A project report on

TOWARDS SAFER ROADS THROUGH COOPERATIVE HAZARD AWARENESS AND AVOIDANCE (CHAA) IN CONNECTED VEHICLES

Submitted in partial fulfilment for the award of the degree of

B. TECH

Information Technology

by

SRISHA BALAJI

(14BIT0023)

SCHOOL OF INFORMATION TECHNOLOGY AND ENGINEERING

DECLARATION

I hereby declare that the thesis entitled "Towards Safer Roads Through Cooperative Hazard Awareness and Avoidance in Connected Vehicles" submitted by me, for the award of the degree of B.Tech (Information Technology) is a record of bonafide work carried out by me under the supervision of Prof. Divya Udayan J.

I further declare that the work reported in this thesis has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Place: Vellore

Date: Signature of the Candidate

CERTIFICATE

This is to certify that the thesis entitled “TOWARDS SAFER ROADS THROUGH COOPERATIVE HAZARD AWARENESS AND AVOIDANCE IN CONNECTED VEHICLES” submitted by Srisha B (14BIT0023) SITE School, VIT, for the award of the degree of B.Tech (Information Technology) is a record of bonafide work carried out by him under my supervision.

The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university. The Project report fulfils the requirements and regulations of VIT and in my opinion meets the necessary standards for submission.

Signature of the Guide **Signature of the HOD**

Internal Examiner **External Examiner**

ACKNOWLEDGEMENT

It is my pleasure to express with deep sense of gratitude to Prof Divya Udayan J, Assistant Professor, SITE, Vellore Institute of Technology, for her constant guidance, continual encouragement and understanding. More than all, she taught me patience in my endeavor. My association with her is not confined to academics only, but it is a great opportunity on my part of work with an intellectual and expert in the field of multimedia and graphics.

I would like to express my gratitude to Honorable Chancellor Dr. G. Viswanathan, VP Mr. G V Selvam, VC Dr. Anand A. Samuel, Pro-VC Dr. S. Narayanan and Dr. Aswani Kumar Cherukuri, Dean, SITE and Project Coordinator Prof. Shynu P G, SITE for providing with a environment to work in and for their inspiration during the tenure of the course.

I express ingeniously my whole-hearted thanks to Dr. Dinakaran M, HoD and Associate Professor, all teaching staff and members working as limbs of our university for their not- self-centered enthusiasm coupled with timely encouragements showered on me with zeal, which prompted the acquirement of the requisite knowledge to finalize my course study successfully. I would like to thank my parents for their support.

It is indeed a pleasure to thank my friends who persuaded and encouraged me to take up and complete this task. At last but not least, I express my gratitude and appreciation to all those who have helped me directly or indirectly toward the successful completion of this project.

Place: Vellore

Date: 9 August 2018, Srisha B

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

CV- Connected Vehicles

OBU- On Board Unit

RSU- Road Side Unit

V2V- Vehicle-to-Vehicle Communication

V2I- Vehicle-to-Infrastructure Communication

CHAA- Cooperative Hazard Awareness and Avoidance

DSRC- Dedicated Short Range Communication

WAVE- Wireless Access Vehicular Environment

OEM- Original Equipment Manufacturer

IOT- Internet Of Things

VANET- Vehicular ad hoc Network

ABSTRACT

Automobile accidents are a major public problem in many countries. Despite awareness campaigns, this problem is still increasing due to drivers poor behaviors such as speed driving, unsafe overtaking, drunk driving, riding with no helmet protection, driving without sufficient sleep, etc. The numbers of death and disability are very high because of late assistance to people by any sort of emergency service. These cause huge social and economic burdens to people involved.

Therefore, several automotive research and development groups and major car manufacturers including are developing safety devices and accident prevention mechanisms to protect drivers from such fatalities. However, good safety devices for vehicles is difficult to implement and very expensive. In today's world car manufacturers have car collision and avoidance schemes deployed at exorbitant rates, but a major concern with all of the existing systems are that they are not centralized and each OEM (original equipment manufacturer) has their own method of dealing with an accidental occurrence.

We wish to incorporate the facility of a centralized sophisticated pre as well as post-crash safety measure with the help of on board units that can be installed into existing vehicles and develop a connected vehicle network with the help of roadside units to relay information to all vehicles connected in their vicinity.

CHAPTER 1
INTRODUCTION

1.1 GENERAL INTRODUCTION

On road transportation has always been and will continue to be for a long time, the largest mode of transport with over 10 billion vehicles plying on roads every single day and an additional 20 million adding to that every year. Nearly 1.3 million people die every year due to road accidents. That's about an average of 3300 deaths a day, which according to WHO is the one of the top 10 causes of death globally. Safer roads are a necessity that we must strive for in this day and age to ensure lives are not lost unnecessarily. Early warning systems have been attempted as early as the late 1950s. Not very long ago, it would have seemed astonishing that your car would be able to "see" other vehicles or pedestrians, anticipate collisions, and automatically apply the brakes or take corrective steering actions. But more and more automobiles can do that to some degree, thanks to a growing list of collision avoidance systems.

Some of these capabilities, such as forward-collision warning systems, have been around for a few years, mostly on high-end luxury cars. Others, like steering assist, are just getting ready for prime time. The cost of collision-avoidance systems can still be an obstacle. Most advanced systems today come only as part of a large options package or on a vehicles higher models, more expensive trim versions. These cutting-edge active safety systems rely on a number of sensors, cameras, lasers, and short- and long-range radar. They monitor what is going on around the vehicles, pedestrians, cyclists, and even road signs as well as the vehicle itself. Jumping to the trim line where the safety goodies are offered can add thousands of dollars to a vehicle's price.

Recent investments and governmental initiatives have been critical stimuli in developing the knowledge base needed to make connected vehicle (CV) technologies a reality, while minimizing any potential adverse effect. For the past few years, establishing the basic principles of safer roads within the context of specific advanced communication and messaging technologies has been a challenging endeavor.

The US Department of Transportation (U.S. DOT) commented that while the past 50 years have been about surviving vehicle crashes; the next 50 years will be about preventing them.CV has the potential to transform the way we travel through the use of a reliable, interoperable wireless data communications system that will allow cars, buses, trucks, trains, traffic signals, cell phones, and other devices to automatically communicate with one another. Nowadays, the market of connected vehicles is booming and the global market is expected to reach USD 131.9 billion by 2019.

Despite the impressive developments in vehicle safety (seat- belt, airbags, ABS system, fog lights), car accident remain a serious public concern. Vehicles today are still vulnerable to accidents due to hazardous situations on the road like those triggered by adverse weather conditions (dust, fog, snow and sand storms), and above all by human unintentional errors and recklessness. With advancement in wireless communications, it is now possible to connect vehicles to each other to enable them to communicate and cooperate. In this context of smart vehicles and IOT, Connected Vehicle (CV) technologies are playing a major role in unleashing the true potential for connected vehicles to collect and disseminate pertinent data among each other for the sake of better decision-making and enhanced safety. The term Connected Vehicle is used to broadly designate any smart vehicle with wireless connectivity to the Internet, local network or the Cloud, other vehicles on the road (V2V), personal communication devices, roadside infrastructure (V2I) or control centers as shown in Fig 1. [7]

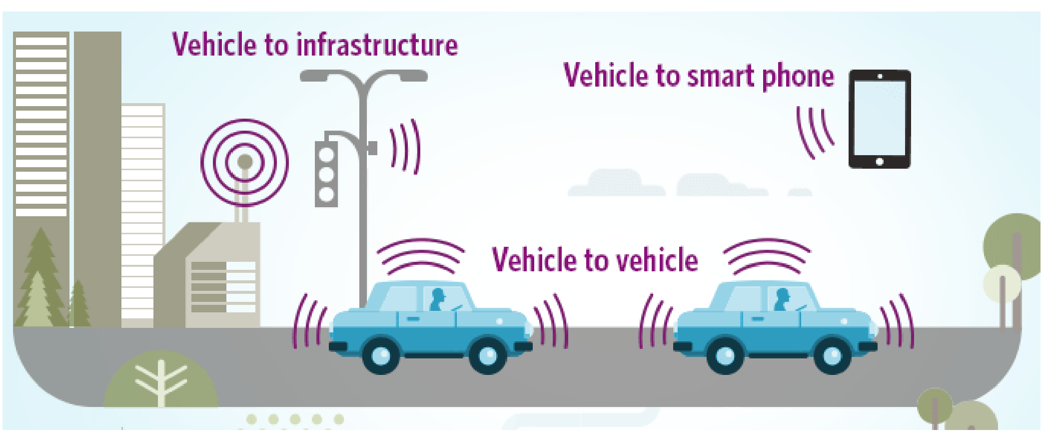

Fig 1 Connected Vehicle Network

Vehicular ad hoc network, consisting of a network of vehicles, moving at a relatively high speed, that communicate among themselves with different purposes, (Fig 2)[8] being the main purpose that of improving security on the road. VANETs have emerged as an exciting research and application area. Increasingly vehicles are being equipped with embedded sensors, processing and wireless communication capabilities. This has opened a myriad of possibilities for powerful and potential life-changing applications on safety, efficiency, comfort, public collaboration and participation, while they are on the road. The high but constrained mobility of vehicles bring new challenges to data communication and application design in VANETs.

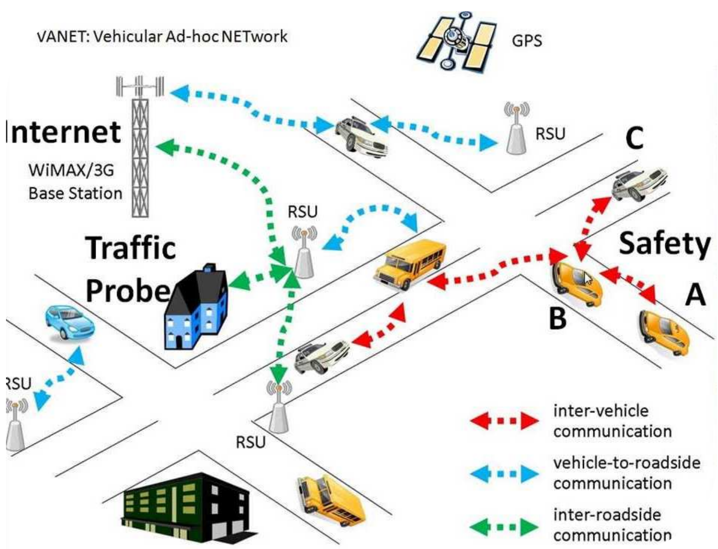

Fig 2 Vehicular Ad hoc Network - VANET

1.2 MOTIVATION

In the recent past Data Analytics, IOT and AI have become core to business sectors in order to serve communities effectively and to achieve desired business outcomes. Having a keen interest to the automotive industry, connected vehicles seem to possibly be the next revolutionary technology in the way vehicles work in close association to one another in a safe and systematic manner. Having had the opportunity to implement a hardware project, we have looked to demonstrate how CV technologies can be implemented in existing vehicles at a marginal cost. Should this technology be adopted soon, it provides immense scope for the betterment of roads and safe commuting environments to people.

1.3 AIM

On contrary to the existing systems in today's world the aim here is to have a cost effective, systematic intelligent network of connected vehicles to avoid road hazards. Pre collision intimation via ultrasonic sensors and in the event of an accident occurring an SOS signal should be transmitted to a relief station with the constituent data as to where an accident has occurred and the severity of the accident. All crash data can be consolidated and accident prone zones can be identified as well as the timestamps of when they occurred to raise awareness to commuters and build safer, more functional roads.

CHAPTER 2
LITERATURE SURVERY

Contrasting data with previously occurred accidents

Obtaining information regarding, our system directly estimates the accident severity by comparing the obtained data with information coming from previous accidents stored in a database. This information is of utmost importance, for example, to determine the most suitable set of resources in a rescue operation. Since we want to consider the information obtained just when the accident occurs, to estimate its severity immediately, we are limited by the data automatically retrievable, omitting other information, for instance about the driver's degree of attention, drowsiness, etc. [1]

Detecting the severity of a cash that occurs

So Young Sohn's research approached to collect information available when a traffic accident occurs, which is captured by sensors, classification accuracy for the severity of road traffic accidents in Korea, installed onboard the vehicles. [2]

Use of radar and laser technology to check proximity to other obstacles

Most of the existing sensor system for automotive adaptive cruise control and collision avoidance uses the radar and laser technology for operation. The main disadvantage of those system is that it will work only if theater space between vehicles is greater than 1 m. [3]

Machine Learning models to predict probability of accidents occurring

Systems tried to ensure the data collected are structured in a packet, and forwarded to a remote Control Unit through a wireless communication ML techniques are applied to discuss the model for predicting future possible accident locations where and when depending on environment conditions of previously occurring accidents. [4]

Real-Time Detection and Estimation of Denial of Service Attack in Connected Vehicle Systems

Advanced connectivity features in today's smart vehicles are giving rise to several promising intelligent transportation technologies. Connected vehicle system is one among such technologies, where a set of vehicles can communicate with each other and the infrastructure via communication networks. Connected vehicles have the potential to improve the traffic throughput, minimize the risk of accidents and reduce vehicle energy consumption. Despite these promising features, connected vehicles suffer from the safety and security issues. Especially, vehicle-to-vehicle and vehicle-to-infrastructure communication make the connected vehicles vulnerable to cyber-attacks. Every solution triggers a new problem so in order to improve safety and security, advanced vehicular control systems must be designed to be resilient to such cyber-attacks. [5]

Cellular communication of traffic signal state to connected vehicles for arterial eco-driving

The main contribution of this paper is experimental validation of a system architecture for providing real time communication of individualized Traffic Signal Phase and Timing (SPaT) data from disparate data sources, tailored to meet the needs of an in-vehicle driver assistance systems. The role of data collected directly from Traffic Management Centers is explored; in addition, the collection and condensation of crowdsourced SPaT data sources is investigated as a complementary solution in situations where timing information is not available directly from a city's Traffic Management Center (TMC). In order to evaluate the effectiveness of communicating the traffic signal state to the in-vehicle driver assistance systems, on-road experiments were carried out by a number of drivers interacting with an implemented in-vehicle speed advisory application in mixed traffic on arterial roads in the city of San Jose, CA. To assimilate the Traffic management data along with the road side units will go a long way in the way traffic is administered with smoother driving conditions. [6]

CHAPTER 3
SYSTEM DESIGN

To demonstrate what our potential CV network would function, we have implemented it utilizing three modules, two of which are OBUs and one of which is an RSU. The two on board units which are to be implanted into vehicles, communicate with one another with regard to two scenarios. Namely, when they are in close proximity to one another and they intimate the possibility of a crash and another scenario where an accident has taken place and the GPS coordinates of the vehicles are transmitted to a roadside unit, which relays the same information to emergency services and also to other vehicles that are nearing that area.

3.1 MODULES

Vehicle Module

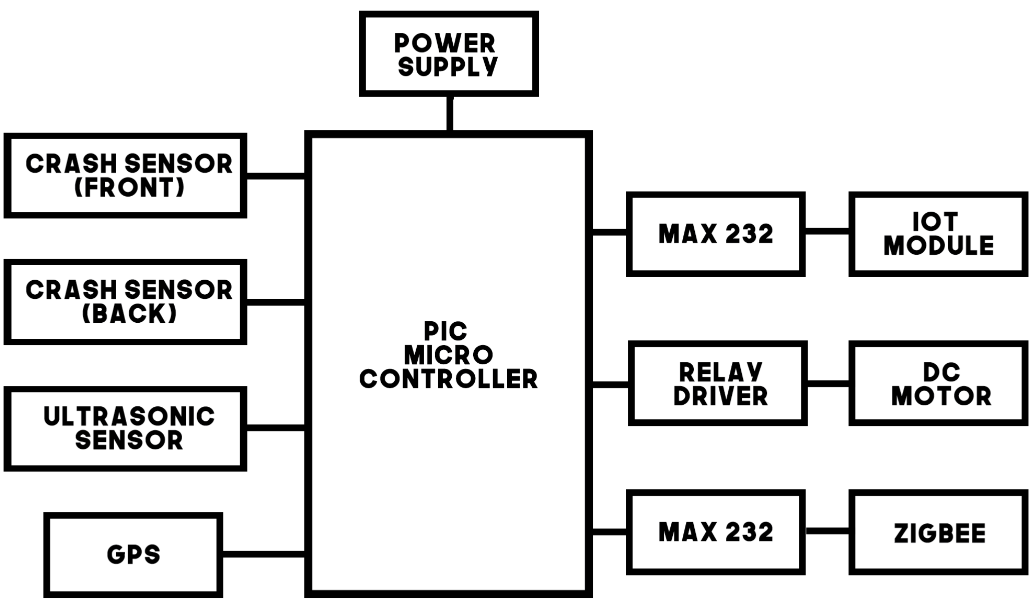

Fig 3 On Board Unit

Here we have the PIC Development Board, which is supplied with a power source and is connected to essentially a vibration sensor, a ZIGBEE Transmitter, an ultrasonic sensor, an IOT module and a GPS module.

The ultrasonic sensor is perpetually detects if there are any other vehicles in its proximity, ultrasonic waves emitted and picked up by the sensor gives us data to calculate the distance between the two vehicles. In the event of an accident, the vibration sensor is set off and the MAX 232 IC is triggered to help send a signal to the emergency system via the ZIGBEE Module. Simultaneously the vehicles' motor is shut off and the buzzer also alarms as a caution. The LCD lights up expressing whether an accident has occurred. A GPS Module has been implemented so as to send the exact coordinates of where the crash occurred to the on road section. (Fig 3)

Vehicle 2 Module:

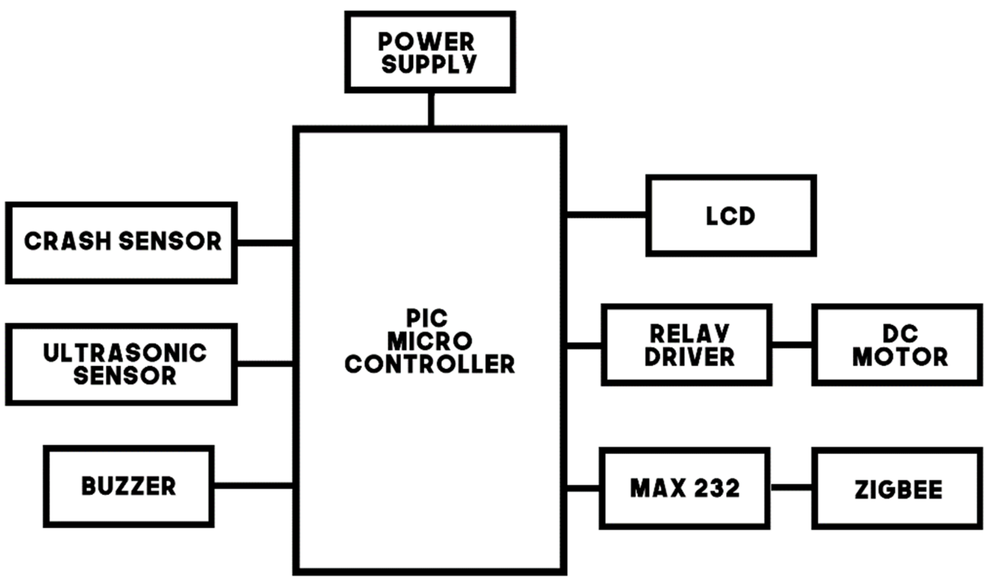

Fig 4 On Board Unit 2

The PIC Development Board which is used to display the distance between and two vehicles relayed via the ultrasonic sensor and the ZIGBEE from a vehicle moving ahead to the one behind it stating that a crash is eminent due to the proximity to another vehicle with the precise distance calculated based on the time taken by the ultrasonic sensor to transmit and read back its own wave. In case of an accident as well the buzzer is set off as a warning to the neighbouring environment. (Fig 4)

On road section:

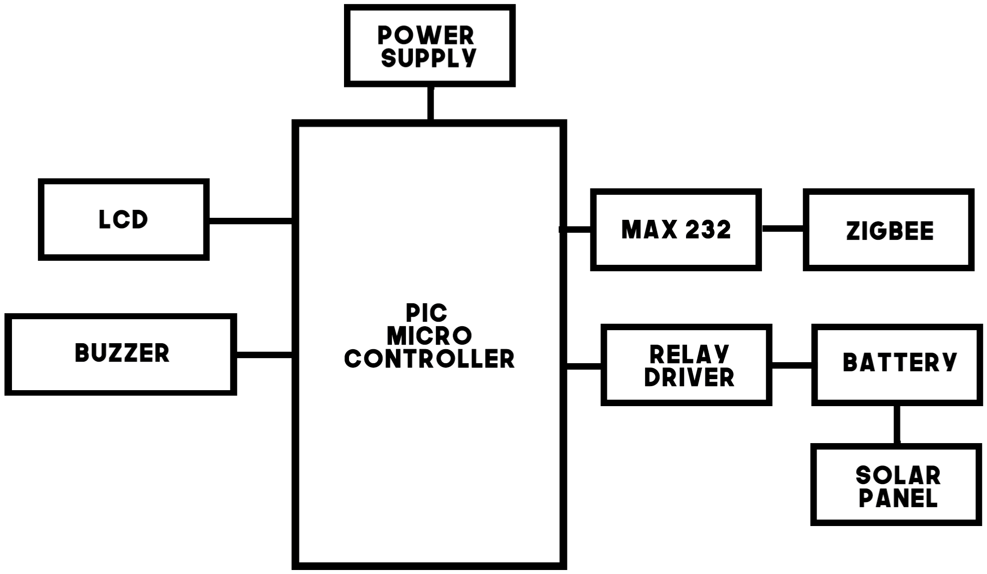

Fig 5 on road SOS/ Emergency Section

As and when an accident occurs the ZIGBEE on this module attains a receiving signal. The serial port will be used to send an appropriate message to be displayed on the LCD with GPS coordinates and a warning that the incident has occurred and triggering emergency services. A warning message can be relayed to other vehicles entering the vicinity. The buzzer is sounded off as an alarm. The power supply to the roadside unit can be supplied via a solar panel to make it more sustainable. (Fig 5)

3.2 HARDWARE COMPONENTS

PIC Microcontroller Development Board (Fig 6) – Central Processing Unit into which Embedded C code is hard wired into. PIC is a family of modified Harvard architecture microcontrollers made by Microchip Technology, derived from the PIC1650 originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to Peripheral Interface Controller. The PIC16F877A CMOS FLASH-based 8-bit microcontroller is upward compatible with the PIC16C5x, PIC12Cxxx and PIC16C7x devices. It features 200 ns instruction execution, 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, a synchronous serial port that can be configured as either 3- wire SPI or 2-wire I2C bus, a USART, and a Parallel Slave Port.

Memory of the PIC16F877 divided into 3 types of memories:

Program Memory - A memory that contains the program (which we had written), after we've burned it. As a reminder, Program Counter executes commands stored in the program memory, one after the other.

Data Memory – This is RAM memory type, which contains a special registers like SFR (Special Faction Register) and GPR (General Purpose Register). The variables that we store in the Data Memory during the program are deleted after we turn of the micro. These two memories have separated data buses, which makes the access to each one of them very easy.

Data EEPROM (Electrically Erasable Programmable Read-Only Memory) - A memory that allows storing the variables as a result of burning the written program.

Each one of them has a different role. Program Memory and Data Memory two memories that are needed to build a program, and Data EEPROM is used to save data after the microcontroller is turn off. Program Memory and Data EEPROM they are non-volatile memories, which store the information even after the power is turn off. These memories called Flash or EEPROM. In contrast, Data Memory does not save the information because it needs power in order to maintain the information stored in the chip.

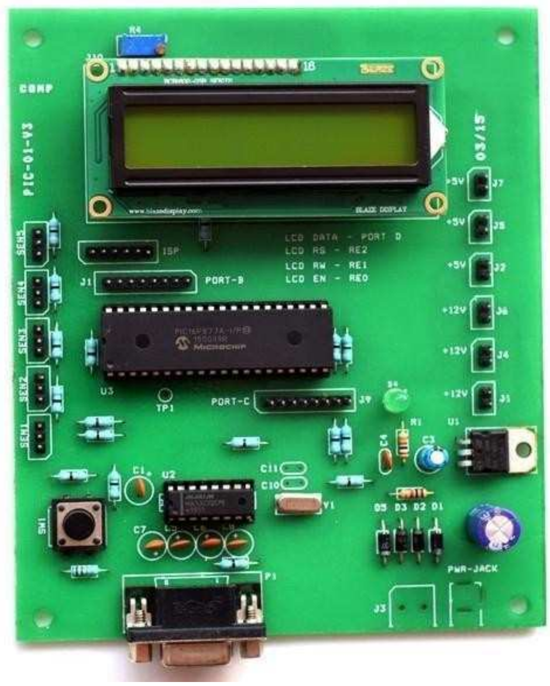

Fig 6 PIC Microcontroller Development Board

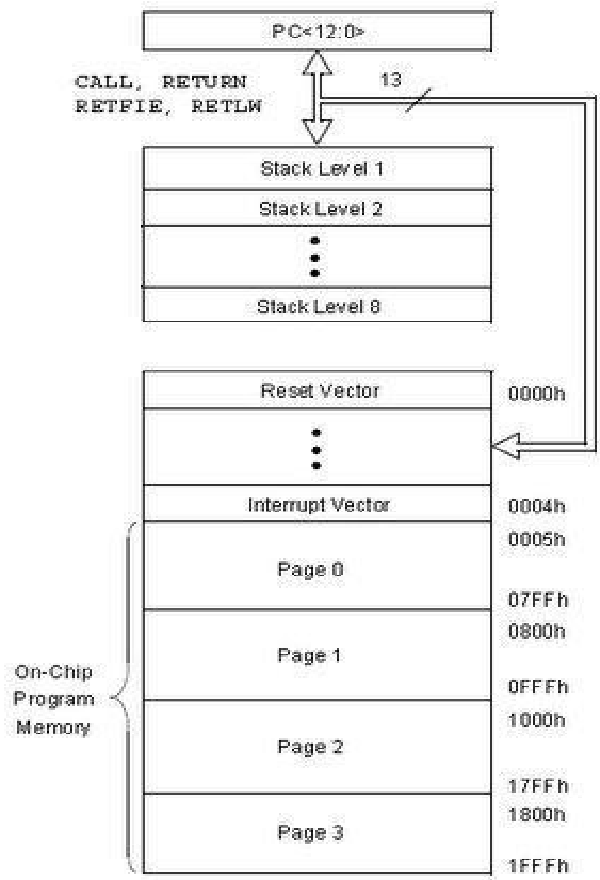

Fig 7 PIC16F877A program memory map and stack

PIC16F877 Data Memory Organization

The data memory is partitioned into multiple banks which contain the General Purpose Registers and the Special Function Registers. Number of banks may vary depending on the microcontroller; for example, micro PIC16F84 has only two banks.

Each bank extends up to 7Fh (128 bytes). The lower locations of each bank are reserved for the Special Function Registers. Above the Special Function Registers are General Purpose Registers, implemented as static RAM. While program is being executed, it is working with the particular bank. The default bank is BANK0. (Fig 7)

To access a register that is located in another bank, one should access it inside the program. There are special registers which can be accessed from any bank, such as STATUS register.

STATUS register (Fig 8)

In most cases, this register is used to switch between the banks (Register Bank Select), but also has other capabilities.

STATUS REGISTER (ADDRESS 03h, 83h, 103h, 183h)

R/W-0	R/W-0	R/W-0	R-1	R-1	R/W-x	R/W-x	R/W-x
IRP	RP1	RP0	$\overline{TO}$	$\overline{PD}$	Z	DC	C
bit 7							bit 0

Fig 8 PIC STATUS register

With the help of three left bits (IRP, RP1, and RP0) one can control the transition between the banks:

IRP - Register Bank Select bit, used for indirect addressing method.

RP1:RP0: - Register Bank Select bits, used for direct addressing method.

PORT register

The role of the PORT register is to receive the information from an external source (e.g. sensor) or to send information to the external elements (e.g. LCD). The 28-pin devices have 3 I/O ports, while the 40/44-pin devices, like PIC16F877, have 5 I/O ports located in the BANK 0.

1. PORT A is a 6-bit wide, bidirectional port. The corresponding data direction register is TRISA. Setting a TRISA bit (= 1) will make the corresponding PORT A pin an input. Clearing a TRISA bit (= 0) will make the corresponding PORT A pin an output.
2. PORT B is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISB. Setting a TRISB bit (= 1) will make the corresponding PORT B pin an input. Clearing a TRISB bit (= 0) will make the corresponding PORT B pin an output.
3. PORT C is an 8-bit wide, bidirectional port. The corresponding data direction register is TRISC. Setting a TRISC bit (= 1) will make the corresponding PORT C pin an input. Clearing a TRISC bit (= 0) will make the corresponding PORT C pin an output.
4. PORT D is an 8-bit port with Schmitt Trigger input buffers. Each pin is individually configurable as an input or output.
5. PORT E has three pins (RE0/RD/AN5, RE1/WR/AN6 and RE2/CS/AN7) which are individually configurable as inputs or outputs. These pins have Schmitt Trigger input buffers.

Serial Communication with PIC16F877 microcontroller

Our communication component USART (Universal Synchronous Asynchronous Receiver Transmitter) located within the PIC. It is a universal communication component (Synchronous/Asynchronous), which can be used as transmitter or as receiver.

We set USART in order to allow communication between PIC to PIC or between PIC to a personal computer. We have a multi-bit word of the crash data that we want to transmit it from one PIC to another or to the PC. When using the serial communication we transmit the multi-bit word bit after bit, as shown in Fig 9, when at any given moment only one bit will pass.

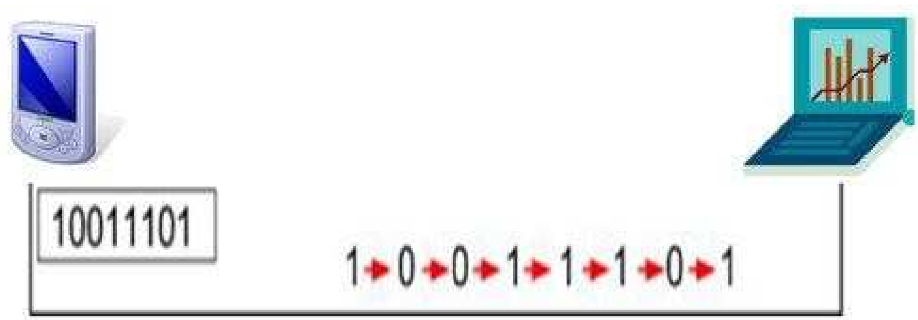

Fig 9 Transmitting the word 10011101 using serial communication.

We use synchronous communication because the information is transmitted from the transmitter to the receiver in a sequence, bit after bit, with a fixed baud rate and the clock frequency is transmitted along with the bits. That means that the transmitter and the receiver are synchronized between them by the same clock frequency. The clock frequency can be transmitted along with the information, while it is encoded in the information itself, or in many cases there is an additional wire for the clock. This type of communication is faster compare to the asynchronous communication since it is constantly transmitting the information, with no stops.

MAX 232 – Dual Receiver/Transmitter. IC to identify Serial Port. MAX232 pinout. The integrated circuit first created in 1987 by Maxim Integrated Products that converts signals from a TIA-232 (RS-232) serial port to signals suitable for use in TTL-compatible digital logic circuits. (Fig 10)

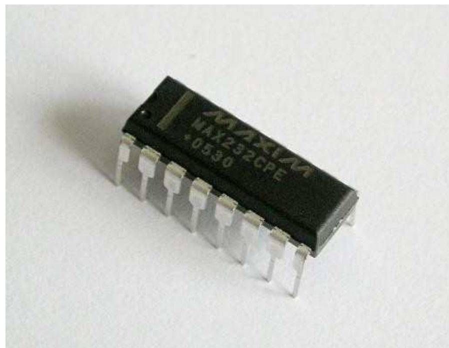

Fig 10 MAX232

Vibration Sensor – Sensor to detect as and when collision occurs to trigger the accident state in all the modules. (Fig 11)

Fig 11 Vibration Sensor

ZIGBEE TX/RX – Wireless Transmitter and Receiver. Zigbee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios, The ZigBee (cc2530) is a true system on chip (SoC) solution for IEEE 802.15.4 applications. (Fig 12)

It combines the excellent performance of a leading RF trans receiver with an industry-standard enhanced 8051 MCU, in system programmable flash memory, 8 kB RAM, and many other powerful features. Received Signal Strength Indicator (RSSI) is a measurement of power present in a received radio signal. In an IEEE 802.11 system, RSSI is an indication of the power level being received by the receive radio after the antenna and possible cable loss. Therefore, the higher the RSSI number, the stronger the signal.

Fig 12 ZIGBEE

GPS – To send exact location of accident this device allows the easy and cost-effective addition of location and tracking capabilities to virtually any product. The Global Positioning System (GPS) is a global navigation satellite system that provides location and time information in all weather conditions. The GPS operates independently of any telephonic or internet reception, though these technologies can enhance the usefulness of the GPS positioning information. GPS satellites transmit signal information to earth. This signal information is received by the GPS receiver in order to measure the user's correct position. (Fig 13)

Fig 13 GPS Module

Transformer- It is a general purpose chassis mounting mains transformer. Transformer has 240V primary windings and centre tapped secondary winding. The transformer has flying colored insulated connecting leads. The Transformer act as step down transformer reducing AC -240V to AC - 12V. (Fig 14)

Fig 14 Transformer

Ultrasonic Sensor- Ultrasonic sensor emit ultrasonic pulses, and by measuring the time of ultrasonic pulse reaches the object and back to the transducer. The sonic waves emitted by the transducer are reflected by an object and received back in the transducer. After having emitted the sound waves, the ultrasonic sensor will switch to receive mode. The time elapsed between emitting and receiving is proportional to the distance of the object from the sensor. (Fig 15)

Fig 15 Ultrasonic Sensor

Buzzer- Buzzer is an integrated structure of electronic transducers, DC power supply, widely used in computers, printers, copiers, alarms, electronic toys, automotive electronic equipment, telephones, timers and other electronic products for sound devices. Active buzzer 5V Rated power can be directly connected to a continuous sound, this section dedicated sensor expansion module and the board in combination. We set it off in case of an accident as a sort off warning intimation. (Fig 16)

Fig 16 Buzzer

IOT Module – It is a small electronic device embedded in objects, machines and things that connect to wireless networks and sends and receives data. Sometimes referred to as a "radio chip", the IoT module contains the same technology and data circuits found in mobile phones but without features like a display or keypad. Another key differentiator of IoT modules is that they provide always on connectivity. We use it to transmit and store data from the development boards to be loaded onto an online cloud server. (Fig 17)

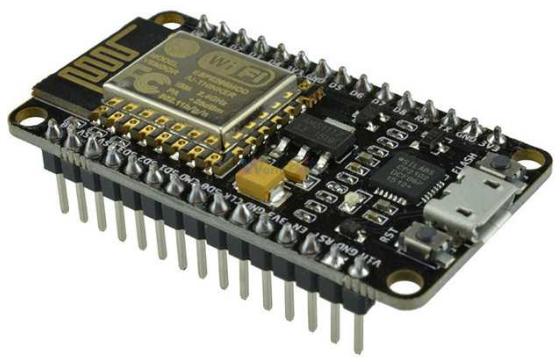

Fig 17 IOT Module

3.3 SOFTWARE REQUIREMENTS

Keil Microcontroller Development Kit

Keil Compiler is the complete software development environment for a wide range of Arm Cortex-M based microcontroller devices. MDK includes the Vision IDE and debugger, Arm C/C++ compiler, and essential middleware components, one of which is our PIC16F877.

MPLAB

MPLAB is a proprietary freeware Integrated Development Environment for the development of embedded applications on PIC and dsPIC microcontrollers. We have used it to integrate the IOT module to serially transmit data from the PIC development board to a cloud server.

PUTTY

PuTTY is a free and open-source terminal emulator, serial console and network file transfer application. We use it to connect the development board to a serial port for data to be transmitted and stored on a PC. PuTTY is available for various operating systems.

Embedded C

Embedded C is a set of language extensions for the C programming language by the C Standards Committee to address commonality issues that exist between C extensions for different embedded systems. Both the on road sections and road side unit's functionality is coded on an Embedded C platform.

CHAPTER 4

4.1 IMPLEMENTATION

With proper sensors and data communication techniques, a motorist will become better aware of his or her driving environment. To this end V2V and V2I wireless communications that are used to share real-time information about the road environment such as potential incidents, threats and hazards with an increased time horizon and awareness distance, beyond current in-vehicle technologies (radars or cameras) and what the driver can visualize. The primary challenge in a CV network is to develop scalable, robust, low-latency and high throughput technologies for safety applications that will significantly reduce collisions, save lives and minimize property loss.

DSRC/WAVE (Dedicated Short Range Communication/ Wireless access in the vehicular environment) is the only wireless technology that can potentially meet the extremely short latency requirement for road safety messaging and control. There are two types of devices in a WAVE system. The on-board unit (OBU) and the roadside unit (RSU) that are equivalent to the mobile station and the base station in a cellular system, respectively as depicted in Fig 18 [9] Both of these units are enabling V2V and V2I communications. However, unlike the case of cellular environment, the OBU in a vehicle directly communicates with other OBUs within the coverage area. This direct V2V communication reduces the message latency, as low latency is an essential requirement for safety applications such as collision avoidance.

Vehicle-to-vehicle (V2V) is a technology crafted to allow automobiles to interact with each other. V2V communications form a wireless ad hoc network on the roads. Such networks are also referred to as Vehicular Ad Hoc Networks (VANETs). The systems use a region of the 5.9 GHz band set aside by the United States Congress, the unlicensed frequency also used by Wi-Fi. The US V2V standard, commonly known as WAVE is based on a suite of IEEE P1609.x standards, which are built over the IEEE 802.11p standard. WAVE provides the basic radio standard for Dedicated Short Range Communication in VANETs.

DSRC is the wireless communication protocol for the vehicular networks, established in the United State in 1992. DSRC was approved by the United State Federal Communication Commission FCC to support the Intelligent Transport System applications in the short-range communication in vehicular networks, all of which is built on the framework for Connected Vehicles allowing Cooperative Hazard Awareness and Avoidance (CHAA) system through V2V communication.

DSRC architecture fully supports peer-to-peer two-way communications. In the transportation context, a peer can be a moving vehicle or a stationary roadside unit.

- Onboard unit (OBU) refers to equipment embedded in the mobile applications that allow information about the mobile user to be communicated to other applications.
- Roadside unit (RSU) consists of roadside-installed equipment that is used to relay messages using DSRC radio communications. RSUs are the first point of contact between DSRC-enabled mobile devices and the transportation communications network.

The implementation consists of three working sections as mentioned in the module section of chapter 3, two to depict the On board units (OBUs) on the vehicles and one to depict the road side unit . For the car section i.e. on board units we have used a vibration sensor, ZIGBEE, DC motor, ultrasonic sensor, battery, LCD, GPS and PIC Micro controller. The ultrasonic sensor constantly detects if there are any other vehicles in its proximity, ultrasonic waves emitted and picked up by the sensor gives us data to calculate the distance between the two vehicles. This information is sent to the other vehicle in its proximity as a cautionary measure. The vibration sensor is triggered when an accident has occurred. As and when a crash is detected the engine of the vehicle will be automatically shut off. PIC controller will set off a wireless transmission via the ZIGBEE to the on road station mentioning that the accident has occurred and rescue operations can be deployed based on the severity of the accident. The roadside unit consist of ZIGBEE, LCD, buzzer, solar panel, battery.

Generated power is stored in the battery. Received values are displayed in the LCD and buzzer will give intimation to people nearby to the occurrence.

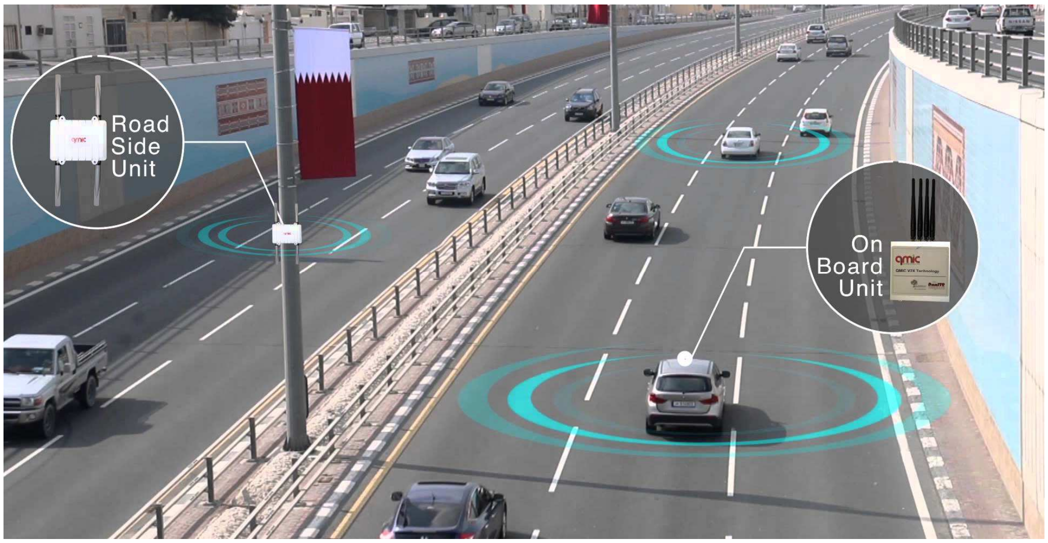

Fig 18 A Connected Vehicle Environment with OBU and RSU

The real time application of such a network is to have a seamless system of connected vehicles wherein data with regard to the environment of each and every vehicle can be relayed to a road side unit which would behave as a medium to transmit the same information to other vehicles that enter the vicinity of the road side unit for greater understanding of the environment it has entered as a caution to any sort of potential accidental occurrence. Our approach is based on an alert system that allows vehicles to geo-broadcast messages indicating a "Collision occurred" situation or "eminent collision occurrence" to warn other vehicles so that they can proactively adjust their speeds before it becomes too late. This approach is also applicable to other hazardous driving situations such as those due to a stalled vehicle in the roadway or to the presence of a physical obstacle on the road.

The ultimate goal of these alerts is to eventually reduce the variance in the cars speed by requesting speeding cars to slowdown in order to maintain a safer distance as cars enter a hazardous zone. The road hazard can be detected by a roadside unit RSU or by a vehicle equipped with sensors. Once a car detects a hazardous condition, it processes it and then sends an alert to all vehicles in the "Alert zone", whose range is predetermined. The message is geo broadcasted. When a vehicle in the broadcast zone receives the message, the alert message will be processed then forwarded to its neighbors. Only vehicles going towards the hazard zone processes the message, the others can just relay it to their neighbors because they will not reach the hazard zone.

To demonstrate what the on board unit and road side units would look like we have formulated a hypothetical crash scenario. Fig 19 and Fig 20 shows us what the OBU would look like in its idle state before it is triggered for proximity detection or crash detection.

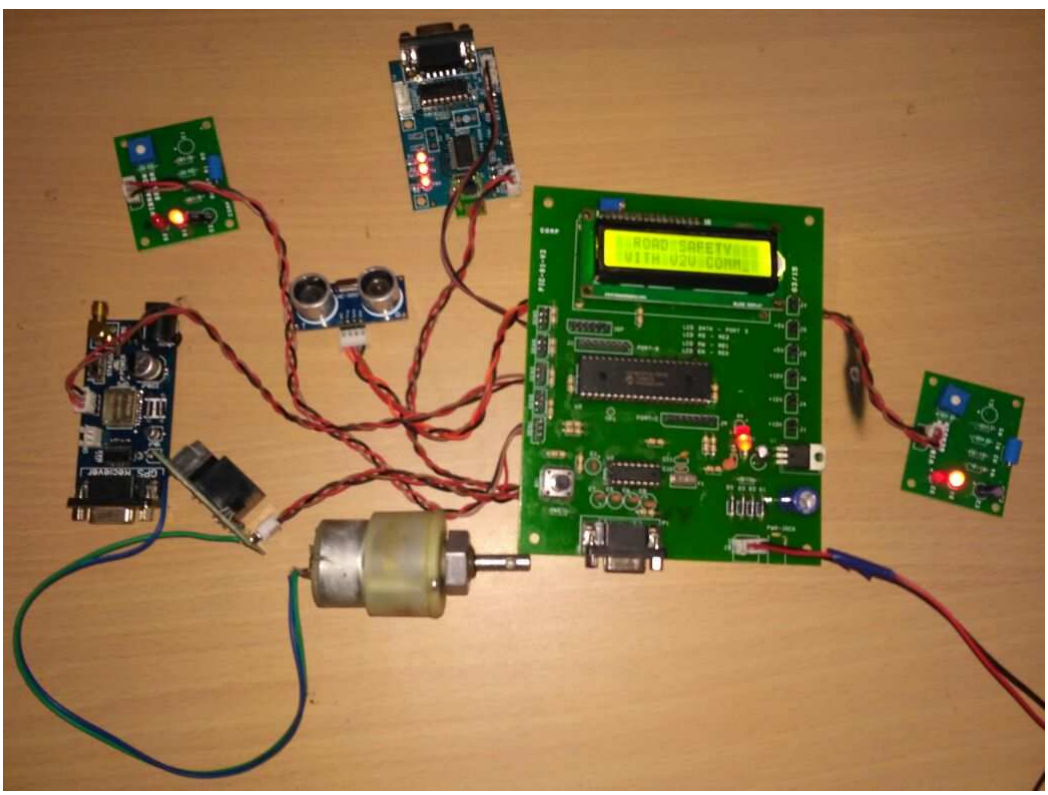

Fig 19 PIC Microcontroller representing an on board unit in idle state

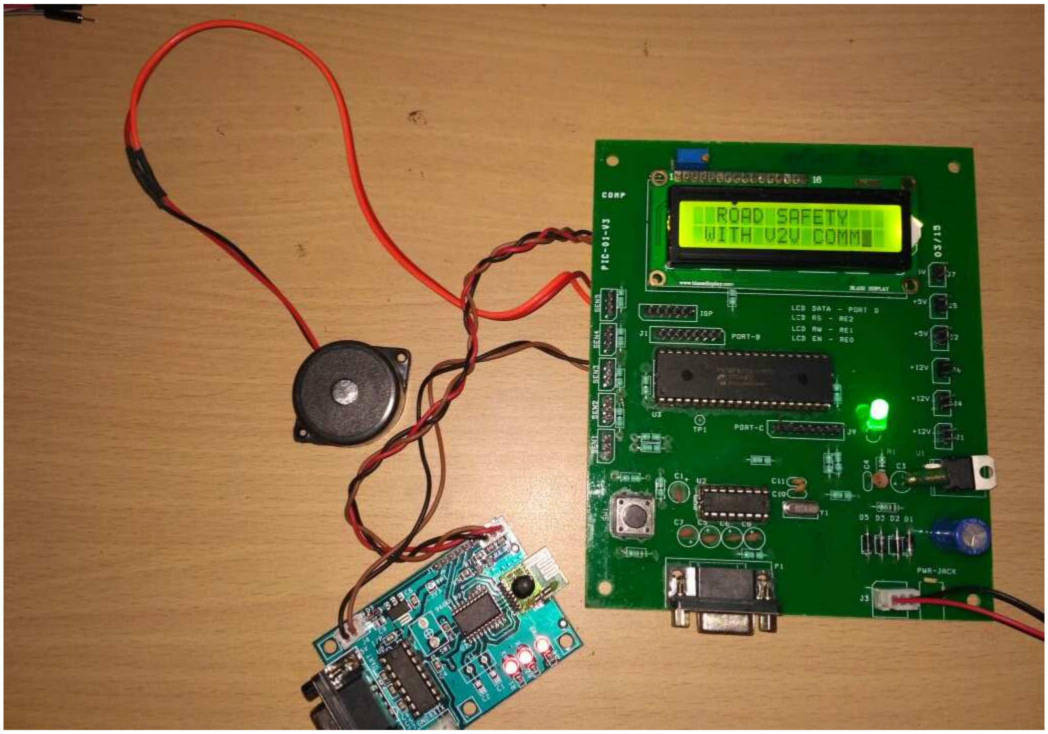

Fig 20 PIC Microcontroller representing another on board unit in idle state

In Fig 21 As and when two vehicles are too close to one another one OBU receives a signal from the other specifying the exact distance (with the help of the ultrasonic sensor) between the two vehicles as a caution.

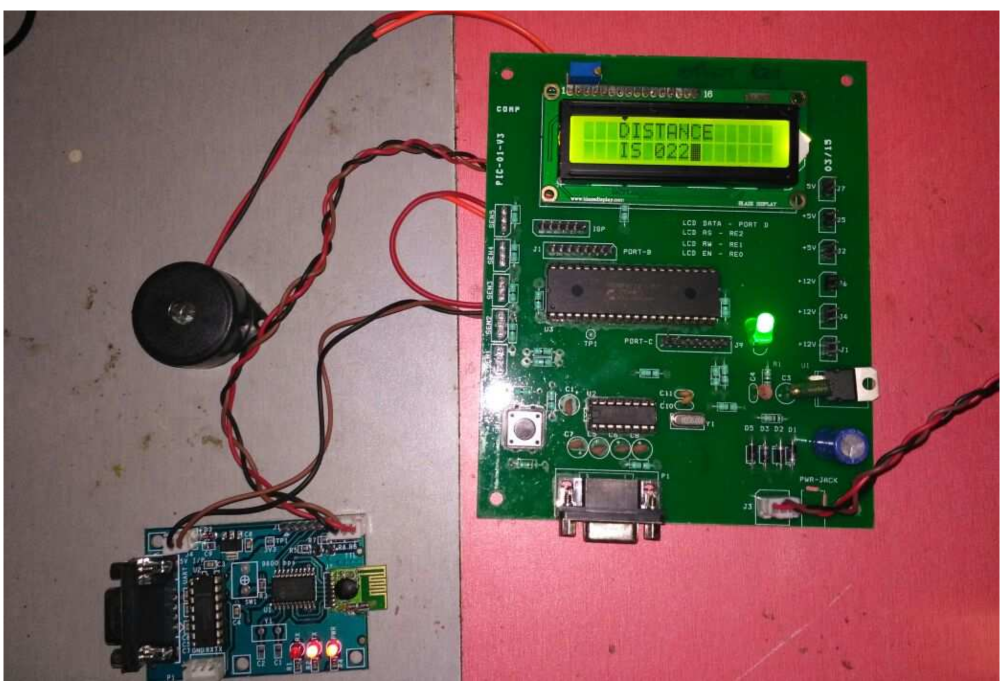

Fig 21 Measure of distance between two vehicles close to one another.

As seen in Fig 22, when the vibration sensor is triggered due to an accident, the DC motor is shut off and the GPS module on the OBU transmits its precise latitude and longitude to the roadside unit which calls for emergency services.

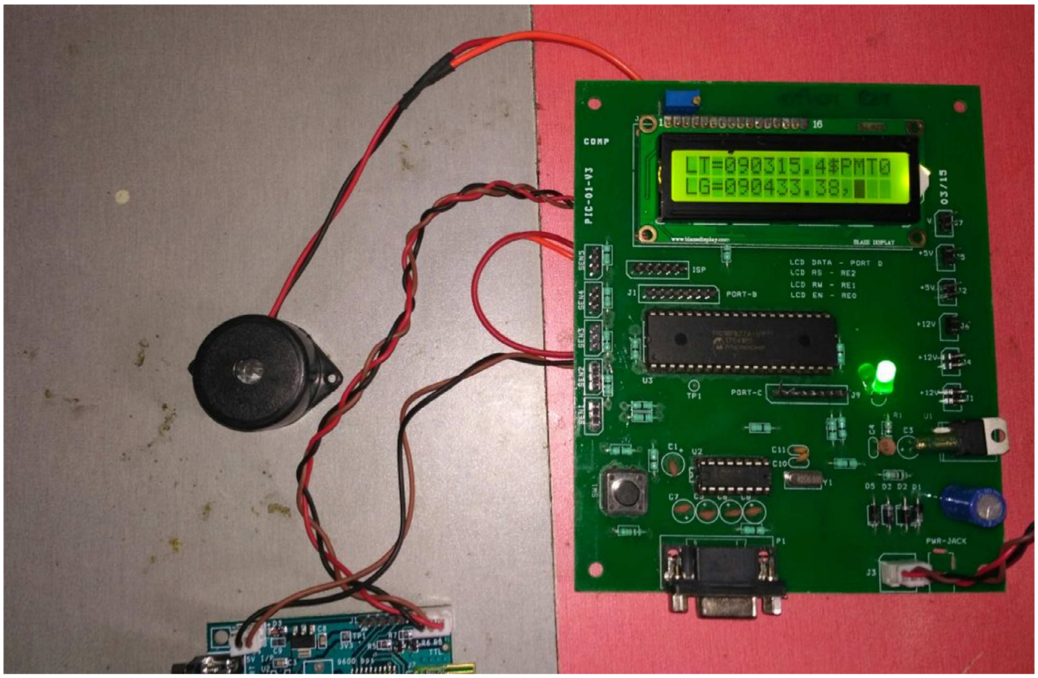

Fig 22 On occurrence of a crash and setting off of vibration sensor GPS coordinates are sent to the Road Side Unit, to trigger emergency services

As shown in Fig 23 all crash data is stored on a cloud server with the help of the IOT Module. Data analysis of these data sets will give us insight into what conditions caused the accident and what the hotspots for such accidental zones are, allowing us to make these areas less susceptible to accidents by making appropriate changes to its physical environment.

Date			
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,121906.083,V,,,	NA	NA	2018-03-29 05:49:19
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,121852.299,V,,,	NA	NA	2018-03-29 05:49:05
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,121838.300,V,,,	NA	NA	2018-03-29 05:48:51
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,121824.081,V,,,	NA	NA	2018-03-29 05:48:37
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,000524.559,V,,,	NA	NA	2018-03-29 05:48:24
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,000510.357,V,,,	NA	NA	2018-03-29 05:48:09
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,000456.357,V,,,	NA	NA	2018-03-29 05:47:55
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,000442.358,V,,,	NA	NA	2018-03-29 05:47:40
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,000428.358,V,,,	NA	NA	2018-03-29 05:47:28
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,000414.358,V,,,	NA	NA	2018-03-29 05:47:14
ACCIDENT_OCCURED.EMERGENCY.LOC=_MC,000359.800,V,,,	NA	NA	2018-03-29 05:46:59
ACCIDENT_OCCURED.CRASH_FRONT_END._EMERGENCY.LOC=_M	NA	NA	2018-03-29 05:46:44
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:46:29
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:46:24
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:46:18
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:46:14
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:46:10
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:46:05
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:46:01
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:56
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:53
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:47
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:43
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:38
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:34
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:29
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:25
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:21
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:15
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:11
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:06
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:45:03
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:44:58
DISTANCE_IS_023.6	NA	NA	2018-03-29 05:44:52

Fig 23 Crash data recorded on cloud server via IOT

The existing security measures in today's vehicles are just not sufficient to have a systematic and safe driving experience. The Table 1 tells us how our proposed system is a much more feasible and easily implementable alternative safety system we should adopt.

Existing system	**Proposed system**
There are no large scale Sensor Networks available to detect and rescue the accident. Cannot live track the vehicle until unless it is GPS enabled. Emergency services are time consuming and mostly depend on external entities to deploy them. There is no automated alerting system in vehicles of mediocre range. Possibilities for traffic collision is still relatively very high.	WSN are used to find the severity of accident. Solar energy can be used to power the on road sections. Automated system. Fast response. Easy to implement. Advanced collision avoidance is possible.

Table 1

The idea is to have a sufficiently large stable system that involves automobiles associated to one another on such a connected network to have a symbiotic relationship as seen in Fig 24 to warrant that roads would be a lot safer with having ample knowledge with regard to each individual vehicles immediate environment.

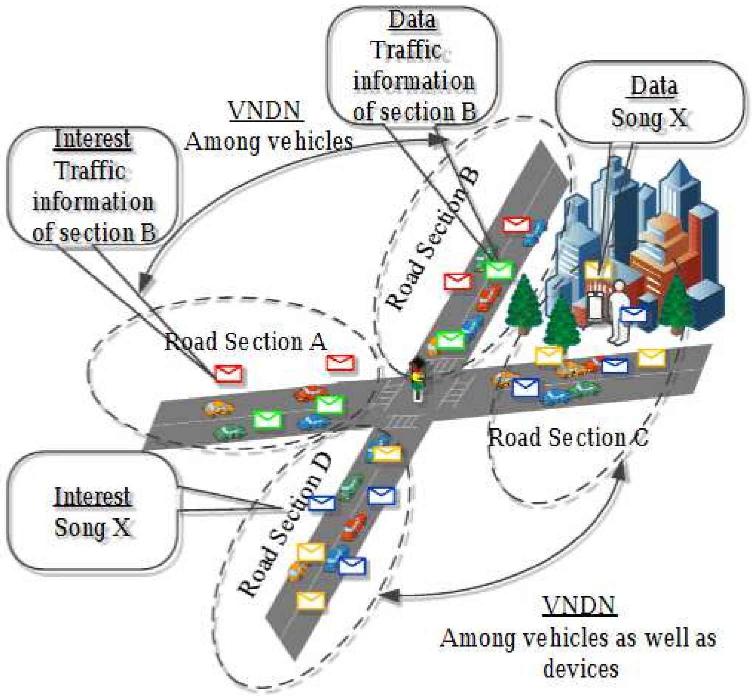

Fig 24 Large Scale Implementation of CV communication

4.2 SAMPLE CODE

CAR SECTION (ON BOARD UNIT)

```
#if defined(__PCM__6)
#include <16F877A.h>
#device adc=10
#fuses HS,NOWDT,NOPROTECT,NOLVP
#use DELAY(CLOCK=16000000)
#use rs232(baud=9600,xmit=PIN_C6,rcv=PIN_C7)

#BYTE oprg = 0x81
#BYTE tmr0 = 0x01


void lcd_init();
void comand(char c);
void sensors();
void lcd_disp();

char rx1(void);
void tx1(char);

char rx(void);
void tx(char);
char w,gps[80];
char tu[]="  ROAD SAFETY !";
char tl[]=" WITH V2V COMM!";
char ac[]="ACCIDENT OCCURED. !";
char es[]="EMERGENCY. ATTENTION REQUIRED. !";
char lc[]="LOCATION = !";
```

```
char dt[]="DISTANCE IS !";

char cf[]="CRASH-FRONT END. !";

char cr[]="CRASH-REAR END. !";

float a,v1,v2;

unsigned int i=0,st=0,j=0,check=0,cnt,v;

unsigned long int val,th,h,t,o;

unsigned long int dis=0;

float dis1=0,dist1,dist;

void main()

{

delay_ms(100);

output_bit(pin_a5,1);   //Buzzer

output_bit(pin_b2,1);   //Motor

output_bit(pin_e1,0);   //Read or Write

oprg=0x07;

delay_ms(100);

disable_interrupts(global);

setup_adc(ADC_CLOCK_INTERNAL);  //enables the a/d module  and sets the clock to internal
adc clock

setup_adc_ports(RA0_RA1_RA3_ANALOG );

delay_ms(250);

lcd_init();

for(i=0;tu[i]!='!';i++)

{

 comand(tu[i]);

 delay_ms(50);

}

output_bit(pin_e2,0);

comand(0xc0);

output_bit(pin_e2,1);
```

```
for(i=0;tl[i]!='!';i++)
{
 comand(tl[i]);
 delay_ms(50);
}

delay_ms(2000);

while(1)
{
sensors();

output_bit(pin_c0,1);
delay_us(10);
output_bit(pin_c0,0);

do
{

}
while(input(pin_c1)!=1);
tmr0=0x00;
do
{

}
while(input(pin_c1)!=0);
dis=tmr0;
dis1=dis;
//dis1=dis1/58.82;
dis1=dis1+1;
dist=(0.01718*dis1*62.5);
```

```
dist1=dist/2;
dist1=dist1-1;

if((v1>2.5)||(v2<2.5))
{
st=1;
output_bit(pin_b2,0);
}

else if((v1<2.5)&&(v2>2.5))
{
st=0;
output_bit(pin_b2,1);
}


if(st==1)
{
do
{
 w=rx();
}while(w!='$');
do
{
 w=rx();
}while(w!='R');

j=0;

do
{
w=rx();
```

```
gps[j]=w;
j++;
}while(w!='*');
gps[j]='*';
j++;
gps[j]='*';
delay_ms(100);

putc('*');
tx1('*');
delay_ms(150);

putc('A');
tx1('A');
delay_ms(150);


for(i=0;ac[i]!='!';i++)
{
 putc(ac[i]);
 tx1(ac[i]);
 delay_ms(150);
}


if(v1>2.5)
{
for(i=0;cf[i]!='!';i++)
{
 putc(cf[i]);
 tx1(cf[i]);
 delay_ms(150);
```

```
}
}

else if(v2<2.5)
{
for(i=0;cr[i]!='!';i++)
{
 putc(cr[i]);
 tx1(cr[i]);
 delay_ms(150);
}
}

putc('$');
delay_ms(150);


for(i=0;es[i]!='!';i++)
{
 putc(es[i]);
 tx1(es[i]);
 delay_ms(150);
}

for(i=0;lc[i]!='!';i++)
{
 putc(lc[i]);
 tx1(lc[i]);
 delay_ms(150);
}
putc('&');
delay_ms(150);
```

```
for(i=0;gps[i]!='*';i++)
{
 putc(gps[i]);
 tx1(gps[i]);
 delay_ms(150);
}

putc('#');
tx1('#');
delay_ms(150);

 output_bit(pin_a2,1);
  delay_ms(500);
  output_bit(pin_a2,0);
  delay_ms(500);

}

else if(st==0)
{
dist1=dist1*10;
val=dist1;
th=val/1000;
val=val%1000;
h=val/100;
val=val%100;
t=val/10;
o=val%10;
putc('*');
tx1('*');
delay_ms(150);
```

```
putc('D');
tx1('D');
delay_ms(150);
lcd_init();
comand(' ');
delay_ms(150);
for(i=0;dt[i]!='!';i++)
{
putc(dt[i]);
comand(dt[i]);
tx1(dt[i]);
delay_ms(150);
}
output_bit(pin_e2,0);
comand(0xc0);
output_bit(pin_e2,1);
comand(' ');
delay_ms(150);
comand(' ');
delay_ms(150);
comand(' ');
delay_ms(150);
putc(th+0x30);
tx1(th+0x30);
delay_ms(150);
putc(h+0x30);
tx1(h+0x30);
delay_ms(150);
putc(t+0x30);
tx1(t+0x30);
```

```
delay_ms(150);
putc('.');
tx1('.');
delay_ms(150);
putc(o+0x30);
tx1(o+0x30);
delay_ms(150);
putc('#');
tx1('#');
delay_ms(150);
}
}
}

void sensors()
{
set_adc_channel(0);
delay_ms(50);
a=read_adc();
delay_ms(10);
v1=a/204.6;
delay_ms(50);

set_adc_channel(1);
```

```
delay_ms(50);

a=read_adc();

delay_ms(10);

v2=a/204;

delay_ms(50);

}



void lcd_init()

{

output_bit(pin_e2,0);//register select - Control Register

delay_ms(10);

comand(0x01);     //Clear Display

delay_ms(1);

comand(0x06);     // Entry mode

comand(0x38);     // Function set

comand(0x80);     // Starting Address for 1 row

comand(0x0F);     // c on d on b on

output_bit(pin_e2,1);   //Data register

}

void comand(char c)

{

output_d(c);//d=data

output_bit(pin_e0,1);//enable to send data to LCD

delay_ms(1);

output_bit(pin_e0,0);

}
```

```
#use rs232(baud=9600,xmit=PIN_b6,rcv=PIN_b7,STOP=1,PARITY=N)
void tx(char ch)
{
putc(ch);
}

char rx(void)
{
 char rx_ch;
 rx_ch=getch();
 return(rx_ch);
}

#use rs232(baud=9600,xmit=PIN_b0,rcv=PIN_b1,STOP=1,PARITY=N)
void tx1(char ch1)
{
putc(ch1);
}

char rx1(void)
{
 char rx_ch1;
 rx_ch1=getch();
 return(rx_ch1);
}
```

SECOND CAR SECTION
(ON BOARD UNIT)

```
#if defined(__pcm__)

#include <16f877A.h>

#fuses HS,NOWDT,NOPROTECT,NOLVP

#use delay(clock=16000000)

#use rs232 (baud=9600,rcv=pin_c7,xmit=pin_c6)


char rx(void);

void tx(char);

char w;

void main()

{

delay_ms(500);

//tx('$');

delay_ms(500);

//output_bit(pin_b0,0);

//output_bit(pin_a0,0);

while(true)

{

//tx('$');

do

{

 w=rx();

 putc(w);

}

while(w!='R');

do

{

 w=rx();
```

```
}while(w!=',');
do
{
 w=rx();
}while(w!=',');

do
{
 w=rx();
 putc(w);
}while(w!='*');
putc('\n');
delay_ms(500);
}
}
#use rs232(baud=9600,xmit=PIN_b6,rcv=PIN_b7,STOP=1,PARITY=N)
void tx(char ch)
{
putc(ch);
}
char rx(void)
{
 char rx_ch;
 rx_ch=getch();
 return(rx_ch);
}
```

ROAD SIDE UNIT

```
#if defined(__pcm__)

#include <16f877A.h>

#fuses HS,NOWDT,NOPROTECT,NOLVP

#use delay(clock=16000000)

#use rs232 (baud=9600,rcv=pin_c7,xmit=pin_c6)

void lcd_init();

void comand(char c);

char rx(void);

void tx(char);

char w,msg[50],m,n[12],e[12];

unsigned int i=0;

char tu[]="  ROAD SAFETY !";

char tl[]=" WITH V2V COMM!";

char dt[]="   DISTANCE!";

void main()

{

delay_ms(500);

output_bit(pin_e1,0);   //Read or Write

delay_ms(500);

output_bit(pin_a5,1);

lcd_init();

for(i=0;tu[i]!='!';i++)

{

 comand(tu[i]);

 delay_ms(50);
```

```
}
output_bit(pin_e2,0);
comand(0xc0);
output_bit(pin_e2,1);
for(i=0;tl[i]!='!';i++)
{
 comand(tl[i]);
 delay_ms(50);
}

while(true)
{
do
{
 w=rx();
 putc(w);
}while(w!='*');

m=rx();

if(m=='D')
{
do
{
 w=rx();
}while(w!=' ');

 do
{
 w=rx();
}while(w!=' ');
```

```
i=0;
do
{
 w=rx();
 msg[i]=w;
 i++;
}while(w!='#');
lcd_init();
for(i=0;dt[i]!='!';i++)
{
 comand(dt[i]);
 delay_ms(50);
}
output_bit(pin_e2,0);
comand(0xc0);
output_bit(pin_e2,1);
comand(' ');
delay_ms(50);
comand(' ');
delay_ms(50);
comand(' ');
delay_ms(50);
for(i=0;i<6;i++)
{
 comand(msg[i]);
 delay_ms(50);
}
}

else if(m=='A')
```

```
{

do
{
 w=rx();
}while(w!=',');

do
{
 w=rx();
}while(w!=',');

i=0;
do
{
 w=rx();
 n[i]=w;
 i++;
}while(w!=',');
n[i]='*';

do
{
 w=rx();
}while(w!=',');

i=0;
do
{
 w=rx();
 e[i]=w;
 i++;
```

```
}while(w!=',');
e[i]='*';
output_bit(pin_a5,0);

lcd_init();
comand('L');
delay_ms(50);
comand('T');
delay_ms(50);
comand('=');
delay_ms(50);
for(i=0;n[i]!='*';i++)
{
comand(n[i]);
delay_ms(50);
}

output_bit(pin_e2,0);
comand(0xc0);
output_bit(pin_e2,1);

comand('L');
delay_ms(50);
comand('G');
delay_ms(50);
comand('=');
delay_ms(50);
for(i=0;e[i]!='*';i++)
{
comand(e[i]);
delay_ms(50);
```

```
}
}
}
}
#use rs232(baud=9600,xmit=PIN_b0,rcv=PIN_b1,STOP=1,PARITY=N)
void tx(char ch)
{
putc(ch);
}
char rx(void)
{
 char rx_ch;
 rx_ch=getch();
 return(rx_ch);
}

void lcd_init()
{
output_bit(pin_e2,0);//register select - Control Register
delay_ms(10);
comand(0x01);     //Clear Display
delay_ms(1);
comand(0x06);     // Entry mode
comand(0x38);     // Function set
comand(0x80);     // Starting Address for 1 row
comand(0x0F);     // c on d on b on
output_bit(pin_e2,1);   //Data register
}

void comand(char c)
```

```
{
output_d(c);//d=data
output_bit(pin_e0,1);//enable to send data to LCD
delay_ms(1);
output_bit(pin_e0,0);
}
```

CHAPTER 5

5.1 CONCLUSION

The emerging trend in roadway safety is not just to mitigate the effects of automobile accidents, but also to prevent their occurrence all together. This involves making vehicles and roadways smarter through a new generation of advanced electronics and communication systems, which are the pillars of next generation Intelligent Transportation Systems. The goal of next-generation V2V and V2I-based safety systems is to enhance drivers' situational awareness about their driving environment via the dissemination of proactive warning messages so that vehicles can take the proper action to avoid accidents and cascaded collisions, which typically occur when visibility is impeded. Motivated by this important safety concern, we have proposed a new road safety system allowing cooperative hazard awareness and avoidance CHAA.

For the past five years, both the US and European car manufacturers have been working on embedding Cooperative Intelligent Transport Systems (CITS) in their new vehicles. Japan has already deployed vehicles with V2I CITS capability. With over 85% of Australians cars being imported, vehicles with CITS capabilities can be expected on Australian roads soon after they are deployed internationally.

Following are some sample predictions from major auto- mobile manufacturers and technology companies regarding the increased levels of adoption of intelligent automation technologies and the booming of CV technology.

- 2017: U.S. DOT anticipates enacting a rule that mandates V2V technology in all new vehicles.
- 2017: General Motors intends to equip the Cadillac CTS with V2V technology.
- 2018: Nissan anticipates offering a feature that enables vehicles to autonomously maneuver on multi-lane high- ways.
- 2018: Google expects to release autonomous car technology on the market.
- 2020: Volvo envisions cars that make drivers and passengers immune from crash related injuries and fatalities

- 2020: General Motors, Mercedes-Benz, Audi, Nissan, BMW, Renault, Tesla and Google all expect to be selling vehicles (or enabling components in vehicles) that can drive themselves at least part of the time.
- 2024: Jaguar expects to release an autonomous car.
- 2025: Daimler and Ford expect autonomous vehicles on the market.
- 2025: Most new General Motors vehicles will have automated driving functions and V2V technology.

The above trends clearly show that CV technology will soon prevail from an early adoption stage to a diffusion phase that will eventually lead to ubiquitous deployment. This technology still in its budding stage has immense scope for development and will revolutionize the way the automotive sector functions as a whole proving to be another marvel in today’s world. We hope to move from an introductory phase of this technology to its maturity phase as soon as possible by being able to develop the on board units and installing them in older cars so there is room to install such a versatile security measure at a very small cost.

5.2 FUTURE WORK

The CV market is still in a budding stage and automotive enthusiasts suggest that the next few decades will see a lot of growth in this domain with the capital being invested in this sector to cross over 100 billion US dollars by the end of 2019. Our aim being, to make this technology a reality by helping people adopt CV and all its constituent technologies as early as possibly by incorporating them in existing vehicles at a marginal cost.

Our implementation could be advanced several fold to make it a truly usable technology in our world.

The SOS and On Road rescue sections could be made compliant with a solar panel so that each roadside unit is capable of functioning with little to no maintenance.

Having a more sensitive vibration sensor to tell us the severity of the accident based on the level of vibration as well as the displacement from the point of contact.

Consolidating all crash data and running analytics on these data sets to tell us about accident-prone areas will pave the path to grow more functionally safe roads.

Sensors to detect weather conditions could tell drivers how the vehicles should be driven for optimum efficiency and safety on road. These weather conditions can be relayed to other drivers entering a given area in real time giving them a choice to use alternative routes.

Every automotive manufacturer will invest a great deal in research and development towards connected vehicles in the coming future, the ideal situation for this technology to be globally accepted and to be integrated in our lives on a daily basis solely rest on the hope that all CV networks will be decentralized and work in compatibility with one another.

REFERENCES

[1] Shelly, G., Cashman, T., and Rosenblatt, H. (2001). Systems Data Analysis and Design. Boston, MA: Course Technology

[2] "Data fusion, ensemble and clustering to improve the classification accuracy for the severity of road traffic accidents in Korea," Safety Sci., vol. 41

[3] K.P. Sreevishakh, and S.P. Dhanure (2015) "A Review Paper on Automotive Crash Prediction and Notification Technologies" IEEE Paper

[4] Connected Vehicle Systems: Communication, Data, and Control by Yunpeng Wang Daxin Tian , Zhengguo Sheng , Wang Jian.

[5] Real-Time Detection and Estimation of Denial of Service Attack in Connected Vehicle Systems (February 2018) Zoleikha Abdollahi Biron ,Satadru Dey ,Pierluigi Pisu.

[6] Cellular communication of traffic signal state to connected vehicles for arterial eco-driving (2017) Grant Mahler ; Andreas Winckler ; Seyed Alireza Fayazi ; Martin Filusch ; Ardalan Vahidi

[7] A Primer on Driverless and Connected Vehicles. https://hillnotes.ca/2016/10/31/a-primer-on-driverless-and-connected-vehicles/

[8]Use of Big Data Technology in Vehicular Ad-hoc Networks https://www.researchgate.net/figure/VANET-Architecture-8_fig1_266148960

[9]Internet Of Vehicles: Layered Architecture, Network Model, Challenges and future aspects. https://www.researchgate.net/publication/306079546_Internet_of_Vehicles_Motivation_Layered_Architecture_Network_Model_Challenges_and_Future_Aspects

[10] Automotive Fleet Magazine http://www.automotive-fleet.com/channel/safety-accident-management/news/story/2017/11/ford-teams-with-telecom-firms-on-connected-vehicle-project.aspx