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An Autonomous IoT Infrastructure for Forest Fire Detection and Alerting System

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Abstract— As human advances in technology, manmade and natural disasters are increasing exponentially. It is essential to protect our environment and nature. In this modern age, the technology can be used to provide a conducive environment to live by preventing the catastrophic failure. One such nature event is the forest fire. The objective of this work is to design an IoT based device with autonomic features embedded to detect the forest fire as early as possible and also to take speedy action before the fire destroys and spreads over a large area. The main aim of the system is to detect the fire and protect our entire system from fire related calamities. In addition to this the proposed model is designed to incorporate with the Autonomic features like self- monitoring and self healing so that the ubiquitous environment that is created for a specific objective can be attained with robust and fault tolerant system, by embedding analytics as a service and, by providing intelligence at the periphery of the network.

Keywords— Fire Detection, Arduino, GSM module, Sensors, Authentication, Notification.

I. INTRODUCTION

Forest fire is an uncontrolled fire occurring in nature. Once the fire starts ignited it rapidly spreads all over area in the forest. Forest fire spreads on hot summery day when drought conditions peak, something as small as a spark from a train cars wheel striking the track can ignite a raging wildfire This could result in massive destruction. Forest fire always starts by one of two ways – natural caused or man-made caused. A natural fire are generally started by lightning, with a very small percentage started by spontaneous combustion of dry fuel such as sawdust and leaves on the other hand, human caused fires results from campfires and burning of the waste materials.

Over the past decade there is a massive destruction in forest. The majority of those accidents were caused by forest fire. On May 2016, the fire had damaged around 3500 hectares of land and claimed at least seven human lives apart from loss of fauna and flora in Uttarakhand. In 2015 wildfire that burned across the state of California. In which 8,745 fires burned a total area of 893,362 acres. On August 2014, 2 people died and 20 were seriously injured when fire broke out at the Vastmanland . This incidents shows that forest do not have proper fire prevention and rescue system. Moreover, most of the forest departments do not have an automatic system to stop fire. And it takes a lot of time for the fire service to reach the disaster spot. In this perspective, a system to detect fire and alert the forest department before it breaks out. In this paper, we designed an IOT Infrastructure for forest fire detection and alerting system to help detect fire as soon as possible and save precious human lives. The system will use several sensors to detect any symptoms of fire. The sensors will be placed on proper places after doing surveys. After choosing the best places for placing the sensors, the sensor will be activated. The data collected by

sensors will be sent to Arduino microcontrollers placed on various places. The microcontroller will then process the data. At the same time the system will send SMS using GSM module to the nearby fire service station informing them of the incident. The system will also inform the location of the fire to the administrator using GPS module. Several types of sensors will be used, for example, temperature sensor, gas sensor, smoke sensor, flame sensor, etc.

II. RELATED WORKS

Ahmed Imteaj et al [1] designed and implemented a fire detection system for factories using Raspberry pi3. They used temperature, flame and smoke sensors for sensing fire. The system also can extinguish fire in 20 seconds and they used the air-conditioning system for extinguishing fire.

Abhinav Kumar et al [2] have proposed Forest fire detection system is proposed to detect the fire by monitoring the values of CO2 level and temperature. In this project, we have built fire detector using Raspberry PI which is interfaced with a temperature sensor, a smoke sensor and buzzer. Whenever fire triggered, it burns objects nearby and produces smoke. In this project, we have built fire detector using Raspberry PI which is interfaced with a temperature sensor, a smoke sensor and buzzer. With the help of IoT technology, we have tried to make it smarter by connecting the whole monitoring process to the webpage naming "Fire Security System " created by the PHP tool and controlled by the Arduino programming.

Wireless sensor network is a network in which a large number of sensors are deployed and data is collected from them and send to a particular system for processing. Some of those techniques had been included for fire detection using image processing and sensors in this work [3]. Fire detection using ZigBee is a kind of personal area network.

In [4] the proposed system is capable of early detection of fire and generating alarm in case of emergencies. The period of computation is too small for the fire to spread from one pillar to another. To increase the dynamics of the fire detection, a pre-alert for the nodes is generated which can potentially captured during fire, in the next computation stage. A soft intermediate threshold between sensing threshold and proximity threshold is used. It is called warning threshold.

Akash V. Bhatkule1 et al [5]. designed and implemented an affordable, flexible and fast monitoring home security system using Raspberry pi with GSM technology. The system is designed to detect man made hazards and fire related hazards. The messenger has the feasibility of activating and deactivating the alarm system with the additional control for some home appliances switching using relays. Two advantages provided by the system is that, Necessary action can be taken in short span of time in the case of emergency condition and design of a PCB board which is also small in size. Reduced size makes it more applicable for commercial manufacturing and distribution.

Sathish Kumar et al [6] presented a review on existing fire-detector based on automated fire voice alerting system for alerting any fire incidents in industrial premises. This can benefit to the industries by saving their life during accidents using the automatic voice recorder instructions to operate the fire extinguisher. GSM is placed inside the system in order to send the up to date information about the status of surrounding area to the company IP address.

The author in [7] have proposed stand-alone boxes which are to be deployed throughout a forest which is equipped with different sensors. But they measure the corresponding parameters periodically for every 15 minutes and it is updated in the back end server. Since this mechanism is implemented with periodic update it is found to be less efficient. smoke and methane sensor. These sensors are always in active mode.

John clement et al [8] have proposed method standalone boxes, with each box consisting of various sensors like humidity and temperature sensors. These boxes are spread around the entire forest area so that a complete coverage is obtained. The sensor should cover the entire forest with minimum number of nodes 2. The distance between the sensors must be equal so that it is easy to calculate the rate of spread of fire 3. The sensors must be positioned such that false alarms are avoided These sensors collect the data wirelessly and transmit the data to a base station. The sensors form a cluster and are active always. They sense the parameters every 15 minutes and if there is a possibility of fire detected then the parameters will be measured every 2 minutes. This is to reduce the usage of battery power. These sensors cannot be powered using electricity as they need to be deployed deep into the forest hence rechargeable batteries that are powered by solar panels are used.

Arun Ganesh et al [9] have proposed method for Satellite-based Fire Detection System is based on MODIS the Moderate Resolution Imaging Spectroradiometer was sent to space by NASA for capturing the Earth surface to detect Forest Fires. The problems associated with this system is that it has a long scanning cycle (Fukuda et al.) i.e., it takes maximum of two entire days to capture the entire surface of the Earth before sending it to the Earth station for Forest Fire Detection analysis. It can be ensured that the system developed can be implemented on large scale due to its promising results. The system can also be upgraded with low-power elements, higher versions of ZigBee and a novel, high efficiency MPPT Algorithm in order to make the system run for longer periods.

Ahmad AA Alkhatib et al [10] have proposed Distributed wireless sensors randomly spread in the forest and to create a self-organized and robust network. When the fire is detected, all of the sensors in the area of vicinity will become active and commence the mandatory start and routing tasks. As the sensors are provided with small wireless range transmitters the data need to be travel from sensor to another to reach the sink. Hence it is found to be less efficient if the intermediate sensor nodes is failed to function. Based on the information received, the fire department will then be able to assess the extent and gravity of the situation to arrive at an optimal decision.

Hence, our objective is to design an intelligent early warning fire detection and alarming system to detect the fire in the forest zone which has to overcome the deficiencies observed in the earlier system.

III. SYSTEM DESIGN

The proposed system consist of two modules viz. IoT sensor node and web application deployed in the central location. The IoT sensor node is designed and integrated with Raspberry Pi. Here all the sensors are integrated with the Raspberry PI. The proposed architecture of Forest fire detection is shown in the Fig 1. The various steps of proposed work are explained in this subsection. The first step of forest fire detection is, before the fire starts ignited it monitor the temperature level of the battery and the sensors integrated in the Raspberry pi such as Temperature sensor, Smoke sensor, Fire sensor, Rain sensor. If there is any raise in temperature or it reaches above the threshold value it push the notification SMS to the forest department. Simultaneously it can be detected by using the various sensors such as rain, fire, smoke. If there are any such natural calamities like lightening, burning waste material sensors integrated in the Raspberry PI detects and sends signal to the Wi Fi inbuilt shield of GSM modem. The signals from the Raspberry PI are not directly send to the GSM modem it converts into Analog to Digital and then it sends into the GSM modem from which the signals are processed. And then send information to the admin if there is a high increase of temperature. With the help of temperature

sensor it detects and sends the signal to the admin. According to sensor behavior all the

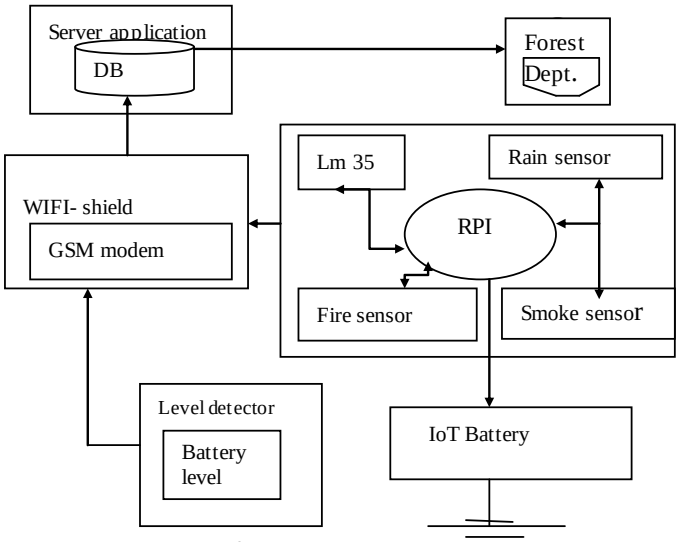


Fig.1. Architecture for Forest Fire Detection and Alerting system

Detected signals are sent to the forest department admin. Signals from the GSM modem are Processed and sent in to the server side application. Then in the second step of forest fire detection. By using IoT battery we can calculate how long the sensor battery will sustain. To monitor IoT battery there is a component called battery level indicator, by using this we can detect the battery life time of the sensors. If the battery level goes down it push the notification to the forest department. Finally all the sensor related values are stored in Database server for future purpose so that Forest department admin can login and can retrieve the details regarding forest fire. So that they can ensure the sensor values that to be set as a threshold hold value for a future purpose.

A. Deployment Setup

For deploying the system of forest fire detection, two different types of micro-controllers, the Arduino Mega and the Raspberry PI. The code written Arduino would contain specific IP address for each Arduino to identify the each of them. Each Arduino acting as Server takes the analog readings from the sensors compares them to the threshold value. If the sensor values get to reach of threshold, the Arduino performs necessary actions, including pushing the notification to the user. Fig 2 explains the deployment diagram for the Forest fire detection and alerting system. Deployment consists of two setups including original and duplicate setup.

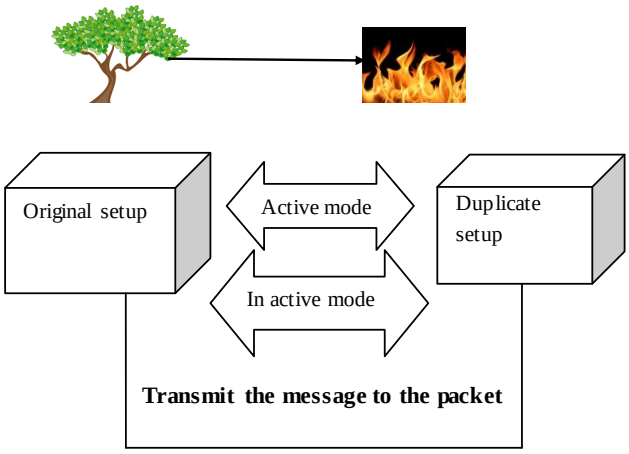


Fig.2. Deployment Diagram for Forest Fire Detection

Original setup is integrated with the Arduino Mega and the Duplicate setup is integrated with the Raspberry PI. Once fire starts ignited both Arduino Mega and Raspberry PI detecting and sensing the fire. If Arduino is in inactive mode, it transmits the packet that I am Inactive, so that Arduino Mega gets active and sense the fire and send signals to the Database server. In another case if Arduino Mega is in inactive mode, it transmit the packet that I am Inactive , so that Raspberry PI gets active and started to sense the fire and sends the signal to the Database server.

IV. IMPLEMENTATION AND RESULTS

For implementation of the system, two different types of micro controllers, the Raspberry pi3 and the Raspberry PI are used. The mother boardnamed Raspberry pi 3 acting as a client is both a micro-controller and a CPU which has a processor of 1.2Ghz 64-bit quad-core ARMv8 Cortex A53 CPU alone with 1 GB ram of 900Mhz, 4 USB ports, 1 HDMI port, 1 audio I/O port and 1 Ethernet port in it, including 40 GPIO pins which can be configured as digital input or output. The board Raspberry pi3 has built in wireless LAN and Bluetooth 4.1 including BLE feature by which we can receive and transmit the data wirelessly without any other partial device. The communication with the administration and the system will be maintained by GSM modem. The GSM module will be connected with the Raspberry pi 3 and it will send the SMS to the User by using AT command.

A. Steps of implementation:

Step 1 (Configure the Programmable Devices):

A software module for each programmable device which are Arduino Mega and Raspberry PI, GSM module SIM900A, Temperature Sensor, Rain Sensor, Smoke Sensor, Fire Sensor. Program in Raspberry PI is implemented in embedded C which program should also have the functionality to communicate with SIM 900A GSM module Where the cell number of the administration should be mentioned. SIM 900A GSM module should be set with a SIM card in it and it should configure as a GSM module.

Step 2 (Setting up code in Raspberry PI)

The R-PI code should be burnt to each sketch of all the configuring the code. The program for the Arduino may be kept in any folder but the path of the file should be mentioned at arduino.cc, so that the program runs automatically on the startup and Arduino could act as a micro-controller.

Step 3 (Integrating the sensor modules):

Each RPI would be connected to 4 sensors. Rain sensor, Smoke sensor, Fire sensor, Temperature sensors are integrated with the Raspberry PI.

Step 4 (Connecting the SIM900A GSM module with Raspberry PI):

Signals from the RPI are sent to the WIFI-shield called GSM Modem SIM 900A.

Step 5 (Powering up all the devices):

In the proposed system, the main devices that will be directly connected to the power source are the Raspberry PI, SIM 900A GSM modem. Arduino needs to be connected with a 5v-2.5v power supply. The SIM 900A draws a good amount of power, so it need a power supply adopter of 7v~12v to be functional. The voltage of the router depends on its model but it is generally 12v

B. Details about the sensors

Flame Sensor

A flame detector is a sensor designed to detect and respond the presence of a flame or fire. The Flame sensor is used to detect fire flames. The module makes use of Fire sensor and comparator to detect fire up to a range of 1 meter.

Fig.3. Flame Sensor

Specification

1. Allows your device to detect flames from upto 1 M away
2. Typical Maximum Range :1 m .
3. Calibration preset for range adjustment.
4. Indicator LED with 3 pin easy interface connector.
5. Input Voltage +5VDC

Rain Sensor

The rain sensor module is an easy tool to detect rain detection. In our proposed system of forest fire detection .Fire can comes out in both natural as well as man-made disasters. In that perspective we have designed a system with the Rain sensor. It can be used as a switch when raindrop falls through raining board and also for measuring rainfall intensity.

Fig.4. RF-04 Rain Sensor

Specification

1. Adopts high quality of RF-04 double sided material.
2. Area=5cm*4cm nickel plate on side.
3. Anti-oxidation, Anti-conductivity with long use time.
4. Comparator output signal clean waveform is good, driving ability, over 15 mA
5. Working voltage 5v
6. Output format: Digital switching output(0 and 1) and analog voltage output A0
7. Small board Pcb size: 3.2 cm*1.4 cm

Smoke Sensor

Smoke sensor module is an easy tool to detect any type of gases or smoke occurred in the forest. Burning of waste materials or cigarettes causes' fire to overcome this issue system is integrated with the smoke sensor.

Fig.5. Smoke sensor

Specification

1. Dimension: 32mm x 22mm x 30mm Specification
2. Operating voltage: 5V
3. Detection Zone: 300 – 10000ppmm
4. Characteristic Gas: 1000ppmm
5. Response time: <10s
6. Recovery time: <30s
7. Measuring Voltage: <24
8. Ambient Temperature: -20C -55C
9. Humidity: <95%
10. Oxygen Content: 21%

GSM Modem SIM 900A:

GSM modem just looks like a mobile phone using the transmission and reception pins, a modem can receive and send the message and it could be interfaced with the pc or to a microcontroller. GSM Modem detects the signals from all the sensors integrated with an RPI so that if there is any abnormal increase in value of sensor it will send alert notification to the forest department.

Fig.6. GSM SIM 900A

Specification

1. Raspberry pi
2. 5v power supply

3. Wires
4. Mobile phones
5. Sim card

V. EXPERIMENTED RESULT

The experiment setup is designed and fabricated. The experiment is performed in various stages and finally on integration the entire setup is tested with various conditions. Experiment setup is created by 3 sensors deployed at different location within the experimental area. The following test cases are generated and tested. Artificially created fire, smoke, rain, is all tested at various time. On encouraging different situation system is found to be reliable and tolerant to faults. In addition the proposed experiment setup at different energy level battery power. To ensure energy level at various conditions when the energy level goes down in the battery level indicator nodule generates the alert notification to the admin. Thereby the failure of the sensor node is completely prevented. Values and results for all the sensors such as Flame sensor, Rain Sensor, Gas Sensor and GSM modem Interface with the Arduino and alert notification is sent to the user are listed below.

Fig.7. When fire gets ignited

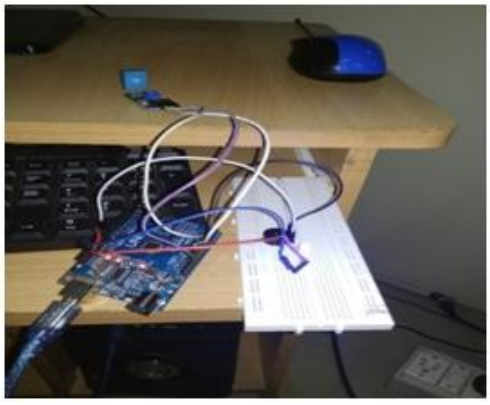
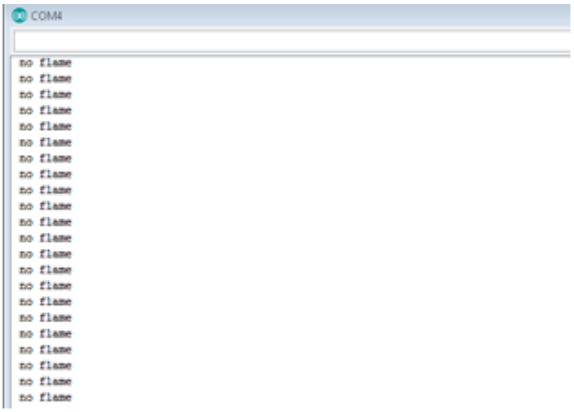


Fig.8. Flame Sensor interfaced With Arduino

Fig 8 explains that Flame sensor is integrated with the Arduino microcontroller board with buzzer connection. The main idea behind the flame sensor is to detect the fire and alert the forest department admin to indicate that there is an fire explosion.



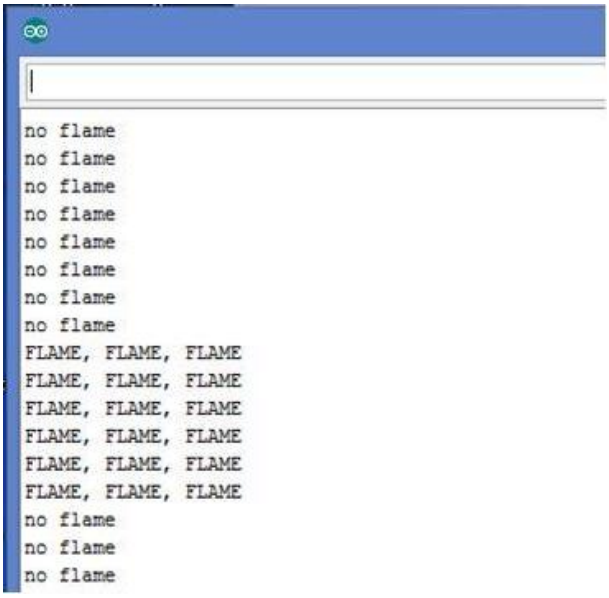
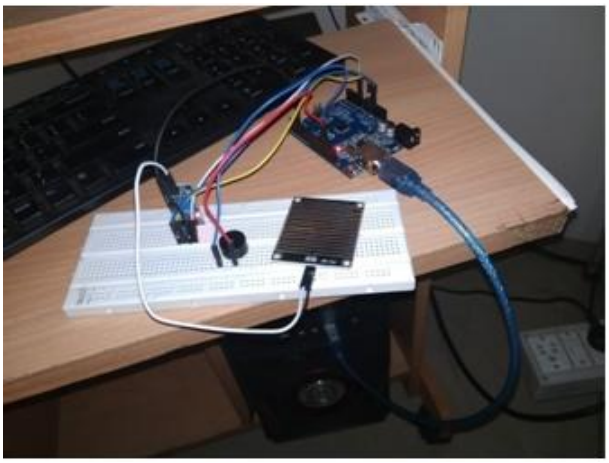


Fig.9. Arduino IDE setup for Fire sensor

Fig 9 explains the Arduino IDE setup for the fire sensor. The program is embedded into the Arduino microcontroller board,output of the sensor indication will be display in the serial moniter. Here there are two cases case 1 is that if there is no explosion of an fire result will be displayed as as “no flame”,”no falme”, case 2 is that if there is an explosion of an fire sensor gets activated it will dispaly as “Flame”,”Flame” with the buzzer sound. So that forest department gets alerted that there is an indication of the fire in the forest.



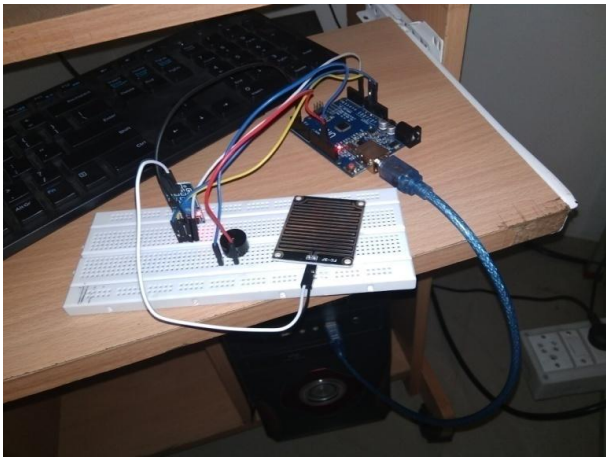


Fig.10. Rain Sensor Interfaced With Arduino

Fig 10 explains the Rain sensor integrated with the arduino. Forest can occur in both natural as well as man made disasters. Due to rain fall or strikinig of sparks from thunder may lead to forest fire, to overcome this issues our system is interfaced with the Rain sensor.

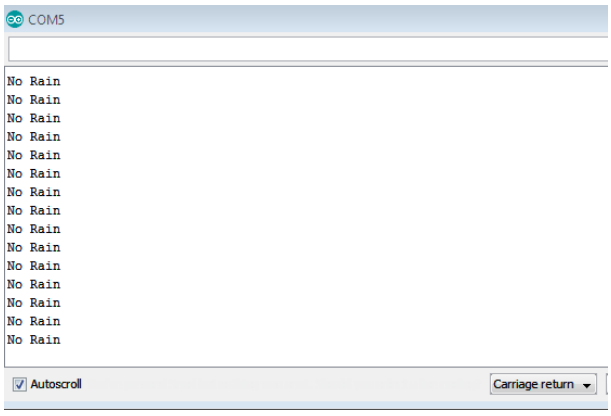


Fig.11. Arduino IDE setup for Rain Sensor

Fig 11 explains the Arduino IDE setup for the Rainsensor. The program is embedded into the Arduino microcontroller board,output of the sensor indication will be display in the serial moniter. If there is no rain fall in the forest. Rain shield will not be activated so that result will be displayed as “no rain”,”no rain”.If there is rain fall in the forest. Rain shield will be activated if amount of rainfall is normal it displays the result as “moderate rain”

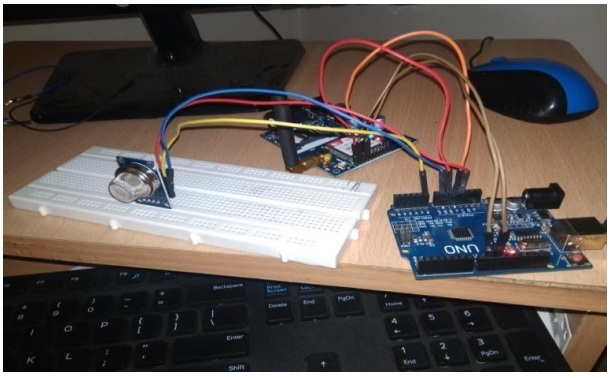


Fig.12. Gas/Smoke Sensor Interfaced with Arduino

Fig.13. Arduino IDE Setup for Smoke Sensor

Fig 13 explains the Arduino IDE setup for the gas or smoke sensor. If there is no explosion of gas or smoke the values will range from 45-80. When there is explosion of gas or smoke values certainly increases from 100-250.

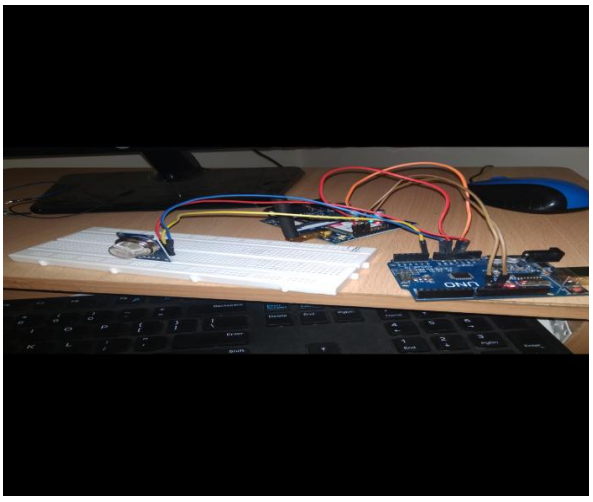


Fig.14. GSM interfaced with Smoke sensor and Arduino

Fig 14 explains the GSM interfaced with the Arduino and Gas sensor. If there is any explosion of gas or smoke. Sensor gets activated and it sends the signals to the GSM modem via GSM modem it sends the alert message to the forest department admin.That there is an indication of gas leakage alert or high explosion of the smoke, so that admin gets alerted.

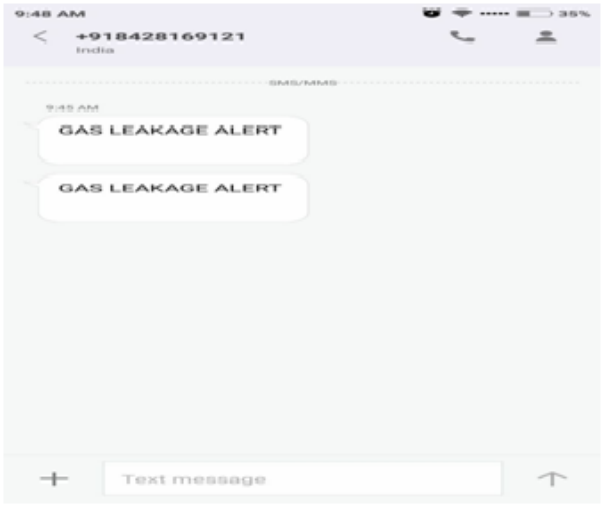


Fig.15. Notification SMS

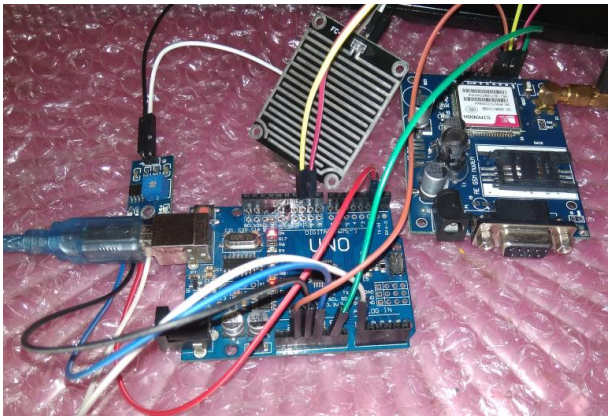


Fig.16. GSM interfaced with Rain Sensor

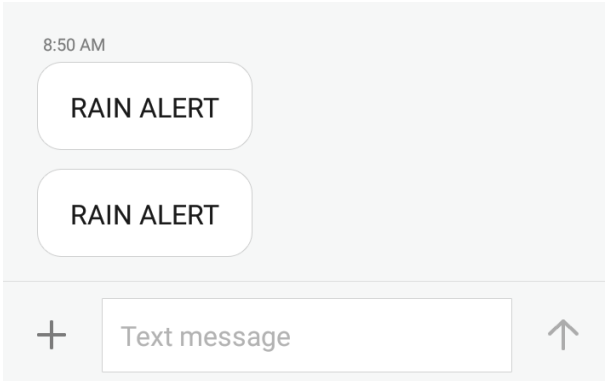


Fig.17. Alert Notification

CONCLUSION

In this work the system is designed and evaluated for its effectiveness as well as scalability due to the improvement of sensor technology In this work, the latest technology can help to reduce catastrophic accidents caused due to fire. With the improvement of IoT sensor technology, the system is more efficient and

useful.

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