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Vehicle Fire Outbreak Detection Communication System

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Abstract : *Vehicle fire outbreak has caused a tremendous amount of losses to the lives of individuals and to insurance companies. Money or lives or both are saved if vehicle fire outbreak is detected or stopped before great damage is caused. As regards to that it was prudent to design and implement a system that can curtail such a devastating menace. This paper presents the design of an easy and economical method to monitor vehicle temperatures that leads fire outbreak. Furthermore, it presents the method that minimizes the response time taken by emergency teams to attend to the scene of fire outbreaks of Vehicles. In the design, Arduino microcontroller (ATmeage328P) is placed at the heart of the whole system designed. It is interfaced with the LM35 heat/temperature sensor which measures the vehicle temperatures. A GPS receiver module is used to gather the location coordinates of the vehicle when the temperature reading exceeds the threshold temperature value. Then the information is sent to the appropriate response authorities in the form of SMS messages using a GSM modem.*

Keywords: *Communication, Detector, Fire, System, Sensor, Vehicle*

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I. Introduction

There are different causes of vehicle fire outbreaks. These may include human errors, chemical or mechanical issues, or a combination of other factors. The most common causes can be split into two broad categories, namely combustible liquids and the electrical system [1]. As most vehicles use gasoline or diesel, there are risks involved in all vehicles. Similarly, thinking of all the electrical equipment contained in a truck, for instance – electric windows, GPS (Global Positioning System), CD (Compact Disc) player, to name a few. If any of the wires shorts or sparks, there is the possibility that it could lead to a fire outbreak. Furthermore, this may be worsened by the highly flammable materials used in the vehicle. Here are some of the more common reasons for outbreak of fires in vehicles [1]:

- Negligence in manufacturing- this seldom causes fire outbreak on its own, however, it can create an environment for other issues to occur, and act as a catalyst to a blaze.
- Lack of maintenance- this is another cause that may not directly cause an outbreak. However, it can combine with other factors to worsen an electrical or mechanical problem, thereby contributing to a fire outbreak.
- Accidents-In cases of accidents, most vehicles are designed to crumple in specific places to prevent severe injuries to passengers and to prevent the vehicle from flaming up. This system is not always dependable as the petrol or diesel tank, for example, could be hit and create a leak, which could spark a blaze.
- Engines overheating-this in itself is not likely to cause a fire, however, it can lead to other issues that will cause the fire outbreak. For example, internal fluids like oil could overheat due to the engine getting too hot, and these can leak and ignite.
- Fluid spilled - there are numerous kinds of fluids in cars and trucks. These including the engine coolant, oil, power steering fluid and petrol or diesel. These can lead to a spark and result in a blaze.
- Fuel leaks- many factors could cause a fuel leak, such as an accident, as mentioned. However, sometimes there is no warning for these and this is what makes them highly dangerous.
- Although fuel is ignited in the engine when driving in order to power the car, if this happens outside of the engine block, it can be devastating.

Because of the fact that most of the aforementioned factors are present in vehicles, it is likely that an outbreak of fire can occur in vehicles.

II. Problem Statement

It was reported on the news in Ghana on January 8th 2014 that three passengers of a taxi cab were burnt to death while the driver sustained serious injuries due to an outbreak of fire in the vehicle. The injured driver was rushed to the nearest hospital by compassionate residents who happened to be around the scene of the accident and was saved. However, the three passengers at the back seat were not fortunate enough and remained trapped and eventually got burnt to death along with other personal properties and the cab itself [2]. According to the severity of the injuries sustained by the driver, it can be said that the driver could not have survived had it not been the help of the residents who happened to be around the scene. Furthermore, it can be said that the other three passengers might have been saved if emergency response teams hurriedly came to the scene of the accident. One could say that the driver was saved due to luck. Human lives must not be left to chances and luck. Fire on a moving vehicle can be more catastrophic since fanning by winds helps to spread the fire rapidly. The worst can happen if these accidents occur in remote areas or during the night. Therefore, there was the need to have in place a system that will help to solve vehicle fire outbreak problem. The problem brought about the focus of designing and constructing a system that is capable of detecting fire outbreak as early as possible, and to alert the appropriate authorities so that swift actions can be taken to rescue victims and properties. Significance of project The designed system serves as a supplement to fire extinguishers in vehicles. It enables emergency services to follow up on any vehicle involved in fire outbreak to ensure that passengers are not endangered. Also through this research, robbery cases in which vehicles involved are burnt to remove evidence can be successfully tracked.

III. Scope And Limitation

This project is suitable for the detection of fire outbreak in environment where excessive heat is generated such as in vehicles and also in heavy industrial environments (where lot of heat is generated by the working machinery). However, it is limited to locations where the band of frequency for GSM (Global System for Mobile telecommunication) SIM900 module is used. These locations include Africa and Europe. Since the GSM module uses a network SIM (Subscriber Identity Module) card it will not be suitable to use this project in a no network coverage area. Also, programming a particular ambulance service unit or fire service unit number into the microcontroller becomes problematic since vehicles may travel outside their district or region and as such these emergency responders may not be nearest to the accident scene.

IV. Literature Review

4.1 Fire Detectors

Fire detectors can be categorized as Heat or Thermal Detectors, Smoke Detectors, Flame Detectors and Fire-gas Detectors [3] [4]. Heat detectors are of two types. The fixed temperature and the rate of rise heat detectors [4]. These devices are able to detect heat by one or more of the three primary principles of physics; Expansion of heated material, melting of heated material or changes in the resistance of heated material. They are designed to detect heat in a relatively small area surrounding the spot they are located. The fixed temperature devices are designed to activate upon reaching a predefined temperature. The rate of rise heat detectors operate on the principle that the temperature in a room will increase faster from fire than from atmospheric temperature. Hence these detectors are designed to activate when there is an abnormal rise in temperature (when the rate of rise in temperature exceeds 7-8 Degrees Celsius). Heat or thermal detectors are the oldest types in use, relatively inexpensive and least prone to false alarms [3].

Smoke detectors are relatively newer invention as compared to heat or thermal detectors. These detectors usually detect fire in early flaming or smoldering stages [3]. There are two basic types of these detectors having different operating principles, namely - photoelectric detectors and ionization detectors [4]. Photoelectric or optical smoke detectors include various components, mainly, a light source (usually an infrared LED), and a lens to converge light rays into a beam, and a photodiode. In normal condition, the light beam passes straight. But whenever smoke interrupts the path of light into the photodiode, the smoke detector is activated. This detector is more sensitive to smoldering fires. Ionization smoke detectors are based on ionization from radioactive elements like americium-241. This radioactive isotope emits alpha particles into an ionization chamber, which comprises of electrodes. The alpha particles ionize the air inside the chamber, resulting in current flow between the electrodes. Now, whenever smoke particles from a nearby fire passes through the chamber, the ions get attached to smoke particles, and thereby interrupts the current flow between the electrodes, and activates the detector. This type of detectors is more suited to rapid flaming fire outbursts. Ionization based detectors have safety issues and possess threats to environment, because of americium-241. Therefore, on the basis of performance and safety concern some countries have banned ionization based alarms, and different fire authorities and associations have reports not recommending use of these detectors [3].

Flame detectors come in various types depending on the light wavelength they use. There are Infrared (IR), near infrared, ultraviolet (UV) and combination of UV/IR type flame detectors [4]. These are the most sensitive to detect fires but also easily activated by non-fire conditions such as welding, sunlight, etc. When using flame detectors, the device must be positioned with an unobstructed view of the protected area otherwise the device will not activate if its line of site is blocked. The Infrared (IR) flame detectors work within the infrared spectral band (700 nm - 1 mm). Usual response time of these detectors is 3 - 5 seconds [4]. UV detectors generally work with wavelengths shorter than 300 nm. This type of detectors can detect fires and explosions situations within 3 - 4 milliseconds from the UV radiation emitted from the incident [4]. However, to reduce false alarm triggered by UV sources such as lightning, arc welding etc. a time delay is often included in the UV flame detector. The near Infrared sensor or visual flame detectors work with wavelengths between 0.7 to 1.1 μm. One of the most reliable technologies available for fire detection, namely multiple channel or pixel array sensors, monitors flames in the near IR band. The combined UV/IR flame detectors compare the threshold signal in two ranges to detect fire and minimize false alarms.

Gas detectors are usually designed to monitor levels of carbon dioxide and carbon monoxide which are common to all fires. These work by the principle of chemical reaction taking place between gas from fire incident and semiconductor material present inside the sensor. The semiconductor material used in these sensors is metal oxides, generally Tin dioxide (SnO_2), Tungsten oxide (WO_3) [3], etc. Under normal circumstances, the surface potential acts as a potential barrier to restrict electron flow within the sensor circuitry. However, the deoxidizing gases from fire incidents diminish the oxygen surface density, and thereby reduce barrier potential to permit electron flow. The associated electrical circuitry detects the rise in conductivity due to electron flow, and activates alarm to undertake necessary measures [4].

4.2 GSM Networks

Global System for Mobile Communications (GSM) is the first digital second-generation (2G) cellular network, which was set up by the Conference of European Posts and Telecommunications (CEPT) in 1982, as a standard for mobile telephone system that could be used across Europe. GSM is now an international standard for mobile service which offers high mobility, and allows subscribers to easily roam worldwide and access any GSM network. The system uses Time Division Multiple Access (TDMA) system and is the most widely deployed digital network in the world today. It is currently being managed by the European Telecommunications Standards Institute (ETSI) [5] [6]. The physical architecture of the GSM network consists of four main components: The Mobile Station (MS), the Base Station Subsystem (BSS), Network and Switching Subsystem (NSS) and the Operation and Support Subsystem (OSS) [5] [6]. The MS is made up of the Mobile Equipment (ME) - mobile phone and the Subscriber Identity Module (SIM) card. The SIM card in a GSM handset is a microprocessor smart card that securely stores various critical information such as the subscriber’s identity as well as the authentication and encryption algorithms responsible for providing legitimate access to the GSM network. Each SIM card has a unique identification number called the International Mobile Subscriber Identity (IMSI) [5].

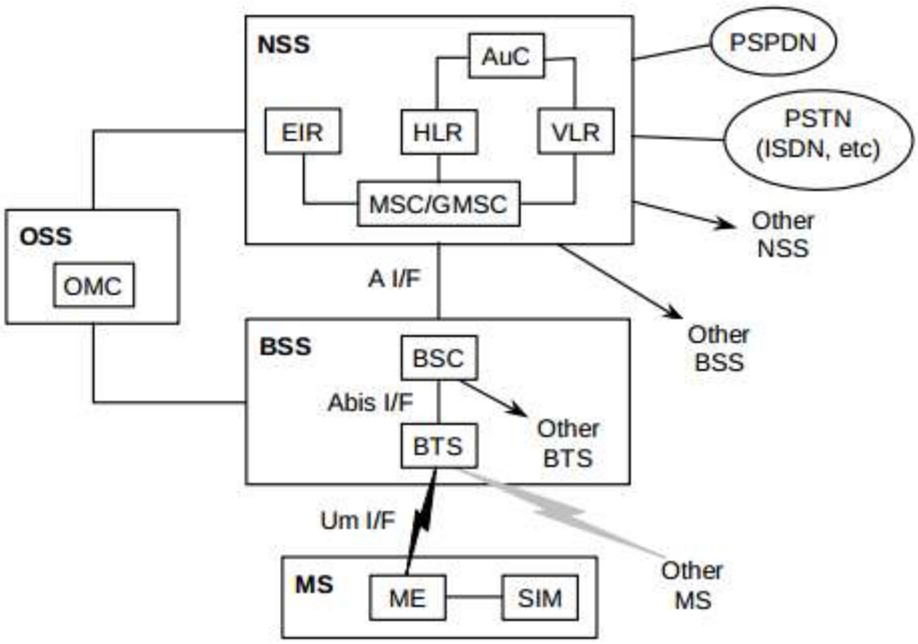

Figure 0: GSM Network Architecture

The BSS connects the MS to the NSS and consists of the Base Transceiver Station (BTS) and Base Station Controller (BSC). It is in charge of transmission, reception and management of radio resources. The BTS is responsible for providing the wireless connection between the handset and the wireless network [5]. A BTS is comprised of a set of radio transmitters and receivers, and antennas to connect the mobile to a cellular network for pursuing the required call handling tasks. It takes in the calls within its coverage zone and ensures their proper handling. The BSC controls a group of BTS (from tens to hundreds) and manages their radio resources. It is principally in charge of handovers (passing a subscriber from one cell to another with no degradation to the quality of the communication), frequency hopping, exchange functions and control of the transmitter power levels of the BTS [6].

The Network and Switching Subsystem (NSS) is made up of the two essential elements, Mobile Switching Center (MSC) and Gateway Mobile Switching Center (GMSC), along with its supporting elements: the Home Location Register (HLR), the Visitor Location Register (VLR), the Authentication Center (AuC), and the Equipment Identity Register (EIR) [5]. The NSS establishes communications between a cell phone and another MSC, and takes care of the Short Message Services (SMS) transmission. The MSC controls call signaling and processing, and coordinates the handover of the mobile connection from one base station to another as the mobile roams around. Each MSC is connected through GMSC to the local Public Switched Telephone Network (PSTN or ISDN) to provide the connectivity between the mobile and the fixed telephone users. The HLR is a database used for management of the operator's mobile subscribers (the user's profile, subscriber's international identity number, and telephone number) and temporary data (the user's current location). The VLR is responsible for a group of location areas, and stores the data of those users who are currently in its area of responsibility. The AuC performs security functions such as authentication of subscriber and encryption of user's data. The GSM distinguishes explicitly between the user and the equipment, and deals with them separately. The EIR registers equipment data rather than subscriber data. It is a database that contains a list of all valid mobile station equipment within the GSM network, where each mobile station is identified by its International Mobile Equipment Identity (IMEI) [6].

The OSS comprises the Operation and Maintenance Centre (OMC). It links to the different components of the NSS and to the BSC, in order to control and monitor the GSM system. The OSS also controls the traffic load of the BSS [6]. GSM networks operates different frequency bands for different countries. It can operate four distinct frequency bands [5] – [7]:

- GSM 450: GSM 450 supports very large cells in the 450 MHz band. It was designed for countries with a low user density.
- GSM 900: The original GSM system was called GSM 900 because the original frequency band was represented by 900 MHz. It has uplink frequency range of 890 - 915 MHz and a downlink frequency range of 935 - 960 MHz. To provide additional capacity and to enable higher subscriber densities, two other systems were added afterward:
- GSM 1800: This is an adapted version of GSM 900 operating in the 1800 MHz frequency range. Any GSM system operating in a higher frequency band requires a large number of base stations than for an original GSM system. The availability of a wider band of spectrum and a reduction in cell size will enable GSM 1800 to handle more subscribers than GSM 900.
- GSM 1900 (or PCS 1900): PCS 1900 (Personal Communications System) is a GSM 1800 variation designed for use on the North American Continent, which uses the 1900 MHz band.

The GSM system provides many services beyond basic telephony (voice calls over any telephone network). It provides services such as Short Message Services (SMS). An SMS message comprises a string of up to 160 text characters which can be sent to or from a mobile. Other services provided by the GSM network include emergency calls, fax mail, voice mail, Advice of Charge (call charge information), Call hold, Call Waiting services, et cetera [6].

4.3 GPS System

The Global Positioning System (GPS) is a satellite-based system that can be used to locate positions anywhere on the earth. It was developed by the U.S. Department of Defense (DoD) in the early 1970s as a military system to fulfill U.S. military needs. However, it was later made available to civilians. GPS provides continuous (24 hours/day) positioning and timing information, anywhere in the world under any weather conditions [8] – [9]. The GPS system consists of three segments: The space segment, the control segment, and the user segment. The space segment consists of 24 satellites known collectively as the GPS constellation. There are four satellites placed in 6 orbital planes and each of the 6 orbital planes is inclined 55 degrees relative to the equator [8]. Each GPS satellites is powered by sun-seeking solar panels and transmits a signal, which has a number of components: two sine waves (also known as carrier frequencies), two digital codes, and a navigation message. The carriers and the codes are used to determine the distance from the user's receiver to the GPS satellites. The navigation message contains the coordinates of the satellites as a function of time [9].

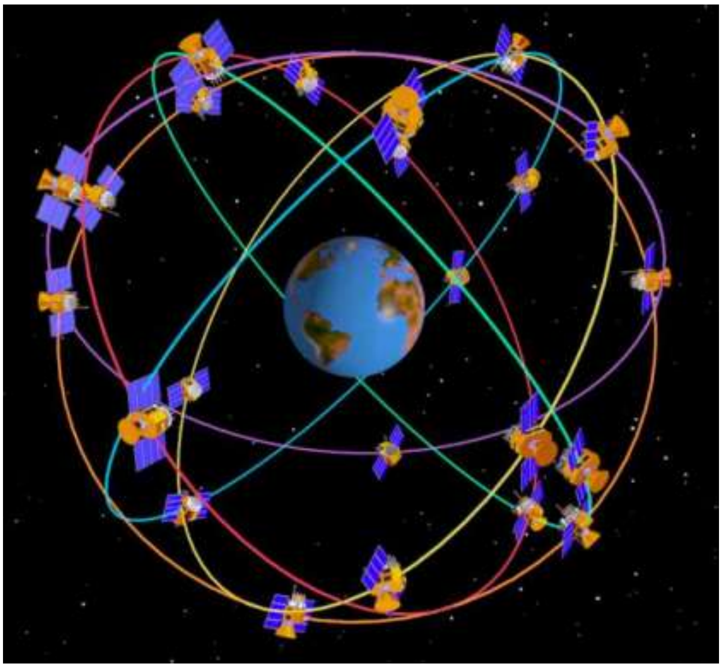

Figure 04a: GPS Constellation

The control segment of the GPS system consists of a worldwide network of tracking stations, with a master control station (MCS) located in the United States at Colorado Springs, Colorado. These control stations measure satellite orbits precisely and transmits any discrepancies between predicted orbits and actual orbits back to the satellites. The satellites can then broadcast these corrections, along with the other position and timing data, so that a GPS receiver on the earth can precisely establish the location of each satellite it is tracking [8].
The user segment includes the military and civilian users. The U.S. military uses GPS for navigation, reconnaissance, and missile guidance systems. Civilian uses of GPS ranges from applications such as surveying, transportation, natural resource management, agriculture, timing, mapping and a whole lot of things. Any person with a GPS receiver can access the system and it can be used for any application that requires location coordinates.

When a GPS receiver is switched on, it will pick up the GPS signal through the receiver antenna. Once the receiver acquires the GPS signal, it will process it using its built-in software. The partial outcome of the signal processing consists of the distances to the GPS satellites through the digital codes (known as the pseudoranges) and the satellite coordinates through the navigation message. Theoretically, only three distances to three simultaneously tracked satellites are needed. In this case, the receiver would be located at the intersection of three spheres; each with a radius equal to the distance between the receiver and the satellite and is centered on that particular satellite [9].

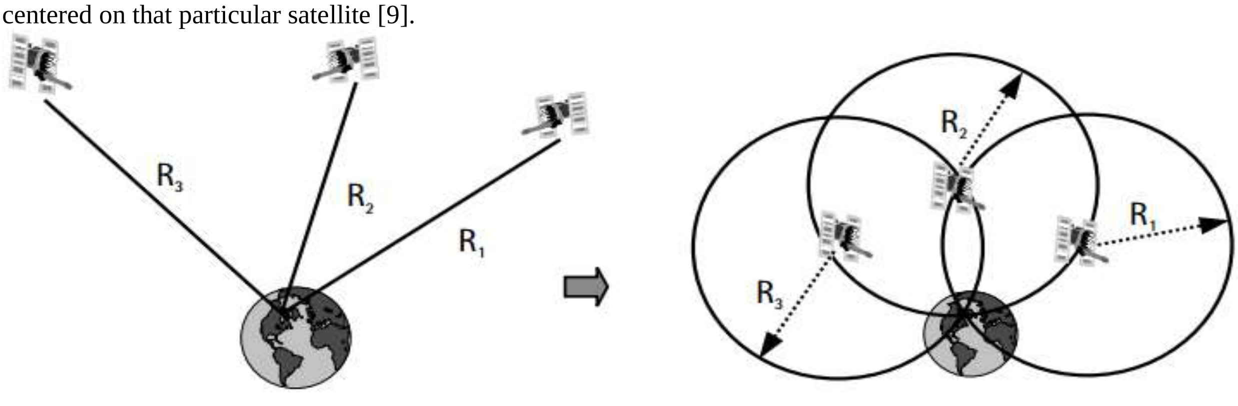

Figure 04b: Basic Idea of GPS positioning

4.4 Fire Detection and Notification System in Trains

This research work was conducted and reported on by Kuncham Viswa Teja and Suresh Angadi and was published in the International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET) Volume 2, Issue 4 on April 2013. The aim of the research was to reduce or eliminate the delay time between when fire outbreaks in trains occur and when first responders (emergency services personnel) are dispatched to the scene in order to reduce the damages. The project helps to notify passengers through a buzzer, and emergency services personnel are notified by an alert SMS sent using a GSM modem. The SMS alert sent to the emergency personnel contains information of the fire incident such as the GPS location of the train at the time of outbreak [10].

The components used in this project include a microcontroller interfaced with a GPS module, GSM modem, fire sensors, an LCD display and a buzzer. The microcontroller used is an AT89C52 microcontroller from Atmel industries. It uses RS 232 protocol for serial communication between the GPS module and the GSM modem. The mobile number of the emergency services personnel is stored on an EEPROM. To detect fire outbreak on the moving train ZigBee fire sensors are used. These sensors are installed in every compartment of the train. Whenever there is an outbreak of fire in any of these compartments the ZigBee sensor in that compartment senses it immediately and sends signals to the microcontroller. A ZigBee sensor is a wireless sensor network, which combines computer and communication technology with the technology of sensor network. It is composed of numerous micro sensor nodes which have the ability to communicate and calculate. The nodes can monitor, sense and collect information of different environments and various monitoring objects cooperatively. These sensors are interfaced to the microcontroller through Bluetooth wireless technology.

To gather the location of the train at any time of incident, a GPS location module GS-87 is used. This is a third generation GPS receiver chip which consists of a radio frequency integrated circuit, a digital signal processing circuit and a standard embedded GPS software composition. The GPS module in kept ON at all times and continuously tracks the movement of the train. After identifying a fire outbreak in the train, it gathers the longitudinal and latitudinal position of the train and transmits it to the microcontroller which in turn sends it to the GSM module. The system uses a GSM SIM900 modem for its operation. This modem operates in the 900/1800 MHz frequency band and is used in a variety of places such as Asia, Europe and Africa. The GSM modem is also kept ON at all times and after receiving the longitude and latitude values from the microcontroller, a message in the form of an SMS is sent from this modem to the emergency unit alerting them of the dangerous situation. Power is supplied to the whole system from an AC voltage supply of 230V which is rectified using a center tapped step down transformer and Zener diodes and then, regulated at 5V using an LM7805 voltage regulator. When fire is detected, the microcontroller is supplied with power and immediately the buzzer in turned ON to notify the passengers. Message of fire detection is also displayed on an LCD display screen [10].

4.5 Design of Microcontroller Based Temperature Controller

In this work, a system is designed to control the temperature of any device according to its requirement for any industrial application. The goal of this project is to design an ambient temperature measurement and control circuit. The system is to be utilized in temperature sensitive environment such as chemical manufacturing industries, food processing plants, pharmaceutical industries, etc. where temperature is one of the main parameter to be controlled. This system is an ON-OFF type close loop control system whereby temperature is sensed, displayed on an LCD and then, compared with preset value. If this sensed temperature is greater than the default value, the heating system is switched off. If it is less than the default value then heating system is switched on. The components used in this project include an ATmega32 microcontroller, a 16x2 LCD display, an LM35 temperature sensor, Heater, relay, transistor and an AC power supply [11].

The ATmega32 microcontroller controls the whole function of this system. It is an 8-bit high performance microcontroller and has 10-bit, inbuilt ADC converters, which means, there is no need to interface it to additional ADC converters hence reducing the number of external peripherals considerably. This device has low power consuming capabilities. To accurately measure the temperature of the environment, an LM35 temperature sensor is used. The output voltage of this sensor is linearly proportional to the temperature in Celsius. In order to convert the analog voltage into digital data, the output pin of the LM35 sensor is connected to one of the ADC input pin of the ATmega microcontroller. The system displays the temperature on an LCD in the range of -55 to +150 degrees Celsius. The temperature measured by the LM35 temperature sensor is compared with a stored value (preset temperature value), and if the temperature goes beyond the preset value, heating system is switched off. The heater is switched on if the temperature goes below the preset value. Relays are used when it is necessary to control a circuit by a low-power signal, or where several circuits must be controlled by one signal. They allow one circuit to switch a second circuit. For instance, in this project there is the need for a low voltage battery circuit to switch a 230V AC mains circuit and as such, a relay is required. A normally closed relay was interfaced to Port B of the ATmega32 with the help of a BC547 transistor to turn off the heater when temperature is above the set point. The BC547 is an NPN general purpose transistor which is used in general purpose switching and amplification. For the purpose of this project, the transistor acts as a switch to turn ON/OFF the relay. The software code for this system is developed using AVR Studio 4. Win AVR is used to compile the C-code and to generate its HEX code. Sinaprog 2.0 is used to burn the hex code into the microcontroller [11].

4.6 Development of Vehicle Tracking System Using GPS and GSM Modem

This research investigates the ability to track vehicles using a GPS module and a GSM modem interfaced with a microcontroller. It was carried out and reported by Hoang Dat Pham on December, 2013.

The ability to track vehicles is useful in many applications including security of personal vehicles, public transportation systems, fleet management and others. Furthermore, the number of vehicles on the road globally is also expected to increase rapidly. Therefore, the development of vehicle tracking system using the Global Positioning System (GPS) and Global System for Mobile Communications (GSM) modem is undertaken with the aim of enabling users to locate their vehicles with ease and in a convenient manner.

The system designed to provide users with the capability of tracking vehicles remotely through the mobile network. This work details the development of the vehicle tracking system's hardware prototype. Specifically, the system will utilize GPS to obtain a vehicle's latitudinal and longitudinal coordinate and transmit it using GSM modem in the form of an SMS message to the user's phone through the mobile network.

The main hardware components of the system are u-blox NEO-6Q GPS receiver module, u-blox LEON-G100 GSM module and Arduino Uno microcontroller. The developed vehicle tracking system demonstrates the feasibility of near real-time tracking of vehicles and improved customizability, global operability and cost when compared to existing solutions [12].

4.7 Wireless Accident Information System Using GSM and GPS

This work was researched and conducted by Rathinakumar and D. Manivannan in 2012. The aim was to reduce the fatalities of vehicular accidents caused by vehicular collisions. The system consists of collision sensors, microcontroller, GPS module and a GSM modem [13].

Vibrational sensors are used in this system to detect collisions in vehicles. These sensors are connected to a central ATmega16 microcontroller which controls all the actions of this system. At the instance collision occurs, the GPS module is activated to gather the present location of the vehicle. This information is communicated to the microcontroller in terms of latitude and longitude. The microcontroller relays this message to the GSM SIM300 modem which in turn sends an SMS alert to the first responders so that immediate medical care can be given to victims. The system is designed to eliminate the delay time between when collision accidents occur and when medical assistance arrive at the scene of incidents. Instructions for the microcontroller are written using C-programming language. Power is supplied to the system through a 230V AC mains and this is rectified using a step down transformer and a bridge rectifier. The resulting voltage is then regulated at 5V using an LM7805 voltage regulator. The whole system is implemented on a Printed Circuit Board (PCB) [13].

4.8 GPS and GSM based Vehicle Tracing and Employee Security System

This work was researched and conducted by S.S. Pethakar, N. Srivastava and S.D. Suryawanshi in 2013. The aim of this work is to improve the safety of employees of a company and also help in tracking of the vehicles wherever they are at every instance. The system comprises of a GPS receiver, Microcontroller and a GSM Modem [14].

The GPS Receiver retrieves the location information from satellites in the form of latitude and longitude real-time readings. The Microcontroller has two main tasks: to processes the GPS information to extract desired values and to transmit this data to the server using GSM modem by SMS.

The modem receives the SMS that includes GPS coordinates and employee id, cab id information. This text is processed using a Visual Basic program to obtain the numeric parameters, which are saved as a Microsoft Office Excel file. The received reading of the GPS is further corrected by Kalman filter. To transfer this information to Google Earth, the Excel file is converted to KML (Keyhole Markup Language) format. Google Earth interprets KML file and shows automobile's location and engine parameters on the signal is not sent with the data. Each word is synchronized using its start bit, and an internal clock on each side, keeps tabs on the timing. The RS-232 levels are generated internally using switching latches and capacitors of 10uf each.

The system comes with a very special facility which is the Emergency button. Emergency button is a part of car unit. There are three to four emergency buttons in the car. These buttons are placed at such position so that employee can access them easily i.e. near the door unlocking handle. If employee finds himself/herself in a problem, he/she will press the button. Microcontroller will detect the action & sends a signal to the GSM which will coordinate with to the company unit and police. Microcontroller will also send a signal to the relay which will turn off the car ignition & stop the car [14].

4.9 GSM based Automatic Irrigation Control System for Efficient Use of Resources and Crop Planning by Using an Android Mobile

This research work was carried out with the main aim of using artificial methods to supply water to the roots of the plant. The system involves GSM module, Android, SMS, microcontroller, Temperature sensor, soil moisture sensor and regulated power supply.

The centralized unit communicates with the system through SMS which will be received by the GSM with the help of the SIM card. The GSM sends this data to ARM7 which also continuously receives the data from sensors in some form of codes. After processing, this data is displayed on the LCD. Thus in short whenever the system receives the activation command from the subscriber it checks all the field conditions and gives a detailed feedback to the user and waits for another activation command to start the motor. The motor is controlled by a simple manipulation in the internal structure of the starter. The starter coil is indirectly activated by means of a transistorized relay circuit. When the motor is started, a constant monitoring on soil moisture and water level is done & once the soil moisture is reached to sufficient level the motor is automatically turned off and a massage is sent to subscriber that the motor is turned off. The water level indicator indicates three levels; low, medium, high and also empty tank [15].

V. Methodology

5.1 System Operation

This paper presents a system that detects fire outbreaks in vehicles as soon as they start and then alerts the response authorities automatically so that the victims, their properties, and the vehicle can be rescued. The system consists of a temperature sensor that detects any increase in heat. This heat sensor is connected to a central microcontroller which is programmed with the default maximum temperature. Control signal is sent to the GSM (Global System for Mobile telecommunication) module as soon as the system's temperature exceeds the default maximum temperature. The GSM module then sends out an SMS (Short Message Services) which contains the GPS (Global Positioning System) location of the vehicle to the right authorities. In addition to that, a buzzer and a reset key are provided. When activated, the buzzer alerts the passengers of the situation and the reset key is used to notify the emergency team of the seriousness of the fire outbreak. In a less catastrophic situation where the driver is able to stop the spread of fire using the fire extinguisher the reset key is pressed and no SMS is sent. However, in a more catastrophic situation, the reset key is not pressed and the SMS is sent to notify the appropriate authorities such as the fire service unit, the ambulance unit, and the police. Both hardware and software components were needed to complete the development of the system.

Figure 5.1 below shows the flowchart of the operation of the system

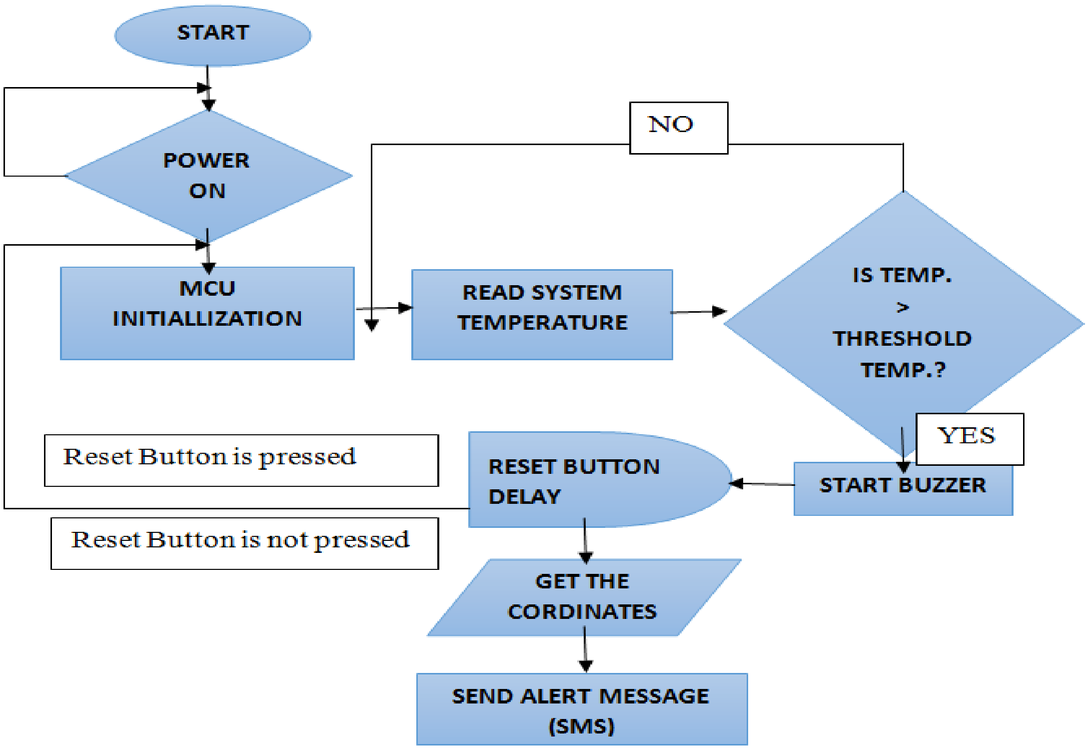

Figure 5.1: Flow Chart

5.2 Hardware Components

The hardware components needed for this project are as follows;

Microcontroller – Arduino UNO R3

At the heart of this project is a microcontroller unit which is interfaced with the heat/fire sensor, GPS receiver module, GSM network connector modem and the other peripherals. The microcontroller is programmed with the default temperature of the system which is 90 degrees Celsius above which the circuit is activated to send SMS message to the intended authorities.

In this project the Arduino board with its central ATmega328P microcontroller is used. Arduino consists of both physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on computer. It is used to write and upload computer code to the physical board. The Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board –simply, a USB cable can be used . The board consists of 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button [16].

Figure 0.a: Arduino Board

Heat sensor – LM35 Temperature Sensor

The normal operating temperature for most engines is in the range of 195 to 220 degrees Fahrenheit (90.556 to 104.444 degrees Celsius). Hence to measure such high temperatures, a sensor with wide range of temperature readings is required. The LM35 heat sensor which has a temperature range of -55 to 150 degrees Celsius accomplishes this task well.

The LM35-series devices are precision integrated-circuit temperature sensors, with an output voltage linearly proportional to the Centigrade temperature. The LM35 device has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from the output to obtain convenient Centigrade scaling. The LM35 device does not require any external calibration or trimming to provide typical accuracies of ± ¼ °C at room temperature and ± ¾ degrees Celsius over a full −55°C to 150°C temperature range. The low output impedance, linear output, and precise inherent calibration of the LM35 device makes interfacing to readout or control circuitry especially easy. The device is used with single power supplies, or with plus and minus supplies. As the LM35 device draws only 60 μA from the supply, it has very low self-heating of less than 0.1°C in still air. The temperature-sensing element is comprised of a delta-V BE architecture. The temperature-sensing element is then buffered by an amplifier and provided to the V_{OUT} pin. The amplifier has a simple class A output stage with typical 0.5-Ω output impedance therefore the LM35 can only source current and it's sinking capability is limited to 1 μA [17].

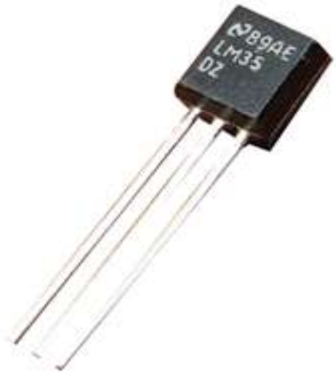

Figure 0.a: LM35 Temperature Sensor

Name	Type	Description
V_{OUT}	Output	Temperature sensor analog output
GND	Ground	Device ground pin, connected to power supply negative terminal
$+V_S$	Power supply	Positive power supply pin

Table 5.2.2.a: Pin Functions of LM35 Temperature Sensor

In the system design, the input pin (+Vs) of the LM35 sensor is connected to one of the 5V supply pin (pin 3) and the output (middle) pin (V_{out}) is connected to the analog pin (A0) on the Arduino board. The ground pin is then connected to ground on the Arduino board. This ensures that, the Arduino continuously receives temperature updates from the LM35 sensor.

Buzzer and Reset Key

A buzzer and a reset key are provided in this system. The purpose of the buzzer is to alert the passengers of situations of fire outbreaks, and that of the reset key is to notify the emergency team of the seriousness of the fire outbreak. For instance, in a less catastrophic situation where the driver is able to stop the spread of fire using the fire extinguisher the reset key is pressed and no SMS is sent. However, in a more catastrophic situation, the reset key is not pressed and the SMS is sent to notify the appropriate authorities such as the fire service unit, the ambulance unit, and the police. The Arduino board comes with a pre-installed reset button hence there is no need for extra reset buttons. The buzzer used is a Piezo Electronic Buzzer. The buzzer which is a digital component is connected to digital pin 8 on the Arduino and is activated in the program code using an "If statement". This means that the buzzer only buzzes if, the LM35 sensor senses a certain degree of temperature (the default temperature of 90 ^{o}C).

GPS Module – u-blox NEO-6M GPS Receiver

The GPS receiver module is the component that gathers the geographic location of the vehicle incident and sends this data to the GSM Modem to be sent as an SMS message. Any person with a GPS receiver can access the GPS system, and it can be used for any application that requires location coordinates. The NEO-6 module series is a family of stand-alone GPS receivers featuring the high performance u-blox 6 positioning engine. These flexible and cost effective receivers offer numerous connectivity options in a miniature 16 x 12.2 x 2.4 mm package. Their compact architecture and power and memory options make NEO-6 modules ideal for battery operated mobile devices with very strict cost and space constraints. The 50-channel u-blox 6 positioning engine boasts a Time-To-First-Fix (TTFF) of within 1 second. The dedicated acquisition engine, with 2 million correlators, is capable of massive parallel time/frequency space searches, enabling it to find satellites instantly. Innovative design and technology suppresses jamming sources and reduces multipath effects, giving NEO-6 GPS receivers excellent navigation performance even in the most challenging environments [18].

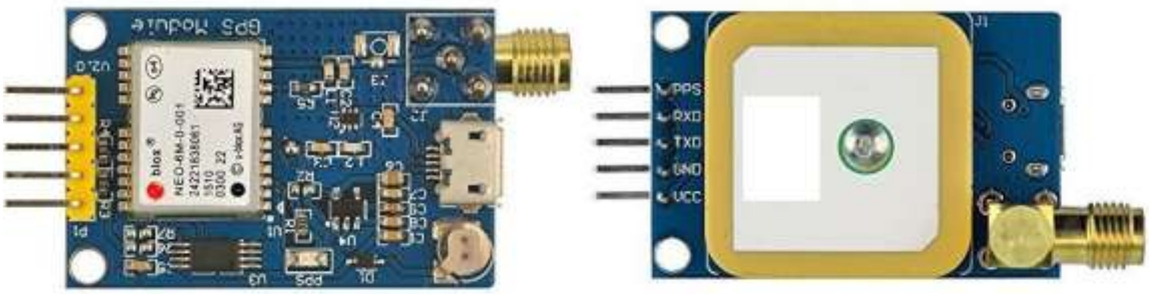

Figure 0.a: u-blox NEO-6M GPS Receiver

The Rx Pin of the GPS module is connected to the Tx pin on the Arduino and the Tx pin is connected to the Rx pin on the Arduino. The input pin is connected to Arduino's 3.3V power supply and then, the ground pin is grounded. The GPS module continuously sends GPS data to the Arduino in the form of National Marine Electronics Association (NMEA) sentences. The software aspect is programmed so that only the latitude and longitude at the time of incidents are transmitted to the GSM module to be sent via SMS messages.

GSM Modem

The alert message can be sent to distant remote locations using various means like: wireless networks (RF Tx/Rx pair), wireless sensor network, Ethernet, GSM network etc. Among these, GSM based mobile network is most feasible for its availability all over the globe and cost-effectiveness. GSM modem SIM900 is used in this project because it has the suitable frequency range (900 MHz) for Ghana [7]. GSM (Global System for Mobile) / GPRS (General Packet Radio Service) TTL - Modem is SIM900 Quad-band GSM / GPRS device, which works on frequencies 850 MHZ, 900 MHZ, 1800 MHZ and 1900 MHZ. It is very compact in size and easy to use as plug in GSM Modem. The Modem is designed with 3.3V and 5V DC TTL interfacing circuitry, which allows User to directly interface with 5V Microcontrollers (PIC, AVR, Arduino, 8051, etc.) as well as 3.3V Microcontrollers (ARM, ARM Cortex XX, etc.). The baud 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. It is suitable for SMS as well as DATA transfer application in mobile phone to mobile phone interface. The modem can be interfaced with a Microcontroller using USART (Universal Synchronous Asynchronous Receiver and Transmitter) feature (serial communication) [19].

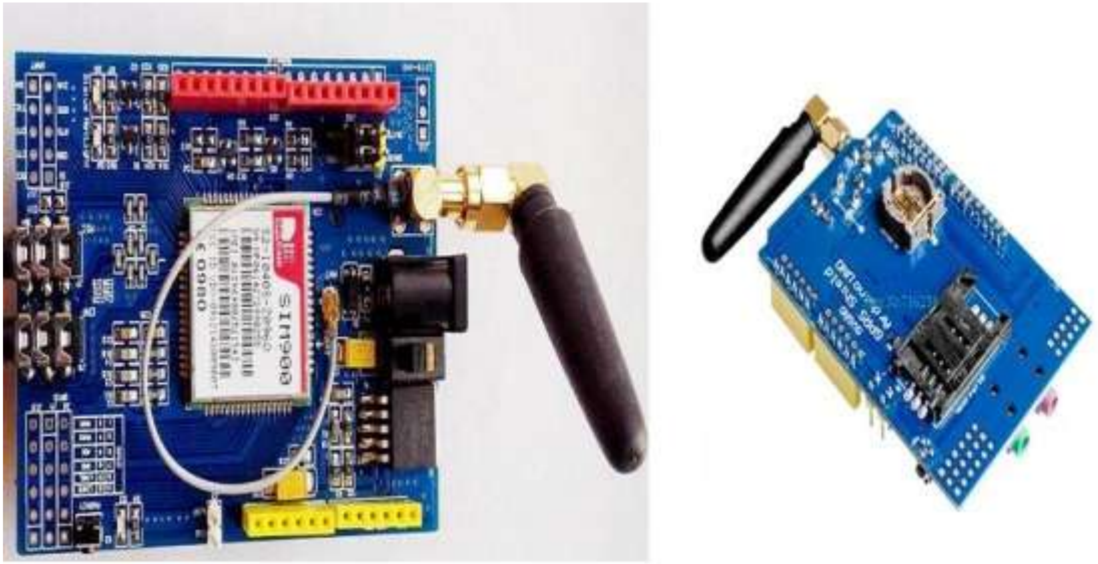

Figure 0.a: GSM Modem

By installing and including the "Software Serial" Library in the program code, any of the digital input/output pins can be turned into a serial pin just like the transmission (Tx) and the reception (Rx) pins. In this case digital pin 10 is configured as an additional Tx pin and digital pin 11 is configured as an additional Rx pin. The Tx pin of the GSM modem is then connected to digital pin 10 of the Arduino (which is now acting as a Tx pin) and the Rx pin of the GSM modem is connected to digital pin 11 of the Arduino (which is now acting as a Rx pin). The input pin (Vcc) of the GSM modem is connected to the 5V supply of the Arduino board. The GND pin is connected to that on the Arduino board. In the case of fire or high temperature detection, the Arduino sends the latitudes and longitudes received from the GPS receiver to the GSM modem. This information is then transmitted by the GSM modem in the form of SMS message to an already programmed mobile receiver. The SMS message is formatted as:

"Fire Detected at:
Latitude: ____
Longitude: ____"

Power Supply

The Arduino board 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 started [16].

Software Components

The software component consists of a C programmed language built using the Arduino IDE version 1.8.1, which is the current version of the Arduino IDE. The program is written and compiled using the Arduino IDE and the HEX code is downloaded unto the microcontroller using a USB cable. The Arduino IDE uses a simplified version of C++, making it easier to program.

System Architecture

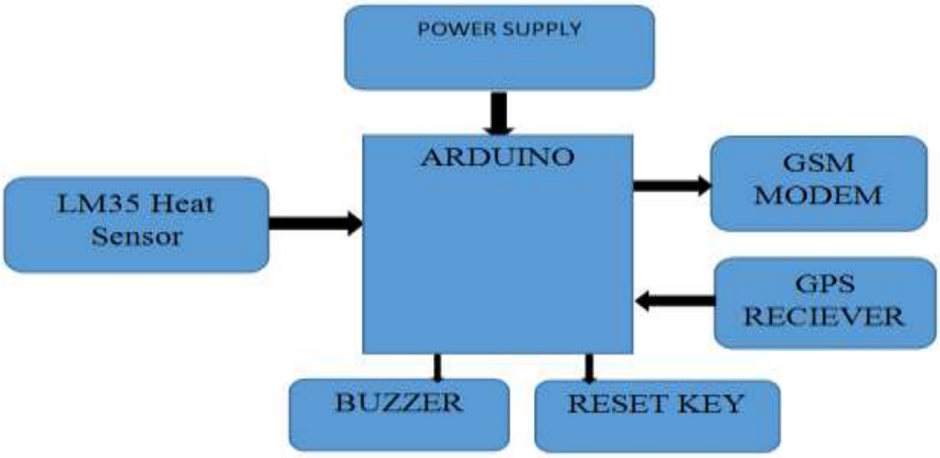

Figure 0a: Block Diagram

Step 1: Interfacing Arduino with LM35 heat sensor.

1. Connect one of the 5V power supply on the Arduino to the input pin (+Vs) of the LM35 sensor using a jumper wire.
2. Connect the ground pin (GND) of the LM35 sensor to any of the ground pin on the Arduino.
3. Connect the middle pin (V_{out}) of the LM35 sensor to the Arduino analog pin A0.

Step 2: Interfacing Arduino with Piezo Electronic Buzzer.

1. Connect the positive terminal of the buzzer to Arduino digital pin 7.
2. Connect the negative terminal to ground.

Step 3: Interfacing Arduino with NEO-6M GPS Receiver.

1. Connect the V_{cc} pin on the GPS receiver to the 3.3V on the Arduino board.
2. Connect the GND pin on the GPS receiver to any of the ground pins on the Arduino board.
3. Connect Tx pin of GPS receiver to Arduino Rx pin (digital pin 0).
4. Connect Rx pin of GPS receiver to Arduino Tx pin (digital pin 1).

Step 4: Interfacing Arduino with GSM SIM900 modem.

1. Connect the V_{cc} pin on the GSM modem to 5V power supply on the Arduino board.
2. Connect the GND pin to ground on the Arduino.
3. Connect Tx pin of GSM modem to Arduino digital pin 10.
4. Connect Rx pin of GSM modem to Arduino digital pin 11.

Step 5: Upload software code.

1. Connect the Arduino board to the computer using a USB connector.
2. Open the Arduino code (Project_Code).
3. Click on UPLOAD to download the software code onto the Arduino microcontroller.

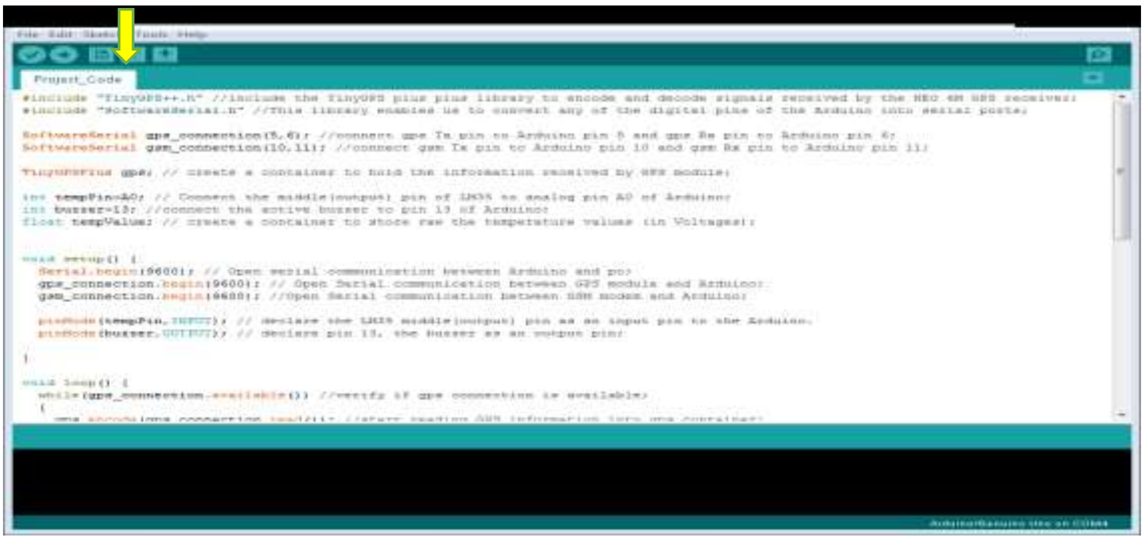

Figure 0a: Upload Software unto Arduino

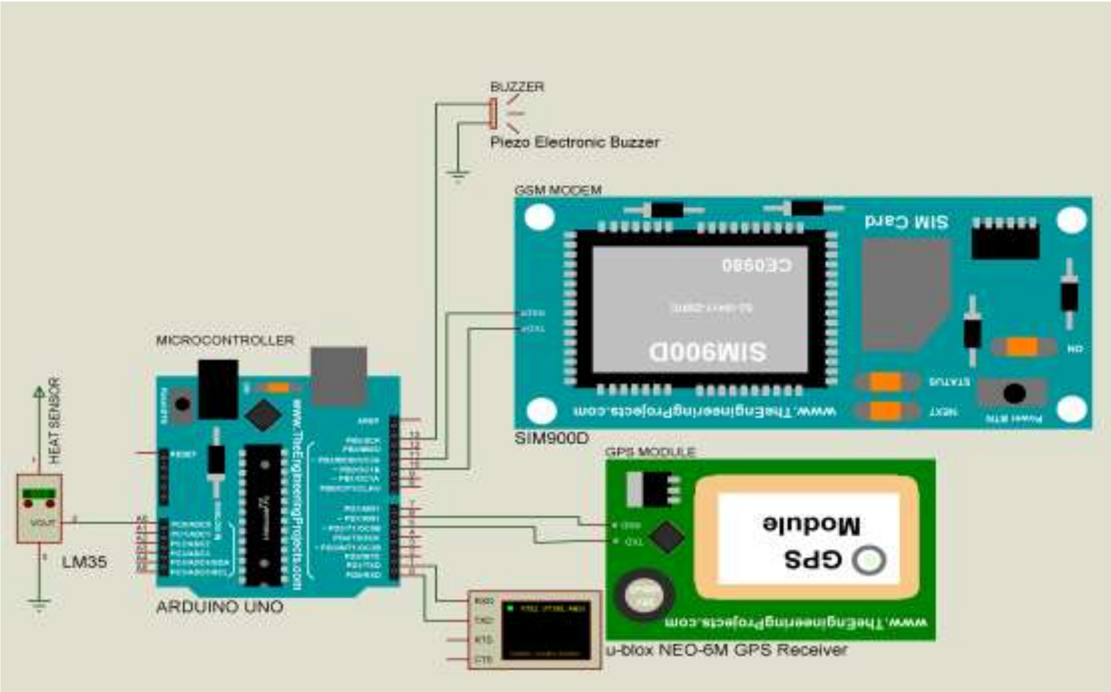

Figure5.4: Schematic Diagram

VI. Results And Discussion

The system was tested under adverse temperature conditions and in different locations to observe its performance and response in these different test conditions. The experimental results and testing method of this project work was based on both the designed computer software simulation and the constructed hardware prototype.

Computer Software Simulation is an imitation of the operation of a real-world process of system over time. It is used to show the real effects of alternative conditions and courses of actions. To simulate a system, it is required to first develop a model that represents the key characteristics or functions of the said physical or abstract system or process. The model represents the system itself, whereas the simulation represents the operation of the system over time. Simulation is used in diverse scenarios, such as training, simulation of technology for performance optimization, testing, education, video games, etc. The tests involving the hardware prototype is to determine if the constructed system functions as it was intended, to observe the time taken to successfully send the SMS alert message when the system exceeds the threshold temperature and also to verify if the correct locational coordinates are the ones sent in each alert SMS.

6.1 Simulation Results – Proteus ISIS

The proposed system was therefore simulated using Proteus ISIS (Proteus Design Suit) version 8 software. Proteus is a Virtual System Modelling (VSM) and circuit simulation application suit containing schematic capture, simulation and PCB layout modules. It is developed by Labcenter Electronics Ltd and runs on the Windows operating system. It has a wide range of components in its library. These components includes sources, signal generators, measurement and analysis tools like oscilloscope, voltmeter, ammeter, etc., probes for real time monitoring of the parameters of the circuit, switches, displays, resistors, capacitors, inductors, transformers, digital and analog integrated circuits, microcontrollers, processors, sensors, and many more.
Proteus has the ability to simulate the interaction between software running on a microcontroller and any analog or digital electronics connected to it. It simulates Input / Output ports, interrupts, timers, USARTs and all other peripherals present on each supported processor [20].

6.1.1 Simulation of System Start Up

When the system is first switched ON, it displays the name of the project work together with the names of the students who submitted the work as shown in Figure 4.1.1a. This is then followed by a system delay of half a second (500 milliseconds) before it starts reading the system temperature (Figure 4.1.1b).

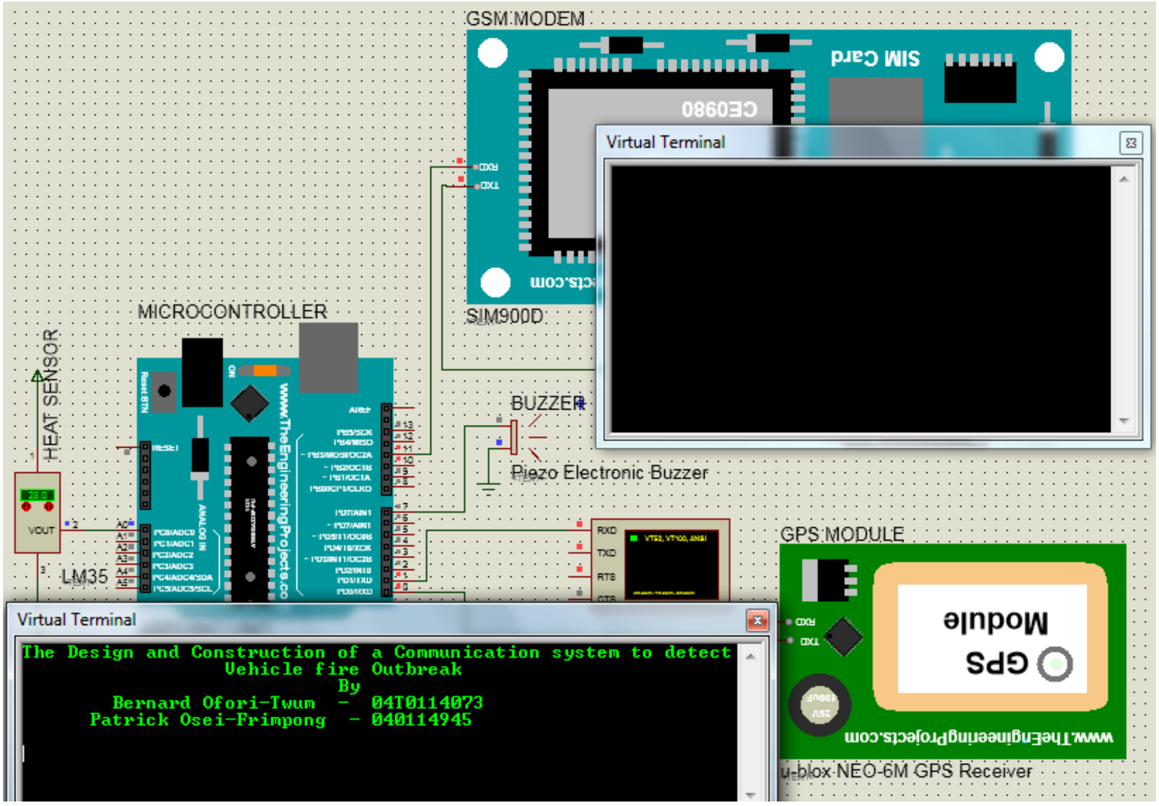

Figure 6.1.1.a: System Start Up

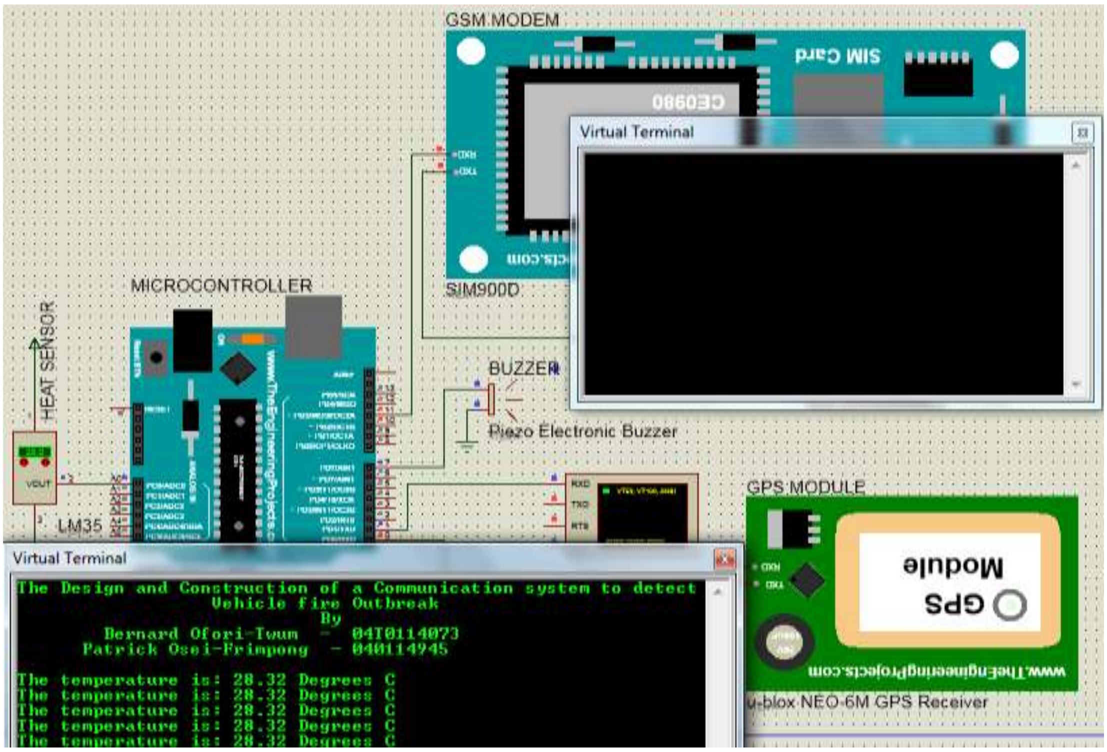

Figure 6.1.1.b: System Temperature Readings after Start Up

6.1.2 Simulations below threshold Temperature

After start up, the system is simulated at temperatures below the threshold value of 90°C. The system is simulated with temperatures such as 43°C, 57°C, 69°C, 77°C and 84°C to verify if the buzzer is activated and also to see if an SMS alert message is sent/received. As shown in Figure 4.1.2, the buzzer is not active and also no SMS alert message is sent/received.

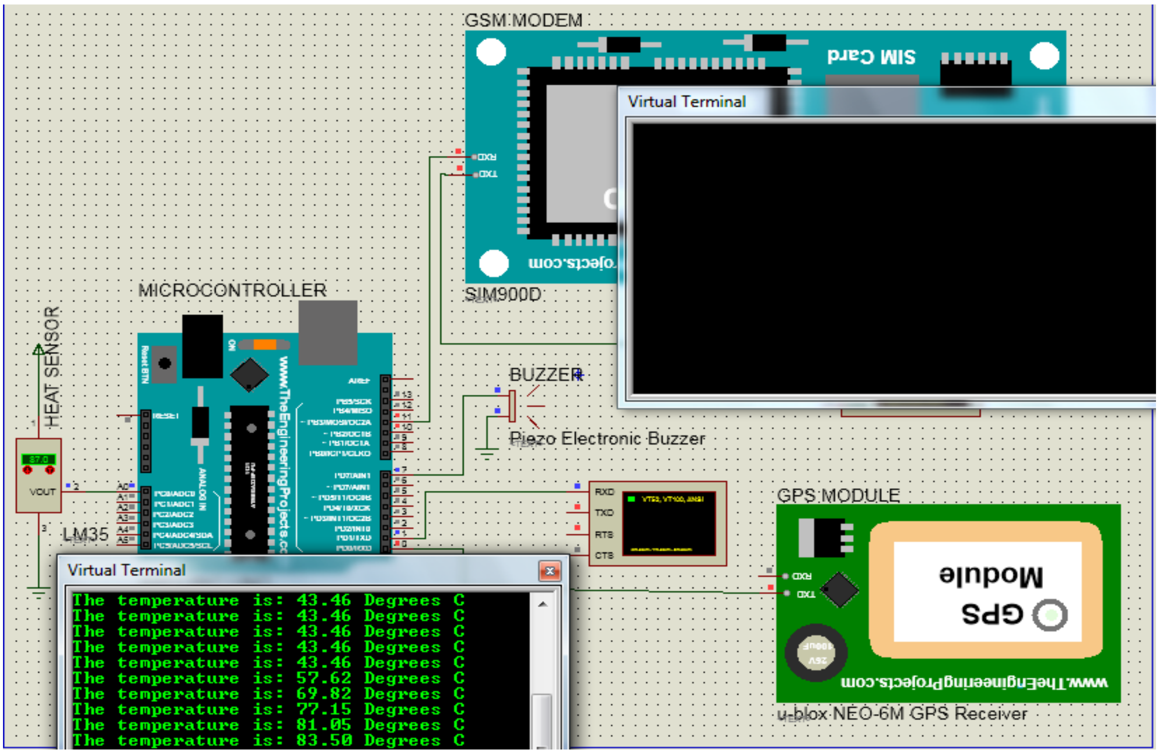

Figure 6.1.2.a: System Simulation below threshold temperature

6.1.3 Simulations Above threshold Temperature

The system is then simulated above the threshold temperature at values of 90.33°C and 94°C to observe if the buzzer is activated and also to observe if an SMS alert message with the latitudinal and longitudinal location is sent/received. As shown in Figure 4.1.3, the buzzer is activated and also an SMS alert message containing the latitudinal and longitudinal location is sent/received. After sending the SMS message, the system delays for 2 seconds before resuming the reading of the temperatures again. This delay is to enable the GSM modem to successfully go through the process of sending the SMS so as to ensure that the message is successfully received.

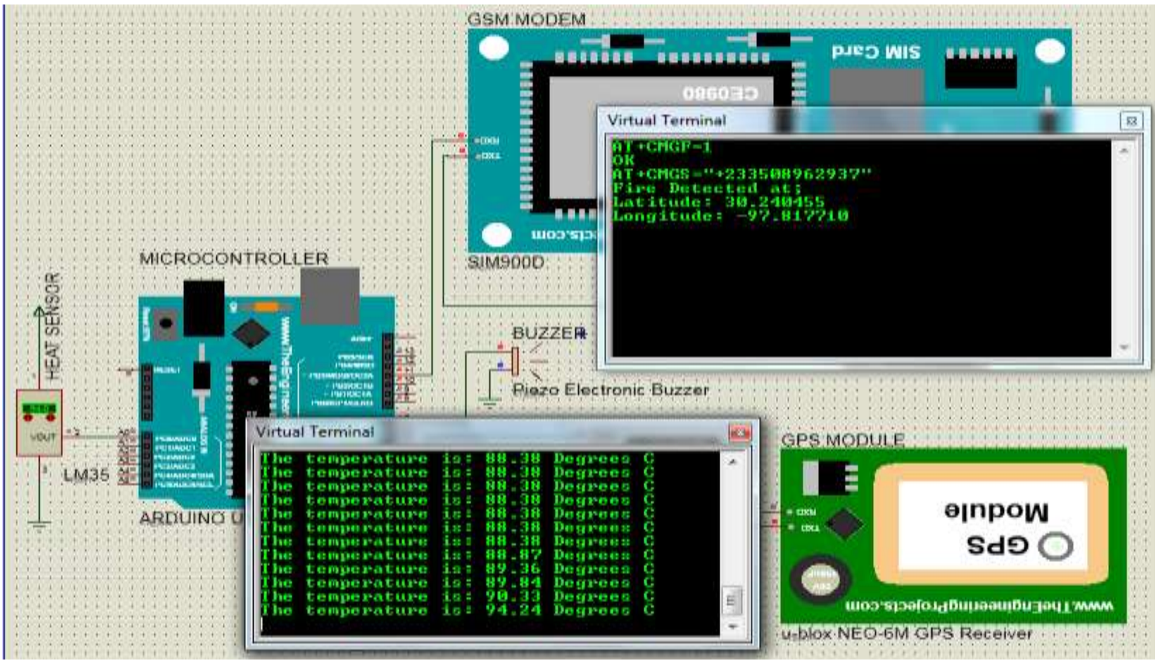

Figure 6.1.3.a: System Simulation Above threshold Temperature

The table below gives a summarized result of temperature values used to simulate the system and the system response to these parameters.

Simulating Temperature	Buzzer Activated	SMS alert sent/received
43°C	No	No
69°C	No	No
84°C	No	No
90.33°C	Yes	Yes
94°C	Yes	Yes
100°C	Yes	Yes
57°C	No	No
99°C	Yes	Yes

Table 6.1.3.a: Simulation values and Results

Hardware Prototype Testing

The constructed hardware prototype of the system was test is different geographic locations and under different temperatures. The problem encountered with the hardware prototype testing is the lack of a system (apart from vehicles) that could successfully raise the LM35 temperature values above the defined threshold value (90 degrees). To overcome this setback, the default temperature value is reduced to 70 degrees. This enables the hardware prototype to be tested to see it response to temperatures below and above the threshold value and also to obtain the parameters for maximum system efficiency. In scenarios where an SMS alert message is sent, the latitudinal and longitudinal coordinates received through the SMS are verified using Google Earth to see if the coordinates match the current location of the system. Google Earth is a free program from Google that allows you to "fly" over a virtual globe and view the Earth through high-resolution graphics and satellite images. The images are detailed enough that in most populated areas you can clearly see your house, objects in your yard, and recognize your car parked along the street. A digital elevation model within Google Earth allows you to view the landscape in 3D. Most of the images in Google Earth were acquired within the past three years, and Google is continuously updating the image set for different parts of the Earth. Large cities generally have more recent and higher resolution images then sparsely inhabited areas. Google Earth is a free downloadable program that you install on your Windows, Mac, or Linux desktop computer. The program requires very little space on your hard drive because the images are stored on Google's servers and streamed to your computer upon demand. Google Earth is also available as a browser plug-in and mobile app to be installed on smartphones. Google has been offering the program for free and improving it regularly since 2005 [21].

6.1.4 System setup and start up

The components are connected one to another to assemble the hardware prototype and the whole system is connected via a USB cable to the computer for power supply as shown in Figure 4.2.1a.

After starting up the Arduino Serial Monitor, the system first displays the name of the project work along with the names of the students who built it. Then, after a brief delay (500 milliseconds), it starts reading the temperature as displayed in Figure 4.2.1b.

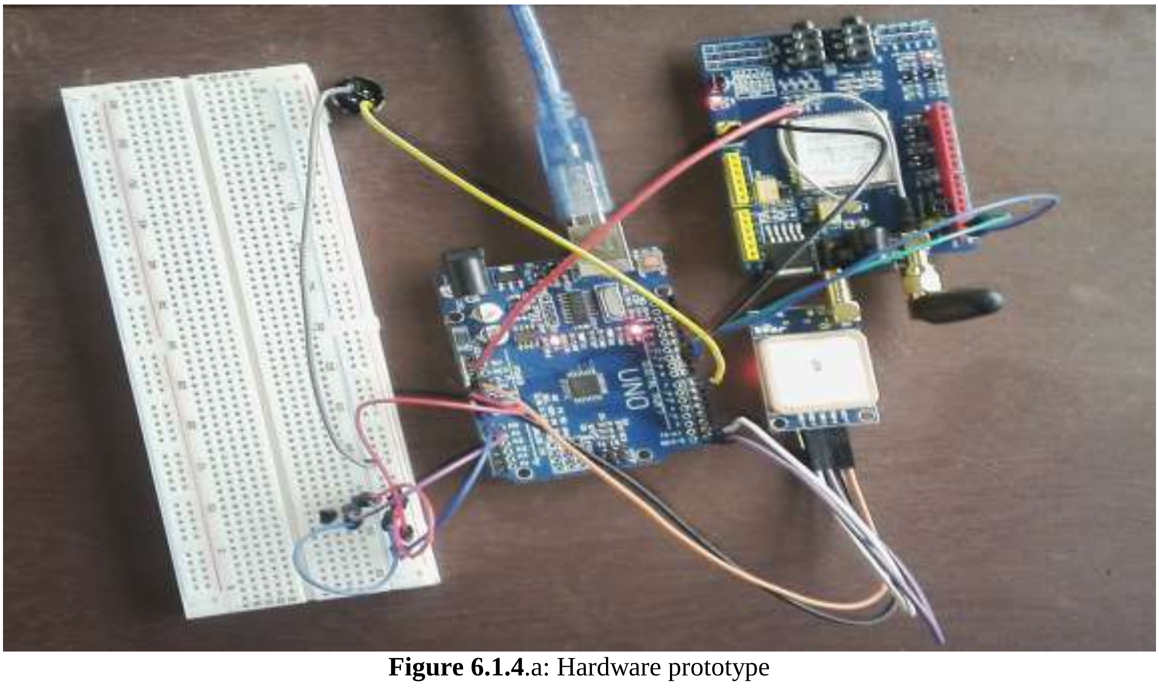

Figure 6.1.4.a: Hardware prototype

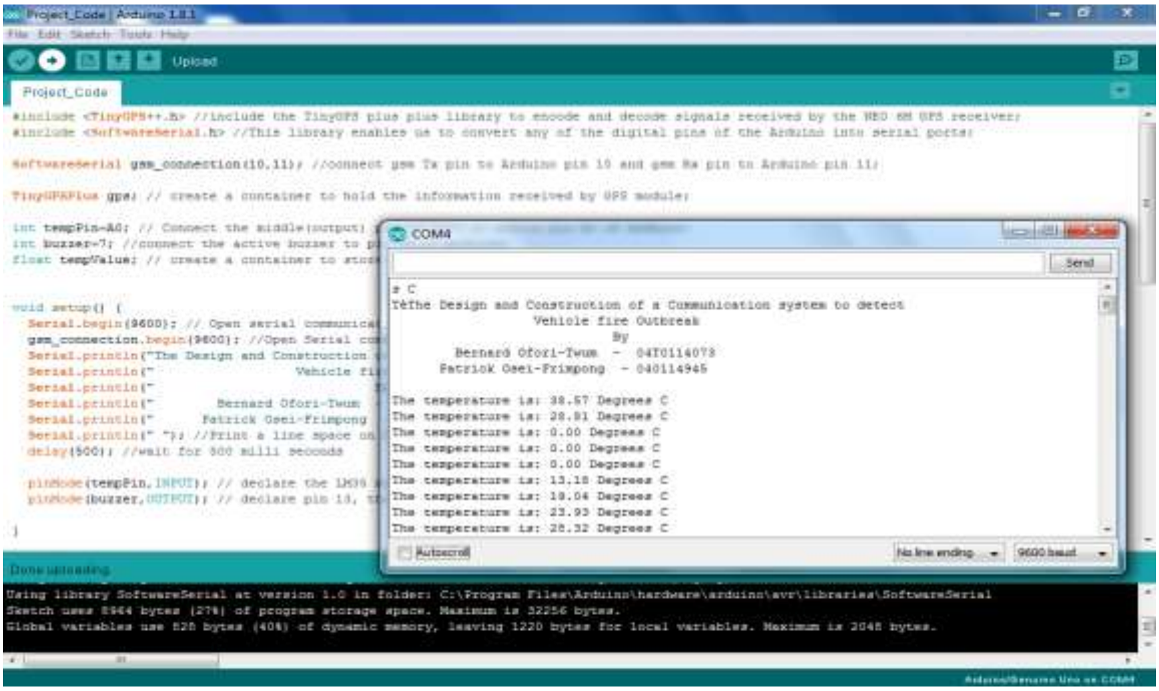

Figure 6.1.4.b: Prototype Startup – Serial Monitor

6.1.5 Test Results of temperatures below threshold value

The system is now tested using temperatures below the defined threshold value by directly subjecting the heat sensor to extreme heat. Some of the recorded temperature values used below the threshold value are 40°C, 55°C, 60°C and 75°C. In all these cases, the system responds correctly by not activating the buzzer or sending any SMS alerts.

6.1.6 Test Results of temperatures above threshold value

The system is again tested using temperatures above the threshold value by subjecting it to extreme heat. Once the system detects fire outbreaks (when threshold is exceeded), the duration between time of fire detection and time of message received is measured. Also, the coordinates are verified using Google maps/ Earth to verify if coordinates are correctly received. The results shows that the system correctly responds when the temperature exceeds the threshold value. Figure 6.2.3, displays the SMS message sent/received in response to a fire outbreak.

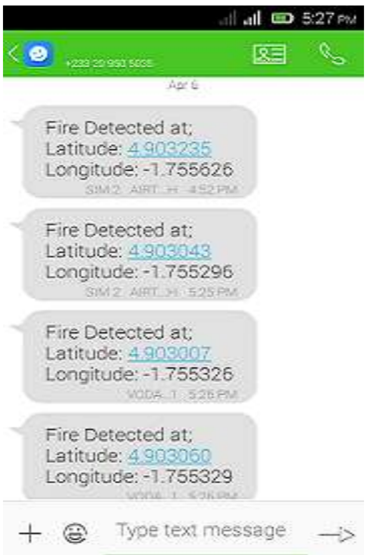

Figure 6.1.6.a: SMS Alert Message

Table 6.1 gives a summary of the result when tested both below and above the threshold temperature vale.

Test Temperature	Buzzer Activated	SMS sent/received	Duration of SMS	Coordinates correctly received
40°C	No	No	-	-
60°C	No	No	-	-
73°C	Yes	Yes	5 sec	Yes
65°C	No	No	-	-
75°C	Yes	Yes	3 sec	Yes
71°C	Yes	Yes	3 sec	Yes
35°C	No	No	-	-
77°C	Yes	Yes	5 sec	Yes

Table 6.1.6.a: Result of hardware prototypes testing

6.2 Parameters for Maximum Efficiency

During the hardware prototype testing it was found that the GPS module works best when it is exposed to the sky (to enable it detect multiple number of satellites – 4 and above). This would enable it detect the location of the system much more accurately. An antenna can be mounted on the GPS module to improve its ability to detect GPS satellite signals.

VII. Conclusion

The designed fire alarm system is simple but it has wide area of application in vehicle and industrial safety. Using this system, quick and reliable alert response is possible to initiate preventive measures to avert danger of fire hazards and minimize losses of life and property. It is a low cost system with reliable performance and can be easily installed. The test results indicates that the designed vehicle fire outbreak notification system meets the designing goal. By reducing the threshold temperature, the system can be easily installed in homes to help ensure domestic safety from fire hazards.

VIII. Recommendation

This project only detects fire in terms of overheating, but other sensors such as flame sensors and gas sensors can be integrated into the system to detect fire outbreaks from other sources. The system can be further developed to include an automated fire extinguisher which will serve as a first preventive measure to ensure that the fire does not spread quickly. For the system to work efficiently all over the country, it is highly recommended that the government set up a First Emergency Responder Unit which will receive these alert messages and then relay it to the nearest Ambulance unit, Fire Service unit or police personnel around the scene of the incident.

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