International Journal of Computer (IJC)

ISSN 2307-4523 (Print & Online)

http://ijcjournal.org/

SEN-Iot: A Smart Emergency Notification System Suitable for Developing Countries using Internet of Things

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Abstract

Research has shown that disaster effects on properties and lives can be drastically reduced through wide dissemination of information on the impending danger to people at the appropriate time. Generally, the emergency alert systems are usually proactive systems; they are meant to gather data in surrounding using the necessary tools, alert the specified listeners about an impending danger and gives suggestion on the necessary actions to be taken in each situation. In addition, some emergency alert systems also activate automatic responses. Furthermore, the integration of Internet of things (IoT) technology with emergency notification systems is rapidly attracting new discovery in this domain. In this paper, an effective smart emergency notification system named SEN-IoT was design using IOT technology. SEN-IoT was modeled to manage domestic hazard with a scope of water, fire and gas leaks; by creating an emergence notification and immediate response systems. The SEN- IOT was implemented using arduino, sensors and the GSM module. The system was tested for maintainability, functionality, efficiency, usability and reliability, and results revealed that SEN-IoT can effectively handle domestic hazard.

Keywords: Emergency notification system; IoT; Fire and Flood disaster.

1. Introduction

Disasters are complex situations in which the consequences of an event are beyond the capability of an affected jurisdiction to respond effectively. Generally, disasters are grouped into natural and man-made [1].

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Natural disaster can be hydro-meteorological (such as flooding, tornados, hurricanes, ice storms), geological (for example; earthquakes, volcanic eruptions) or biological (e.g., influenza pandemics). On the other hand, Man-made disaster are unintentional or deliberate, examples of man-made disasters are terrorist attacks including bioterrorism, chemical spills, radiation releases, wild fires, engineering failures, civil conflicts and many more [2]. Different countries and reigns currently face various types of disasters, governments are attempting to adopt more information and communication technology(ICT) to improve emergency response and rescue operations [3], For example, prevention of fire and fire risk level control diffculty are increased on daily basis. Fire-fighting and monitoring situations are very serious today. Public securities keep on insisting in increase of technology in fire fighting and monitoring, thereby, giving special attention to improve the science and technology in resisting fire disasters [4]. Major emergencies, disasters and other crises are social, economic and political events. For decades now, the total number of catastrophic events has almost doubled, showing a trend line from approximately 450 to 800 major emergencies per year. This increase is most marked in middle and low income countries, where emergency preparedness is often insufficient [5]. Using Nigeria as a case study, research revealed that a total of 283 people died while a whooping total of 453 people were involved as casualties in building collapse in some cities in Nigeria (that is, Lagos, Port-Harcourt, Enugu, Lokoja, Abuja and Ogbomoso) between 1990 and 2009 [6]. Furthermore, the 2012 flooding in Nigeria was described to be the worst incidence so far in the history of the country. Over 28 out of the 36 states in the country were affected by the ravaging flood which left thousands of people dead, properties worth billions of naira destroyed, about 18,000 injured and over 2.1 million people were completely homeless who were registered as internally displaced within their communities [7]. Fire disaster is another factor that have caused a lot of casualties in Nigeria over the years, National Emergency Management Agency (NEMA) said it recorded over 8,000 disaster victims majorly from fire and windstorm disasters in Lagos, Ogun and Oyo State, in the first two months of the 2015 [8]. Thus, there is an urgent need for new research and methodologies on emergency notification techniques in middle and low income countries. The recent advancement in technology especially in the field IoT has expanded the of area of applying the technology and the rise of the IoT paradigm is expected to connect to the Internet more than 30 billion devices by 2020 [9]. The integration of IoT paradigm into web services and cloud computing gives opportunity to handle thousands of sensors and their data. In this regard, sensing as a service model has recently emerged and the data generated by these sensors can be reused by different users and applications within IoT middleware solutions [10].IoT is an adaptive self configuring network that enables the communication and interaction between the physical objects; this transforms these objects from being blind to be smart [11]. IoT system is made up of three components: sensor, actuator, connectivity devices [12]. The IoT is the new era in transforming the existed systems to amend the cost effective quality of services for the society. To make emergency response real time, IoT enhances the way first responders and provides emergency managers with the necessary up-to-date information and communication to make use those assets [13]. In this paper, we present a new smart emergency notification system called SENIoT. SEN-IoT is an IoT based emergence notification system which provides a platform for emergence notification and immediate response from users. The other parts of the paper are organized as thus: section 2 discusses existing literature. Section 3 presents the SEN-IoT architecture and methods. The results and discussion are given in section 4 and section 5 concludes this paper and discusses potential future direction.

2. Literature Review

IoT paradigm is based on intelligent and self configuring nodes (things) interconnected in a dynamic and global network infrastructure. It represents one of the most disruptive technologies, enabling ubiquitous and pervasive computing scenarios [14]. IoT allows users to achieve a deeper automation, analysis and integration within a system. They improve the reach of these areas and their accuracy. IoT utilizes existing and emerging technology for sensing, networking and robotics [15]. IoT essentially makes virtually anything smart, meaning it enhances every aspect of life with the power of data collection, artificial intelligence algorithms, and networks [16]. From a logical viewpoint, an IoT system can be depicted as a collection of smart devices that interact on a collaborative basis to fulfill a common goal. At the technological floor, IoT deployments may adopt different processing and communication architectures, technologies, and design methodologies, based on their target [17]. IoT represent the next big leap ahead in the ICT sector. The possibility of seamlessly merging the real and virtual world, through the massive deployment of embedded devices, opens up new exciting directions for both research and business [18]. The IoT holds the promise of improving peoples’ lives through both automation and augmentation. The capabilities offered by the IoT can save people and organizations time and money as well as help improve decision making and outcomes in a wide range of application areas [19]. Several researchers have successfully implemented IoT technology to various applications. A mobile IoT system prototype for outdoor traceability was presented in [20]. The scheme is a complete IoT Solution from sensor based hardware design, to cloud services. The printed circuit board design takes into account design for manufacturing, assembly and testing, low power consumption and low cost. A comprehensive study on the use of IoT application for vehicular urban traffic system which allows monitoring traffic in normal conditions, congestion traffic, and weather conditions is presented in [21]. The researchers designed and implemented a low-cost IoT proposal, in order to monitor and analyze traffic circulation and provide potential solutions to reduce their associated negative and time-consuming effects. In addition, the system interacts with a device consisting of two electronic Arduino platforms, interacting in a master-slave mode, and which has a distance sensor based on laser for detection of vehicles. Architecture of an e-ticketing system for public transportation which supports open source development was presented by some other researchers in [22]. The process of developing smart city IoT applications from a coordination-based perspective was explored in [23]. An investigation on life-cycle general approach for IoT-enabled smart city service systems was conducted in [24] A survey on the various IoT enable devices and its practices in the area of healthcare for toddler, children, chronic care, monitoring of critical patients, operation theaters and medicine dispenser was conducted in [25]. The architecture of an interface aimed at smart health applications which placed wearable devices in the body area network of a patient and taking into consideration the data flow produced by the IoT healthcare network was designed in [26] . The performance of protocol stacks for the transportation of healthcare monitoring data over the user access network towards a healthcare provider supporting the connected health model was evaluated in [27]. The scheme was tested on top of networking stacks designed for IoT environments that are typically used in the distributed health management model where multiple embedded sensing devices communicate with health monitoring applications over a networking infrastructure. Furthermore, an IoT based healthcare system focusing on cancer care and business analytics/cloud services was implemented in [28]. An investigation on the identification of gaps in the current research concerning cyber-security for the IoT (namely structural-inadequacies, lack of standards and cyber-security vulnerabilities), with an emphasis on the mining and resources industry was conducted in [29]. An IoT architecture based on Software-defined networking, which can support deploying and adjusting security policies rapidly and at fine-grained level was presented in [30]. Reference [31] designed IoTMon, an IoT device physical interaction control system, which can discover all potential inter-app interaction chains and analyze risk levels of those interaction chains. The prototype of IoTMon was implemented and evaluated based on official Smart- Things applications. The evaluation results revealed that IoTMon could effectively capture potential physical interactions among IoT applications and identify high-risk inter-app interaction chains. A ship detection scheme using IoT was presented in [32]. The authors applied four sensors to observe ship-generated waves and combine them using generated formula to detect location of the ship real time. Empirical investigation showed that as the sensor distance increases, the radius detection increases. Moreover, as the ship speed increases, the radius detection decreases.

2.1. Closely Related Work

The state of development of fire detection and alarm systems in the intelligent building was reviewed in [33]. New technologies and concepts developed in intelligent buildings, such as advanced multi-function sensors, computer vision systems and wireless sensors, real-time control via the Internet, and integrated building service systems were discussed extensively. An IoT based water monitoring system that measures water level in real-time was designed in [34]. The system was modeled based on the idea that the level of the water can be very important parameter when it comes to the flood occurrences especially in disaster prone areas. A water level sensor is used to detect the desired parameter, and if the water level reaches the parameter, the signal will be feed in real time to social network like Twitter. Reference [35] presented a new design and integrated IoT to an Arduino-based fire safety system that gives alert to fire-fighting facilities, authorities and building occupants to possibly prevent fire occurrences or reduce the probable damages it may cause. A research was conducted on home security and fire related hazards. The authors are of the opinion there is needs to be given more attention so to reduce fire related accidents. In other to detect fire breakdown, smoke and combustible gas leakage are considered. An ideal sensor is used to sense the presence of liquefied gas and smoke. After detecting the gas or smoke its starts an exhaust fan for removing gas out of the affected areas and send a fire alert as SMS to the registered phone number [36]. The design and evaluation of a wireless sensor network using multiple sensors for early detection of house wires was presented in [37]. The researchers used the Global System for Mobile Communications (GSM) to avoid false alarms. Empirical investigation was performed through extensive simulation and simulation results showed that the system is able to detect early fire, even when a sensor is not working, while keeping the energy consumption of the sensors at an acceptable level.

3. Materials and Methods

This section presents the basic components used in SEN-IoT, the detailed description of the SEN-IoT model, system flow chart and the activity diagram

3.1. SEN- IoT Components

A brief description of the basic components utilized in SEN-IoT are given as follows:

Arduino: Arduino is an open source, PC paraphernalia and programming organization, endeavour, and client group that plans and produce microcontroller packs for constructing programmed devices and intelligent object that can detect and control questions in the real world [38]. The SEN-IoT was build using Arduino Uno. The Arduino Uno (Arduino ATmega328 microcontroller) is an embedded board with 14 digital input/output pins (of which 6 are used as pulse width modulation outputs), 6 analog inputs, a 16 MHz crystal oscillator, ATMEGA 328, a USB connection, a power jack, an IN-circuit system programmer header and a reset button. It contains everything needed to support the microcontroller, simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get it started. Sensor: Sensors are devices that monitor characteristics of the environment or other objects such as temperature, humidity, movement, and quantity. When multiple sensors are used together and interact, they are referred to as a wireless sensor network (WSN). Wireless sensor networks contain the sensors themselves and may also contain gateways that collect data from the sensors and pass it on to a server. While sensors sense the state of an environment or object, actuators perform actions to affect the environment or object in some way. Actuators can affect the environment by emitting sound, light, radio waves or even smells. These capabilities are one way that IoT objects can communicate with people [19]. In this work, we use temperature sensor, smoke sensor, flame sensor and humidity sensor. The temperature and humidity sensor used for SEN-IoT is the DHT11 sensor. The DHT11 is a temperature and humidity sensor complex with a calibrated digital signal output. By using the exclusive digital-signal acquisition technique with temperature and humidity sensing technology, it ensures high reliability and excellent long term stability. Also, the smoke (gas) sensor used for SEN-IoT is the MQ2 Sensor. The sensitive material in this sensor is SnO2. This sensor has good sensitivity to combustible gas in wide range, it has a long lasting duration and it is highly sensitive to propane, hydrogen. These characteristics make it the best for this research because the sensor can work effectively in a room with wide range. Furthermore, the flame sensor used for SEN-IoT is the LM393. It is an integrated circuit that can detect infrared light with a wavelength ranging from 700nm to 1000nm. The far-infrared flame probe converts the light detected in the form of infrared light into current changed. GSM Module: GSM is a cellular network, which means that mobile phones connect to it by searching for cells in the immediate vicinity. GSM networks operate in four different frequency ranges. Most GSM networks operate in the 900 MHz or 1800 MHz bands. There are four different cell sizes in a GSM network - macro, micro, pico and umbrella cells. The coverage area of each cell varies according to the implementation environment[39]. The modem used for SEN-IoT is designed with 3V3 and 5V DC TTL interfacing circuitry which allows user to directly interface with 5V microcontrollers (PIC, AVR, Arduino, 8051) as well as 3V3 microcontrollers (ARM, ARM Cortex XX). The band rate can be configurable from 9600-115200 bps through AT (attention) commands. This GSM/GPRS TTL Modem has internal TCP/IP stack to enable user to connect with Internet through GPRS feature.

3.2. SEN-IoT Conceptual Model

The SEN-IoT uses of a lot of sensors for detection of fire and flood. The conceptual model is depicted in Figure 1. To effectively detect fire, the temperature sensor, the humidity sensor, the smoke sensor and the flame sensor and all these are used to effectively confirm if there really is a fire or just a situation that has a lot of heat involved or has flames e.g cooking, smoking e.t.c. The temperature sensor would be used to read the temperature of the room. The standard temperature of a room is 280C but if the temperature sensor reads the temperature of the room to be more than normal and if the humidity sensor checks the humidity in the room and it also turns out to be very low or below 0, there is a possibility that there is a fire in the room.

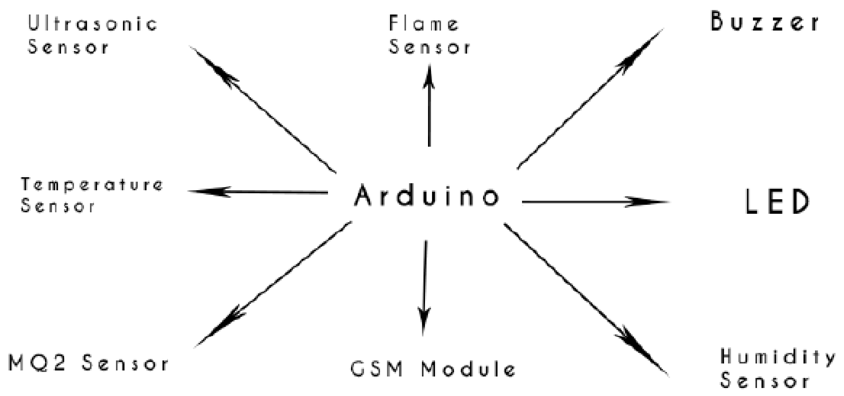

Figure 1: SEN-IoT Conceptual Model

To further confirm this disaster, the smoke sensor checks for smoke and this sensors deals with intensity and if the smoke (gas) detected is the smoke expected from a fire, it finally checks for flame which is always present in a fire and if all these confirmation comes out to be positive, there is definitely a fire and then the resident of the environment is notified about the disastrous situation which results to calling for emergency responders. To be on a safer side, the fire detection part of the system works with three conditions to trigger a warning message and sends to the user and they are:

i. when temperature is above normal, humidity is below normal, smoke is detected and flame is detected;

ii. when smoke and flame is detected;

iii. when smoke is detected

These conditions deal with most possibilities of every situation that can cause fire in the domestic environment e.g electricity spark, busted gas and many more. The ultrasonic sensor is used to detect water level in a room. This sensor considers that there could be a case of leakage in the room and water may flood the room a little which allows the location of the sensor in a room to be a reasonable level and once the water level in the room is above expected, a warning message is sent for the users mobile device to retrieve. All these sensors are used together with Arduino UNO which is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PMW outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller and all that needs to be done is to simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. When all the sensors work with the Arduino and the disaster is confirmed, a warning or notification message is sent to the user via SMS which is an offline message and this allows immediate action to be carried out by residents of the environment. Figure 1 shows the architectural diagram of the project. The Arduino seats at the middle of the operation coordinating communication between the necessary components and keeping the system running.

3.3. System Flow Chart

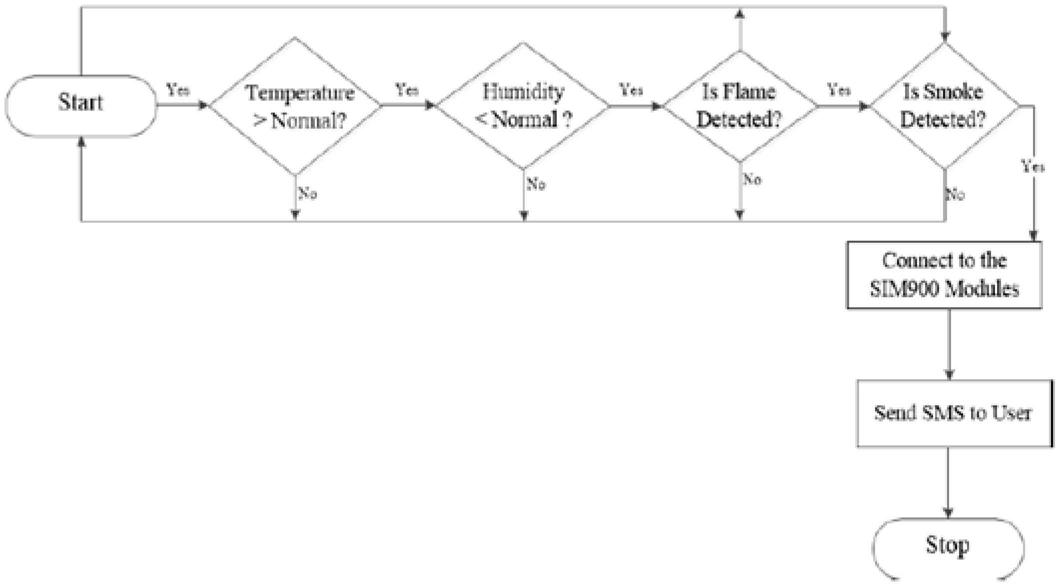

Figure 2: Flow Chart for Fire Detection

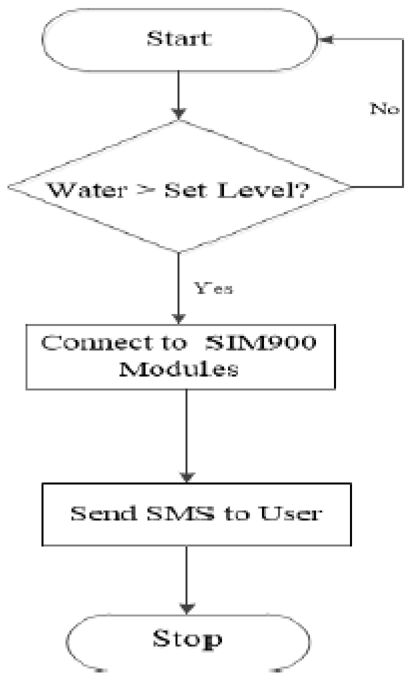

Figure 3: Flowchart for Water Detection

The flow chart of both the fire detection and the water detection are displayed in Figures 2 and 3 respectively. The flow chart was separated in other to provide better understanding of the system. For the fire system, four sensors are used: the temperature sensor, the humidity sensor, the smoke sensor and the flame sensor.

The system triggers a message and sends to the user if temperature is greater the standard temperature, humidity of the room is below normal, smoke is detected and flame is detected or when smoke and flame is detected or when smoke is detected. After any of these specified conditions are verified to be true, the system connects to the SIMCOM GSM Module and sends an SMS message to the user/resident of the environment. For the flood system, the water level sensor is used to detect the level of water in a room and if this exceeds the normal level, an SMS is also sent to the user and immediate action is carried out.

3.4. Activity Diagram

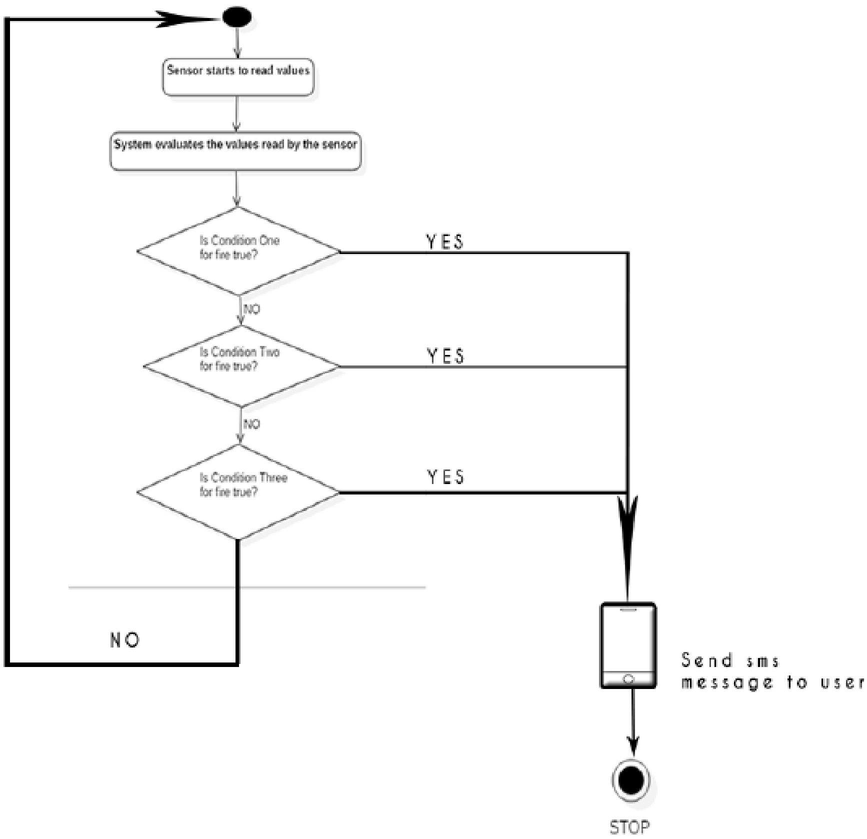

Figure 4: Activity Diagram of the System

For the fire monitoring part of the system, the system is started and the sensors read values which are sent to the system for evaluation. The values sent to the system and measured against set conditions and if any of the conditions are true, the system connects to the GSM Module and allows an offline message to be sent to the number of the user via SMS. The user then takes further action. For the water monitoring part of the system, the sensor just constantly checks for water level above normal in the house. These readings are also sent to the system for evaluation. Detection of water above a particular level triggers a message and sends this message to the users device via the GSM Module. Figure 4 shows the activity diagram of the system

4. Results and Discussion

The SEN-IoT is design using IoT i.e arduino, sensors and the GSM module (for SMS interaction). This is used because of its effectiveness. The functionality and procedure of this system is straight forward and easy to interact with. The system allows just a one-way operation and uses three conditions to carry out the major operation (sending SMS to users). In constructing the system, a lot of hardware was used and each of these hardware and sensor have their specific function. They are all connected using wires (jumper cables). The major hardware system (Arduino) is programmed using the Arduino IDE platform which supports C and C++ programming languages. This system was connected using the jumper wires and each part of the connection/module of connection worked just fine. This operation of this system was demonstrated in a small house and the results were evaluated carefully against set conditions and at any positivity of a set condition specified, an SMS is sent. The system was tested under maintainability, functionality, efficiency, usability, reliability.

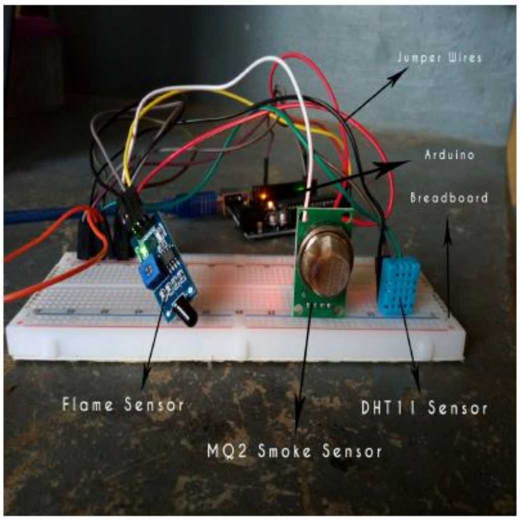

Figure 5: System Connection

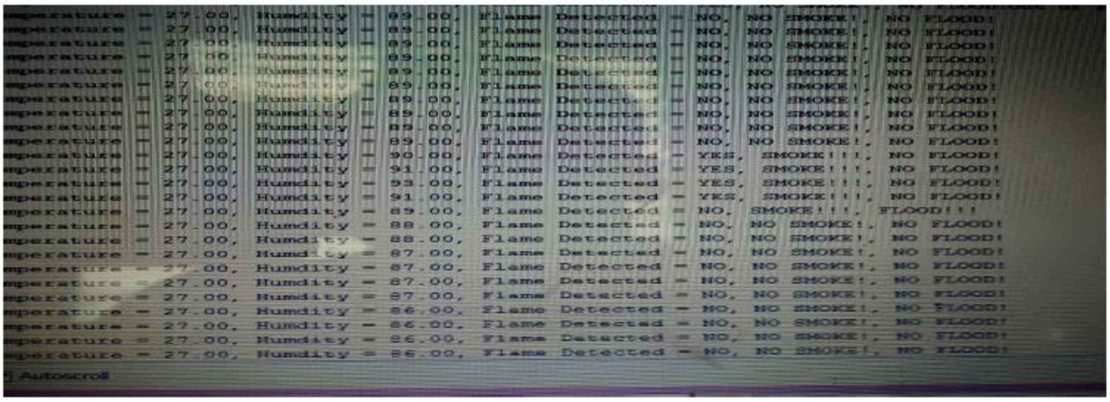

Figure 6: Readings from Temperature and Humidity Sensor

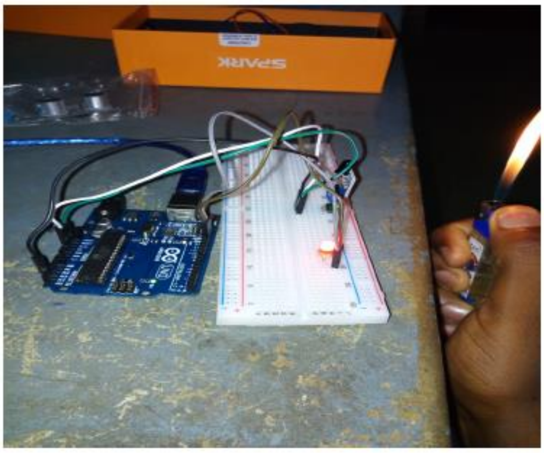

Figure 7: Flame Sensor Connection

Figure 5 shows the connection of the DHT11 sensor to the system and temperature and humidity values are read. The Blue LED light is on either because the temperature is more than or the humidity is less than a specified value in the program of the system. The sample of the readings from the temperature and humidity sensor is given Figure 6. Furthermore, Figure 7 shows the flame sensor being connected to the system and the RED LED light goes on when ame is detected and the reading of the flame sensor connection is presented in Figure 8

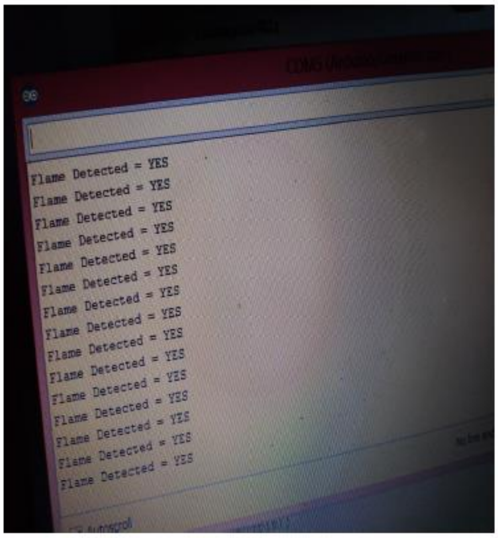

Figure 8: Reading of the flame sensor connection

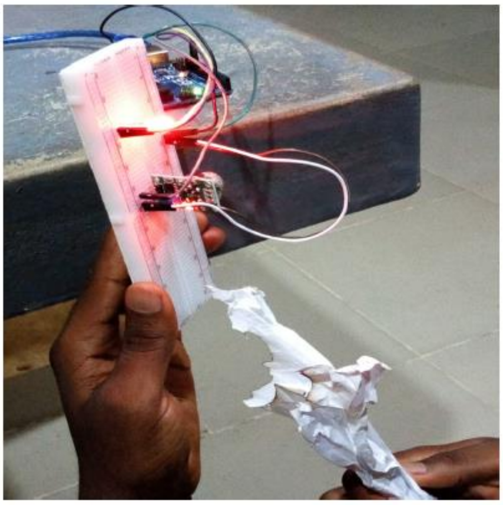

Figure 9: MQ2 Smoke Sensor Connection

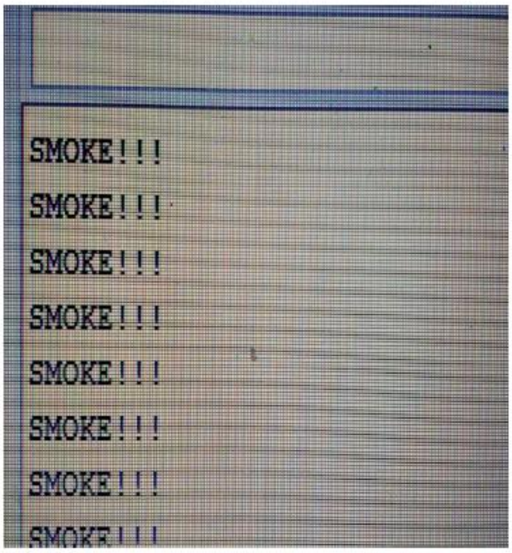

Figure 10: Readings on the MQ2 smoke sensor connection

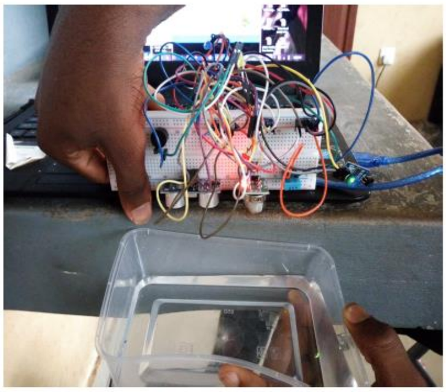

Figure 11: Connection of the Ultrasonic sensor

Figure 9 shows the connection of the MQ2 sensor to the system and the RED LED light is on because smoke is detected and the reading on the MQ2 smoke sensor connection is presented in Figure 10. The ultrasonic sensor is connected to the system as shown in Figure 11, to determine water level and if this level is above normal (level is specified in the program), the Green LED light goes on. The interface of the SMS alert for users during flood and fire is presented in Figure 12. Lastly, the modeled house of the implemented system is presented in Figure 13.

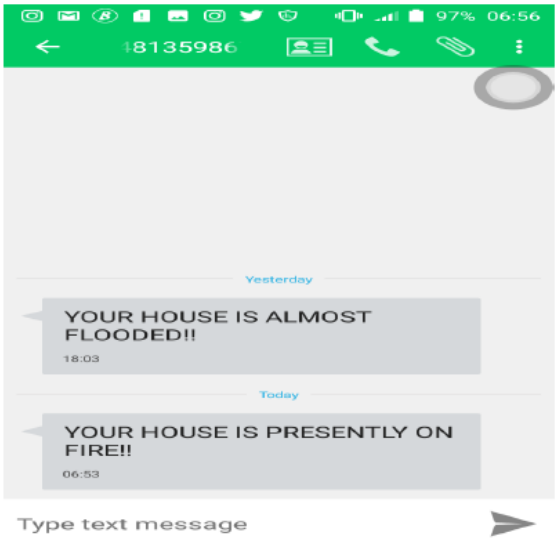

Figure 12: SMS Alert for users during flood and fire

Figure 13: A modeled house containing the implemented system

5. Conclusion

This paper presents a new emergency system using IoT (SEN-IoT). SEN-IoT was designed to handle domestic hazard such as water, fire and gas leaks; with the capacity of sending emergence notification to users and can also receive immediate responses/feed for the affected end-users. The SEN-IOT was successfully implemented using arduino, sensors and the GSM module. The SEN-Iot was tested within a low-income environment (that is, Nigeria), where emergency preparedness is often insufficient. The evaluation results revealed that SEN-IoT can dynamically manage domestic hazard, hence, this scheme is suitable in solving problems relating to late emergency notification.

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