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Development of a Remote Monitoring and Localisation of Smart City Infrastructure for Securing Telecommunication Underground Duct and Streetlight in a Metropolitan City

[1]*James Agajo, [2]Onyebuchi Nosiri, [3]Mathew Emeka Nwanga, [4]Chukwuemeke Henry, [4]Abdulqawiy, O.O

[1]Department of Computer Engineering, Federal University of Technology, Minna, Niger State, Nigeria, james.agajo@futminna.edu.ng

[2]Department of Electrical/Electronic Engineering, Federal University of Technology Owerri, Imo State, Nigeria, buchinosiri@gmail.comcom

[3] Department of Information Technology, Federal University of Technology Owerri, Imo State, Nigeria, emwanga95@gmail.com

[4] Department of Electrical and Computer Engineering, Federal Polytechnic Auchi Edo State henroify@gmail.com

**Corresponding Author: James Agajo;* james.agajo@futminna.edu.ng

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Abstract: *Development of A Remote Monitoring and Localisation of Smart City Infrastructure involve Monitoring of different infrastructures, previous monitoring in time past were done manually making it very difficult and cumbersome with little efficiency .Various works have been developed to solve this problem of conventional monitoring in modern city, but most of them don't monitor accurately because they turn out to be expensive when implemented on a large scale .This work developed a system for remote monitoring and localization of city infrastructure with particular emphasis on streetlight and underground duct using wireless sensor network, Global Positioning system (GPS) with other associated items. The system is capable of monitoring unauthorized access and tampering of these infrastructures within the smart city with real-time feedback features which can be uploaded to a dynamic database in the cloud server. The system was able to monitor these infrastructures accurately.*

Keywords: *Smart City, Security, Infrastructure, Remote Monitoring, Wireless Sensor Network, IoT.*

INTRODUCTION

Insecurity has become a challenge faced by developed and developing countries. With Nigeria being a typical example. Furthermore, the security of life and property is of essence for any developing country. Without adequate security, a country becomes prone to vulnerabilities and threats (Agajo *et al.,* 2016). With the threat of securing infrastructure, achieving the country's goal is put to task.

With the development in urban places, city infrastructure such as street light and Telecommunication duct have therefore become necessary, the need to deploy more and more of this infrastructure suffers due to activities of vandals and theft. The consequence of such problems is that it disrupts the production process and prevents investors from coming to invest in a country like that. This work intends to overcome this problem using remote monitoring with geo-location facilities for real-time monitoring and tracking of city infrastructures. Government and Industries benefit from nearly every form of remote monitoring not only because it prevents theft, loss and damage but also because a large chunk of investments is usually put into infrastructures and their replacement and maintenance costs are extremely high. Remote wireless technology offers a relatively inexpensive solution to monitor revitalization efforts by offering a truly wireless' solution that does not need to be connected to the intending infrastructure which can be very expensive.

Wireless Sensor Network (WSN) is gaining increased attention because of its suitability for enormous range of applications with respect to remote monitoring. The importance of WSN that makes it so attractive for different application in different areas due to the fact that the sensors are small, cheap, simple and easy to deploy. Many potential applications can utilize WSNs such as habitat monitoring, health application, structural stability monitoring and military application (Akyildiz, and Vuran, 2010). WSN uses radio frequency transmission to transmit data from node to base station. There are various type of WSN which like Bluetooth, ZigBee, infrared and Wi-Fi. The Wi-Fi is IEEE (802.15.1) standard which is a transmitting medium with a very short range, it communicates between 8 devices and uses the 2.4 GHZ,915MHz and 868 MHz radio bands to communicate, Wi-Fi and the ZigBee which are proprietary based medium of WSN based on IEEE (802.15.4) standard (Askay *et al.,* 2018). It is a low power consumption and a simple configuration and there is also infrared which uses line of sight for transmission (Asma *et al.,* 2012). The deployment of wireless sensor network in the field of infrastructure monitoring has improved efficiency, productivity and profitability in the various system of monitoring practice. The real time information gathered from the infrastructures helps the system by reducing the cost of maintenance and also helps in also reducing cost by tracking in the advent of theft and recovering the infrastructure's when deployed in the field they communicate wirelessly and are often self-organized (Boyinde and Akintola, 2009).

Theft of various infrastructures such as streetlight in a metropolitan environment has been a lingering problem for some time now, where hoodlums/criminals will vandalize these infrastructures ranging from street light to solar panels to underground duct without any type of remote monitoring security check put in place to counter such actions, all these pose significant challenge to all the residence and also investors of such a city .Using Abuja city in Nigeria as a case study ,there are no form of security for underground city facilities and tracking their location when stolen could be challenging and also pose threat at actualizing Country's Smart city dreams, This work proposes an effective remote monitoring and localization of smart city infrastructures with underground Telecommunication Duct and street lighting systems this will drastically reduce the rate at which these infrastructures are stolen and vandalized.

A smart city is an urban development using Information and Communication Technology (ICT) and Internet of Things (IoT) to provide useful information to effectively manage resources and assets. The concept is shown in Fig. 1. Smart city involves data collected from citizens and mechanical devices, that are processed and analyzed to monitor and manage traffic and transport systems, power plants, water supply networks, waste disposal, etc. Their main goal is to reconcile technological innovation with the economic, social and ecological challenges of the city of tomorrow (David, 2009). They use different types of electronic Internet of Things (IoT) sensors to collect data and then use insights gained from that data to manage assets, resources and services efficiently, in return using that data to better improve the operations across the city. This includes data collected from citizens, devices, buildings and assets that is processed and analyzed to monitor and manage traffic and transportation systems, power plants, utilities, water supply networks, waste management, crime detection, information systems, schools, libraries, hospitals, and other community services (Juray and Jan, 2011).

Fig. 1 Smart city concept

Wireless Sensor Network is a sensor network that consist of spatially distributed low-power multifunctional autonomous network devices that use sensor to gather physical and environmental data. Each device is usually referred to as nodes as shown in Fig. 2. The basic component of a sensor node is sensors unit, a power unit, a communication unit, an ADC (Analog to Digital Converter) and a CPU (Central Processing Unit) which is shown in Fig. 3. The sensor node is micro electro-mechanical system that senses or measure physical data either physical or environmental condition such as pressure, temperature, motion, light. The continual analog signal being sensed by the sensors is digitized by an analog to digital converter and sent to a controller for analysis and processing. The nodes are of very small size, operated in high volumetric densities and consume extremely low energy. Each node has a particular coverage area for which it can reliably and accurately report the condition of physical or environmental condition that it is observing. Consumption of energy in the sensor are usually signal sampling, signal conditioning and analog to digital conversion (Agajo *et al.,* 2016; Salihu *et al.,* 2017).

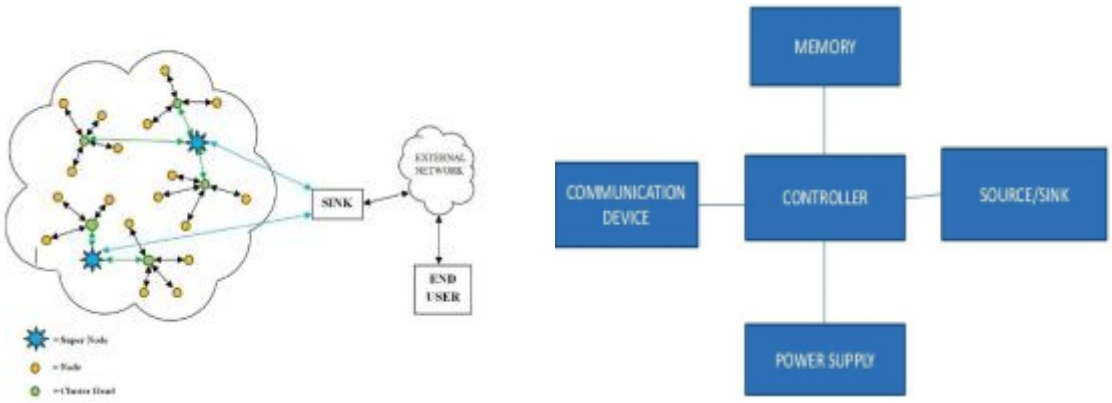

Fig. 2 Node component of the WSN

Wireless sensor network is known for their reliability, accuracy, low cost, efficiency, ease of use with its flexibility and they are built on the IEEE 802 standards. As shown in Fig. 3, The four common wireless sensor network topologies are:

a) Point to Point Network Topology,
b) Star Network Topology,
c) Tree Network Topology, and
d) Mesh Network Topology.

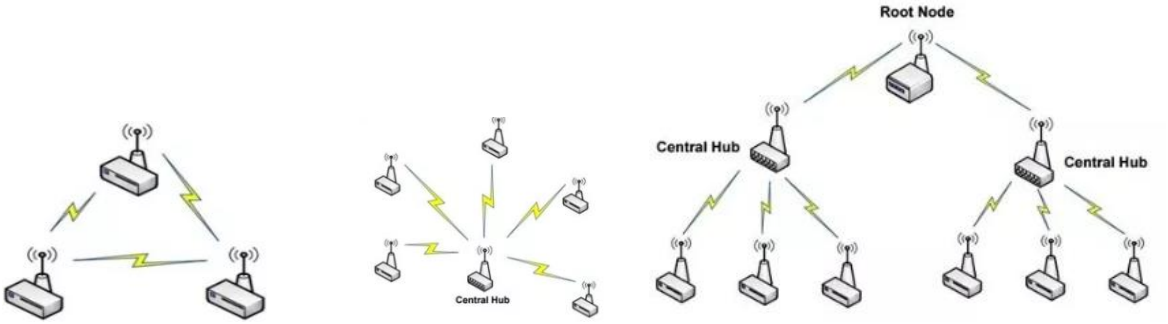

Fig. 3 WSN Topologies

Wi-Fi stands for wireless fidelity and is used to define the wireless technology in the IEEE 802.11b standard. It operates in the unlicensed 2.4 GHz radio spectrum; it supports variable data up to 11 Mbps. Wi-Fi is a system of wirelessly connecting devices that uses radio waves that allows for connection between devices without the expense of cumbersome cables and also without needing them to face one another (Vandana, 2006). There are several specifications in the 802.11 family:

i. *802.11* - applies to wireless LANs and provide 1 or 2 Mbps transmission in the 2.4 GHz band using either frequency hopping spread spectrum (FHSS) or direct sequence spread spectrum (DSSS)
ii. *802.11a* - an extension to 802.11 that applies to and provides up to 54 Mbps in the 5GHz band. 802.11a uses an orthogonal frequency division multiplexing encoding scheme rather than FHSS or DSSS
iii. *802.11b* also referred to as 802.11 High Rate or Wi-Fi is an extension to 802.11 that applies to wireless and provides 11Mbps transmission (with a fallback to 5.5,2.0 and 1.0Mbps) in the 2.4GHz band. The 802.11b uses only DSSS
iv. *802.11g* – applies to wireless LANs and provide 20+ Mbps in the 2.4 GHz band.

A IoT of researches and work have been carried out on some form of infrastructure such as street lightning, solar panel, fibre optic cable monitoring all with different idea and perspective, each with their strength and weakness. Sang and Soo (2015) proposed a remote monitoring of the fibre of optical cables. In their work they proposed a system whereby the monitoring and control is achieved with the use of automatic continuous probing of the fibre by means of reflectometer and also a remote fibre test system (RFTS) which contains a remote test unit (RTU) and also a Geo information system (GIS), a Test system controller (TSC) .The reflectometer is used to monitor traffic carrying fibre which makes fault detection in a cable possible.The GIS application makes it possible to represent information on the localization of fault. Senthilnath *et al.* (2015) proposed a pipeline monitoring using multi-sensors. The author utilized a GSM sensor network to detect pipeline location, a GSM module to send notification while the sensor used to monitor the pipeline were PIR motion sensor, sound sensor and vibration sensor. The design consists of an ATMEGA8 micro-controller device, PIR motion sensor, vibration sensor, sound sensor, LCD, GPS, GSM module, 74HC4052 serial port multiplexer and power supply. When there is presence of possible vandal in the area detected, the system will detect and send GPS coordinate of the location through the GSM network to the appropriate authorities. Agajo *et al.* (2016) proposed an intelligent street light system based on WSN.

The system uses pyroelectric infrared sensor(PIR) to detect pedestrian and vehicles. Toanna (2012) proposed a remote monitoring technique with geo-location facilities for real-time monitoring and tracking of security personnel and equipment. The system comprises of an Arduino Uno which is used for processing all the functionality of the module integrated with it, a GPS module which is used for capturing the longitude and latitude of the security personnel or the equipment being tracked and transmit the data, a GSM module helps in communicating remotely the location being captured by the GPS and transmitted to the user, a buck converter act as a step down converter due to the fact that the system consumed a lot of power it was used to extend the battery life ,reduce heat and also allow for small gadget to be built while the battery was to supply power to the system. The system also has a GUI application which was developed using C# and a SQL database system, the application was used to track each security and equipment location and saves the tracking details on a database.

MATERIALS AND METHODS

This section provides information about the procedures used in developing the remote monitoring system and the methods to be employed for accomplishing this work. The system comprises of hardware components and software to run on the Arduino Nano incorporated. The system block diagram is shown in Fig. 4. The component list is as follows:

i. Ebyte 32-TTL Lora Transceiver
ii. SW-420 Vibration Sensor Module
iii. ACS712T Current Sensor
iv. PIR Sensor
v. Power Supply
vi. GPS Ublox Neo 7M
vii. Sim900L GSM Module
viii. Arduino Nano
ix. Voltage Regulator
x. LED
xi. Solar Panel
xii. Lithium Battery

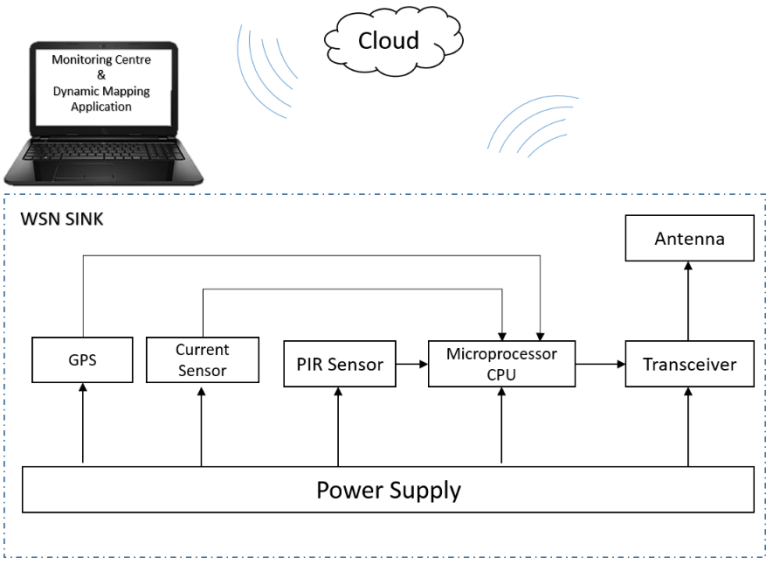

Fig. 4 System Proposed Block Diagram

The remote monitoring system is made up of the hardware and software components. The system is subdivided into two sections, which are the underground duct and the streetlight. The hardware is comprised of the controller unit, sensing unit, power supply unit, an antenna, a current sensor, a PIR sensor. The software components are the web GUI. The remote monitoring system block diagram shows the interaction between different components. The Arduino Nano functions as the control unit of the machine. It is the component that receives data from the sensing unit, manipulates the data and provides feed back to the output unit. The components used in the system and the overall integration of these unit will result in the intended Remote Monitoring System. Agajo et al (2016)

A. Controller Unit

The control unit consist of an Arduino Nano. Which is a controller board based on the ATmega328P(data sheet). The Arduino Nano has a wide range of application .It has 22 input/output pins in total of which 14 of these pins are digital pins while 8 of them are analogous pins. Other features of this micro controller are ,It has a crystal oscillator of 16 MHz, It also has a reset button, A key advantage of this micro-controller is that it supports different ways of communications which are the :Serial protocol,I2C Protocol and SPI protocol .The control unit has a plethora of ports that enables the input and output units to be interfaced appropriately. The security – data encryption and information hiding protocols will be run on the control unit, it will also control the routing of data from different node. It will also send the data to the cloud. The control unit will receive the data collected from the current sensor, PIR sensor after which it will process and arrange the data before sending the data to cloud which it also received at the monitoring centre. If and when the information is verified and the location of the incident will have responded to by issuing the appropriate alarm condition remotely.

B. Power Supply Unit

The power supply will power the control unit. The input units will receive power from two lithium battery with a rated output of 7.4V and 500mA. However, with the use of a voltage regulator ,5V will be pushed to the Arduino Nano for the master node while for other nodes are powered with a single lithium battery which is having an output of 3.7V.

C. PIR (Passive Infrared) Sensor

PIR sensors uses the concept of Pyro electricity to detect the presence of persons or moving objects. This is an electronic sensor which measures infrared(IR) light radiating from objects in its field of view. Which will be used to sense the presence of the movement of people around the devices to be monitored. PIR are inherently low-cost, power components in sensors capable of developing an electrical signal in response to a variation of the incident thermal radiation, the circuit is shown in Fig. 5.

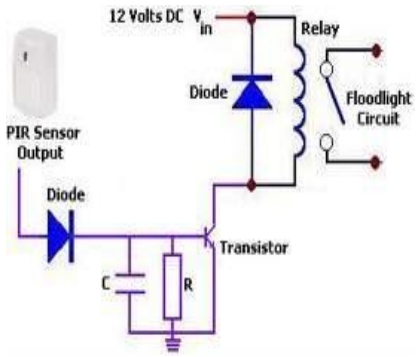

Fig. 5 The circuit diagram

D. Current Sensor

This is a device incorporated in the system that detects and converts current easily to an easily measured output voltage which is proportional to the current through the measured path. When a current flows through a wire or in a circuit, voltage drop occurs. Also, a magnetic field is generated surrounding the current carrying conductor. Both of these phenomena are made use of in the design of current sensors. The ACS712T Current Sensor will be used for this project .This module uses the famous ACS712 IC to measure AC or DC current using the hall effect principle .It can measure current ranging from +5A to -5A, +20A to -20A and +30A to -30A with the user selecting the right range for the project due to the trade-off for accuracy for higher range modules. This module outputs Analog voltage(0-5V) based on the current flowing through it.

E. Communication Link

This unit comprises of the GPS and the GSM module and helps to get the coordinates of the ongoing monitoring, then communicates it through GSM network to concern authorities. Thus a GPS and GSM modules were used to achieve this stage. The Global Positioning System (GPS) is a space-based navigation system that provides location and time information in all weather conditions, anywhere on or near the Earth where there is an unobstructed line of sight to four or more GPS satellites. The system provides critical capabilities to military, civil, and commercial users around the world. The GPS module is shown in Fig. 8.

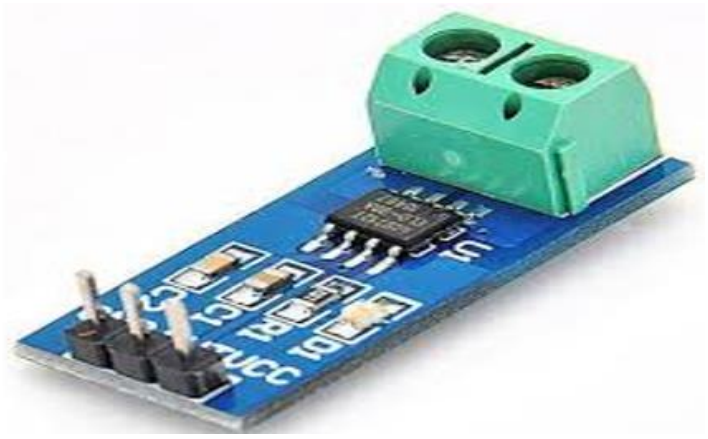

Fig. 6 Current sensing modules

Fig. 7 GPS Sensor Module

In the case of intrusion detection, the micro-controller reads the coordinate of the location and sends an update to the monitoring centre with an alert flag of a human presence been detected using the available GSM network.

The major Nigeria network providers (MTN, Airtel, Etisalat, and Globacom) have been used as a means of communication between the remote monitoring system and the GSM module on the devices.

F. GSM Module

A GSM (Global System For Mobile Communication) module is a digital based mobile telephony device system which uses time division multiple access (TDMA) technique to enable wireless communication between sender and receiver. For the completion of this project , we make use of the GSM module in sending and receiving short messages. The module is equipped with a SIM (Subscriber Identity Module) which gives it the functionality of able to sending and receiving SMS to respective personnel according to how it is been programmed without any limit in range. The module been used is a SIM800L GSM module. The SIM800L is a miniature cellular module that enables GPRS transmission, sending and receiving SMS and make and receive voice calls. Low cost and small footprint and support quad band frequency making this unit ideal for any project that require long distance connectivity. After connecting the power-module boots, searches for the cellular network and connect automatically. A LED board displays the connection status (no network coverage - rapid flashing connected - slow blink). The module also has two antennas embedded in it, the first one is made up of wires (which solders directly to NET pin on PCB) which is very useful for narrow places. While the second one is a PCB antennas with double sided tape and attached pigtail cables with IPX connector which has an advantage of having better performance and also allows for us to put the module in a metal case so long the antenna is outside.

Fig. 8 GSM Module

G. 3GPS Module

The GPS module being used is the Ublox Neo 7M GPS module which is a module that includes an HMC5883L digital compass. Its characterized by its high sensitivity and also low power consumption. It has 56 channels and an output precise position updates at 10 Hz. It comes with a moulded plastic case which keeps the module protected against the elements making it ideal for this project. The Ublox Neo 7M GPS module uses an active circuitry ceramic patch antenna to provide excellent GPS signal which outperforms other GSM module available .Its also comes with a rechargeable backup battery to allow for HOT start and also includes an EEPROM to store the configuration settings (Wang, 2006).

Fig. 9 Ublox NEO 7M GPS

H. Transceiver

A transceiver device is incorporated comprising of both transmitter and a receiver, these two are combined and share common circuitry or a single housing. When no circuitry is common between transmit and receive functions, the device is a transmitter-receiver System. The transceiver can handle both analog and digital signal. The Ebyte 32-TTL Lora Transceiver will be used for design of this projects, this is a 100mW wireless transceiver module with LoRa spread-spectrum technology, operates at 410~441MHz . The module adopts LoRa spread-spectrum technology, which means the transmitting distance is much longer than before. The advantage of this module is that it concentrate power density with better anti-interference performance (Xiao *et al.*, 2010; Ajao *et al.*, 2016)

Fig. 10 Ebyte Lora Module

I. Hardware Design

In this paper, a micro-controller (Arduino Nano) based embedded hardware system is built to monitor any intrusion into the monitored infrastructure and was accomplished with the use of an Arduino IDE. The Arduino IDE(Integrated Development Environment) which is a multi multi-platform program that is written in java programming language. Its functions as a tool for writing and uploading programs to the Arduino Nano boards .It supports the C and C++ programming language using special rules for its code structuring .Arduino IDE supplies a software library from the Wiring project ,which provides many common input and output procedures. User-written code only requires two basic function for starting the sketch and the main program loop, that are compiled and linked with a program stub main() into an executable cyclic executive program with the GNU tool-chain, also included with the IDE distribution. The Arduino board was programmed using C++ which is a general purpose cross-platformed language created as an extension of the C programming language.

The language has expanded significantly over time and modern C++ has object oriented ,generic and functional features in addition to facilities for low level which was used for the programming of all the controls .

J. Developing the Street Light Circuit

The street light module comprises of a power unit which is a 5V 3500mAH Lithium battery with a solar panel being provided as a failsafe and the components that needs power supply which are the Arduino Nano, Light Bulb, PIR sensor, GPS sensor, GSM sensor, transceiver. The street light module also consist of the Arduino Nano which contains the micro-controller that does the control operation and the component being attached to the Arduino Nano being the PIR sensor, GSM module, transceiver. In the design of this project, 3 street light where constructed for the prototype out of which there is a master streetlight while two others function as slaves. All data from the two slaves are all routed through the master street light to the cloud server. See Fig. 11 and 12.

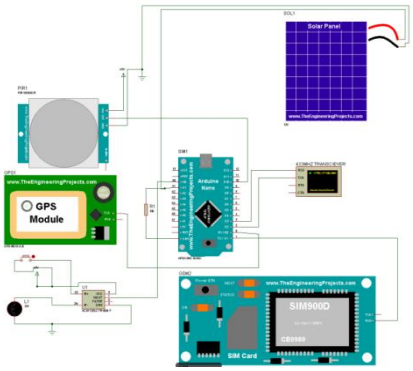

Fig. 11 Master Streetlight Circuit

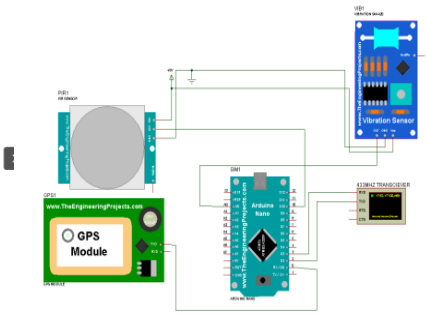

Fig. 11 Slave Streetlight Circuit

K. Developing the Underground Duct Circuit

This module comprises of the design of an Underground Duct prototype which will consist of a 1(one) meter PVC pipe which will serve as the prototype and the control units comprises of Arduino Nano which is integrated with other functional components such as PIR sensor, GPS module and a vibration sensor .The vibration sensor is used to detect damages or tampering attempt along the underground fiber optics cable channel while also the PIR sensor will be installed on the underground duct itself to detect and unauthorized access when an intruder attempt to access the duct. The system is powered by a 5V lithium battery . See Fig. 12.

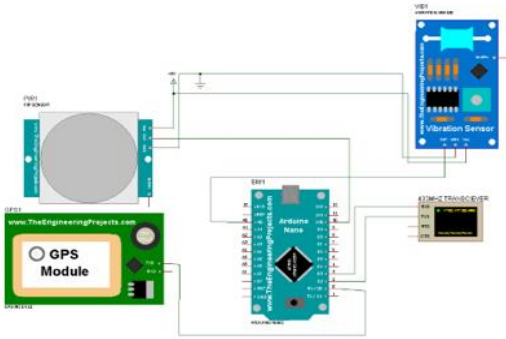

Fig.12 Underground duct circuit diagram

L. Software Design

The Software design process is a sequence of steps that enables the designer/programmer to define all scope of the software for building. Creative skills, past experience, a sense of a good graphical user interface (GUI) are critical success factors for a slick software design. During the course of this research work, some factors were taken into consideration in the software design phase which includes;

i. The platform the software is meant to run whether it will be on the web, or android phone, on a personal computer, on a micro-controller such as Arduino, or on a microprocessor such as raspberry pie.
ii. The language to be used for the software design, as well as the language level i.e., object oriented, structural or procedural programming language.
iii. The maintainability of the software which is how flexible the software can be in terms of bug fixing and applying updates.
iv. The reliability of the software to providing the solution to the problem ascribed within the software design phase of this project without or with minimum negligible error.
v. Security of the software was taken into consideration as there is always a need to protect and secure data accessed and created by the software from intruders or attackers.

After careful evaluation of different factors and consideration of available resources, a web hosted application was selected to be the platform on which the software control and monitoring applications would be built. The software design of this project comprises of the development of a web based application integrated with a cloud server for the storage, monitoring and maintenance of data retrieved from the different nodes. The web application provides an interface in which all records of any intrusion, vandalism or faulty facilities are stored and the proper corresponding operations are carried out

M. Cloud Server Design

A cloud server is a virtual server(rather than a physical server running in a cloud computing environment in which it can be built, hosted and delivered via a cloud computing platform and can be accessed remotely. This is where all the data collected from all the sensor nodes are stored .Cloud servers offers various advantage as opposed to physical servers for this project such as faster service, easy scalability and easy to upgrade, see Fig. 13.

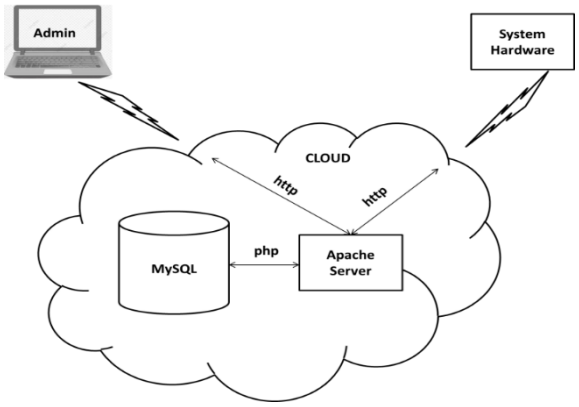

Fig. 13 Cloud Server

N. Apache Web Server

Web servers are applications/tools used to serve various range of files such as mails, pictures, text document, videos on the internet as they act as a middleman between the servers and client machines. They function by making a pull requests for contents on the server when requested by a user and delivers it to the web. Various servers exist such as file servers, database servers, mail servers and web servers which all uses various kind of server software. Apache Web Server is a software that runs on a server with its primary job being to establish a connection between a server and the browser of the websites visitors (Firefox, Google chrome). When a visitor to a website wants to load a page on your website, their browser sends a request to your server and then Apache returns a response with all the requested files such as image, text etc. HTTP protocol is used for communication between the server and the client machine and Apache is responsible for the smooth and secure communication between the two machines.

O. PHP Programming Language

PHP(Hypertext Pre-Processor) programming language is a general programming language initially created for the web development. It is a programming language that is concurrent, class-based, object-oriented and specifically designed to have as few implementation dependencies as much as possible. Code written in PHP are usually processed by a PHP interpreter which is implemented as a module in a web server or a common gateway interface(CGI) executable. PHP code be executed with a command line interface, embedded in HTML code or used in combination with various web template system, management systems and web frameworks.

P. MySQL Database

MySql database is an open-source relational database management system which was initially written in C and C++ and its SQL parser was written in yacc while utilizing a homer brewed lexical analyzer. It was the database used in this project for the storage of the different data gotten from the different sensors which is transferred to the cloud server. MySql database offers a some peculiar advantage when compared to other database such as an open source tools such as phpmyAdmin , mysqldump which is a logical backup tools ,cross-platform support and information schema among the rest.

Q. 000webhost.com

They are a VPS provider which provide website hosting with PHP, MySQL and cpanel for zero cost. There services were utilized for hosting the monitoring centre which is a web application. After the design of the web application ,the FIG below shows the homepage of the monitoring centre with details of each node with their components such as the GPS unit, Led light ,the location coordinate, and also a status of if there is human presence.

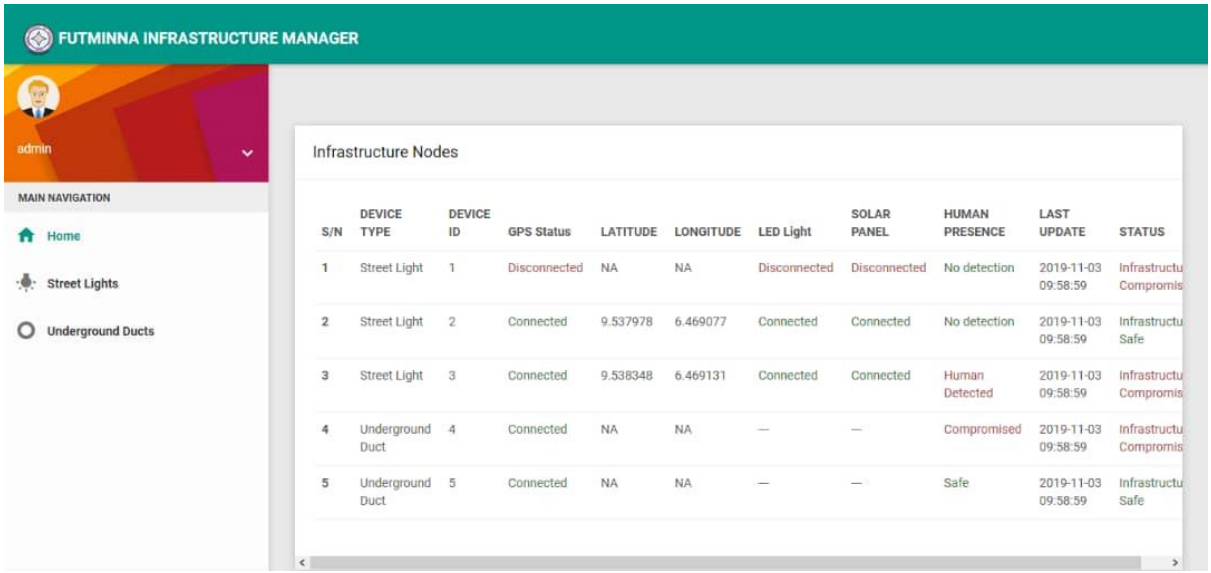

Fig. 14 Web Application

R. Implementation of the Street Light

The Arduino Nano was mounted to test the base functionality at this point, proper care was taken during the mounting stage to avoid damage to the pins of the micro-controller .Each pins of the Arduino Nano must be ensured it entered each of its respective pin ports of the socket and too much pressure should not be applied to avoid damage to the pin. The Fig. 15 the soldering part of the design. This was done in such a way that all connections between one points to another is been provided space so that other connections can be made when the need arises.

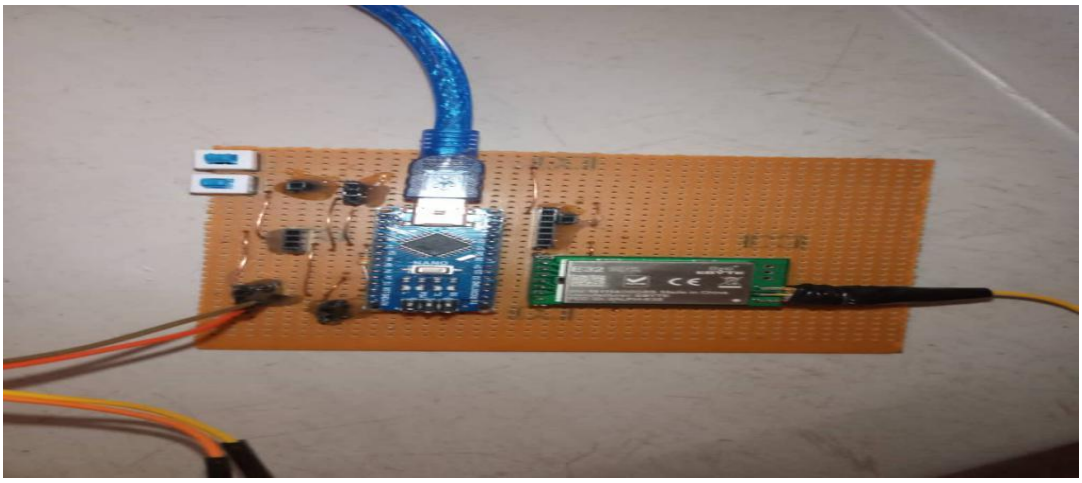

Fig. 15 Soldering of the Arduino Nano

The FIG below shows the complete system design of a streetlight .The performance of the system was been tested be connecting the system to the power supply .Once it is connected, we tested the system by implementing a button that will short circuit the light when clicked after which a real-time response was gotten from the web app indicating the particular system that was tampered with and the real time geo-location of the device was retrieved. In any design, safety and aesthetics must be put into consideration ,for the complete design of the system.

S Implementation of Underground Duct

The veroboard was adequately clean and all the other components to design the power supply unit was put in place for the underground duct .The design of the power supply unit is shown in the Fig below. The micro-controller unit was also soldered to the veroboard .Precautions was carefully taken in this stage so as to ensure that each components was connected firmly so as to ensure continuity when it is required to attain the required output. Two circuit was designed for the underground duct in which one was placed directly on the pipe ,this circuit contained a power supply unit ,a vibration sensor ,a control unit which is the Arduino Nano and a transceiver while the second circuit was placed on the underground duct. This circuit contained a power supply unit, a PIR sensor ,a control unit which was the Arduino Nano. The Arduino Nano was mounted on the veroboard and the basic functionality was tested and after which all the component to design this unit was put in place for the underground duct .The Arduino Nano was soldered to the veroboard .Precautions was taken in this stage to ensure that the each components was connected firmly to ensure the system reliability when it is required to ensure that we attain the required output.

RESULT AND DISCUSSION

This section comprises of the testing of different component, system performance and different techniques utilize for evaluating the performance of the system. Both systems was analyses based on their power consumption, latency and cost of implementation.

Developed Hardware

The hardware components selected for these project compose of the Arduino Nano been used as the control unit for the master and slave node for the streetlight and also the underground duct ,GPS sensors, a GSM module, PIR sensors and vibration sensor and power supply all enclosed in their designated designed package. The entire package of the underground duct is in two sections, the unit placed in the underground duct is placed at the bottom as it holds all the sensors .The second unit is placed on top of the channel itself. The complete package for the underground duct is tightened and held together by screws for easy assembly and disassembly. For the streetlight the lamp pole has a storage box constructed within it for placement of the control unit and the power supply. A GPS module was attached to the solar panel.

Developed Software-Database and GUI

The developed system utilizes PHP and MySQL to implement the monitoring and detection system. PhpMyAdmin was used to view the system table as shown in Figure .the tables (Users and the different sensor metrics)

System Graphical User Interface

A user friendly graphical user interface was developed for the team at the monitoring center to aid remote interaction with the monitoring system. Figure 16 and Figure 17 shows some of the views of the GUI .Figure shows the login page and the functionality ascribed to it such as allowing the admin to login into the system and have full access to the range of functionality the system provides such as the real time location of the monitored components.

Fig. 16 Login Page

Fig. 16 shows the homepage of the monitoring centre which entails the device type with each device ID followed by the GPS status of the device and the state of the monitored components of Solar Panel, LED light either it is connected or disconnected and lastly if any human presence has been detected in the monitored perimeter.

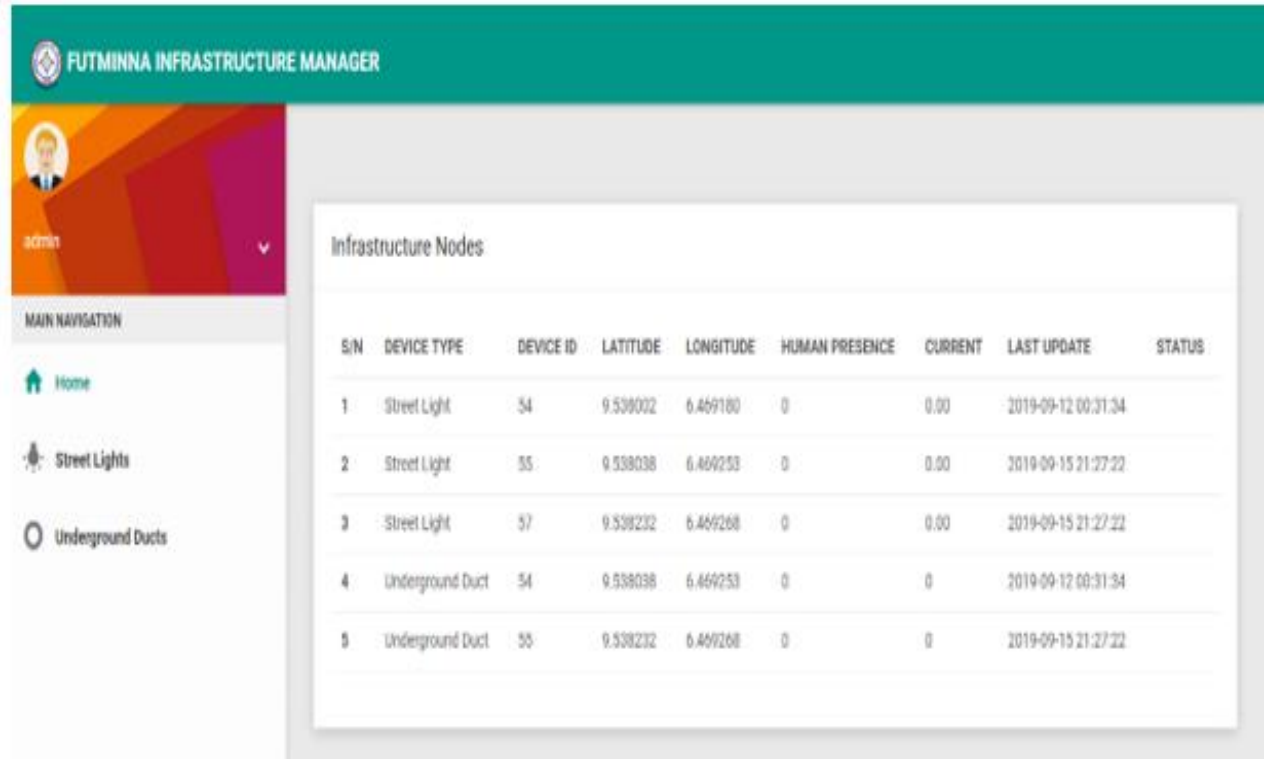

Fig.17 System Dashboard

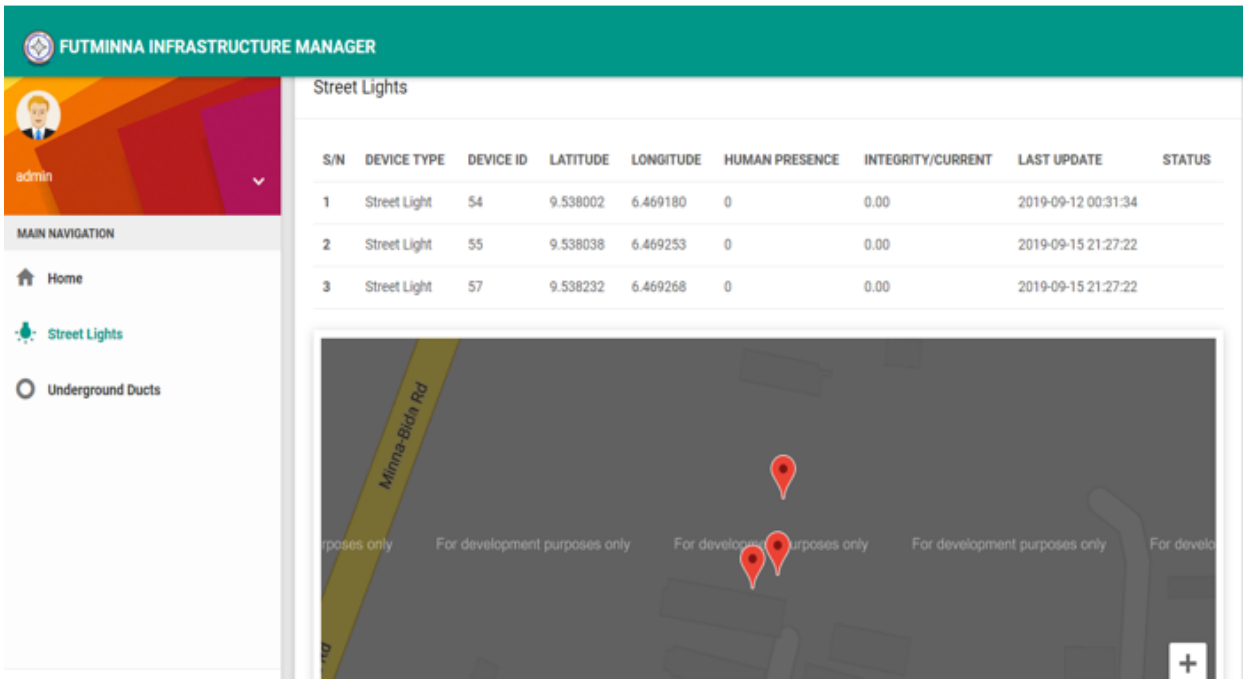

Fig. 18 Streetlight Showing Location on Map

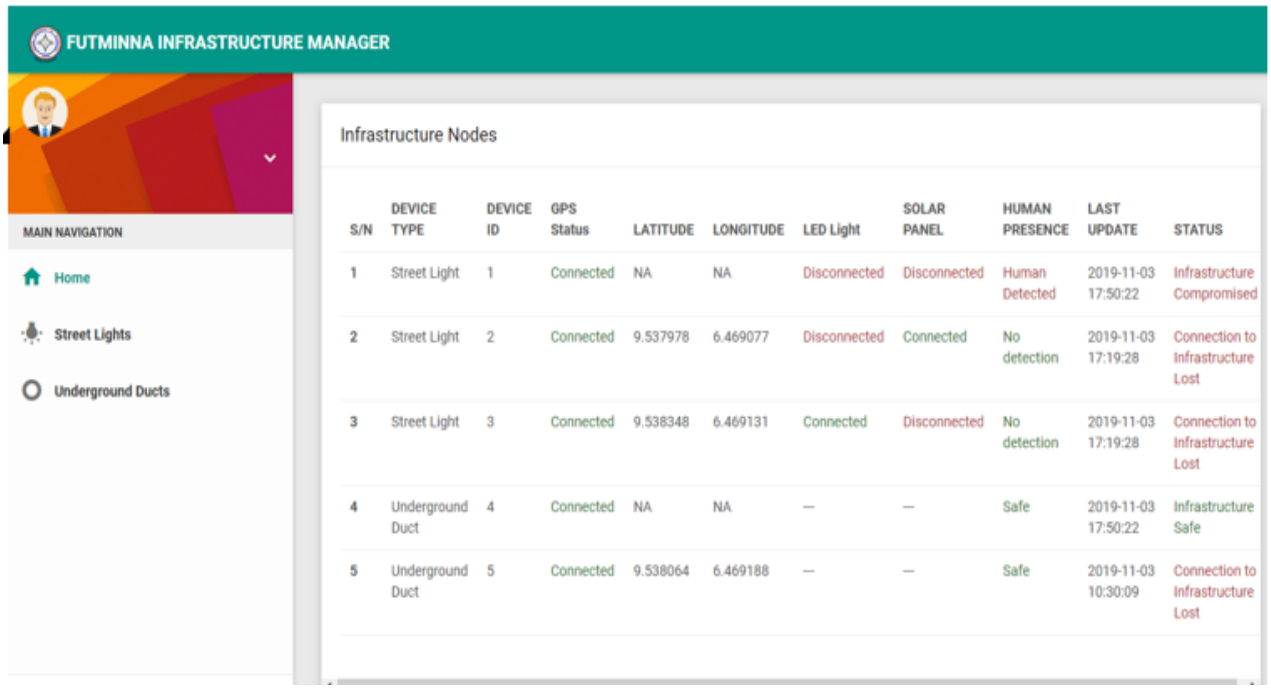

Fig. 19 Infrastructures showing its status

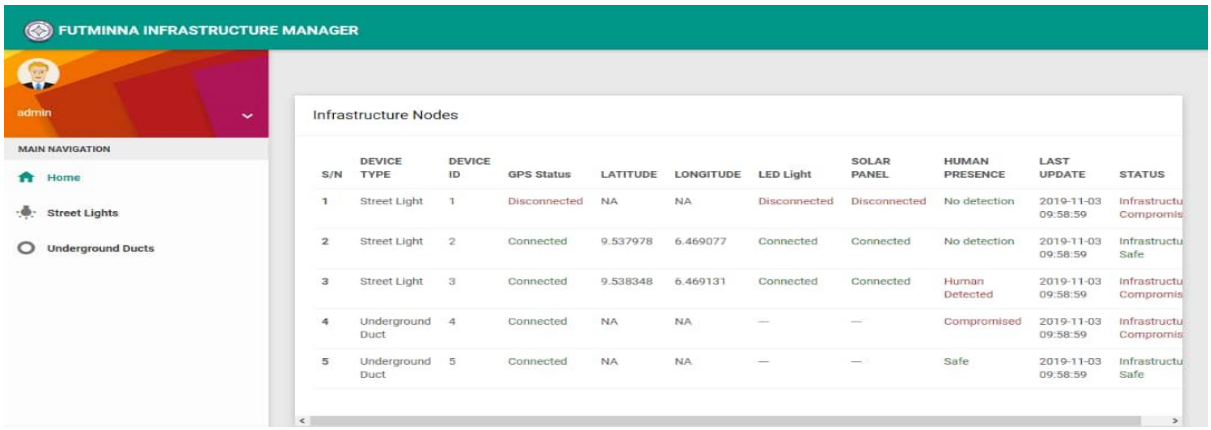

Fig. 20 Monitoring Centre Web Application

A shot of the underground Pipe and duct is shown in Fig. 21 and 22 respectively.

Fig. 21 Underground Pipe

Fig. 22 Underground Duct

The Street lighting system shown in figure 23 comprises of three different units, the master unit and the slave units, hardware installation are house here.

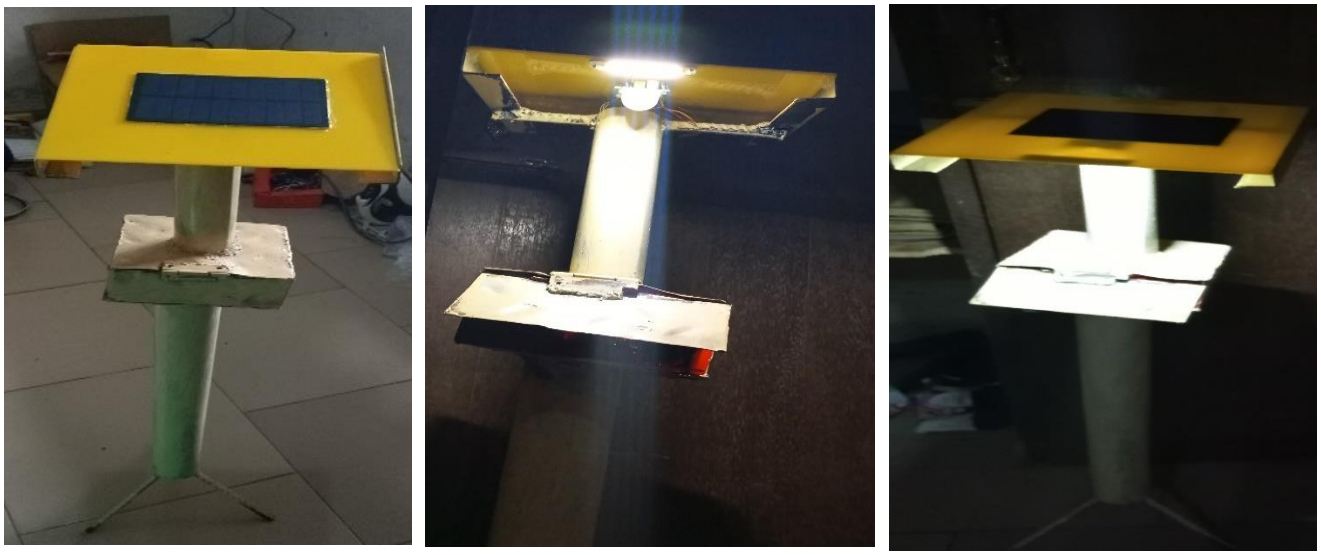

Fig. 23 Street lighting system

Every components used in achieving the design was properly tested in order to ascertain their conforming to requirement. Then each of the component that was used in the underground duct and the streetlight was also evaluated and tested after their implementation. As a monitoring system, the performance is significantly dependent on the power consumed by the system. The power supply unit is designed to obtain a +5v from the D.C which is required to power each unit of both the underground duct and the streetlighting system. Multimeter is used to measure the output voltage of these unit and the percentage error is obtained as shown below in the Table below. here were also various test that are carried out in this aspect such as polarity test, voltage amplitude and short circuit test. The power supply was detached from the circuit and the output voltage was been measured using a Multimeter to ascertain the that a steady +5V is been obtained from the multimeter, while the power supply is still been disconnected the overall circuit test was carried out to ensure that there was no short circuit .Polarity test was also carried out for each terminal to ensure that they were placed on the right spot by ensuring that terminals marked vcc are on the +5v and terminals marked ground are on 0V. The performance of the system was determined based on the power consumption ,the location accuracy and the cost of implementation as discussed in the beginning of the chapter. The main objective of using this metrics is to help future researchers to carefully select their components and procedures. The response time of the system is the time difference from the system detection of intrusion ,tampering or theft to when the information reaches the server. Factors that determine the response time of the system.

CONCLUSION

With the advancement of wireless sensors, wireless sensor network has been used in various sectors of our daily life. This research focuses on the utilization of wireless sensor network in remote infrastructures monitoring .Wireless sensor network has been used in monitoring various facilities in different sectors and this has drastically assisted in efficiently reducing vandalism and theft rate .This project is based on the utilization of Arduino Nano in the monitoring of streetlights and underground duct with Wi-Fi been used as the wireless protocol to transmit data from the different slave node station to the master node station before being transferred to the monitoring centre which resides on the cloud server .The slave station acts as the data acquisition unit on each of the streetlight unit and the underground duct.

For the streetlight , they are capable of monitoring three environmental parameters which are the location ,presence of intrusion through detection of motion and the current flowing through the system. While for the underground duct ,this unit is able to detect three environmental parameters which are the geo-location, the level of vibration and intrusion detection through motion. This system aims to drastically reduce the rate of vandalism and theft of various components of these infrastructures and also provide a means for statistical analysis of data gotten from the different station.

CONFLICT OF INTEREST

There is no conflict of interest for this research work.

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