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

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Abstract

The gas distribution sector is a good fit for wireless communications, especially considering how often distribution facilities are located in distant areas. The underlying communications infrastructure needs to be extremely dependable, with a resilient system that links sensors and controls throughout a vast field area network, when working with accumulated and real-time data. The resulting detail assists managers in creating and modifying business processes, managing the station site fully, and increasing operational efficiency. A wireless gas station offers an architecture based on Wi-Fi standards for applications that track and collect data all the way down sto the sensor level. The goal of the research was to install a wireless infrastructure network at a service station. When used in a gas station, plant, enable users to access real-time information, exchange and share sensor readings from the access point, and develop a smart wireless access point system with higher secure encryption than the generic wireless network. The NodeMCU microcontroller, which broadcasts the real-time data to the clients, receives inputs from a temperature, pressure, and humidity sensor. This allows the system to do such activities. It was believed that the built wireless infrastructure will enhance the existing LAN infrastructures. A few basic prerequisites are taken into account. First and foremost, a microcontroller, a sensor unit, software design, and compliance with IEEE 802.11 standards were required.

Keywords: Implementation, Gas station, Swap-GS, Wireless, Wireless network

INTRODUCTION

The ability to effectively and productively disseminate information within an organization's body is crucial. This is now more effective and simple thanks to computer networks. These days, the majority of organizations use this technology (Datey and Ansani, 2015). There are two ways that an organization can build up a network. They have two options for networking: fully wired networks, which link computers by networking cables, or wireless networks, which link computers via radio waves. Due to the increased mobility that wireless networks have provided, enterprises are now utilizing a combination of wired and wireless networks. While the two types of networks' core hardware layouts are rather similar, an organization needs additional gear in order to transition to wireless networking. Networks offer ease, but they also put the company at risk for privacy and security issues (Kim and Kim, 2016). In the case that a business encounters security problems, there are solutions available to mitigate such risks in the future. As you continue reading, you will discover how the network has grown to be a crucial component of modern businesses, which is why sthis research design and installation of a Smart Wireless Access Point for a Gas Station (SWAP-GS) is necessary (Beard and Stallings, 2011).

The act of electrically linking computers with the intention of sharing data is known as networking. Files, programs, printers, and software are examples of common data shared in a networking environment. Because networking enables a wide variety of user collaboration, its benefits in terms of security, efficiency, manageability, and cost effectiveness are evident (Chang *et al.,* 2015). In essence, a network is made up of physical elements that make up the network infrastructure, such as computers, hubs, switches, routers, and other devices. These are the equipment that are crucial to the movement of data between locations via wires and radio waves, among other technologies. The networking industries offer a wide variety of network kinds, with the most widely used ones being Local Area Networks (LANs) and Wide Area Networks (WAN).(Chow and Bucknaill, 2012) Two or more computers connected over a short distance, typically at home, in an office building, or at a school, make up a local area network (LAN). WANs typically span cities, nations, even the entire planet and have a larger coverage area than LANs[4]. A WAN can be created by connecting multiple large LANs together. Given the number of devices connected to the network, it's critical to prevent data collisions when multiple devices try to use the data channel at once. To identify and stop collisions in networks, a set of guidelines known as Carrier Sense Multiple Access / Collision detection is employed (Weitnauer *et al.,* 2015).

Over time, it has been noted that most people have grown acclimated to the restrictions associated with wired networks. Because they are sharing a single network, users may find themselves crammed into a tiny location due to a lack of space for cabling, immobilized equipment, and undersized cables utilized by the business or school in an attempt to cut costs (Kumar, 2016).. Over the last few years, corporations, political organizations, and educational institutions have all become interested in wireless communication due to its increasing popularity. Although wireless technology has demonstrated its ability to alleviate traditional network bottlenecks, there is still much room for improvement. The goal of the current study was to create and deploy a Smart Wireless Access Point for a Gas Station (SWAP-GS) (Jino and Jaukuline, 2017). In contrast to previous studies, this one aims to accomplish numerous data transmissions within a network at the same time. Our objective is to provide the efficient transfer of numerous data (sensor readings) via Wi-Fi technology just between the access point and its end devices, with the access point producing the necessary data to be transferred from a generic sensor (Raj, 2014). In other words, the access point can produce one or more readings and deliver the various readings to its end users at the same time. Because it addresses the issue of network connectivity in remote locations lacking internet access and in need of extremely secure network connectivity, this research is significant.

METHODS

System Design

This project was designed using a top-down methodology. This is due to the fact that the top-down approach to system design has the benefit of allowing one to view the proposed system as a whole before breaking it down into more manageable jobs, which is in line with the project design purpose. Using this method, a system overview is created that describes any first-level subsystems but does not go into detail. Each subsystem 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 in Figure 1 below, which serves as a guide to design the system, hence providing a high level overview of the major system component, process participants, and important working relationships of the entire design as shown in Figure 1 below.

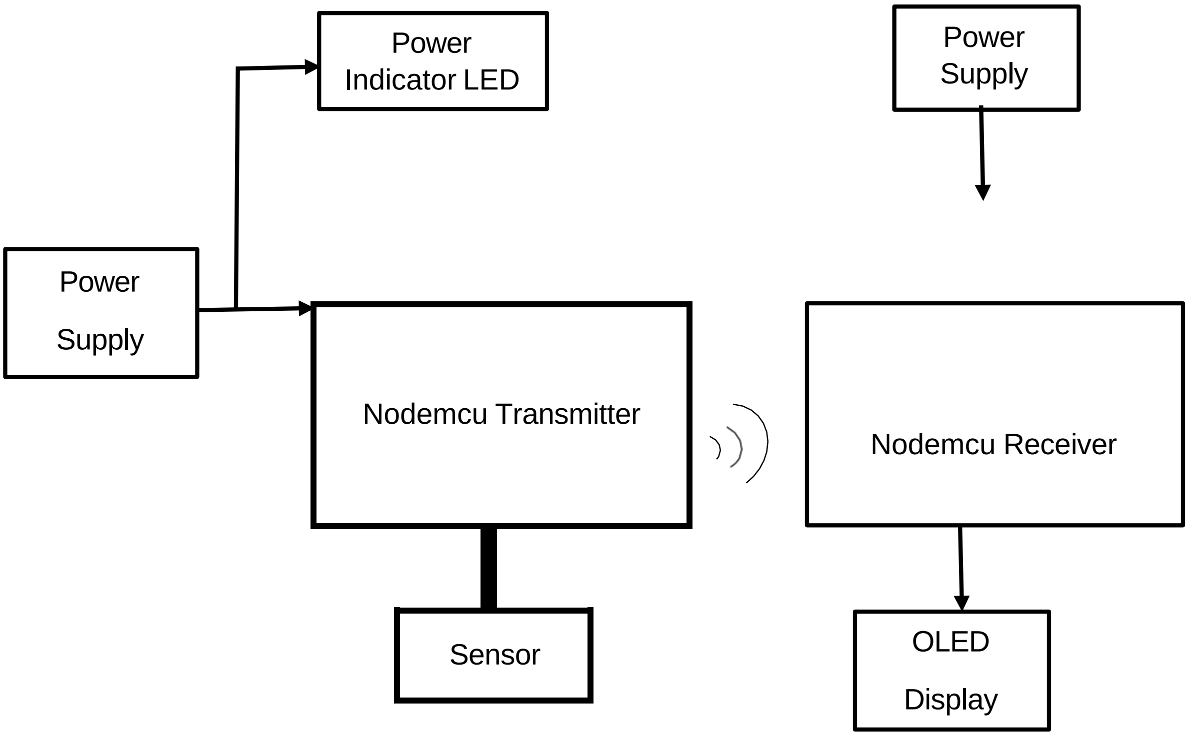

Figure 1. System block diagram

Signal Flow

The temperature, humidity, and pressure sensor receives analog signals from the surrounding environment based on the block diagram shown in Figure 3.1. The sensor's built-in analog-to-digital converter samples, conditions, and converts these analog signals into digital signals. The microcontroller receives the sensor's output. The microcontroller uses the created software algorithm to process the signals further. The microcontroller's output is then amplified and propagated through the transmitter antenna, and the antenna on the receiving side receives the propagated signal. The received packets serves 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.

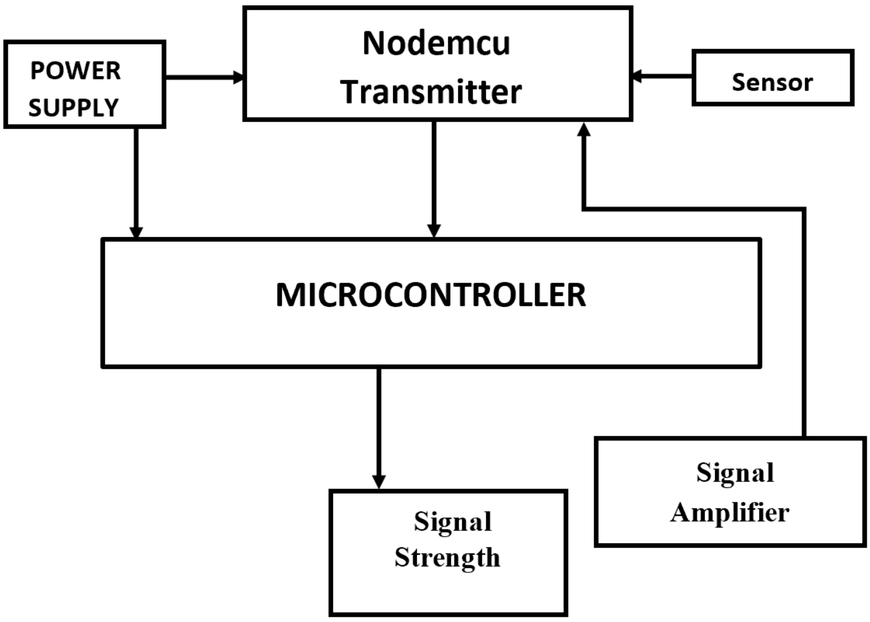

Figure 2. System block diagram of transmitter

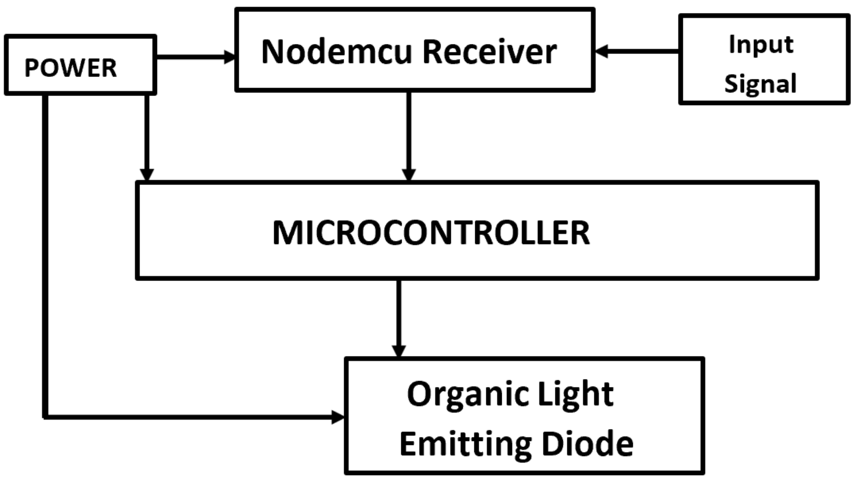

Figure 3. System block diagram of receiver

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.

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 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.

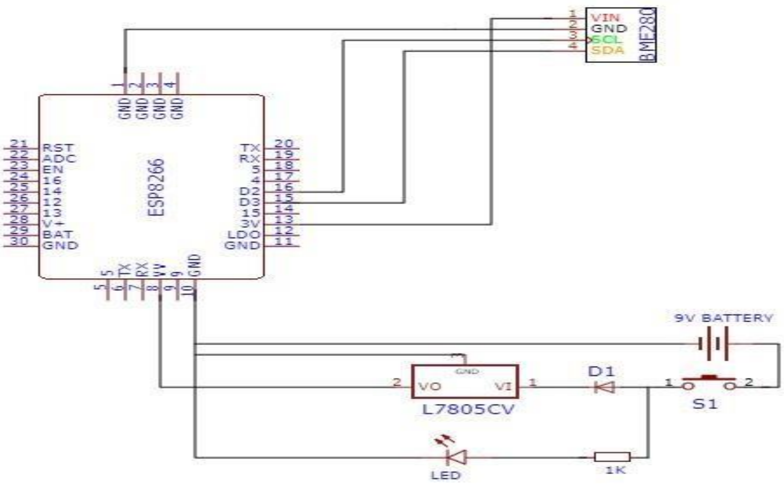

Figure 4. Circuit diagram of transmitter

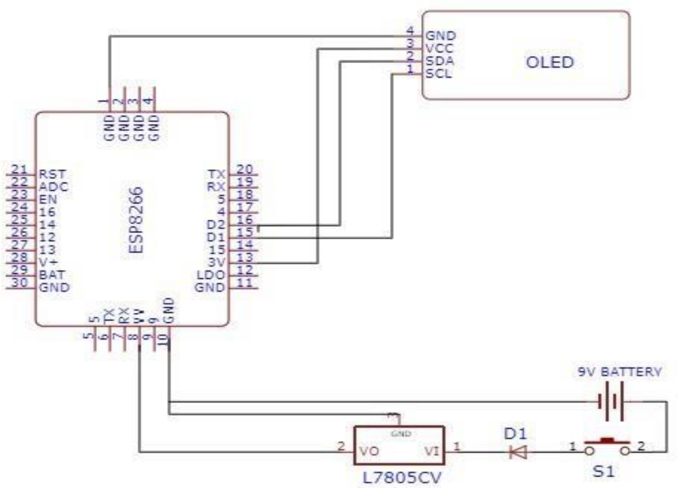

Figure 5. Circuit Diagram of receiver

Detailed Design

1. 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 DC 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.

2. Sensing Unit

This device serves as an additional input to the system; it uses a BME280 sensor, which combines temperature, pressure, and digital humidity detection. The humidity sensor offers high overall accuracy over a broad temperature range and a very quick response time for quick context awareness applications. The pressure sensor is an absolute barometric pressure sensor with a remarkably low noise level, remarkable accuracy, and resolution. The integrated temperature sensor has been tuned to produce the highest resolution and least amount of noise.

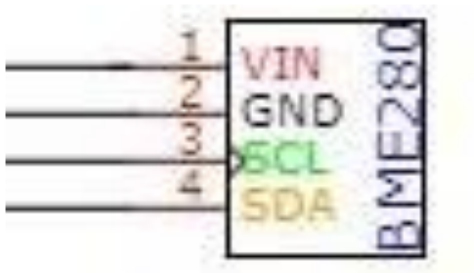

Figure. 6. Sensor

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 the 12C serial communication interface 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.

3. The ESP8266

The ESP8266 Wi-Fi Module is a self-contained SoC with integrated TCP/IP protocol stack that can give any microcontroller 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 firmware, 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 selfcalibrated RF allowing it to work under all operating conditions, and requires no external RF parts[26].

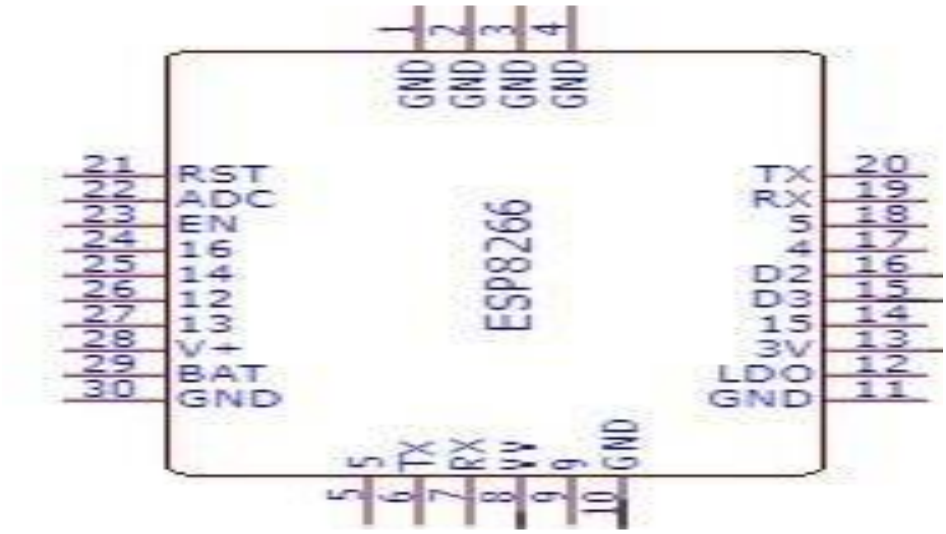

Figure 7. Layout of generation ESP8266 microprocessor

4. 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: OLEDs are economical and Ease of programming for characters and graphics. The I2C OLED uses only two-wire communication protocol, which is 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 pins of 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.

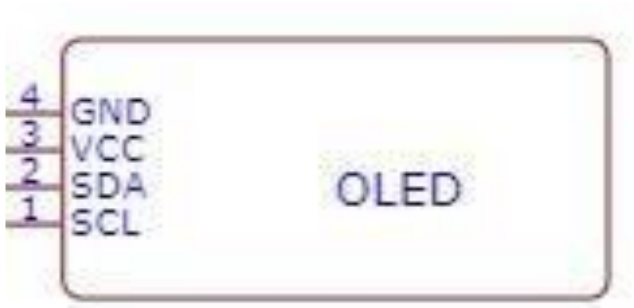

Figure 8. OLED

Software Design

In This stage of the design the Programming Language code used to program the ESP8266 NodeMCU generated. This is important because the code determines if the microcontroller performs the function of either the server or client. We achieve this by first developing an algorithm and flowchart. The system algorithm shows the step by step process of operation in accordance to the specific objectives in chapter one.

1. **System Algorithm**

The following are the system algorithm; Initialization of the controller ports, Sensors intimate with the environmental conditions, OLED screen display, Wi-Fi module wakes up from the Sleep mode, sensors ready to send data packet from the transmitter to the receiver wireless, Wi-Fi module transmitter ready to send to the receiver, Wi-Fi module receiver 1 and receiver 2 ready to receive data from the transmitter concurrently, controller gets ready to get data from the transmitter and displays on the OLED screen using I2C data packet transmission protocol, receiver controller finally receives data from the transmitter controller and displays on the OLED screen, and transmitter module updates its sensor data packet and sends to the receiver and the processes repeat.

2. **System Flowchart**

The System Algorithm has been carefully represented in a form of flowcharts presented in Figure 9 and Figure 10:

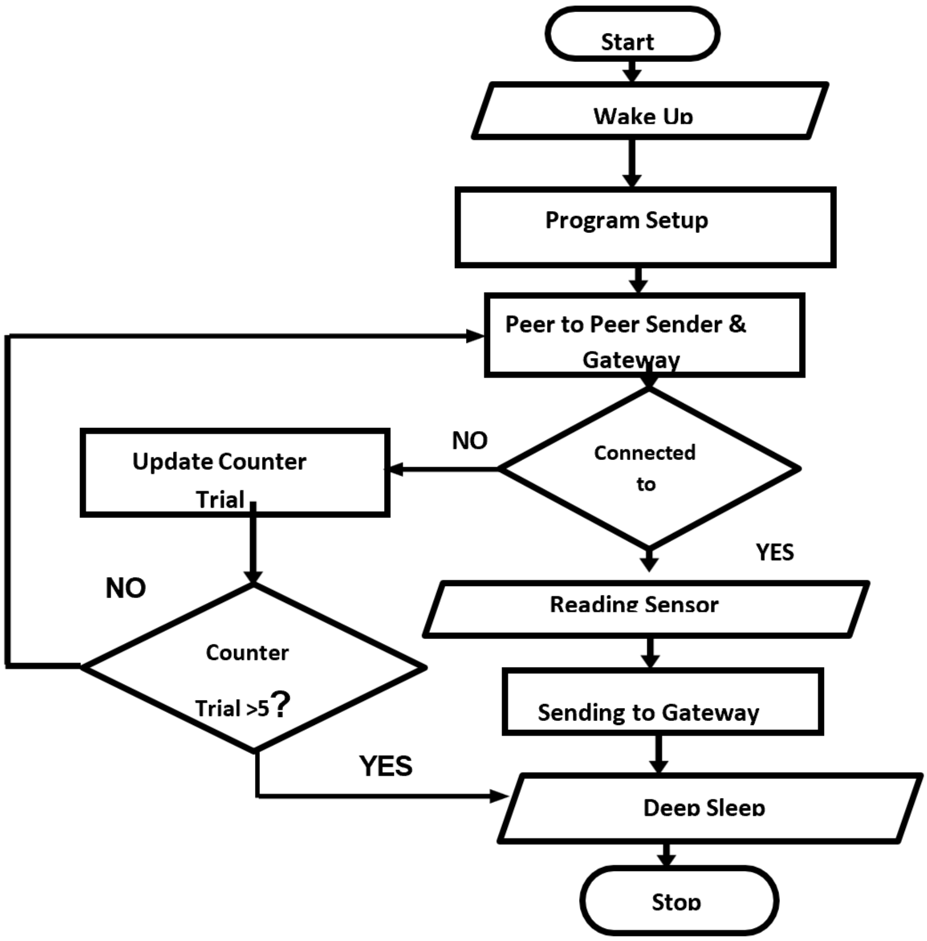

Figure 9. Flowchart of a wireless access point server

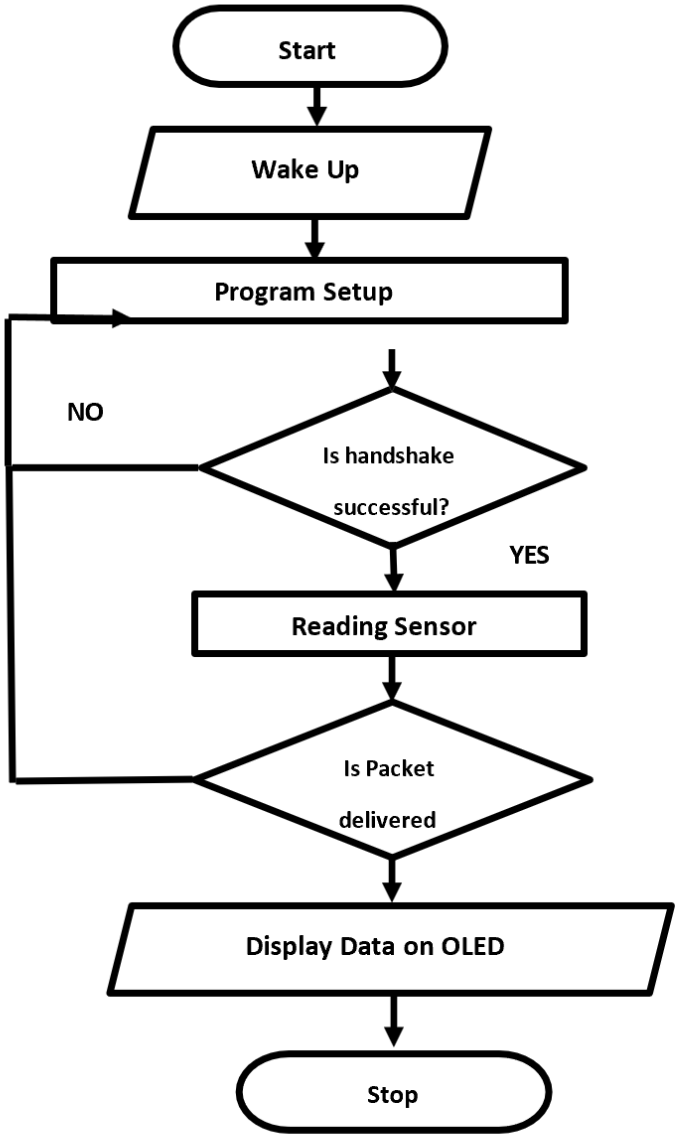

Figure 10. Flowchart of Wireless Access Point client

1. 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 NodeMCU. The design was packaged using plastic pattress box, and an integration test was done to ensure accurate performance. Figure 11 below shows the gradual steps taken to produce the complete project.

Figure 11. Stsep by step integrition of the project

Source: Snapshot

2. ***System Testing***

Testing is the processing of checking if the designed project met the objective for which it was designed. In the design of the smart wireless access point for a gas station, the following tests were conducted: unit test, integration test, and beta test. Unit test 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 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. 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 NodeMCU.

Figure 12. Multimeter reading during the test

Source: Snapshot

3. ***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. Figure 13 below shows the test carried out in the gas station.

Figure 13. Test carried out at the gas station
Source: Snapshot

RESULTS

Case 1: When the Client is on but the Server is Off

Following the design and implementation of the smart wireless access point for gas station control system, the following results were obtained for case 1 to case 4 as shown below. The developed system comprised of a server and two clients communicating wirelessly with help of the Wi-Fi network for file and data sharing.

In this mode, the client was put ON and was searching for the Wi-Fi hotspot of the server but it does not connect. The outcome is that the client display was blank while it continually searched for the connection as shown in Figure 14 below.

Figure 14 . The receiver (client) is off and displaying a blank screen
Source: Snapshot

Case 2: When Both the Client and Server are On

In this mode, the client displayed the temperature, humidity and temperature readings simultaneously on the OLED display after connecting to the server hotspot. The server continually sent updated data of the readings taken by sensor and as the client received the data and immediately updated the display as shown in Figure 15 below.

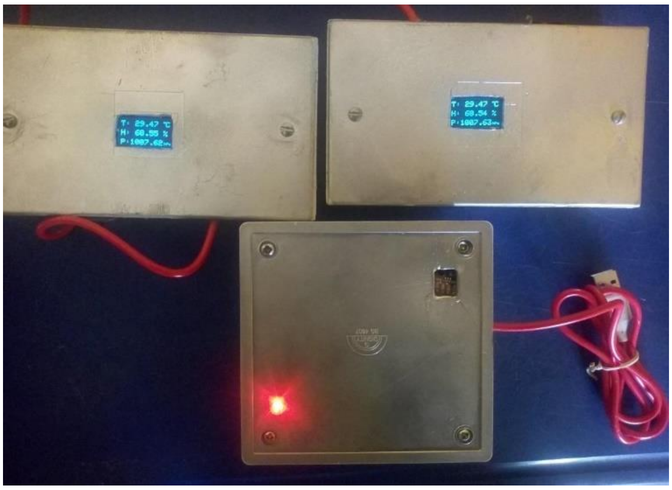

Figure 15. The receiver (client) is ON and displaying the sensor readings on the OLED screen
Source: Snapshot

Case 3: When Both the Server and Client are ON but are Not Within Range

In this mode, the access point was ON and continually sent temperature, atmospheric pressure and humidity readings taken by the sensor connected to it but the client could not receive the signal because it was out of range as shown in Figure 16 and Figure 17.

Figure 16. The server is ON but the clients are not within inetwork coverage
Source: Snapshot

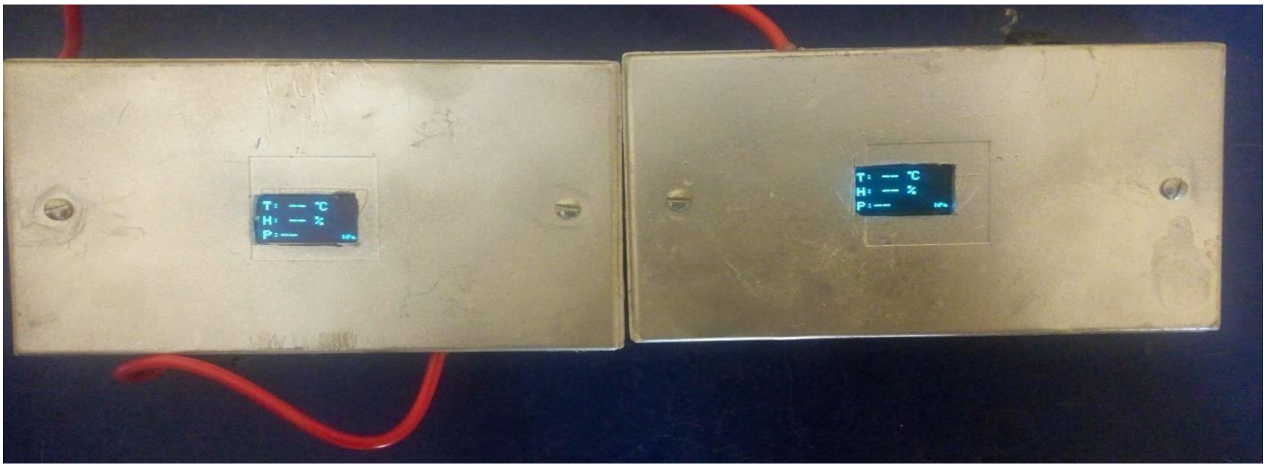

Figure 17. Showing When both the server and Receiver is On, but the reading are not displaying on the screen because they are not with the coverage area of the server

Source: Snapshot

Case 4: Interfacing the Access Point with Mobile Phone

Figure presents case 4 arrangement of the server, client and mobile phone. In this mode, the server was ON, the mobile phone acted as the client or the receiver, after which, the following steps were employed to display the sensor readings on the phone: (i) the Wi-Fi of the mobile phone was switched ON, (ii) the hotspot of the Access Point was then connected to, (iii) the web browser was opened, (iv) the Ip address, 192.168.4.1 was entered, (v) 192.168.4.1/temperature was to display temperature, (vi) 192.168.4.1/pressure was to display pressure reading, (vii) 192.168.4.1/humidity was to display humidity reading. The figures below reveals screenshots of the temperature, pressure and humidity readings respectively, taken with the mobile phone.

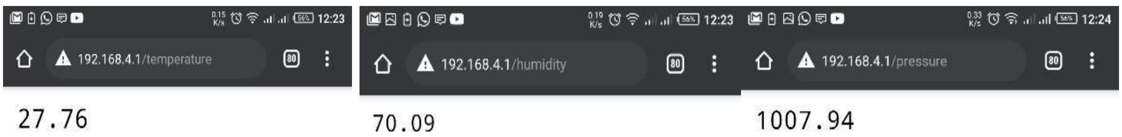

Figure 18. Webpage layout of the sensor readings

Source: Screenshot

Elan Gas plant Tests

Following the design and implementation, and upon confirming that the designed system worked as programmed, 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. Tables and Figures showing results of the tests conducted are presented below.

Table 1. A table 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 OC	Pressure(hPa)	Humidity	Temperature OC	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

Table 2. A table showing the test carried out at Elan Gas plant on the 5th of August 2021 after converting the presssure from hPa to PSI

Time	Reading Inside The Gas Plant			Reading Out The Gas Plant		
	Temperature OC	Pressure(psi)	Humidity	Temperature OC	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

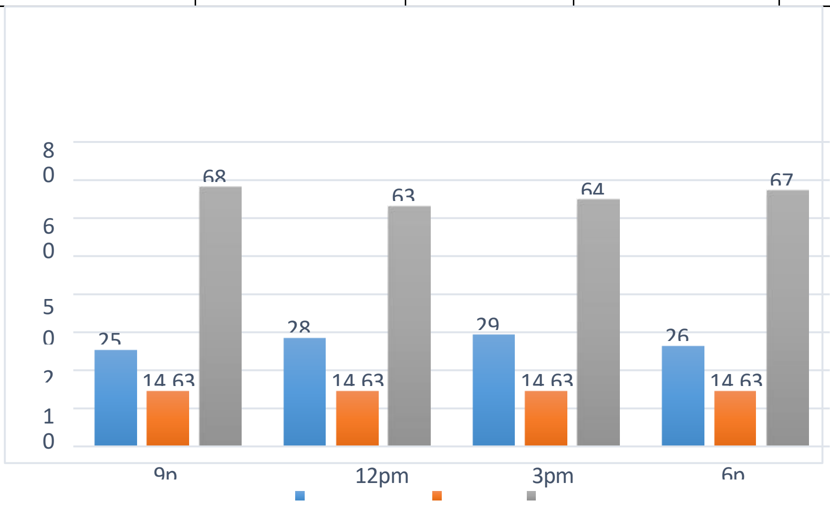

Figure 19. A Graph showing the test carried out at Elan gas plant on the 5th of August 2021 inside the gas plant

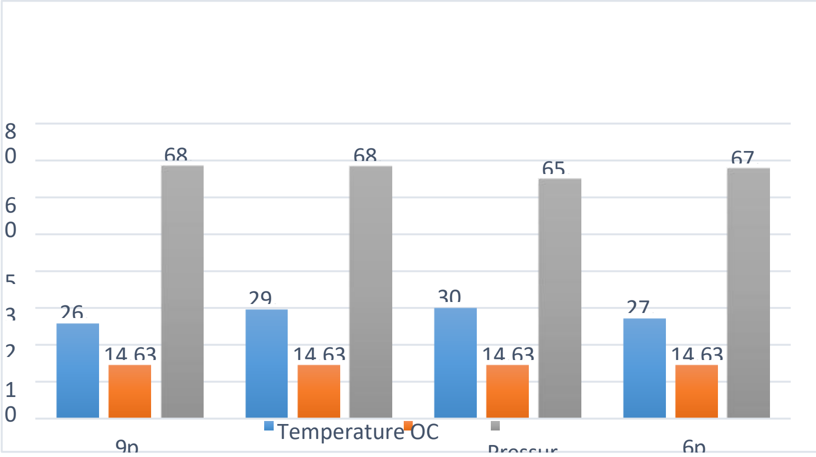

Figure 20. A Graph showing the test carried out at Elan gas plant on the 5th of August 2021 outside the gas plant

DISCUSSION

Over time, it has been noted that most people have grown acclimated to the restrictions associated with wired networks. Because they are sharing a single network, users may find themselves crammed into a tiny location due to a lack of space for cabling, immobilized equipment, and undersized cables utilized by the business or school in an attempt to cut costs (Forouzan and Fegan, 2007). Over the last few years, corporations, political organizations, and educational institutions have all become interested in wireless communication due to its increasing popularity. Although wireless technology has demonstrated its ability to alleviate traditional network bottlenecks, there is still much room for improvement. The present research aimed at designing and implementing Smart Wireless Access Point for a Gas Station (SWAP-GS) (Weitnauer *et al.,* 2015).

The study's conclusions showed that the access point, which functioned as the transmitter, was successful in sending data wirelessly to the clients. This was perceived as successful since the information gathered by the sensor attached to the access point could be sent wirelessly to the client without requiring the internet, and the client could view the data on its OLED display. The temperature, pressure, and humidity readings obtained within the gas plant during the test at Elan Gas Station were found to be marginally lower than the readings obtained outside, demonstrating the sensitivity and accuracy of the BME280 sensor that was employed.

CONCLUSION

A smart wireless access point for petrol stations has been successfully designed, implemented, and tested. The various pieces of software and hardware as well as the approach have all been adequately explained. The developed system provides a comprehensive and effective method of monitoring the environmental parameters of any gas plant, including temperature, pressure, and humidity. It accomplishes this automatically by wirelessly and concurrently transmitting data from the sensor to multiple clients through the access point, all without the need for an internet connection. The equipment works in 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 mentioned in the design's significance, a smart wireless point can be used in a gas control and monitoring station to protect the confidentiality of environmental data and the integrity of control variables. This is because only clients who have the necessary network credentials can access the data that the server transmits. The significance of this research lies in its ability to serve as an automated monitoring system in remote locations lacking internet availability, which requires highly secure network communication.

Acknowledgement

We acknowledge everyone that contributed to the success of this work.

Conflict of Interest

All authors of this work declared that there was no conflict of interest.

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