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Driver Assistance and Safety System for Accident Prevention Using Embedded Automotive Sensors Integration

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Abstract- World Health Organization's Global Status Report on Road Safety has outlined severity of road accidents. Traffic accidents happen due to various factors such as driver's declined alertness, drunk driving, racing and disobeying traffic regulations. Current systems have partially helped in preventing accidents from happening, but there has been no extensive research on the situation of post accident course of action. In this article, the design and implementation of an on-board unit for vehicle safety monitoring system with a network of sensors is elaborated. With the data provided by the various sensors, the on-board unit directs a restorative course of action to the vehicle to supersede any human involvement to prevent the accident. A vehicular network is established where vehicles can communicate with each other. The Data collected in our centralized infrastructure can be analyzed to geotag various locations that are prone to a particular type of accident. In case of an accident, the nearby hospital that can provide immediate help is identified to mitigate the trauma undergone by the victims. The article discusses the vehicle safety monitoring system which is built using ATmega2560 microcontroller and Arudino integrated development environment (IDE) tool is used to develop necessary program for monitoring various sensors.

Keywords: Digital Media; Hijab; Islamic Law; Modern World. Road Safety, Driver Assistance System, Vehicular Network, Sensors, Automotive ECUs

I. INTRODUCTION

With the upsurge in the automobile industry over the past few decades, vehicle and passenger safety are becoming the need of the hour. Long hours of driving and heavy traffic on the roads lead to the driver losing his concentration. The cumbersome routes and pollution may add to the chaos by rendering the driver tired and drowsy. Every year, 1.25 million people lose their lives as a result of a road accident [1]. 20 to 50 million people suffer grievous injuries, many of whom incur a disability as a result of these injuries. An effective system or standards should be implemented in order to prevent such destruction [2]. To ensure vehicular safety and security in today's fast paced world, various electronic driver assistance systems have been employed [3]. This driver assistance system reduces the risks that may be caused, by constantly monitoring the driver and his surroundings and warns the driver about the risks they may encounter. If a collision is unavoidable, it ensures that corrective measures may be taken immediately. Through decreasing the harshness of an accident, any damage in the property, injuries or loss of life can be avoided. To achieve this, using several sensors based collision avoidance systems that have an ability to detect the unavoidable obstacles in front of a moving vehicle.

Road traffic injuries may cause significant economic losses to passengers and to family, nations as a whole. These losses ascend from the treatment cost and lost productivity for those disabled by their injuries, and for family persons who need to take time off work or school to take care for the injured persons. Road traffic crashes cost most countries 3% of their gross domestic product. To reduce these losses, various electronic circuits have been used to efficiently track different parameters that help ensure the safety of the vehicle and passengers. Some of these are crash sensor, heart beat sensor, temperature sensor, ultrasonic sensor, GPS (Global Positioning System), GSM (Global System for Mobile Communication), alcohol sensor. A camera is used to detect the drowsiness of the driver. These functions require a good communication protocol to communicate and transfer information between multiple devices. For simplicity, Zigbee protocol is used for current implementation.

All sensors used in this system are placed near the driver. Each of the sensor values is compared with a pre-set threshold value. If an abnormality is found, a pre-set action is called upon. The heartbeat, eye blink sensor and alcohol sensor are all electronic circuits that are used here to detect red flags or acute risks.

Once the eye blink or alcohol sensors give values that are higher than the threshold, the vehicle is stopped [4]. An SMS (short Messaging Service) is then sent to the contact of a standby person, a display is made on the dashboard screen and a cab is booked using a third-party cab booking app [5]. If the ultrasonic sensor produces a value greater than the pre-set threshold, the driver is alerted using the display system. It also slows down the Revolutions per minute of the vehicle. If the temperature sensor produces a value greater than the threshold, the nearest service centre is called and the vehicle is stopped. If the heart beat sensor or the crash sensor produces a value greater than the threshold, the vehicle is stopped, the corresponding display is made to the driver and an ambulance is called [6]. The sensors provide these values to the microcontroller at regular intervals, these measured values are sent to the cloud (or to the app as per the requirement) using MQTT protocol and ESP8266 module [7]. The MQTT protocol is extremely light weights publish/subscribe messaging transport, machine- to-machine (IOT- Internet of things) connectivity protocol. It is adept at communicating even to remote locations or where connectivity is an issue.

Several authors have reported multiple ways of improving vehicle and passenger safety. *Manuel Fugue et al.* proposed a system that ensures that each vehicle capable with an On-Board internal Unit that transfers the received data to an external unit that evaluates the severity and later allocates the essential resources for the support [8]. *Naidu et al.* uses an alcohol sensor, eye blink sensor and heart beat sensor to identify whether a person is in the drunken state or not and also identify if the vehicle has met with an accident or not [9]. *Zhang et al.* proposed a system that consists of several wireless network devices such as GPS and Zigbee [10]. This determines the location of the vehicle. Based on vehicle motion, report is generated and to be taken by emergency services.

The data obtained from each of these sensors is sent to neighboring vehicles in case of any abnormality in the sensor values. This is done using a short-range communication protocol such as Zigbee. The surrounding vehicles may now use this information to make an informed decision about the future course of action [11]. They may decide to stop their own vehicle, choose a new route or even venture into the scene of the collision or breakdown in order to provide assistance. The same concept may be used to communicate with the ambulance and other such services to reduce the response time. Such a communication shall provide a good mitigation method to reduce the severity of consequences that the accident or breakdown may have caused otherwise. In this proposed system a microcontroller such as ATMega328P is used. Future enhancement of this proposed system can be made on done on the areas such as real time implementation, inclusion of IoT and Artificial intelligence. Similarly, the Zigbee may be substituted with CAN [12] or Flex ray communication protocols.

The data collected from the sensors is analyzed to collect statistical output regarding the collisions that have occurred [13]. The data once collected, is marked based on the location of accidents. This is used to understand the most common cause of occurrence of collision in that location, in other locations and monitor other parameters as well. The subsequent parts of this paper refer to the data acquisition system for advanced driver assistance systems that provide an overview of sensors. It goes on to detail the existing system and certain drawbacks of the same. The proposed system along with relevant information of sensor specification and system usage is provided. The paper concludes with future areas in which this scope of work can be applied, a conclusion and references to the papers made throughout this document.

II. Sensors Interfacing

The MQ3 Alcohol sensor is used to detect the presence of alcohol in the breath of the driver just like a breathalyzer [14]. The Figure 1(a) depicts the interfacing of alcohol sensor with ATMega328P microcontroller. The sensor is highly sensitive and has a very small response time. The sensor is fitted on the steering wheel to continuously check for the level of alcohol consumption [15]. When alcohol is detected in the breath of the driver, the on-board system is instructed to take control of the vehicle and stop the vehicle safely to prevent accident due to drunk and driving [16]. Successively, a notification system is initiated to the driver's emergency contact to seek assistance. An IR sensor is used to determine the rate of the eye blinking [17]. The Figure 1(b) depicts the interfacing of alcohol sensor with ATMega328P microcontroller. The rate of blinking is used to determine whether the driver is drowsy or not. The sensor is fit next to the sun shade blade inside the car focusing on the face of the driver to monitor the eye blinking [18]. Once the drowsiness of the driver is detected, the vehicle is stopped to prevent accidents.

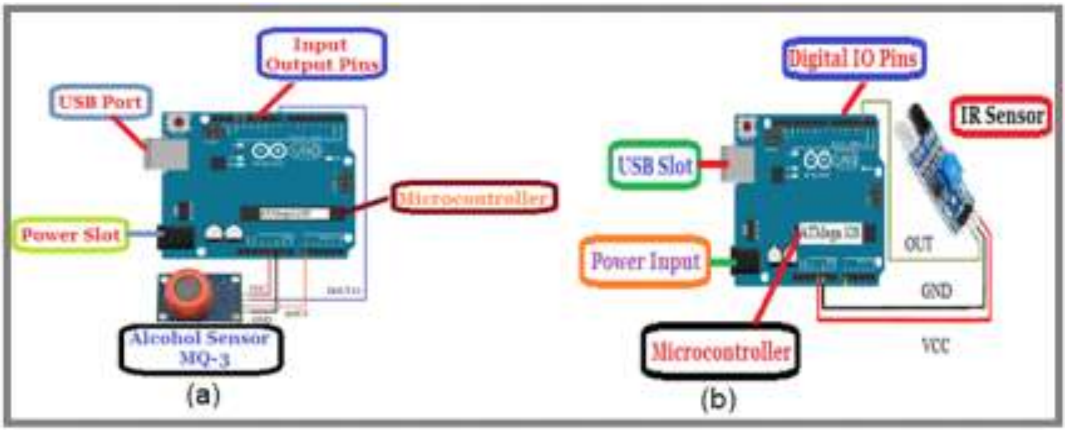

Figure 1. (a) Alcohol Sensor Interfacing Circuit and Figure 1. (b) Infrared Sensor Interfacing Circuit

The heart beat sensor (KY-039) monitors the pulse of the driver. The Figure 2 (a) depicts the interfacing of Heartbeat Sensor with ATMega328P microcontroller. If the pulse of the driver is very high that requires medical assistance, the vehicle is stopped to prevent any accidents [19]. To save the life of the driver, the sensor is integrated with the emergency notification system to alert the hospital nearby [20]. The heartbeat sensor is fit across the seat belt to perfectly be positioned on the driver's chest.

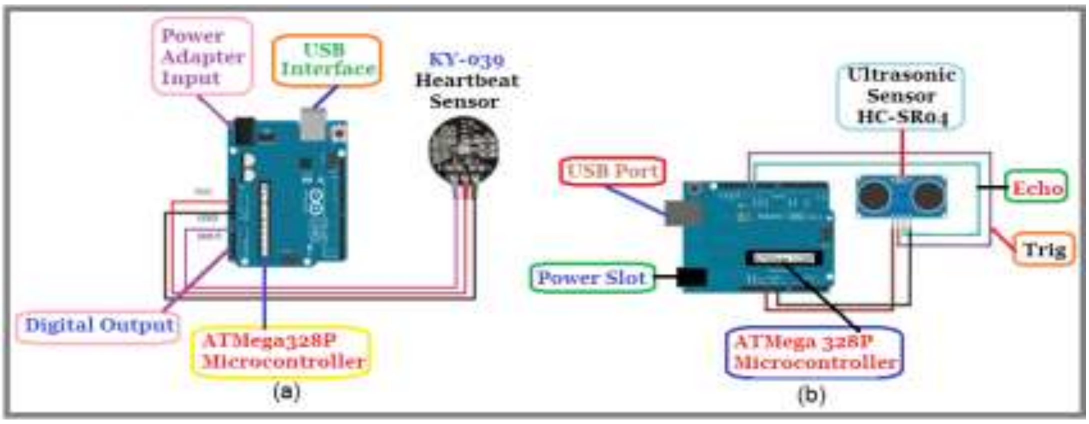

Figure 2. (a) Heartbeat Sensor Interfacing Circuit and Figure 2. (b) Ultrasonic Sensor Interfacing Circuit

The ultrasonic sensor (HC-SR04) is used to determine the headway distance with the vehicle in front [21]. The Figure 2(b) depicts the interfacing of Ultrasonic Sensor with ATMega328P microcontroller. To avoid accidents during emergency braking, the headway distance is set such that it is never less than a certain threshold value [22]. If this distance was to reduce, the speed of the vehicle is regulated to reduce it and hence maintain the minimum headway distance required. The ultrasonic sensor is fitter at the front bumper of the vehicle. The temperature sensor LM35 is used to determine the temperature within the car. The Figure 3(a) depicts the interfacing of Temperature Sensor with ATMega328P microcontroller. If the temperature is set to a value in order to detect if any fire has occurred to due to any reason [23]. The temperature sensor is fit near the dashboard where the possibility of a fire ignition is high.

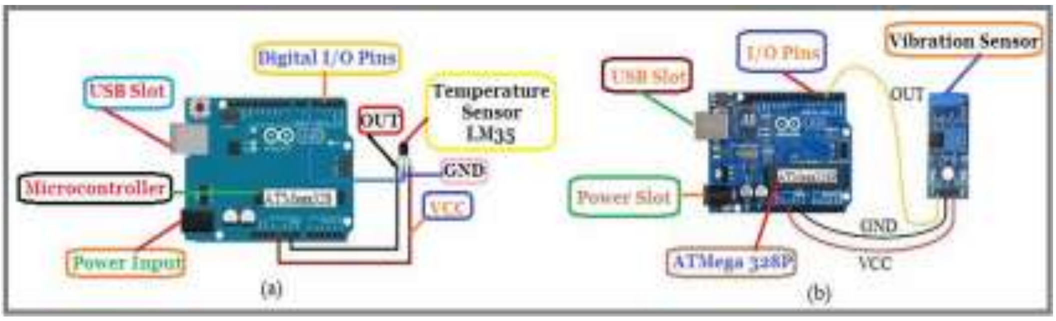

Figure 3. (a) Temperature Sensor Interfacing Circuit and Figure 3. (b) Vibration Sensor Interfacing Circuit

The vibration sensor is used to detect the crash of the vehicle. The Figure 3(b) depicts the interfacing of Vibration Sensor with ATMega328P microcontroller. Greater the intensity of the crash, greater is the frequency of the vibration [24]. This principle is used to set the threshold to define an impact as a severe accident [25]. If the intensity of the crash is high, the emergency notification system is triggered. Here the automobile service centre is intimated in addition to an ambulance. The Table 1 describes the various automotive sensor used and its model number along with the threshold value that determines the abnormality event.

Table 1. Characteristics of Various Sensors

Sl No.	Sensor Name	Model Name	Threshold value
1	Alcohol Sensor	MQ3	0.05mg/L-10mg/L
2	IR Sensor	-	3s
3	Heartbeat Sensor	KY-039	Hb>150 or Hb<50
4	Ultrasonic Sensor	HC-SR04	D<30cm
5	Temperature sensor	LM35	T>40 Degree
6	Crash sensor	-	150kHz

III. Proposed System Architecture

The Primary car is interfaced with multiple sensors to monitor the vehicle. The Figure 4(a) depicts the interfacing of the sensors, GPS, GSM and Zigbee modules with the ATMega328P microcontroller. Crash Sensor, Eye Blink Monitoring system, Alcohol Sensor, Ultrasonic sensor, Heartbeat Sensor and Temperature Sensor continuously monitors the system to check for any events. The Global Positioning System (GPS) tracks of the location of the vehicle to provide timely assistance for the emergency services team. Global System for Mobile Communication (GSM) is used in the notification process in the event of an accident. Vehicle to Vehicle communication is achieved using a Zigbee transceiver. The Figure 4(b) depicts the secondary vehicle on the road that receives and displays the message from the primary car. The secondary vehicle is used to demonstrate the vehicle to vehicle communication. It is expected for every vehicle to have both the sections in order to sense its own surroundings and to transmit or receive messages.

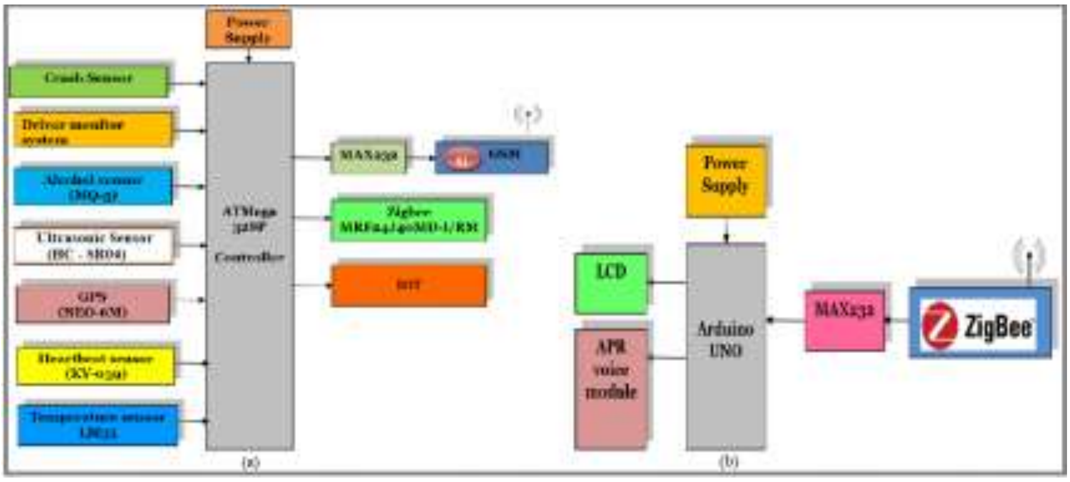

Figure 4. (a) Primary Vehicle Segment and Figure 4. (b) Secondary Segment of a Vehicle

Data acquisition systems used to sample signals from the outside world and convert them to digital signals to be processed by computers have the general disadvantage of having a high latency period. When multiple such sensors values are connected to the same microprocessor, a high possibility for burnout exists. More efficient microcontrollers increase the cost structure of the system. The Advanced Driver Assistance Systems are used to assist the driver to detect various parameters and avoid adverse situations. The existing systems have a high latency period and have high software and hardware expenditure. Multiple systems will use data loggers to perform DAS. These can read values from multiple sensors but distributing and processing this data is a daunting task. Data obtained is incompatible with multiple systems and would require different operations to make it compatible. The sensors used in the proposed work provides the measured values to the microcontroller at regular intervals, these measured values are sent to the cloud (or to the app as per the requirement) using MQTT protocol and ESP8266 module. The MQTT protocol is an extremely light weight publish/subscribe messaging transport, machine to-machine and IOT (Internet of things) connectivity protocol [26]. It is adept at communicating even to remote locations or where connectivity is an issue. The values obtained and processed, are transmitted to the appropriate web servers using MQTT protocol. In comparison with the preceding works, the proposed system is developed with low-cost microcontroller devices that reduce the complexity of the system. The proposed ECU with body control module (BCM) can be very robust for communication among ECU communication. In addition, the establishing of vehicle to infrastructure (V2I) enables to save the life of accident patients. The developed android application creates the vehicle user to perform time effective communication thereby the sensor dates will be given to on-board unit without any delay. The system can be directly placed inside the vehicle, tested to control and monitor the sensor data ECUs.

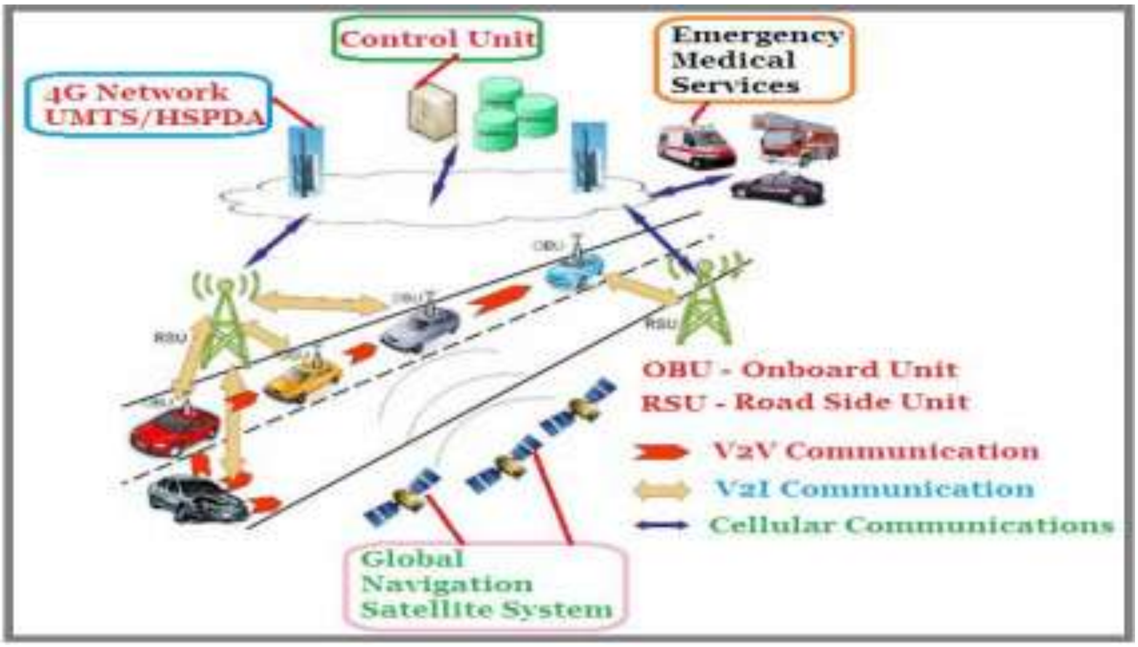

Figure 5. V2V Communication and Notification System

These cloud-based applications therefore allow the users to track and record these parameters which can be used for later processing. In this proposed work V2V communication is used to prevent chain collision. It is implemented using ZIGBEE protocol. This protocol is used to send an alert to the vehicles in the proximity in case of an accident. The range of the ZIGBEE protocol is thrice that of Bluetooth. The Figure 5 depicts the various events that happen when a collition occurs.

In this proposed system, the accident patterns are analyzed and establish accident prone zones. These accident-prone zones are classified further to analyze the cause of the accident. The classification is done by clustering the data recorded in the IOT infrastructure by analyzing the cause of accident in accident prone zones. By geo-tagging each location to a specific reason of an accident, we can take more informed decisions by using various data science tools. The Figure 6 depicts the process of geo tagging the events. Some parameters for taking decisions include location, type of accident, time and other parameters from the ADAS such as age and gender of the driver. These data help us provide a specific assistance in each accident. The data collected from the sensors are displayed using various applications or websites. This data is analyzed to collect statistical output regarding the collisions that have occurred. The data once collected, is marked based on the location of accidents. The accidents that occur in a particular geographical location can be collated together. This can then be monitored to understand the most common cause of occurrence of collision in that area. The next step is to find out how many such accidents have occurred in a given time period in the given location. Further analysis can be done to find out the frequency with which collisions of the given cause happens in that location. Such analysis is done with the help of data mining techniques for collecting the data. Once the data is collected, data analysis methods are employed to present a statistical overview of the conclusions from the same. The same system is followed to find out relevant statistical information regarding different geographical locations and other parameters as well.

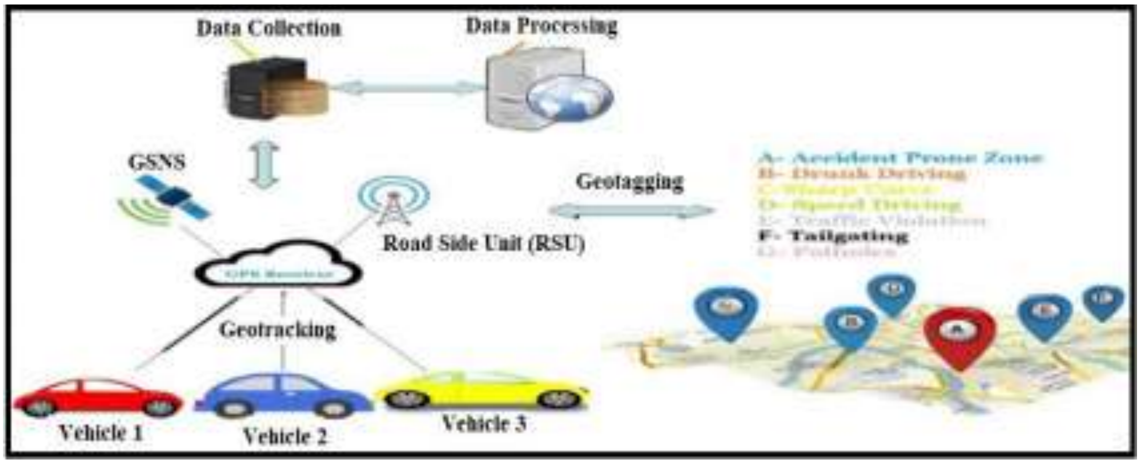

Figure 6. Data Stored in Cloud is Analyzed and Mapped

IV. RESULT

A low-cost power efficient system capable of sensing the driver and vehicle conditions is developed. The system is suitably fitted into the vehicles as mentioned in the article. The system is capable of reducing the accidents. The Figure 7 is the hardware module of the primary section of the vehicle implemented around the ATMega2560 microcontroller. The Figure 8 is the hardware module of the secondary section of the vehicle built around ATMega328P microcontroller. In an event of a crash, the system provides an efficient notification system to the emergency services such as ambulance, fire station and police services. In addition to the emergency services, a designated alert receiver receives the message which helps in identifying the next of kin.

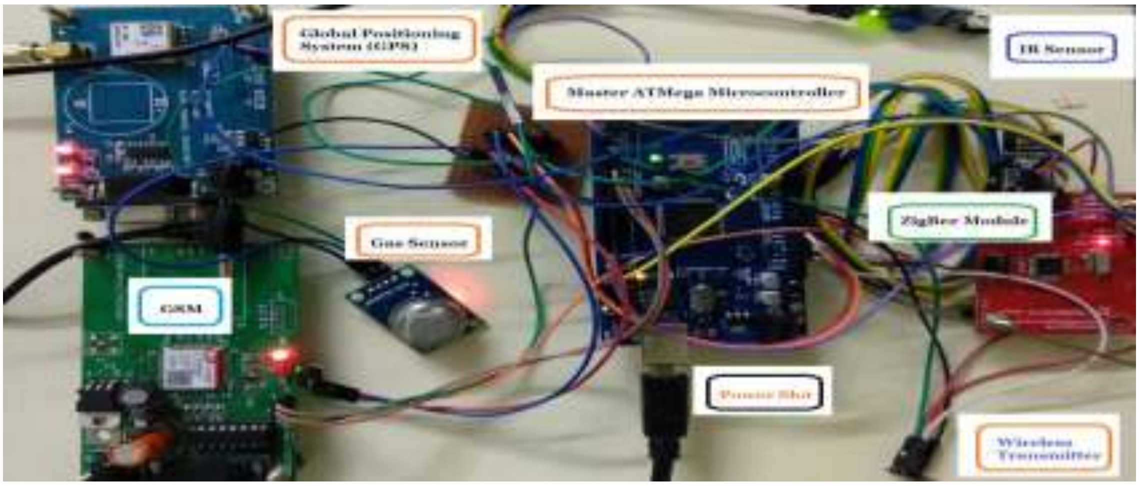

Figure 7. On Board Unit of Driver Assistance System

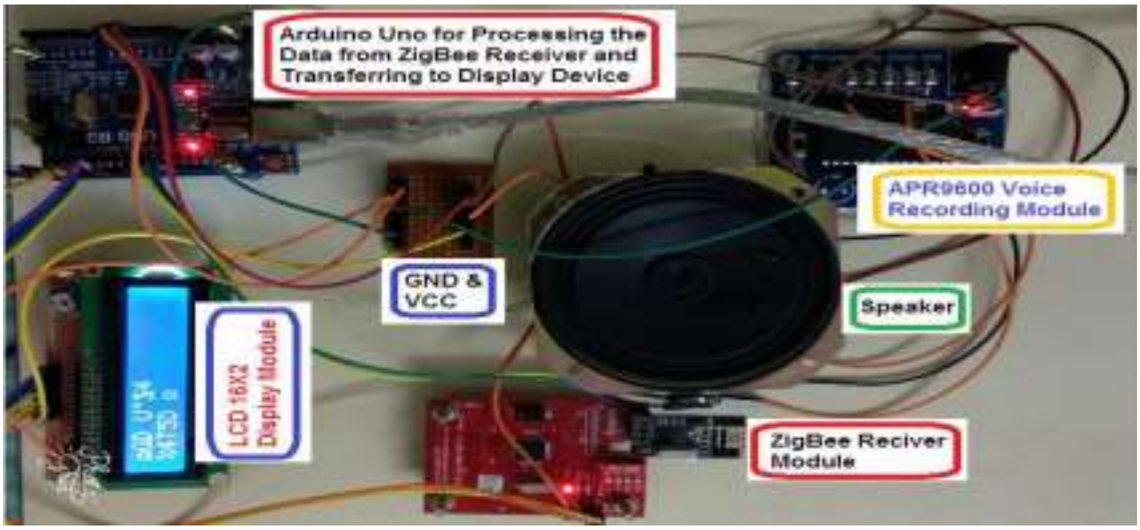

Figure 8. Receiver System Placed in Vehicle

The Figure 9 depicts the notification system via an SMS to the next of kin in an event of an accident. The system is also capable of reducing a chain collision on national highways. This is achieved by the vehicle to vehicle communication where vehicle communicate with each other to alert the nearby vehicles. By establishing vehicle to vehicle communication this system can provide immediate first aid to the accident victims

Figure 9. Sms Notification System

The system is interfaced with the internet to provide live monitoring of the driver and the vehicle conditions. The Figure 10 depicts the IOT platform where the data of the sensors are recorded. The data obtained in the IOT platform is analyzed and regions are identified with specific reasons for the accident. This helps us make much more informed decisions with deployment of recourses such as police personal, mobile ambulances, sign boards, speed breakers.

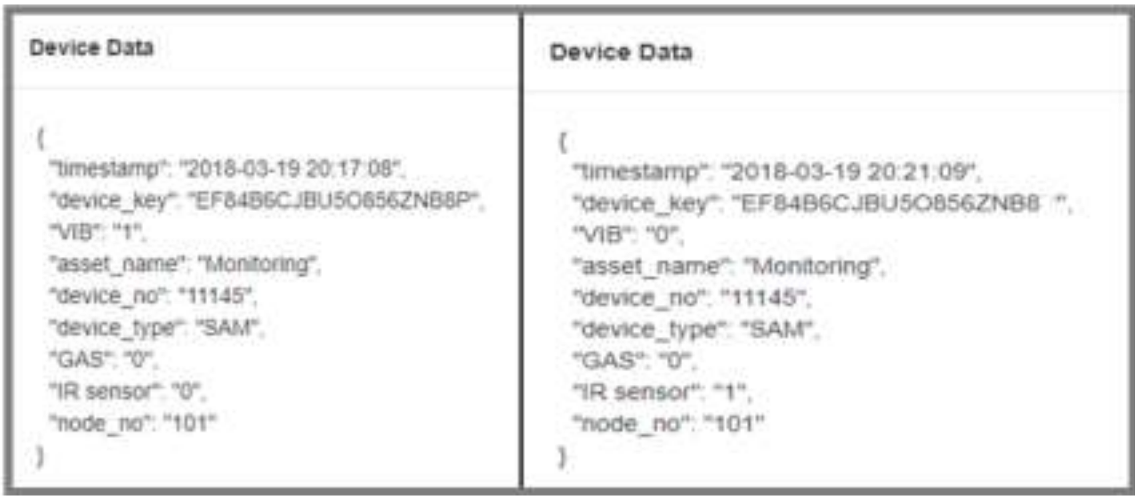

Figure 10. Data Stored in the Cloud

V. Conclusion

In the event of an accident, the golden period to save the injured is a small window. This window is taken advantage of by making use of this project. The proposed system is capable to efficiently monitor and process the various driver supportive constraints like eye blinking of driver, heartbeat and alcohol consumption. It also measures several automobile factors such as presence of harmful gases, crash sensor, ultrasonic sensor, and temperature sensor along with vehicle location. The input taken from these sensors interfaced with the system rapidly convey the dangers that arise. The inputs from these sensors are compared with a pre-defined threshold value. If the values exceed the threshold, alerts are sent either to the driver, or to the neighboring vehicles, or both. This V2V communication is done using ZigBee protocol. The data produced by the sensors are also displayed on the driver's mobile or mounted device. This is facilitated by uploading this data to the cloud using the MQTT protocol. The data can then be displayed on the devices connected to the internet. It can also produce alerts to the driver regarding the potential dangers. This way, a potential accident is avoided. If an accident does occur, it prevents a further chain of collisions from happening by alerting the neighboring drivers of said accident. It also sends out an emergency message to a standby entity, thus alerting them about the collision. The geo tagging of the accident-prone zones enables the driver to take cautious decisions to enable safe driving. The design and implementation of a prototype driver assistance and vehicle safety monitoring system has thus been implemented. The proposed system is implemented using ATMega328P. The same can be implemented using machine learning and Artificial Intelligence. AI enables the vehicles to learn to respond aptly in various scenarios to be fool proof. Using CAN Protocol to receive messages from various sensors will enhance the response time of the system. The vehicle to vehicle communication of the proposed work can be implemented using Vehicular Ad hoc Networks (VANETs). The use of Machine Language & AI can be extended to a broad range of applications such as driverless vehicles.

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