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## Evaluating Data from Sensors in Smart Farmlands Using Internet of Things (IoT)

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### ABSTRACT

*This research has created a monitoring system by employing wireless sensor networks technology to monitor environmental conditions of greenhouses using the NRF24L01+ module with an Arduino board. In this system, the connection between the sensor node and base station is established by the NRF24L01+ module, and the data gathered is transferred by the sensor node to a base station. Gathered data, having been transferred to the base station, will be transferred to an Internet database to be stored so that the user can utilize the data through his/her mobile phone or by visiting web pages. This research examines the sensors used in a greenhouse environment and calculates some evaluating parameters, such as reliability, average packet transfer delay, power consumed and data transfer rate. Consistent with these evaluations, the proposed system's reliability at the 10-meter distance from the base station was 92.25%, being acceptable for this application. The average delay of the packet transfer was 206 milliseconds in one hour, being insignificant. This indicates that the sent packets were transferred to the base station in a very short time. The total energy consumption of 36 Watts per day suggests that the module had a low energy consumption. The wireless transfer module used in this project was also compared to other wireless transfer modules. It was determined that this module was more effective than other modules regarding the coverage rate and data transfer.*

**Keywords:** smart greenhouse, precision farming, IoT, smart farmland, data evaluation

### INTRODUCTION

Smart farming also called the third Green Revolution, is an emerging concept that refers to a set of farmland management techniques using information and communication technologies that can radically transform the agriculture industry, producing more high-quality products in large numbers. One of the manners in which the quantity and quality of agricultural products can be increased is to use new up-to-date technologies. Thus, we can make our farmlands smart and connect those farmlands by using “precision farming” or “smart farming” and use the data received to improve products and lands. In this connection, IoT is believed to play a major part in farming, forest products, and all farming regions.

IoT refers to a system involving computation equipment, digital and mechanical machines, objects, animals and humans with a unique ID capable of data transfer on the network without human interaction and intervention. Today, IoT applications are widely used in most industries,

including agriculture, construction management, medicine, energy and transportation. This certainly involves a direct relationship with the ever-increasing coordination between electronic engineers and software developers who work on IoT products and systems.

Precision farming techniques have been introduced in recent decades. Meanwhile, they were utilized by some innovative farmers, as the smart use of farming data is still limited (Aubert et al. 2012). IoT has expanded the concept of precision farming into smart farming, in which the farmland converts into an interacting smart web of farming objects (Wolfert et al. 2010). The whole farming management perspective that concerns the unified integration of measurement and monitoring in real-time, smart analysis, smart control and smart planning of all farming processes is a critical subject. Other subjects include improved ease of use, viability and simplification of existing solutions, engagement of the main farmers' community, and initial adopters (Kruize et al., 2013).

Tanmay Baranwal et al. (2016) designed an IoT-based device that analyzed the sensor-based data and then transferred them to the users. This device could be remotely monitored and implemented for farmlands and cold storage security objectives. This article aimed to solve such problems as identifying rodents, threats against agriculture products and providing immediate warnings using data analysis and processing without human intervention.

Mehmet et al. (2018) provided an IoT-based communication architecture and a basic measurement technology, together with communication mechanisms. Moreover, in addition to recent theoretical developments, underground wireless communication applications were reported.

Terteil et al. (2018) did research to create a monitoring system for precision farming with low costs and less energy consumption that would produce low greenhouse gas emissions; also, they established a user-friendly interface to get farmers to monitor the changing farming parameters (e.g., climate status, soil, water, detection of pests, detection of permeation and fire detection) using their smartphones in a cyclic period at every point and at any time.

Manishkumar et al. (2018) also proposed to use the cloud-based IoT in farming. Precision farming is, in fact, a concept that seeks to appropriately provide suitable sources on accurate timing. These sources can include water, light, pesticides, etc.

In IoT-based smart farming, a system is in place for monitoring farmlands. This system provides us with integrated data using sensors (light, air humidity, temperature, etc.) and helps automate land irrigation. Using this system, farmers can monitor their lands wherever they are. IoT-based farming systems are not only applicable in traditional farming methods but are also usable in small domestic, organic and modern farmlands.

The proposed system gathers the data from sensors and wirelessly transfers it to the base station, where the data are received and stored on the Google Sheets, which will be displayed in the local HTML network. The proposed smart system, together with the user interface, greatly contributes to the farmer increasing the quality of the farming products. This system can also send warnings and provide daily reports to the farmer in case a crisis unfolds so that the farmer and the experts can take precautionary measures.

### **Proposed Method**

This technique was experimentally designed in a greenhouse which measures three meters long and two meters wide. The sensor node and base station begin operating simultaneously in this



technique. Then, a radio network using the RF24L01+ module is established, connecting the base station to the wireless IoT modem. Later, because the base station still does not have the sensor-based data, it applies to the data sent by the sensor node. The sensor node, having received data from the base station, examines the sensor data and then sends them to the base station, simultaneously comparing the data with the threshold limit and controlling the related relays if necessary. The base station also receives data to create an HTML page, displays the data and sends the data to the database simultaneously.

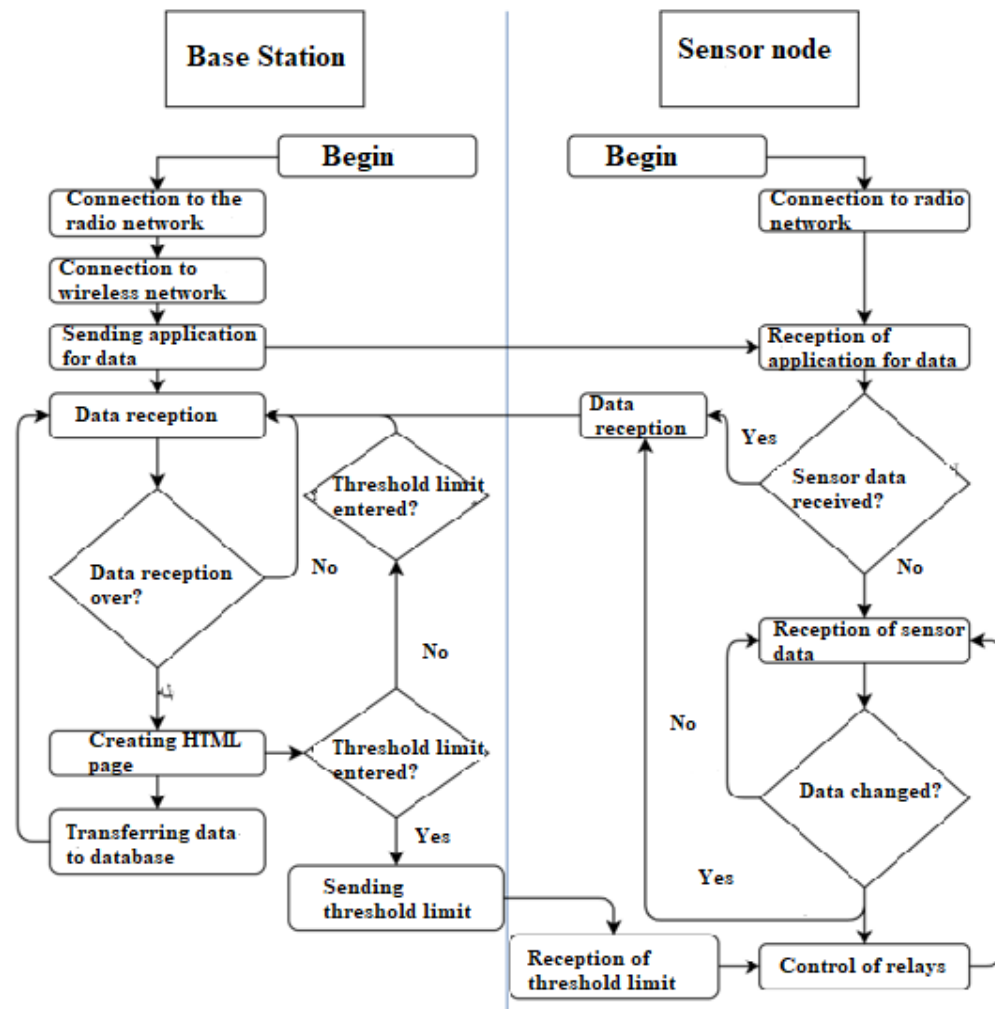


Figure 1: Proposed technique flowchart



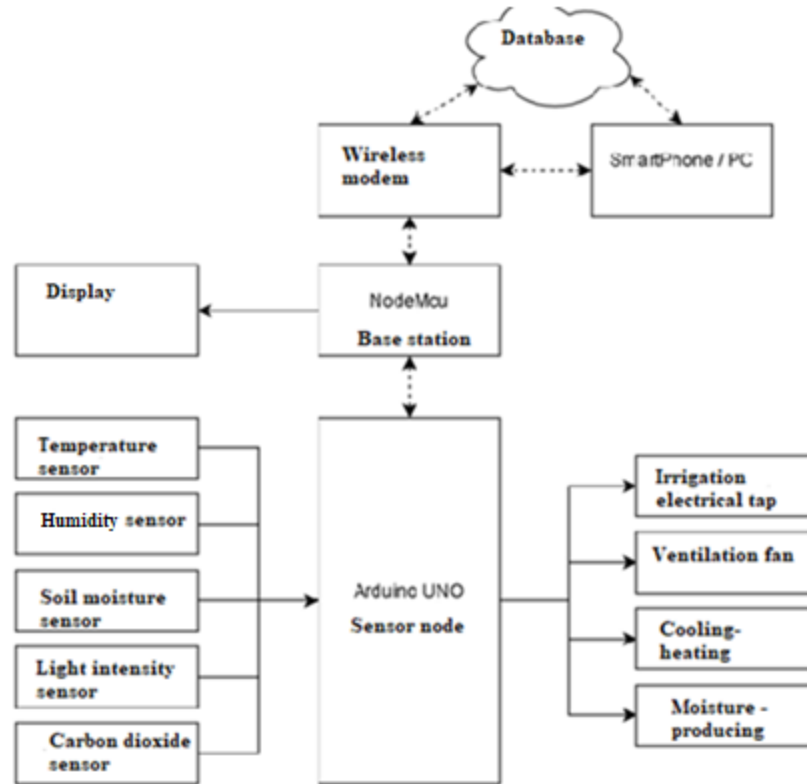


Figure 2: Components of the proposed system

### 1. Sensor Node Hardware

UNO Arduino is the most famous and applicable type of Arduino. UNO Arduino establishes the connection between communication techniques and various modules. A rational number of PINs on them enjoy appropriate processing speed and sufficient memory for many tasks. The image below illustrates the UNO Arduino board, which establishes wireless communication between sensors and the base station. This procedure follows: the sensors and a wireless transfer module are connected to an Arduino board. A wireless transfer module must also be connected to the base station. This way, sensors and the base station are connected wirelessly and exchange data.



Figure 3: UNO Arduino board

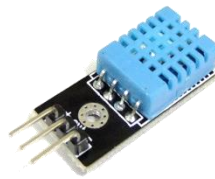
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NodeMCU module is a development board specifically used in the IoT. This module has a firmware installed on a ESP8266 WiFi chip and used to control objects in open text form, and is programmable.



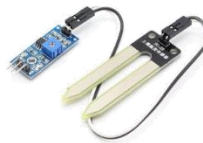
**Figure 4: NodeMcu module together with a CH340G chip**

DHT11 temperature and humidity sensor is low-cost to measure temperature and air humidity. The small size of this sensor, as well as its low energy consumption and capability of transferring the signal to a distance of over 20 meters, make it one of the best choices to be used in various projects.



**Figure 5: DHT11 humidity and temperature sensor module**

Today, it is imperative to measure soil moisture in farming usages. To have a high-quality product, you need to timely and correctly irrigate its land, and it is here that you will need a soil moisture sensor.



**Figure 6: YL-69 Soil moisture sensor module**

TSL2561 light sensor is a complicated sensor capable of detecting a large spectrum of visible lights.





**Figure 7: TSL2561 light intensity sensor module**

MQ-135 sensor is a device to detect air quality. This sensor can detect smoke, alcohol, gas, and carbon dioxide in the air. The heater of this sensor uses 5V voltage.



**Figure 8: MQ-135 air-quality detection sensor module**

NRF2401+ module uses radio waves of 2.4GHz frequencies to communicate with various devices from a maximum of 100 meters.



**Figure 9: NRF24L01+ wireless sender and receiver module**

This project used this module to establish wireless communication between the nodes and the base station, as the NRF24L01+ module is connected to the NodeMcu base station, and a NRF24L01+ module is also connected to the Arduino board, connected to the intended sensors. These two modules will then exchange data together.



**Figure 10: Two-channel relay module**

This project uses a relay to control the water pump, moisture-producing device, cooler and ventilation fan. LCDs are determined by the number of characters they show; for example, the 2\*16 model suggests the LCD has 16 columns and two rows.



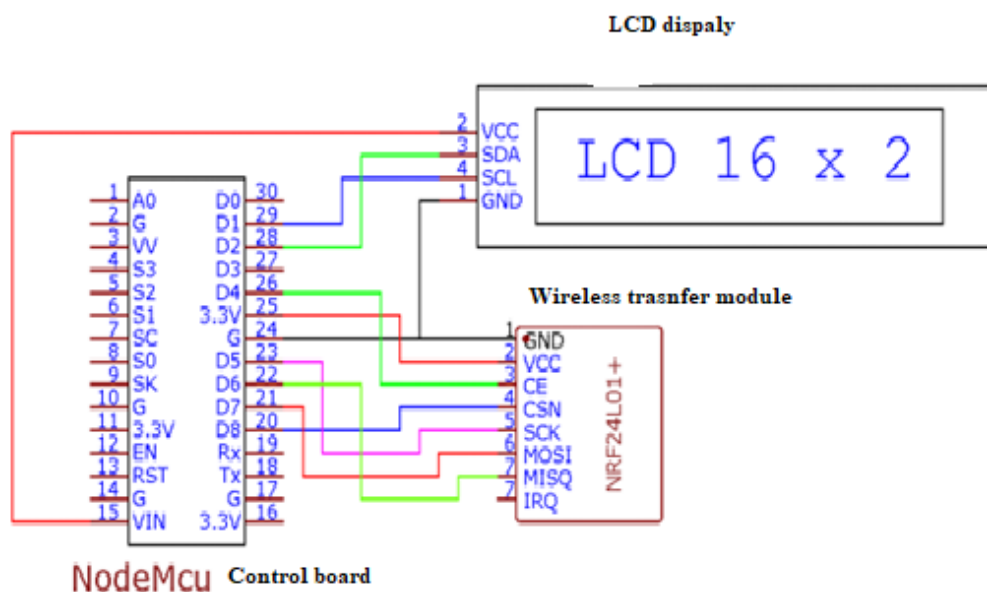
**Figure 11: LCD with 2\*16 characters**

This display is used to show the base station's data.

This project also uses the following parts to set up the base station:

- NodeMcu - CH340G control board
- 2\*16-character LCD
- NRF24L01+ receiver and sender module
- Micro USB cable
- 5V 1 Amp Adaptor
- Jumper wire

The above parts, having been completed, are connected as follows:



**Figure 12: Circuit schematic of the base station (Master)**

After communication between the NodeMcu board and NRF2401+ transfer module and the display, Google Sheets must be created on the Internet platform to store the data received from the sensors in the file. After the intended file was created, the Google Script Editor was used to

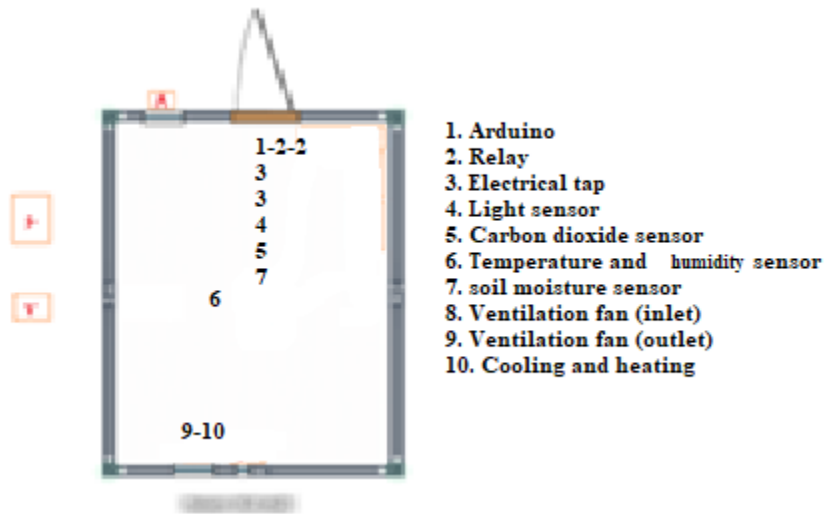
load the script codes, which load the data sent from the base station in the file. This system also displays the data stored in a diagram.

### Smart Greenhouse Scenarios

One of the scenarios about environmental parameters is as follows: the temperature or humidity of the greenhouse environment is either high or low. Using temperature and humidity sensors installed at different points of the greenhouse, cooling, heating and air ventilation equipment can be controlled in proportion to the temperature and humidity situation. Under critical conditions, necessary warnings can be given to farmers to reduce the likelihood of quality drops or loss of the products. Another scenario occurs when soil moisture is low, and the plant faces thirst. Using soil moisture sensors installed at different greenhouse points, plant irrigation can be monitored and regulated. The farmer may not have access to the greenhouse, as a remote-control scenario allows him to control the greenhouse equipment and monitor the situation remotely. Using wireless modules, sensor data can be stored on the Internet and be informed of the changing environmental parameters via diagrams.

### Placement of the Sensors at the Greenhouse

The place sensors are deployed to the greenhouse is determined based on the scenarios defined in the previous section. Figure 15-3 illustrates the proposed greenhouse map, as well as the deployment of the sensors, taking into account the facilitation of agricultural affairs and administration of various scenarios.



**Figure 13: Proposed greenhouse map and placement of the sensors**

The proposed greenhouse is 3 meters long, 2 meters wide, and 2.5 meters high, with each of the sensors placed in specified sections given their applications. Temperature and humidity sensors are deployed at the height of 2 meters in the central part of the greenhouse to obtain the temperature and relative humidity of the greenhouse. The soil moisture sensor is deployed at the farthest point from the irrigation system to yield the least soil moisture value. The figure below indicates the circuit of the sensors' installment.

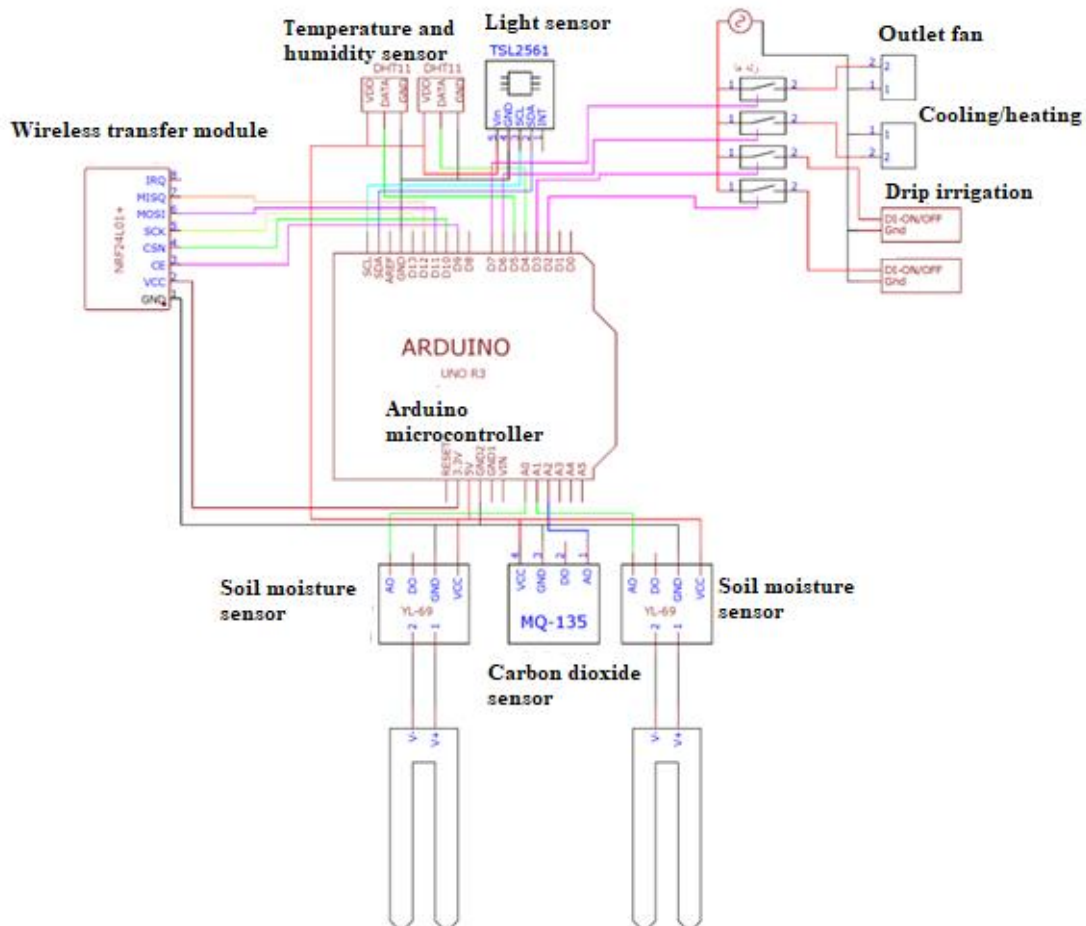


Figure 14: Circuit schematic of the sensor node (slave)

### Setting up the Software

Designing and implementing the HTML user interface is appropriate for displaying the data stored in the Google Sheets System. This user interface is in direct interaction with the base station. Using the HTML language, an interface was designed to display the updated sensor data on a webpage and a diagram of data stored on the Google Sheets in a 24-hour diagram.

1. Momentarily display of the sensor data: This section displays the data of temperature and humidity, soil moisture, carbon dioxide, and light intensity sensors momentarily and updates them automatically.
2. Definition of the parameters' threshold: This section defines intended limitations, including maximum temperature and humidity, soil moisture, and sending the data by clicking the button Submit through the base station to the sensor station.
3. The 24-hour diagram of the greenhouse: Data from sensors are sent every one hour to the Google Sheets platform to be stored. Using a diagram, sensor data are seen in the form of a diagram.
4. 24-hour diagram outside of the greenhouse
5. Webpage address section, locally defined.

In this research, a field variable in the Arduino programming language was used to display the user interface containing the HTML user interface file. In this interface, the GET method received the settings, with the intended parameters sent to the base station through the URL.



NodeMcu wireless control board was also used to create a server connected to the wireless modem using the ESP8266WiFi.h library and the definition of SSID and the password. Then, data from sensors were displayed in the form of text/HTML through the ESP8266WebServer.h library and use of the Send class. This class receives the HTML file and sends it to the server.

Also, to store data in the Google Sheets platform, the HTTPSRedirect.h library and the connect (host, httpsPort) are used to connect to the above system; then, the created unique spreadsheet code is used to access the place where data are stored, and the intended parameters are sent through the URL. In the end, the script written for the file is used to examine and store the file.

The Chart tool was used to display the diagram of sensor data on the Google Sheet platform, as the Publish Chart option is used to replace the above diagram with the <iframe> tag in the HTML file.

## Findings

### Assessing Sensor Data

Sensors were placed in different parts of the greenhouse. Considering the wireless communication of the sensors with the base station, the sensors must be connected to the Arduino microcontroller and NRF2401+ wireless transfer module to be used for wireless communications; thus, the above sensors were brought together in a group to save cost and energy. After the sensors were installed, the data they sent were received in the base station, which, having been stored on the Google Sheets platform, were displayed by an explorer on a computer or mobile phone through the HTML user interface. To assess the efficiency and tolerance of the wireless sensor network, some parameters, including reliability, average packet transfer delay and consumed energy, were calculated, which will be later discussed.

#### 1. Reliability

In the network, every node may break down or fail due to environmental factors such as fire, water leakage, impact or depletion of power source. Reliability denotes that if a node breaks down, the network's performance is not affected. This project's premise is to use unreliable components to create a reliable network. The reliability of the network and relevant protocols is a major debate in the wireless sensor network. This project aimed to create a system to manage and control a smart greenhouse that should enjoy higher reliability and coefficient of tolerance so that it can send data gathered from sensors to the base station and rely on the sent results, which would help the farmer take appropriate measures. To measure reliability, it should be investigated how many nodes sent from the node to the base station will reach safely at the destination. In this project, the number of 3600 data packets sent from the node to the base station were stored in a file. The reliability of the node was calculated by dividing the number of data that reached safely at the base station by the number of data sent from the node.

**Table 1: Node's reliability at different distances**

Distance from the vase station (m)	Number of packets sent	Number of received (safe) packets	Reliability
2	3600	3474	96.5
10	3600	3321	92.25
15	3600	3194	88.72

As noted by the table, as the distance of the sensor node increases from the base station, the system's reliability decreases, indicating that the wireless transfer module faces problems with the communications as it distances from the station, with the number of lost packets also increasing. To send data from each sensor, a unique key was used to detect the relevant data. The following image illustrates the file stored in the node and the base station.

```

node01 - Notepad
File Edit Format View Help
node01 Temp=27
node01 Temp=28
node01 Co2=197
node01 Light=1183
node01 Temp=27
node01 Soil=53
node01 Hum=42
node01 Light=1021
node01 Hum=49
node01 Soil=61
node01 Co2=176
node01 Hum=63
node01 Light=837
node01 Temp=25
node01 Soil=66
Ln 3600, Col 16 100% Windows (CRLF) UTF-8

gatewayLog - Notepad
File Edit Format View Help
node01 Temp=28
node01 Co2=197
node01 Light=1183
node01 Temp=27
node01 Soil=53
node01 Hum=42
node01 Light=1021
node01 Hum=49
node01 Soil=61
node01 Co2=176
node01 Hum=63
node01 Light=837
node01 Temp=25
node01 Soil=66
Ln 3474, Col 16 100% Windows (CRLF) UTF-8

```

Figure 15: Log file stored

As the image shows, the node01 file contains data of 3600 packets sent from the node to the base station, as the gatewayLog file contains data received from the base station. The file includes two columns; the first one pertains to the key of the node, while the second column pertains to the sensor data where Light, Co2, Soil, Hum, and Temp indicate light, carbon dioxide, soil moisture, humidity and temperature.

## 2. Average packet transfer delay

The second parameter of assessment is the average packet transfer delay. The table below gives the average delay rates of node packets is calculated within one hour, assuming a packet transfer of every second.

Table 2: Average delay of packet transfer

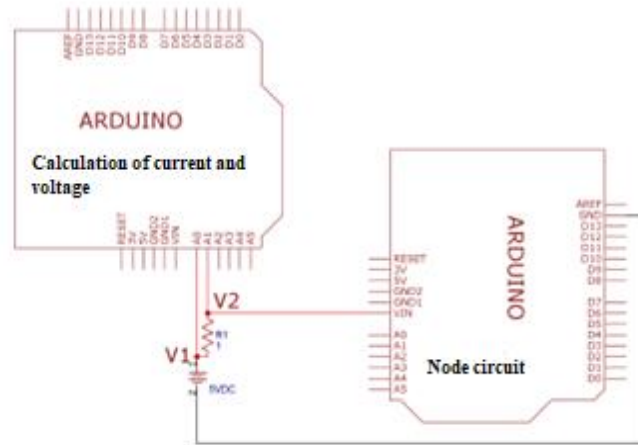
Time (second)	Total delay	Average delay of packet transfer (milliseconds)
3600	741676	206

In a monitoring system, receiving the packets sent from the sensors with some delay is very important. Otherwise, the system does not give necessary warnings to the farmers on time or implement the necessary commands. As the table shows, within an hour and assuming the transfer of data from the sensors every second to the base station, the average delay was calculated to be 206 milliseconds which was very desirable.

## 3. Power Consumed by the Nodes

To calculate the current and voltage, the following circuit is used.





**Figure 16: Circuit to calculate the power consumed by the node and base station**

Because the consumed power is constantly changing, the voltage and current must be continuously measured to determine the average power consumption. To do so, an Arduino microcontroller was used, which continuously measured the voltage and the current at a time interval and multiplied them by each other. At last, the average values were calculated and displayed. The momentarily current consumed by the circuit was equal to the current passing through the resistor. Resistance current was also calculated by measuring the voltage of the two-sided resistors. The following formula measures the circuit current.

$$V_1 - V_2 = R \cdot I_{R1} \xrightarrow{I_{R1}=I_S} I_S = \frac{V_1 - V_2}{R}$$

The resistance used in this circuit must be very small to prevent the circuit from voltage drop. For this, 2.2 ohm resistance in the circuit was used. As a result, the circuit current is calculated from the following formula.

$$I_S = \frac{V_1 - V_2}{2.2}$$

The circuit voltage is  $V_2$  which is measured as current is then multiplied by its voltage to calculate the circuit's power value.

**Table 2: Average power consumed by the sensor node and base station**

Circuit	$V_1$	$V_2$	$I_s$	The average power consumed (W)
Sensor node	4.80 V	4.32V	0.22A	0.95W
Base station	4.90V	4.64V	0.12A	0.55W

As noted in the table, the sum of the average power of the entire system was 1.5 Watts. The following formula yields the total power consumed, which is 300 mAh.

$$P = V \cdot I$$

#### 4. Rate of Data Transfer

The table below gives the data transfer rate of three applicable wireless transfer modules and their coverage.

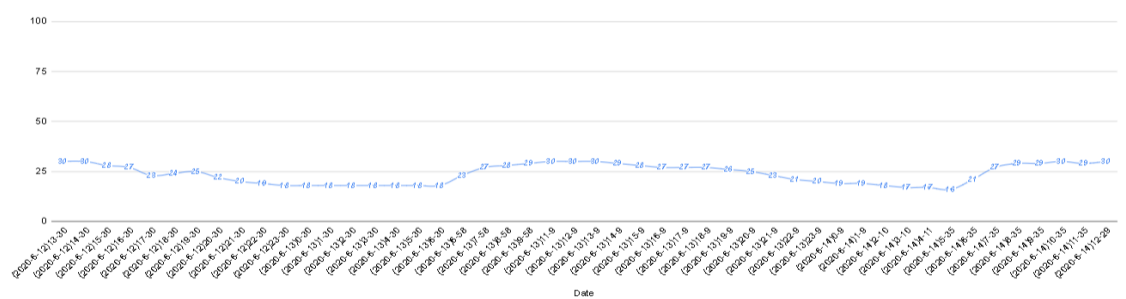
**Table 3: Comparison of transfer rate and coverage**

Module	Rate of data transfer	Coverage (m)
NRF240L01	1-2Mbps	10-100
ZigBee	20-250Kbps	10-100
Bluetooth	1-3Mbps	2-10

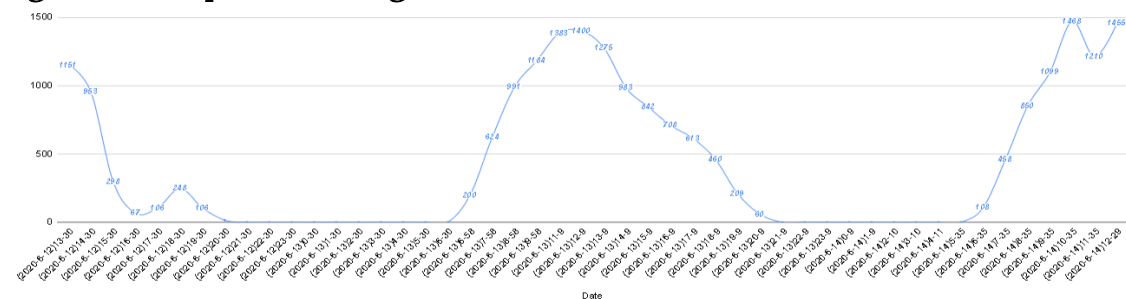
As noted, the transfer rate of the NRF240L01 module used in this project was greater than the ZigBee module but less than the Bluetooth, though its coverage was greater than that of the Bluetooth.

**Examining Data Stored**

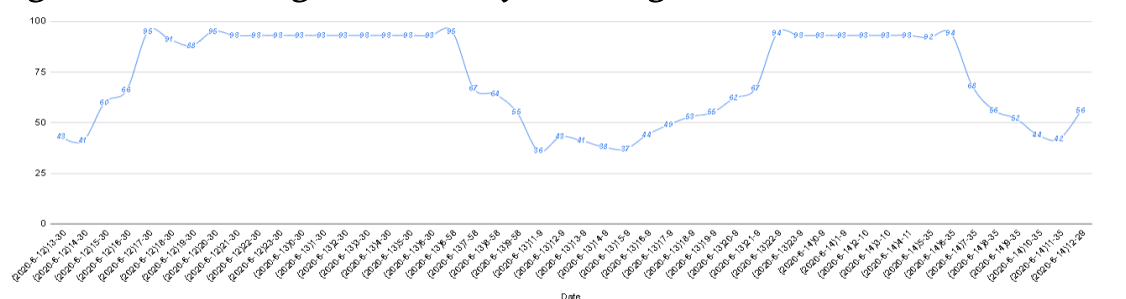
To test the proposed system, stored data were displayed by the Google Sheets platform chart. The following figures illustrate the diagram of the data stored for the last 48 hours.

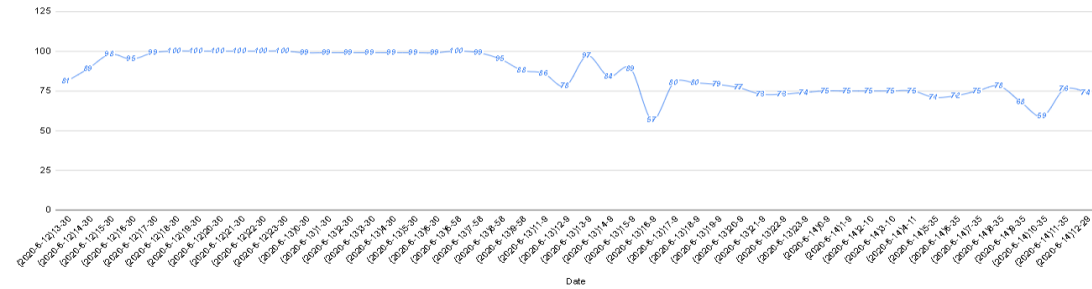
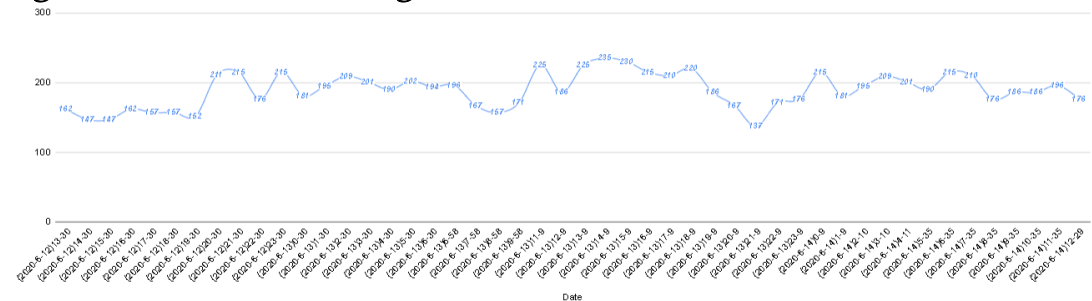


**Figure 17: Temperature changes in the last 48 hours**



**Figure 18: Light intensity changes in the last 48 hours**



**Figure 19: Air humidity changes in the last 48 hours****Figure 20: Soil moisture changes in the last 48 hours****Figure 21: Carbon dioxide changes in the last 48 hours**

As noted in Figures 17 and 18 of temperature and light intensity diagrams, as the light intensity increases, the temperature gradually increases. When it reaches the defined default threshold of 30 °C, it will activate the cooling and air ventilation system by sending a command to the relay, thus preventing the excessive temperature increase in the greenhouse environment. Figure 19 shows that the air moisture diagram is reversely related to the temperature and light intensity diagram, as increased light intensity and temperature reduce the air moisture in the environment.

### Conclusion

This research designed and implemented a smart greenhouse considering the farming needs and the problems that may arise for the farmers. A smart greenhouse system is characterized by having different sensors, various warnings at critical times, providing a simple user environment for remote control, economic design and implementation, etc. Also, an HTML user interface was designed to display the sensor data and warnings. This research examined the sensors used in the greenhouse environment. Also, some evaluation parameters, including reliability, average packet transfer delay, consumed power and data transfer rate, were calculated. Data from the past 48 hours were also reviewed. After the sensors were installed in the greenhouse, some evaluation parameters, including reliability, average packet transfer delay, consumed power and data transfer rate, were examined. It was noted that the reliability of the proposed system at the 10-meter distance from the base station was 92.25%, indicating higher reliability. The average packet transfer delay was 206 milliseconds within an hour, which was insignificant. The total energy consumption of 36 watts per day indicated low energy consumption. The total current consumed by the system was 300 mAh, which was very low compared to other projects, though acceptable. It is recommended that future climatic data are provided in direct contact with the base station and meteorology organization.

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