Internet of Things Security System Using ESP8266 Wi-Fi Module and Dual-Tech Sensors

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Abstract— The deployment of internet of things on smart systems is based on ease of every user in accessing and controlling the system remotely with the help of internet. By using internet of things technology in case of smart home, users can access and control all devices in the home anytime and anywhere through mobile devices as long as the mobile devices are connected to the internet. An efficient, low power consumption and low cost embedded control system for smart security and remote monitoring based on motion detection is very important for wide range of commercial and security application. This Project offers introduction and reviews on various internet of things based security systems, Global System for Mobile module, motion detection and the relevance of an ESP8266 Wi-Fi module microcontroller with an efficient software algorithm. A comprehensive set of detailed design and implementation of internet of things security system to send SMS and E-mail to the user. The project employs an ESP8266 wireless module microcontroller coupled with SIM900A Global System for Mobile module in which HC-SR501 passive infrared sensor and RCWL-0516 Microwave radar sensor (the dual-tech sensors) are connected to detect an un-authorize entry of a person to a restricted area and alert the user via SMS and Email. The system can be further expanded to take pictures and view the video of an intruder.

Index Terms— Power Supply, Voltage Regulator, Internet of Things, wireless module, GSM module, Passive Infra-Red sensor, Microcontroller, Microwave Radar Sensor and Security System.

1 INTRODUCTION

Internet of Things (IoT) security cameras, sensors and software has upgraded facility/home security beyond basic alarm systems. Facility/home security devices like the burglar alarm and motion detection system has become absolutely pre-eminent in daily life of household and industrial works [1]. Securing life and properties is something that is related to all of us and involves the hardware and a personal security practice. The hardware would be the doors, alarms, lock systems and different type of sensors like Infra-Red sensor, LDR sensor, acoustic sensor etc. to detect unfavourable condition [2]. In case of personal security practice involving doors locking, activating alarms, closing the windows and many other daily life tasks are performed to prevent a theft. In the present time a lot of unsolicited activities like burglary are increasing continuously so there is need to modify the functionality of existing security systems. Apart from unauthorized entry, fire gas leakages in the house etc. are some of the challenges experienced when dealing with securing the society [1, 2]. With the rapid growth of smart devices and high speed networks, the Internet of Things (IoT) has gained wide acceptance and popularity as the main standard for low-power loss networks (LLNs) having constrained resources. It represents a network where ''things'' or embedded devices with sensors are interconnected through a private or a public network. The term, Internet of Things (IoT), a system of interconnected devices, was first proposed by Kevin Ashton in 1999 [1]. It is a major technological revolution that has updated the current Internet infrastructure to a concept of much more advanced computing network where all the physical objects around us will be uniquely identifiable and ubiquitously connected to each other [2, 3].

Progress work has been done on home security devices like the burglar alarm and motion detection systems in terms of improving the frequency radio wave signals between the devices, use of cameras installed along and around the buildings and placement of many sensors in the system which has resulted to frequencies overlap thereby leading to false alarms. The size of the system tends to be large and the cost of the entire system is expensive [2, 3].

In this project, ESP8266 Wi-Fi module microcontroller with an efficient software algorithm using C-language, self-contained Wi-Fi network solutions that carry software application was employed to implement of internet of GSM module in which HC-SR501 passive infra-red sensor and RCWL-0516 microwave aradr sensor (the dual-tech sensors) are connected to detect an un-authorize entry of a person to a restricted area and alaert the user via SMS and Email.

The significant of the project are; constant protection, deterrent to criminals, the system is fully automated and lower insurance rates. This project has its main application in securing residential homes, housing estates, hospitals, banks, government buildings, vehicle tracking, recreational parks, online

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banking, E-commerce, educational institutions, military units and country borders. Figure 1 gives the block diagram of the construction. The block diagram presents a pictorial explanation of how each component is connected in the physical implementation.

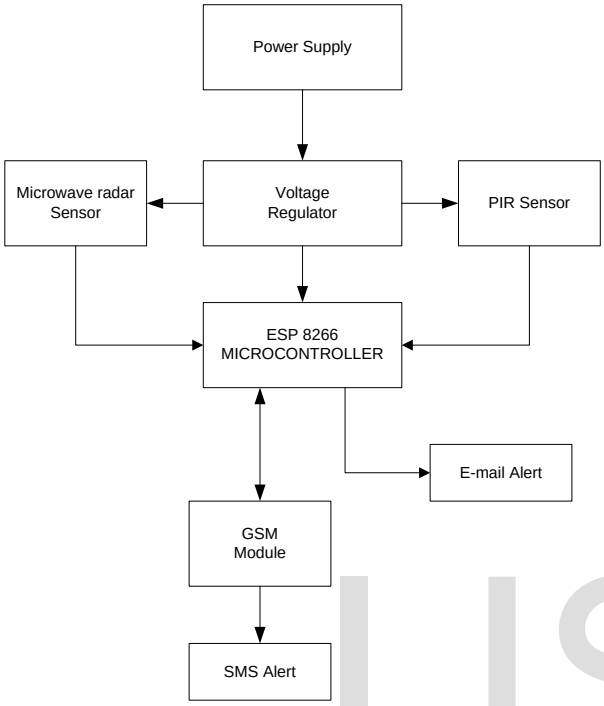

Figure 1: System Block Diagram

2. LITERATURE REVIEW

2.1 Internet of Things Security System

Internet of Things (IoT) security is the technology segment focused on safeguarding connected devices and networks in the internet of things (IoT) [4]. IoT involves adding internet connectivity to a system of interrelated computing devices, digital machines, object, animals and people. Each of the mentioned is provided a unique identifier and the ability to automatically transfer data over a network [4]. Industrial smart security and surveillance systems which are all IoT based security systems, combine sophisticated technology including connected devices, sensors, artificial intelligence, video technology, high-uptime networks and IoT-based alarm systems. The benefits of smart security and surveillance systems are to prevent disasters and ensure facility protection. Avoid unnecessary intervention for false alarms. Protect critical assets from loss and compose informed decisions to improve processes [5]. Facility/home security systems form safer environments to supervise conditions remotely with Wi-Fi or cellular connectivity, ensuring facilities are secure without on-site personnel and delivering security alerts to mobile devices [5].

2.2 Global Systems for Mobile Communication Module

A GSM modem or GSM module is a device that uses GSM mobile telephone technology to provide a wireless data link to a network. GSM modems are used in mobile telephones and other equipments that communicate with mobile telephone networks [6]. The GSM/GPRS module connects to the GSM network using a SIM (Subscriber Identity Module) and Radio Waves. The common radio frequencies in which a typical GSM module operates are 850MHz, 900MHz, 1800MHz and 1900MHz. GSM/GPRS module uses Attention Commands (AT Commands) to perform the following tasks; make/ receive or reject calls. Send, receive or delete SMS messages in the SIM cards. Send and receive data to/from the GSM/GPRS network [6]. The frequency bands can also be set by AT commands. The baud rate is configurable from 1200-115200 through AT command. The GSM/GPRS module has internal TCP/IP stack to connect internet via GPRS. Other features include; supply voltage range 5V, low power consumption 1.5mA and operation temperature -40^{o}C to 85^{o}C [7, 8]. Such wireless connectivity now opens up to wide range of applications like home automation, home security systems, disaster management, medical assistance, vehicle tracking, online banking etc.

2.3 Microcontroller

A microcontroller is considered a self-contained system with a processor, memory and peripherals and can be used as an embedded system. The majority of microcontrollers in use today are embedded in automobiles, appliances, Wi-Fi connectivity and peripherals for computer system [9, 10]. Microcontrollers provide real-time operating system (RTOS); interrupt events, analog to digital conversion, time save power consumption etc. Wi-Fi microcontrollers enable Wi-Fi connectivity for devices so that they can send and receive data and accept commands. Such microcontrollers are used to bring ordinary devices into the realm of internet of things [11, 12].

2.4 Motion Detection Sensor

A motion sensor (or motion detector) is an electronic device that is designed to detect and measure movement. Motion sensors are used in homes, government buildings, museums, research and development centers, military units and business security systems [13]. Several types of motion detection are in wide use: passive infrared sensor (PIR sensor), microwave, and ultrasonic and video camera software and gesture detector. Many modern motion detectors use combinations of different technologies. While combining multiple sensing technologies into one detector can help reduce false triggering. For motion to be detected effectively both sensors must trip together. Many dual-tech sensors combine both PIR and microwave sensor into one unit [13]. Microwave sensor is an active sensor as it emits microwave signal for detection. PIR sensor is passive sensor as it senses infrared signal emitted by various

objects including human body [14].

2.4.1 Passive infrared Sensor

Passive infrared (PIR) sensors houses pyro-electric sensor, it generates energy when expose to heat. Human or animal body radiates energy in the form of infrared radiation. Hence when human/animal come in the range of PIR sensor, it receives thermal energy and hence motion is detected by the sensor. PIR sensors are suitable for smaller and compact premises. PIR sensors consume about 0.8 to 1.0watt electricity [15].

2.4.2 Microwave Sensor

The microwave sensor detects motion through the principle of Doppler radar and is similar to a radar speed gun. A microwave sensor emits frequency in the microwave region and will analyze the returned/reflected microwave frequency for determining motion. Microwave sensor has higher sensitivity, suitable for large area security applications and it consumes about 1.1 to 1.5watt electricity [16].

3. MATERIALS AND METHODS

3.1 The Power Supply

The power supply is the unit of the system that supplies the required electrical power to the various parts of the circuit. The system function based on a minimum voltage supply of 5V DC and maximum current consumptions of about 2.5A during transmission and reception of messages from the GSM sensor. A voltage regulator and some other power components regulate the power supply to the required range of voltage as needed by the various parts of the circuit to function properly. The hardware design involves the design of the circuitry in each of the functional blocks of the system and integrating them together to function as a whole. The various units of the system functions independently but depends on the microcontroller to achieve the desired result.

The microcontroller node MCU has 32 pins. Pin VCC was connected to the power source, pin GND was connected to the ground, pin 29 was connected to PIR Sensor, Pin 5 was connected to the microwave radar sensor, pins 21 and 22 was connected to the GSM Module.

3.1 Microcontroller ESP8266

The system-on-chip (SOC) microchip ESP8266 Wi-Fi module, low cost and branded as ultra low power was employed in this project for the development of end-to point IoT application. It is a 2.4 GHz Wi-Fi module and support WPA/WPA2, built-in-sleep modes, WEP authentication and open networks for GSM/GPRS and Email communications. It is programmed using Arduino IDE and it was interfaced with a microcontroller, it required only 3.3 volts power supply, it is based on the L106 RISC 320bits microprocessor core and runs 80MHz. Input and output source current is 12mA (max), 512KB flash memory, provides 10-bit analog to digital conversion and available in a compact size at a very low price.

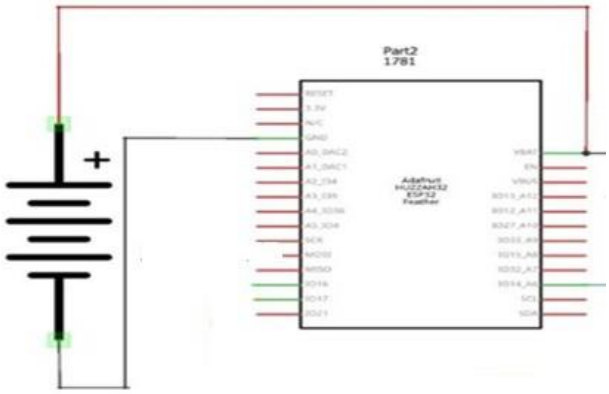

Figure 2: Microcontroller ESP8266 connected to power source 5VDC

3.2 Interfacing Passive Infra-Red Motion Detection Sensor

The passive infrared (PIR) motion detector sensor SR501 as shown in figure 3 was employed in this project for the detection of moving objects, particularly human beings or living thing that radiates energy in the form of infrared radiation. The SR501 PIR sensor used in this project consume about 0.8 to 1.0Watt electricity, very suitable for smaller and compact premises (residential homes, warehouse, garage etc). It used only +5V input voltage.

Figure 3: HC-SR501 PIR Sensor [14]

The SR501 sensor as shown in figure 4 has three terminals, pin VCC was connected to the power source, pin GND was connected to the ground, pin OUT connected to the microcontroller. Pin OUT is the alert pin, normally it remains low when no infrared source is in PIR range. Whenever infrared radiation is detected by the PIR sensor out pin goes high. This change in pin OUT voltage can be read by external controller and an alarm can be rung to notify the owner about intrusion/presence also an SMS is sent on a mobile number and an

Email via internet whenever there is intrusion PIR sensor out pin goes high. Two variable resistors/potentiometers are also part of the HC-SR501 PIR sensor. One is used to set the sensitivity/range of the PIR motion detector and other one is used to set the delay time of out pin. Delay time means how long the out pins remain high whenever the presence of a body is detected. HC-SR501 delay time can be set between 0.3 seconds to 5 minutes and sensitivity range can be set up to 7 meters.

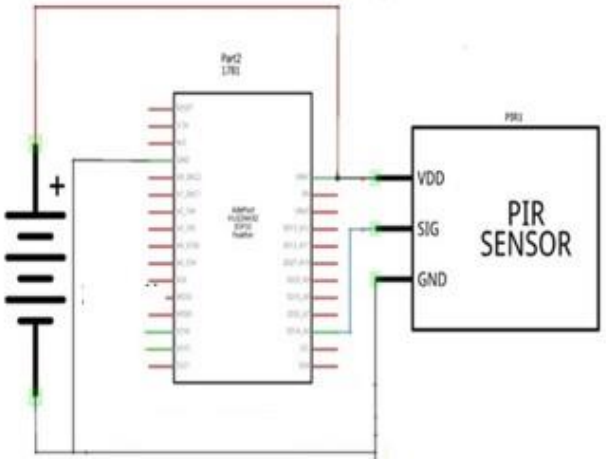

Figure 4: PIR Sensor connected to microcontroller

3.3 Interfacing Microwave Radar Motion Detection Sensor

The RCWL-0516 microwave radar senor as shown in figure 5 is employed in this project for the detection of motion through Doppler microwave technology through walls and other materials. The Doppler radar works by transmitting a microwave signal to a target and then analyzing the change in frequency of the return signal. The variations in the received signal frequency usually help measure the target's velocity with respect to the radar. RCWL-0516 sensor key features: 5V supply voltage, 3.2GHz operating frequency, transmit power at 20mV, sensing distance up to 7m and provide more stable performance and will function at temperature low as -20°C and as high as 45°C. When triggered output pin will switch from LOW (0V) to high (3.3V) for 2 to 3 seconds before returning to its idle LOW state. The RCWL-0516 sensor has five terminals and the pin VIN is connected to the power source, pin GND is connected to the ground, pin CDS sensor disable and pin OUT is connected to the microcontroller.

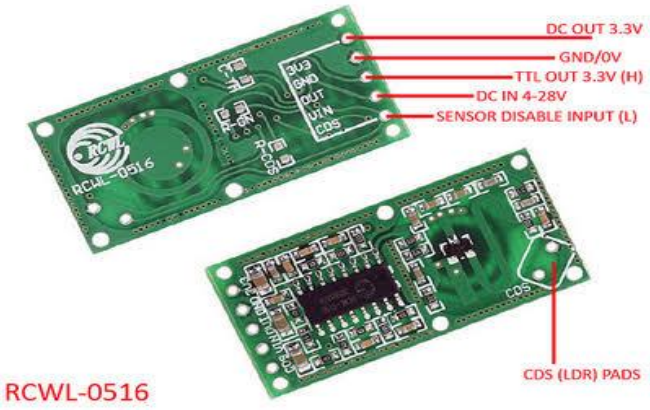

Figure 5: Microwave radar sensor of RCWL-0516 [16]

3.4 Interfacing the Global System for Mobile SIM900A Module

SIM900A module as shown in figure 6 was employed in this project, this module is built with Dual Band GSM/GPRS based SIM900A from SIMCOM. The module offers GPRS/GSM technology for communication with the use of mobile SIM. SIM900A is an ultra compact and reliable wireless module. It works on 900/1800MHz frequency band and allows users to receive/send mobile calls and SMS.

Figure 6: GSM Module [7]

The GSM Module has seven pins where VCC is connected to the power source, GND to ground, SIM RXD Pin and SIM TXD were connected to the microcontroller as shown in figure 7. The SIM900A was set to search the two frequency bands automatically. The frequency bands were set by AT command (tester tool). DATA GPRS: download transfer max is 85.6KBps, Upload transfer max 42.8KBps.

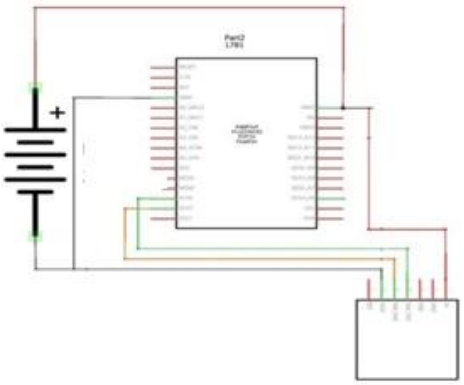

Figure 7: GSM module connected to microcontroller

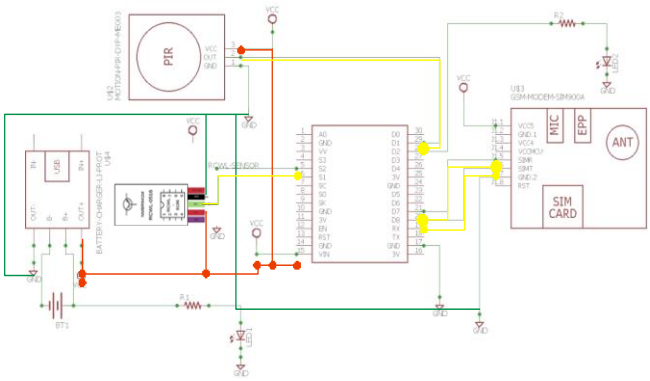

Figure 8: Circuit Diagram

4. SYSTEM DESIGN

4.1 System Description

This section describes how the hardware design was developed by integrating together the physical components building up the systems block diagram shown in Figure 1. The software design developed from interpreting the system flow chart controls the hardware components of the system with an efficient software algorithm using C-language. The internet of things (IoT) security system in its simplest form employs an arduino IDE programmed ESP8266 microcontroller coupled with SIM900A GSM module in which HC-SR501 passive infra-red sensor and RCWL-0516 microwave radar sensor (the dual-tech sensors) are connected to detect an un-authorize entry of a person to a restricted area and alert the user via SMS and Email.

The microcontroller received data from the motion detection sensors with the help of a built analog to digital converter. The sensors output voltage changes whenever it detects any motion or change in frequency of the return signal. If the measured data is greater than a specified limit, the microcontroller sends commands to the GSM module. The GSM module sends SMS to the user. For sending Email via ESP8266 Wi-Fi module, first an email account is created at smtp2go.com then signed-up for a new email address and password. Once the sensors detect motion or change in frequency, the microcontroller initiates an email alert to the user. Therefore a complete analysis of the system is shown on circuit diagram figure 8 using a professional circuit designer.

The software program was developed using a suitable integrated development environment (arduino IDE) as shown in figure 9. The arduino integrated development environment (IDE) is a software application that provides comprehensive facilities to computer programmers for software development. An IDE normally consists of a source code editor, build automation tools, and a debugger. This arduino IDEs have intelligent code completion, a compiler and an interpreter.

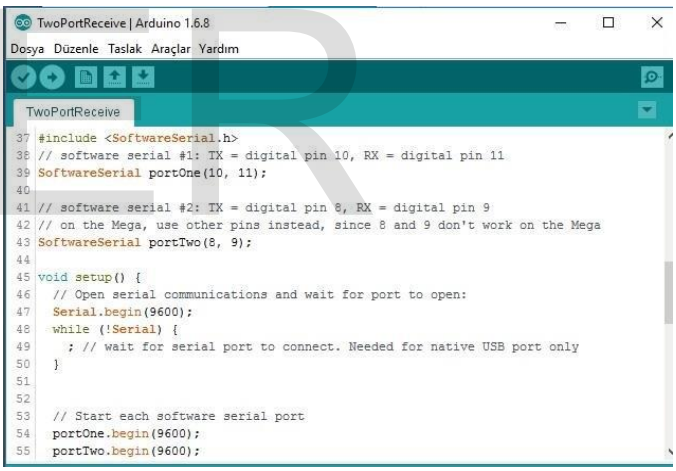

Figure 9: The IDE program

Microsoft office Visio was used to design the system flow chart in figure 10. The entire system was initialized at power ON then the passive infra-red PIR and the microwave radar sensors are set to send signal to the microcontroller once it detects motion around the system. The microcontroller also communicates with the GSM module to send SMS to a registered number and send Email to the user registered account. The user receives both an Email and SMS alert with an attachment with date and time.

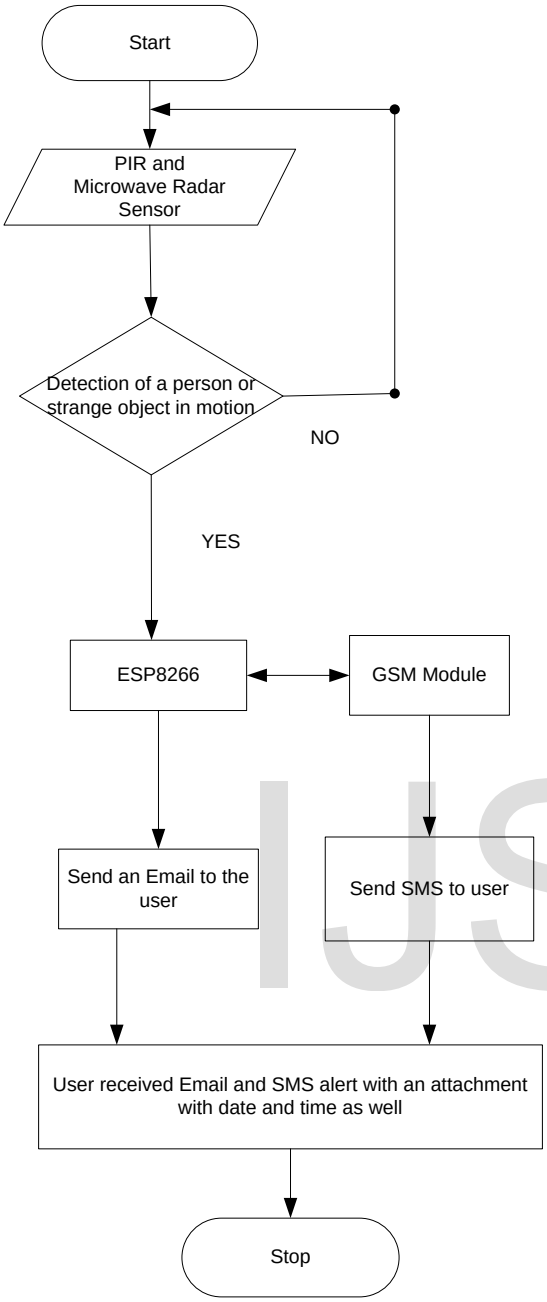

Figure 10: Flow Chart

5. RESULT AND DISCUSSION

In this section, all manuscript works that pillared the project design were made handy by physically incorporating the hardware and software component of the design. Testing was carried out immediately the components were connected together following the implementation of the system circuit diagram which clearly interpreted the system block diagram and the program flow chart. The components were tested to determine the operating characteristics of the components and comparing it to the datasheets of the components. The major components used in the component testing are the digital multimeter and the Arduino Uno board. This section was also done in stages based on the system block diagram to avoid complexity in troubleshooting any abnormality when the whole project reaches completion.

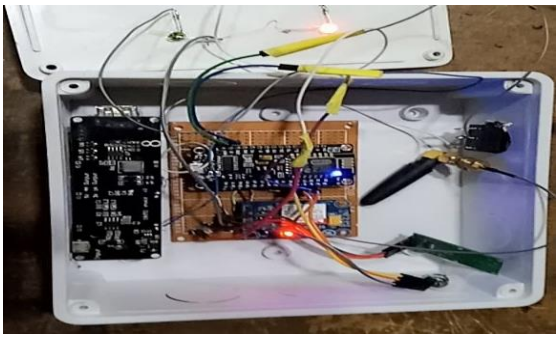

Figure 11: The system circuit board when powered

Figure 12: The System circuit when detected an intruder

The project was first built on breadboard where from the power supply to the dual-tech sensors were monitored on operation to give a satisfy result. Then the project work was repackage and soldered on a vero board for proper presentation. The packaged system circuit board when power ON the yellow light goes ON as shown in figure 11. The packaged system circuit when it detects motion the red light goes ON as shown in figure 12. The SMS alert and the Email alert sent to the user are shown in figure 13 and figure 14 respectively.

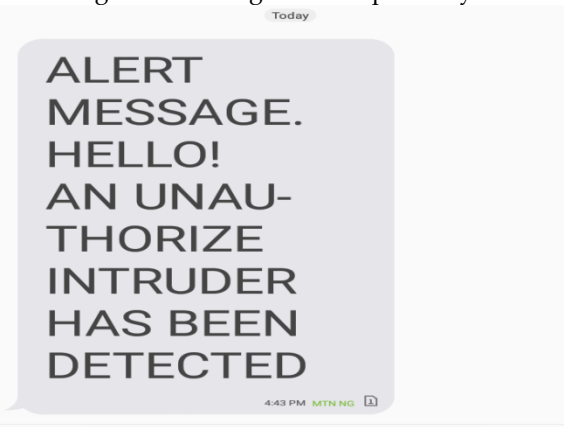

Figure 13: Result of SMS Alert

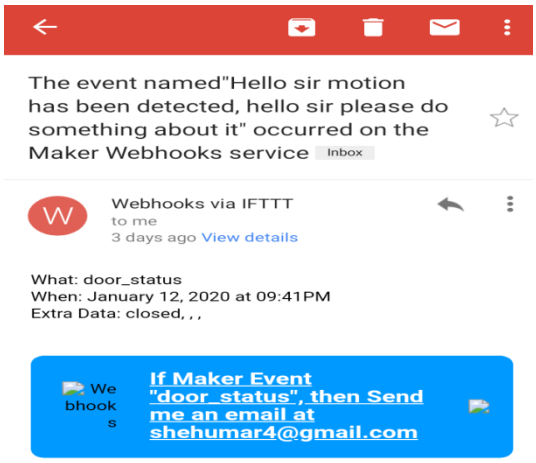

Figure 14: Result of Email Alert

5.1 Passive Infra-Red operating performance

All passive infra-red sensors operate by detecting the temperature difference between the ambient air temperature and a moving heat source (person). Outside air temperature changes have the greatest effect on the operating performance of PIRs.

Table 1: PIR operating performance with moving heat source at 37°C

Moving heat source (Temperature °C)	Ambient Temperature (°C)	Variations (Operating performance of PIRs)
37	25	12
37	20	17
37	15	22
37	10	27
37	5	32

Table 2: PIR operating performance with moving heat source at 36°C

Moving heat source (Temperature °C)	Ambient Temperature (°C)	Variations (Operating performance of PIRs)
36	25	11
36	20	16
36	15	21
36	10	26
36	5	31

Table 3: PIR operating performance with moving heat source at 35.5°C

Moving heat source (Temperature °C)	Ambient Temperature (°C)	Variations (Operating performance of PIRs)
35.5	25	10.5
35.5	20	15.5
35.5	15	20.5
35.5	10	25.5
35.5	5	30.5

The variations values in table 1, table 2 and table 3 clearly shows the sensitivity of the sensor increases on cold nights (ambient temperature at low value) and decreases on hot nights (as the ambient temperature increases). On cold nights, the difference intemperature between a person (nomral body temperature is 37°C) and the outside air temperature is relatively large, giving an apparent increase in performance of sensor was observed. On hot nights (ambient temperature at high value) this difference in temperature is relatively small and a decrease in performance of the sensor was observed.

5.2 Microwave operating performance with moving target object

The Doppler Effect is the basis for the operation of microwave detectors. The Doppler Effect device is responsive only to moving target object. An antenna transmits the frequency (f_o) which is defined as the ratio between the speed of light in air (C_o = 3x10^{8}m/s) and the wavelength (λ_o).

$$f_o = \frac{C_o}{\lambda_o} \qquad (1)$$

Table 4: Microwave Doppler Effect in motion detectors

Distance between Sensor and target object λ_o (metres)	Frequency of reflected radiation f_o (Hertz)
1	0.3
2	0.15
3	0.10
4	0.075
5	0.060
6	0.050
7	0.043

As observed in table 4, when the target object moves toward the transmitting antenna the frequency of the reflected radiation will increase while when the target object moving away from the transmitting antenna the frequency of the reflected radiation will decrease.

6. CONCLUSION

This report has detailed design and implementation of internet of things security system using ESP8266 wi-fi module and dual-tech sensors. It gave enough exposure to electronics circuit design techniques. The best results were achieved by installing both microwave sensor and PIR sensor to leverage advantage of both sensors. From the system design, an efficient software program in C-code was developed using Arduino IDE to operate the ESP8266 microcontroller with PIR sensor and microwave radar sensor set activate once motion is detected with excellent precision and immediately send SMS to a registered number and Email alert via the internet to the user.

These dual-tech sensors employed in this project is a vital aspect in securing and monitoring both government and private assets of national concern. The contribution of this research to the existing body of knowledge is the use of internet of things with a dual-tech sensor to secure both lives and properties.

7. RECOMMENDATION

The system can be expanded to take pictures and view the video of an intruder. Further improvement could be achieved by building the printed circuit board (PCB) of the circuit to enhance efficiency.

8. ACKNOWLEDGMENTS

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