A Smart Accident Detection and Control System in Vehicular Networks

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***Abstract*—Road accident is one of the major concerns in Bangladesh because vehicles in the roads are increasing day by day and still there is the use of traditional traffic management. The road transportation is cursed with road accidents. A lot of valuable lives are losing because of these accidents where immediate necessary services are unavailable. Vehicular network is not only a solution to reduce the road traffic significantly but also it can save many of lives from the road accidents by utilizing smart and intelligent devices in the road-side. In this paper, a Smart Accident Detection and Control System (SAD-CS) for intersecting road ('Plus' junction) is proposed. The system can be developed by using Raspberry Pi and Microcontroller where an on-board unit in every vehicle is required. The proposed system is capable of detecting the vehicle accident automatically, takes the necessary steps to help the affected people, and propagates the warning messages to the road side vehicles to avoid the further accidents.**

Keywords— Microcontroller, Raspberry Pi, RFID, GSM, GPS, CBI, OBU, Router

I. INTRODUCTION

As a developing country, Bangladesh has more than enough road traffics and the number of accidents are much more than that where the consequences are not reversible. There are various reasons for road accidents such as carelessness and inexperience of drivers, defective and obsolete vehicles, paucity of roads and narrow roads, overtaking tendency, lack of dividers in roads, violating traffic rules, reckless driving, lack of implementation of strict traffic laws, and so on. This in turn has an adverse effect on the economy of the country as well as the loss of the valuable lives. Therefore, the road accident is considered as one of the major concerns in Bangladesh.

The trend of accidents in Bangladesh from the year 2010 to year 2015 is shown in Table I [10]. The total number of 14,580 accidents was happened that resulted 14,130 deaths and 10,467 injured respectively. It can be easily observed that every year the number of road accidents are between 2000 and 3000 during the mentioned period. Therefore, a keen attention is needed to minimize the number of accidents and ensure the road safety.

The current situation of the country demands a digital system which could notify real time accidents and can prevent further accidents on the affected area. Vehicular network can be used smartly to overcome these situations. The vehicular network is a network where a set of vehicles can communicate with each other for exchanging the information by forming a network which is Vehicular Ad Hoc Networks (VANETs). By using the principles of Mobile Ad Hoc Networks (MANETs), the VANETs is created. In MANETs, the wireless technology is used to exchange the data between nodes. It is introduced to the networking technology in 2001. Then the VANETs were introduced under "car-to-car ad hoc mobile communication and networking" applications. Vehicular communications can be divided into two forms. One of them is Vehicle to Vehicle (V2V) and another is Vehicle to Infrastructure (V2I) communications.

TABLE I. ROAD ACCIDENT STATISTICS

Road Accidents and Causalities Statistics (2010 – 2015)			
Year	***No. of Accidents***	***Death***	***Injury***
2010	2827	2646	1803
2011	2667	2546	1641
2012	2636	2538	2134
2013	2029	1957	1396
2014	2027	2067	1535
2015	2394	2376	1958
Total	**14580**	**14130**	**10467**

Vehicle to Vehicle (V2V) communications use the wireless transmission for exchanging the data between the vehicles. One of the main challenges of V2V communications is to prevent accidents. The vehicle's driver may simply receive a warning message that informs about a risk of an accident or the vehicle itself may take preemptive actions such as braking to slow down [8]. On the other hand, Vehicle to Infrastructure (V2I) is a communication model that allows vehicles to share information with the components like Access Point Infrastructures (APIs). Such components include RFID readers, traffic lights, lane markers, streetlights, signage, parking meters and so on. V2I communication is typically wireless and bi-directional [9]. There are two types of V2I communications: Push and Pull methods. In Push method, infrastructure (data

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center) pushes the data among all the available vehicles in the network. On other hand, data can be pulled from the infrastructure by the available vehicles in the network in pull method [8].

In this paper, a smart accident detection and control system (SAD-CS) is proposed. In this system, when an accident happens, SAD-CS units automatically detects the accidents by getting the emergency code from the affected vehicles and take the necessary actions immediately that helps to avoid the further accidents. After addressing the road accidents problem in section I, section II discuss the related work. Section III presents the proposed system where system model, devices description, placement of devices, forwarding process, and additional features are explained in detail. Section IV conclude the paper with few future directions.

II. Related Work

Road traffic accidents is considered as perennial disaster as the have claimed far more lives than any of the natural disasters. Road safety status is extremely poor in Bangladesh as it is following the traditional road traffic management. To minimize the road accidents, several approaches have been proposed by utilizing the smart devices and technologies such as inductive loop, infrared, microcontroller, router, beacon, radar etc.

Traffic Management System using Emergency Vehicle Alert is proposed to provide better and smart traffic signal management [1]. This system keeps a track of the vehicles using Microcontroller, LED Display, and Microcontroller PIC 16F877A to detect the road traffic accidents. This is mainly focuses on traffic signal management by using density calculations and assigning priority for the emergency services such as fire services, police vehicles, ambulances, and so on.

To tracks and detects the crash of the vehicles, an approach is presented in [8]. An accelerometer is used in a car alarm application so that dangerous driving can be detected. It is also used as a crash or rollover detector of the vehicle during and after a crash. With signals from an accelerometer, a severe accident can be recognized. When a vehicle meets with an accident immediately, Vibration sensor will detect the signal or if a car rolls over, a Micro Electro Mechanical System (MEMS) sensor will detects the signal and sends it to ARM controller.

To detect any accident, different types of sensors and microcontroller are utilized in a system that presented in [7]. When an accident occurs, the different sensors (such as vibration, fire, and alcohol), Global System for Mobile Communications (GSM) and Global Positioning System (GPS) technologies are used to find the vehicle position. A Subscriber Identity Module (SIM) card is used with GSM to build a two-way communications that sends a delivery message to the saved number.

The Automatic Vehicle Accident Detection System (AVADS) has been proposed based on ARM and GPS [6]. In AVADS, vibration sensor or MEMS sensor takes the role to detect the vehicle accidents. The location of the vehicle accident captured by using the GPS module and afterwards a message is transmitted with the help of GSM modem.

Timely accident notification, vehicle theft control, and vehicle pollution alerts are offered in [12]. The proposed system records the parameters of vehicle at regular intervals of time through a "smart device" installed in the vehicle. It sends these values onto the cloud, vehicle owner or a third party. Based on the information, appropriate algorithms are implemented to send the alerts that initiates the necessary actions. The system will facilitate the users in a number of ways such as notification for immediate aid in case of accident, tracking the vehicle in cases of theft, disabling the vehicle remotely, and monitoring the sensor values in order to send alerts for air pollution caused by the vehicles. The system is developed using the .Net framework, MS Access, MS Azure Cloud, and related services. The hardware components include the "smart device" installed in the vehicle and a mobile phone for user interaction.

Accident occurrence and location detecting system are proposed in [11]. When an accident occurs, the proposed system delivered a place notification to the predefined mobile number. Global System for Mobile Communications (GSM) and Global Positioning System (GPS) technologies are used to detect the vehicle's position. A microcontroller is also used to get the signals from the added vibration and fire detectors in the vehicles. In case of the emergency, the microcontroller operates the relay to blow the airbag resulting automatically locks the brakes.

Two methods to monitor traffic where computer vision is applied to intelligent vehicle highway systems are presented in [2, 3]. The first method uses the traffic parameters such as flow rates, speeds and link travel times are estimated to avoid the accidents quickly. On the other hand, the second method uses the sensor technology which tracks the vehicle and measures the distance between other vehicles. It uses ARM7 based transmission station to upload information about immediate states of the traffic.

III. Smart Accident Detection and Control System (SAD-CS)

In this paper, a Smart Accident Detection and Control System (SAD-CS) for intersecting road is proposed. The SAD-CS detects the accident in the intersecting area, takes the immediate steps to avoid the further accidents, minimize the loss of lives and prevent to create unusual traffic jam on the road. The system model, device descriptions, placement of devices, forwarding process and additional features of SAD-CS are explained respectively to present the proposed work.

A. System Model

Fig.1. illustrates the system model of Smart Accident Detection and Control System (SAD-CS). There are two intersecting roads ('plus' junction) where four directions of the roads are present such as east, west, north, and south directions. In the plus junction, four lanes are assumed for north-south directions and two lanes are assumed for east-west directions. Vehicles use these lanes for entering to and leaving from the SAD-CS area according to the traffic rules. An Access Point Infrastructure (API) has placed at the center of the 'plus' junction. It is possible to extend the coverage of SAD-CS area by deploying multiple APIs in different intersections where the

same Control Room (CR) and Control Box Infrastructure (CBI) can be utilized.

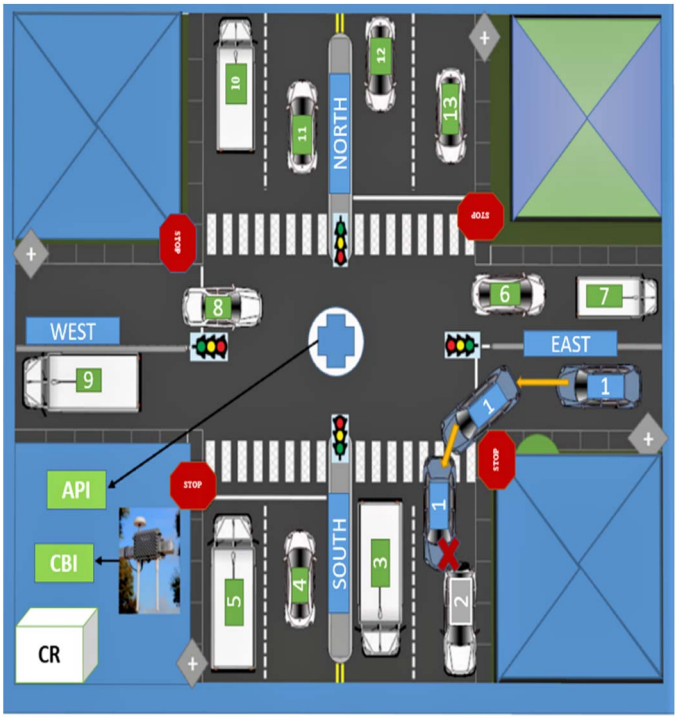


Fig.1. System Model of SAD-CS

A vehicle enters into the SAD-CS area listen the wireless radio frequency. The microcontroller is used for establishing the connections between the vehicles and the Access Point Infrastructure (API). The data transmission system uses the push and pull methods to establish effective communications in between the vehicles and the API. The infrastructure uses the push method for broadcasting the messages to the vehicles. On the other hand, the pull method is used by vehicles for retrieving the data from the infrastructure. Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I) and Infrastructure to Vehicle (I2V) communications can be in action according to the situation demands.

B. Device description

The system consists of an AT89S52 microcontroller which does all the function with the help of Accident Detection Unit (ADU). Power supply is given to the microcontroller. Along with microcontroller the system used several sensors with the raspberry-pi. The raspberry-pi unit is called here as ADU is connected with the microcontroller.

In Smart Accident Detection and Control System (SAD-CS), active Radio Frequency Identification (RFID) devices are used. RFID tag emits the radio signals that can be captured by devices such as routers and coordinators. Central router is not only capable to capture the tag data but also relay the data to either another router or coordinator in its range. Coordinators have a serial interface through which external Global System for Mobile Communications (GSM) devices can be interfaced to make it a dual-radio device. Out of them, one is 2.4 GHz radio interface and the other is GSM interface. Coordinator receives data from the router or tag by using its 2.4 GHz RF interface and capable to communicate with remote server using its GSM interfaces. The GSM modem of Waveform is used for our testing and the module operates at fixed rate.

1) Global Positioning System

Global Positioning System (GPS) is a network about 30 satellites orbiting the earth at attitude of 20,000 km. GPS satellites circle the earth two-times/day in a precise orbit. It gives geo-location and time information to a GPS receiver in all climate conditions anywhere on or close to the earth by satellites. GPS position is determined using data coming from satellites. GPS receiver computes distance to satellites and using their position calculate on its own.

2) Microcontroller

The proposed system uses the AT89S52 microcontroller. It is a microprocessor of 8051mc. This microcontroller device consists of 40 pins. It has four input/output ports. Each port consisting of 8 bits that are used to place input and output. Microcontroller has 32 input/output pins that are connected to peripheral devices. When microcontroller is configured, configured pin considered as an input (1) or an output (0) which depends on its logical states. When logical one (1) is applied to appropriate port that time the voltage level on appropriate pin will be 5V.

3) Global System for Mobile Communications

The Global System for Mobile Communications (GSM) is used for the different communication purposes in the most recent modern cellular networks. It utilizes SIM900 quad-band developed by SIMCOM in which 850 MHz, 900 MHz, 1800 MHz and 1900 MHz frequencies are available. Inbuilt RS232 level converter circuitry allows the modem to connect the PC serial port directly. The modem works in auto-band mode with starting fixed baud rates. For setting the various baud rates ranging from 960–11520, AT commands are used. This modem is having an internally TCP/IP stack with GPRS facility that can be used to provide internet connectivity where the data and SMS transmissions are allowed. In addition, it supports the extended set of AT commands that are useful for reading, editing, SMS messages, monitoring the charging status, and level of battery charge.

4) Radio Frequency Identification (RFID) Tag

RFID tagging is an ID system uses small radio frequency to track and identify the devices. This system includes the tag itself where read/write, data collections, processing, and transmissions are avaiable. An RFID tag also known as RFID transponder consists of a chip, some memory and an antenna. There are two types of RFID tags: active tags and passive tags. Active tags contain their own power source whereas passive tags do not.

5) Raspberry Pi

The Raspberry Pi is a low cost; Single-Board Computer (SBC) built on a single circuit board with microprocessor(s), memory, input/output (I/O) and other features. Single board computers with integrated functions are made for developing the different types of system.

6) Fire Sensor

A Fire Sentry i9040 (flame detector) is a sensor designed to detect and respond to the presence of a flame or fire that allowing flame detection. Flame detection responses are depend on the installation process that includes sounding an alarm, deactivating a fuel line (such as a propane or a natural gas line), and activating a fire suppression system.

7) Gas Sensor

The Grove - Gas Sensor (MQ2) module is for detecting the gas leakage that can happen in different environments. It is suitable for detecting H2, LPG, CH4, CO, Alcohol, Smoke or Propane. Due to its high sensitivity and fast response time, measurement can be taken as soon as possible. The sensitivity of the sensor can be adjusted by potentiometer.

8) Shock Sensor

A SS302 MEMS (shock sensor) is a device which indicates whether a physical shock or impact has occurred. These sensors are also known as shock overload devices that have a binary output. Shock sensors can be used metal-to-metal impact and pyroshock, crash testing, vibration and shock monitoring, impact testing, penetrator and launch tests, consumer electronics drop testing, blast loading and survivability of structures, fuse, safe and arm.

C. *Placement of Devices*

The placement of devices of SAD-CS are given here:

- The AT89S52 microcontroller is connected to a continuous power supply in vehicles.
- The Global Positioning System (GPS) modem is connected to the AT89S52 microcontroller.
- Global System for Mobile Communications (GSM) is connected to the AT89S52 microcontroller. GSM is used to send Short Message Service (SMS) to predefined emergency mobile number.

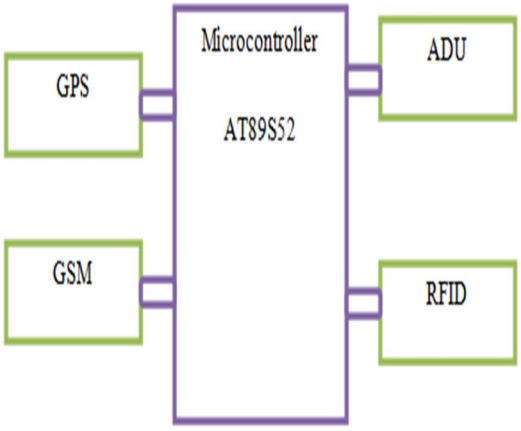


Fig.2. Connection architecture of devices with Microcontroller

- On Board Unit (OBU) is placed in every vehicle and connected with power supply.
- The Access Point Infrastructure (API) is placed in the middle in an assumed intersecting point of roads, where four directions of the roads are present such as East, West, North, and South directions.
- The Accident Detection Unit (ADU) detects the accident which is connected with the microcontroller.
- Radio Frequency Identification (RFID) tag is attached to the microcontroller and transmits the id.

Fig.2. shows the complete connection architecture of devices with microcontroller.

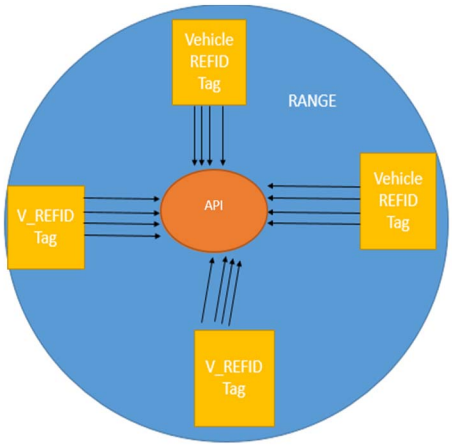


Fig.3. Actual RFID devices in operation

The placement of API and the exchange of RFID tag between the Vehicles and API are shown in Fig. 3.

- The three crash sensors (Gas, Shock, and fire sensors) are interfaced with raspberry pi to detect the accident types as shown in Fig.4. Sensors and raspberry pi are placed in vehicles.
- The road side unit Control Box Infrastructure (CBI) is placed beside the road to establish connection in between the API and Control Room (CR).

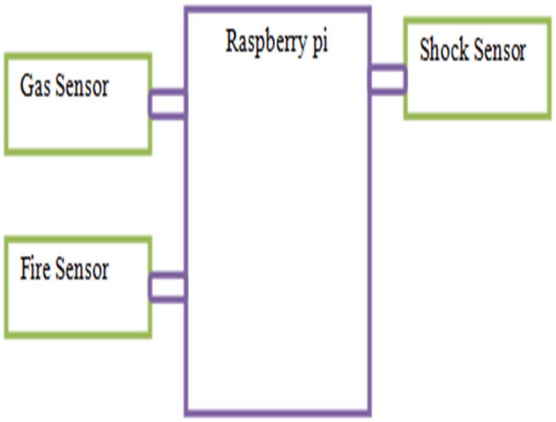
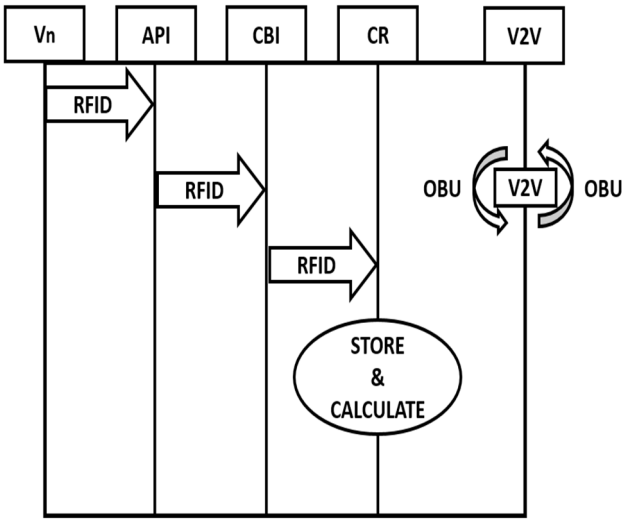


Fig.4. Accident Detection Unit (ADU)

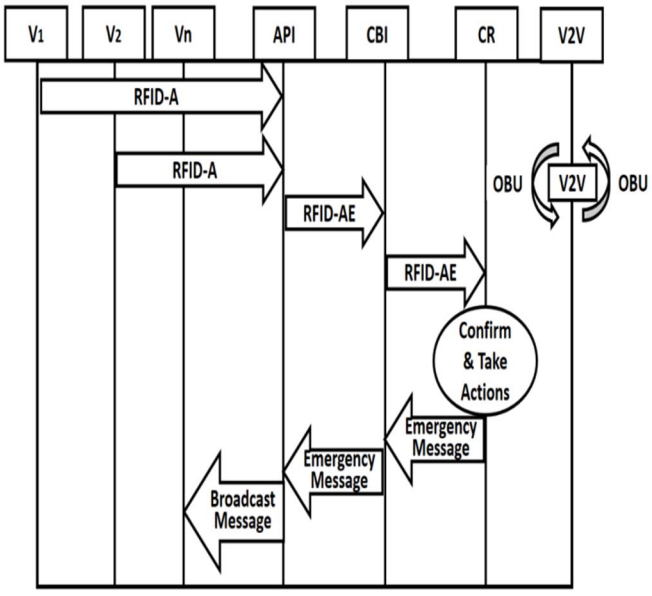
The vehicle has the ADU that is equipped with several sensors. Several information such as fire detection, gas leakage, crash, and so on will be available if one of the

incidents is occurring. These sensors are fixed at a predetermined value. The value the sensors changes depending on the situations. GPS and GSM technology are utilized to locate the vehicle location as well as message sending purposes.

D. Forwarding Process of SAD-CS



(a) RFID Registration Process of SAD-CS



(b) Accident Alert Process of SAD-CS

Fig. 5. Complete Forwarding Process of SAD-CS

When a Vehicle enters into the SAD-CS area, it must go for RFID registration process that has been shown in Fig. 5 (a). Where *Vn* indicates the number of vehicles on the road. Vehicles send their individual RFID number to the API. Then API sends the RFID number to the CR through CBI. CR stores all the RFID numbers of the vehicles. It can be calculated the approximate number of vehicles that have entered in to the lane.

When an accident occurs, message forwarding process of SAD-CS has shown in Fig. 5(b). According to the SAD-CS system, the Access Point Infrastructure (API) gets the RFID-A tag from the affected vehicles (V_1 and V_2) where the *A* in RFID is variable. It has different predefined values for different sensors such as gas sensor for gas leaks, fire sensor for fire, and shock sensor for tremendous push to detect the affected situations. After getting RFID-A, API attaches an emergency code with RFID-A forms RFID-AE and sends it to Control Room (CR) via Control Box Infrastructure (CBI). CR finds the matching of the received RFID tag number with the stored one in database, identify the lane number, and the location of the affected vehicles. If the RFID tag number matched, CR pushes emergency message to API via CBI. Finally, the emergency message is going to be broadcasted to all the available vehicles by API in SAD-CS area. Therefore, available vehicles on the roads are going to be warned about the accident and the affected area should be avoided by the vehicles for a certain amount of time.

E. Additional features

The proposed accident detection system SAD-CS not only detects the accident and pushes the emergency message to the other vehicles for avoiding further accidents but also it has the ability to take the necessary steps for helping the affected people and clearing the place of affected area. The Control Room (CR) can easily inform the location of the affected area to the nearest hospital, fire service station etc. Therefore, it is possible to provide the quick emergency services in the affected area.

Currently, the proposed system has considered only the four or more wheels' vehicles for accident detection. In Bangladesh roads perspective, other vehicles such as rickshaw, auto-rickshaw and so on can be taken into consideration for making the accident detections more accurate.

There are many other additional features can be added to CBI like pushing advertises such as shopping mall discount offers, restaurant discount coupon, emergency cell or telephone phone numbers (e.g., Hospital numbers, Police station numbers), location of different restaurants, city maps, availability of parking lots and so on. These features can improve the comfortability of the drivers.

F. Comparisons

We have compared the proposed Smart Accident Detection and Control System (SAD-CS) with the other User Alerting System for Vehicle Accident Detection System (UAS-VADS), and Real Time Vehicle Accident Detection and Tracking (RT-VADT).

Unlike the compared systems, the SAD-CS system provides the vehicle to vehicle communication as well as the V2I, I2V communications. It provides the warning message broadcasting system to other vehicles about the accident and the lane no. Therefore, the other vehicles can avoid the affected lane. Providing such kind of information, SAD-CS reduce the traffic haphazard and loss of the valuable lives. The comparisons of SAD-CS, UAS-VADS, and RT-VADT are presented in Table II.

TABLE II. COMPARISONS OF SAD-CS, UAS-VADS, AND RT-VADT

Key Terms	*SAD-CS*	*UAS-VADS*	*RT-VADT*
Devices	Raspberry pi, Sensors (Gas, Fire, Shock), GSM, GPS, Microcontroller, OBU, API,CBI	Buzzer, Vibration sensor, Arduino, GSM modem, GPS module	GPS, GSM, microcontroller AT89S52, Accident detection
Methods	Push and pull methods	Android application based system	SMS Technology
Communication Types	Vehicle to Vehicle (V2V), Vehicle to Infrastructure (V2I), Infrastructure to Vehicle (I2V)	Vehicle to Smartphone	Vehicle to Specific Cell Phone
Notification Time	Before (In case of gas leakage) and after the accident	After the accident	After the accident
Broadcasting System	Warning message broadcasting system to other vehicles available	Not Available	Not Available
Identification System	Radio Frequency Identification System	No identification system	No identification system

IV. CONCLUSION

In this paper, a Smart Accident Detection and Control System (SAD-CS) for intersecting road ('plus' junction) in vehicular networks is proposed. The system utilized Raspberry Pi and Microcontroller where an on-board unit in every vehicle is required. While lifesaving in favor of accident detections during the occurrences immediately, the system is capable of detect the location of the affected vehicles and easily measure the suitable steps to get rid of the worst situations. It is considered as a digital system to detect the unavoidable circumstances on the road automatically. If every vehicle on the road uses modern equipment, then the proposed SAD-CS can provide better result compared to the present manual traffic control management system in terms of minimizing the road accidents.

This is our first initiative for minimizing the road accidents in Bangladesh which is one of the major problems in the recent time. There are several future scopes are present to extend this work. Some of them are:

- The system can be updated for the long route accident detection system by using satellite and airbag system.
- Eye blink sensors can be used to monitor blink rate of the driver for detection of drowsiness.
- High end sensors can be deployed for better accuracy and efficiency.
- Performance evaluation will be demonstrated through the virtual simulations.

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