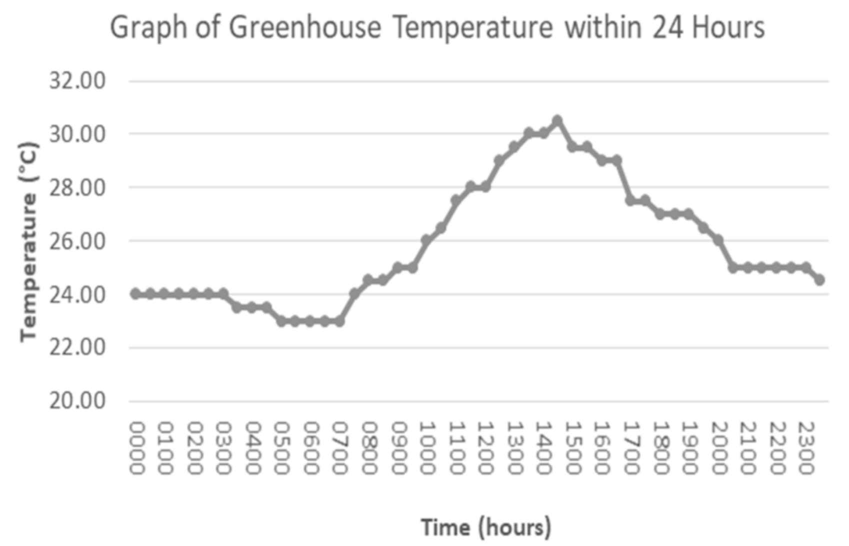

Fig. 5. 24-hour temperature data monitoring

Figure 6 shows the graph of Greenhouse humidity and soil moisture level collected on the same day as in Figure 5. The chart records the highest humidity of 100% from 7 am to 9.30 am, while the lowest humidity is 66%, which happened at 2 pm. Once again, the pattern depicted in the graph can be correlated with the ambient temperature. At elevated temperatures, there was increased water condensation from the surrounding air, resulting in a subsequent decrease in air humidity. Conversely, the humidity is higher in the early morning and night because the water traps in the surrounding atmosphere at a lower surrounding temperature. From the plotted data, the average humidity value is 88.75%.

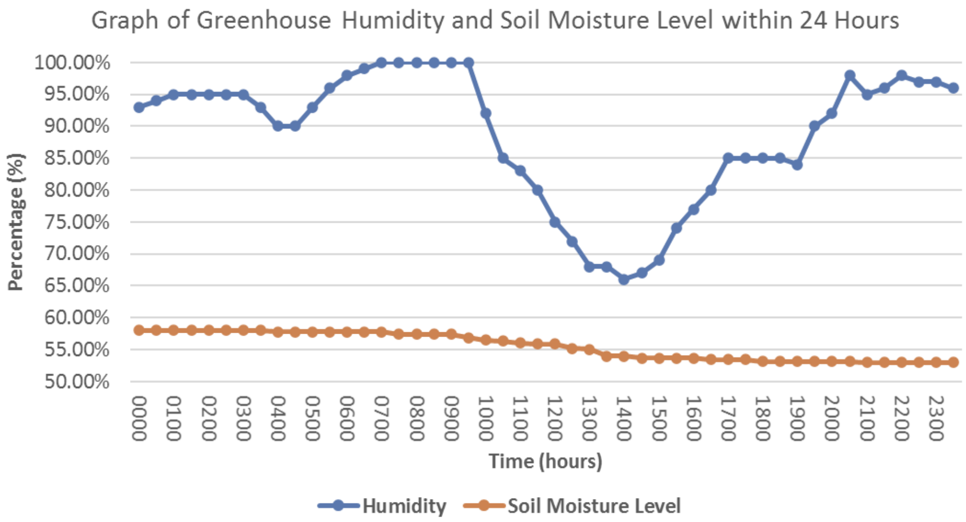

Fig. 6. 24-hour humidity and soil moisture level

The soil moisture level did not vary significantly within 24 hours, as depicted in the similar figure. The plotted data only shows a difference of 5 %, fluctuating between 53% and 58%. Therefore, the average soil moisture level for that day is 55.5%. The data indicates that the soil's water absorption is good and consistent throughout the day. However, the soil humidity is anticipated to be higher during the rainy season and lower during the dry season.

For demonstration purposes, a testing signal of Soil Moisture value = 0.2% and humidity = 48% was sent from the LoRa communication. It should be noted that the controlled parameter was not met in this instance. As shown in Figure 7, an SMS alert was triggered immediately to the user without waiting for 30 minutes. The previously recorded time was 16.53, and dummy data was inserted into the system two minutes later. A message indicating ABNORMAL READING with the details was sent to the user at 16:55. As the dummy data was reset, the system resumed retrieving the data at 17:23 (30 minutes later).

Figure 8 showed SMS responses when the user typed *GET* to retrieve the current conditions data from the system. The diagram indicates that the system immediately replied to the user with the current parameters reading. From these results, one can conclude that the system has worked as expected.

Fig. 7. SMS alert when over the threshold condition detected from the sensors

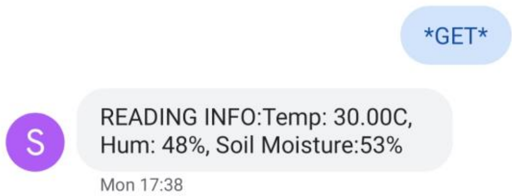

Fig. 8. The user requests real-time parameter by typing *GET*

6. LORA Coverage

Another experiment that was carried out was the maximum distance for the LoRa data transmission. The control node is in the designer house for this testing, mimicking the farmer's office/house. Therefore, an electrical supply can power the control unit, and the house's location falls within the coverage area of the GSM data network.

Since the sensor node is designed to be mobile and easily relocated, the node is placed at several distances from the designer's house. An example of the shortest (point-to-point) distance calculation in this experiment is shown in Figure 9. Here, the Google Maps application was used for measuring the distance. Even though the apps showed only Road Distance, the application rulers can be used to measure the point-to-point distance, as depicted in the figure.

In examining the LoRa data transmission, the sensor node is located at the testing location. Then, the user near the control node typed *GET* to request the real-time sensor data. A replied SMS message will be received if the sensor node is within LoRa coverage. In this experiment, the tested point-to-point distances are 0.3 km, 0.7 km, 1.0 km, 2.5 km, and 5.0 km. Therefore, the proposed system's maximum LoRa data transmission distance of up to 2.5 km has been achieved. The limited range of LoRa communication is attributed to the placement of the two nodes, which were tested in a densely populated area in Kapit, Sarawak.

Nevertheless, the maximum distance can be improved by modifying the greenhouse to be less occupied to reduce the signal distortion. Nonetheless, a circular parameter of 2.5 km is sufficient for the data communication between sensors and control nodes. The illustration of the maximum 2.5 km distance is shown in Figure 10.

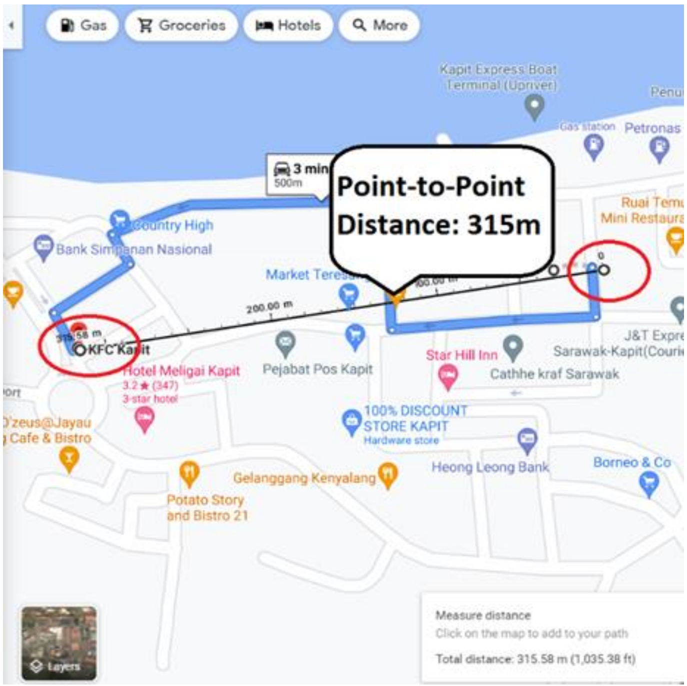

Fig. 9. Illustration of point-to-point measurement

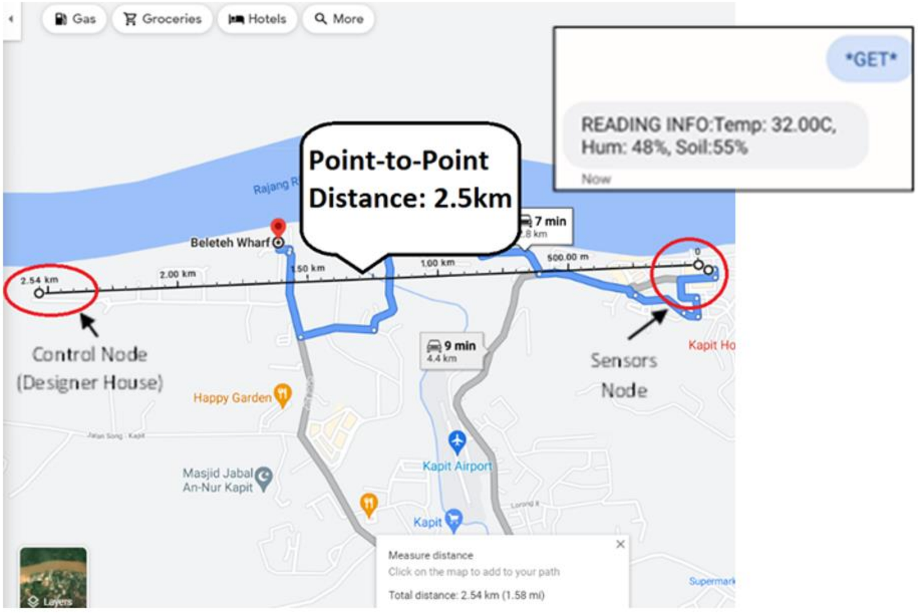

Fig. 10. Distance between sensors node and control (approximately 2.5 km). The onset shows that the SMS was received after the data was requested

7. Conclusions

In summary, the proposed monitoring system for a fig plantation in a greenhouse was successfully demonstrated. The system consists of two essential nodes: the sensors and the control node. An Arduino UNO MCU was used at each node. LoRa performed the data communication between sensors and the control node, whereas the communication with the user was performed using GSM signals. The controlled parameters in this system are temperature, surrounding humidity, and soil moisture. These parameters were recorded by the sensors connected to the sensor's node. These three parameters were constantly updated to the user every 30 intervals in normal conditions. A trigger alert through SMS will be sent to the user if the system detects abnormalities in one of the monitored parameters. The system also allows users to request real-time data from the controller node through SMS communication. Furthermore, the distance limitation of the LoRa data transmission of the proposed system has been tested, proving that it could reach up to 2.5 km in a point-to-point configuration. The system can be further improved by incorporating more automated functions, such as irrigation patterns based on the controlled parameters, and enabling the complete control of the system by the user.

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References
[1] Baudoin, Wilfried, Remi Nono-Womdim, N. Lutaladio, Alison Hodder, Nicolás Castilla, Cherubino Leonardi, Stefania De Pascale, Muien Qaryouti, and R. Duffy. "Good agricultural practices for greenhouse vegetable crops: principles for mediterranean climate areas." *FAO plant production and protection paper (FAO)* (2013).

[2] Isa, M. M., M. N. Jaafar, K. F. Kasim, and M. F. A. Mutalib. "Cultivation of fig (Ficus carica L.) as an alternative high value crop in Malaysia: A brief review." In *IOP Conference Series: Materials Science and Engineering*, vol. 864, no. 1, p. 012134. IOP Publishing, 2020. https://doi.org/10.1088/1757-899X/864/1/012134
[3] Sakthipriya, N. "An effective method for crop monitoring using wireless sensor network." *Middle-East Journal of Scientific Research* 20, no. 9 (2014): 1127-1132.
[4] Anand, Aprajita, Akansha Parasar, and A. Prabhakar. "GSM based agriculture monitoring system." *Int Res J Eng Technol (IRJET)* 4, no. 03 (2017).
[5] Mythili, R., Meenakshi Kumari, Apoorv Tripathi, and Neha Pal. "IoT based smart Farm Monitoring system." *International Journal of Recent Technology and Engineering (IJRTE)* 8, no. 4 (2019): 2277-3878.
[6] Chikankar, Pravina B., Deepak Mehetre, and Soumitra Das. "An automatic irrigation system using ZigBee in wireless sensor network." In *2015 International Conference on Pervasive Computing (ICPC)*, pp. 1-5. IEEE, 2015. https://doi.org/10.1109/PERVASIVE.2015.7086997
[7] Dan, Liu, Wan Hongli, Zhang Mengya, and Xiang Jianqiu. "Intelligent Agriculture Greenhouse Environment Monitoring System Based on the Android Platform." In *2017 International Conference on smart grid and electrical automation (ICSGEA)*, pp. 358-361. IEEE, 2017. https://doi.org/10.1109/ICSGEA.2017.169
[8] Zulkifli, C. Z., and N. N. Noor. "Wireless Sensor Network and Internet of Things (IoT) Solution in Agriculture." *Pertanika Journal of Science & Technology* 25, no. 1 (2017).
[9] Liu, Y., and M. Wang. "Wireless greenhouse environment monitoring system based on lora network." *Journal of Food Science & Technology* 4, no. 8 (2019): 889-902.
[10] Ahmad, Nur Irwany, Mohamad Syafiq Mohd Rafi, Diyya Hidayah Abd Rahman, Nazrul Azril Nazlan, Wan Azani Mustafa, Habibah Mokhtaruddin, Nurhafiza Azizan, and Norhanisa Kimpol. "Monitoring and Controlling Water Pumping System Using IoT for Agriculture Purpose." *Journal of Advanced Research In Applied Mechanics* 62, no. 1 (2019): 1-15.
[11] "The Fruit and Vegetable Lexicon." Libertyprim. Accessed June 18, 2023.
[12] "What Are Lora® and Lorawan®?" LoRa Developer Portal.
[13] Dan, Liu., Cao Xin, Huang Chongwei, and J. I. Liangliang. "Intelligent agriculture greenhouse environment monitoring system based on IOT technology." In *2015 International Conference on Intelligent Transportation, Big Data and Smart City*, pp. 487-490. IEEE, 2015. https://doi.org/10.1109/ICITBS.2015.126
[14] Zulkifli, C., H. Hassan, W. Ismail, and S. Semunab. "Embedded RFID and wireless mesh sensor network materializing automated production line monitoring." *Acta Physica Polonica A* 128, no. 2B (2015). https://doi.org/10.12693/APhysPolA.128.B-86
[15] Choudary, Tanya. "29 Amazing Benefits and Uses of Figs for Skin, Hair and Health." STYLECRAZE, May 30, 2023.
[16] Zieman. "Big on Figs." The Star, May 4, 2015.
[17] "Smart Greenhouse: 2019 Guide to Best Sensors and Remote Automated Monitoring Software." Postscapes, December 6, 2019.
[18] Muangprathub, Jirapond, Nathaphon Boonnam, Siriwan Kajornkasirat, Narongsak Lekbangpong, Apirat Wanichsombat, and Pichetwut Nillaor. "IoT and agriculture data analysis for smart farm." *Computers and electronics in agriculture* 156 (2019): 467-474. https://doi.org/10.1016/j.compag.2018.12.011
[19] Li, Ru-an, Xuefeng Sha, and Kai Lin. "Smart greenhouse: A real-time mobile intelligent monitoring system based on WSN." In *2014 international wireless communications and mobile computing conference (IWCMC)*, pp. 1152-1156. IEEE, 2014. https://doi.org/10.1109/IWCMC.2014.6906517
[20] Mathana, J. M., and T. S. Nagarajan. "Secured IoT based smart greenhouse system with image inspection." In *2020 6th International Conference on Advanced Computing and Communication Systems (ICACCS)*, pp. 1080-1082. IEEE, 2020.
[21] Zainal, N., N. Mohamood, M. F. Norman, and D. Sanmutham. "Design and implementation of smart farming system for fig using connected-argonomics." *International Journal of Electrical and Computer Engineering* 9, no. 6 (2019): 5653. https://doi.org/10.11591/ijece.v9i6.pp5653-5662
[22] Andrianto, Heri, and Ahmad Faizal. "Development of smart greenhouse system for hydroponic agriculture." In *2020 international conference on information technology systems and innovation (ICITSI)*, pp. 335-340. IEEE, 2020. https://doi.org/10.1109/ICITSI50517.2020.9264917
[23] Ilie-Ablachim, Denis, George Cristian Pătru, Iulia-Maria Florea, and Daniel Rosner. "Monitoring device for culture substrate growth parameters for precision agriculture: Acronym: MoniSen." In *2016 15th RoEduNet Conference: Networking in Education and Research*, pp. 1-7. IEEE, 2016. https://doi.org/10.1109/RoEduNet.2016.7753237
[24] Malik, Tanveer. "SX1278 Lora RF Module." Microcontrollers Lab, May 28, 2020.