"A Low Cost Automated Accident Notification System: Design, Simulation and Experimental Results"

A Project Report

Submitted by

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B.Eng., Gujarat Technological University, 2012

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Abstract

The last decades have seen the appearance and development of new embedded systems and IoT devices to improve car safety, such as auto brake, lane alignment, airbag, collision warning to name a few. However, despite the availability of new safety focused features, we still cannot put a break on increase in the number of car crash resulting in deaths. One of the main reasons for high death rate is late medical response to crash site or insufficient treatment of victims due to lack of knowledge of victim's condition at the time of response.

National statistics clearly show that despite a growing wireless communication network and the availability of medical transport, the time to notify emergency personnel of a crash and respond to the crash victims can be quite lengthy. For fatal crashes in Canada, the average pre-hospital time is approximately 20 minutes in urban areas and 45 min to one hour in rural areas.

In this project, a new system was designed to notify the crash to health agencies and families via email, which is based on concepts of embedded system and IoT. There are several existing systems which also give the same results but the biggest asset of the proposed system is its ability for quick response with detail of seriousness of crash and image of the condition of victims in the car. Other features which similar system lack is the ability to communicate with each other. When we have lack of Internet due to no network on the phone or any other reason, systems of the crashed car will communicate with other systems in passing cars to relay the notification. In the project, two different kits were developed to work as two systems to test their performance and their ability to communicate with each other. The new system uses the hotspot feature of smartphone to provide Internet connection to send email when a crash occurs.

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List of Abbreviations

EMS	Emergency Medical Services
WHO	World Health Organization
CAGR	Compound Annual Growth Rate
UWB	Ultra-wideband
UN	United Nations
UNRSC	United Nations Road Safety Collaboration
GPS	Global Positioning System
GSM	Global System for Mobile communication
F_IR_1	IR sensor in Front of Car 1
F_IR_2	IR sensor in Front of Car 2
F_IR_3	IR sensor in Front of Car 3
S_IR_1	IR sensor in Side of Car 1
S_IR_2	IR sensor in Side of Car 2
S_IR_3	IR sensor in Side of Car 3
S_IR_4	IR sensor in Side of Car 4
S_IR_5	IR sensor in Side of Car 5
S_IR_6	IR sensor in Side of Car 6
B_IR	IR sensor in Back of Car
BC Transit	British Columbia Transit
IC	Integrated Circuit
Cm	Centimeter
ISP	Injury Severity Prediction
AV	Abnormal Vehicles
EWMs	Emergency Warning Messages

DSRC	Dedicated Short Range Communications
AACN	A low cost Automated Accident Notification system

List of Symbols

#	Number of X
%	Percentage
A	Excellent quality Vehicle
B	Very Good quality Vehicle
C	Good quality Vehicle
D	Acceptable quality Vehicle
E	Use with Caution quality Vehicle
F	Too Unreliable to be Published quality Vehicle

1. Introduction of Problem

1.1 Aim

The objective is to present the design of “A low cost Automated Accident Notification system (AACN)”, and the results of performance tests to date.

1.2 Motivation

The thought of designing the AACN because I wanted to design a system, which can be helpful in Post-Crash Response. The reason behind the thought was death toll due to delayed crash response and/or delayed notification of crash. Once the crash occurs, immediate notification of crash and/or on time crash response can play a significant role in whether the injury will result in fatality or not. Of course, due to advent of trauma centers, the fatality rate of persons reaching a hospital after a car crash has dropped dramatically over the last twenty years. Still, with these much advancement in technologies we have high death toll in Post-Car crash. According to the WHO 16 people out of 100, 000 people die due to fatal road traffic injury in North America. Globally rate is even higher reaching to 20 [3].

In 2015 alone, over 2500 crash victims died in the Canada before ever reaching the hospital and 11,000 got seriously injured [4]. Undoubtedly, some fraction of these deaths resulted from catastrophic crashes. However, many of these deaths can be attributed to the failure of Emergency Medical Services (EMS) personnel to reach the victim during the so-called “Golden Hour” after the accident when emergency medical treatment is most effective. National statistics clearly show that despite a growing wireless communications network and the availability of medical transport, the time to notify emergency personnel of a crash and respond to the crash victims can be quite lengthy. For fatal crashes in the Canada, the average pre-hospital time is approximately 20 minutes in urban areas and 45 min - 1 hour in rural areas. In report published by WHO, stats suggest that there has been no overall reduction in the number of people killed on the world's roads [3]. We have provided more detail about this in section 1.3.

Therefore, the AACN is the key to reduce the response time in Post car crash. We have 20 min response time in urban areas as mentioned above which we can reduce to 15 min but the response time in rural areas can be reduced dramatically by using AACN to 25 min depending situation. If we combine AACN with some existing system such as "Emergency Corridor Utilizing Vehicle to Vehicle communication" by Ford Global Technologies [24], we can reduce the response time even further around 12 min and 15-20 min for urban and rural respectively.

1.3 Problem Summary

According to WHO, road traffic crashes take the lives of nearly 1.3 million people every year, and injure 20–50 million more. Road traffic injuries have become the eighth leading cause of death for people aged 15–29 years [11, 12]. In addition to the grief and suffering they cause, road traffic crashes result in considerable economic losses to victims, their families, and nations as a whole, costing most countries 1–3% of their gross national product. Without action, road traffic crashes are predicted to result in the deaths of around 1.9 million people annually by 2020. Only 15% of countries have comprehensive laws relating to five key risks: speeding, drinking and driving, and the non-use of helmets, seat belts and child restraints. In 2004 survey, Road traffic Injuries is 9^{th} ranked for cause of death which will become 5^{th} ranked in 2030 [12]. It is a big cause for concern that even with modern technology we cannot control road traffic deaths [3].

Currently, emergency personnel must rely on passing motorists, highway patrol's, and traffic reporters to report crashes. Often the individual reporting the emergency may not know where he or she is, let alone be able to direct help to his or her location. These delays can be especially lengthy in rural, relatively unpopulated, areas where a crash site may go undetected for hours – and occasionally days.

Crucial to getting help to a crash victim is prompt notification that (a) a crash has occurred, (b) the location of the crash, and (c) some measure of the severity or injury-causing potential of the collision. A low cost Automated Accident Notification system (AACN) capable of performing many of these tasks have been installed as expensive options on a limited number of high-end luxury cars.

1.4 Detailed Problem Description

1.4.1 Number of Vehicle Registered

Vehicles	Canada	B.C.	N.L.	P.E.I.	N.S.	N.B.
Total vehicle registrations	**33,771,855**	**3,615,373**	**689,129**	**96,236**	**758,467**	**743,118**
Total road motor vehicle registrations	**24,269,868**	**3,130,526**	**390,574**	**82,473**	**636,986**	**584,533**
Vehicles weighing less than 4,500 kilograms	**22,410,030**	**2,901,758**	**361,096**	**74,795**	**595,895**	**538,760**
Vehicles weighing 4,500 kilograms to 14,999 kilograms	**590,023**	**113,244**	**7,045**	**1,692**	**10,971**	**8,589**
Vehicles weighing 15,000 kilograms or more	**462,908**	**42,356**	**5,411**	**2,624**	**9,485**	**12,479**
Buses	**90,643**	**9,838**	**1,468**	**314**	**2,041**	**3,421**
Motorcycles and mopeds	**716,264**	**63,330**	**15,554**	**3,048**	**18,594**	**21,284**
Trailers	**7,269,669**	**430,948**	**64,350**	**11,468**	**60,225**	**100,721**
Off-road[1], construction, farm vehicles	**2,232,318**	**53,899**	**234,205**	**2,295**	**61,256**	**57,864**

Table 1 Motor vehicle registration in Canada and Provinces (2016)

The number of vehicles registered in Canada for year of 2016 is shown in Table 1[1]. These data show that the total number of vehicles increased from 17 million in 2000 to 20.5 million in 2009. This represents an annual average growth rate of about 2% and overall growth of 19.1%. In 2016 total number of vehicles increased to approx. 34 million. That is double than number of vehicles in 2000. Therefore, from 2000-2016 we have almost 100% growth in vehicles. Which means we have almost 81% growth from 2000 in last 7 years compare to 19.1% in 9 years.

However, these numbers are probably overestimates as personal vehicle owners register their vehicles and pay the road tax once when they buy the vehicle and are not required to pay an annual tax. Because of this, a large number of vehicles remain on the official record even when they are not in use any more.

1.4.2 History of Accident in Canada

Table 2 [4] shows the number of road traffic deaths and injuries from 1996 to 2015. We have two sections: Collison and Victims of Collison. In Collision, we have Personal Injuries and fatal injuries (Leads to death) of people involved in collision and number of deaths as we mentioned above. We have also presented the serious injuries of the victims of the crash. We can see from the table that the total number of deaths has decreased in the period 1996-201, but it remained same around 2000 after 2010. Traffic deaths has been taken as an indicator of the health burden of road traffic crashes on society at the city, regional, or national level. At the individual level, what is of consequence is the risk of injury per trip, and the total number of trips is proportionate to the population. Therefore, traffic deaths per unit population can be taken as a rough indicator of risk faced by individuals. The risk of being involved in a fatal road traffic crash has obviously been increasing for Canadian citizens over the past few years. While some of this increase can be attributed to increase in the number of motor vehicles per capita in Canada. However, increasing vehicle ownership need not result in higher death rates, if we implement adequate safety measures.

Year	Collisions		Victims		
	Fatal	Personal Injury	Deaths	Serious Injuries	Injuries(Total)
1996	2740	153,944	3,129	18,734	227283
1997	2660	147,549	3,076	17,294	217401
1998	2583	145,615	2,919	16,410	213319
1999	2632	148,683	2,980	16,187	218457
2000	2548	153,290	2,904	15,581	222,848
2001	2415	149,023	2,758	15,296	216,542
2002	2583	153,832	2,921	15,894	222,665
2003	2487	150,493	2,777	15,110	216,123
2004	2438	145,150	2,735	15,572	206,104
2005	2551	145,559	2,989	15,792	204,701
2006	2586	142,517	2,971	16,044	199,976
2007	2455	138,615	2,753	14,410	192,745
2008	2193	127,571	2,431	12,851	176,394
2009	2007	123,449	2,216	11,955	170,770
2010	2021	123,615	2,238	11,796	172,081
2011	1849	122,350	2,023	10,940	167,741
2012	1837	122,663	2,079	11,087	166,479
2013	1731	120,370	1,954	10,663	164,493
2014	1709	113,782	1,852	10,397	155,312
2015	1669	116,735	1,858	10,280	161,902

Table 2 Road traffic deaths in Canada

Road User Class	2011	2012	2013	2014	2015
# Drivers	1023	1025	964	924	925
%Drivers	50.6	49.3	49.3	49.9	49.8
#Passengers	401	457	369	352	360
%Passengers	19.8	22	18.9	19	19.4
#Pedestrians	321	326	306	301	283
%Pedestrians	15.9	15.7	15.7	16.3	15.2
#Bicyclists	57	63	69	42	47
%Bicyclists	2.8	3	3.5	2.3	2.5
#Motorcyclists	175	175	198	190	200
%Motorcyclists	8.7	8.4	10.1	10.3	10.8
#Not states/other	46	33	48	43	43
%Not states/other	2.3	1.6	2.5	2.3	2.3
#Total	2023	2079	1954	1852	1858
%Total	100	100	100	100	100

Table 3 Traffic deaths by category of road user in Canada (2011-2015)

Table 3 [4] shows traffic deaths by category of road users in Canada. These data show that car occupants are a big proportion of the total deaths almost 70%. Vulnerable road users (pedestrians, bicyclists, and motorized two-wheeler riders) accounted for 30% of deaths. This pattern is very different from that obtained in low-income countries. The high proportion of car occupancy is due to the high level of car ownership at 50 per 100 persons compared to than 15 per 100 persons in low-income countries [3]. From Table 1 we can predict that car users are likely to remain the dominant in vehicle ownership in Canada for the next few decades. We can control the incidence of road traffic deaths in the coming years, if road safety policies put a special focus on the safety of vulnerable road users and car users. The probability of pedestrian death is estimated at less than 10% at impact speeds of 30 km/h and greater than 80% at 60 km/h, and the relationship between increase in deaths and increase in impact velocities is governed by a power of four [4]. Small increases in urban speeds can increase death rates dramatically.

Figure 1 [4] shows number of collisions by location. From the results we can conclude, rural areas have more fatal injuries means we have more deaths as crash result while urban areas have injuries that are more personal so the death rate is less in cities.

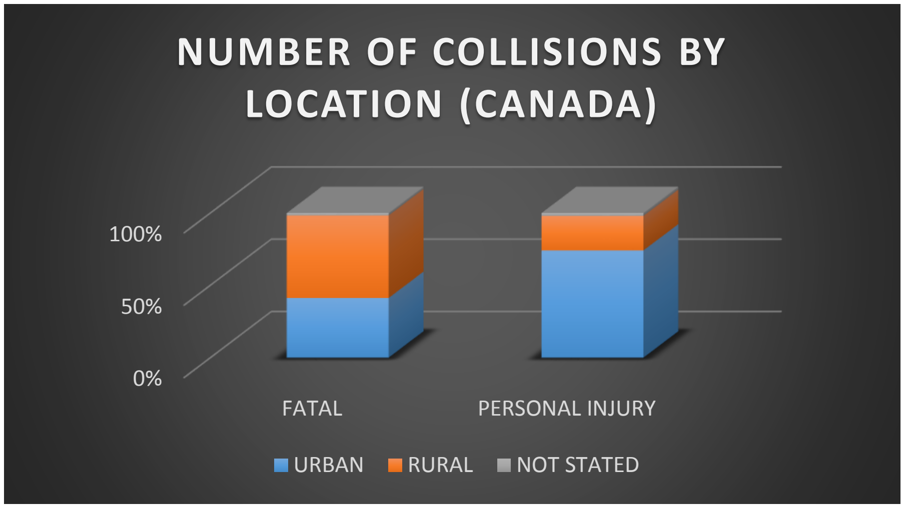


Figure 1 NUMBER OF COLLISIONS BY LOCATION (2015)

Figure 2 [4] and 3 [4] shows the fatality rates (Injury which leads to death) for provinces of Canada with respect to avg. injury and fatality rate in Canada for the year of 2015 per 100,000 population. Manitoba has the highest injuries while Prince Edward Island has highest deaths. Yukon and Saskatchewan have second highest deaths. Populated province like Ontario and Quebec has less injury and fatality rate than other less populated provinces. From fig 1 and 2 we can confirm our prediction that isolated/rural areas have higher response time for medical help, which can be one the cause for more deaths.

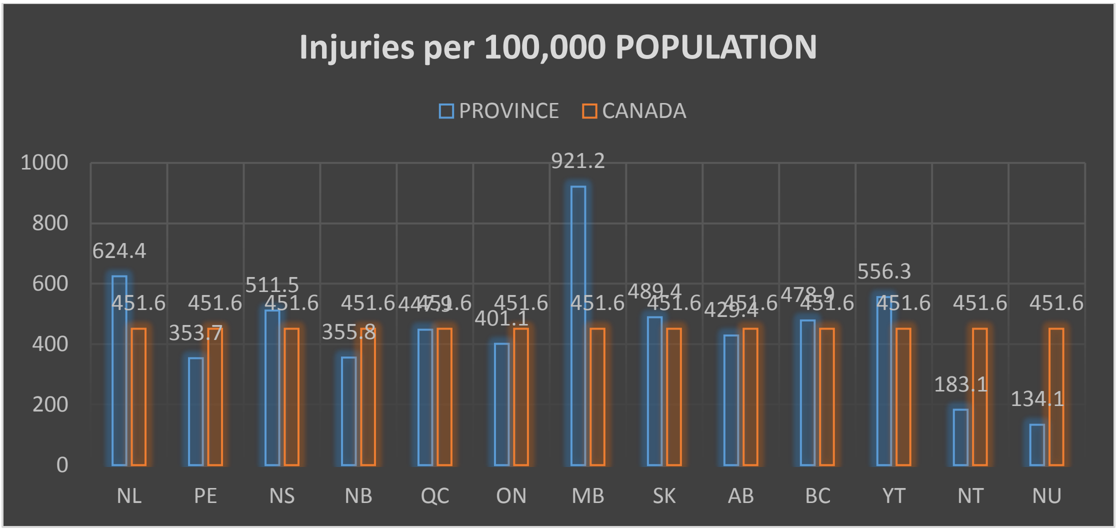


Figure 2 Injuries in 2015 by Province (Canada)

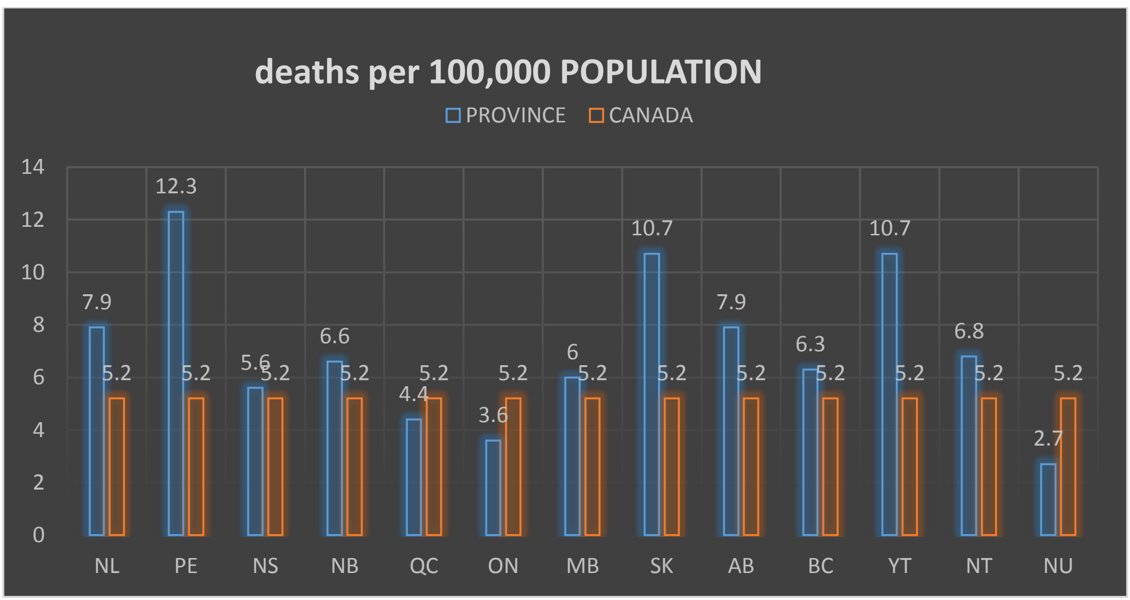
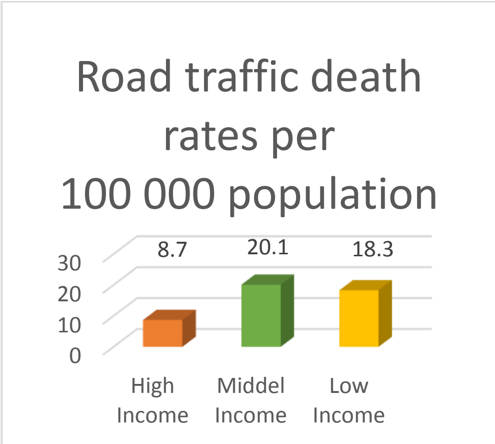


Figure 3 Deaths in 2015 by Province (Canada)

1.4.3 History of Accident in World



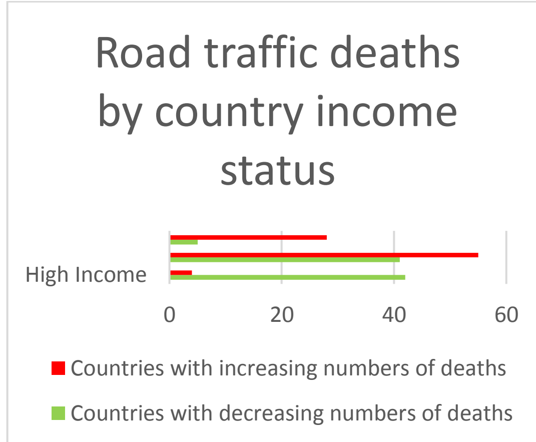


Figure 4 Road traffic death Rates Per 100 000 population, By Country Income status

Figure 5 Countries with changes in numbers of road traffic deaths (2007–2010), by country income status

In Fig 4 [13] and Fig 5 [13] we have plotted number of deaths based on income of the country. We can see that Middle-Income country has the most number of deaths, which is natural as it covers almost 70% of world population. In figure 5 we have classified the number of countries which has shown increase and decrease in the number of road traffic deaths over period of 2007 to 2010. 88 countries have shown decrease in the number of deaths while 87 countries have shown increase in number of deaths.

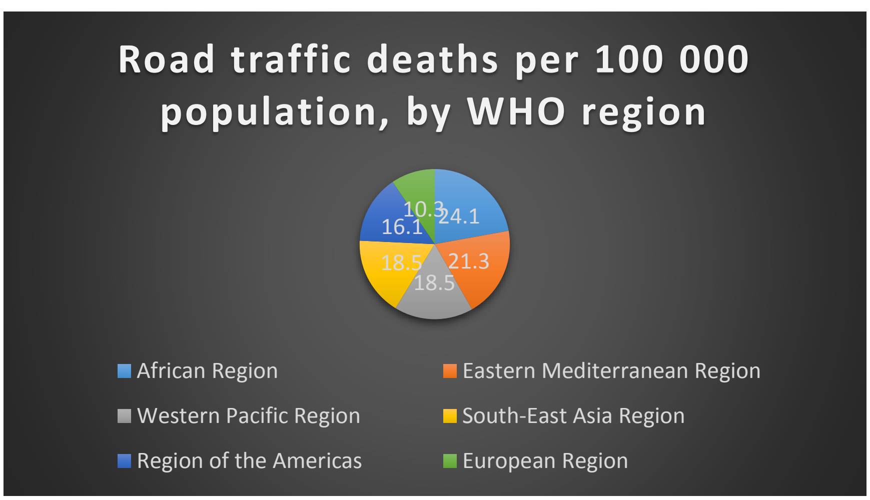


Figure 6 Road traffic deaths per 100 000 population, by WHO region

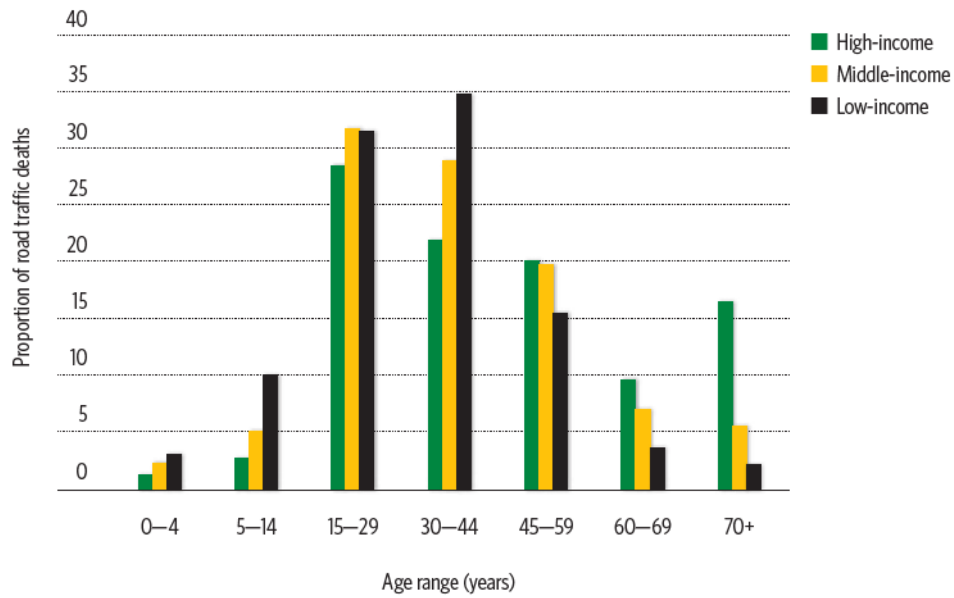


Figure 7 Proportion of road traffic deaths by age range and country income status (Copied from [13])

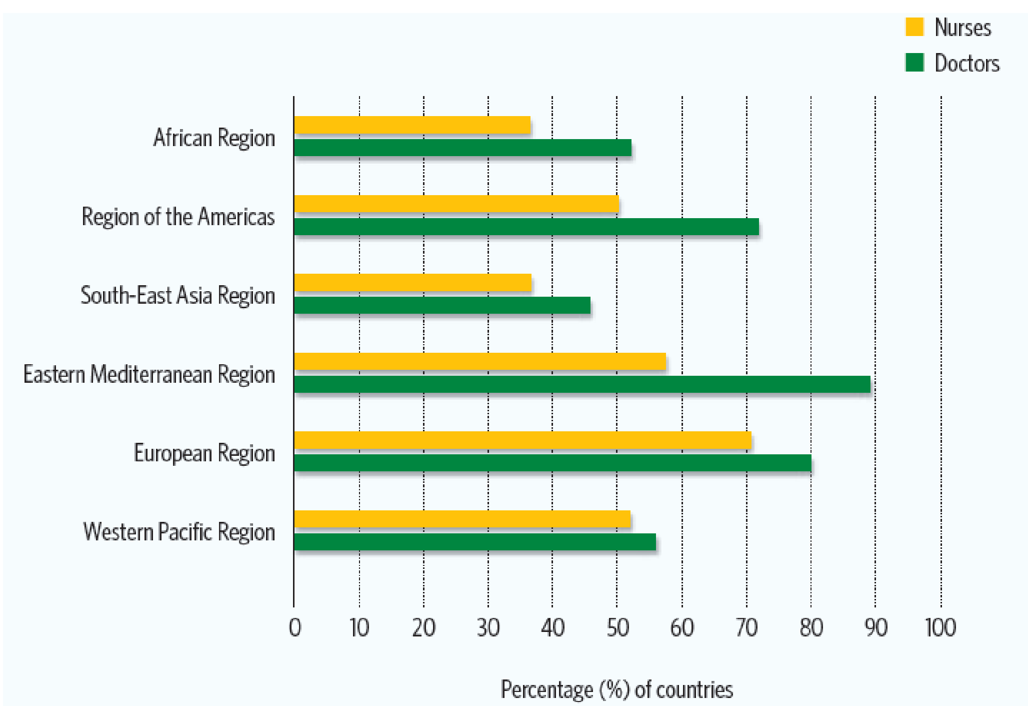


Figure 8 Proportion of countries providing access to emergency medical training for doctors and nurses, by WHO region (Copied from [13])

In Fig 6 [13] we have classified number of road traffic deaths per 100,000 population based on WHO regions. Africa region has most number of deaths 24.1 and European region has least number of deaths 10.3 In Fig 7 [13], we have presented proportion of road traffic deaths by age based on income of the country. We can safely say that youth is backbone and future of the society. We can conclude from Fig 7 that age group of 15-29 and 30-44, in other word youth has most number of deaths, which can be a major factor in future shaping of the society. This leads us to the problem, which is loss of future generation and economical loss. The other major factor is shortage of medical trained personal. In many cases, an important factor related to outcome of patient following a road traffic crash is the quality of care received from hospital staff. Figure 8 [13] shows number of trained doctors and nurses. In countries based in American Region average number of nurse versus required is around 50% and number of doctors is around 70%. From Fig 8 we can say that number of nurses is as low as 40% and as high as 70%, and number of doctors is as low as 45% and as high as 90%. We can say that the difference between high and low for trained nurses and doctors is very high in both cases.

2. Introduction of Project

2.1 Objectives

UN has started “DECADE OF ACTION FOR ROAD SAFTETY 2011-2020” lead by WHO, following successful Global Ministerial Conference on Road Safety hosted by the Russian Government. They have predicted that if we don’t take proper measurement to reduce road traffic crashes by 2020 the loss of human life will be around 2 million annually. Out of which around 70% of them will be vehicle owners including motorcyclist. According to the WHO 16 people out of 100, 000 people die due to fatal road traffic injury. Globally rate is even higher reaching to 20.

The United Nations Road Safety Collaboration (UNRSC) and stakeholders from around the world developed “DECADE OF ACTION FOR ROAD SAFTETY 2011-2020”. It is divided in five Pillars.

1. **Pillar1** is based on “Road Safety management”. In this pillar, emphasis is given on strengthening of institutional capacity to further national road safety efforts.
2. **Pillar 2** is based on “Safer roads and mobility”. Improvement of the safety of road networks for the benefit of all road users, especially the most vulnerable: pedestrians, bicyclists and motorcyclists is the focus of this pillar.
3. **Pillar 3** is based on “Safer vehicles”. Harmonization of relevant global standards and mechanisms to accelerate the uptake of new technologies, which influence the vehicle safety, is the highlight of this pillar.
4. **Pillar 4** is based on “Safer road users”. This pillar focuses on developing comprehensive programs to improve road user behavior. Organizing activities to spread public awareness and education to increase seatbelt and helmet wearing and to reduce drinking and driving, speeding and other risks.
5. **Pillar 5** is based on “Post-crash response”. This pillar promotes the improvement of health and other systems to provide appropriate emergency treatment and longer-term rehabilitation for crash victims.

According to WHO if this ambitious target is achieved, a cumulative total of 5 million lives, 50 million serious injuries and US$ 5 trillion could be saved over the Decade.

This inspired me and I came with an approach for my paper. My idea revolved around **Pillar 5**. It started with me trying to find a way to decrease the number of deaths by helping health/other medical systems to determine a degree of injury.

A number of technological and sociological improvements have helped reduce traffic deaths during the past decade, e.g., in 2015 around 35 people died due to not using seat belt [4]. This is the one of the reason for introduction of **Pillar 4.** Crash analysis studies have shown that approximately 34% of fatal traffic accidents could have been prevented with the use of electronic stability control [5], which is the goal behind **Pillar 3**. Moreover, each minute that an injured crash victim does not receive emergency medical care can make a large difference in their survival rate, e.g., analysis shows that reducing accident response time by 1 min correlates to a six percent difference in the number of lives saved [6]. Which is the overall goal of **Pillar 5** and our project.

An efficient way of reducing traffic deaths is to reduce the time between a crash and first response, such as medical personnel, are dispatched to the scene of the accident. Automatic collision notification systems use sensors as base embedded in a car to determine when an accident has occurred [7, 8]. Emergency personnel are dispatched based on the signal from these systems. Eliminating the time between accident occurrence and first responder dispatch reduces deaths by 6% [8].

To remove the reliability on conventional modules like GSM we can use smartphones. Smartphones, such as the iPhone and Google Android, have become common and their usage is rapidly increasing. In the 2017, approx. 2.32 billion people had smartphones and it is predicted that 2.87 billion people will have smartphones by 2020 [9]. This large and growing base of smartphone users presents a significant opportunity to extend the reach of automatic accident reporting systems. Moreover, smartphones are widely used by the teenage demographic, which is historically the most accident-prone driver age group.

The low cost of smartphones compared to other traffic analysis and accident prediction systems makes them an appealing alternative to in-vehicle accident detection and reporting systems [10]. Moreover, smartphones travel with their owners, providing accident detection regardless of whether or not the vehicle is equipped with an accident detection and notification system. Furthermore, because each smartphone is associated with its owner, automatic notification systems built on smartphones can aid in the identification of victims and determining what electronic medical records to obtain before victims arrive at the hospital.

Another key smartphone attribute for accident notification is that they provide a variety of network interfaces for relaying information back to centralized emergency response centers, such as 911 call centers. We can use smartphones as base for communicating medium. We can send an email or upload location of the crash to a server. Health agencies and family members can have access to that. We can also generalize the zone prone to accidents and develop and app or notify via government agencies when you enter the zone. Smartphones also include hotspot wireless interfaces that can communicate directly with the onboard computers in many newer cars.

This paper shows how the sensors and smartphones can be used to overcome the challenges of detecting traffic accidents. I came up with an approach for using smartphones as network provider when a vehicle and its occupants experience a crash we will provide AACN, which contains accident detection system, and automatic emergency notification mechanism. The approach detailed in this paper uses the different sensors to detect a crash, Arduino Mega as a base system, Raspberry Pi 3 to send Email and to provide hotspot connection from the Smartphone. When we don’t have network on the smart phone, we can use Wi-Fi Cheap /Bluetooth/ZigBee to communicate with other kit in the passing car and send the Email using the other Kit by using chain communication technique. The idea behind the paper is to find best device to use for the system.

2.2 Related Work

One of the earliest work on auto crash notification system [14,15] uses components like GSM, GPS and sensors to detect crash and send the GPS location via message using GSM module to relative agencies. In [19,20] in event of accident detection e-call is placed. In [20], we have a system that gathers vehicle data and sends it to a centralized database in case of an accident. Upon a trigger signal the accident is detected though one or several sensors located in the vehicle. In [19] in system uses an accelerometer to detect crash. In [22] author have used accelerometer like [19] but uses Bluetooth module to communicate with mobile app to send message and instead of E-call. In [23] system uses the in-built vibration sensor, the GPS, ZigBee to send an alert message to the emergency numbers pertaining to the location of the accident by searching the database. In [16] author have used wi-fi module to communicate with web server instead of ZigBee used in [23]. In [21,25] author have developed an application for accident detection. It uses the in-built car sensor. This can decrease the accuracy of crash detection. In [14-16,19-23] authors have designed systems to detect the crash using different devices/methods like Bluetooth, ZigBee, Wi-Fi, Mobile Application but no one has really focused on the action when we have possibility of no network condition. In [17] the author works around the possibility of drivers and vehicles communicate with each other and with roadside base station. We have focused on part where author presents three devices Bluetooth, ZigBee and UWB for that. Which can be helpful to pass the relay the message to other cars. In [18] author works on principle of relaying emergency warning messages (EWMs) using DSRC in case of emergency or similar situations. When a vehicle becomes Abnormal Vehicle(AV) it generates EWMs and receiver of the EWMs can determines the relevancy of the emergency based on their location. This can prevent accident and/or other vehicles becoming AVs.

2.3 Project Outline

The outline of the project report is as follows: Chapter 1 covers the Introduction to the problem and detail of crash reports in Canada as well as globally. Chapter 2 covers the review of the AACN and motivation behind the project. Chapter 3 explains the operating principle of auto crash notification, components used and assumptions made to perform the project. Chapter 3 contains the AACN design. In Chapter 4 has experimental results is discussed and analyzed. Chapter 5 gives the conclusion and suggestions for future work.

3. Introduction of System

3.1 Introduction of Auto Crash Notification System

In order to contribute in **"Pillar 5: Post-crash response",** I had to come up with a system which can produce "An automated response" after crash occurs.

In 2.2 we have reviewed various systems which provides the automated crash response. In all the systems we have reviewed main idea is to detect the crash and report it via some device. But no report talks about what happens if that device is not able to use service provider or it is a dead zone for service provider. Our paper also focuses on detecting crash and notify authorities about it, but it also focuses on communicating with other cars in case we have dead zone for service provider and relay the notification of the crash to other cars so they can send the notification if they have the service or relay it to other cars until it is delivered. After reviewing different systems, I decided to use a paper by Gregory S. Bickel "Inter/Intra Vehicle Wireless Communication". In this paper author talks about the possibility of drivers and vehicles communicate with each other and with roadside base station. It presents three devices Bluetooth, ZigBee and Wi-Fi (UWB) for communication. It gave me the idea of possibility of the relay of communication chain between passing vehicles on the road. After that, the main thing to decide was which device will be most effective for communicating between vehicles. Therefore, I decided to use all three devices Bluetooth, ZigBee and Wi-Fi (UWB) and have them compared to find the best one.

To design an AACN first we had to figure out what method/device can be used for crash detection. In 2.2 I have analyzed different sensors used for different systems and based on that I decided to use Analog sensors. The reason behind the choice was analog sensors are cheap, easy to replace and easy to install at desired location. Second was deciding a base device to communicate with system components. I decided to use Arduino Mega 2560 Rev3, and the reason is that I have worked on Arduino Mega 2560 before, the other thing is we need to communicate with 4 devices and it has 4 ports to communicate with them. Also communicating with Mega is easy for analog sensors. We will use GPS to acquire Location. The other major device was device we will use for sending Location and Image. Conventional GSM is not that reliable and as we have discussed in 2.1 the number of smartphone users are increasing so we decided to use Raspberry Pi 3 with Camera and send an Email instead of Text/MMS because it is much more safer and cannot be easily compromised by DOS Attack. Camera in Pi 3 will take a pic of crash and send it with the E-mail so medical personal can have better understating of medical aid required for crash. We also decided to put an Emergency switch just in case of other critical medical conditions like Heart attack. Car user will just have to press the switch and email will be sent with Image and Location of Car with message saying critical medical condition. Therefore, AACN contains Sensors, GPS, Camera, Emergency Switch, Bluetooth, Wi-Fi chip, ZigBee, Raspberry Pi 3 and Arduino Mega.

We have used different sensors for different purpose. The list of sensors used is, IR Sensor, Fire Sensor, Smoke Sensor, Proximity Sensor and Motion Sensor. We have mainly emphasized on IR sensor. We place IR sensor at different locations in car [4.2] and based on breach of sensor and its location we generate response. We can use Glass + Switch sensor instead of IR sensor if need to be. In 3.1.1, we have provided the link to datasheet and detailed working and specifications of components.

3.1.1 Components

1. **Raspberry Pi 3 Model B with Camera**: Microprocessor used Quad Core 1.2GHz Broadcom BCM2837 64bit CPU with camera
   https://www.raspberrypi.org/products/raspberry-pi-3-model-b-plus/
2. **Arduino Mega:** Microcontroller Used ATMega2560
   https://store.arduino.cc/usa/arduino-mega-2560-rev3
3. **ZigBee**: XBee Pro 60mW Wire Antenna - Series 1 802.15.4
   https://www.sparkfun.com/products/8742
4. **Bluetooth:** HC-05 Wireless Bluetooth Host Serial Transceiver Module Slave and Master RS232 for Arduino

http://www.electronicaestudio.com/docs/istd016A.pdf

https://cdn.makezine.com/uploads/2014/03/hc_hc-05-user-instructions-bluetooth.pdf

5. **GPS:** Invento GPS U-Blox Neo-6M Module Aircraft Flight Controller For Arduino Mwc Imu Apm2

   https://www.u-blox.com/sites/default/files/products/documents/NEO-6_DataSheet_(GPS.G6-HW-09005).pdf

6. **Wi-Fi chip :** Wi-Fi Module - ESP8266

   https://www.sparkfun.com/products/13678

7. **Smoke Sensor:** Smoke Detection using MQ-2 Gas Sensor

   https://www.pololu.com/file/0J309/MQ2.pdf

   https://www.mouser.com/ds/2/321/605-00008-MQ-2-Datasheet-370464.pdf

8. **Motion Sensor**: HC-Sr501

   https://www.mpja.com/download/31227sc.pdf

   https://www.allelectronics.com/mas_assets/theme/allelectronics/spec/PIR-7.pdf

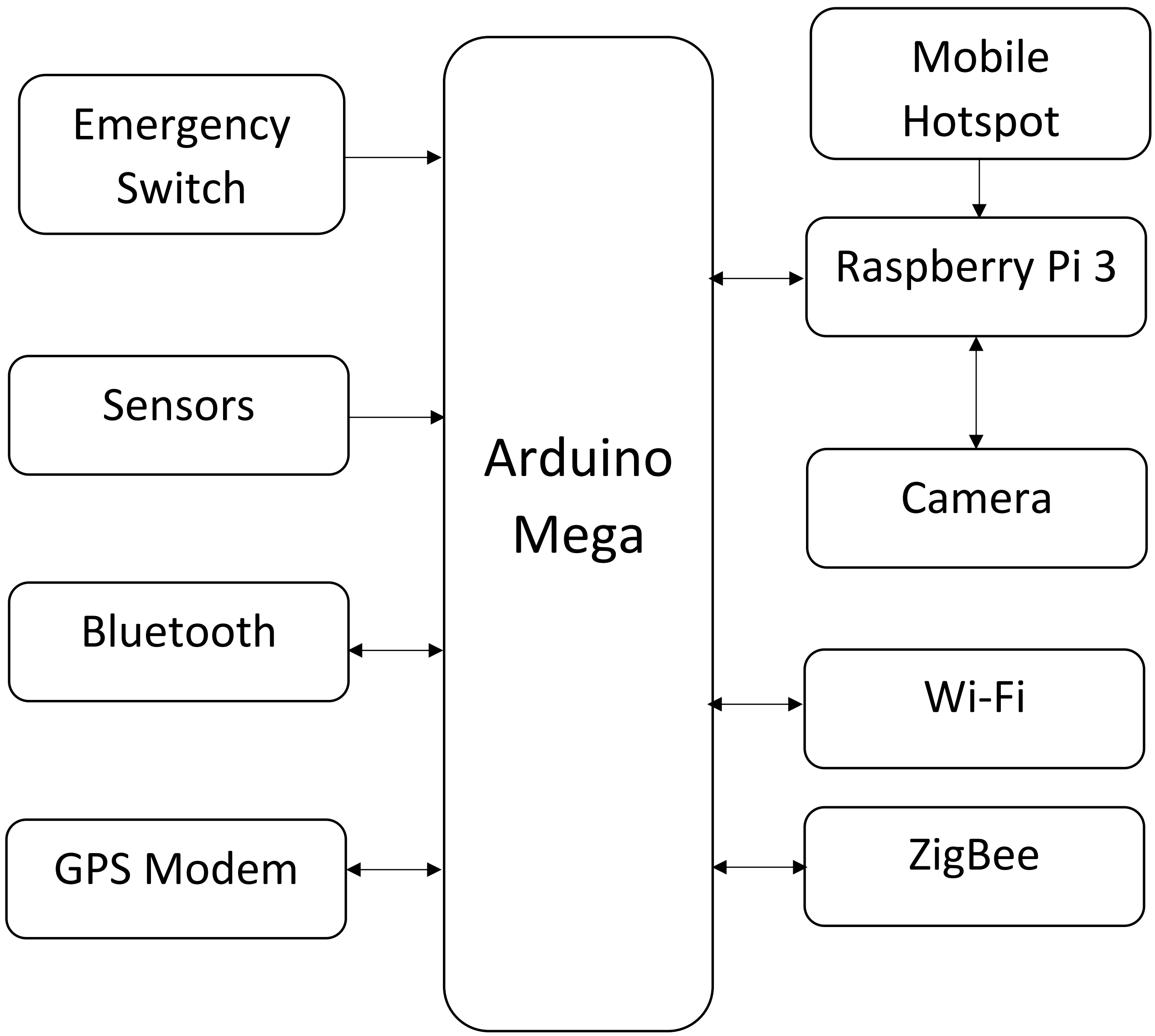
9. **Proximity Sensor:** NPN NO Type

   https://www.schneider-electric.com.hk/documents/energy-efficiency-cup/Inductive-proximity-sensors.pdf

10. **Fire Sensor and IR sensor:** LM358 IC

    http://www.ti.com/lit/ds/symlink/lm158-n.pdf

3.2 Top View of Block Diagram of AACN



In 3.1 I have discussed how I decided which components to use for the system. In this section, we have presented a top view of block diagram; it shows which component work as input and which one work as output. Sensors, GPS Modem, Smart Phone and Emergency Switch work as Input. Arduino Mega work as base system. Raspberry Pi 3, Bluetooth, Wi-Fi and ZigBee work as output.

3.3 Algorithm for AACN

Algorithm used for designing of the AACN is

Step 1: Start.

Step 2: Wait until GPS, Arduino Mega, Raspberry Pi 3, Camera and Sensors are ready

Step 3: Wait for mobile hotspot connection to Wi-Fi of the system.

Step 4: Wait for breach on sensor/s or Emergency switch use.

Step 5: Arduino Mega send Command to GPS and Camera via Raspberry Pi 3

Step 6: GPS take longitude and latitude, Camera take a photo

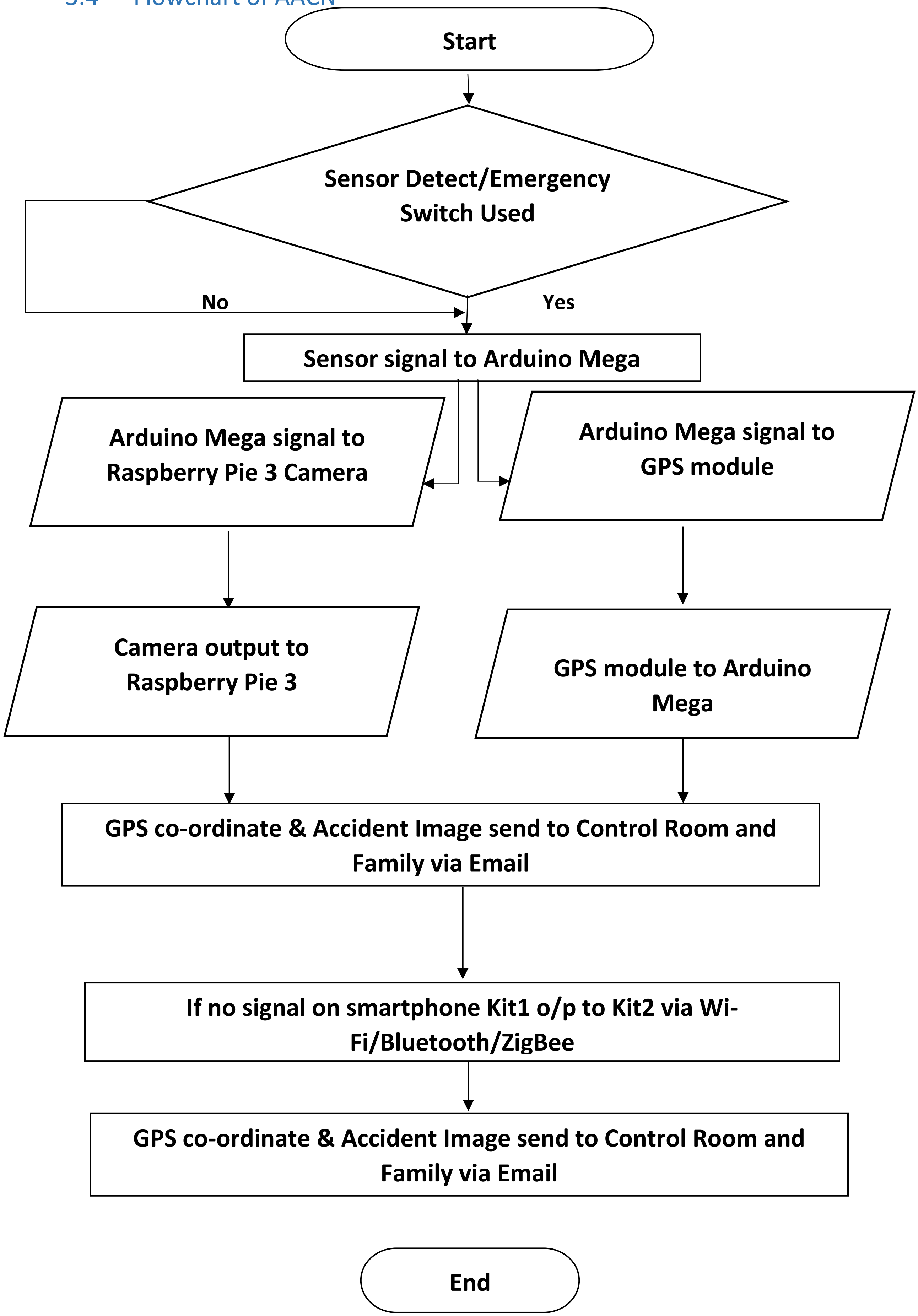
Step 7: Longitude and latitude and pic is send by email

Step 8: If we don't have internet/signal we wait for other car to pass and kit1 will send location and pic to kit 2 via ZigBee/Bluetooth/UWB which ever gets accessed first and Kit2 will send the email, if no signal on kit 2 it will pass the o/p to kit 3 and so on.

Step 9: Wait for next breach on sensor/s or Emergency switch use.

Based on the algorithm we have designed a flowchart [3.5] for the system.

3.4 Flowchart of AACN



3.5 Specification of Devices

	Bluetooth	ZigBee	UWB
Range	10 m	10 m	< 10 m
Data Rate	Medium	Low	High
Throughput	Medium	Low	High
Interference	Good	Good	Excellent
Media	Voice/Data	Data	Video/Radar
SIG	Consortium	Alliance	Forum
Main Layers	5	5	Evolving
Data Payload	2744	104	Evolving
Power Requirement	Low	Very-Low	Ultra-Low
Tx Power	1 mW	< 1 mW	200 uW
Security	Good	Good	Excellent
Installed Base	Very Large	Small	Small
Tx Penetration	Good	Good	Excellent
Spec Stability	Excellent	Good	Evolving
Mode	FHSS	DSSS	DS, MBOA
Frequency	2.4 GHz	0.8,0.9, 2.4 GHz	3.1-10.6 GHz
Channels	23 or 79	1,10 or 16	Evolving
Error Correct	8-bit, 16-bit	16CRC	Evolving
Topology	Star	Star, Mesh	Peer to Peer
No. of Nodes	7, or more	65534	Evolving
Link BW	1 MHz	20-250 KHz	120Mhz-1GHz

Table 4 Theoretical Comparison Of Devices [27]

4. System Design

4.1 Circuit Diagram of AACN

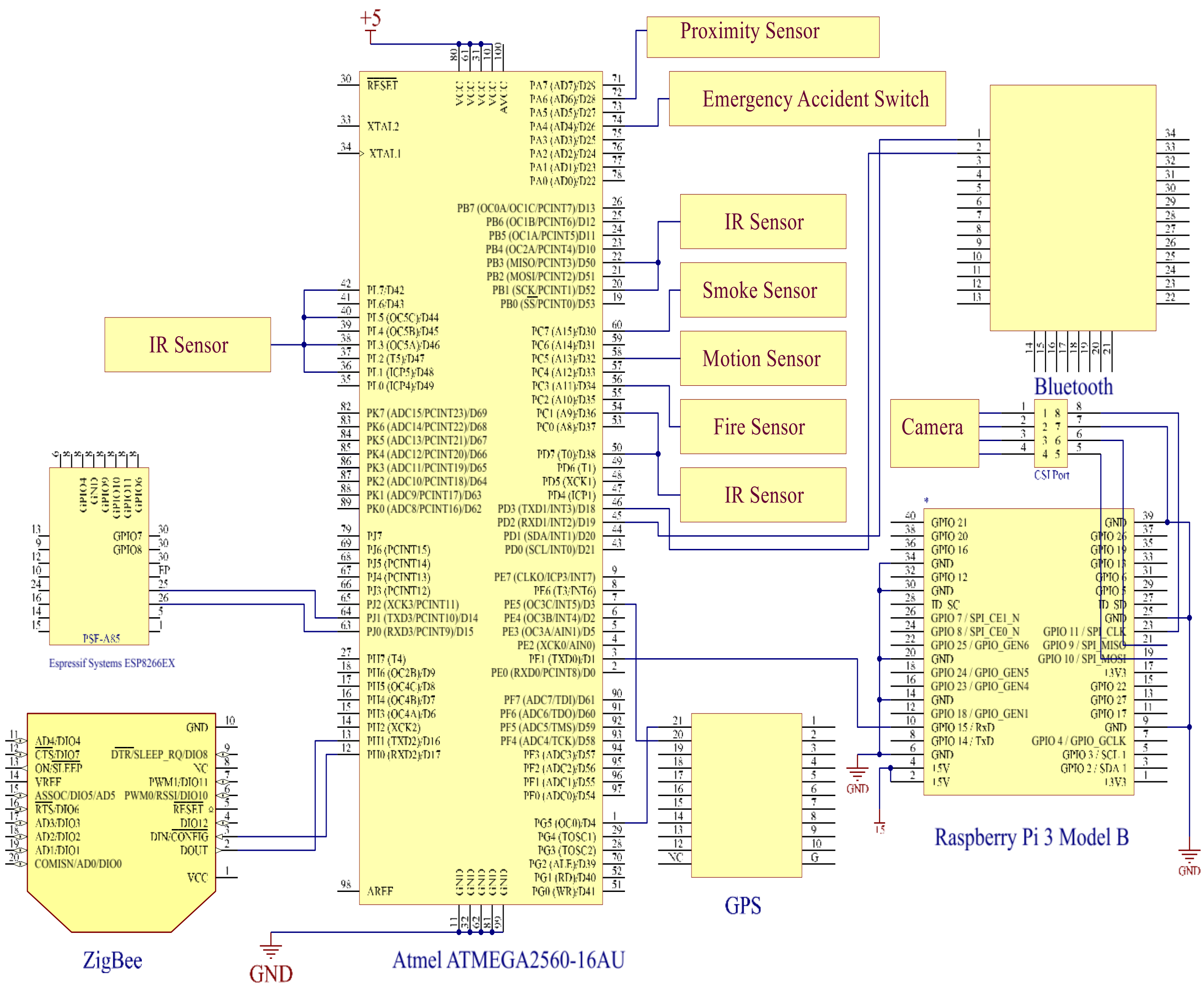
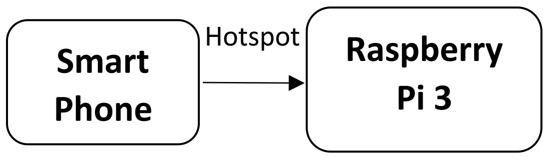


Figure 9 Circuit Diagram of AACN

In 4.1 we have presented electrical circuit of AACN .

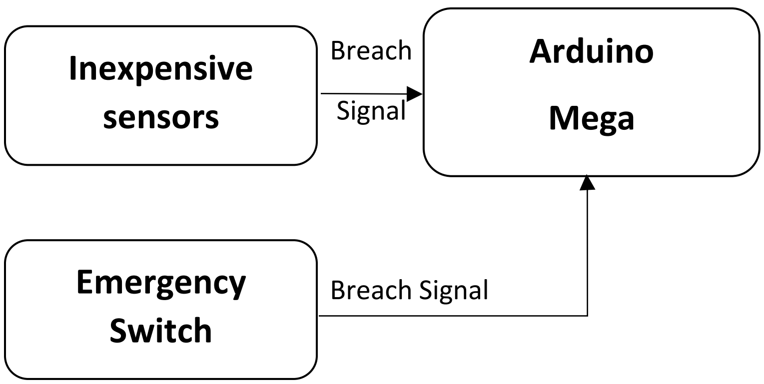
4.2 Block Diagram

Step 1:



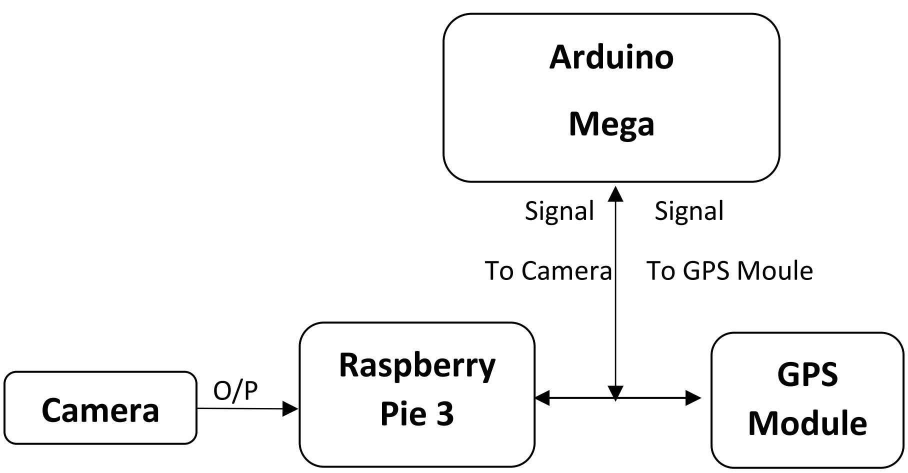
First step is to connect hotspot from smartphones to Raspberry Pi 3 kit1 and kit2.

Step 2:



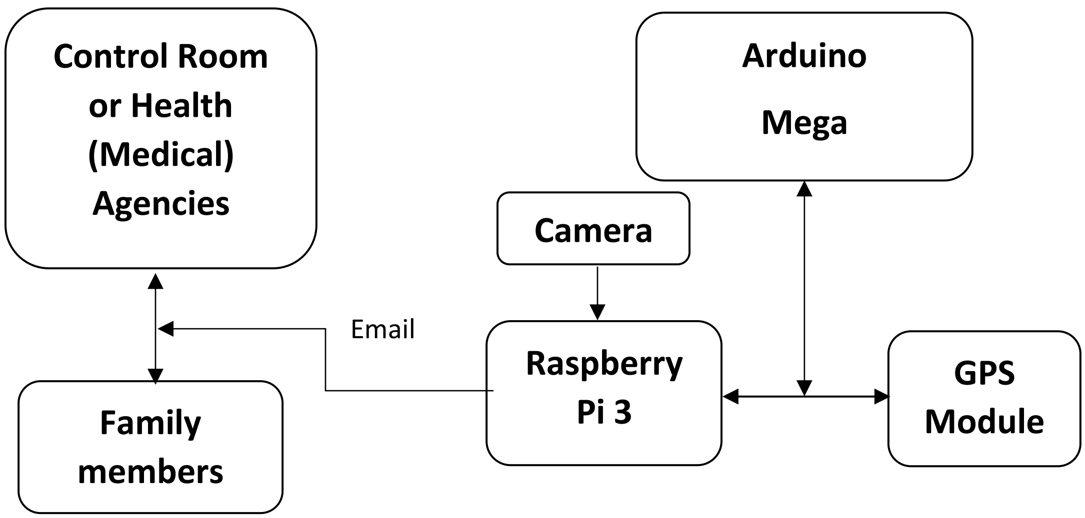
In step 2, we wait until we detect breach on sensor/s or Emergency Switch. If we have breach on Sensor/s or Emergency switch, it will send a signal to Arduino Mega 2560.

Step 3:



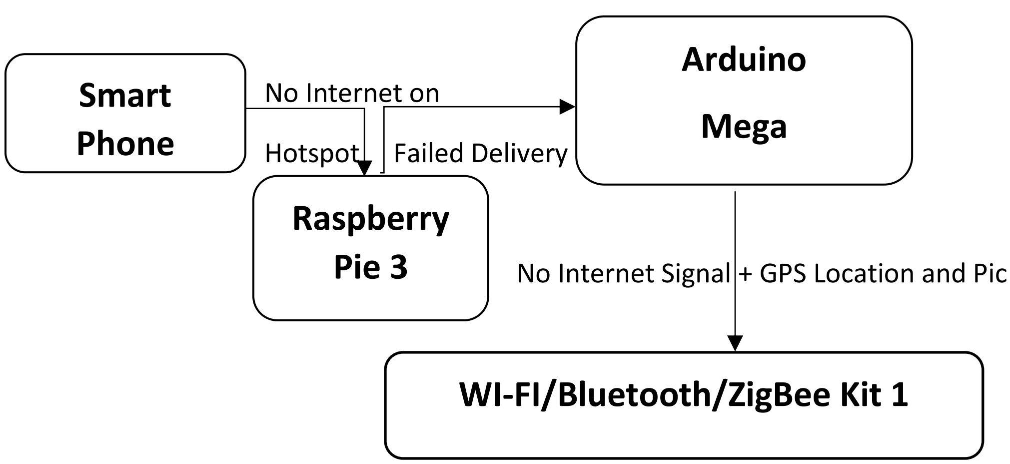
In step 3, we have detected a breach and we have breach signal on Arduino Mega. After receiving breach signal Arduino Mega will send a signal to Camera via Raspberry Pi 3 Kit 1 to take a pic inside of car. Simultaneously it will send a signal to GPS modem to get Location of crash.

Step 4:



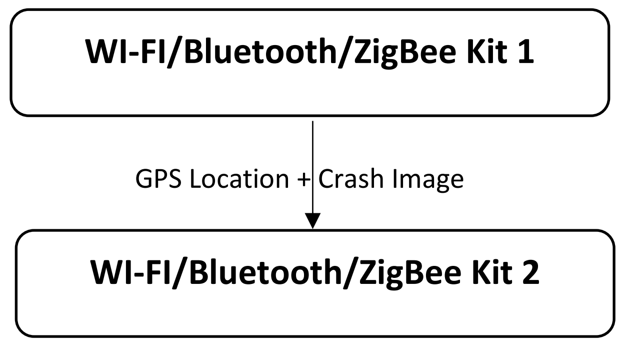
In step 4, Arduino Mega will send a GPS Location and Pic taken by Camera via Email using Raspberry Pi 3 to Family members and Medical Authorities.

Step 5:



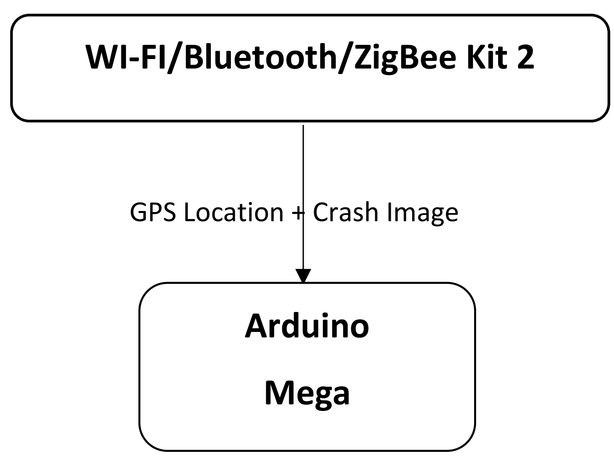
In step 5, we do not have internet/Network on smartphone, so we can't send Email using Raspberry Pi 3 of Kit 1. Raspberry Pi 3 will send failed delivery signal to Arduino Mega. After receiving that, Arduino Mega will send No internet signal to all three devices. We will also send GPS location and Image of crash to all three devices.

Step 6:



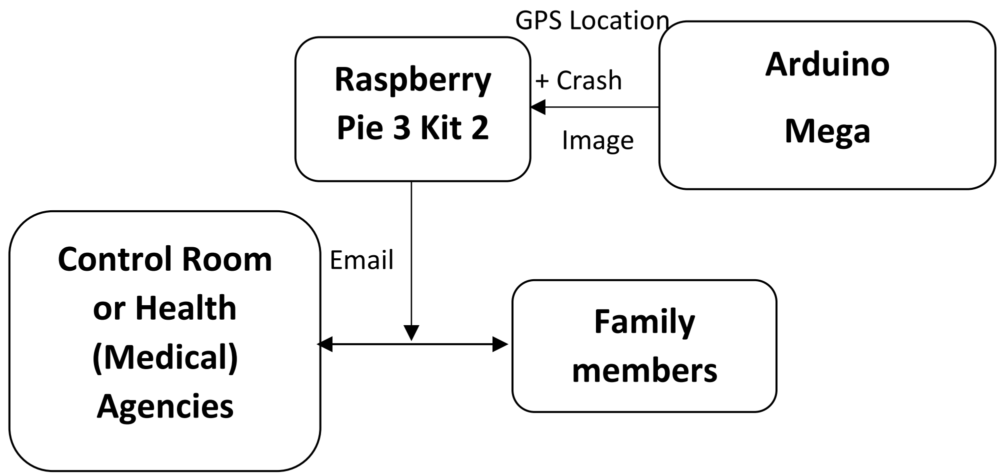
In step 6, all three have received GPS location and Crash Image, which they will send it to three devices of kit 2 by communication with them.

Step 7:



In step 7, all three devices of kit 2 will send GPS location and Crash image of Kit1 (Car1) to Arduino Mega of Kit 2(Cra2).

Step 8:



In step 8, Arduino Mega send GPS location and Crash image of Kit1 (Car1) to Raspberry Pi 3 of Kit 2 and Pi send the Email containing that to health authorities and families.

4.3 Working of sensors of the System in the Car

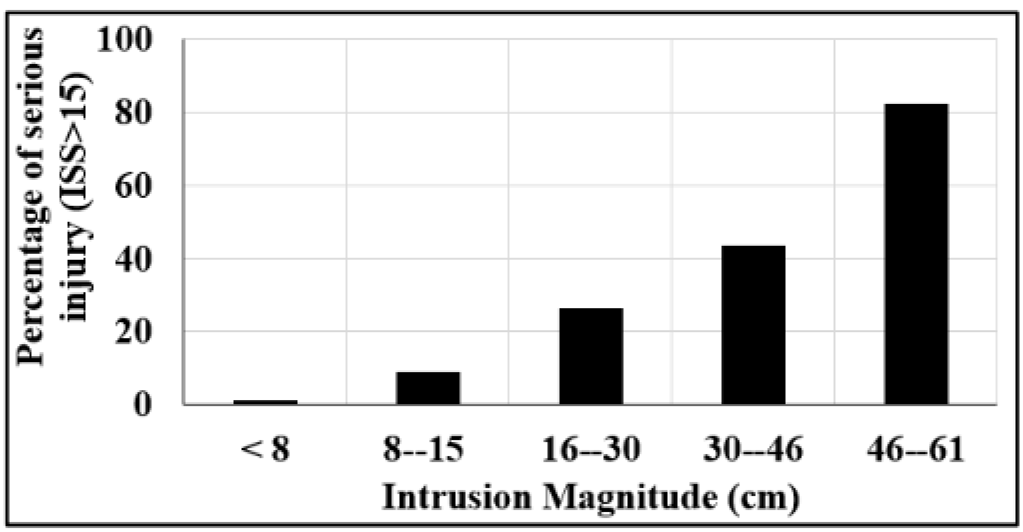


Figure 10 Variation of serious injury (ISS>15) percentage with respect to compartment intrusion magnitude Copied From [27-Fig7]

In [26] author talks about Improving the accuracy of Injury Severity Predictions (ISP). In [26] Fig 7 copied as in Fig 10 we have graph between Intrusion Magnitude and Percentage of Serious Injury. The higher the intrusion, the higher seriousness of injury. So, we can say they are perorational in the context. More than 30 cm can be considered as a good indicator of serious injury. Based on these we have decided the location of the sensors in the car, which can be seen in Fig. [11-13].

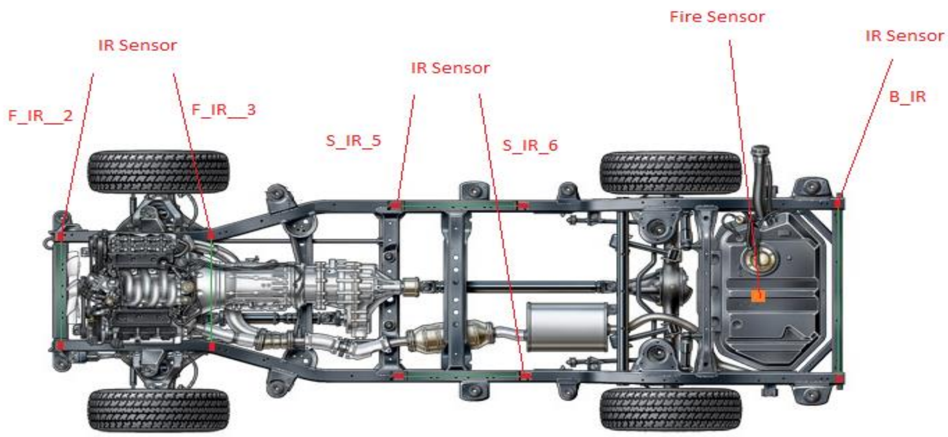


Figure 11 Bottom View of the Car

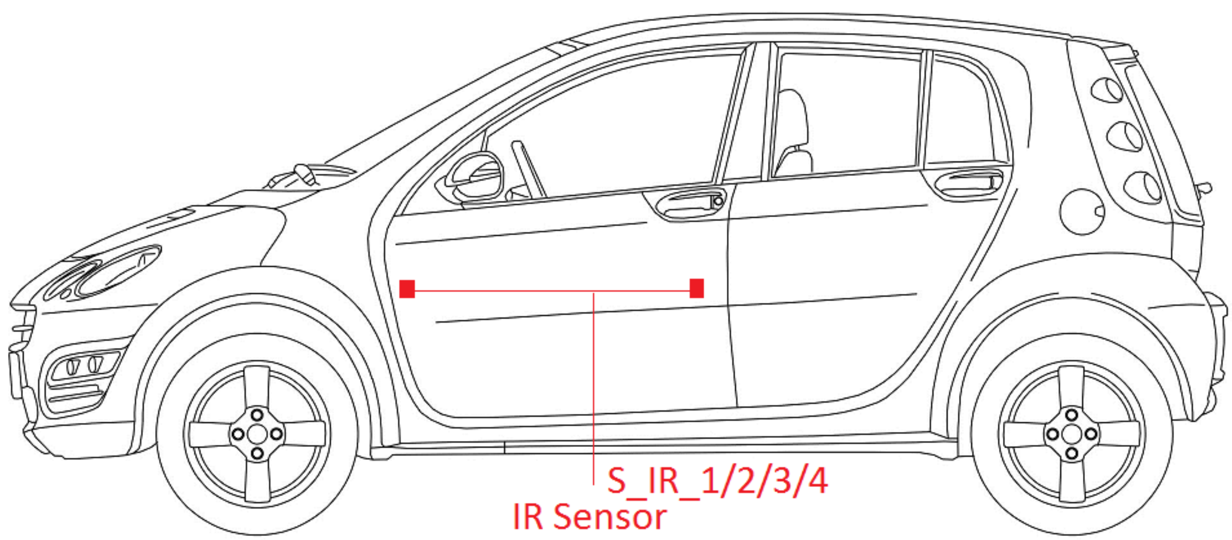
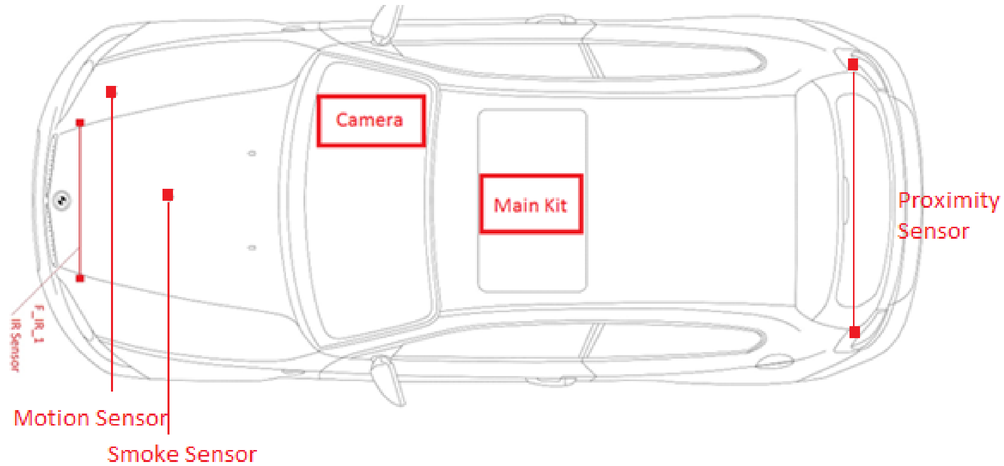


Figure 12 Side View of the Car



MAIN KIT - GPS, RASPBERRY PI 3, ARDUINO MEGA, BLUETOOTH, ZIGBEE, EMERGENCY SWITCH, WI-FI CHIP

Figure 13 Top View of Car

We have used different sensors in different location of car to get the appropriate response from them. In fig 11 we have bottom view of car, in fig 12 we have side view of car and fig 13 we have top view of car. We have used IR sensor in front, back and side of car to detect the crash. We have divided them in three categories, which is discussed below [4.4]. IR sensors are used in more number because when we have breach between receiver and transmitter of IR Sensor we can confirm that crash has occurred. We can replace IR sensor with Glass+Switch sensor. This sensor works on principle that, when glass is broken we will have release on push button or switch. We have placed fire sensor on top of gas tank to detect ignition of fire. We have used smoke sensor in front of car to detect sudden fire or malfunction. Motion sensor is used to detect deployment of sensor used for airbag. Proximity sensor works for collision warning from behind.

4.3 Code Category

We have placed IR sensors and Fire Sensor for accident and fire detection. F_IR is front IR sensor, S_IR is side IR sensor and B_IR is Back IR sensor. Depending on the Location of sensors and intrusion magnitude, we have divided the response in three categories:

1. Code Green: It is a category 1 accident. Ex: F_IR_1, Smoke Sensor

   When Intrusion magnitude is <8 cm and 8-15 cm in Fig10, we decided to label it as Code green. In terms of crash, the situation where accident occurs but injuries are not much serious is code green.

2. Code Blue: It is a category 2 accident. Ex: F_IR_2, Smoke Sensor.

   Code blue is for the situation where accident occurs and injuries are serious but not fatal. In Fig.10, this will be from 15- 30 cm and 30-46 cm Intrusion Magnitude.

3. Code Red: It is a category 3 accident. Ex: F_IR_3., S_IR_1/2/3/4/5/6, B_IR, Fire Sensor, Smoke Sensor

   Code red is for the situation where accident occurs and injuries are fatal. In Fig.10, this will be from 30-46, 46-61 cm Intrusion Magnitude depend on location of sensor/s. However, for side doors it is only 8-15 cm or more.

This will give some idea about the seriousness of the situation and camera pic will tell us what kind of medical aid will be needed. Therefore, we can have necessary tools for help at the site. In addition, the key factor is Location of crash site provided by GPS. All of these together can be the difference we need to have proper medical aid and help save the lives.

4.4 Operating Principle

4.4.1 Assumptions

We have made some Assumptions to perform the project:

1. The sensor detection in the AACN will work same as the time of the crash in real time.
2. Hotspot connection is always active
3. System is turned off in case of repairs, maintains of car etc.
4. Bluetooth will be binded from Manufacturer
5. GPS can obtain Co-ordinates at all location.

4.4.2 Working of the AACN

We have used Smartphone feature hotspot to provide internet connection to Raspberry Pi 3. Arduino Mega works as base. GPS provides Location. Camera will provide image and Raspberry Pi 3 will send an email with the image and location to family members and health agencies. When we do not have hotspot connection Bluetooth/ZigBee/WI-FI will communicate with other kits (other cars) to perform chain operation and send email using them. In addition, we have installed emergency switch just in case of fail detection of accident or other medical emergencies like heart attack etc.

We have placed sensors in different location [4.2] in the car, and when accident occurs parts associated with the crash will move and we will detect that breach. It will trigger the signal to Arduino Mega. In case of destruction of sensor/s, Arduino Mega will perform same operation as when sensor/s are breached. Once breach is detected Arduino Mega will send a signal to camera to take an image of the inside of car after crash, and simultaneously Arduino mega will also send a signal to GPS to collect the Location the Crash. Once Arduino mega has both image and location it will send a signal to Raspberry Pi 3 to send those information via Email to health authorities and family members. If we don't have network on smartphone which will result in no internet situation, Raspberry Pi 3 will send a failed to delivery signal to Arduino Mega as it won't be able to send an Email.

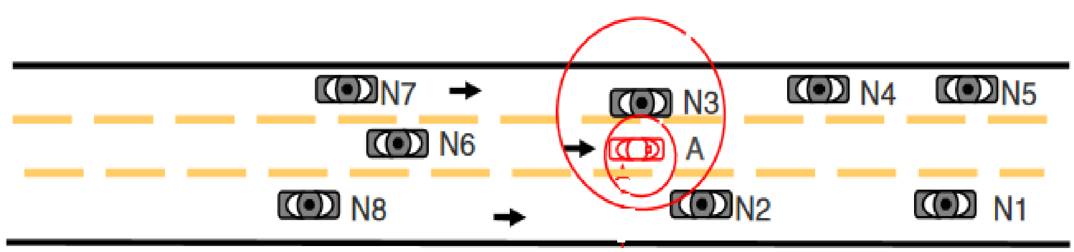
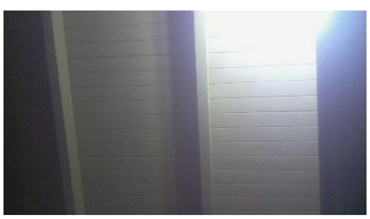


Figure 14 Chain Communication in Cars [24]

Once Arduino Mega receives this signal it will initialize all three devices and will send GPS location and Crash Image to them to forward to Kit2(N2/N3 in Fig 14.). Once all three devices will receive these data, they will wait for other car/s to pass. When the other car/s will pass, all three devices of kit 1(A in Fig.14) will forward the data to Arduino Mega of Kit 2 via all three devices of Kit2. Once Mega will get these data, it will send it to Raspberry Pi 3 of Kit 2 to send an Email to health Authorities with those data. If Kit of other car Kit 2 also don't have the internet than it will also wait for other car to pass and repeat the process and send the data to Kit3(N4/N5/N1/N8/N6/N7 in Fig14.). This repeat process will formulate a relay chain. As shown in Fig. 14

In nut shell, when we will have detection on sensor/s a signal will be send to Arduino Mega. Than Arduino Mega will send signal to GPS and Camera to obtain Location and Image of the crash respectively. Location of the crash, image of the crash and level of seriousness of the crash [4.3] based on which sensor/s is detected will be send via Email to health agencies and family using Raspberry Pi 3. In case of no hotspot connection availability, we will wait for other car to pass and if it has signal, the Kit 1 will send GPS location and image to Kit 2 via Bluetooth/ZigBee/Raspberry Pi 3. If Kit 2 do not have hotspot connection, it will pass the o/p to Kit 3 and so on until Email is send.
Email will look like this,

"Accident at location MEGA1: LAT= 48.463695: LON= -123.309501:SMOKE_RED "



Here we have Latitude and Longitude of the Crash with Image of the Crash. SMOKE_RED means smoke sensor has detected and seriousness of the crash is Code Red [4.3].

MEGA 1 is for Raspberry Pi 3 of kit 1. Therefore, this email is send by Raspberry Pi 3 only.

These are some possible scenarios:

1. "Accident at location MEGA2: LAT= 48.463695: LON= -123.309501:MOTION_RED "
2. "Accident at location XBEE_1MEGA2: LAT= 48.463695: LON= -123.309501:FIRE_RED "

3. “Accident at location Wi-Fi1MEGA2: LAT= 48.463695: LON= -123.309501:F_IR_1_GREEN “
4. “Accident at location BT_1MEGA2 LAT= 48.463695: LON= -123.309501:B_IR_RED “
5. “Accident at location XBEE_2MEGA1 LAT= 48.463695: LON= -123.309501:S_IR_3_RED “
6. “Accident at location MEGA1: LAT= 48.463695: LON= -123.309501 BT_1MEGA2LAT= 48.463695: LON= -123.309501:F_IR_2_BLUE “
7. “Accident at location Wi-Fi2MEGA1: LAT= 48.463695: LON= -123.309501:F_IR_1_GREEN “

In 1 we have detection on kit 1 and hotspot is available on Kit so we have used Raspberry Pi 3. In 2 ZigBee of Kit 1 has used to communicate with Kit 2 send email via Raspberry Pi 3 of kit 2 because we don’t have hotspot connection available on kit1. In 3, 4 we have communication via wi-fi of kit1, Bluetooth of kit 1 respectively instead of ZigBee in 2. In 5 we have similar situation as 2 but kits have reversed ZigBee of Kit 2 has used to communicate with Kit 1 send email via Raspberry Pi 3 of kit 1 because we don’t have hotspot connection available on kit2. In 6 we have detection on kit 1 and 2 and hotspot is available on both Kits so we have used Raspberry Pi 3 of both kits. In 7 Wi-Fi of Kit 2 has used to communicate with Kit 1 send email via Raspberry Pi 3 of kit 1 because we don’t have hotspot connection available on kit2.

4.5 Challenges

In AACN we have used different components for different purposes. All components have some limitation which can affect its performance. In case of IR sensors and Smoke sensor we can have problem of false detection. When we install IR sensors in the car, we have chance of tiny rocks or similar objects accidently getting launched in the car when it is being used. It can trigger the false notification if it will breach the infrared line between receiver and transmitter. In this scenario I think Glass+ Switch sensor can be a better fit but it also has same risk factor if the rocks or similar objects hit the glass with enough force it can be broken and generate false notification. And also, use of Glass+Switch sensor is more expensive and we are trying to provide the system which is low cost and has same working efficiency. In case of smoke sensor, we can have false notification if we put it in the front section of the car and some part of car will become faulty and generate smoke. Our smoke sensor works on what is the level of CO_2 in the smoke. I believe the smoke from faulty part will have same CO_2 level and can generate false notification.

In case of Bluetooth, to communicate with each other they have to be from same manufacture. Because most commonly when we have Bluetooth from same manufacture we don't have to ask for permission to communicate with each other. The other way is we have to bind them using coding to have permission to communicate with each other but it is impractical and not applicable if produce our system in mass quantities. One of the biggest challenge was to send the mail with code category we have designed(4.3), name of the sensor/s which generated the trigger, GPS location and Image of the crash with the identity of device used to communicate with other kit or send the Email. For example, "Accident at location MEGA1: LAT= 48.463695: LON= -123.309501: SMOKE_RED" is the Email we will get if smoke sensor has been beached, it is code red category and Raspberry Pi 3 of kit 1 send the mail as explained in 4.4. If we use the name we have given to sensors and category as it is we are not able to send the Email. Thus, to overcome this problem we have given a character to each string like for Somke_Red we have assigned letter "C". Same we assigned different numbers or letters to each sensor-code category combination. Table 5 shows those combination.

Letter/ Number	Sensor-Code Category Combo
1	(F_IR_1) F_GREEN
2	(F_IR_2) F_BLUE
3	(F_IR_3) F_RED
4	(B_IR) B_GREEN
5	(B_IR) B_RED
6	(S_IR_3/4/6) L_GREEN
7	(S_IR_3/4/6) L_RED

8	(S_IR_1/2/5) R_GREEN
9	(S_IR_1/2/5) R_RED
A	FIRE_RED
B	MOTION_RED
C	SMOKE_RED
D	PROXI_GREEN
E	ACCIDENT_SWITCH_RED

Table 5 Letters to Each Sensor-Code Category Combination

The other major problem is connecting hotspot to Raspberry Pi 3. We have to configure the Raspberry Pi 3 with the smartphone we want use to provide internet connection. If we have configured different phone and we don't have the phone with us or battery of the phone is died than we have to rely on other cars to send an Email and It can increase our response time. Usually we will need around 30 seconds to establish hotspot connection with the Raspberry Pi. We can do it any point of time but as we have assumed it has to be on when we detect crash. If hotspot is providing internet, system's response time will be between 30 seconds to 90 seconds. But if we have to rely on other passing cars response time can increase depending on availability of car passed and whether or not that car is using the kit or not. The response for device communicating with other car will be little more as we have to wait for fail to deliver signal from Pi and after that we will initialize those devices. Response time for that is around 90 seconds to 150 seconds.

5. Experimental Results

5.1 Test 1 [Hotspot Connection Available on Kits]

Number	Raspberry Pi 3 Kit 1	Image Kit1	Location Kit1	Raspberry Pi 3 Kit 2	Image Kit2	Location Kit2
1	YES	YES	YES	YES	YES	YES
2	YES	YES	YES	YES	YES	YES
3	YES	YES	YES	YES	YES	YES
4	YES	YES	YES	YES	YES	YES
5	YES	YES	YES	YES	YES	YES
6	YES	YES	YES	YES	YES	YES
7	YES	YES	YES	YES	YES	YES
8	YES	YES	YES	YES	YES	YES
9	YES	YES	YES	YES	YES	YES
10	YES	YES	YES	YES	YES	YES
11	YES	YES	YES	YES	YES	YES
12	YES	YES	YES	YES	YES	YES
13	YES	YES	YES	YES	YES	YES
14	YES	YES	YES	YES	YES	YES
15	YES	YES	YES	YES	YES	YES
16	YES	YES	YES	YES	YES	YES
17	YES	YES	YES	YES	YES	YES
18	YES	YES	YES	YES	YES	YES
19	YES	YES	YES	YES	YES	YES
20	YES	YES	YES	YES	YES	YES
21	YES	YES	YES	YES	YES	YES
22	YES	YES	YES	YES	YES	YES
23	YES	YES	YES	YES	YES	YES
24	YES	YES	YES	YES	YES	YES
25	YES	YES	YES	YES	YES	YES

Table 6 Test -1 Success Rate Comparison

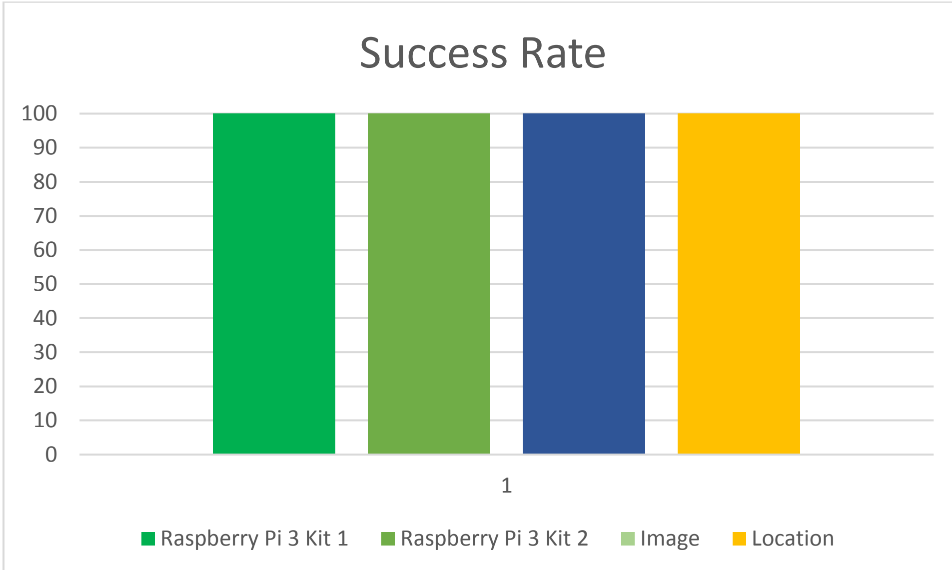


Figure 15 Test -1 Success Rate % of Raspberry Pi 3

The table 6 shows the summary of our simulated test results. We simulate the accident on different sensors and try to see that our system is able to detect it or not. As shown in table we have used results of the 25-test run. The first column shows if kit 1 were able to detect the accident or not. The next two column shows that whether kit1 was able to send image and location each time. The 4,5,6 columns show the same result for kit 2. YES means it was able to send and NO means it was not.

We have plotted the results of table in Fig.15. We can see that kit 1 and 2 were able to successfully send the location and image each time making the 100% success rate. This clearly shows that the kits were able to send the emergency data proving our theory right that we can use the AACN to detect the crash and successfully notify it. This system will use safety-real time components of better quality in production environments. Therefore, it will increase the reliability many times. This is an essential for such safety systems and as per our goals.

5.2 Test 2 [Hotspot Connection Not Available on Kits]

5.2.1 Trail 1 (5m Distance)

Number	Wi-FI	Bluetooth	ZigBee
1	NO	YES1	YES2
2	NO	YES1	YES2
3	NO	NO	YES1
4	NO	YES1	YES2
5	NO	YES1	YES2
6	NO	NO	YES1
7	NO	YES1	YES2
8	NO	YES1	YES2
9	NO	YES1	YES2
10	NO	NO	YES1
11	YES2	NO	YES1
12	NO	YES1	YES2
13	NO	YES1	YES2
14	NO	YES1	YES2
15	NO	YES1	YES2
16	YES2	NO	YES1
17	NO	YES1	YES2
18	NO	YES1	YES2
19	NO	YES1	YES2
20	NO	YES1	YES2
21	NO	YES1	YES2
22	YES3	YES1	YES2
23	NO	YES1	YES2
24	NO	YES1	YES2
25	NO	YES1	YES2

Table 7 Success Test of All Three Systems 5m

YES1 = Received

YES2 = Received

YES3 = Received

NO = Not Received

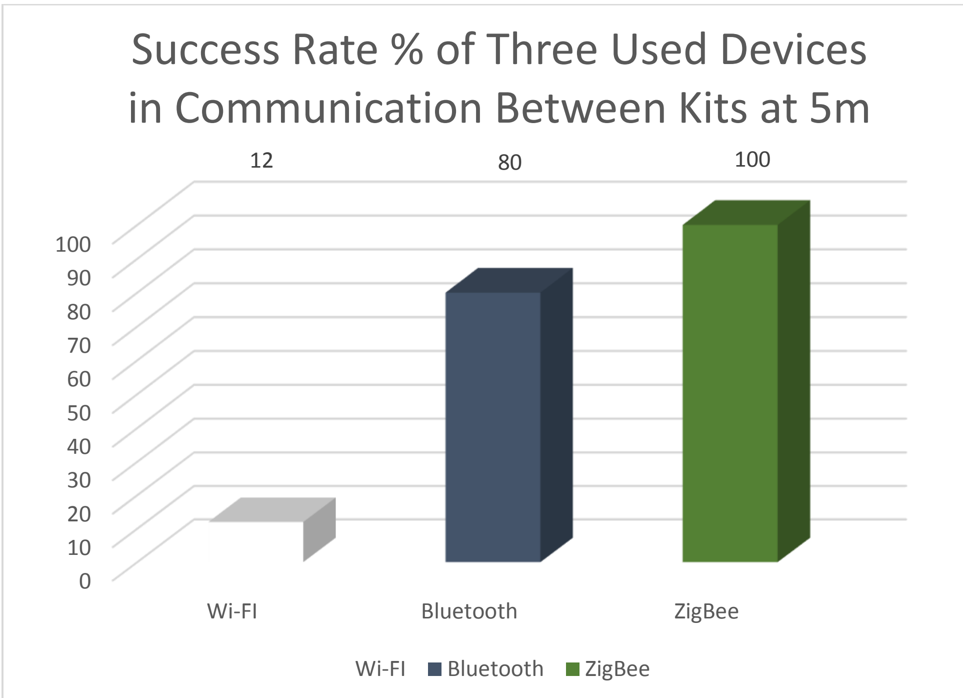


Figure 16 Success Rate % of Three Used Devices in Communication Between Kits (5m)

In Table 7 Test-2 (5m distance) we have used the responses of the AACNs when crash is occurred on Kit 1 but we don't have internet/network. As we have discussed above when we don't have access to internet via hotspot we will use the three devices to communicate with the same three devices of other AACN to transfer data of first AACN to second AACN to send the Email to authorities. We have used 25 responses to measure the success rate of three devices when they are around 5m distance with each other. In the table we have four terms YES1, YES2, YES3 and NO. YES1 is for the system which delivers the data first. YES2 is for the system which delivers the data second and similarly YES3 is for the system which delivers data third. And NO is when that system didn't deliver the data or didn't needed to deliver the data. In Figure 16 we have plotted those results.

In 25 responses, ZigBee is used 5 times as first response device, out of those 5 times3 times it was used as only device to response and 2 times with wi-fi as second response device. And also 20 times as second response device making the success rate 100%. Bluetooth on the other hand is used only for 20 times out of 25 but it was always first responder. Wi-Fi on the other hand was used only three times, two times as second and one time as third responder.

5.2.2 Trail 2 (10m Distance)

Number	Wi-FI	Bluetooth	ZigBee
1	NO	YES1	YES2
2	NO	YES1	YES2
3	YES2	NO	YES1
4	NO	YES1	YES2
5	NO	NO	YES1
6	NO	NO	YES1
7	NO	YES1	YES2
8	YES2	NO	YES1
9	NO	YES1	YES2
10	NO	YES1	YES2
11	NO	YES1	YES2
12	YES2	YES1	NO
13	NO	YES1	YES2
14	NO	YES1	YES2
15	NO	YES1	YES2
16	NO	YES1	YES2
17	NO	YES1	YES2
18	YES1	NO	NO
19	NO	YES1	YES2
20	NO	YES1	YES2
21	NO	YES1	YES2
22	NO	YES1	YES2
23	NO	YES1	YES2

24	**NO**	**YES1**	**YES2**
25	**NO**	**YES1**	**YES2**

Table 8 Success Test of All Three Systems 10m

YES1 = Received

YES2 = Received

YES3 = Received

NO = Not Received

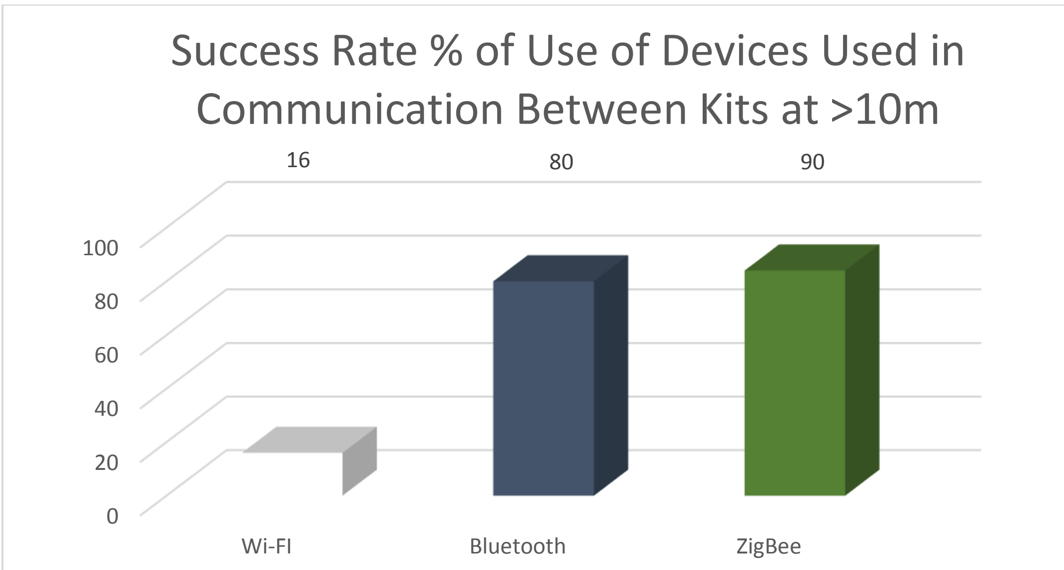


Figure 17 Success Rate % of Three Used Devices in Communication Between Kits (>10m)

In Table 8 Test-2(>10m distance) same as Table 7 we have used 25 responses to measure the success rate of three devices when they are around 10m distance with each other. Also in the table we have used same four terms YES1, YES2, YES3 and NO. Where, YES1 is for the system which delivers the data first. YES2 is for the system which delivers the data second and similarly YES3 is for the system which delivers data third. And NO is when that system didn't deliver the data or didn't needed to deliver the data. In Figure 17 we have plotted those results.

In 25 responses, ZigBee is used 4 times as first response device, out of those 4 times 3 times it was used as only device to response and 1 times with wi-fi as second response device. And also 19 times as second response device making the success rate 90%. Bluetooth on the other hand is used only for 20 times out of 25 but it was always first responder. Wi-Fi on the other hand was used only 4 times, 3 times as second and one time as first responder.

So, we can conclude from both experiments (Table 7 and 8), as expected Bluetooth module is the best system out of three, because every time it was accessed first. Proving the theory that for short distance communication Bluetooth is best device. Though ZigBee is used in more responses in both cases making it more useful. The reason for only 12% and 16% use of wi-fi is because in coding we have initialized Bluetooth first, then ZigBee and lastly Wi-Fi. And also, when we get the signal for communication on devices wi-fi needs to do initialization process before it can be used to communicate. So other two devices will communicate with other kit even before wi-fi is ready to use. And in our coding because they are getting accessed first kits didn't get a chance to use Wi-Fi. But if both Bluetooth and ZigBee cannot communicate with other kit due to high speed of vehicle Wi-Fi can still communicate. But overall system success rate is 100% in both the cases (Table 7 and 8) as at least one of the device was able to forward the message to other kit and send the Email via that. Which proves our theory that we can successfully deliver the Email using other kit if we don't have the network on main kit.

5.3 Summary

5.3.1 Pros

1. 100% detection rate of the Crash.
2. 100% success rate for the notification of the crash with and without Internet.
3. Code category based on location of the sensor to measure the seriousness of the crash.
4. Image of the crash to get the better understanding of required medical aid.

5. Easy to combine with other existing technologies to improve the performance.
6. AACN is low cost.

5.3.2 Cons

1. Need to have hotspot ON all time which can drain battery.
2. If we don't have internet or battery of phone dies and next car don't have the kit or time between crash and next car is long than goal of reducing the response is not fulfilled.
3. We have used 4 devices (Raspberry Pi 3, Bluetooth, ZigBee, Wi-Fi) which can make the system prone to DOS attack.
4. IR Sensor and Smoke sensor can trigger false notification.

5.4 AACN Cost

Arduino Mega	50$
Raspberry Pi 3 with Camera	80$
ZigBee	72.50$
Bluetooth	25$
GPS	105$
Wi-Fi	18$
Smoke Sensor	25.50$
Motion Sensor	10$
Proximity Sensor	10$
Fire Sensor	2.5$
IR sensor*8	20$
Total Cost	323.50$

6. Future Work

This paper focuses on post-crash response. In this paper we have discussed a way to identify the crash and level of seriousness of crash and provide the image of crash to determine the medical aid needed for treatment of injured. We have also provided the location of crash. In our paper to improve the reliability and to reduce the risk of DOS attack we can replace used 4 devices (Raspberry Pi 3, Bluetooth, ZigBee, Wi-Fi) with any of the device out of these three: AirLink® GX450, AirLink® MP70 and AirLink® MG90. These are devices developed specifically for vehicle networking by Seirra Wireless. If we use one this device we don't have to use GPS module also, which can make the kit very compact and easy to provide the protection layer.

In future, we would like to upload the location of the crash with the image to a dedicated server for help agencies. In the server we can design a system which sort out the accident-prone zones. We can divide them in different zones based on number of accident occurs. We can divide them in five zones starting from level 1 to level 5. We can also develop an App like BC Transit which can tell you the Level of zone when you enter in it and if there is any accident has occurred or we can have server sending text message same as Emergency messages send by Government Authorities in case of natural disaster. Based on zones and record of number accident we can locate the location where maximum crash are occurring and try to resolve the issue by taking necessary steps. We can also find out where base systems are not sending the signal and we have to rely on passing vehicles. We can than request service providers to put more base station in that area if required.

We can combine "Emergency Corridor Utilizing Vehicle to Vehicle communication" by Ford Global Technologies [24] to our system to achieve maximum output and cut the time to reach at the crash location. In this system server notifies the vehicle drivers on the route that emergency vehicle is approaching and that way we have no wait time in traffic for emergency vehicle providing better response time. We can combine pre-crash response systems like “A vehicle-to-vehicle communication protocol for cooperative collision warning” [18] with our design to avoid crash where it is possible.

7. Conclusion

To conclude, we can say we have designed a system (AACN) which can notify us when crash occurs or in case of emergency switch used by passenger/driver. We are able to get the location of crash using GPS and level of seriousness based on location of part which is involved in crash used by our sensors placement mechanism (4.2) and image of the crash using camera. From 5.1 we can say we are able to deliver the above things by email using Raspberry Pi 3 to health agencies and families each time. In case when internet is not available via hotspot connection/ no hotspot connection we can use the three devices used to form a relay chain to communicate with other cars(kits) and notify health agencies and families using connection from other kit and successfully delivering the message each time(5.2).

So, from data we have presented in this paper, we can predict that we can save at least 30% victims crash victims which is around 500 people in Canada and around 250 thousand people all over the world every year. And combining with other technologies mentioned in future work we can increase that to 60% making the numbers 1000 people in Canada and 500 thousand people can benefit all around world.

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9. Appendix

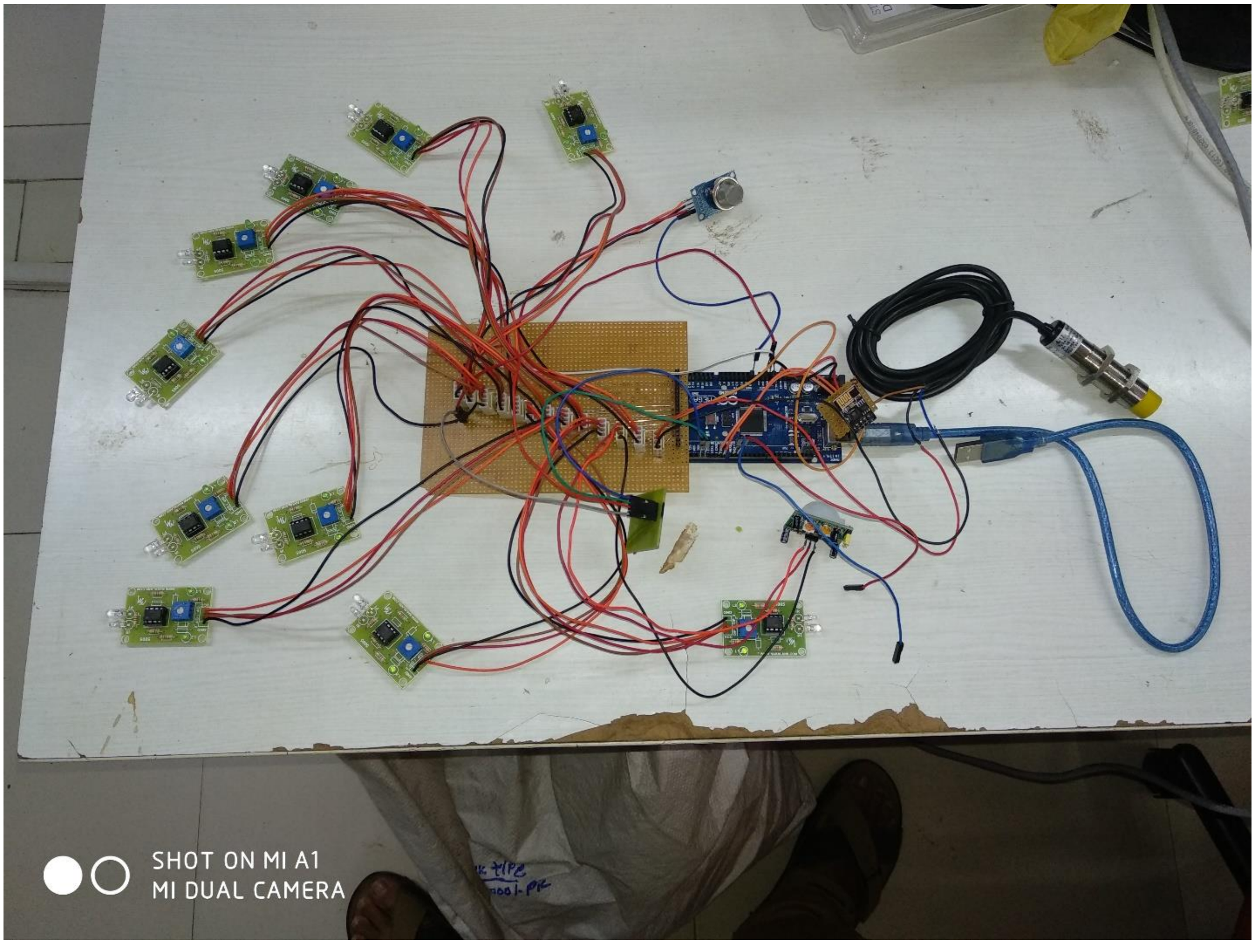

Figure 18 Arduino Mega with All Sensor

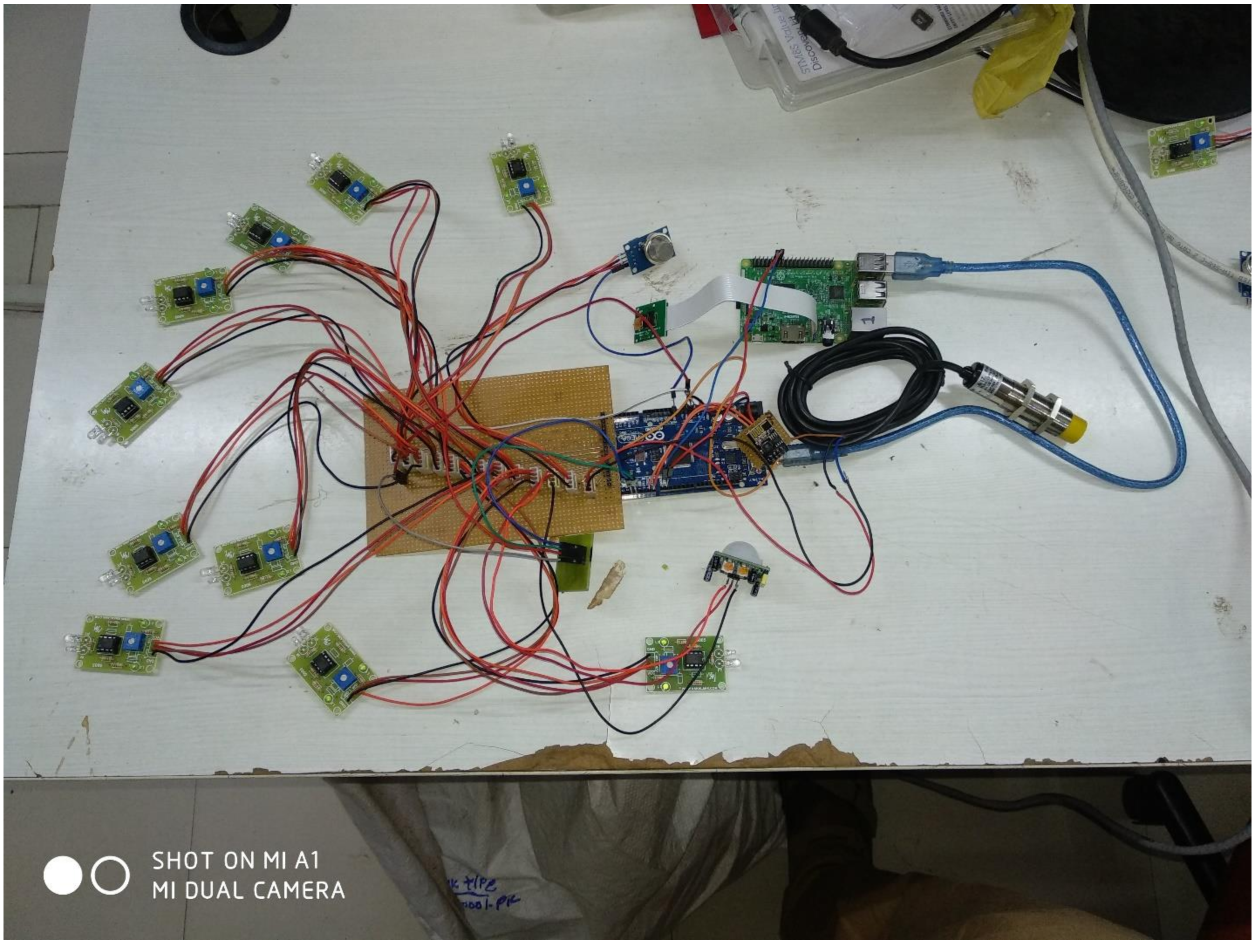

Figure 19 Arduino Mega with Raspberry Pi 3

Figure 20 Raspberry Pi 3 with Camera Module

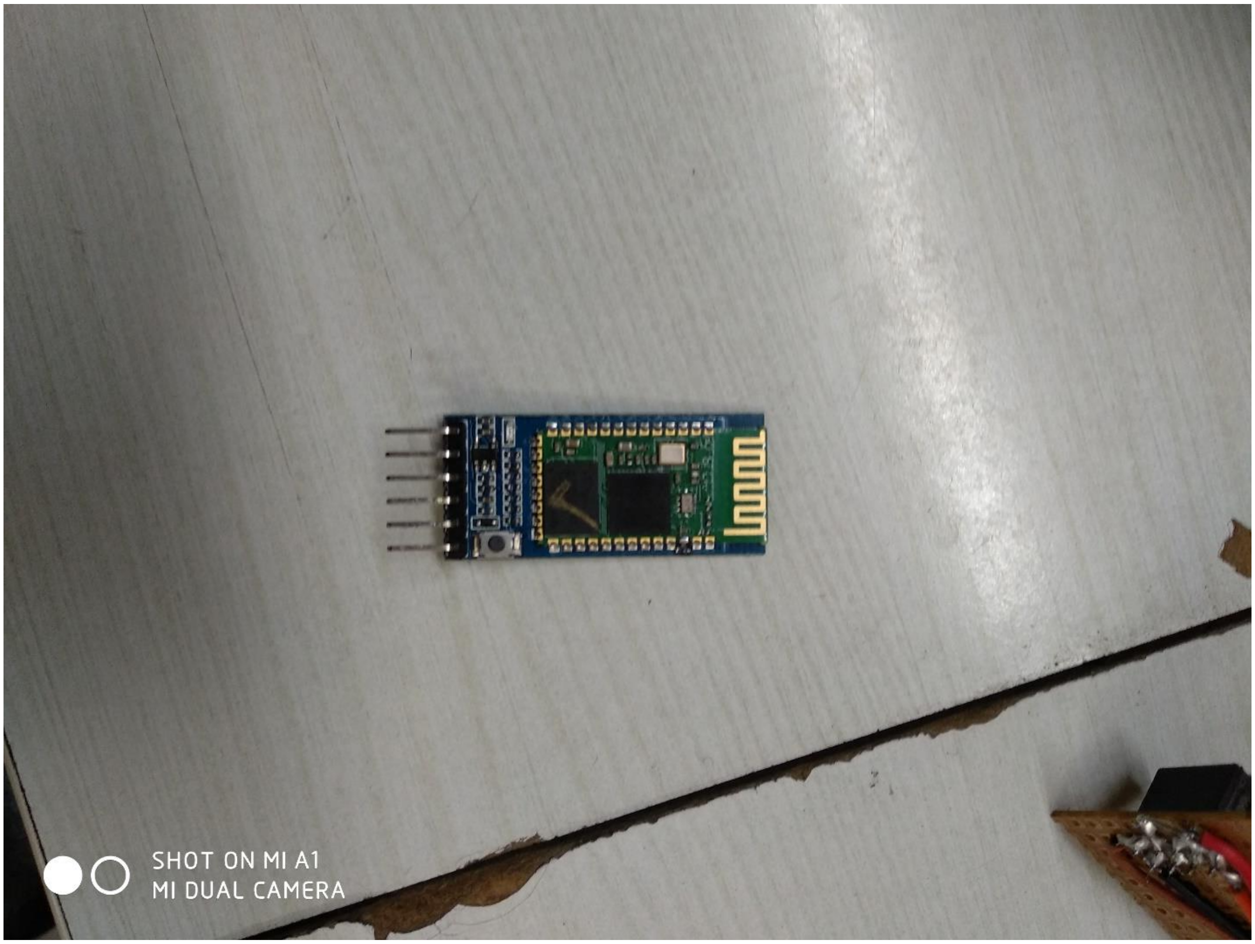

Figure 21 Bluetooth Module

Figure 22 Wi-Fi Module

Figure 23 ZigBee Module

Figure 24 Fire Sensor

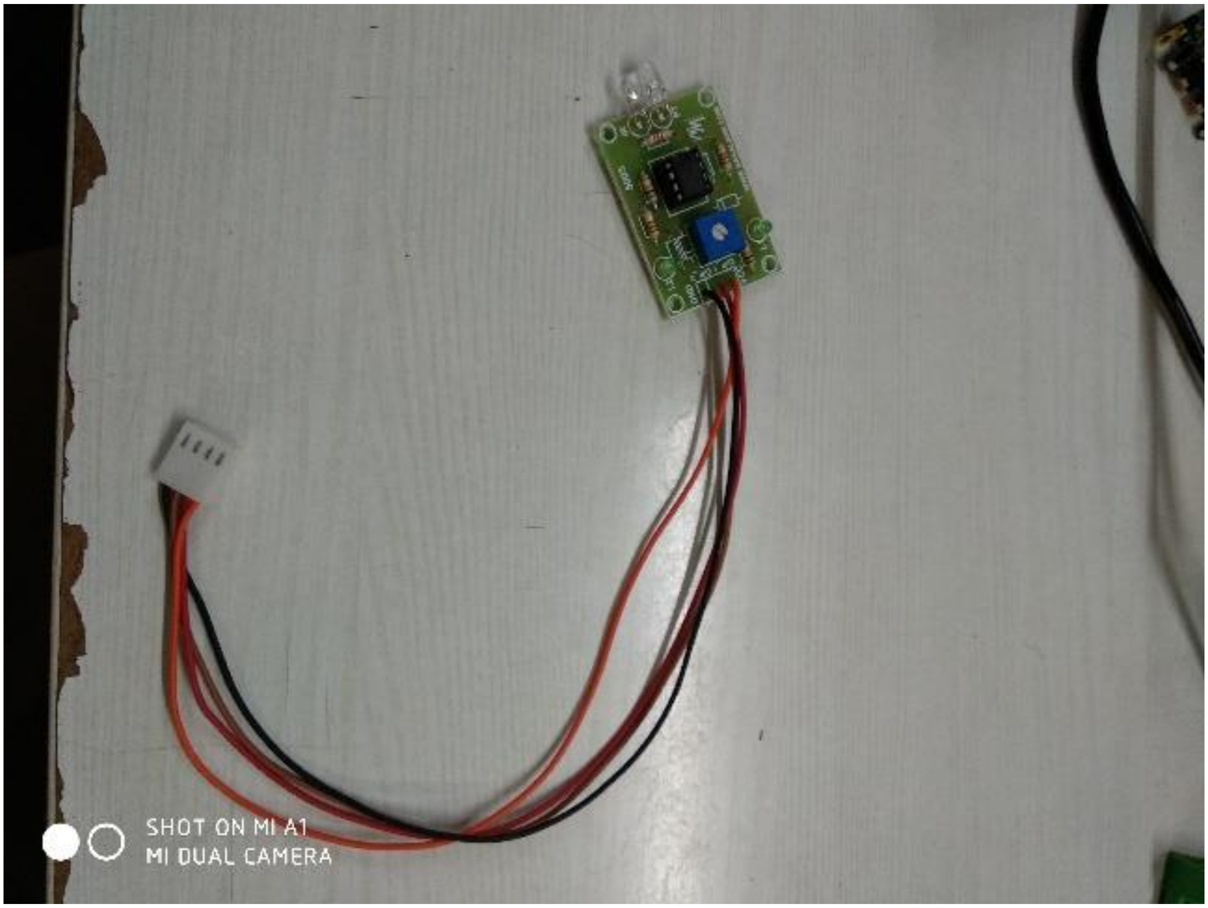

Figure 25 IR Sensor

Figure 26 Smoke Sensor

Figure 27 Motion Sensor

Figure 28 Proximity Sensor