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Near Field Communication Intelligent Remote Livestock Monitoring System (Nigeria)

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Abstract

The continual emphasis on the development of the Nigerian economy with agriculture as an attendant alternative to the existing oil driven economy, has made it imperative to mechanize agriculture. Research has shown that livestock in the farm are mostly affected by diseases and that the proximity between animals and humans has made the latter more vulnerable to infectious diseases of animals. However, building a functional as well as cost effective miniature device that is capable of remotely detecting cattle's health status and location in real-time has been quite challenging. Hence, this paper proposes an Internet of Things (IoT) and Near Field Communication (NFC) system for monitoring and tracking the health status as well as the location of any cattle by using sensors, and Global Positioning System (GPS) module respectively. The system implementation was carried out using the software program to drive the hardware system. Sensors such as temperature sensor, pulse rate sensor, humidity sensor, and GPS location sensor interfaced to the Node MCU microcontroller with embedded ESP8266 Wi-Fi chip. This Wi-Fi chip serves as an (IoT) gateway for sending data to a remote server from where farmer's get notification about the health and location of their animals. The test carried out shows that the developed system is flexible, reliable and capable of monitoring cattle remotely. The system can also be deployed in a farm settlement with any kind of cattle production system in use because of its compact design, affordability, and complementary support for areas of poor network infrastructure.

1. Introduction

There are no recent human activities, processes or facets of life that preclude the use of technology as an asset to transform the laborious and time-consuming task of mankind. Nowadays, modern farming is not unaffected by technology. Recent innovations and researches have enabled man to get rid of the manual efforts that he put into agriculture. Efforts are on top gear to find new ways of improving agriculture to achieve the long-term development goal.

Information Technology (IT) based agriculture has opened up opportunities, like any other business, for farmers to not only manage farm operations, but to change the way they manage crops and livestock to boost productivity and efficiency.

It is against this backdrop of global challenge of food production that the Food and Agriculture Organization (FAO) made a prediction of a shoot in the population in the world to 9 billion by 2050, and that 70 percent increase in food production would have to emerge to counter this growth [1]. This translates that farmer will have to increase food production, with less resources such as water and land. Consequently, modern and innovative technologies are being considered in various agricultural sectors to meet the goal. This stride needs to be accelerated by integrating Internet of Things (IoT) while making the agriculture smart and simple in nature [2].

Mobile applications offer farmers the opportunity of gathering, and updating real-time data using their smartphones. Radio and wireless technologies are no exceptional devices in the hands of farmers for tracking and monitoring the location of farm animals, produce, and for detecting counterfeit produce in the market [3]. In spite of the proliferation of these emerging technologies and their numerous benefits, farmers are yet to leverage on them. Hence, this work proposes an Internet of Things (IoT) Based Livestock (particularly cattle) Farm Remote Monitoring System with the use of the Near Field Communication (NFC) technology for Michael Okpara University of Agriculture Umudike's (MOUAU) farm settlement, as a test bed. The Internet of Things (IoT) has been described by Keertana and Vanathi in [4] as the network of physical objects-devices, vehicles, buildings and other items embedded with electronics, software, sensors, and network connectivity- that enables these objects to collect and exchange data. It also provides a remote monitoring capability for objects across existing network infrastructure, thereby enabling close interaction between the computer-based systems and the real world.

The Near Field Communication (NFC), however, refers to a subset of Radio Frequency Identification (RFID), wireless communication technology that operates at a frequency of 13.56 MHz, has a low bandwidth and supports a threshold data transfer rate of 424 Kbit/s. According to López-de-Ipina [5], the Near Field Communication technology is described as one of the enablers for ubiquitous computing that requires bringing two NFC compatible devices close (about 10 centimeters) together. In his work, he referred to it as, "a combination of contactless identification and interconnection technologies". Thus, this technology makes it possible for users to interact with any smart object (either an NFC tag, NFC reader, or another NFC mobile) using their NFC enabled mobile phone. The communication of near field devices is based on inductive coupling between transmitting and receiving devices. The NFC technology also allows people to integrate their daily-use credit cards, and loyalty cards into their handsets. Thus, the data or mobile services received by NFC mobile during communication with other smart object or another NFC mobile in proximity can be used to access other online applications or web pages. NFC technology simplifies transactions and opens up innovation opportunities to mobile communications. Little wonder they are often used for bus ticketing, mobile payment system, asset tracking, access control, counterfeit detection and many more to mention but a few [6].

1.1. Related Literature

Meenakshi and Snehal [7] developed an advanced cattle health monitoring system for cows. Sensors used for detecting various health parameters of the cows included: temperature sensor, humidity sensor, respiration sensor, heart beat sensor and rumination sensor. The sensors were interfaced with Arduino Uno microcontroller. They also made use of ESP8266 Wi-Fi module as a transceiver for I-Chart web application. Although the work appears feasible, the exact names of the sensor devices or circuits for the respiration and rumination detection were not mentioned. There was no experimental result in display for the data that generate I-Chart graph for disease prediction.

Mohan *et al.* [8] presented a review on animal welfare monitoring system using IoT. In their proposed system, the conditions of animals were collected for the purpose of analysis. The authors used various sensors for sensing the humidity, temperature, animal behaviour and disease detection of different animals such as cattle, poultry and stable horses. Their system used Arduino microcontroller as the main processing device that monitors the farm environment and animals. They emulated the cloud using a web-based database and saved sensors data to it. These authors have done well by extending massively to other livestock but modifications can be done by putting the location of the animals into consideration. Moreover, the system is bulky as it does not have an in-built Wi-Fi module [9].

Sunil *et al*. [10] presented a pervasive and personalized smart healthcare system using Internet of Things (IoT). The research authors proposed an innovative idea to monitor patient's biological health parameters in real time. In a bid to provide better healthcare services to the needy patients, the authors put forward a Pervasive and Personalized smart Healthcare System (PPHS) using Internet of Things (IoT). The system relied on various inter-dependent technologies such as, Near Field Communication (NFC), Wireless Sensor Network (WSN), and accelerometer for motion detection using smartphones amongst others.

The smart devices used in the work cooperate with each other using a Constrained Application Protocol (CoAP) NFC and Simple Object Access Protocol (SOAP) network infrastructure. The PPHS had the ability to collect, in real time, the physiological parameters of patient via a sensing network consisting of nodes integrating NFC and WSN functionalities. The sensor data were delivered to a control center where an administrator application in cloud makes them easily available to both local and remote users through a SOAP web service. This work had been designed with a combination of various IoT enabling technologies and exhaustively on human; making it seemingly intelligent and efficient. However, modifications can be made to the work so that it can be used for farm animals.

Roger *et al.* [11] reviewed recent advances in IoT based wireless sensors for cattle health management. In their paper on the research work, the authors stated that benefits can be realized from technologies that have the ability to discover the presence of diseases in their early stage and thereby prevent its spread. According to the researchers, the IoT based cattle health and environment monitoring system can monitor various health parameters of cattle which include body temperature, heartbeat and animals' location.

Kirti and Sayali [12] developed a system for tracking and identification of animals for a Digital Zoo using Radio Frequency Identification (RFID) and Internet of Things (IoT). The authors also made use of sensor nodes that sense body temperature of animals and Global Positioning System (GPS) that locates the animals and their cages. So, the RFID was used for identifying the animals individually based on the information from the tag attached to their body, while the wireless sensor cameras were distributed over the area for capturing animals' movement. The captured data was then stored in the database and made accessible to the users (zoo visitors, zoo keepers and veterinarians) through the RFID tag attached to a particular animal in the zoo. This research work is highly commendable and the network of camera sensors used makes for better understanding of animals' behaviour but the large number of cameras deployed makes this work bulky and expensive. Besides, the Near Field Communication (NFC) technology could have better been used instead of the RFID. First, unlike the RFID, the NFC device makes data accessible over NFC support devices like phones and tabs and secondly, the NFC tag can be reused over different animals since it can be reprogrammed. Thus, making it cost-effective.

2.0 Materials and Method

2.1 Materials

The materials used in achieving this research are grouped into two broad categories: hardware tools and software development tools. The hardware devices consist of the NFC tag, PN523 NFC reader, Global Positioning System (GPS) Module and NodeMCU Microcontroller as shown in Figure 1. While the software development tools include: Hypertext Pre-processor (PHP), Hypertext Mark-up Language (HTML), JavaScript and mariaDB data base.

2.1.1 The Hardware Components

The hardware devices integrated to develop the system are discussed thus:
NFC Tag: An NFC Tag consists of three basic components: an NFC chip, an antenna and a jacket to keep it firmly bounded. The NFC chip is a tiny microchip which contains a small amount of memory and the technology to allow it to communicate. The antenna is a coil or loop of wire which in the case of a sticker will be an etching a fraction of a millimeter thick. An NFC tag is generally regarded as being a reference to data rather than a data store itself. e a phone call, can launch a URL, or can send a Short Message Service (SMS).

a. NFC reader (PN532 module):
The PN532 module is a radio frequency module with an **integrated chip** based on the **80C51 microcontroller core** and used for contactless communication at 13.56MHz. It can also perform a read/write operation. However, it is only used in this work to read the unique content of the NFC tags placed near it. This high frequency range makes it suitable for use as both an NFC and RFID device.

b. NodeMCU
The NodeMCU is an open source IoT platform that contains Lua firmware which runs on the ESP8266 Wi-Fi System on a Chip (SoC) developed by Espressif Systems and the hardware is based on the ESP-12 module with Transmission Control Protocol/Internet Protocol (TCP/IP). The ESP8266 Integrates **802.11b/g/n Wi-Fi transceiver**, so it can not only connect to a Wi-Fi network and interact with the Internet, but it can also set up a network of its own, allowing other devices to connect directly to it. This makes the ESP8266 NodeMCU even more versatile. The NodeMCU board supports different serial communication protocols like: UART, SPI, I2C and more which can be used to connect serial devices like I2C, Liquid Crystal Display (LCD), Magnetometer, MPU-6050 Gyro meter + Accelerometer, Real-Time Clock (RTC) chips, Global Positioning System (GPS) modules, touch screen displays, Secure Digital (SD) cards *etcetera*.

c. Temperature and humidity sensor (DHT11)
The temperature and humidity chip or module with part number DHT11 is a dual sensor for temperature and humidity detection. In this work, the temperature and humidity of the cattle is measured using the DHT11 sensor. This sensor has a built-in dedicated Negative Temperature Coefficient (NTC).to measure temperature in degree Celsius (˚C) and an 8-bit processor to output the values of temperature and humidity as serial data.

d. NEO-6M global positioning system (GPS) module
The NEO-6M GPS module shown in is a very popular, cost-effective, high-performance GPS module with a ceramic patch antenna, an on-board memory chip, and a backup battery that can be conveniently integrated with a broad range of microcontrollers. The module has an in-built voltage regulator that supports a direct current input voltage between 3.3V to 5V ranges. The NEO-6M module includes one configurable Universal Asynchronous Receiver and Transmitter (UART) interface for serial communication, but the default UART or Transistor Transistor Logic (TTL) baud rate is 9,600. The data delivered by the NEO-6 GPS module follows the standard 0183 from the National Marine Electronics Association (NMEA), which supports one-way serial data transmission from a single talker to one or more listeners [10].

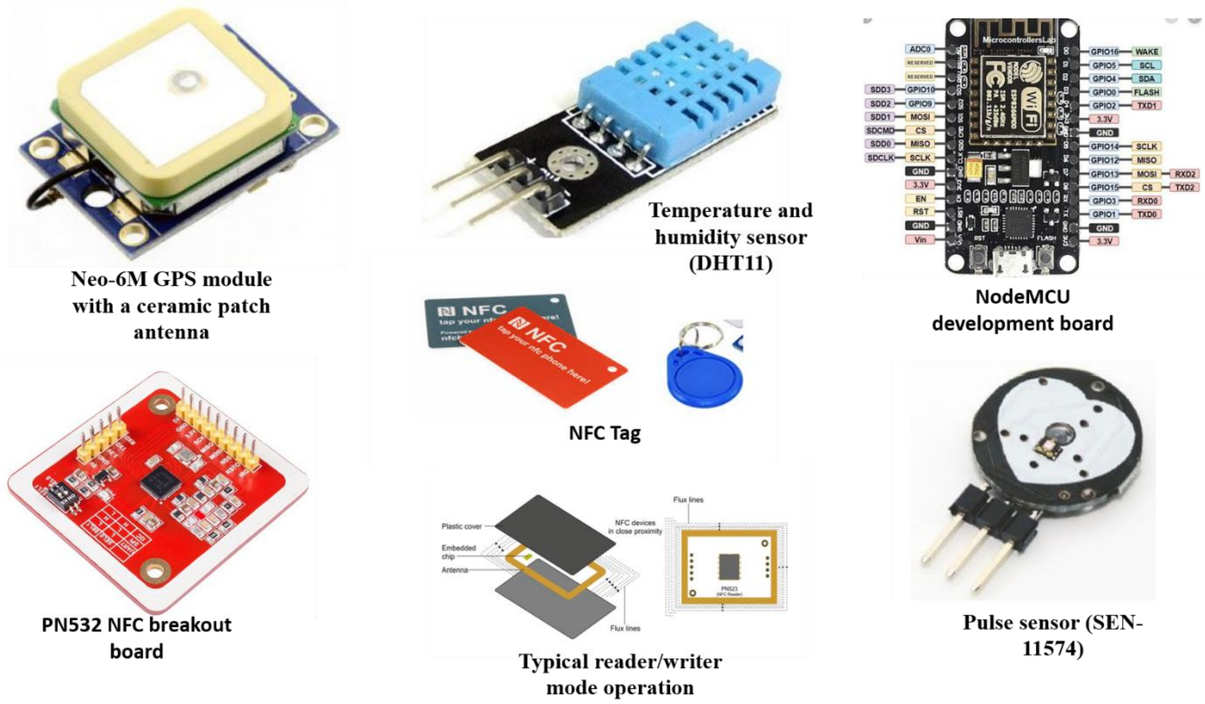


Figure 1: Description of all hardware components

2.1.2 Software development tools

The software development tools used include in this work are discussed as follows:

a. MariaDB: MariaDB was used for data and information storage. Its development is led by some of the original developers of MySQL. The MariaDB intends to maintain high compatibility with MySQL, ensuring a drop-in replacement capability with library binary equivalency and exact matching with MySQL Application Programming Interface (API) and commands.

Hypertext Mark-up Language (HTML): Since the proposed system consists of a web-based platform for tasks such as online remote cattle monitoring system, the HTML was chosen as a result of the fact that it is the standard mark-up language for creating web pages and web applications. Web browsers receive HTML documents from a web server or from local storage and render them into multimedia web pages.

Hypertext Preprocessor (PHP): It is a server-side scripting language designed primarily for web development and also used as a general-purpose programming language. This programming language was chosen for the development of the API which serves as an intermediary between the web application and the database.

JavaScript: To achieve the client-side execution of tasks in the web application of the remote livestock monitoring system, JavaScript was chosen. It is a widely used client-side scripting language on the web. It is used alongside with HTML and Cascading Style Sheet (CSS) to control some logical operations on the client side.

2.2 METHODS

2.2.1 System Description

System flowchart

The flowchart contains various sections of the modules that are interfaced to the NodeMCU microcontroller. First, the Global Positioning System (GPS) module is connected to the NodeMCU microcontroller to get latitude and longitude of a cow in the pasture. To achieve that, the Arduino IDE software was used to program the code. In the coding, two libraries: softwareSerial.h and TinyGPS.h were included. After these libraries were initialized, Tiny GPS object was created. If any data was received, then it will be fetched into the "**.** read ()" method. Then, if "**.** encode ()" method return true, longitude, latitude data will be printed on the serial monitor. Together with the other sensor output, the received data is delivered to the remote server. The longitude and latitude in the data are necessary for displaying the geographical location of the cattle monitored. This location is visible through a Google map Uniform Resource Locator (URL) which uses a key for authentication. The Google map URL is also attached to the SMS sent to the user. The Google Map API key was gotten from **https://console.developers.google.com.** [13]

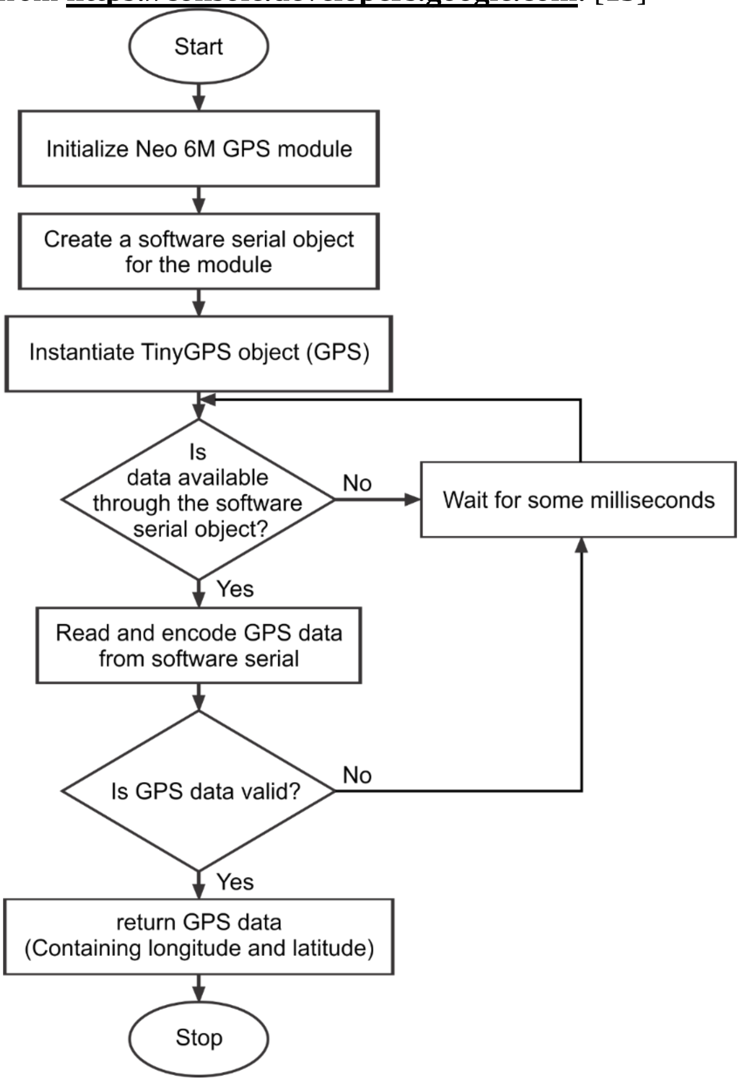


Figure 2: Flowchart description of the proposed system

The heart of the hardware component used in this design is the NodeMCU microcontroller which forms a choice over other microcontrollers or development boards used in other similar existing systems because of its compact size, memory and on-board Esp8266 Wi-Fi router for cloud computing. This ESP8266 chip as described by [9] is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor. The hardware components also include sensors such as temperature, humidity, pulse rate and location, and a multiplexer for interfacing these sensors to the one analog input pin of the NodeMCU microcontroller. Figure 3a shows the circuit diagram of the livestock monitoring system as formed from the connection of the various hardware components while Figure 3b shows the communication flow in the system and 3c shows the complete architecture of the entire system.

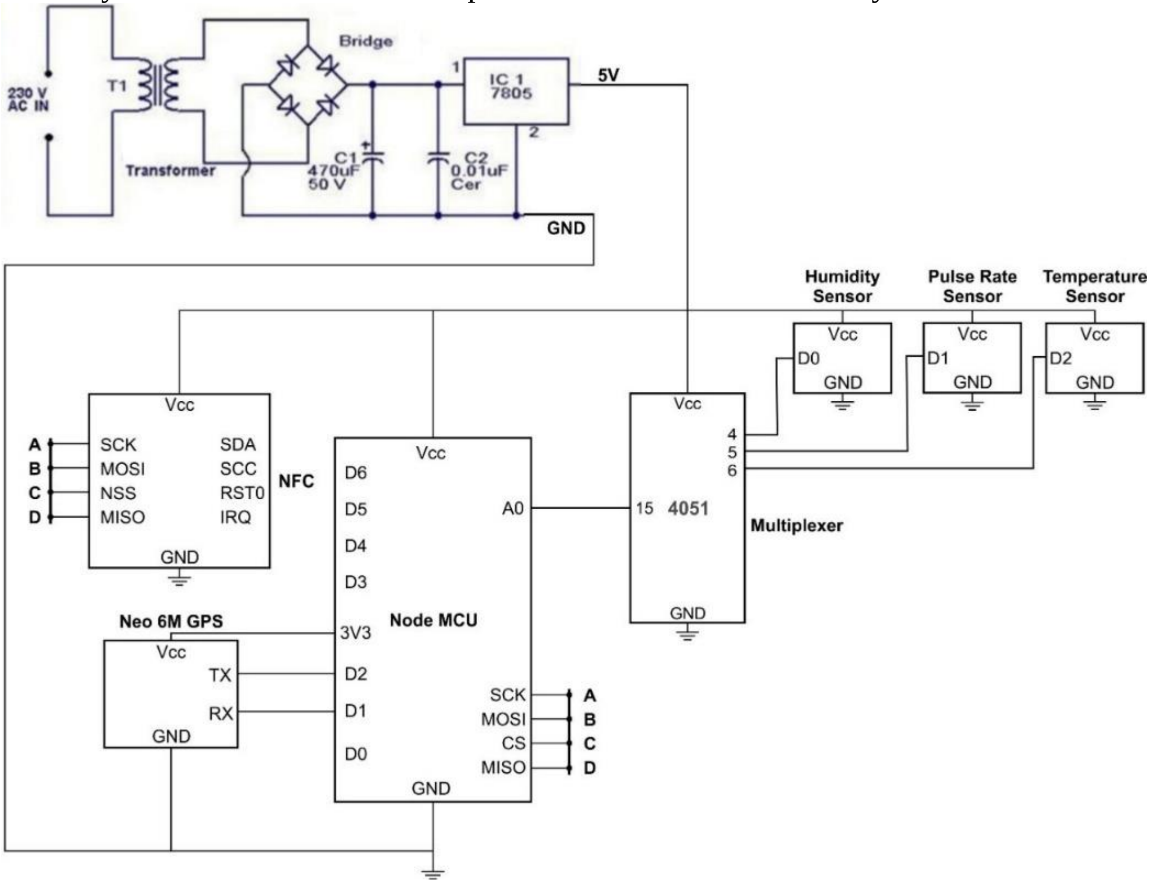


Figure 3a: Circuit Diagram for the system development

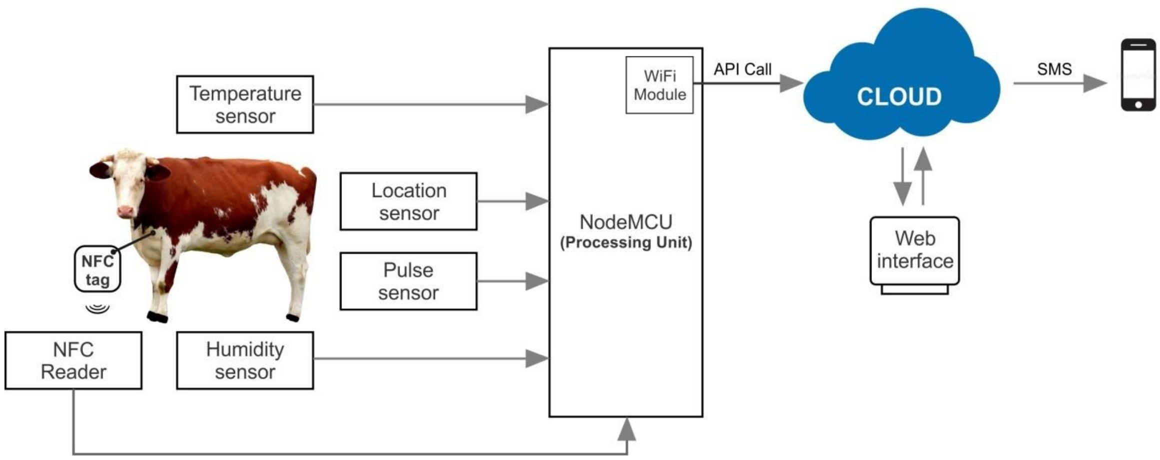


Figure 3b: Communication Architecture of the system

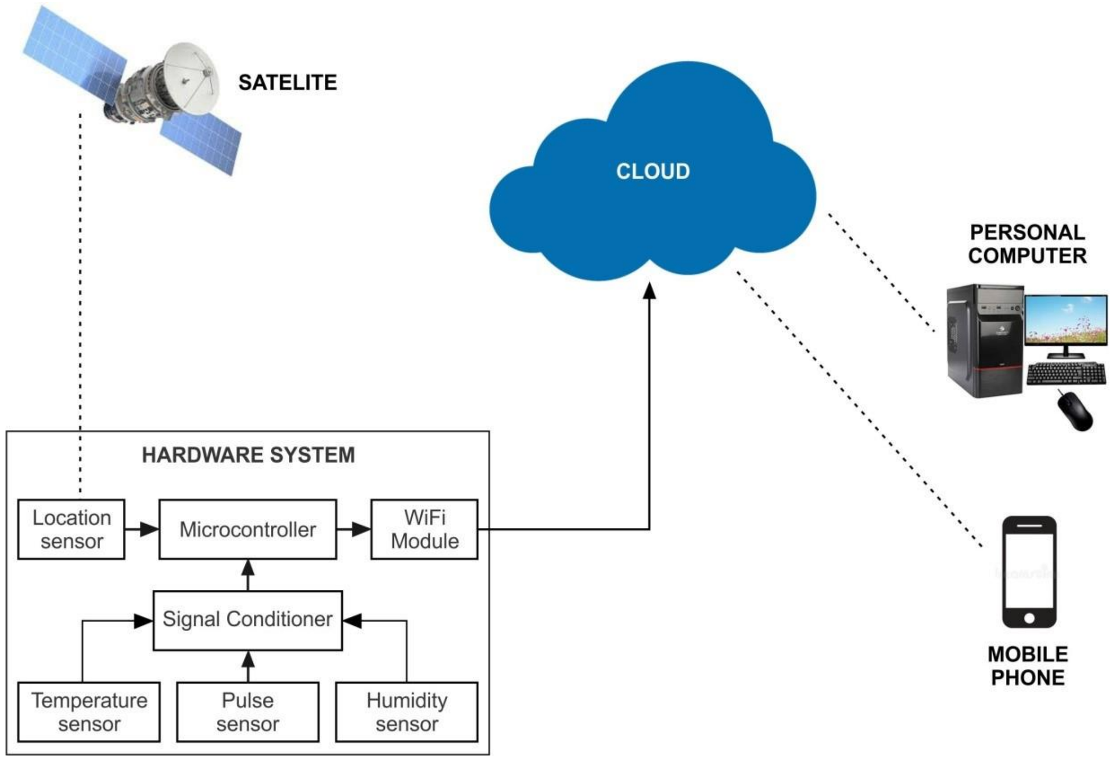


Figure 3c: Complete Proposed system Architecture

2.2.2 Software description

The system software establishes communication between the various hardware devices; making it possible for the creation of an interface between the hardware and the user application. The software development involves two ends program: the frontend and the backend program development. The backend and frontend were developed using Laravel and Vue respectively. Laravel is a PHP framework that enables developers to build application using the Model-View Controller (MVC) software architecture while Vue is a JavaScript framework for developing the user interfaces of web applications. The Visual Studio Code and Arduino Integrated Development Environments (IDE) were the two selected IDEs used for the programs. The program that controls the hardware system was written in C++ on the Arduino IDE while the frontend and backend code of the web application were written on the Visual Studio Code IDE. The algorithm used to achieve the functionality of the software is shown thus:

i. Initialize all the hardware components
ii. Set the interval to 12 hours
iii. Connect the hardware system to the remote server
iv. If the system was successfully connected to the server, proceed to 5 else go to 3
v. Get the details about livestock such as temperature, humidity, location and pulse rate
vi. Send the captured data to the remote server
vii. Wait for 12 hours
viii. If elapsed time is equal to 12 hours, then go to 5 else go to 7

3.0 Results and Discussion

3.1 Implementation and Testing

i. Web application

The web application, which is developed using PHP programming language, provides a platform for virtual livestock remote monitoring and data repertoire from which the various sensors: temperature, humidity, pulse rate, location and other parameters are collected, stored and retrieved through any computing devices-mobile phones, tablets, laptops, desktops, etc. for use at anytime and anywhere. The web application provides an optimized Application Programming Interface (API) that allows the hardware system to communicate with the server. It also keeps track of the database and the interface is user friendly which makes it easy to be used by any farmer who is unaware of the current technologies.

For the purpose of avoiding unauthorized access to the administrator area, the system provides an administrator login page for access authentication. The PHP language provides various cryptographic operations: Hash functions such as MD2, MD5 and SHA-1; asymmetric encryption such as RSA; and symmetric encryption such as DES, triple DES, AES etc. We have implemented SHA-1 to secure the login password of the system user. Figures 1 to 4 show the web interface of the developed system.

ii. Login section: is the part that provides a security layer for the web application. It ensures that data are secured from unauthorized users. In this section, a user is expected to supply a username and password in order to login. If a user is successfully logged in, he/she is granted access to use the system. The login page is shown in Figure 4.

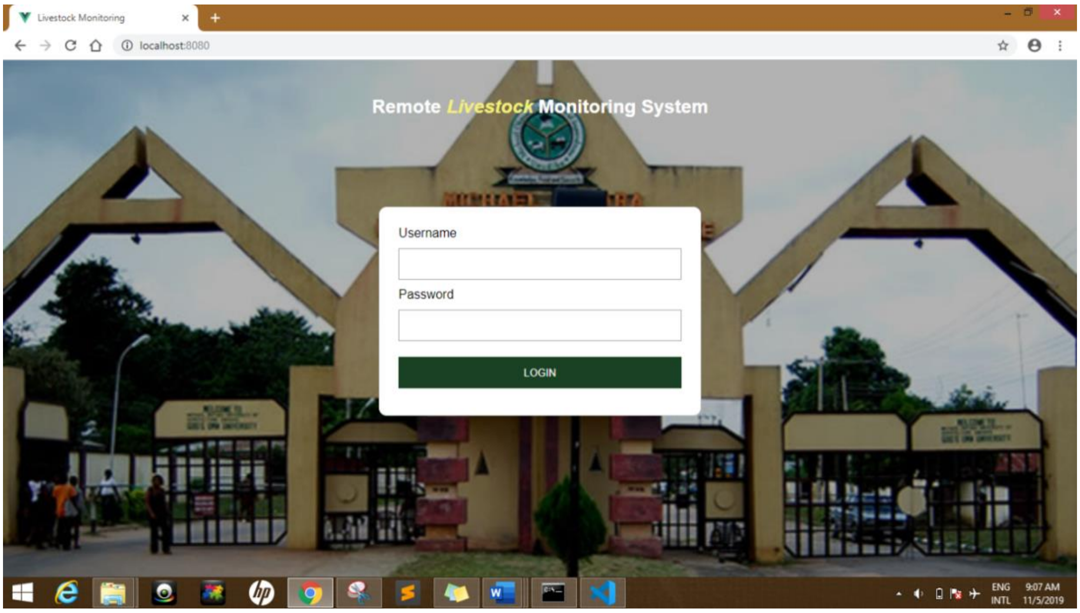


Figure 4: System login page for password authentication

iii. Home page: After a successful log in, a user is redirected to the home page where he/she can view the details of livestock located remotely. These details are the ones captured by the hardware system and sent to the server through the developed API. From this page, the unique ID of a livestock can be entered to retrieve the details of that livestock. Details of all the livestock can also be retrieved. Retrieved data can be filtered using date and time. The home page is shown in Figure 5.

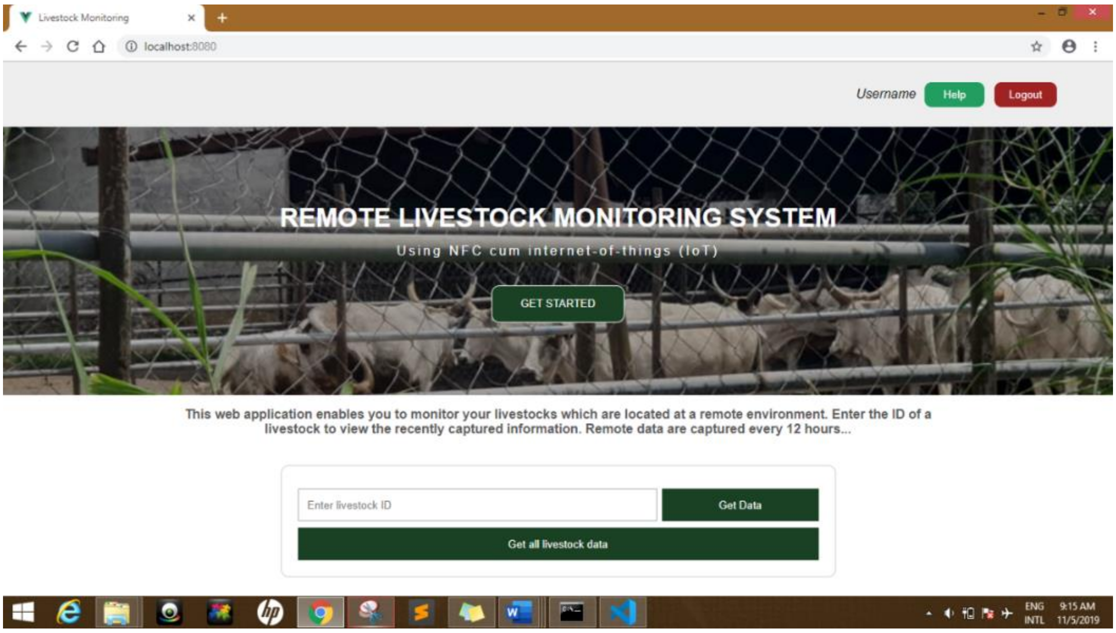


Figure 5: System home page after successful login

iv. Help page: is a page on the web application that provides relevant tips about the remote livestock monitoring system. This is to ensure that the system can be used by anybody no matter the level of intellectual ability. The interface is shown in Figure 6.

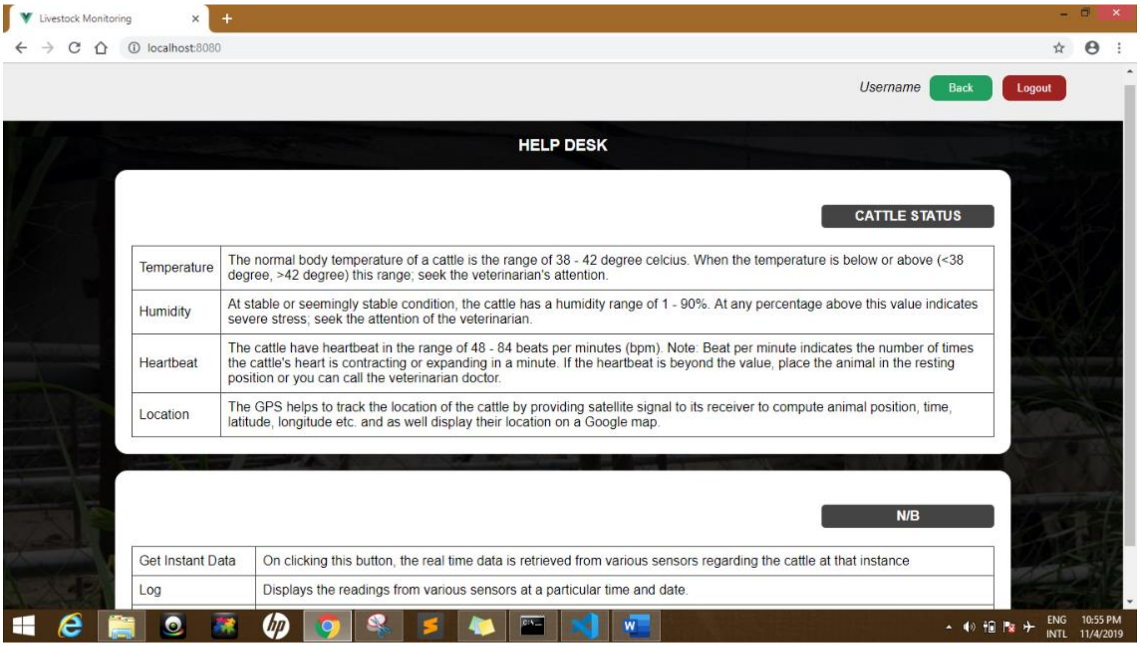


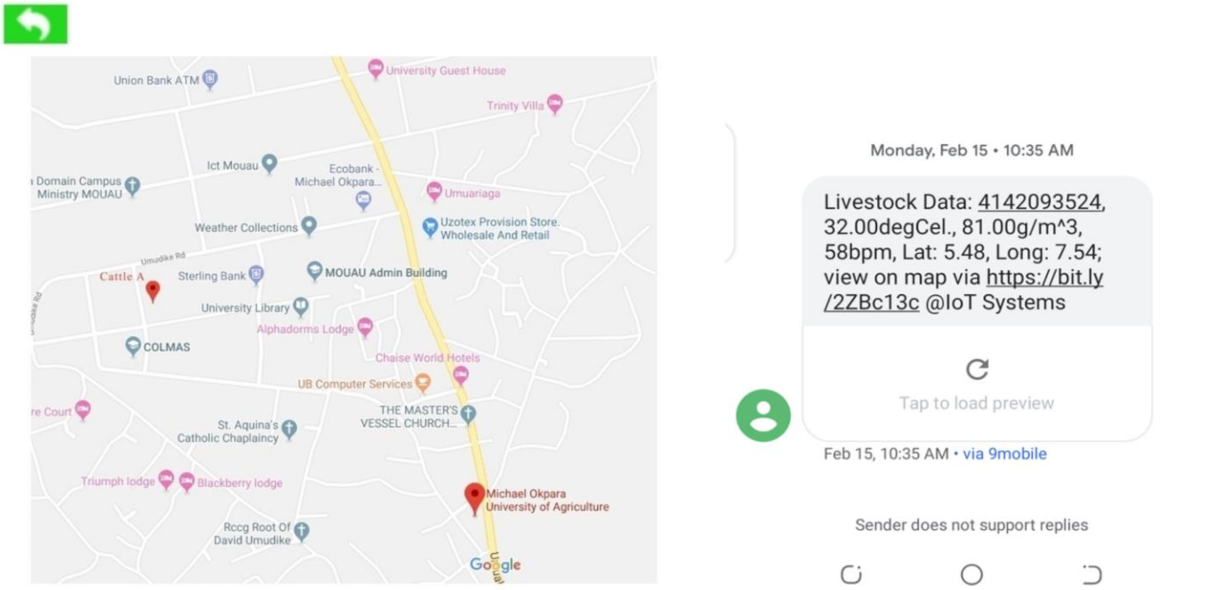
Figure 6: System help menu for user tips

v. Google map

The system is integrated with maps that are based on Google Maps data to the web application with the help of Google Maps Application Programming Interface (API). The API automatically controls access to Google Maps servers. Figure 7 shows the location on Google map obtained in Michael Okpara University of Agriculture Umudike during the testing phase of this work.

vi. Short messaging service (SMS)

For monitoring the cattle's health parameters, this work includes the feature which will send SMS to the farmer or herder on request. The SMS also includes the location value of latitude and longitude of the cattle. A distinct feature of this design is the attachment of a link with the SMS, so that farmers can access cattle's location by using Google map through their mobile devices as shown in Figure 7.



Animal Location on the Map SMS notification with location details

Figure 7: Location of animal and SMS notification with map details

3.2. Hardware implementation result

The results after the hardware implementation are presented using pictures of the prototype system. Figure 8 shows the prototype in an unpowered state and the display when it is in a powered state and enclosed in a rectangular plastic chassis with sensors attached at the top and front corner of the chassis emitting light. At the powered state, the health parameters and the location information are not captured until the NFC tag is brought in close proximity with the PN532 reader. When the Unique Identity (UID) of the tag is captured, other parameters are also captured through the sensors. As a prototype system, communication with the remote server is done when the number of captures is divisible by 5. The activities can be observed through the serial monitor as shown in Figure 9. In relation to [4] which used Zigbee technology to receive and transmit signals from animals through a graphical user interface (GUI), this proposed system used NFC technology to transmit the received signals from the animal which are being tracked and the information are managed through a web-based interface. Both proposals leveraged on the power of sensors to generate sensory data form the animals. Such sensors include the temperature sensor, heart rate sensor, pulse rate sensor and the respiratory sensor.

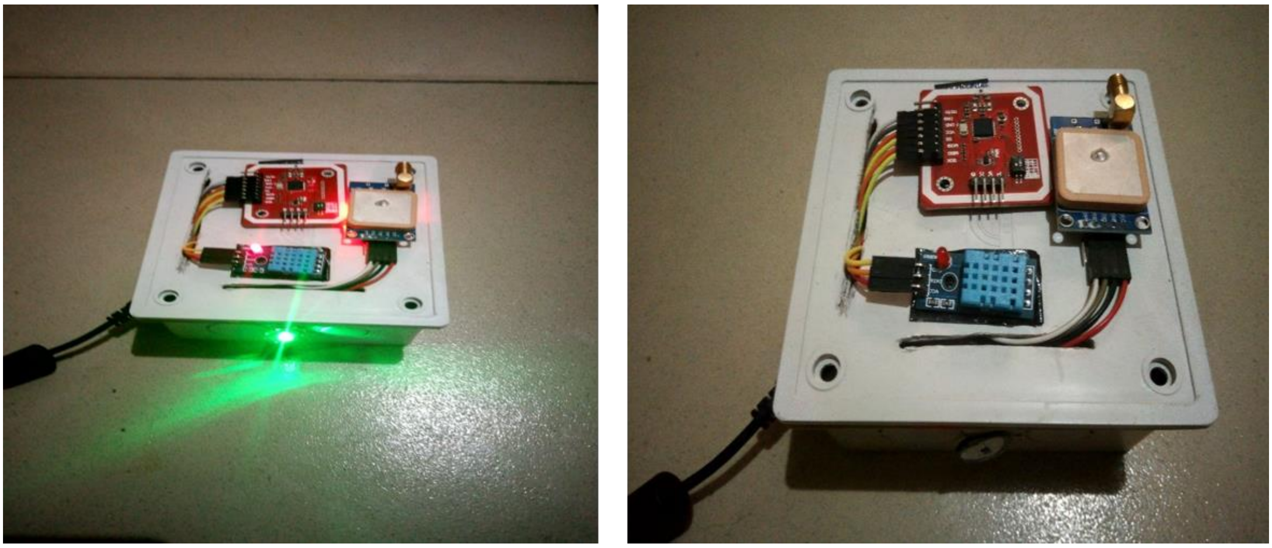


Figure 8: The Complete prototype and the function state.

4.0 Conclusion

Farm animals have become an integral part of human lives as they dine with us, they serve as food to man, they provide clothing through hide and skin, their dung serve as nutrient to the soil, and their resources help to boost our economy. In spite of the above numerous usefulness of these animals to mankind, its health has become a threatening global issue that demands urgent attention. Like animals, humans also are being affected by various kinds of diseases. To this extent, innovative approaches, like the use of internet of things (IoT) technology for livestock health management, has gained recognition. These IoT devices encompass sensors and actuators that are at various levels of integration, but are making their way into the practical use and application in the domain of animal health. The adoption of an IoT cum Near Field Communication technology in this work for the development of an intelligent remote livestock monitoring in Michael Okpara University of Agriculture Umudike has really proven to be reliable, flexible, cost effective and simple.

This system could be adapted to any farm settlement regardless of the cattle production system in use to gather ecological parameters that would enable farmers monitor animals from outside the farm. This system would also improve farmer profitability, productivity and consumer livelihood with better work environments, food safety and food security. After appropriate design, implementation and testing, the system proved to be efficient, functional and reliable NFC-based remote livestock monitoring system.

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