Development Of an IoT-Based Gsm Signal Strength and Meteorological Parameters Monitoring Device

AKINTOMIDE O.[1], ADEDAYO K. D.[2]

[1, 2] *Department of Physics (Electronics), Federal University of Technology Akure, Nigeria*

[1] *Department of Physics with Electronics, University of Medical Sciences Ondo, Nigeria.*

Abstract- Abstract- Subscribers to mobile networks in developing nations like Nigeria are not satisfied with the quality of service that is provided by their GSM service operators. Also, the GSM operators have challenges too. This study is aimed at developing a portable and low-cost electronic device that is not readily available locally in the nation to address these identified issues. The developed device consists of subsystems such as a sensing unit, a microcontroller unit, a display unit, an IoT data storage unit, and a power supply unit. GSM modules are used to detect the received signal strength in dBm of Nigerian GSM networks (MTN, Glo, Airtel, and 9mobile or Etisalat). Simultaneously, sensors in the circuit track meteorological parameters (temperature, pressure, relative humidity, and UV index) and air pollutants (methane) in the research location. Thereafter, the real-time data of the GSM modules and sensors is extracted by microcontroller. Then the retrieved data is displayed on the LCD module and it is also uploaded to the IoT analytical platform via WiFi in real-time. The IoT features give visualization in the form of graphs and enable the user to access the data storage using an internet facility from any remote location in the world. Also, the system gives room for monitoring, radio planning, and further study of the large volume of data that is generated with time such as the relationship between the received signal strength and the meteorological parameters, the air pollutants, or both.

Indexed Terms- GSM networks, real-time data, meteorological parameters, portable electronic device, IoT analytical platform

I. INTRODUCTION

A GSM signal strength and meteorological parameters with IoT monitoring device (GSS-MPD) is an embedded system that has been carefully developed locally to solve problems. The portable multipurpose device can perform four major functions. That is, it is an integration of a GSM signal strength meter, a meteorological parameters station, an air pollution station, and an Internet of Things (IoT) monitoring system. The dimensions of the casing are 19 cm by 11.5 cm by 5.5cm. The system is composed of electrical and electronic components that are wired together on a board and then carefully packaged in a waterproof plastic casing. It is automatic in operation, so it does not require specialised training by any user to operate it, unlike most equipment that is bulky, expensive, and requires highly trained personnel to use it.

In an attempt to study GSM signal strength, meteorological parameters, or air pollutants, researchers across many countries, especially in developing nations, often face measuring equipment issues. They tend to rely on satellite data from the archives of weather stations in developed nations [1] to study meteorological parameters. Some researchers are left with no option but to perform simulations [9], whereas others tend to install software on smart devices to study the quality of mobile networks in their countries [14], [3]. Unfortunately, some of these software make their users cough out exorbitant amounts of money. Another usual practice among researchers across many nations is the adoption of very bulky, expensive, and large numbers of measuring instruments to carry out their studies [14], [3]. Also, some researchers often measure some physical phenomena singly and then synchronise the output results from the multiple instruments as one final output [14], [3]. We know how complex it can be in an attempt to integrate measurements from different sources, apart from the unavoidable significant errors that will be equally recorded in the process. GSM signal strength monitoring is of utmost importance to the service provider, subscriber, and regulatory governmental agencies. For instance, it will assist in radio planning and improve the available telecommunication infrastructure on the part of the network service providers. Also, government agencies can advise, fine, sanction, or commend any telecommunications operator in their domain based on the quality of service they are providing to their citizens. The monitoring of GSM signal strength is of high interest to researchers in every country. This is because the output of the work of researchers is of great importance to all and sundry. The researchers must advise the subscribers of every mobile network that a certain type of network is suitable at a particular location after conducting an extensive study. Furthermore, measurements of meteorological parameters and air pollution estimation are very important too. They find direct applications in every facet of life, such as the health sector, agriculture, and global climate change issues. Therefore, this study aims to address these issues that researchers are facing by innovating low-cost portable hardware with IoT features. The electronic device has the capacity for measuring and monitoring the GSM signal strength (MTN, Glo, Airtel, and 9mobile), meteorological parameters (temperature, relative humidity, pressure, and UV index), and an air pollutant (methane) simultaneously. In addition, the real-time data from the measurements can be accessed on the IoT analytic platform remotely from anywhere in the world where there is an internet facility. The large amount of data from various GSM networks, meteorological parameters, and air pollutants can be used for scientific predictions with the aid of artificial intelligence (AI). Furthermore, the data uploaded to the cloud can be used by researchers across various disciplines, such as engineering and physical sciences, for further study.

II. COMPONENTS DESCRIPTION

2.1 GSM module (SIM 800L). The SIM 800L module is a small chip for IoT systems in which a SIM card can be slotted to perform various functions that a normal cell phone can perform. It has 12 different pins for various functions or connections, an operating voltage of 3.4 V to 4.4 V, and supports baud rates of 1200 bps to 115200 bps, among other features. The module is connected to the internet using GPRS technology.

2.1.1 Environmental sensor (BME 280). The BME 280 is a sensor used to sense meteorological parameters. That is temperature, barometer pressure, and relative humidity in the environment. It is manufactured by Bosch. It has a high level of accuracy, such as temperature at +/- 1 °C, barometer pressure at +/- 1 mbar, and relative humidity at +/- 3%. In addition, it has an operating voltage of 3V or 5V and different protocols (I2C or SPI) for communicating with microcontrollers or other devices. The module is superior to the earlier versions, which are BMP 085, BMP 180, and BMP 183.

2.1.2 Gas sensor (MQ5). The MQ5 is a module that is used to detect natural gas leakage. It has four different pins, a fast response time, high sensitivity, stability, and other features. The module is used to measure methane (CH_4) in this research. It is suitable for the detection of gas leakage in the environment.

2.1.3 UV sensor (UVM 30A). The UV sensor module is composed of photodiodes or phototransistors, which are very sensitive to UV light. Its output is an electrical signal that is directly proportional to the intensity of the incident UV radiation. The module is used to detect the level of ultraviolet radiation in the environment. Also, it is used to monitor the risk of sunburn or damage to the skin and eyes. Its operating voltage ranges from 3.3V to 5V, so it is suitably compatible with microcontroller connectivity and other applications.

2.1.4 Microcontroller (ESP 32). This system-on-chip was introduced by Espressif Systems Shanghai in China. Different types of ESP 32 modules are available on the market today. This module has many features, such as high memory, Bluetooth, many pins, and low power consumption. In addition, it has a dual-core 32-bit processor, many pins for various connections, and operates at a frequency of 240 MHz. The operating voltage of the module ranges from 2.2V to 3.6V, current (80mA), data rate (54Mbps), protocol (802.11 b/g/n/d/e/i/), sensitivity (-98 dBm), and operating temperature (-40^{0}C to 85^{0}C). The module also has different serial interfaces, such as I2C, I2S, SPI, and UART, to communicate with peripheral devices at a high speed. This module finds applications in smart homes, wireless control systems, IoT-based monitoring systems, and many others.

2.1.5 Battery. The lithium-ion rechargeable battery (Li-ion battery) in the 18650 battery pack is used in the system. It has a current supply of 3000 mAh and a voltage of 3.7 volts. It is used inside the system for energy storage and also to ensure an uninterrupted power supply to the system.

2.1.6 Charger. The charger converts 230 VAC from the mains to 5 V DC, which is used to power the device. It is made up of a step-down transformer, rectifiers, filters, voltage regulators, and other electrical and electronic components of high quality.

2.1.7 Liquid crystal display (RC2004A, 20*4 module). The LCD module has 20 characters by 4 lines in monochrome, and the maximum dimension of this module is 98mm*60mm*13.6mm. Also, it has a character size of 2.95 mm by 4.75 mm, a viewing area of 77 mm by 25.2 mm, and an active area of 70.4 mm by 20.8 mm. In addition, it has an in-built IC (ST 7066), a power supply of 5V or 3V, and accepts different interfaces (6800, SPI, or I2C) to communicate with microcontrollers or other systems.

2.1.8 Internet of Things (IoT) cloud storage. The IoT analytical platform that is used for the system is ThingSpeak. It is an open-source platform where each of the uploaded data is distributed into the field. Here, the platform uses AI to display the instantaneous uploaded data with time in the form of a graph. Also, it allows the user to access the data from any remote location. Apart from the fact that the analytic platform can be used to display the real-time data of physical phenomena, it can also handle data storage in the cloud [16], [11].

III. LITERATURE REVIEW

The Internet of Things (IoT) is a wireless network of electronic devices that allows embedded systems to track the data from any physical phenomenon in real-time and then upload the extracted data through the internet facility to remote cloud storage. The sensors, actuators, GSM modules, and transducers can be integrated into the IoT technology, which gives it a wide variety of applications such as environmental monitoring, smart agriculture, smart homes, precision medicine, smart cities, and so on [16], [11].

Zafar *et. al.* (2018) in Pakistan developed an IoT-based system for monitoring the environment. They used an Arduino Uno, an ESP 8266, a WIFI module, a DHT11 sensor, and other components to measure meteorological parameters (temperature and relative humidity). They obtained real-time data on their environmental monitoring and then transmitted the extracted data to the analytic cloud storage. The researchers then developed a phone application for their work. Therefore, the user interface of the systems can be computer systems, Android phones, or any other compatible smart devices. In addition, Mohammed *et al.* (2022) conducted an experimental study at a research location called Andhra Pradesh in India. They develop an IoT-based electronic device for monitoring meteorological parameters (temperature and relative humidity) and gas (LPG) in the environment. They used an Arduino Uno, an ESP 8266, a WIFI module, a DHT11 sensor, an MQ6 sensor, and other components to develop their device. Therefore, the front-end user interface is a computer system and related smart devices. The measured real-time data from the environment was uploaded to the IoT analytic cloud. Also, Babalola *et al.* (2022) carried out a study at a research location in Oye-Ekiti, Nigeria. They developed a weather reporting device for temperature, relative humidity, light intensity, and rainfall intensity. The researchers used ESP 32, DHT 22, a tipping bucket, TSL 2561, and other components to develop their devices. In addition, they used solar energy to power the system. The real-time data of the physical phenomena was displayed on the LCD and transmitted to a platform (VIVA FUOYE) on the computer system.

Mas *et al.* (2022) in Malaysia developed an LPG gas leakage detection device. They used the ESP 32, MQ 2 sensor, LCD, buzzer, and other electronic components to create the device. If a gas leakage occurs near the device, an alarm will be triggered by the system, and information will also be displayed on the LCD screen. The duty of the ESP 32 in the system is to transmit the sensed data. Furthermore, Gouda *et al.* (2014) developed a microcontroller-based real-time weather monitoring device at a research location in India. They obtained the measurements of temperature, relative humidity, pressure, and dew point in the environment with the aid of sensors. All the measured real-time data were transferred over a GSM network to the computer system for analysis and data storage. The researchers used PIC16F877A, an LCD, a GSM module, sensors (for temperature, relative humidity, and pressure), and other electronic components to develop the weather monitoring device. From the available literature, researchers have conducted an extensive study on IoT-based research in terms of environmental monitoring and other important areas to address issues. However, they are yet to develop a portable IoT-based device that is capable of measuring and monitoring the signal strength of four GSM networks, five meteorological parameters, and an air pollutant simultaneously. This developed device with IoT integration will not only fill this research gap, but it will also address the issues of scarce, costly, and bulky materials in the study of the quality of GSM service, meteorological parameters, and air pollution monitoring. It will equally serve as an alternate or suitable replacement for the simulation work and subscription to the expensive software used by researchers in communication systems, especially in institutions.

IV. MATERIALS AND METHODS

This explains the systematic procedures used for the system design and architecture. Also, it describes the design of the architecture of the IoT system for data collection and transmission to cloud storage. The major part of the hardware is the GSM module, BME280, MQ5, and UVM30A, and how it interfaces with the microcontroller, display unit, and analytic cloud. The methodology, consideration, and specification of the developed device were recorded. The microcontroller was programmed with C++ to receive signals from both the GSM modules and the sensors once they were activated.

The system design and architecture are made up of electrical and electronic components that are integrated into a single functional unit. They are:

i. A microcontroller (ESP 32)
ii. Four GSM module (SIM 800L).
iii. Sensors (BME 280, MQ5, and UVM30A)
iv. Liquid crystal display, LCD, (RC2004A)
v. IoT analytic platform (ThingSpeak)

3.1 Hardware Design Approach

The system is a development of GSM signal strength and meteorological parameters with an IoT integration (GSS-MPD). The central unit of the entire system, which serves as the main processing unit, is an ESP 32 microcontroller. It interfaces with all the input and output modules that are connected to it. That is, it receives data from the GSM modules, and the sensors then transmit the extracted data to both the LCD and the IoT platform via WiFi. It therefore means that the real-time data of the received signal strength of GSM networks, the meteorological parameters, and the air pollutants are displayed on the LCD and also on the IoT analytic platform.

The block diagram in Figure 1 shows that these units are integrated into the system.

i. Power supply unit
ii. Microcontroller unit
iii. GSM modules unit
iv. Sensors unit
v. Display unit
vi. Cloud storage unit

3.1.1 Power supply unit

The uninterrupted power supply unit consists of the charger and the Li-ion battery. The charger supplies 5VDC to the system, whereas the Li-ion battery (3000mAh, 3.7V) inside the system serves as a power bank to ensure an uninterrupted source of power inside the system. The Li-ion battery 's voltage remains steady for a long period, and whenever it runs out of energy, the charger is switched on to supply input energy to it. The importance of this power supply unit cannot be overemphasised because, without it, the entire system will not function.

3.1.2 Microcontroller unit

The microcontroller (ESP 32) is the central hardware component or the processor of the system. It has different sets of pins for specific connection with its peripherals hardware components. That is, power pin, enable pin, analogue pin, dac pins, input and output pin, serial pin, external interrupt pin, pwm pin, hspi, aref pin, capacitive touch pin, rtc pin, and iic pin . The microcontroller was wired and programmed to interface with the GSM modules for signal strength, sensors for meteorological parameters, and sensor for air pollutant, LCD, and other components in the systems.

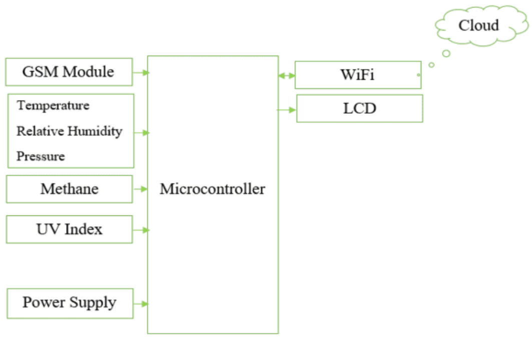

Figure 1: *Hardware Block Diagram of GSS-MPD system*

3.1.3 GSM modules unit

The GSM modules unit of the GSS-MPD serves as an input in the system. It is made up of four SIM800L. It has 12 pins for specific functions. The four SIMs from Nigerian mobile networks (MTN, Airtel, Glo, and 9mobile) were inserted singly into each of the four GSM modules. It uses GPRS to track the received signal strength of each of the networks at the research location. It senses the received signal strength of each of the four networks in dBm and then sends the measured real-time data to the microprocessor for further processing.

3.1.4 Sensors unit

The sensor unit of the GSS-MPD serves as an input in the system. It is made of meteorological parameter sensors (BME280 and UVM30A) and an air pollutant sensor (MQ5). The BME 280 module senses temperature in °C, relative humidity in %, and pressure in mbar. UVM30A senses the UV index, and MQ5 senses the air pollution gas (methane in ppm) in the system. All the measured real-time data from the sensors is sent to the microcontroller for further processing.

3.1.5 Display unit

The display unit of the GSS-MPD serves as an output in the system. A 20-character by 4-line monochrome (20*4) module was used to display instantaneous alpha-numeric values of the physical quantities. It has 16 pins for specific functions, and it is a 5x8 dot matrix module. The standard operating voltage of this module is 5 volts DC, but it can be modified to accept 3 volts. The LCD module is connected to the microcontroller through the I2C adapter. The I2C is a serial bus that uses just two bidirectional lines (the serial data line, or SDA, and the serial clock line, or SCL) to communicate with the microcontroller or other electronic component in a system. Thus, apart from VCC and GND pins, two pins (SDA and SCL) were used on the LCD for connections or communication with the microcontroller via the I2C.

3.1.6 Cloud storage unit

The IoT analytic platform of the GSS-MPD serves as an output and data storage system in the system. ThingSpeak, which is an open-source platform, was used in this study. It receives the extracted data from the GSM modules and sensors from the microcontroller via WiFi. The IoT platform helps us monitor all the readings in real-time at any remote location where an internet facility is available in the world. In addition, it uses AI to plot the graph of each quantity against time automatically. Therefore, all the real-time data is distributed singly into fields in graphical form. Then the measured data is stored in cloud storage. The data on the IoT platform gives room for scientific predictions from the measured data and further study on the large datasets that are generated over time.

3.2 Software Design Approach

The software implementation is crucial to the integration and working of the GSS-MPD hardware design. Arduino IDE, which is open source, was installed on a computer system. The microcontroller was programmed in C++ to receive real-time data from the GSM modules and the sensors. Then the microcontroller, via its WiFi, uploads the received data to the IoT platform. The IoT platform for this study is ThingSpeak, which is used to aggregate and visualize the uploaded real-time data with its in-built AI technology.

3.3 System Flowchart

The flowchart of the GSS-MPD system is shown in Figure 2. The algorithm of the system can be subdivided into three parts. They are the booting of the system, the measurement from both the GSM modules and the sensors, and the retrieved data being displayed on the LCD or being uploaded automatically to the IoT analytic platform.

Step 1: Switch on the device.
Step 2: Try to connect to WiFi.

Step 3: If the WiFi connects successfully,
Step 4: Then obtain real-time data from the GSM modules and the sensors.
Step 5: Store the obtained data.
Step 6: Upload the retrieved data.
Step 7: Stop
Step 8: If the WiFi fails to connect,
Step 9: Return to Step 2

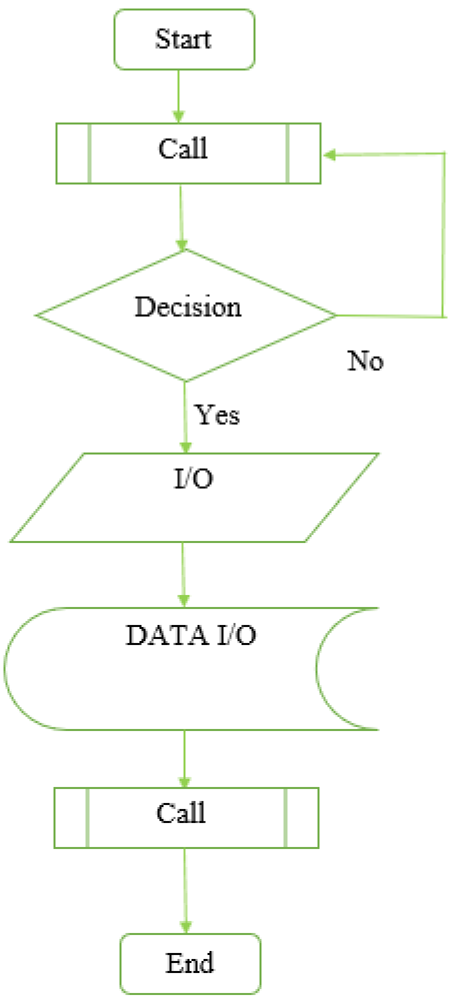

Figure 2: *Flowchart of GSS-MPD system*

IV. RESULTS AND DISCUSSION

4.1 Results

The device was carefully developed and tested to work perfectly. It was used to generate data for some time at a research location. The hardware implementation of the complete and working system is shown in Plates 3 and 4. SIM800L tracks the signal strength of each network via the activated SIM card of the particular network service provider. BME28 tracks the temperature, relative humidity, and pressure at the research location. Also, UVM30A senses the UV index, whereas MQ5 tracks methane gas in the environment. All the modules are monitoring and measuring real-time data simultaneously without interference. The SIM800L, BME28, UVM30A, MQ5, and ThingSpeak clouds are interfaced with each other using the Arduino IDE.

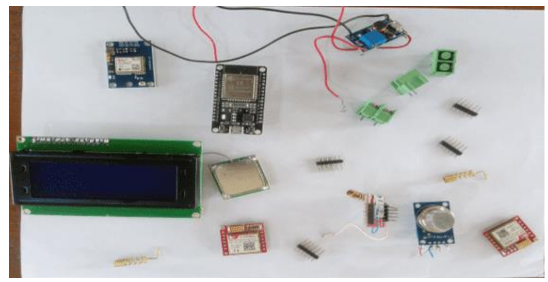

Plate 1: *Some Components*

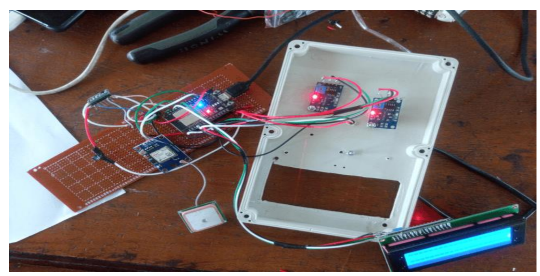

Plate 2: *Integration of Components in the Lab*

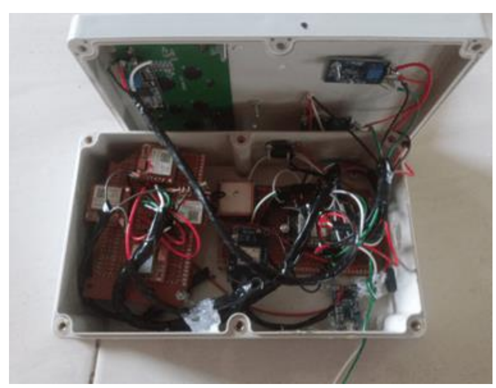

Plate 3: *Internal Circuitry of GSS-MPD*

Plate 4: *Pictorial View of GSS-MPD*

4.2 Discussion

Plates 1 and 2 show the components and the process of integrating the developed device in the laboratory. Plate 3 shows the internal circuitry of the GSS-MPD. The electrical components were tested individually and carefully assembled on a veroboard, as shown in Plate 1. The functional electronic was then packaged in a portable water-proof container with a dimension of 19 cm by 11.5 cm by 5.5cm.

Plate 4 shows the tracking of the received signal strength of the major GSM network operators in Nigeria and also the selected meteorological parameters with the air pollutant simultaneously without interference on the 20*4 LCD of the GSS-MPD. The microcontroller was configured to communicate with all the input and output components. The entire system's operation is dependent on the software codes that are programmed into it.

4.2.1 Graphical Display on the IoT Analytic Platform

To address the issue of the storage of large amounts of data over some time, remote monitoring of the device, and prediction using the measurement data, the device logs all the real-time data in the cloud. The IoT platform (ThingSpeak) uses artificial intelligence to plot the time series of each real-time piece of data in an assigned field.

Figure 3 shows the time series graphs of pressure and temperature, respectively, on the analytic platform. Also, Figure 4 shows the graph of relative humidity against time and that of 9mobile (Etisalat)/Glo against time on the analytic platform.

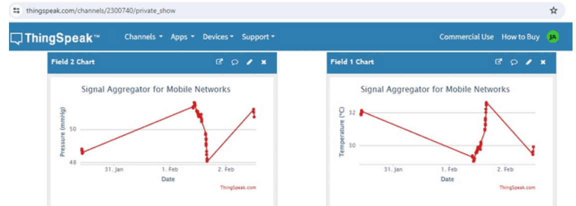

Figure 3: *Time series of Pressure and Temperature on an IoT Analytic Platform*

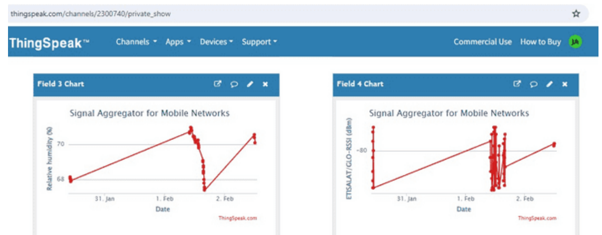

Figure 4: *Time series of Relative Humidity and Etisalat/Glo RSSI on an IoT Analytic Platform*

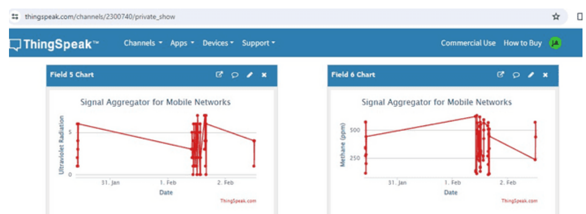

Figure 5: *Time series of Ultraviolet Radiation Index and Methane on an IoT Analytic Platform*

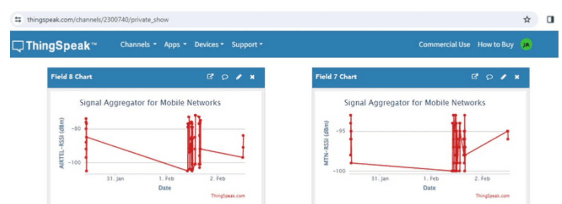

Figure 6: *Time series of Airtel and MTN RSSIs on an IoT Analytic Platform*

Figure 5 shows the time series plot of the UV index and the time series plot of methane on the analytic platform. Also, Figure 6 reveals the time series graph of Airtel and also the time series graph of MTN on the analytic platform.

CONCLUSION

This paper presents the development of a portable IoT-based embedded system on GSM signal strength, meteorological parameters and air pollutants (GSS-MPD). The GSM modules measure the received signal strength of four Nigerian GSM networks (MTN, Glo, Airtel, and 9mobile or Etisalat) in dBm. Also, the sensor modules in the system track four meteorological parameters (temperature in °C, relative humidity in %, pressure in mbar, and UV index) and an air pollutant (methane in ppm). All the measurements of the real-time data on physical quantities are done simultaneously in the system. It is displayed on the LCD and uploaded to the IoT cloud storage automatically. The analytic platform uses its in-built AI to display the uploaded real-time data in graphical visualisation, which can be accessed at any location on the globe over the internet by the user. The uploaded data over some time can be downloaded or subjected to further AI analysis, research, or prediction. This system is crucial in IoT applications such as the visualisation or monitoring of GSM signal strength, meteorological parameters, and air pollution data in real-time. Also, it can serve as a data bank for GSM signal strength and a weather station for meteorological parameters and air pollutants. More importantly, it will solve the issue of scarcity, bulky and expensive research instruments in developing countries. It is also a close substitute for simulation or software procurement for the quality of GSM network research in developing countries. During this study, it was observed that the data of Glo (62150) and 9mobile or Etisalat (62160) merged as one data on the IoT platform, which may be traced to the close operator IDs of these two networks.

ACKNOWLEDGEMENT

The authors would like to thank the management of the Federal University of Technology Akure, Nigeria, and the University of Medical Sciences Ondo, Nigeria for allowing us to use their facilities.

REFERENCES

[1] Adedayo K. D. (2016). “Statistical Analysis of the Effects of Relative Humidity and Temperature on Radio- Refractivity over Nigeria using Satellite Data”. *African Journal of Environmental Science and Technology*. Volume 10(7), 221-227

[2] Babalola T. E., Babalola A. D., and Olokun M.S. (2022). “Development of ESP-32 Microcontroller Based Weather Reporting Device”. *Journal of Engineering Research*. 22(11): 27-38. ISSN: 2582-29

[3] Ewona Igwe and Ekah Ukoette (2021). “Influence of Tropospheric Variables on Signal Strengths of Mobile Networks in Calabar, Nigeria”. *Journal Science and Engineering Research*, 2021,8 (9):137-145

[4] Fetfov O.M., Nikolov L.G., and Kulev N.Z. (2014). “Cellular Radio Channel Aggregation Motivation and Benefits Overview”. *International Scientific Journal “Machines, Technologies, Materials”* Year VIII (5), 3-5.

[5] Giusappe Piro, Luigi A.G., Gennaro B., Francesco C., and Pietro C. (2010). “Simulating LTE Cellular Systems: Open Source Framework”. *IEEE Trans. Veh. Technology*, 2010.

[6] Gouda K. C., Preethan V. R., Swamy M .N. S. (2014). “Microcontroller-Based Real-Time Weather Monitoring Device with GSM”. *International Journal of Science, Engineering and Technology Research*. Volume 3, Issue 7. ISSN: 2278-7798

[7] Kay Romer and Friedemann Mattern. (2004). “The Design Space of Wireless Sensor Networks”. *IEEE Wireless Communications 2004.*

[8] Kebede T.,Wonde Y., Steinbrunn J., Kassa H. B., and Kornegay K. T. (2022). “Multi-Carrier Waveforms and Multiple Access Strategies in Wireless Networks: Performance, Applications, and Challenges”. *IEEE Access*. Volume 10, pp 21120-21140.

[9] Liston Kiwoli, Anal Sam, and Emmanuel Manasseh. (2017). “Performance Analysis of Carrier Aggregation for various Mobile Networks”. *International Journal of Wireless and Mobile Network*. Volume 9 (5), pp 41-53.

[10] Mas G. A, Nur F. I. A., and Norazlina AM (2022). “Development of LPG Gas Leakage Detection using ESP32”. *International Journal of Research and Innovation Management*. Volume 8, No 1 (2022). ISSN 2462-1293

[11] Mohammed SAS, Aluri A, Duru KK., Praneash, Kara C, Kalluri S. (2022). “IoT based Humidity, Temperature and Monitoring using Arduino Uno”. SRM University-AP, Andhra Pradesh, India. *ECS Transactions April 2022*. DOI: 10.1149/10701.6435ecst.

[12] Nigerian Communication Commission (NCC) Website. 2020 Subscriber/Network Data Report. www.ncc.gov.ng. Accessed on 17/09/2023.

[13] Nwankwo VUJ, Akinnubi RT, Ajakaiye MP, Obisaesan OE, Akinsola TO, Ahmed TS, Ebong NU, Oyanameh OE, Fatoye OV, Ajamu J, Adams A, Orokhe JE, Olatunji M, and Akintomide O (2023). “Trends of Diurnal Variations of Meteorological Variables Received at Anchor University Space-Lab weather Station”. *Anchor University Journal of Sciences and Technology*. Vol.3 No 1, pp 81-92. ISSN: 2736-0067 Online.

[14] Osahenvemwen O. A. and Omatahunde B. E. (2018). “Impacts of Weather and Environmental Conditions on Mobile Communication Signals.” *Journal of Advances in Science and Engineering*. Vol. 2018 (1), pp 33-38.

[15] Vemula Naveen and BABU N. P. (2020). “IoT Based Environmental Monitoring System for Real Time Using Arduino”. *Journal of Emerging Technologies and Innovative Research*. Volume 7, Issue 11. ISSN: 2349-5162

[16] Zafar S., Miraj G., and Baloch R. (2018). “An IoT Based Real-Time Environmental Monitoring Systems Using Arduino and Cloud Service”. *Engineering, Technology and Applied Science Research*. Volume 8, No.4, 3238-3242

[17] Zhengyang D. Weiwei M., Mingxuan Z., Wei L., Rui L., Jun Zou, and Chen X. (2019). “Integration of LTE 230 and LTE 1800”. *Future Internet*. 11 (221).