DESIGN AND CONSTRUCTION OF A GREENHOUSE MONITORING SYSTEM WITH WIRELESS SENSOR NETWORKS

BY

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A PROJECT REPORT SUBMITTED TO DEPARTMENT OF ELECTRICAL AND INFORMATION ENGINEERING IN PARTIAL FULFILMENT FOR THE AWARD OF THE DEGREE OF BACHELOR OF ENGINEERING INFORMATION AND COMMUNICATION ENGINEERING

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AUGUST 2021

DECLARATION

I hereby declare that the work reported in this project was carried out by me under the supervision of Dr. Joke A. Badejo in the Department of Electrical and Information Engineering, Covenant University. Also, I declare that to the best of my knowledge, no part of the report has been submitted here or elsewhere in a prior application for the award of a degree. All sources of knowledge used herein have been duly acknowledged.

…………………………………….

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CERTIFICATION

This is to certify that the project titled Greenhouse Monitoring System Using Wireless Sensor Networks by ANYAOGU Chisimdiri Chiherebama (16CK020883), meets the requirements and regulations governing the award of the Bachelor of Engineering, B.Eng. (Information and Communication Engineering) degree of Covenant University and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this project to God Almighty for His grace, love, and guidance through my years in this University. I also dedicate this project to family and friends for their unconditional love, support and advice during the course of this degree.

I also dedicate this project to my supervisor, Dr. Joke A. Badejo for her guidance, counsel, discipline, work ethics, and encouragement.

ACKNOWLEDGEMENTS

I would like to acknowledge God for his divine wisdom and direction. He has been my source of inspiration, and it's by His grace that this project is complete.

Also, I acknowledge my Parents Mr and Mrs Anyaogu, for their guidance and my dear lecturers for their efforts throughout this degree and My siblings Chiko, Chibudike, Chidera and Chinebulielu for their support all through the duration of this project. My loyal and loving friends, Ogu Tamaramiebi, Ekwenibe Adaobi, Oriaku Ogeya, Dogunro Oluwatobi, Olumide Agbede, Olumide Oluleye, and Amlabu Kolade for being a source of motivation for this project.

I would also like to acknowledge my supervisor Dr. Joke A. Badejo, for her unending support all through the period of this project.

Most of all I would like to acknowledge the lecturers in the Department of Electrical and Information Engineering for their incredible work ethic and impacting me with the knowledge to take on this project.

ABSTRACT

The continuous improvement in science and technology has significantly impacted the development of modern tools in the agricultural sector. For example, smart greenhouse monitoring systems have evolved to meet data transmission, remote monitoring, and data acquisition requirements. In this project, a smart greenhouse monitoring system was developed using the concept of Wireless Sensor Networks (WSNs). The WSN consists of small-size wireless sensor nodes equipped with a radio for communicating in the network. The greenhouse monitoring system consists of the WSN, a data display system, remote control system, management system and a login management system. The monitoring system detects the environmental conditions and alerts the grower/farmer once a threshold value is exceeded. The system parameters can also be viewed on a designated database server to know the status of the system and support crop growing and general farm management decision-making. The system was implemented and tested to ensure its proper functioning.

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CHAPTER ONE

INTRODUCTION

1.1 Background Information

A greenhouse is a building where plants are grown[1]. These structures protect plants from too much cold or heat, bad weather such as blizzards and prevent rodents and pests. We know that greenhouses are used primarily for the seasonal growth of unsustainable plants, which provides conditions needed for a plant growth cycle to increase its yield. Planting crops is a very demanding activity for the environment. Most farmers rely on their experiences and feelings in traditional control modes when managing crops, with little to no scientific knowledge. In this modern era of agriculture, information about the environment such as; temperature, humidity, carbon dioxide (CO_2) concentration, the light intensity, researchers have scientifically studied, and the best standards researchers have obtained. These studies resulted in the Internet of Things (IoT) being incorporated into greenhouse management/monitoring systems[1].

The most crucial factors considered when checking the productivity and quality of plants and crops are humidity, temperature, light, and CO_2 intake. Continuous monitoring of these environmental parameters gives information to the farmer to better understand how each of these parameters affects growth, productivity, and how to manage crop/plant yield. A single measuring point in the building center was sufficient to transmit information to the greenhouse monitoring system in prior greenhouse monitoring systems. However, the idea could not adjust heating/temperature, light intensity, Ventilation, and other activities, all of which would impact the greenhouse's long-term weather conditions. Modern greenhouses have brought about a change to the previous systems that farmers and growers are using. Nowadays, greenhouses provide more options to adjust the temperature, cooling system, and light intensity[2]. Automatic agricultural monitoring systems have advanced rapidly in terms of technology in recent years. Sensors for remote monitoring and controlling devices controlled through SMS (Short Message Service) using GSM (Global System for Mobile Communications) and Bluetooth modules. This technology presents systems with features designed with low cost and effectiveness objectives while reducing power consumption. Using SMS (Short Message Service) technology from the GSM module, the system alerts the farmer to any abnormal situations such as reduced moisture content, rising temperature, insufficient light intensity, and even CO_2 levels. Even though Bluetooth minimises the cost of the network to a great level, the range of operation is limited to several meters. Farmers cannot remotely monitor and control devices using this technology. Adding dedicated Bluetooth modules to each of the devices will defeat the advantage of reduced cost, increasing expenses exponentially. Interference caused by barriers in the building can also be a problem using this technology. [3]WSNs (Wireless Sensor Networks) are networks of battery-powered sensors connected over a wireless channel and are often used to serve a specific application purpose. [2]A wireless sensor network (WSN) can be an essential part of the architecture automation system in modern greenhouses. Wireless communication collects data and communicates between the centralized control and actuators positioned throughout the greenhouse. In advanced WSN solutions, some control system components can be implemented in a distributed fashion on the network, allowing for local control loops. WSN installation is quick, inexpensive, and simple when compared to cabled systems. Furthermore, the measurement locations can be easily relocated within a communication range of the coordinator device by simply transferring sensor nodes from one place to another. The small and lightweight nodes are placed to the plant's branches if the greenhouse flora is high and dense [3]. The structure of a WSN can vary from a simple star network to an advanced multi-hop wireless mesh network. The method of propagation between nodes in the network can be flooding or routing[4]. Ever considered the possibility of having a greenhouse in every home? And not just a greenhouse, one with its greenhouse monitoring system that updates the grower on its temperature levels, humidity levels, and light intensity. WSN's would extensively allow users to understand better the behaviour and survival conditions of crops and plants grown in the greenhouse. Imagine growing excellent and healthy crops in a backyard without having to worry about if the plants are getting sufficient sunlight. Furthermore, those crops are under stable temperatures and humidity because data from those parameters are sent to a mobile device on demand from a web server and not having to worry about the high power consumption of the system due to the cheap cost of power proposed by Zigbee technology.[1] Zigbee is a low-power wireless technology developed by a collaboration of 16 firms in 2002. Zigbee uses the IEEE standard 802.15.4.2003. It is aimed at intelligent power monitoring meters, home automation, remote control, and agricultural monitoring systems and introduces mesh networking to the low-power wireless area. Zigbee, which runs on wireless sensor technology for greenhouses, provides mobility and flexibility, mainly when saving money and energy on wiring. The greenhouse network has five aspects to consider: cost, data rate, number of wireless nodes, and power usage, and battery life span[5]. In short, Zigbee technology offers small size sensors, long-lasting batteries, high reliability, and in general, a low-cost system. Consequently, it serves as one of the most favourable options for greenhouse monitoring systems than other wireless mediums.

1.2 Significance and Motivation for the Project

This project aims to show the advantages of having a greenhouse monitoring system, encouraging more people to invest in greenhouses and monitoring systems to create ease in farming. Consequently, this system is going to provide users a source of food in their backyard for feeding. Aside from home growers, this project would also benefit commercial growers because larger greenhouses effectively monitor parameters. Researchers and scientists give them the chance to study the best conditions that would allow various plants to flourish. Lastly, it provides more data for students interested in this area of expertise. Also, the coolness of the technology could serve as an attraction to students, consequently increasing the number of educated farmers in society.

Due to the increase in demand for food products around the increasing population today, it is vital to monitor and maintain the greenhouse's happenings to increase crop yields. The advancement in agriculture has helped push greenhouse systems and helps to properly understand what conditions best suit a specific crop/plant, but with high power consumption. The proposed model in this project delivers a cost-effective system in terms of lesser power consumption than the previous technology. Another motivation towards this study is the need for more uncomplicated techniques to collate data concerning the kinds of conditions that would best suit our crops present in the greenhouse. Thus there is an urgent need for solutions to these challenges.

1.3 Problem Statement

One of the problems that led to this project's development was understanding the best environmental conditions for various plants and crop planting by farmers/growers to produce healthier and more productive crops. Just as it applies to human beings, living in a healthy environment with moderate temperatures increases comfort. Good humid conditions leave the body looking much better; plenty of sunlight would also make one look better and feel more confident. This situation is also the case for plants, and a healthy plant yields a healthy food supply. Another problem that led to the development was the need for an improved system to control the equipment present in the greenhouse remotely. Take, for example, and a grower gets an alert of a high rise in temperature in the greenhouse, which would be bad for the plants present. From a location, turn on the fans in the greenhouse to effectively bring down the temperature and avoid damages to plants.

The Zigbee technology has an RF power rating of about 1mW, frequency bands of 868/915 MHz, 2.4GHz with a decent data rate of 20-250kbps, proportional to the amount of power it consumes. Consequently, the problem of excess power consumption in previous monitoring systems. Finally, this project addresses the issues faced by the conventional means of data collection and retrieval. This system would provide better means of accessing historical data at will, which is a great plus.

1.4 Aim and Objectives of the Project

This project aims to design and construct a greenhouse monitoring system.

The specific objectives of this project are to:

i. design a greenhouse quality monitoring system;
ii. implement the system design using software and hardware components;

iii. test the air greenhouse monitoring system; and
iv. deploy the greenhouse quality monitoring system in any area of interest.

1.5 Methodology

The Wireless Sensor Network, designed with two nodes, acts as the sensor node and reports to the gateway node. The gateway node is consequently reporting the data from both nodes to a server. Temperature, humidity, and light intensity, three agricultural characteristics, were measured using their respective sensors. The Arduino Pro Mini communicates with these sensors. The Arduino micro-controller was programmed using the Arduino Integrated Development Environment (IDE), which uses C programming language. The control unit, which consists of the second Zigbee sensor node, interfaces with the Node MCU and is also the gateway node because it sends its report to ThinkSpeak IoT web servers.

1.6 Project Organization

The design and implementation of the Greenhouse Monitoring System with Wireless Sensor Networks in the five (5) chapters of this project report, which are as follows;

Chapter One: Introduction. This paper contains an overview of this project, the background of the study, aims & objectives, problems the project would be looking to solve, and the methodology used in the development of this project.

Chapter Two: This is the literature review, which discusses past works related to the project area. It also talks about their concepts and theories, which sheds more light on this project.

Chapter Three: This project's methodology in full detail discusses the design, components used, the block and circuit diagrams, and class diagrams.

Chapter Four: This chapter discusses how the project's implementation and the testing phase of this report. The results of the tests performed in the project are here also.

Chapter Five: This is the concluding part of this report and includes recommendations to further the technology used in the project. It also discusses notable achievements of this project.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter provides an introduction of greenhouse monitoring systems and other intelligent agricultural monitoring approaches so that you may better comprehend the processes and the expected outcomes. Previous research on the application of greenhouse monitoring has been evaluated. According to the studies discussed above, environmental monitoring is a major problem in the sector. The finest solutions for monitoring greenhouses, according to popular opinion, are intelligent systems. As a result, human error and restrictions can be circumvented. Data on soil qualities and environmental conditions must be collected and stored. In order to improve green housing conditions in order to improve the conditions of greenhouse monitoring, the current project will focus on improving the solution to cost-efficient ways to store data and save power.

2.2 Definition of Key Terms

1. Sensor Node: A sensor node is responsible for processing information, collating information, and communicating between other nodes in a wireless network. A sensor node measures the distance with the sensor regularly and compares it to the previous measurement. It sends an advertisement message to the cluster leader if the result has changed. [6].

2. Sink Node: This is a small device with properties similar to that of the standard sensor nodes but performs more functions than normal nodes. It is used for data gathering in WSN's by multi-hop forwarding technique. This stationary node

listens on selected channels indefinitely to transfer packets from the cluster head to the management station. [6].

3. Gateway Node: This device connects between the networks of sensors and the data server which all the data from the network ends up[3].

4. Cluster Heads: The cluster head keeps an eye on the greenhouse while also waiting for advertisements from the other sensor nodes. It collects data and sends it to the sink node. [6].

2.3 Architecture of Greenhouse Monitoring System

The greenhouse monitoring and control system is developed to tackle hundreds of greenhouses in the agricultural production base. If each greenhouse interacts with the distant server individually, the construction is vast, and the cost is expensive. As a result, we will require a gateway to collect data and deliver it to a single remote server. The greenhouse monitoring and control system comprises the acquisition and control system in the greenhouses, the gateway, and the higher computer. The ZigBee coordinator is a component of the gateway in terms of function. The acquisition function sends data from the ZigBee coordinator to the MCU, encapsulating the data in the appropriate format and sending it to the upper computer. The control function sends data from the top computer to the MCU, encapsulating it and sending it to the acquisition and control system through the ZigBee coordinator[7].

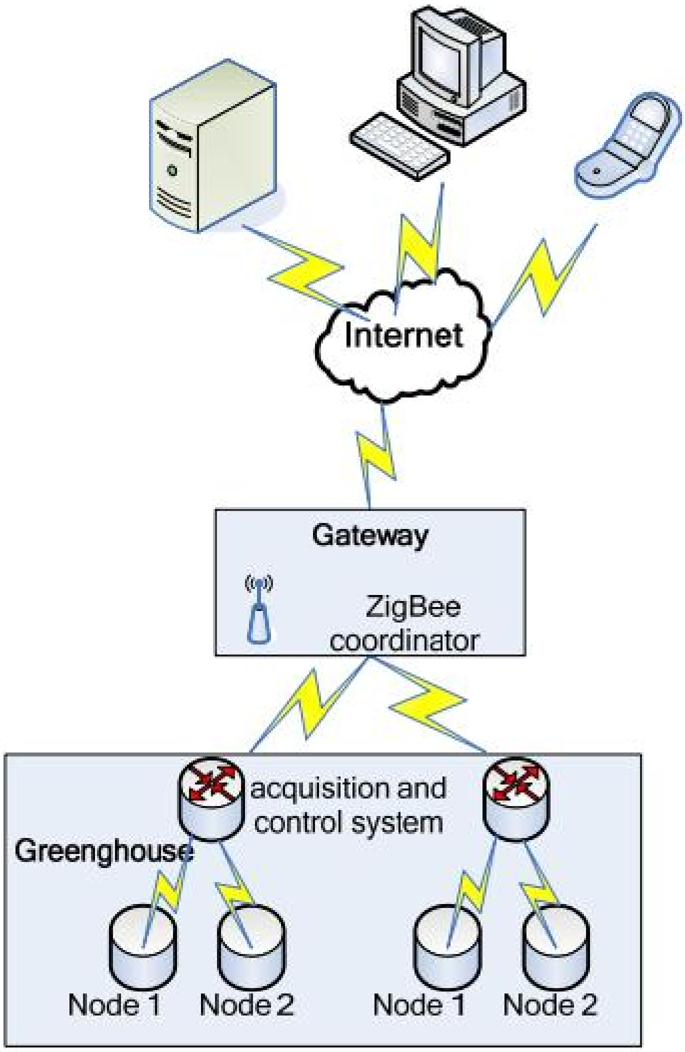

Figure 2.1: Greenhouse Monitoring System Architecture[7]

2.4 Review of Related Works

There are numerous studies in this area that look into helping in proposing a system with problem-solving efficiency in greenhouses.

Nachidi et al. [7] proposed a system for managing air temperature and humidity concentration in greenhouses utilizing synchronous ventilation and heating systems, based on Takagi-Sugeno (T-S) fuzzy models and the Parallel Distributed Compensation (PDC) concept. The robust fuzzy controller efficiently supplies the appropriate climate conditions in a greenhouse, according to this T-S fuzzy model. Stability analysis and control design were replaced in previous models by Linear Matrix Inequalities (LMIs).

Stipanicev and Marasovic [8] proposed an embedded web server unit system based on the TINI board that stores data from dispersed sensors and actuators over a simple 1-wire local network. The web server accesses via an ethernet or dial-up network in parallel. In comparison to PC-based systems, they claimed that the developed system provides all of the benefits of Network Embedded System Technology (NEST), such as the ability to change physical topology, low dimensions, and affordability, while maintaining complete functionality.

Quin et al. [9] compared the benefits of Zigbee to two other wireless networking protocols, Wireless-Fidelity and Bluetooth, and offered a Zigbee-based wireless system for greenhouse monitoring and control. It is possible to develop Chinese protected agriculture by using Zigbee technology in a Chinese greenhouse. The wide self-organization capabilities, self-configuring, self-diagnosing, and self-correction capabilities of the Zigbee-based monitoring and control system enable practically infinite installation preference. It provides transducer versatility, improves network resiliency, and is very cost effective.

Using Sensinode Inc's commercial wireless sensing technology, Elmusratiet al [2] proposed a somewhat different technique for implementing WSN in a greenhouse setting. The hardware for the system consists of a Sensinode Micro 2420U100 as the primary measurement node and four commercial sensors (e.g., humidity, temperature, light, and CO2). The purpose of this project is to test the dependability and feasibility of a prototype wireless environment monitoring system in a commercial greenhouse.

According to the experiment's findings, the network was able to detect local variations in the greenhouse climate caused by a variety of environmental perturbations.

Palaniappan et al. [10] proposed an embedded greenhouse monitoring and control system that delivers extremely comprehensive micro-climate data for plants within a greenhouse setting, as well as a novel way for cultivating temperate crops in tropical microclimatic conditions. Traditional wired sensors in the greenhouse provide readings of the ambient temperature, light intensity, and temperature of the nutrient solution in the mixing tank. The nutrition solution's acidity and concentration were manually measured and changed as needed. This technology uses high-resolution data to create a network of wireless sensors that will offer enough data to develop a model for growing these crops under aeroponic settings. The study also claimed that the star network's reliability was rather high, with many nodes achieving data transfer rates of above 90%. The minimal data transfer rate for all nodes, on the other hand, was 70%.

Sahu and Mazumdar [11] created a microcontroller-based (Atmel) circuit to monitor and gather temperature, humidity, soil moisture, and sunshine in a simulated environment. In order to achieve optimal plant development and yield, these quantities are constantly changed and managed. The microcontroller communicates with the numerous sensor modules in real-time to successfully regulate the lighting, aeration, and drainage processes; it uses coolers, foggers, drippers, and lights in the greenhouse according to the conditions. It has an embedded Liquid Crystal Display (LCD) that renders data from the numerous sensors and functions in real time. It has an inbuilt Liquid Crystal Display (LCD) that displays data from the various sensors as well as the operational condition of the various actuating devices in real time.

Alausa Dele and Kolawole [12] presented a microcontroller-based greenhouse control device for automated control and monitoring of greenhouse equipment and quantities. Heating, cooling, temperature, light intensity, soil moisture level, and other quantities/conditions, with effective monitoring of all quantities therein, obviating the requirement for human monitoring. Suggestions for creating solutions to challenges that arise. It also automates all monitoring equipment in the house, thanks to the integration of upgrades. The system takes a flexible and accurate approach to solving the few flaws in conventional systems, while also reducing the need for power and maintenance through a streamlined design and lower cost.

Adbul Aziz et al. [12] have presented a remote temperature monitoring system based on wireless sensors and SMS technology. It contains a temperature sensor that can detect a wide range of temperatures. This technology is designed to notify farmers when the temperature in the greenhouse changes, allowing them to take preventative measures as soon as possible. This system was expanded to include more environmental factors in order to improve the effectiveness of monitoring amounts that aren't critical to the production of fruits and vegetables. Monitoring the soil and water acidity levels in the greenhouse, which is often overlooked yet crucial to product quality, is a wonderful example of reference. Further advancement employs an automation system for actuators such as sprinklers, lighting, and air ventilators.

Rather than simply delivering warning notification messages, the suggested system enhances monitoring by incorporating artificial intelligence components that allow for advanced implementation such as self-learning, prediction, and problem resolution.

Deore and Umale [13]have significance the WSN technique for greenhouse monitoring and control. The design of the control system is comparable to the

ATmega microcontroller. Farmers in underdeveloped countries, on the other hand, might use this practice to maximize yield. Because of a few key properties, Atmega microcontrollers stand out among other microcontrollers. There’s also a 10-bit ADC, sleep mode, a large input voltage range, and more memory. The overall functioning of the design system has been streamlined and improved. The system has a number of benefits, including its small size, low cost, and great accuracy.

Sagar [14] has developed a greenhouse GSM monitoring system. Internal climatic variables and other environmental parameters are collected in real time, with control decisions made by a monitoring system that is also active. An SMS is sent to the user's phone with information about the current procedure. The interoperability of a greenhouse monitoring system made up of a number of interfaced sensor nodes that collect local data so that suitable physical environment decisions may be made; the system is low-cost and efficient.

Othman and Shazali [15] studied wireless sensor network applications for environmental monitoring. In recent years, WSN has profited from embedded systems, Micro Electro Mechanical Systems (MEMS), wireless communications, distributed compute, and wireless sensor applications. Environment monitoring has evolved into a critical control and protection field, allowing real-time system and control links with the physical environment. From the outset of monitoring and managing air quality, traffic situations, and weather scenarios in the monitoring, an intelligent and intelligent wireless sensor network system may collect a great quantity of data.

Jianjunet et al. [16] suggested a system that uses remote monitoring and control software to collect data and provide control in a greenhouse; the temperature, humidity, soil water content, and carbon dioxide concentration inside the greenhouse are all monitored by the system, which is then saved to a database. All three temperatures are taken into account: the current interior temperature, the goal temperature, and the offset temperature. To control greenhouse temperature, the proportional Integral and Derivative (PID) control approach is utilized. The system is made up of low-power, easy-to-install wireless components.

Mohanty and Patil [8]have presented some essential quantities that monitor a greenhouse. It has highlights placed on quantities crucial to agricultural produce. The proposed system builds upon several nodes' interconnection into the realization of a Wireless Sensor Network. The system can efficiently capture the greenhouse environmental quantities, featuring an exemplary connection between the source and the sink node. In allegiance to a green energy source, solar power runs the system.

Gao et al. [18]designed a Zigbee and GSM-based wireless greenhouse monitoring system to eliminate cumbersome wiring and expensive wired networks in existing systems. A remote control terminal and a wireless network make up this system. Following the subdivision of monitoring regions, the establishment of a wireless communication network, with all nodes powered by solar energy. The study established a sophisticated decision system for the remote-control terminal based on the use of fuzzy decoupling control. It can perform precise monitoring and data gathering of greenhouse environmental quantities in real-time and provide accurate decision plans, which has a wide range of applications.

Lambebo and Haghani [19] published an extensive study on the application of WSN in real-time greenhouse gas monitoring. A tree topology WSN consisting of two sensor nodes and a base station was successfully developed and tested to analyze the concentration levels of several greenhouse gases using open source and low-cost hardware. A graphing Application Programming Interface makes the collected data available to the user (API). For optimal performance, the network functions within a 100-meter range.

Nikhade and Nalbalwar [20]have proposed a proposal for a reliable internal greenhouse climate control method. It takes shape in the form of an interconnected wireless sensor network that monitors environmental variables. A low-cost distributed sensory network can be used anywhere, independent of the widespread environmental subjections, due to the advantage acquired from the network's modest size. Greenhouse crops necessitate more automated operations. The WSAN system fills in the gaps, allowing for greater monitoring and management while preventing crop harm from unfavorable internal amounts. The system design focuses on automation, optimization of response time, and delivery of rapid solutions.

Hwang and Yu [21]have proposed leveraging Zigbee networks to create and implement a remote monitoring and control system. The client is provided control over the home automation system via web services and phone applications, with the primary goal of the home network. This technology could be used as a watchdog in elderly home security, museums, and natural catastrophe monitoring systems, among other things.

2.5 Problems Faced in Adoption of Greenhouse Monitoring Systems

Although monitoring systems have numerous advantages and applications, some factors make integrating and implementing factors in all greenhouses. Below are some of these factors.

1. Technological Literacy: Most farmers and a vast Nigerian population are not technologically literate, with only 46.6% of Nigerians being internet users. This

technology would be hard to integrate into existing greenhouses by farmers and growers around the country.

2. Internet Connection: Just as the name of this technology, the Internet of Things, it would be challenging for people in semi-rural and rural areas to have the internet capacity needed to run the proposed system in this paper correctly.

3. Data Handling: Wireless sensor networks produce many data, and the critical system needs to be made available for effective handling of data by the proposed system.

4. Cost: Most farmers and growers might find the cost of the proposed system to be quite exorbitant and termed as an unnecessary expense. Cost is a factor that is also closely related to the lack of proper education to see the importance of this system.

2.6 Conclusion

This chapter contains relevant literature on previous related works and effectively demonstrates their implementation in several ways and the successful evolution Of greenhouse monitoring systems.

CHAPTER THREE

SYSTEM DESIGN

3.1 Introduction

This chapter addresses the process involved in the development of the greenhouse monitoring system with wireless sensor networks. Also, it discusses the various components used to build the hardware. The schematics and the different components used are reviews and display relevant diagrams where necessary. The Arduino IDE is representing the software part of this chapter in this chapter, with appropriate diagrams.

3.2 System Hardware Requirements

The Node MCU and the Arduino Pro Mini micro-controllers represent the hardware design of this project. Although other micro-controllers have a hand in implementing this project, some include Evie, Bolt, and Raspberry pi. The Arduino Pro Mini and Node MCU, chosen for their wide availability of resources. Below is a table showing the different components that make up the hardware and their voltage ratings.

Table 3.1: Table showing the different hardware components and their voltage ratings

Electronic components	**Voltage Specification (VDC)**
Arduino Pro Mini	3.3 or 5 volts
Node MCU	5 volts
Water sensor	3.3 or 5 volts
Light sensor	1.8 – 3.3 volts
Temperature and Humidity sensor	3.3 – 5.2 volts
Zigbee Module	3.6 volts

3.2.1 Arduino Pro Mini

Arduino is an open-source platform that allows anyone to build their own electronic devices. Boards, or pieces of hardware, come in a variety of sizes and configurations.Boards also use other support hardware known as shields. Shields perform a more specific function. Examples of standard Arduino shields include the Ethernet shield and the Wi-Fi shield. The shield is usually made such that it can fit on the top of the Arduino board.

The limitations of the Arduino open-source do not apply to the hardware alone; it also has an Integrated Development Environment (IDE), which uses a variant of the C language for the code. This software aspect allows the user to program their boards to perform specific actions. This project makes use of an Arduino Pro Mini board. The Arduino Pro Mini is a type of Arduino board. It has been used for various projects by hobbyists, professionals worldwide because of its simplicity and ease of use.

The Arduino Pro Mini has 14 digital pins and six analog pins. The digital pins, used for input and output, but they have only two states, HIGH or LOW. A buzzer and an LED are examples of devices that return a digital output. However, to activate an LED bulb, the digital pin should be set to HIGH. Likewise, to turn off the LED, the digital pin should be set to LOW. Therefore, such devices that return a digital output must reach the digital pins of the Arduino Pro Mini. Analog pins return a value from 0 to 1023. An example of an analog sensor is a temperature sensor, and it displays temperature values.

The Arduino Pro Mini contains a USB connector and an ICSP header for powering it from a computer or laptop. It contains a power supply port that may be used to power up the board in addition to the USB port. The reset button is a little red button on the board that allows the user to reset the previous code. When the Pro Mini board is turned on, an LED illuminates and blinks to indicate that fresh code is being uploaded. Two voltage pins, 3.3V and 5V, support two distinct voltages. The Atmega328 micro-controller, on the other hand, is the brain behind the board's computing. The Atmega328 micro-controller contains an inbuilt analog to digital converter, which allows the Arduino to understand analog signals[9.] This is the most important benefit of having the Atmega328 on the Arduino board.

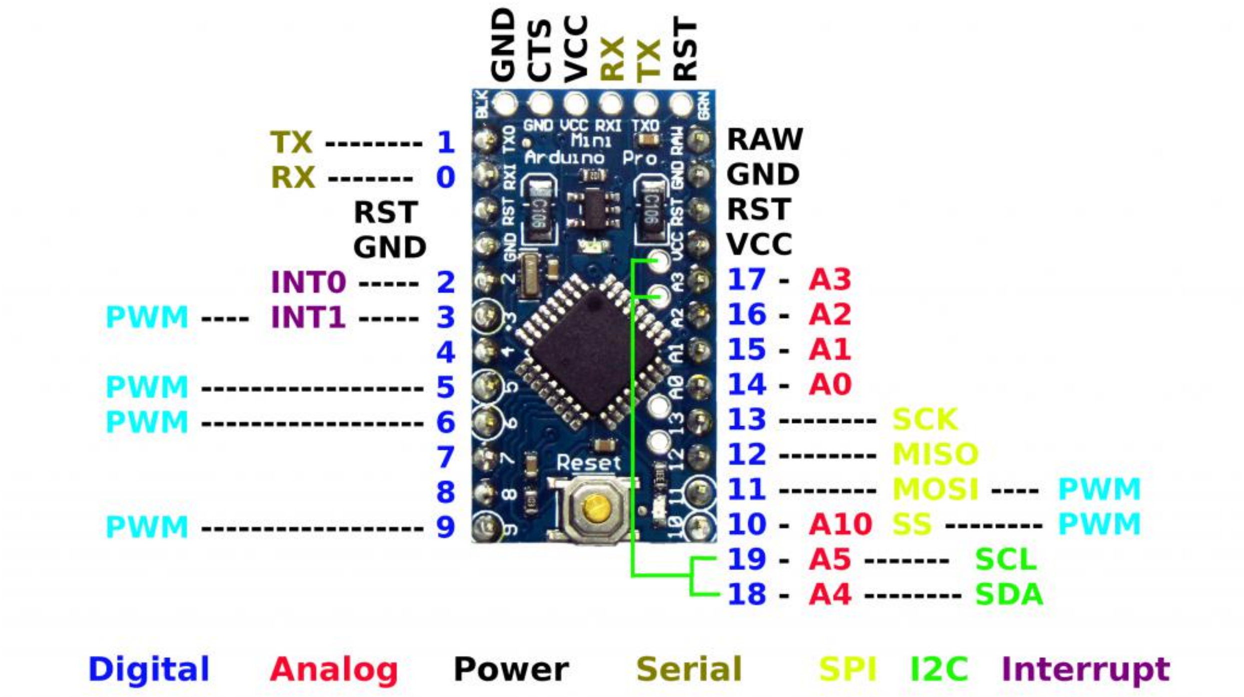

Figure 3.1:Arduino Pro Mini[10]

3.2.2 Zigbee Module

The ZigBee, which makes up the IEEE 802.15.4 standard[11], For Wireless Personal Area Networks (WPANs), the IEEE 802.15.4 standard specifies the physical and medium access control (MAC) layers (WPAN). The ZigBee Alliance has established the higher levels of the ZigBee standard using this standard as a "chassis." The WPAN's key components are devices. The devices, classified into two types: (a) physical and (b) logical. The physical type devices, split into two categories: Full Function Devices (FFD) and Reduced Function Devices (RFD) (RFD). Regardless of its nature, every device can function as a sensor node, control node, or composite device. The FFDs are responsible for just the network's routing functions.

Depending on their network locations, the FFDs may have one or more child devices, for which they perform routing functions. RFDs are unable to produce offspring because they are not responsible for network routing. FFDs may have one or more child devices for which they provide routing functions, depending on their network locations. RFDs are unable to have children since they do not perform routing functions in networks.

The logical type devices, divided into three categories: coordinator, router, and end device. The coordinator, which forms the root of the network tree, is the most capable of these logical devices. At the start of a network tree, each network should have precisely one ZigBee coordinator. It also serves as a connection point for other networks. End devices that use ZigBee have restricted capability and can only interact with a coordinator or router; they cannot transmit data to other devices. Because of their restricted functionality, end devices may "sleep" for lengthy periods and have a long operational life. In a ZigBee network, there are two types of communication: beacon mode and non-beacon mode. A battery-operated coordinator uses the beacon mode to save electricity. A gadget watches for the coordinator's beacons, sent out regularly, and searches for messages targeted to it. The coordinator establishes a timetable for the next beacon for this device after the message transmission is complete. The gadget can go to sleep after it has learned the schedule for the following schedule. The mains-powered coordinator is used in non-beacon mode. A mesh network's devices are all aware of the communication timetable, and they must wake up on time to prevent missing the signal. As a result, the devices are required to be connected to a highly accurate timing circuit. It means that the amount of energy used will increase. When devices remain idle for the most of the time, such as smoke detectors and burglar alarms, non-beacon mode communication is appropriate. So far, ZigBee has a wide range of applications.

Table 3.2: Table showing parameters of Zigbee[12]

Parameters	Description
Data Rate	250 kb/s, 40kb/s, and 20kb/s
Topology	Star or Point to Point
Addressing	16-bit or 64-bit
Multiple Access Technique	Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
Frequency	868 MHz 915 MHz 2.4 GHz
Range	10-20 meters

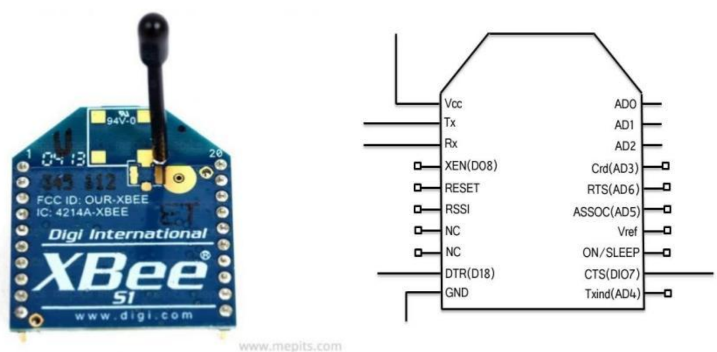

Figure 3.2: Zigbee Module[12]

3.2.3 Temperature and Humidity Sensor (DHT11)

The DHT11 temperature and humidity sensor are composed of a thermistor and capacitive humidity sensor enclosed in a plastic case. It contains four pins. It also has an analog to digital converter on the board, within the plastic enclosure. The sensor measures the atmospheric air condition and sends a digital signal via the digital pin. It has the drawback of being 2 seconds slow; that is, it takes approximately two seconds for the sensor to get new values. The operating voltage is from a minimum of 3.3V to 5.5 VDC max.

Table 3.3: Table showing parameters and their sensitivity[13]

Parameter	Sensitivity
Temperature	-40c to 80c
Humidity	0 to 100% RH

Table 3.4: Table showing DHT pins and their description [13]

Pins	Description
VCC	Power Supply
SDA	Serial data port
NULL	Null pin
GND	Ground

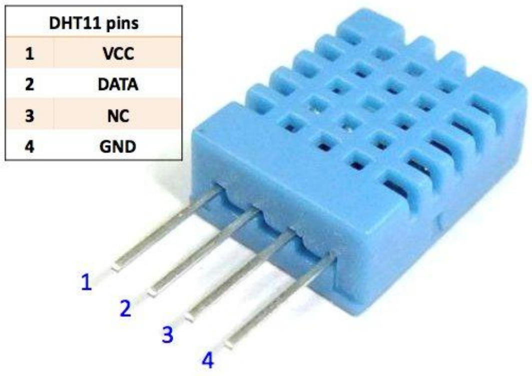

Figure 3.3: DHT11 Temperature and Humidity Sensor[13]

3.2.4 Light Sensor

Light encompasses a wide range of electromagnetic wavelengths. Plants, on the other hand, use wavelengths between 400 and 700 nm. PAR is the abbreviation for this range (Photo-synthetically Active Radiation). It's vital to make sure the plants get enough light to perform photosynthesis. The Light Dependent Resistors (LDR) represented in Figure 3.4 were employed in this application. Depending on the amount of light impinging on the sensor's surface, the internal resistance of an LDR increases or decreases. It measures visible light as seen by the human eye with a fast response and small size using two cadmium photo-conductive cells with spectrum responses comparable to those of the human eye. Cell resistance decreases as light intensity rises. Applications include smoke detection, automatic lighting control, batch counting, and burglar alarm systems. Table 3.5 and Figure 3.4 demonstrate the technical parameters of LDR.

.

Figure 3.4: Light Dependent Resistor[14]

Table 3.5: Technical Specification of LDR

Specification	Value
Voltage AC or DC peak	320V
Current	75ma
Power Dissipation at 30C	250mW
Operating temperature range	-60C to 75C

3.2.5 Node MCU

The NodeMCU is an open-source IoT platform manufactured by Esspressif systems; it runs on the ESP8266 Wi-Fi SoC (Wi-Fi system-on-chip) [15]. The abbreviation MCU stands for microcontroller unit. It is a small, compact device ideal for small systems like mobile phones and robots. Its primary purpose is to connect these systems to the internet.

The NodeMCU has the following features[15];

Compactness

i. High durability

ii. Low power consumption

Integrates a tensilica L106 32-bit RISC processor

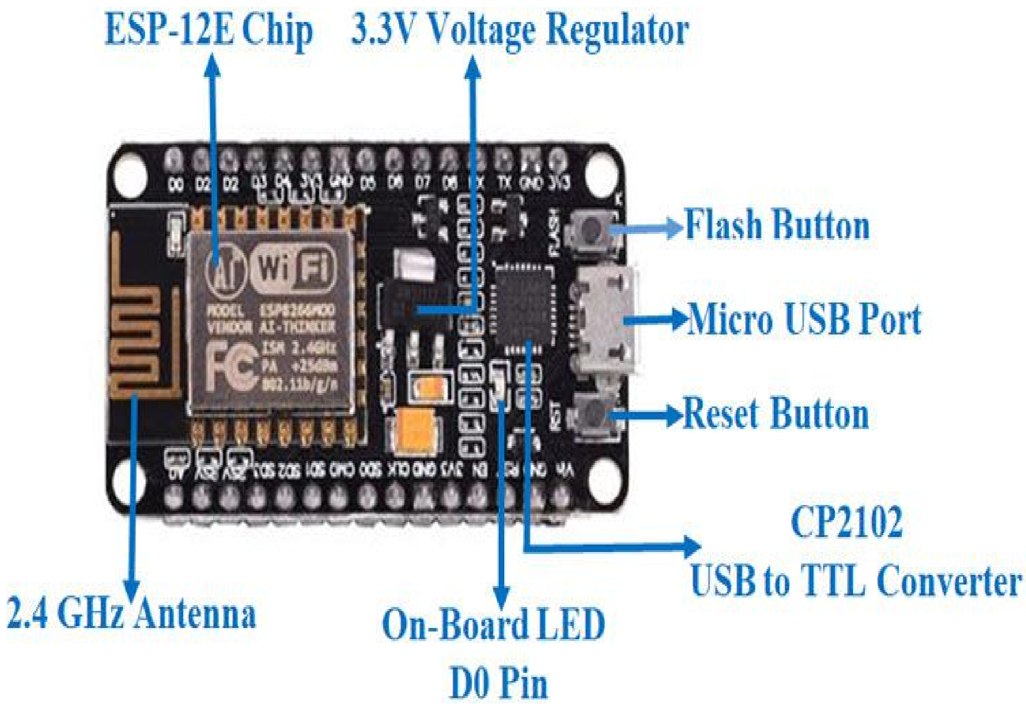

Figure 3.5: Node MCU[15]

3.2.6 Hardware Block Diagram

The hardware connection diagram is in Figure 3.6. depicts the relationship between the various units of this system. The power supply unit being the powerhouse of the system connects to the communication unit, sensor unit, switching unit and the control unit. The communication unit, which is basically the Zigbee module, relates with the control unit which is Node MCU because it is the gateway for the network. The sensor unit is essentially the sensor node which houses the DHT11, LDR1, and the water level sensor.

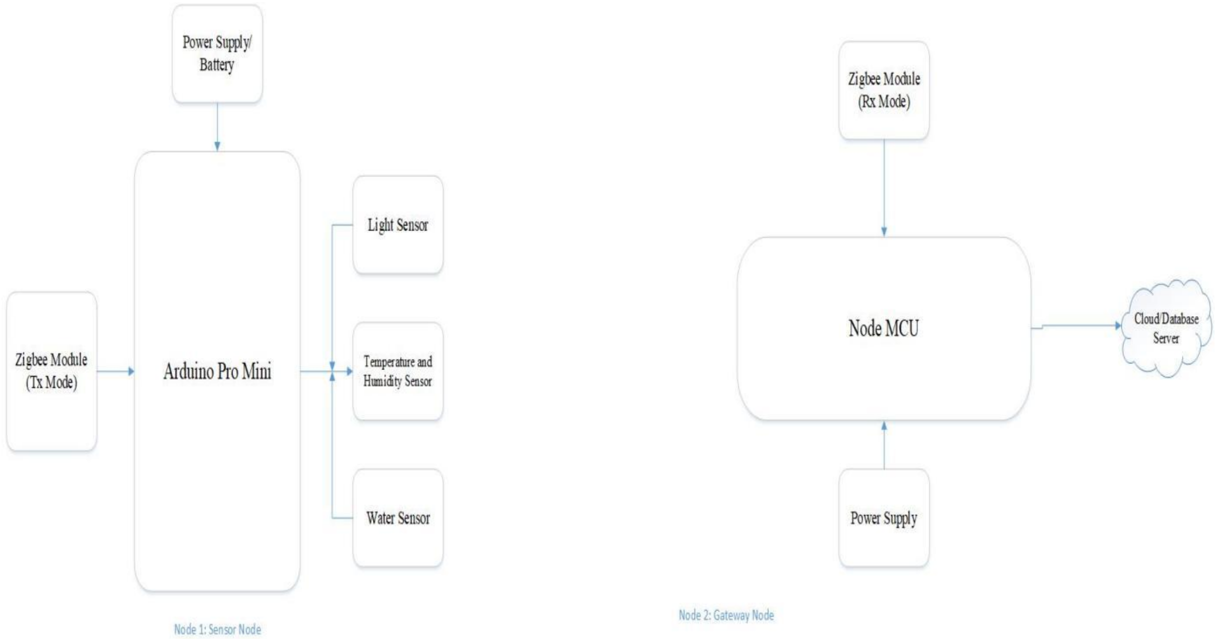

Figure 3.6: Hardware Connection Block Diagram

3.2.7 Control Circuit Simulation

From the hardware block diagram in Figure 3.6, the circuit diagram, obtained, as shown in Figure 3.7 below. The various components of the hardware system, selected from the component menu on the Proteus development package. Each component is selected and dragged to an appropriate part of the development space. The connection then proceeds, as shown in the hardware connection block diagram in Figure 3.7.

In this circuit diagram, there are two micro-controllers, (an Arduino Pro Mini and a Node MCU) used to implement this project. The first one being the Arduino Pro Mini which serves as the sensor node. A single analogue pin serves as the source for the sensor unit. The light sensor, temperature and humidity sensor, and the water sensor are all connected to the A0 pin on the Arduino pro mini, as shown on the left side of fig 3.7. Although, the data port of the sensor unit is connected to a digital pin, 'D9', as shown in fig 3.9. The Zigbee module has its transmitter pin (Tx) connected to a digital pin, 'D7', and the receiver pin connected to a digital pin, 'D8'. They are connected to the digital pin because they have two states: ' HIGH,' which turns it ON, and 'LOW,' which turns it OFF. The battery and the voltage boosters, connected to the power pins of the Arduino pro mini. The second micro-controller, the Node MCU, which serves as the coordinating node, houses the second Zigbee module with its transmitter pin (Tx) connected to a digital pin 'D2' receiver pin connected to a digital pin, 'D4' Because they are digital devices and have two states. Furthermore, the Node MCU forwards data from the sensor nodes to a web database service, ThinkSpeak is he web service for this system.

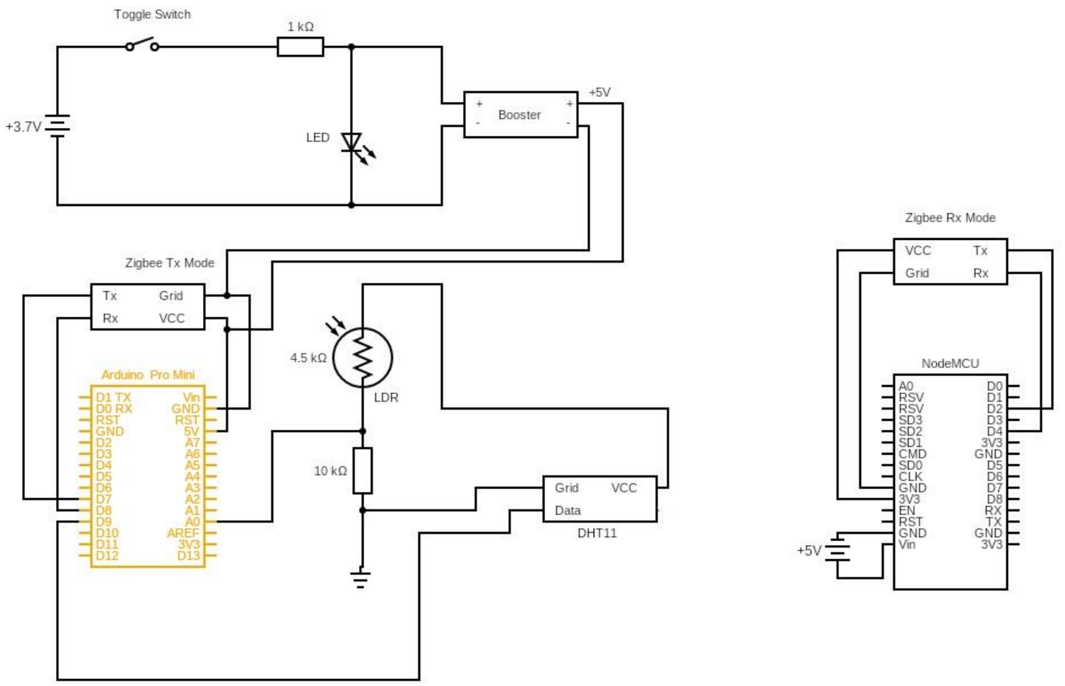

Figure 3.7: Control Circuit Diagram

3.3 System Software Requirements

Due to several variables such as technological breakthroughs and increased client needs, software systems have become increasingly complex and complicated in recent years. [16]. This project aims to retrieve data (in this case, parameters readings) transmitted from the sensor node to the coordinating/gateway node. This data displays on the Arduino IDE. The data obtained from the sensor nodes go through further analysis. They can be a vital tool in predicting specific crops' behaviours and knowing the best conditions under which that specific crop would thrive. The usefulness of this data can prove helpful in providing limitless advantages in agriculture, especially greenhouses.

3.3.1 Arduino Integrated Development Environment

The Arduino IDE is an open-source Arduino programming that made it simple to compose codes and transfer them on the board. It runs on various working frameworks, for example, windows, Mac, Linux. The IDE, written in the C/C++ programming language. It comprises a text editor for composing code, a message territory, a text console, a toolbar for regular functions, and a progression of menus. The projects written in the Arduino IDE are called sketches and are written in the text editor and saved with the file extension (.UNO). Arduino IDE sketches have two individual functions. The Void Setup () and the Void Loop () function.

- Void setup (): The void keyword is utilized uniquely in function declarations. It restores no data to the function from it was called. The setup function initializes variables, pin modes, starts using a library, and so on. The setup function runs only once, after each power-up

- Void loop (): This function is used for running entire programs, again and again, this helps with the consistent execution of specific programs simultaneously.

3.3.2 Flowchart

The flowchart shown in figure 3.8 represents a series of the flow of the system's control. It is in the form of a flowchart diagram [17]. In Fig 3.8, at the start of the process, the system initializes. Sensors read parameters using the sensor nodes. It then transmits said parameters to the coordinating/gateway node. It displays the values on the computer screen, and then the whole process starts all over again. It is a straightforward system, as seen from the activity diagram below in figure 3.8.

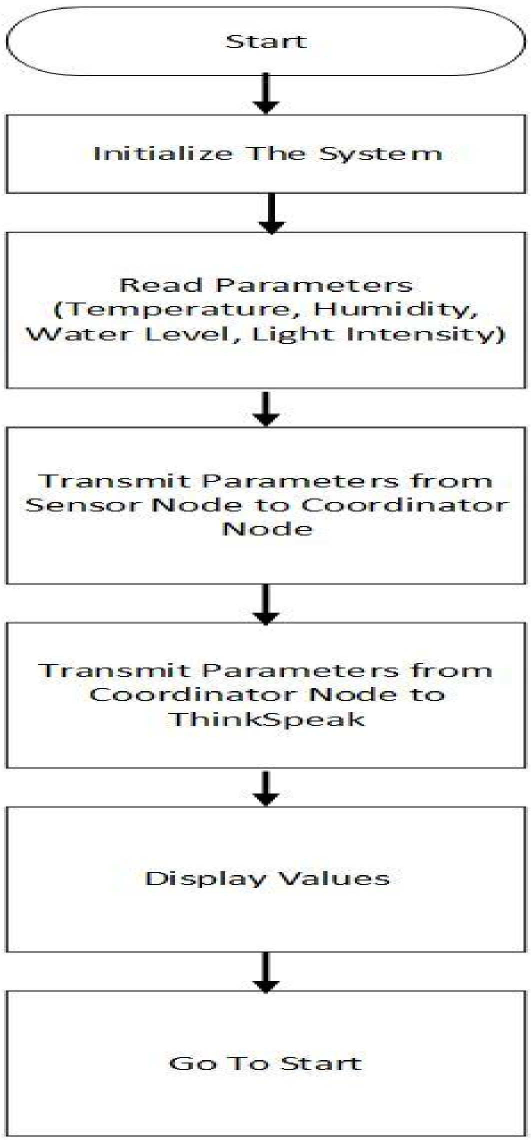

Figure 3.8: Flowchart

3.2.3 Sequence Diagram

The sequence diagram describes how the elements of the system communicate, that is, the exchange of messages between them [18]. The diagram reads from left to right and from top to bottom in the events' sequence. The actor (the user), represented by the figure on the top left corner of the diagram. The elements involved in the interaction side by side. From the diagram, we can see the actors' or objects' existence over some time; when each event represented by a line ends, another event begins. The figure below shows the communication between the farmer and the system elements; in this sequence, represented with a solid line, the elements performing the actions display in [18]. The dashed line, however, represents the necessary reactions [18].

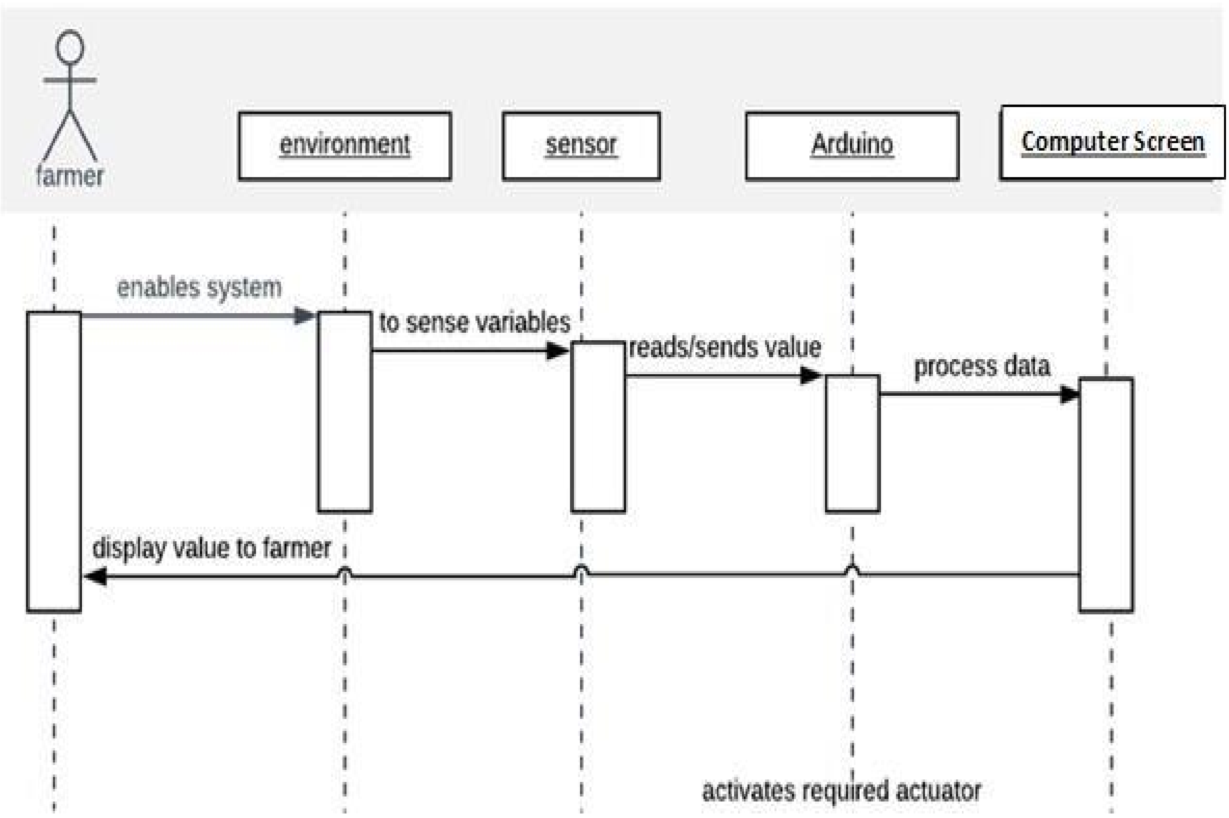

Figure 3.9: Sequence Diagram

3.4 System Interaction

The system interaction shown in figure 3.10 below displays the sensor data collected from the field is passed to the micro-controller through the Zigbee device to the Computer system. The data displays on the web page, which the user would log in to and monitor.

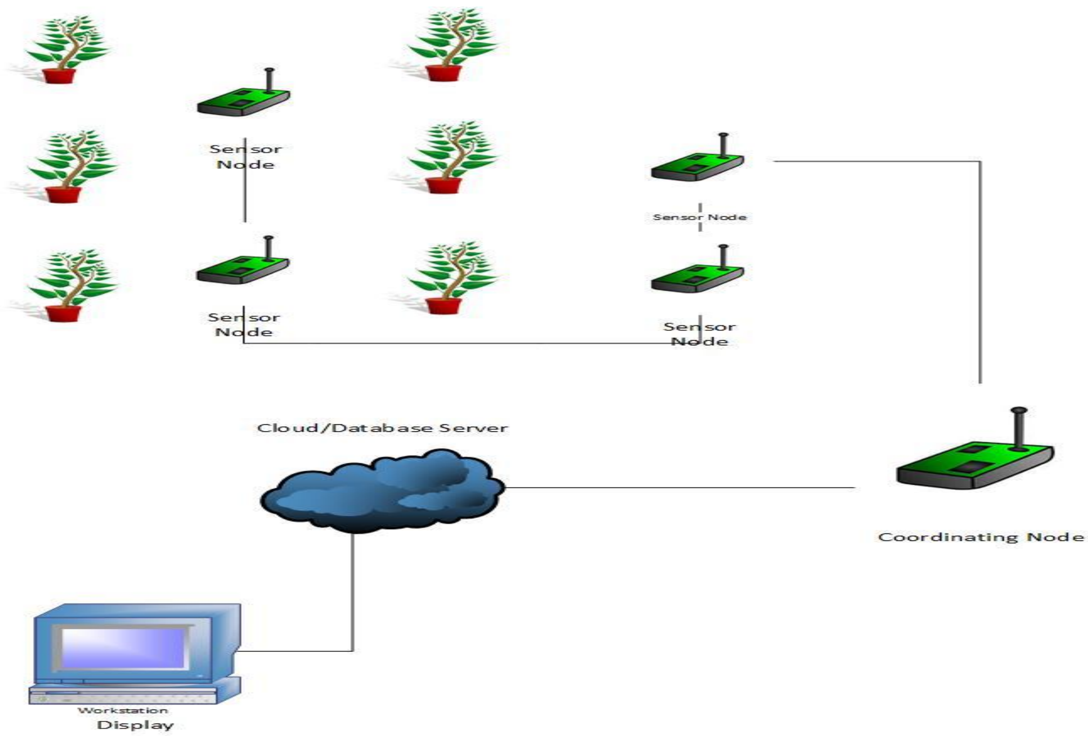

Figure 3.10: System Interaction Diagram of the Greenhouse Monitoring System.

3.5 Conclusion

The various components used to create this system, discussed in this chapter. Presented in this chapter were the principles used for both the hardware and software designs. Also, electronic components, the block diagram, and the control circuit diagram addressed the hardware. As for the software part of the project, activity diagrams, sequence diagrams, and the Arduino IDE dealt with the software in detail.

CHAPTER FOUR

SYSTEM IMPLEMENTATION AND TESTING

4.1 Introduction

This chapter outlines the work completed during the project's development. This chapter covers the implementation of the system's building blocks, as well as the overall performance and component testing. The results of the work done in various sectors of the project are presented in this chapter.

4.2 Implementation Details

The prototype in this project popularly dubbed as a “SensiNode” presents a small structure no larger than a socket. It features an all rounded body made of plastic. The structure is aimed at bolstering mobility and flexibility of location selection.

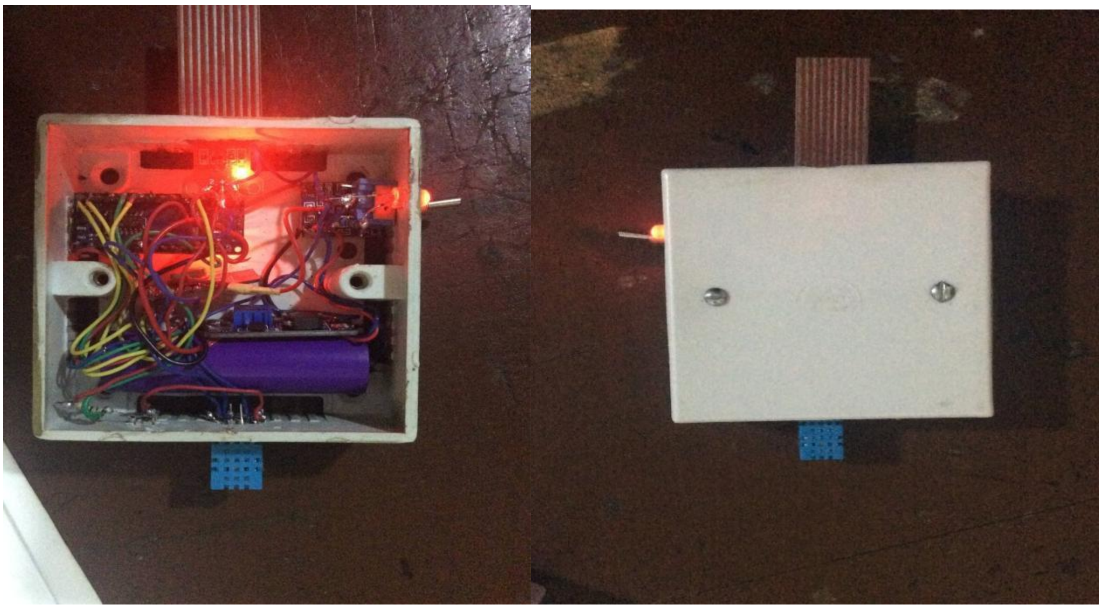

Figure 4.1: Layout of the sensor node

4.3 Testing

After Implementation, tests follow up to ensure the smooth operation of the system.

4.3.1 The Monitoring Unit

On safe booting of the system, an LED comes on to indicate power in the sensor node. In quick succession, the ESP8266 (Wireless Fidelity Module) attempts connection with a pre-selected access point for internet connectivity. For remote monitoring, the values are relayed to a database server via a selected web-based IOT platform. Hence, the web application is enables for monitoring of the system.

4.3.2 Temperature and Humidity Control

In automated intervals, the sensors get the concurrent quantities in the environment. Deviations off predefined thresholds are flagged by influencing actuators. Pertaining to temperature and humidity, the sensor involved here is the DHT11.

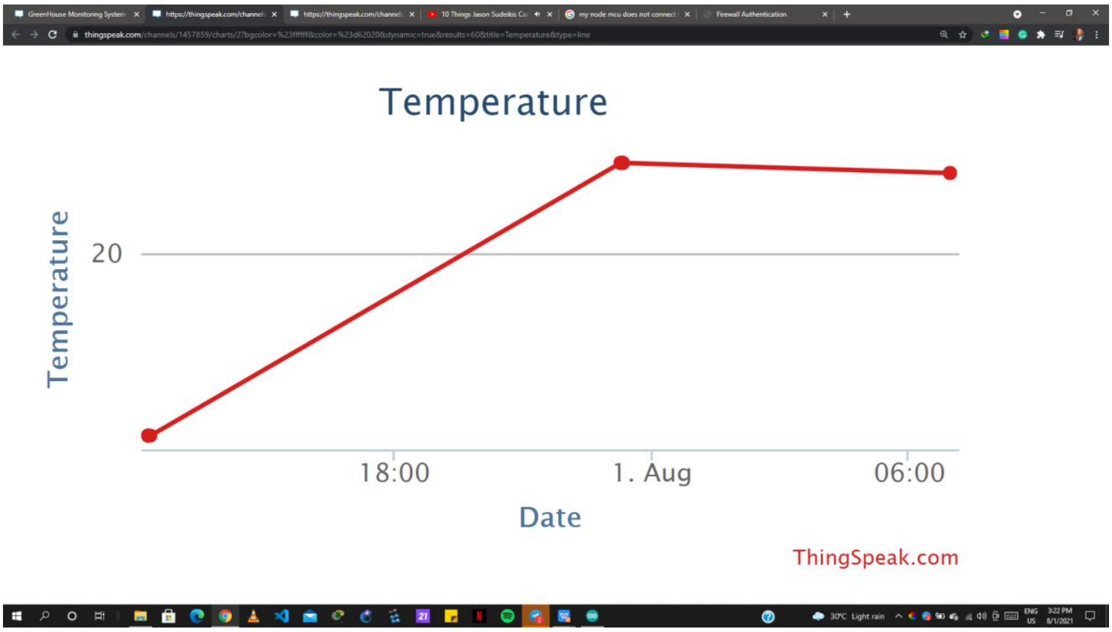

Figure 4.2: Temperature Readings From ThingSpeak

Figure 4.3: Humidity Readings From ThinkSpeak

4.3.3 Soil Moisture

Dry times come, and when they do, the water sensor detects the need for water in the soil. As a result, deviations off predefined thresholds pertaining to soil moisture are flagged by influencing actuators, the sensor in charge of this function is the water sensor.

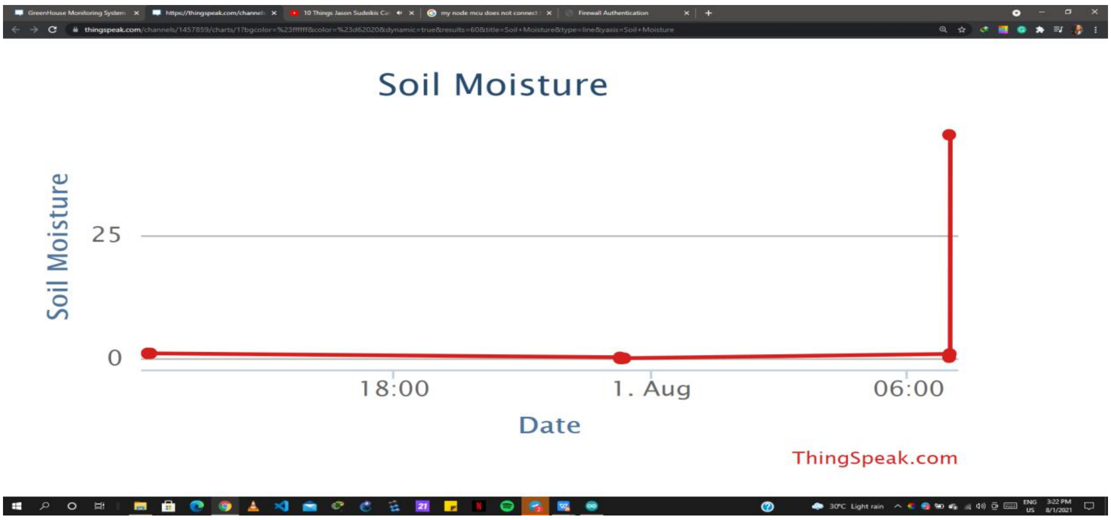

Figure 4.4:Soil Moisture Readings From ThinkSpeak

4.3.4 Light

Sunlight is vital for the survival of any plant, because it aids photosynthesis which is the primary way plant's feed. The LDR1 is responsible for monitoring thresholds of light intensity for crops/plant's. Data produced by this sensor displays on the web-based IOT platform.

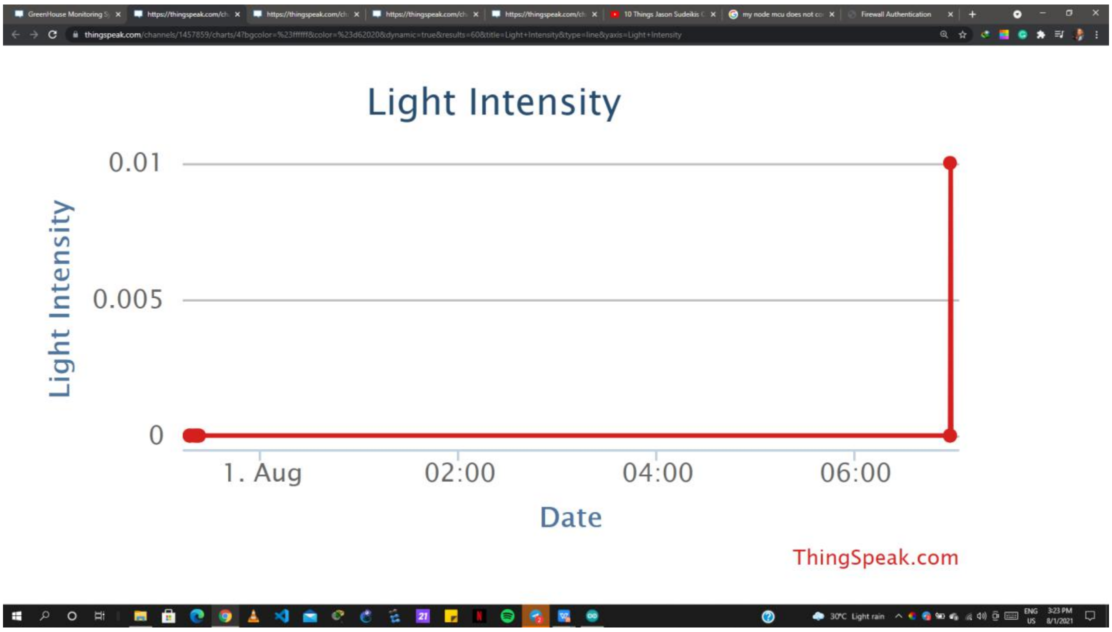

Figure 4.5:Light Intensity Readings From ThinkSpeak

4.4 Bill Of Engineering Measurement and Evaluation (BEME)

NO	ITEM	QUANTITY	PRICE PER UNIT	TOTAL PRICE
1	ARDUINO PRO MINI	1	2,700	2,700
2	NODE MCU ESP8266	1	3,750	3,750
3	ZIGBEE MODULE	2	20,000	40,000
4	DHT11	1	2,000	2,000

NO	ITEM	QUANTITY	PRICE PER UNIT	TOTAL PRICE
5	LIGHT DEPENDENT RESISTOR	1	100	100
6	WATER SENSOR	1	300	300
7	SWITCH	2	10	400
8	RESISTORS	2	10	20
9	5V POWER SUPPLY	2	3,000	6,000
10	LED	1	10	10
11	VOLTAGE BOOOSTER	2	200	400
12	WIRES	1	1,000	1,000
13	CASING	2	1,000	1,000
14	ADHESIVES	1	1,000	1,000
	TOTAL			58,680

4.5 Conclusion

The implementation and testing of the greenhouse monitoring system is described in detail in this chapter. This phase of the project had difficulties, such as programming the Arduino's and the ESP8266 Wi-Fi module. In summary successful completion of all tests for the system.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter highlights the achievements of the project and offers recommendations for further study.

5.2 Summary

Temperature, humidity, soil moisture, and light intensity are four critical characteristics for plant productivity that were proposed and demonstrated in the design of "A Wireless Sensor Network based Monitoring System." The metric data obtained revealed a high level of performance, dependability, and precision.

The primary objectives of this project to achieve the monitoring process were indeed implied efficiently on the subjected environment.

5.3 Recommendations

The following recommendations for possible future work concerning this technology;

i) A more significant number of quantities can be detected, such as soil pH and CO_2 level.

ii) We develop an automatic shed, fire detection, and surveillance systems.

iii) We are utilizing a solar system to minimize the usage of electricity.

iv) Global System for Mobile Communication (GSM) and Short Message Service (SMS).

5.4 Achievements Of The Project

The successful implementation of the following objectives during this project are as follows;

i) Successfully design a low-cost greenhouse quality monitoring system.

ii) Successfully implement the system design using software and hardware components

iii) Successfully test the greenhouse monitoring system.

iv) Successful deployment of the greenhouse quality monitoring system in any area of interest.

The system successfully overcomes the shortcoming of previously existing systems by a significant minimization of the power consumption. The system also serves as rapid access to data for monitoring observational studies and analysing best conditions for crops. In light of the continual decrease in hardware and software costs, a wider acceptance of electronic systems in agriculture will actualize a flexible agricultural industry. Several branches of agricultural production will benefit mainly from a computerized production scheme. Hence, improvements towards developing inexpensive and highly accurate sensors.

5.5 Conclusion

This chapter successfully highlights the achievements of the project and and provides further recommendations to further development of this project.

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