Design and Implementation of a Smart Wireless Access Point for a Gas Station (Swap-GS)

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Abstract

Wireless communications are well-suited for the gas distribution industry, especially given the often-remote locations of distribution facilities. When working with accumulated and real-time data, the underlying communications infrastructure must be a highly reliable, with a resilient system that interconnects sensors and controls across a large-scale field area network. The resulting detail helps managers improve operational efficiency, create and adjust business processes, and comprehensively manage the station site. A Wireless gas station provides a Wi-Fi standards-based architecture for applications that monitor and gathers data right down to the sensor level. The Objective of our project is to implement Wireless Infrastructure network at a Gas Station Plant, facilitate the real time information access, exchange and sharing of sensor readings from the access point among the users and develop a Smart Wireless Access Point System with higher security Encryption than the Generic Wireless Network when employed in a gas station. This system is able to perform such operations by using a temperature, pressure and humidity sensor as the inputs to the Node MCU microcontroller, which then broadcasts the real time data to the clients. The wireless infrastructure created, is seen as complementary to the LAN infrastructures already in place. Some main requirements are taken into consideration. First of all, compliance with the standard IEEE 802.11 is mandatory, software design, a sensing unit and a microcontroller.

Keywords: *Star Topology, Gateway, Bluetooth, Zigbee, Interfacing, Handshakes, Pixels, Flowchart and Algorithm*

Introduction

Organizations rely heavily on the ability to share information throughout its body in an efficient and productive manner. Computer networks have allowed for this to become easier and efficient. this technology is now a part of most businesses today. an organization has two options when it comes to setting up a network. They can use a completely wired network, which uses networking cable to connect computers, or they can use a wireless network, which uses radio frequencies to connect computer. Wireless networks have allowed organizations to become more mobile; therefore, organizations are now using a combination of both wired and wireless networks [1]. The basic hardware layout for the two types of networks **is** fairly similar but for an organization to go wireless it requires a few more hardware components. Although networks provide convenience**,** they do open the organization up to security and privacy risks. if a company is faced with security issues there are ways that they can be fixed to prevent future security risks. As you read on, you will learn how the network has become an essential part of today's organizations hence the need for this research design and implementation of a smart wireless access point for a gas station (Swap-GS).

Networking is referred as connecting computers electronically for the purpose of sharing information. Resources such as files, applications, printers and software are common information shared in a networking [2]. The advantage of networking can be seen clearly in terms of security, efficiency, manageability and cost effectiveness as it allows collaboration between users in a wide range. Basically, a network consists of hardware components such as computer, hubs, switches, routers and other devices which form the network infrastructure. These are the devices that play an important role in data transfer from one place to another using different technology such as radio waves and wires [3]. There are many types of networks available in the networking industries and the most common network is local area network (lan) and wide area network (wan). lan network is made up of two or more computers connected together in a short distance usually at home, office building soar school. WAN is a network that covers wide rare than lan and usually covers cities; countries sand the whole world [4]. several major lan can be **connected** together to form a WAN. As several devices are connected to network, it is important to ensure data collision does not happened when these devices attempt to use data channel simultaneously. A set of rules called carrier sense multiple access / collision detection are used to detect and prevent collision in networks [3].

Materials

In the design and implementation of this project various materials and tools were used to achieve the stated objectives they include the hardware materials, hardware tools and software tools.

Hardware Materials

I. WI-FI Module. Ii. Atmospheric Pressure Sensor, Temperature and Humidity Sensors. Iii. Organic Light Emitting Diode (Oled). Iv. Voltage Regulator. V. Switch. Vi. Resistor. Vii. Led. Viii. Pat Tress Box, Ix. Battery. X. Battery Cap. Xi. Jumper Wire. Xii. Diode. Xiii. Micro Controller. Xiv. Vero Board. Xv. Wax.Xvi. Soldering Lead. Xvii. Bolt And Nut. Xviii. Gas Tank.

Software and Hardware Tools Used

I. Easy EDA. Ii. Arduino Id Iii. Soldering Iron. Iv. Digital Multi Meter. V. Lead Sucker. Vi. Solderinggun. Vii. Drilling Machine. Viii. Saw. Ix. Screw Driver. X. Cutter. Xi. Spray Paint. Xii. Ruler.

Methodology

In the design of this project a top-down approach was employed. this is because the **top-down** approach to system design offers the advantage of looking at the proposed system to be designed wholesomely before proceeding to break it down into smaller manageable tasks, and this suits the project design objective. In this approach an overview of the system is formulated, specifying, but not detail in gany first level sub systems. each sub system was then refined in yet greater detail.

Upon Getting the Materials Required for The Design Of The Project, A Suitable Block Diagram Was Formulated As Shown Figure 3.1, Which Serves As A Guide To Design The System, Hence Providing A High Level Over View Of Them A Jor System Component, Key Process Participants, And Important Working Relationship Soften Tirade Sign As Shown In Figure 3.2 And Figure 3.3 Below.

SYSTEM BLOCK DIAGRAM

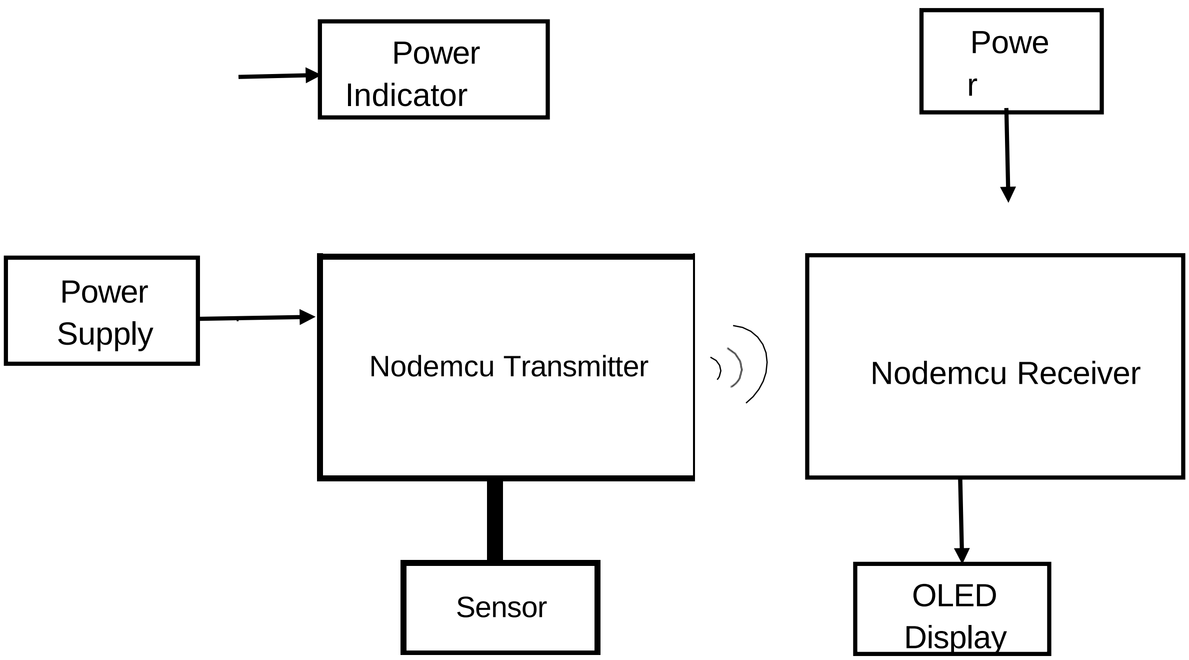


FIG3.11: SYSTEM BLOCK DIAGRAM

SIGNAL FLOW

From the block diagram infigure3. 1 the sensor (temperature, humidity and pressure sensor) takes temperature, pressure and humidity analog signals from the immediate environment. This signals which are analog in nature are sampled, conditioned and converted to digital signals by the analog-to-digital converter inherent in the sensor. The output of the sensors fed to the microcontroller. using the software algorithm developed, the signals are further processed by them micro controller and the output of them micro controller is amplified and propagated through that transmitter antenna, on the receiver side the propagated signal is received by the antenna. The received packets serve as an input and contains the variables under consideration, a connection is established between the server (transmitter) and the receiver (client) thereafter the quantities under consideration are displayed on the organic light emitting diode (oled) display.

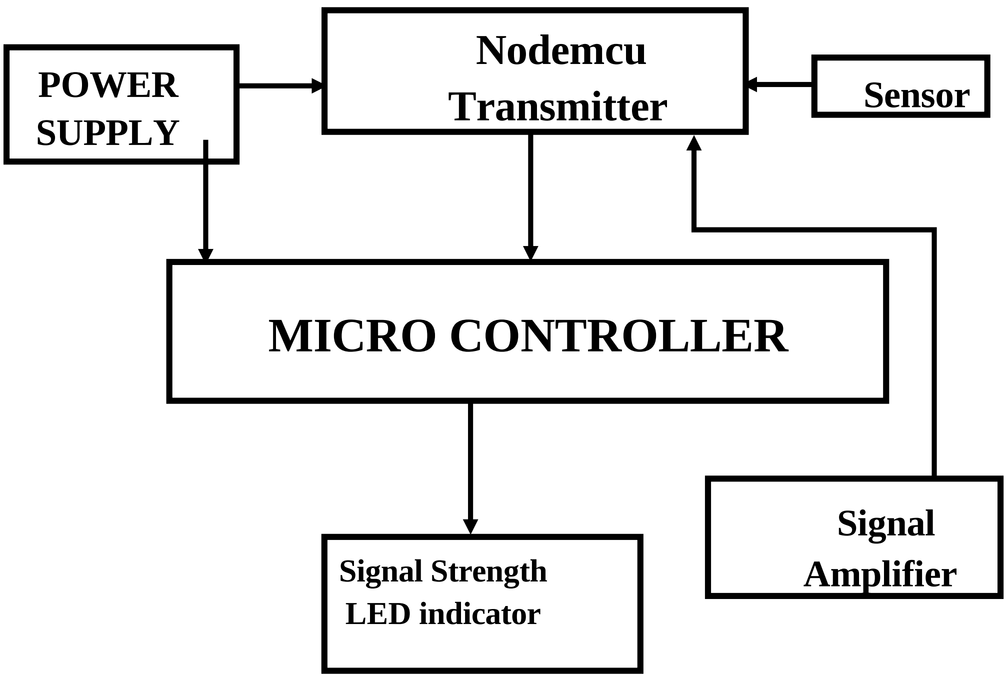


Fig3.12: System Block Diagram of Transmitter

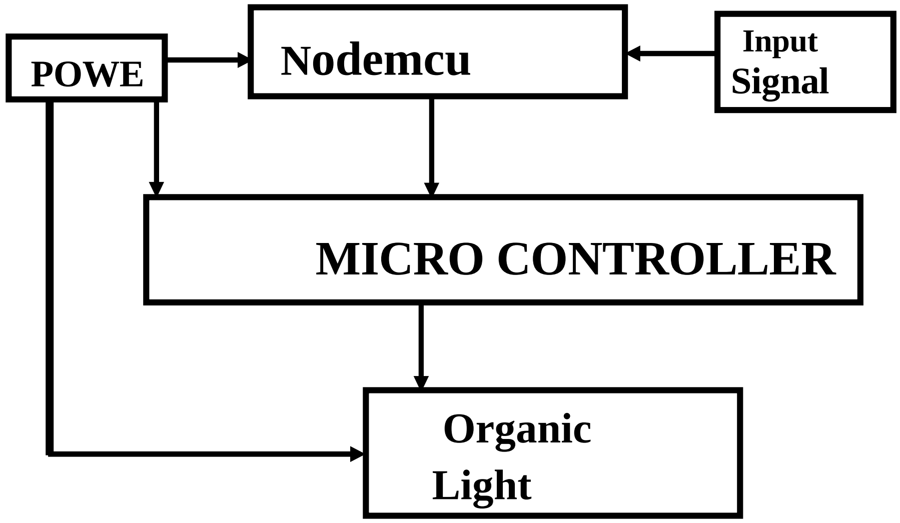


Fig3.13: System block diagram of a receive

DESIGN SPECIFICATION

At this stage of the project development the materials used were properly discussed quantitatively and qualitatively. the company specific name of each component was given and its functions described.

Table 3.1: A **Table Showing the Specific Description of the Materials Used**

S/N	Material	Number	Description
1	Nodemcu Wi-Fi module	3	The heart of access point subunit which helps to create handshakes between the transmitter and Receiver.
2	ESP8266 Controller	3	Embedded controller on the ESP 8266 board for easy interface with Arduino Integrated Development Environment (IDE).
3	BME280 (temperature, humidity and Pressure sensor)	1	This unit combines an individual high linearity and high accuracy sensors for pressure, humidity and temperature in an 8pin metal 2.5x2.5x0.93 mm^3 LGA package: the BME280 sensor is used to dictate the temperature, pressure and humidity readings from the immediate environment.
4	LM7805CV Voltage Regulator	3	This is a fixed voltage regulator that regulates the input voltage of the access point system.
5	1N4007diode	3	A rectifier diode connected to the input of the 7805 voltage regulator to prevent reverse biased current from flowing back to the switch.
6	Organic Light Emitting Diode (OLED)	2	128x64 pixel OLED was Used as a display on the receiver to display T.H.P reading.
7	1KΩResistor	1	This was used to reduce the amount of current flow to the LED.
8	9vBattery	3	This serves as the power supply to the system.
9	Battery cap	3	Thisservesastheconnectorofthe9v batteries to the circuit.

10	Pattress Box	3	2 pattress boxes were used for the receiver, with dimensions 80mmx80mm x 30mm and a single pattress box for the transmitter, with dimensions 80mm x 140mm x 30mm. this was used to house the other circuit components.
11	Light Emitting Diode(LED)	1	A blue LED Serving as a power indicator
12	Jumper Wire	X	This was used to link the components where they needed joining.
13	Vero Board	3	This is where the components were placed before soldering.
14	Bolt and Nut	7	Using to fasten the sensor and the circuit on the pattress box.
15	Control Switch	3	This is for turning the system on and off.
16	Wax	X	This is an adhesive used to hold the different components together.
17	Soldering Lead	X	This was used to hold two or more conductors together for continuity purpose.

System Circuit Diagram

The system circuit diagram consists of two sections which include the Transmitter and Receiver. The temperature and humidity sensors are connected to the Transmitter end. Figure 3.4 shows the circuit diagram of Transmitter network. The data from the transmitter is sent to the receiver in form of packets with a defined password which restricts other receivers within the range of transmission from automation connection or authorized access.

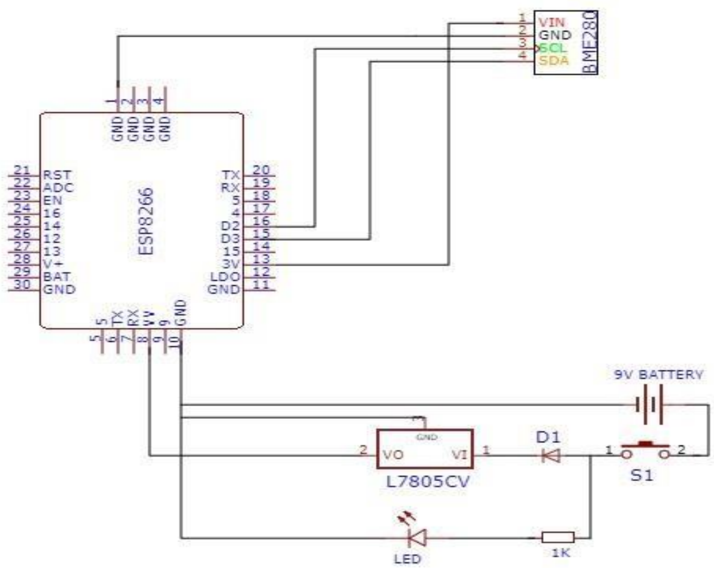


FIG3.14: CIRCUIT DIAGRAM OF A TRANSMITTER

Figure 3.5 below shows the circuit diagram of ESP Receiver network. When the transmitter sends packets, the receiver checks for matching of access credentials before handshake.

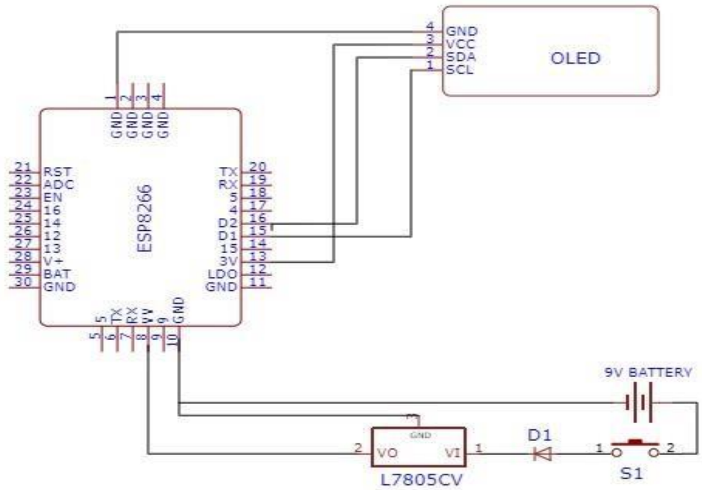


FIG3.15: CIRCUIT DIAGRAM OF RECEIVER

Detailed Design

A. POWER SUPPLY UNIT

The operation of most electronic device requires a D. C power supply to operate. This could be in the form of AC voltage which is converted to a regulated D C voltage or a DC supply from a battery source as employed in the design of this project. A 9v battery was used as the source voltage, since the design is a lower power and a low voltage system that requires 5 volts, a voltage regulator (l7805cv) was used to ensure that only the required voltage level is supplied to the system by generating a fixed output voltage of 5v that remains constant regardless of changes in input voltage.

B. SENSING UNIT

THIS UNIT IS ANOTHER INPUT TO THE SYSTEM, A BME280 SENSOR WHICH COMBINES DIGITAL HUMIDITY, PRESSURE AND TEMPERATURE SENSING WAS USED. THE HUMIDITY SENSOR PROVIDES EXTREMELY FASTER RESPONSE TIME FOR FAST CONTEXT AWARENESS APPLICATIONS AND HIGH OVERALL ACCURACY OVER A WIDE TEMPERATURE RANGE. THE PRESSURE SENSOR IS AN ABSOLUTE BAROMETRIC PRESSURE SENSOR WITH EXTREMELY HIGH ACCURACY AND RESOLUTION AND DRASTICALLY LOW NOISE. THE INTEGRATED TEMPERATURE SENSOR HAS BEEN OPTIMIZED FOR LOWEST NOISE AND HIGHEST RESOLUTION.

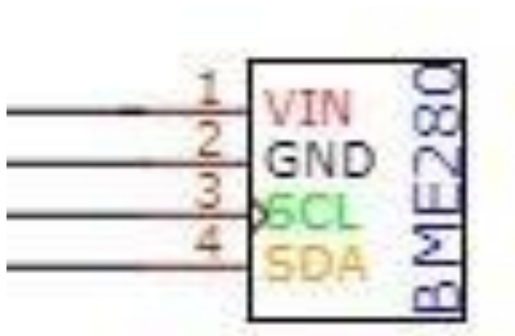


Fig3.16: Sensor

Power is supplied to the sensor through the V_{DD} pin this serves as the main power supply for all internal analog and digital functions. The separate pressure, humidity and temperature sensing elements present in the sensor take the reading of the surrounding environment this readings are sampled and held to convert them to its equivalent digital form after which the sensor logic circuit separately processes the different readings before passing it the12 C serial communication inter face which in form of a two wire half- duplex communication containing the SDA pin which is used to transfer the digital output data to the ESP8266 through the D2 pin and the SCK pin (serial clock) that synchronizes data transmission by the master ,it is connected to the D1 pin of the ESP8266.

C. THE ESP8266

The ESP8266 Wi-Fi Module is a self-contained So C with integrated TCP/IP protocol stack that can give any micro controller access to your Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor.

Each ESP8266 module comes pre-programmed with an AT command set firm ware, meaning, you can simply hook this up to your Arduino device and get about as much Wi-Fi-ability as a Wi-Fi Shield offers. The ESP8266 module is an extremely cost effective board with a huge, and ever growing, community. This module has a powerful enough on-board processing and storage capability that allows it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. Its high degree of on-chip integration allows for minimal external circuitry, including the front-end module, is designed to occupy minimal PCB area. The ESP8266 supports APSD for VoIP applications and Bluetooth co-existence interfaces; it contains a self calibrated RF allowing it to work under all operating conditions, and requires no external RF parts [26].

FIG3.17: LAYOUT OF GENERATION ESP8266 MICRO PROCESSOR

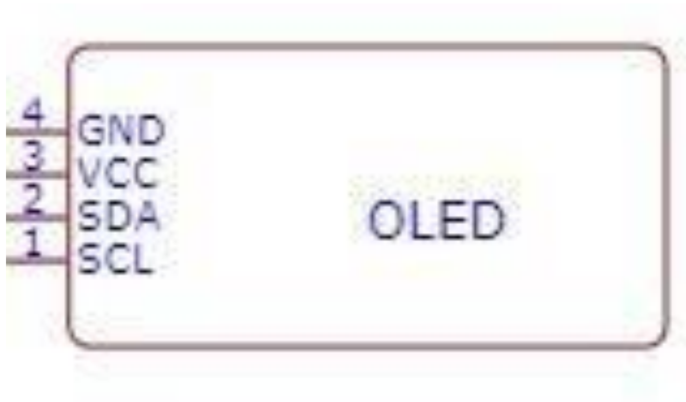
D. **Display Unit**

The OLED (Organic Light Emitting Diode) in this project is used for displaying the current temperature, humidity and atmospheric pressure reading received by the client. OLED (Organic Light Emitting Diode) screen is an electronic display module and find a wide range of applications. A 128x64 pixel OLED (Organic Light Emitting Diode) very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs. The reasons being:
i. OLEDs are economical ii. Ease of programming for characters and graphics.

The I2COLED uses only two-wire communication protocol, which his SDA & SCK for serial communication.

The Arduino Sketch running over the device implements the various functionalities of the project. These functions are reading sensor data, converting them into strings, passing them to I2C communication, and displaying measured temperature, humidity, and atmospheric pressure in I2C OLED Display. The package includes display board, display 4 pin male header pre-soldered to board, where the V_{DD} pin is connected to the 3V pin on the ESP8266 which supplies a voltage of 3.3V, the D1 and D2 pins are the communication pin soft the ESP8266 which handle the clocking of the data being transmitted and the transmission of data to be displayed respectively through their counterparts SCK and SDA on the OLED display therefore displaying the required output for each cycle of reading taken.

FIG3.18: OLED



Software Design

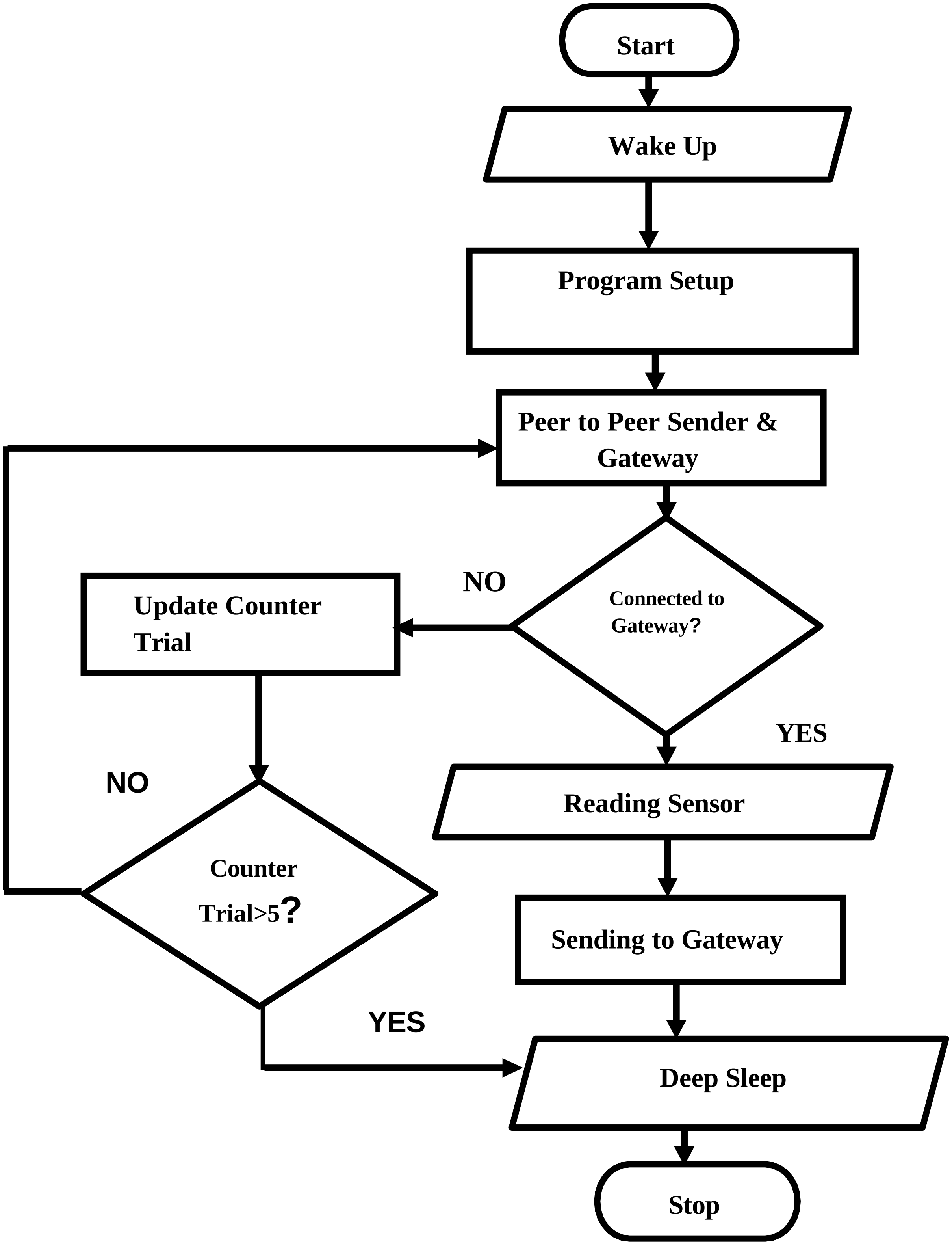
In this stage of the design the programming language code used to program the ESP8266Node MCU generated. This is important because the code determines if the micro controller performs the function of either the server or client. We achieve this by first developing an algorithm and flow chart. The system algorithm shows the step by step process of operation in accordance to the specific objectives in chapter one.

A. System Algorithm

The following are the system algorithm; i. Initialization of the Controller ports, ii. Sensors intimate with the environmental conditions. iii. OLED Screen displays, iv. Wi-Fi module wakes up from the Sleep mode. v. Sensors ready to send data packet from the transmitter to the receiver wireless. vi. Wi-Fi module transmitter ready to send to the receiver. vii. Wi-Fi module Receiver 1 and Receiver 2 ready to receive data from the transmitter concurrently. Viii. Controller gets ready to get data from the transmitter and displays on the OLED screen using I2C data packet transmission protocol. ix. Receiver Controller finally receives data from the Transmitter Controller and displays on the OLED Screen. x. Transmitter module update sits sensor data packet and sends to the receiver and the processes repeat.

B. System Flowchart

The System Algorithm has been carefully represented in a form of flowcharts in figures 3.9 and 3.10.


Start
Wake Up
Program Setup
Peer to Peer Sender & Gateway
Connected to Gateway?
NO
Update Counter Trial
YES
Reading Sensor
NO
Counter Trial>5?
Sending to Gateway
YES
Deep Sleep
Stop

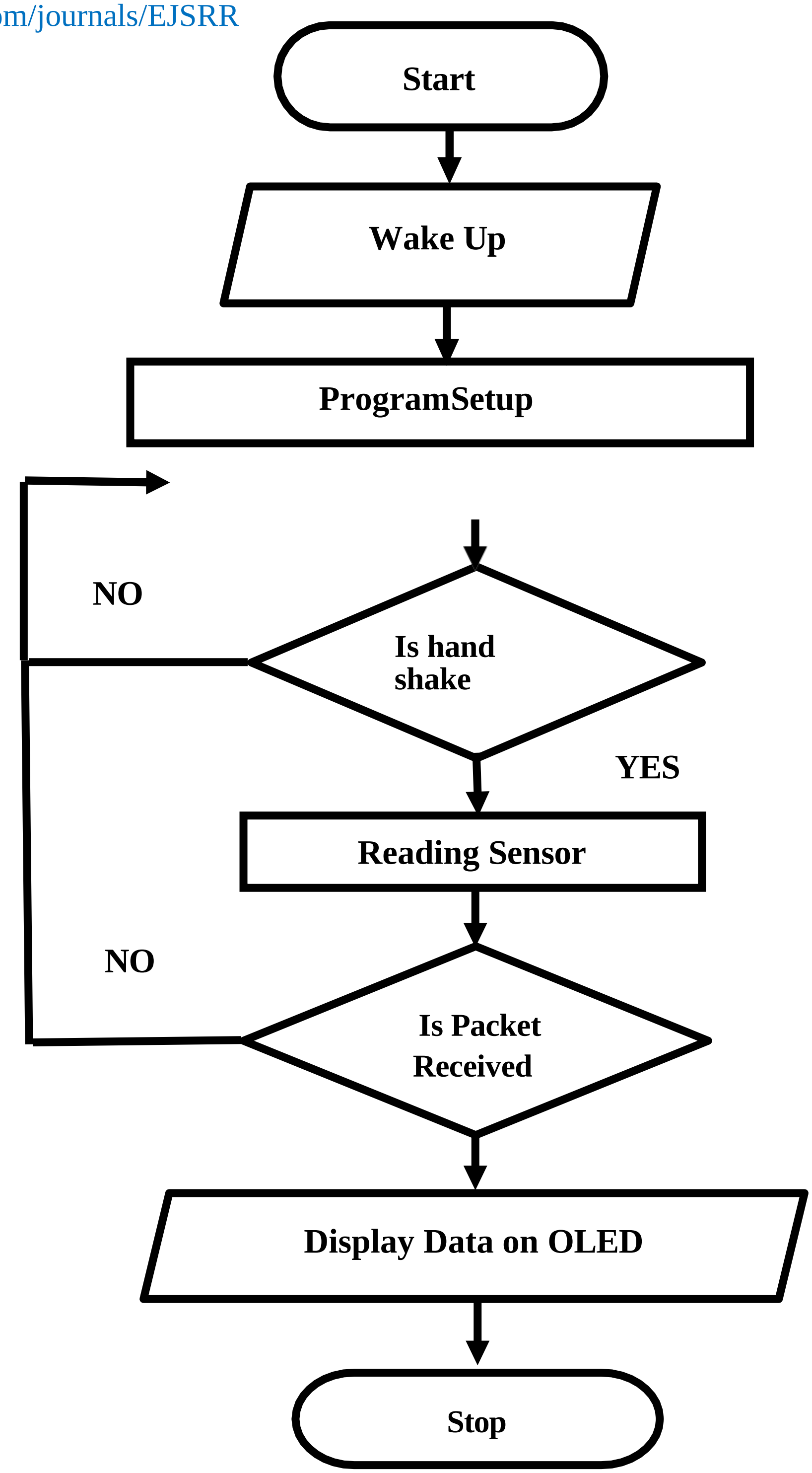


FIG3.19: FLOW CHART OF A WIRELESS ACCESS POINT SERVER FIG3.20: FLOW CHART OF WIRELESS ACCESS POINT CLIENT

IMPLEMENTATION AND SYSTEM INTEGRATION

The system integration was carefully done, starting with uploading the hex file (software) generated from the Arduino IDE to the microcontroller. The software was also tested and debugged to eliminate all errors and ensure optimal functionality before uploading it to the Node MCU. The design was packaged using plastic pattress box, and an integration test was done to ensure accurate performance. Fig. 3.11 below shows the gradual steps taken to produce the complete project.

FIG.3.41: A FIGURE SHOWING A STEP BY STEP INTEGRATION OF THE PROJECT

A. SYSTEM TESTING

Testing is the processing of checking if the designed project meets the objective for which it was designed. In the design of the smart wireless access point for a gas station the following test were conducted.

i. Unit test

ii. Integration test

iii. Beta test

UNIT TEST

This involves the test carried out on the individual units that make up the entire system for proper functionality. These units include the power pack, the sensors, the microcontroller, the Wi-Fi module and the web server interface.

TESTING THE POWER SUPPLY UNIT

We started with testing the power pack because it was the heart of the whole project. Test was carried out to ensure that the required voltage output of 0-5V and also to ensure that the voltage outputs where stable and constant. We used a multi-meter to test the out of the L7805cv voltage regulator and we observed that the voltage was about 4.41v. The meter probes where kept on for about 60secs to monitor the output to ensure it was constant.

Figure3.12 below shows the multi-meter reading during the test.

FIG.3.15: SHOWS THE MULTI-METER READING DURING THE TEST. TESTING THE SENSORS

The BME280 sensor was tested to ensure that in was in a functional state and also the monitored parameters where been correctly measured and that their ranges where in accordance to the range required in doing this we compared the sensor reading with ACCU weather android application. The sensor was powered from the 5v output power given by the Node MCU.

B. Integration test

After testing each unit that make up the design, the system was assembled and a test was conducted to ensure that the design performed as intended the figure below shows the server and the client performing as designed in a close proximity.

BETA TEST

To study the performance characteristics of the of the Smart Wireless Access Point, the system was taken to the gas plant to monitor the temperature, pressure and the humidity of the environment. The test was done in two different conditions. The first test was done inside the environment housing the gas tank and the other test was done outside the gas plant, respectively. To create a different temperature, pressure and humidity, the access point was kept inside the plant and the client or receivers were place in different location and the readings were taken remotely. Fig. 3.13 below shows the test carried out in the gas station.

Fig.3.16: Test carried out at the gas station

COST ANALYSIS

This section presents the cost of implementing the smart wireless access point. Since the objective is to design a low cost, low power and efficient access point that can serve as a sensing unit and as well as perform its primary function, For this reason, some design consideration and adjustment were made and the best and efficient components where assembled.

The total cost for the actualization of this project is shown in the table below:

S/N	DESCRIPTION	QUANTITY	UNITPRICE (NAIRA)	AMOUNT (NAIRA)
1	BME280 Sensor	1	3000	3000
2	ESP8266	3	7000	21000
3	L7805CV regulator	1	700	700
4	OLED	2	2300	2300
5	Resistors	3	10	30
6	Diodes	3	20	60
7	Verro board	3	100	300
8	Male and female headers	2rows	150	300
9	Jumper wires	5yards	100	500
10	Male and female headers	2rows	150	300
11	Battery cap	3	50	150
12	9v battery	3	150	450
13	Pattress box	3	600	1800
14	Pattress box cover	3	150	450
15	LED	1	20	20
16	Soldering lead	1	350	250
17	wax	3	100	300
18	Bolt and nuts	7	50	350
19	Control switch	3	100	300
20	spray	1	1500	1500
21	USB cord	3	300	900

22	logistic	x	10000	10000
23	Miscellaneous		20000	20000
24	Total			₦64,010

Table3.2: A table showing the cost analysis of the project wor

RESULT AND DISCUSSION

RESULTS

After the design and implementation of this work documented in chapter three, the smart wireless access point for Gas station control system worked successfully as proposed. The system comprised of a server and two clients communicating wirelessly with help of the Wi-Fi network for file and data sharing.

CASE1: WHEN THE CLIENT IS ON BUT THE SERVER IS OFF.

In this mode the client is put ON and is searching for the Wi-Fi hotspot of the server but it does not connect. The client display is blank while it continually searches for the connection.

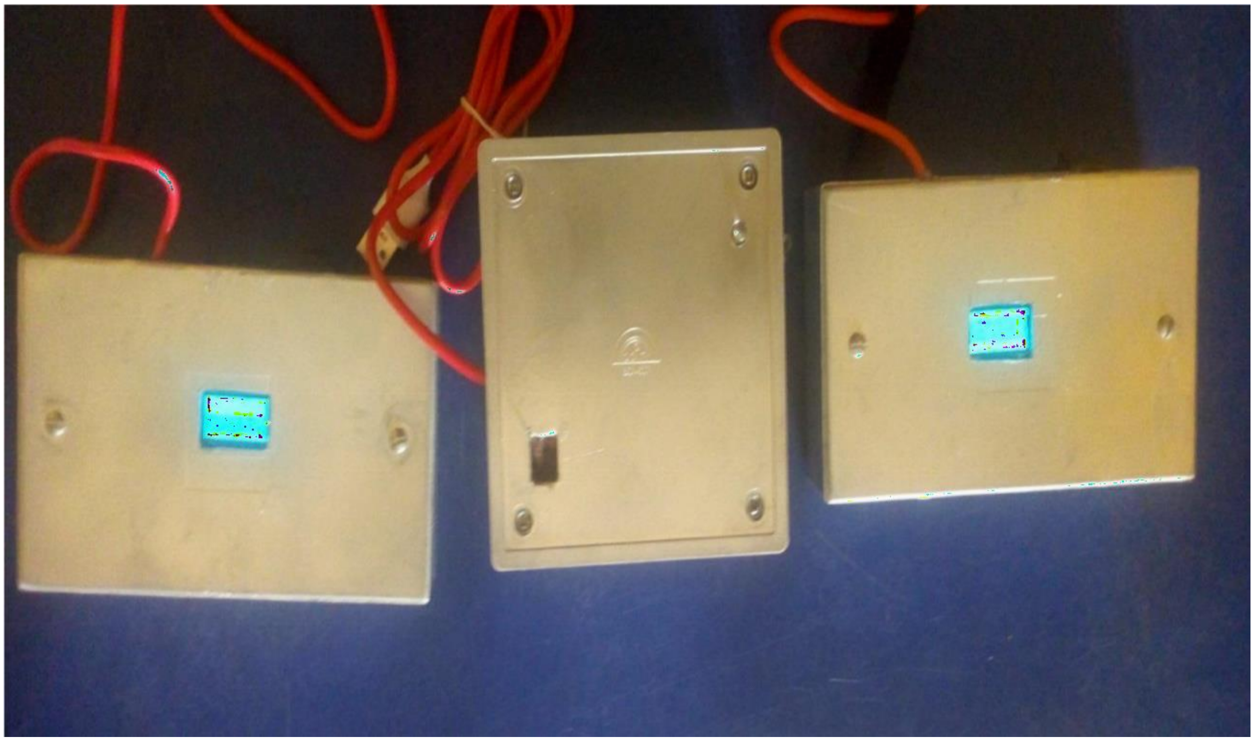


FIG4.5: SHOWING WHEN THE RECEIVER (CLIENT) IS OFF AND DISPLAYING A BLANK SCREEN

CASE2: WHEN BOTH THE CLIENT AND SERVER ARE ON.

IN THIS MODE THE CLIENT DISPLAYS THE TEMPERATURE, HUMIDITY AND TEMPERATURE READINGS SIMULTANEOUSLY ON THE OLED DISPLAY AFTER CONNECTING TO THE SERVER HOTSPOT. THE SERVER CONTINUALLY SENDS UPDATED DATA OF THE READINGS TAKEN BY SENSOR AND AS THE CLIENT GETS THE DATA IT IMMEDIATELY UPDATES THE DISPLAY.

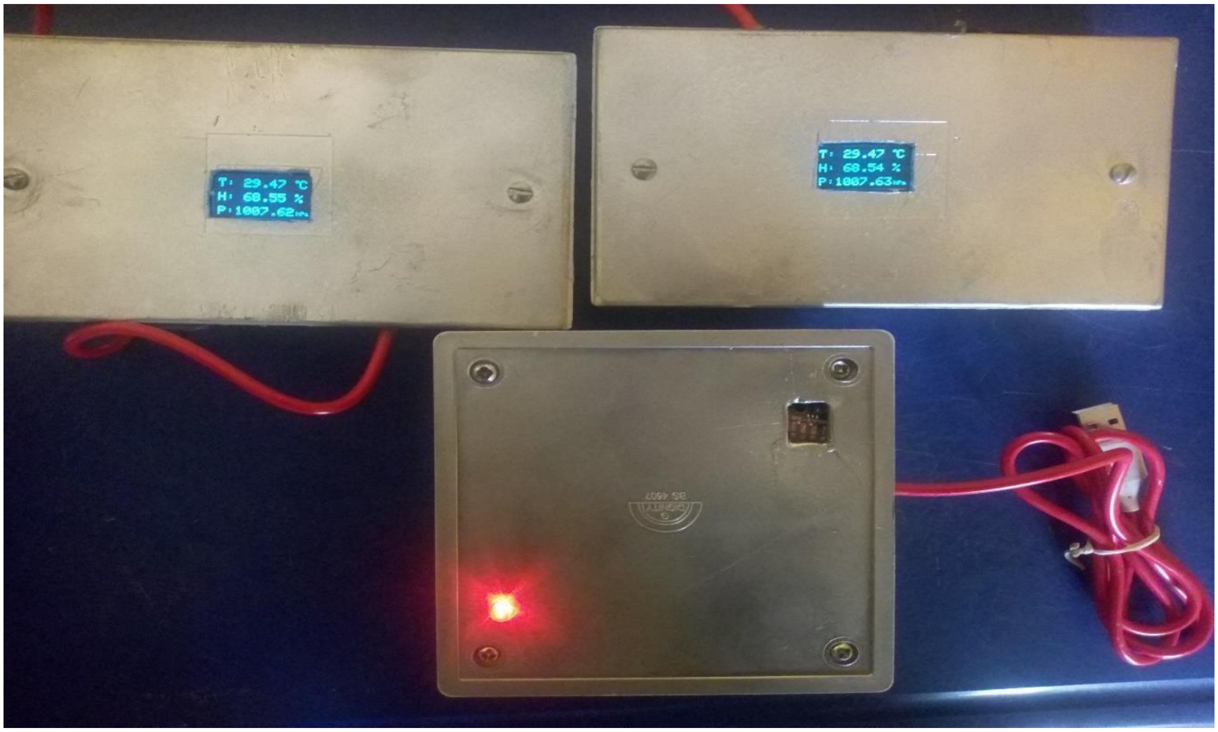


FIG4.6: SHOWING WHEN THE RECEIVER (CLIENT) IS ON AND DISPLAYING THE SENSOR READINGS ON THE OLED SCREEN

CASE3: When the both the server and client are ON but are not within range
In this mode the access point is ON and continually sending temperature, atmospheric pressure and humidity readings taken by the sensor connected to it but the client cannot receive the signal because it is out of range.

FIG4.7: THE SERVER IS ON BUT THE CLIENTS ARE NOT WITHIN ITS NETWORK COVERAGE.

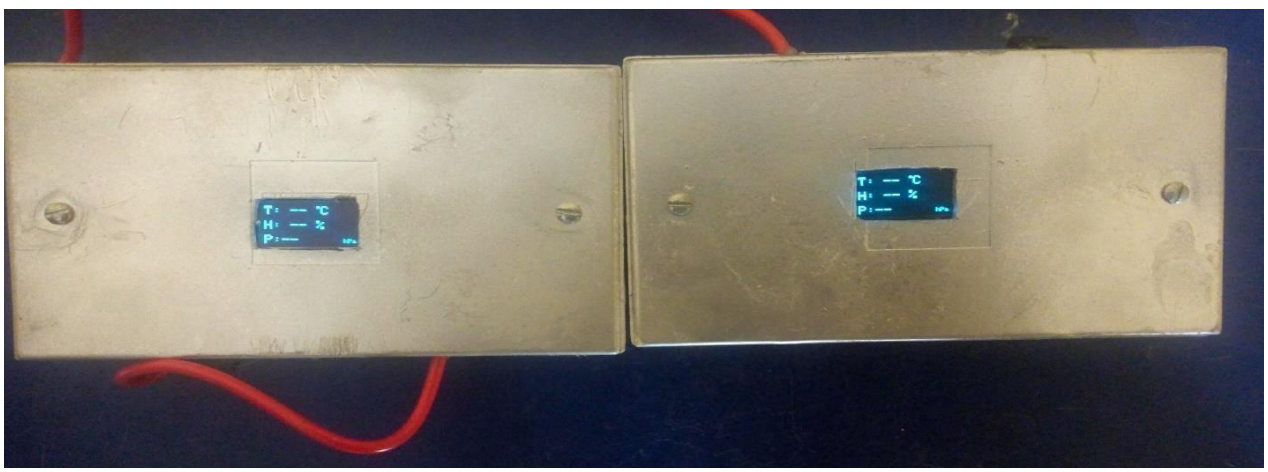


Fig 4.8: Showing when both the server and receiver are on, but the reading are not displaying on the screen because they are not with the coverage area of the server.

CASE4: INTERFACING THE ACCESS POINT WITH MOBILE PHONE

IN THIS MODE THE SERVER IS ON THE MOBILE PHONE ACTS AS THE CLIENT OR THE RECEIVER. THE FOLLOWING STEPS ARE EMPLOYED TO DISPLAY THE SENSOR READINGS ON THE PHONE.

i. Put ON the Wi-Fi of the mobile phone.

ii. Connect to the hotspot of the access point.

iii. Open the web browser.

iv. Input the IP address: 192.168.4.1

v. 192.168.4.1/temperature to display temperature.

vi. 192.168.4.1/pressure to display pressure reading.

vii. 192.168.4.1/humidity to display humidity reading.

The figure below shows screenshots of the temperature, pressure and humidity readings taken with the mobile phone.

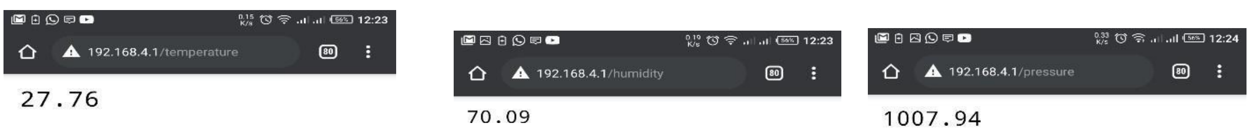


FIG4.5: THE WEBPAGE LAYOUT OF THE SENSOR READINGS

After determining that the system worked as intended, the Smart Wireless Access point was tested at a gas station, in this case Elan Gas station Eziobodo. Two tests were carried out, one inside the Gas station which had a roof covering the Gas tank, while the other test was performed outside the Gas station. A table showing the result of the test conducted is shown in table 4.1 below.

Table4.1: At able showing the test carried out at Elan Gas plant on the 5th of August 2021

Time	Readings Inside The Gas Plant			Readings Outside The Gas Plant		
	Temperature ^{O}C	Pressure (hPa)	Humidity	Temperature ^{O}C	Pressure	Humidity
9pm	25.47	1009.24	68.19	26..03	1009.28	68.59
12pm	28.62	1009.36	63.22	29.74	1009.34	68.47
3pm	29.34	1009.03	64.94	30.22	1009.10	65.05
6pm	26.42	1009.34	67.25	27.32	1009.40	67.83

Table4.2: At able showing the test carried out at Elan Gas plant on the 5th of August 2021 after converting the pressure from hPa to psi

Time	Reading Inside The Gas Plant			Reading Out The Gas Plant		
	Temperature ^{O}C	Pressure(psi)	Humidity	Temperature ^{O}C	Pressure	Humidity
9pm	25.47	14.6378	68.19	26..03	14.6384	68.59
12pm	28.62	14.6395	63.22	29.74	14.6392	68.47
3pm	29.34	14.6347	64.94	30.22	14.6358	65.05
6pm	26.42	14.6392	67.25	27.32	14.6301	67.83

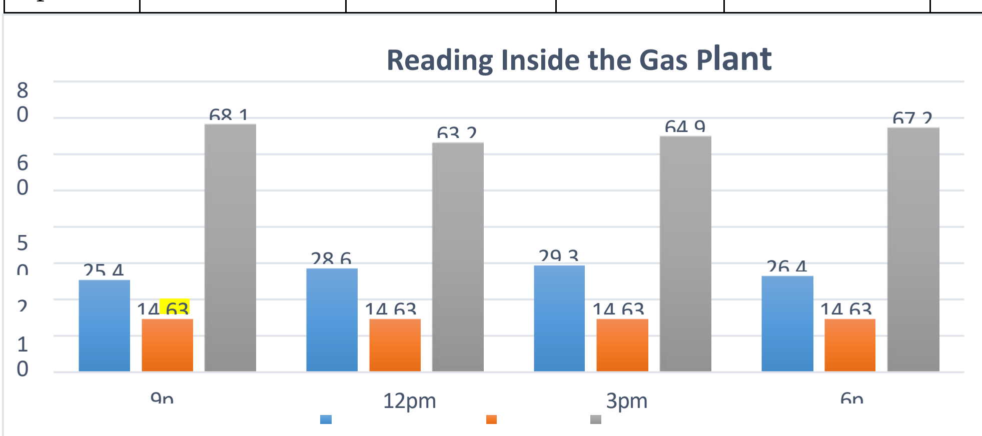


Fig.4.6: A Graph showing the test carried out at Elan Gas plant on the 5th of August 2021 inside the gas plant

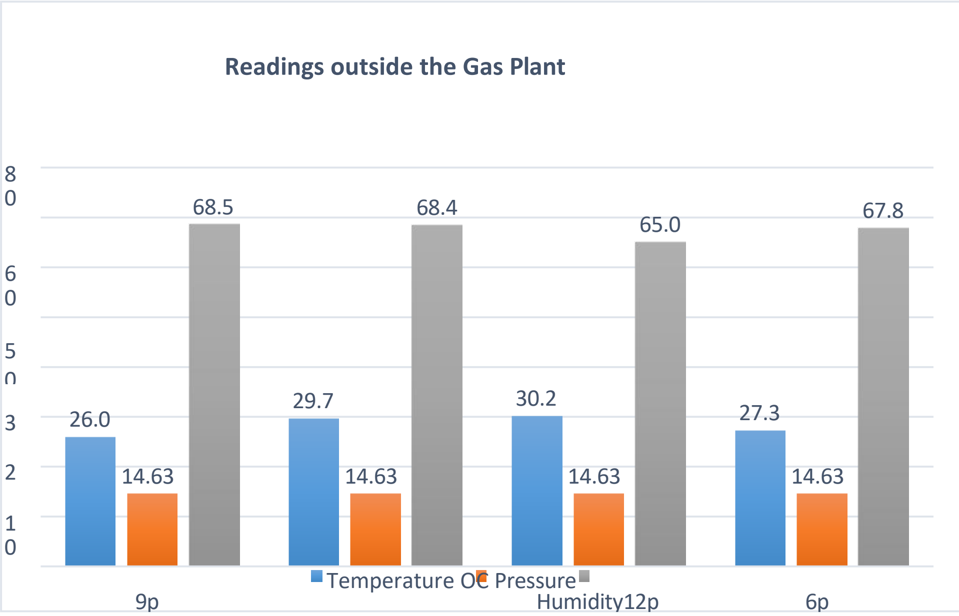


Fig.4.7: A Graph showing the test carried out at Elan Gas plant on the 5thof August 2021 outside the gas plant

DISCUSSIONS

The access point which serves as the transmitter successfully transferred data wirelessly to the clients. this was seen to be successful because the data collected by the sensor connected to the access point was able to be transmitted wirelessly without the use of internet to the client as the data was displayed on the oled display of the client. During the test carried out at elan gas station, it was seen that the temperature, pressure and humidity readings gotten inside the gas plant was slightly lower than the readings taken outside showing the sensitivity and accuracy of the bme280 sensor used.

Conclusion

The design and implementation of a Smart wireless access point for gas station been successfully developed and tested. The different hardware and software component and the methodology have been properly described. The system developed offers a vast and efficient approach of monitoring the environmental conditions such as the temperature, pressure and humidity of any gas plant, these it does automatically by simultaneously transmitting the data from the sensor through the access point to different clients concurrently and wirelessly without any form of internet. The equipment work sin any gas plant, both the access point and the various client also known as receivers can communicate provided that they are within the coverage area.

Recommendation

As stated in the significance of the design the Smart wireless point can be employed in a gas control and monitoring station where data from the environmental are to be kept confidential and the integrity of control variable are to be maintained as only they client with the appropriate network credentials can have access to the data transmitted by the server. This research is important because it plays the role of automatic monitoring system in remote areas that don’t have internet access and needs highly secured network connectivity.

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